

ENGINEERS' AND FIREMEN'S MANUAL.

GENERAL INDEX.

FORMING ONE OF THE TWELVE VOLUMES OF THE REVISED AND
ENLARGED EDITION OF

THE SCIENCE OF RAILWAYS.

BY
MARSHALL M. ^{AYERS}KIRKMAN.

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TABLE OF CONTENTS.

Resumé of the Work, and Dedication,	PAGE iii
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BOOK I.

ENGINEERS' AND FIREMEN'S MANUAL, OR COURSE OF STUDY FOR THOSE WHO SEEK TO BECOME ENGINEERS.

The locomotive engine the key to the railway world.
 Questions regarding selection, trial and work of those in charge. The value of systematic study and careful examinations to those who would become efficient engineers, 5

Steam and its application to the locomotive, 27

Particulars of yearly examinations in regard to the duties and responsibilities of the locomotive engineer:

Fireman's first year's examination,	84
Fireman's second year's examination,	45
Fireman's third year's examination,	61
Examination in regard to the air brake,	100

Further description of the duties and responsibilities of engineers, 183

BOOK II.

COMPOUND LOCOMOTIVES.

Introductory,	PAGE 155
General description—comparison with simple locomotives, 159	
Classes of compound locomotives and their general construction,	171

	PAGE
Questions and answers on the operation of compound locomotives in general,	181

Description and operation of compound locomotives:

	PAGE		PAGE
Baldwin four cylinder,	186	Schenectady, design of 1896,	222
Baldwin two cylinder,	202	Pittsburg,	233
Schenectady (McQueen),	209	Richmond,	246
Schenectady, original type,	209	Rogers,	258
Schenectady, design of 1892,	210	Brooks four cylinder tandem,	278
Schenectady, design of 1892, with Southern Pacific modification,	221	Cooke,	286
		Dickson,	292
		Rhode Island,	297

Accidents to compound locomotives:

	PAGE		PAGE
Baldwin four cylinder,	198	Pittsburg,	243
Baldwin two cylinder,	208	Richmond,	255
Schenectady (McQueen),	231	Rogers,	269
Schenectady, original type,	231	Brooks four cylinder tandem,	283
Schenectady, design of 1892, with Southern Pacific modification,	234	Cooke,	291
Schenectady, design of 1896,	235	Dickson,	296
		Rhode Island,	300

Appendixes:

Appendix A—Air brake tests,	305
Appendix B—Principle of the air pump,	311
Appendix C—The locomotive lubricator,	321

 BOOK III.

GENERAL INDEX TO THE "SCIENCE OF RAILWAYS."

Introduction,	9
General Index to the "Science of Railways,"	11

RESUMÉ OF THE WORK, AND DEDICATION.

With this volume I bring my account of railroads to a close. The subject is a great one and covers, incidentally, the science of political economy, the ethics of business and the methods, habits and morals of men. Economic questions that enter into the calculations of traders, merchants and manufacturers, and the principles that govern those who employ and manage men, form a most important part of it.

Naturally, in my books, practical questions that concern the operations of railroads take precedence of all others.

But those who would comprehend the subject in its entirety must understand the principles of political economy that permeate it throughout as well as more practical details. For this reason I have given the former such space as I have been able.

Railroads are affected in their operations by natural laws—physical, moral and intellectual. Each is a potent factor. In their solution those who own railroads, those who manage them, those who work for them and those who patronize them are concerned.

Each day it becomes more and more apparent that the greater the wisdom exercised in governing railroads, the greater success they achieve; the less friction there is between owners, employes and patrons; the more profitable railway property is; the more contented and happy employes are; the better the public is served, the more friendly it is. Everything that contributes to this end serves a good purpose. Books are as valuable here as in the practice of medicine, law, government, the art of war, or other subjects that are too great to be comprehended by one man.

If in my writings I express anywhere opinions unfavorable to existing methods it is not necessarily because I believe them to be wrong in practice. Managers of railroads are the creatures of circumstances. Railway corporations, like governments, are compelled to accept for the moment situations as they find them and adapt themselves thereto with the best grace possible. However high their aim, present methods must conform to what is practicable. With greater knowledge and better resources the high purposes of today that are merely speculative may become realities.

Many portions of my books are devoted to specific details; to recounting particular methods of administration. In being minute I have erred, if I have erred at all, on the safe side, for while the views of particular men may not be accepted unqualifiedly by others, they are none the less

valuable. In this as in other things, what we read is, as I have before had occasion to remark, very often more valuable for the ideas it suggests than the thoughts directly conveyed. Where so many things have to be considered, as in railroads, before it is safe to act, the more extended our horizon, the greater our knowledge, the safer guides we make. Hence the value of experience, observation, treatises, descriptive books, etc.

In regard to the foregoing eleven volumes, other men, I must believe, have, each in his particular place, given many of the subjects discussed more attention than I. Of their methods, so far as I have been able to gather them, I have been an attentive student all my life. From them I have sought to learn. I have nothing to say, it is probable, in regard to their several lines of thought, that will greatly interest them. On other subjects I hope it may be different. Those I write for, however, are that great class, growing greater each day, whose knowledge of railway operations is necessarily circumscribed and whose opportunities for learning are limited. To these I hope my books will be something more than an exposition of well known facts or possible eventualities. They will open up to them many complex and interesting questions that enter into the origin, working and destiny of railroads, which would otherwise forever remain a sealed book, and without a knowledge of which their prospects in life would be much restricted and their usefulness greatly lessened.

No business interest is so divergent as that of a railway. The corporation itself is perpetual. It is the creature of circumstances. It serves all alike. It is a repository of great and varied trusts. It is at once a manufacturer and trader. It employs myriads of men. Its duties are complex, its responsibilities manifold. In its proprietorship it possesses the conservatism and high constructive qualities necessary to the accumulation and retention of property. Herein it is fortunate, for men of this class are the natural rulers of the world and the highest and best friends of those who do not possess their peculiar attributes. It was through their combinations that men first achieved freedom and the comforts of life. These highly desirable acquisitions cannot be preserved without their assistance and guidance.

In considering the affairs of railways, every interest must be remembered, that of owner, patron, officer and employe. All their rights, ambitions, projects, prejudices, habits, weaknesses and ignorances must be severally weighed and considered. Not to do so would be to jeopardize, certainly to weaken, the whole structure. For these reasons the philosophy of the subject, quite as much as its practical details, finds a place in the accompanying volumes. The theme is the most important of our day, and may truly be called Scientific. I regret my inability to do it greater justice.

I have had many new and original cuts prepared for this edition of the Manual to show not only the details of parts or their working which are not generally well understood, but especially to show the proper method of procedure in case of many accidents. It is a well known fact that no words of explanation, however complete and explicit they may be, can convey the information that a picture instantly affords.

In concluding these volumes, upon which I have been engaged so long, I wish to dedicate them, however unworthy, to the officers and employes of the railroad corporation with which I have been connected during the whole of my business life, now over forty years. This association has bred in me far deeper sympathies than those of a business character merely; in the long years that have passed officers and employes have become brothers, and the property itself has become imbued with life.

MARSHALL M. KIRKMAN.

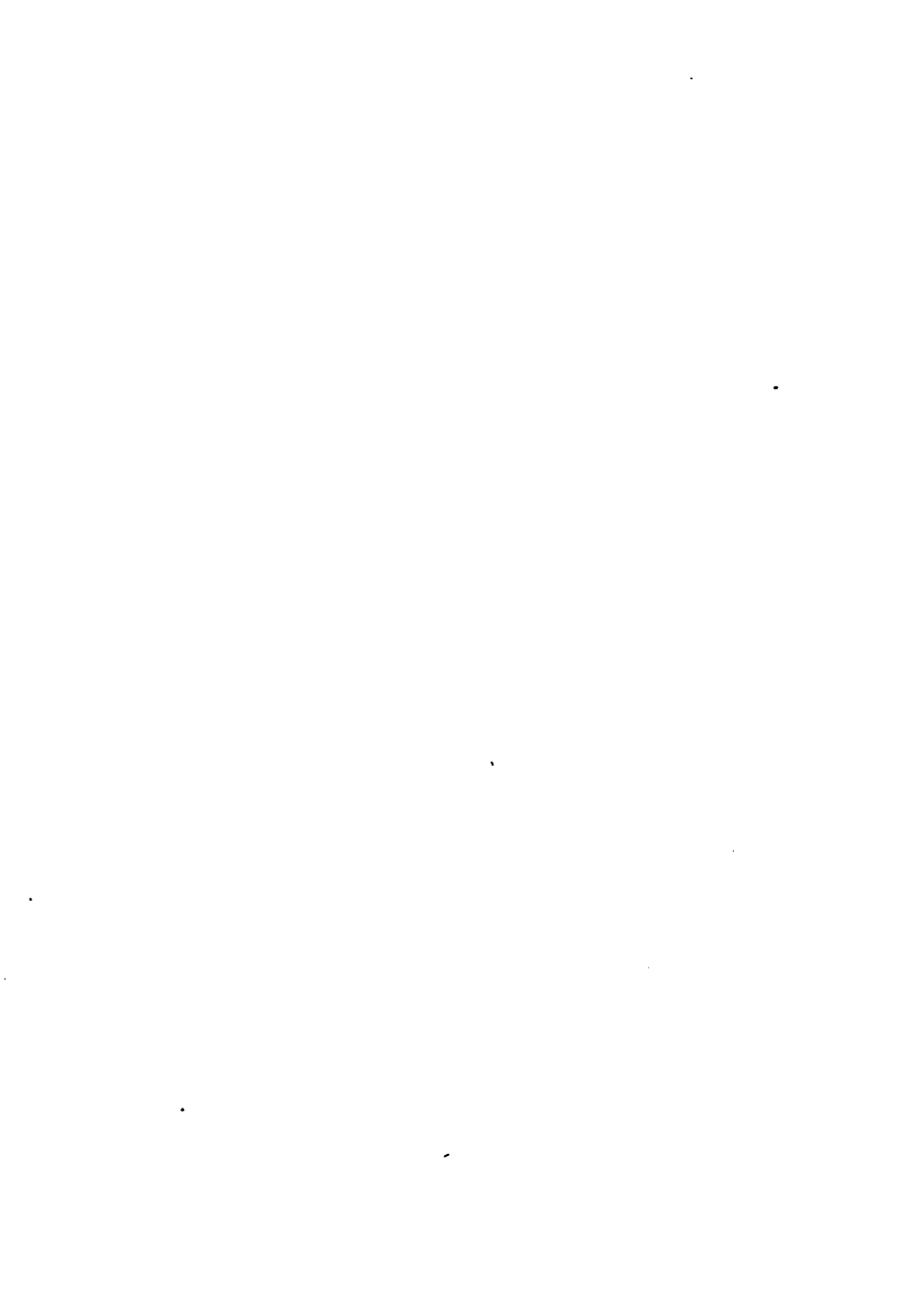


BOOK I.

ENGINEERS' AND FIREMEN'S MANUAL,

OR

**COURSE OF STUDY FOR THOSE WHO
SEEK TO BECOME ENGINEERS.**



ENGINEERS' AND FIREMEN'S MANUAL,
OR
COURSE OF STUDY FOR THOSE WHO SEEK TO
BECOME ENGINEERS.

THE LOCOMOTIVE ENGINE THE KEY TO THE RAILWAY WORLD: QUESTIONS REGARDING SELECTION, TRIAL AND WORK OF THOSE IN CHARGE. THE VALUE OF SYSTEMATIC STUDY AND CAREFUL EXAMINATIONS TO THOSE WHO WOULD BECOME EFFICIENT ENGINEERS.

The books that make up the "SCIENCE OF RAILWAYS," of which this is a part, have much to say, directly and indirectly, about the Equipment and Train Service of railways. Both these subjects bear directly on the duties and responsibilities of engineers and firemen. It is as impossible to afford a separate and connected account of such duties as it is to afford such an account of the duties of superintendents or comptrollers. Railway service laps and interlaps in every direction, and the engineer and fireman to fully understand their duties must also understand the things that are germane thereto. This requires that they should study railroading not piecemeal, but as a whole.

It was the impossibility of separating the duties of particular departments of the service and describing them apart that first constrained me to take up the subject as a whole. I started

out to describe particular branches of the service, but quickly found that their connection with the others was so close as to render a description of the whole necessary. Thus I was led reluctantly and contrary to my original intention to take up the subject in its entirety. What I have been compelled to do, others, who seek to fully inform themselves in regard to particular branches of the service, will also be compelled to do.

While there are many engineers and firemen who take this comprehensive view of the subject, others believe their field lies more apart and that, therefore, it is susceptible of separate delineation and study. There is much interesting and valuable literature extant on the subject of the duties of engineers and firemen, but for the reason stated, it only partially explains their offices. This does not, however, lessen its value, so far as it goes. It is simply incomplete.

Knowledge of the locomotive and how it is operated is only one of many things engineers and firemen must know. They must also be familiar with train regulations, signals, methods of dispatching trains and kindred knowledge. Such things are fundamental. Moreover, as their duties bring them in daily contact with the equipment, they must know something of its construction, care and maintenance. The wider their knowledge, the greater the probability that they may some day become department directors instead of operatives merely.

Nor need their ambition be thus restricted. The nature of their duties affords an admirable opportunity for acquiring the knowledge required by superintendents and managers of railroads. All that is needed is that he who sets out to familiarize himself with the locomotive shall keep on until he becomes acquainted with the needs of other branches of the service. The task is difficult, but not insurmountable. The knowledge may be acquired by experience, study, observation, inquiry and the thousand and one devices ambitious men adopt to further their ends.

A man who seeks merely to be a fireman, and then an engineer, and afterward, perhaps, a foreman, may be satisfied with a mechanical or perfunctory knowledge of the railway world, but such knowledge is not sufficient even for this limited field. However, he can possibly get on thus without scandalizing the service, or seriously jeopardizing the interest of his employer, but if he expects to occupy a position of greater power and influence, he must study railroading as a whole. Only thus can he comprehend the spirit and practices that animate the service, or cope with the many men of talent who fill its offices.

To be an officer of a railroad, or to fill a position of responsibility in connection therewith, requires that the incumbent shall understand the science of government. This science is in essential things alike as regards public and private

corporations. To know how to govern a country or city well, is to know how to govern a great railroad well with its vast army of employes and widely extended and complicated interests. The man who seeks preferment in either must understand how governments are formed and how best carried on for the common good. He must know much about the checks and safeguard; that experience proves to be needed in order to secure a strong and pure government. Such knowledge, as I have said, constitutes a part of the science of railroads, and no man is fully capable of being an officer of a railroad or of holding a position where he must come in contact with the public, without possessing it. This feature of the situation I have sought to explain in my books as conscientiously as I have the basis of rates, safe conduct of traffic, or the faithful handling of a company's money, but the information is not to be found in any particular chapter or book. It permeates every part of the service and it is impossible to discuss any question without more or less reference to it. It is this fact which makes men familiar with the magnitude and homogeneity of the subject, so impatient of those who think that there are departments and branches of the service that may be considered apart from the rest.

Those who work for railroads, no matter where, are interested in acquiring knowledge of every department of the service, and this not perfunctorily, but systematically. Their personal inter-

ests not only require that they should possess this knowledge, but the interests of their employer as well. The more the subject is studied, the more this truth will be apparent. I am not so presumptuous as to believe I have exhausted the science of railways in my books. If a book could be made exhaustive, there would never be but one written. The greatest value that any book possesses is the suggestions it affords the person who reads it. He may find many things upon perusing it, that he did not know before, or only surmised; others again that he had overlooked. He will be refreshed as by a bath, even though he has only acquired a morsel of original information from what he has read, for the reason that his knowledge will have been expanded by the thoughts to which his reading has given rise. Let railway men keep this in mind in reading books on railway and other subjects.

I have sought to treat my theme as fully as circumstances permitted. Where I do not wholly enlighten, I may be pardoned for believing that I have at least pointed the way.

There are few of the books that make up the "Science of Railways" that do not contain matter of more or less general interest and value to those who seek to be firemen and afterward engineers. However, if the latter position is the height of their ambition, then some of the books will not possess as much value as they would under other circumstances, but in every book may be found some account of the practices and

philosophy of railroading with which it is desirable every one should be familiar.

Much of the information that books on the general subject of railroads contain is not necessary to a fireman to enable him to creep up to the place of engineer, any more than salt is absolutely necessary to a potato; but he like every railway man, if lacking in the niceties of his profession (that only general knowledge can supply), will lack flavor and will seek in vain to reach the highest positions in the service.

From the foregoing it will be seen that a consecutive and separate account of the duties of engineers and firemen is impossible. However, there are particular duties imposed upon them that may be described apart. These I shall embody here. While incomplete, the matter is not the less valuable on that account, as it is replete with suggestions. This I may say with the greater freedom, as I am the editor, rather than the author. What I shall have to say is probably known to accomplished railroad engineers, but it is not known to those less favored, and yet they should be familiar with it, in order to be able to look forward with confidence to preferment in their calling. Furthermore, if instead of treating what I have to say as final, the student in search of knowledge will look upon it as rudimentary only and supplement it with acquisitions of his own, he will not only add greatly to his prospects as a railway man (by adding greatly to his value to his employer), but he will increase immeasurably

his ability to secure a position, if through any untoward circumstances, he finds himself without employment.

As the engine is the key of the railway world, so those who operate it share in its supreme importance. While admirable in outline and usefulness, it is after all only an aggregation of metal fashioned into many curious forms, but dead and incomplete without the guidance of the engineer and fireman. Like the world in the beginning when clothed in stillness and death, awaiting the light of day, so the locomotive stands apart, cold and dead, but under the inspiring influence of the Engineer and Fireman pulsates with life, forming not only a magnificent picture in itself, but one of the most useful implements ever designed by men for the use of men.

The locomotive is still in a state of evolution, and, sympathetically, those round about it are changing not only in the particulars of their duties, but in their aspirations and lives. The engineers and firemen of early days bore little resemblance to their brothers of the present period. The latter have not only personally acquired greater skill, but they possess also the accumulated experience of those who have gone before them. It is no exaggeration to say that the fireman of to-day, even if a novice, is much superior in capacity to the engineers who had

charge for a long time after railways were first operated. The first enginemen were by trade, blacksmiths and mechanics, who understood something about metals and machinery, but were ignorant of the uses of steam or the future possibilities of the locomotive. It was necessary to train men for the position. This process has been going on with ever accelerated speed from the first day up to the present moment. There is no end to the road. It grows wider and the horizon expands with each advancing step.

The firemen and engineers of railways constitute as highly a trained class of men as there are connected with the technical world of trade at the present time. Their knowledge and usefulness will increase with time and further experience. It is only reasonable to believe this because we know that possession of knowledge only intensifies the desires of men in this direction. Its acquisition by an ambitious man creates an unquenchable thirst for further light. His mind expands with his opportunities in this direction until the vacuum of the brain appears so much greater than its filled space that the wisest man becomes despondent at the meagerness and superficiality of his knowledge.

It is only the supremely ignorant man whose mind is at rest.

With each passing day, knowledge becomes more and more a necessity to men. The advantages the informed man has over his ignorant brother, are so great that the latter must likewise

acquire knowledge or confine himself to the common drudgeries of life. This is what competition is doing, and it is thus showing itself as useful in this department of life as it has in the production and interchange of material commodities.

Men have no inherent love of study, but the taste grows, and if one man studies, all must eventually study or be outstripped in the race of life. Thus the ambition of a particular man starts the whole forward. When men acquire a desire to learn, moreover, their ingenuity supplements the efforts of others, and in this way accomplishes a double purpose, at once encouraging and beneficent.

As the driftwood carried to the coast of Spain suggested to Columbus the unknown world of America, so the questions and answers embodied further on herein will suggest a host of collateral ideas of great value both to the student and his employer. These inquiries measurably dispel the darkness, but do not fully light up the horizon. And so it is generally in reference to books. A great good that they serve is the thoughts they give rise to in the minds of readers. The capillary attraction of the human mind thus exemplified, if I may thus characterize it, has this attractive feature, that above the water line of acquired knowledge it ever attracts to itself, all that is necessary to nourish or expand it. It is this feature of the brain reaching beyond original limits, that has made man the arbiter of the world, and that makes all things an

open book to him. The only difficult thing in his case is to get his mind in motion; once under way, it never ceases its inquiries until death silences its action.

In the case of engineers and firemen many methods have been devised for adding to their knowledge so that they may better serve themselves and the great industries with which they are connected. In some of the old countries of Europe, and particularly in France, technical schools have been established near the great shops by railroad companies, so that the children of employes may early in life be instructed in the trade they design following, and this under the immediate eye of their father. Thus, as they grow up, they associate themselves with him and afterward, when he is too old to work, succeed him in his calling. In this way, the child is brought at the most receptive period of its life into direct contact with the things that are afterward to occupy its mind exclusively. The advantage of this cannot be overestimated, for we all know that there is a particular period in life that is illuminated more brightly than any other, when what we learn we do not forget nor undervalue. This period, to a great extent, forms the groundwork of every man's life. Consequently, if during such period light is thrown on the work that is afterward to occupy him, it exceeds in value knowledge acquired at any other

period. For this reason, the benevolent intentions of the corporations in providing schools for the children of employes, will, it is reasonable to believe, be followed by the best possible results to themselves. However, the schools are not intended for the children of firemen and engineers alone, but for all employes engaged about the shops.

Usually the effort to educate men for engineers and firemen does not commence until the men have entered the service. This is where the great bulk of the railroads of the world take up the work of instruction. The method they follow in carrying out their object is as diversified as it is in other things connected with the service. Formerly, applicants were put on the locomotive, and told to go to work, their preparatory instruction being of the simplest possible kind. This practice is still extensively followed. In other cases, the fireman is compelled to serve a brief apprenticeship in the roundhouse. In still other cases, the preparatory period is more extended and the labor prolonged. Some companies go so far as to require a man who seeks to become a fireman to commence emptying clinker pits, cleaning and wiping engines, and performing such mechanical duties in connection with the locomotive as occasion requires. If he shows adaptability and industry, he is after a while given an opportunity by being put on the Extra Firemen list. Here his action is carefully scrutinized. If he meets just expectation,

he is in due course made a regular fireman, the assistant and second self of the engineer. Here, while he has his own work to do, and plenty of it, he has an opportunity to familiarize himself with the work of the engineer. The facility with which he does this, will depend upon his ability to learn and his desire to get on in the world, but assuming that he, not less than his older brother the engineer, is animated by an acute intelligence and a laudable ambition, he must also have, like the latter, good health, a strong body, and be free from intemperate habits. These latter qualities are more necessary to those connected with locomotives than to others in the service, although they are necessary to every man who expects to achieve success in life.

It goes without saying, that every man who seeks to be a fireman, or who expects to become an engineer, must have a good character.

The practice of examining into the qualifications of applicants before hiring them grows in popular practice every year. Men are scrutinized more carefully than formerly, and once having entered the service, greater intelligence is exercised in ascertaining their capacity and usefulness. This is especially true of those branches of the service where technical skill is required and perfect trustworthiness needed. In the early days it was sufficient that an applicant for the place of fireman was able to perform the work, which, under the most favorable circumstances, is very severe. Afterward, as experience taught

the necessity of it, railroad companies began to inquire into the antecedents of aspirants. By and by they got to inquiring about their habits, but railroads had been operated in America sixty years before it occurred to them to test the mental capacity and disposition of applicants by careful examinations. As this could not very well be done before applicants entered the service, it had to be done afterward. It took, in a general way, the shape of examinations such as characterize those of students of law and medicine. Meanwhile, the general trustworthiness of the employe was scrutinized and his mode of life, morals, temperament, steadfastness and general fidelity to duty carefully studied. If deficient in these latter respects, intellectual and physical endowments were not sufficient to outweigh objections. On the other hand, if he possessed all the moral qualities, and yet was deficient mentally and physically, he was not considered as affording good material for a fireman, and, prospectively, an engineer. Accordingly, if during the probationary period he broke down, or failed to answer the requirements of the service, he was told to go his way and in some field where his capabilities would be sufficient for the occasion fix his life occupation. This, instead of being a hardship or injustice, has been found to be a kindness to applicants, because it anticipates subsequent failure and saves them the waste of time and mortification that would otherwise ensue.

It also saves the company, and incidentally the public, from the mishaps that attend the service of men inferior in mental and moral qualities. It not only enables the employer to promptly separate the capable from the incapable, but throws around the general public a measure of safety that carriers are always bound to consider.

In order to pass the examinations, careful study and preparation, and experience as well, are required. Applicants must at least have a good common school education, because this is required of engineers. Once having entered the service it is manifest that the efficiency of the incumbent may be greatly heightened by requiring him to commence at once systematically to study the problems of the business with which he is identified, and not solely, be it remembered, with a view of performing his present duties properly, but with the further view of his being promoted to the responsible position of engineer, at a given time, or thereafter when opportunity occurs. Methods of procedure vary on different roads, according to men's views of the subject. Some roads do not make any examinations at all, but the tendency is more and more in that direction as their value becomes more and more apparent. The system which is elucidated further on, and which meets with the approval of some of the most experienced and talented Master Mechanics and Superintendents of Motive Power in the

world,* contemplates a careful and systematic course of study. First, however, the habits and antecedents of applicants are carefully inquired into, as I have intimated. Once the applicants have passed this ordeal, the full confidence of the company is accorded them and every facility afforded them to pursue their inquiries and studies so as to fit themselves for present and future work. Every official of the machinery department holds himself ready to answer questions or respond in other directions so far as it may be proper to aid applicants in this way.

After the applicant for the position of fireman has passed through the preliminary stages, whatever they may be, he is given a series of questions bearing directly on his future duties and responsibilities as an engineer. These he is expected to carefully study, and at the end of the time designated, go before the master mechanic or other authorized officer and answer them categorically, with such other questions of an incidental nature, as are pertinent to the occasion. However, the list of questions given him and the answers thereto constitute the examination in the main.

*Among these, Mr. Robert Quayle, who stands in the first rank in knowledge of railway machinery and equipment and in conscientious effort to make this great department of the service all it should be. He has no superior as a student or executive, and I desire here to thank him for valuable information and assistance. I am indebted to many others but to him especially and particularly.

M. M. K.

Having passed the first examination successfully, he is furnished a further list of questions he will be expected to answer. This constitutes the second examination. Following this he is furnished the interrogatories which close the course of study.

In regard to the last examination, no one is ever sent to take it, whom the master mechanic above him is not willing to accept as an engineer provided he successfully passes it. Another condition and a very proper one is that men sent forward for this examination shall be in their order of service, other things being equal. The final examination, which is so important, is usually conducted by a board appointed for the purpose. This insures impartiality and thoroughness, though the same thing can, it is apparent, be secured by an examination made by the master mechanic and his associates.

All the examinations having been passed and the applicant's work meanwhile having proven satisfactory, he is ready to take charge of a locomotive — is an engineer in fact, ready to fill the first position of the kind that offers. This is the goal he has sought. Such is the procedure.*

* It will not be forgotten, in this connection, that the applicant has long before this demonstrated his moral and physical fitness for the position of engineer. Sometimes the physical examination is conducted by the machinery department, and at other times by the surgical department of the railroad. As will be noticed farther on, each applicant before being passed is examined with a view to ascertaining whether he is perfectly familiar with the time table, or not; also with the signals. The

Different roads vary the details. Its merit is that it affords a course of study, which, with the practical experience of the fireman meanwhile, makes of him a trustworthy engineer. This is what every fireman strives for and what his employer requires of him, for it is thus engineers are made.

If during the progress of the examinations candidates are unable to pass or answer the questions, it is generally thought well to extend the time a reasonable period.

If at the expiration of the time allotted the applicant is unable to pass, then the expediency of his seeking other employment naturally suggests itself, and this last for two reasons, as I have already intimated: First, that the service may not be clogged by men who cannot ultimately be promoted; and second, that applicants shall not be allowed to waste their time upon work not destined to be of lasting advantage to them. And in this connection it is not considered too much by those versed in such matters that applicants shall answer satisfactorily, both in

examinations in regard to these last are sometimes conducted by the machinery department, but more frequently, perhaps, by the operating department. Upon many lines, the superintendent is not satisfied until he personally ascertains that those taking charge of engines are familiar with the rules, familiar with the time table, and familiar with the signals. The machinery department looks especially to the technical fitness of those in charge of locomotives: the operating department requires in addition to this, perfect familiarity with the the rules governing the movement of engines and trains over the road.

writing and orally, eighty per cent of the questions asked them in each of the examinations.

And in regard to applicants, every assistance possible is rendered them, as already intimated, and they are at liberty to go to master mechanics, foremen and others for information in regard to those things they do not fully understand.

It will be seen from the foregoing that in no sense will the course of study be forestalled by the questions that are propounded and the answers thereto that are contained herein. Both the questions and the answers applicants will find it useful to critically study, as students pursue their studies at universities; but they must not only know the correct answers to the various interrogatories (because every engineer must understand them), but must understand their purport, so that they can reply to each question in their own language and according to their understanding of it. They cannot use the answers embraced herein—these are intended to be merely instructive. They must frame answers for themselves. Thus it will be seen that, while the assistance this Manual affords will save them much inconvenience and many inquiries, it will not save them from the necessity of studying and framing an answer of their own to each inquiry that the examinations contain.

Parallel with the examinations, and along the same lines, it is a growing practice on many well managed railroads to maintain schools of instruction for the purpose of teaching train men, and

particularly engineers and firemen, in regard to the construction, use and maintenance of the air-brake, steam-heating apparatus, use of gas and electricity for lighting, and other implements of an intricate or scientific nature that are used on trains. The expense of this systematic course of instruction is more than offset by the increased efficiency of those thus instructed. The efforts of railway companies in this direction are everywhere actively seconded by their employes, as it adds to their usefulness and renders more certain their promotion, or if not promotion, then successful competition in the strife for place and its retention. Accurate and extended knowledge of their duties, aside from its present value, cannot, it is also apparent, but be of the greatest possible use to those who possess it, should they, through the cutting down of a force or otherwise, find it necessary to seek employment elsewhere.

The examination of firemen and engineers has been disregarded on many roads, but it needs little discernment to see that this state of affairs cannot continue always. Companies lacking this element of strength will not be able in the long run to make a showing as against companies whose force throughout has been carefully instructed in technical knowledge of the highest order in regard to their duties. The omissions and mistakes of the inefficient and the scandals they will create, to say nothing of the extra expense such men entail, will compel the companies employing them to adopt a more compre-

hensive plan of selection and instruction, first with a view of preventing inefficient men from entering their service, or in case they have such, to weed them out as soon as possible in the event they prove to be incompetent. In making these examinations the railroads will only forestall the act of the state, for it is only a question of time, and a short time at that, when firemen and engineers will be compelled to go before a State Board for examination as to their fitness, the same as steamboat engineers are required to do, unless the railroad companies forestall such action by themselves making the examination.

The questions that it is proper to propound to applicants for the position of engineer are many and intricate. The answer to each question, it will be observed, is of a nature to familiarize the applicant with his work and to make him of greater present usefulness, to say nothing of the future. The sooner, therefore, the applicant familiarizes himself with his present and prospective duties the better for him and his employer. The quality of service that the fireman renders while fitting himself for promotion, also operates for or against him finally. His work during this period is compared with that of others, as is also the care and intelligence he exercises in the use of oil, fuel and other supplies.

The position of fireman, it is proper to say, is not only one exacting hard work, but considerable knowledge of detail, so that he has an

opportunity to show fitness in this respect, which is all-important in the positions that he aspires to fill.

In propounding the questions that follow, it will be noticed that no fixed or predetermined formula is observed. They are, however, specific and such as are suggested by the practical experience of those versed in such matters. I do not seek here, any more than elsewhere, to be original, but rather useful; to supplement my limited knowledge wherever possible by the wider knowledge and experience of others. The particular form that an examination shall take is not material, if it is effective. The method I have followed is the commonplace one of interrogating the applicant by asking him questions. It is probable that with the growth of the service the list of questions will be extended. That would be of advantage to the applicant if it will extend his knowledge.

In reference to the answers to the various questions, it is not expected, as already intimated, that applicants will restrict themselves either to the scope or words I use. The answers I give, while correct, and such as to throw a clear light on the subject, are not exhaustive.

The fireman who passes an examination is expected to answer the questions correctly or at least eighty per cent of them. The information I give will help him, but it is also intended he shall give the matter exhaustive thought on his own account. The subject is a growing one and

it is expected of firemen as it is of every man connected with railroads, be he high or low, that he will not be satisfied with what he knows, but will strive to keep on acquiring knowledge. I do not here any more than elsewhere seek to forestall personal research, but to add to the desire to acquire it by careful study and thought.

With these explanatory remarks I will take up the several examinations in their order, and first, the inquiries that every fireman (whether already in the service, or just entering it) may at any time expect to be put into his hands to be answered at the end of some specified time. A full knowledge of the questions propounded and the answers thereto will aid him, not only in the direct examinations to which he will be subjected, but in replying to collateral questions which will arise impromptu as the examinations proceed. Afterwards will be taken up the questions that in the natural order of things will be submitted to the fireman after the first examination has passed, to be answered at some specified time. Then those questions which constitute the final examination and upon which depends the appointment of the fireman as an engineer.*

* In the event a railroad company does not require an examination such as I refer to, still a study of the subject as here presented will, as already intimated, materially aid firemen and others in acquiring the knowledge they must possess in order to fit them to run an engine. The subject therefore, no matter how it presents itself, is of interest to them.

The questions and answers, constituting the three examinations are generally familiar to engineers. Nevertheless, in their aspect and grouping, they present new features that will prove interesting and instructive even to them. While designated for firemen seeking advancement, they cannot prove otherwise than useful to such engineers as may, in the natural order of things, be doubtful as to their ability to pass a critical examination, should one be instituted by the state or the railroad company.*

STEAM AND ITS APPLICATION TO THE LOCOMOTIVE.

Before formally taking up the examinations already referred to, it will be proper to preface them by a brief description of the simple and primary application of steam to the locomotive. I know that such matters are well understood by engineers and firemen, and are not, therefore, of value to them; but to those who are not familiar with the subject, they are interesting and instructive. Books and lengthy treatises have been written on the subject, but, stripped of padding and unnecessary words, there is very little to be said if we omit other matters relating to the locomotive, including that of the art of firing, which things I have fully pointed out elsewhere. What I wish

*They appeal especially, so far as they go, to engineers who are not familiar by practical experience with present methods of firing. The engineer not familiar with the needs of to-day and the exacting requirements in regard to the best (scientific) methods of using fuel must lose no time in becoming so, if he desires to maintain a place in the front ranks of his profession.

to say here, therefore, relates simply to the process of getting the locomotive under way.

The power that imparts motion to the locomotive is the expansive force of steam. This force, which has been known for thousands of years, was first utilized for purposes of carriage in the early part of the nineteenth century.

As stated elsewhere, steam is the vapor of water generated by heating water above the boiling point. Hence steam is water in a gaseous state and is colorless and imperceptible to the eye. Saturated steam is steam either in contact with the water from which it was generated or, if separated therefrom, is kept at the same temperature and pressure. Wet steam is steam not only saturated, but also holding in suspension unevaporated water in the form of minute drops; it holds this water in suspension mechanically, due either to the ebullition of the water from which it is generated or else from a rapid flow of steam from near the surface of the water, in a similar manner as the wind off a rough body of water is noticed to carry drops of spray. Dry steam is the term usually used for saturated steam in distinction from wet steam. Superheated steam is steam removed from contact with water and heated above the temperature of the water from which it was generated; it is variously called steam-gas, surcharged steam, or anhydrous steam. Steam more closely resembles a perfect gas when superheated than in any other state, and it is for this reason that in the locomotive the attempt is made to superheat the steam. The boiler has a

dome from which, and at quite a distance above the usual water level, reasonably dry steam is taken, passed through a pipe called the "dry pipe," and branching in the smoke-box or front end of the locomotive where the escaping hot gases have a tendency to superheat it, passes into the two cylinders in which its energy becomes useful.

In steam, as in other gases, there is a natural repulsion between its various particles, each particle trying to separate itself from the others, so that it will fill the receptacle in which it is placed, regardless of the quantity of steam or size of the vessel holding it. Its natural tendency is to expand and thus push out whatever resists expansion. If the steam is enclosed and superheated, therefore, as in the case of a locomotive boiler, the natural tendency of its particles to separate is intensified and we thus obtain, according to its quantity or volume, the steam pressure required.

The vapor seen escaping from a vessel of boiling water, or rolling in clouds from the exhaust pipe of a locomotive, is only a modification or diluted agent of the mighty force that does so much of the world's work. This vapor is steam that is resolving itself back into water; the change or condensation which is visible is caused by its contact with the cold air. Real steam, as just stated, is an invisible gas, or, rather, a transparent fluid, really water changed into gas by the action of heat. Accordingly, to make the steam that an engine requires water must be boiled. To hasten this and to lessen the cost, the boiler is permeated with tubes, or flues, con-

necting with the fire-box, into which the flames therefrom are drawn, thus multiplying the heating surface and, in so far as this is done, hastening the boiling of the water and the generation of steam.* As the water is transformed into steam it rises into the dome, as will be seen by reference to the diagram of the locomotive. From there it is released by opening the throttle valve and is thence conveyed, through what is known as the dry pipe and steam pipes, through the steam chest, thence to the cylinders.

It is, as is well known, the expansive power of the steam operating through the mechanism of the cylinders that affords the propelling power of the locomotive.†

In order to utilize this power there is connected with the cylinders a steam box which is commonly termed the steam chest, in which there is a slide valve, under which are three ports or openings, one leading to each end of the cylinder, and, the third leading to the atmosphere. The slide valve has a reciprocating movement whereby these ports are opened or closed. Motion to the valve is imparted by the revolving driving-wheel axles in various ways, the most common of which is by means of eccentrics and links with connections to the valve stems, as fully explained and illustrated elsewhere herein. The cylinder is

*This as well as other matters relating to the construction and appliances of locomotives is illustrated and described elsewhere herein.

†For diagrams of the various cylinders and the action of the steam therein, see various cuts contained in this work, both of the simple and compound patterns.

fitted with a piston. This is movable back and forth from one end of the cylinder to the other. Thus the steam from the boiler is introduced through the steam chest into one end of the cylinder and forces the piston to the opposite end; then the valve opens the port at the other end of the steam chest and allows the steam to enter at the opposite end of the cylinder, and at the same time connecting the other side of the piston with the atmosphere, thus allowing the steam just used to escape; this reversal of pressure upon it forces the piston back to the place whence it first started. The escape to the atmosphere takes place through the smokestack in order to create a greater draught on the fire. This action back and forth, at first slow, is almost inconceivably rapid when the locomotive is under full headway. The piston described is in its turn, attached to a rod which works through a closely fitting opening in the back end of the cylinder. In this way the motion is carried outside of and beyond the cylinder. To the end of the piston rod just referred to is attached the connecting rod which, in turn, is attached to the crank or revolving shaft of the driver. The backward and forward motion of the piston (called "reciprocating motion") is thus converted into a revolving or rotary motion. It is observed, however, that the connecting rod, when it has carried the crank backward or forward as far as it will go, loses its reciprocating motion and the piston will no longer produce a rotary motion. These positions of the crank are

called its dead points. In the stationary engine this is overcome by a fly wheel, the momentum of which carries the crank past the dead points; then, too, stationary engines of one cylinder are not required to frequently stop and start with a load, as are locomotives. In the case of a locomotive the obstacle is obviated by having two cylinders with cranks, placed at right angles to each other and on the same axle; also, as the service demands the movement of the locomotive in either direction, backward or forward, the valve motion is so constructed that the engine is reversible.

It is thus that the steam is generated and its power applied. I would in this connection refer the reader to the chapter on "Description of the Locomotive."*

*See "*Railway Equipment*," Vol. I.

DUTIES AND RESPONSIBILITIES OF ENGINEERS.

FIREMAN'S FIRST EXAMINATION.

How long have you been in the service?*

How long have you served as a fireman?

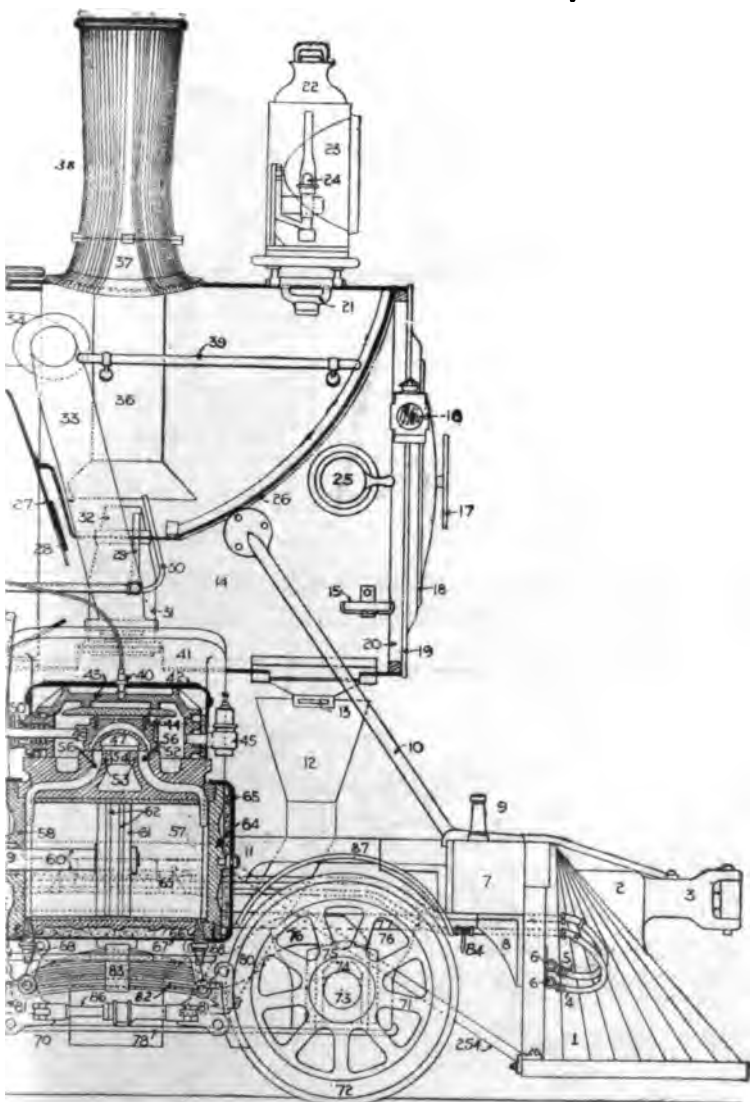
What should you do on arrival at the round-house previous to your departure therefrom with your locomotive? I should draw the necessary supplies and see that the lubricators, lamps, oil cans, tank and sand boxes are filled. If the coal be bituminous, I should see that it is broken and wet down, that the cab and its fittings are wiped, the ashpan cleaned, and the grates straight, so that coal will not drop through them.

When on duty, do you compare your watch with that of the engineer to see that they agree?

As it is the duty of the engineer to show you any train orders that he receives, are you particular to see that the rule is always observed?

Are you familiar with the signals?

*In the army and navy, fitness being the same, promotion is dependent on length of service. Promotion in the railway world also depends on length of service, provided the qualifications of applicants are alike. Continued and trusted service, it will thus be seen, in the employ of a particular railroad company is a matter of the greatest importance to those who seek preferment.



AILWAYS."

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Please describe them.*

In addition to the danger signals enumerated, is there any other signal that you consider a danger signal? Yes, any violent motion made in front of a train.

What is the source of the power of a locomotive? Heat.

What is steam? Vapor, generated by heating water above the boiling point.

What do you understand by the pressure indicated by the steam gauge? The pressure of steam in pounds per square inch above atmospheric pressure.

What is meant by atmospheric pressure? The weight or pressure of the atmosphere, namely: about fifteen pounds per square inch at sea-level.

Has a locomotive a natural or a forced draught while working? It has a forced draught.

Why? Because of the exhaust steam escaping through the smokestack.

How does the exhaust steam create a draught through the fire? By forming a partial vacuum in the smoke-box and in the flues, which the hot air from the fire-box rushes in to fill, thus creating a draught.

*The hand signals that employes use, also the signals that are carried on locomotives and cars (indicating particular things), also the signals connected with the track, are fully described and illustrated in the book on "Train Service" in the *Science of Railways*. Any one seeking to be an engineer, or to answer the questions connected therewith, is respectfully referred to the book in question, as it will without doubt facilitate their research and knowledge of railway practice.

What good effect is produced by opening the fire-box door when the engine is at work? By partially opening the door black smoke and popping are prevented.*

What bad effect is produced by opening the fire-box door when the engine is at work? The chilling of flues and sheets, and thereby, through contraction, causing them to leak and warp.†

Is it necessary to have a large quantity of air to generate steam rapidly? It is, as the air supplies more than half the elements for combustion.

Does this apply to a heavy fire as well as a light one? Yes, the heavier the fire the greater the quantity of air required.

Has improper firing any tendency to cause flues to leak? Yes, in so far as it permits the cold air to strike the flues unnecessarily.

Define black smoke. Black smoke consists of a mixture of gases and carbon. The greater part of it is carbon, which is unconsumed fuel.

*Popping. Locomotive boilers are constructed to hold a steam pressure of a certain number of pounds per square inch (the maximum is about 200 pounds), and are fitted with two safety valves, regulated by springs, to hold that number of pounds. When the steam pressure exceeds that amount the valves open and allow the steam to escape until the pressure is reduced. The escape of steam through the (pop) valve is called "popping" or "blowing off."

†The reason flues leak when exposed to cold air is that the fire expands the flues and flue sheet (to which the flues are fastened), and when the cold air strikes them they contract, and the flues being lighter than the flue sheet, they contract faster, leaving an opening between the flue and its hole in the flue sheet. Pumping a great quantity of cold water rapidly into a hot boiler will have the same effect.

How can black smoke be avoided? By careful and scientific firing.

Why should black smoke be prevented? To save fuel and avoid dirt and annoyance to the public.

Has it been proven in practical service that proper firing will prevent black smoke? It has.

How is such firing accomplished? By the single shovelful process, or never putting into the fire-box, at most, but two shovelfuls at one time.

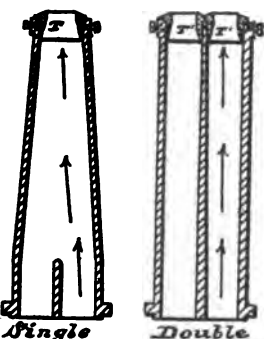
Is this manner of firing productive of economy of fuel? It is; a saving of between 15 and 20 per cent. has been obtained in actual service. It will also cause a more nearly uniform temperature to be maintained in the fire-box, thus lengthening the life of the flues as well as improving the steaming qualities of a locomotive.

Does the size of the exhaust nozzle affect the fire? Yes, by affecting the draught on the fire.

When the amount of fuel burned is greater in the front end of the fire-box than in the back end,

Fig. 2.

Fig. 3.



*The exhaust pipe, as its name implies, is a pipe for carrying the exhaust steam from the cylinders to the smoke-box of the engine and so through the smokestack. Suitably attached to the upper end of the exhaust pipe is the exhaust tip or nozzle, the size of which is altered in accordance with the draught requirements of the engine—a small exhaust creates a powerful draught, and *vice versa*. (See Figs. 2 and 8.) The steam is carried to the smokestack for the purpose of creating a forced draught through the fire-box.

— Exhaust Pipes —

what does it denote? It denotes that the greatest amount of draught passes through the bottom flues.

When the amount of fuel burned is greatest under the fire-box door, what does it indicate?

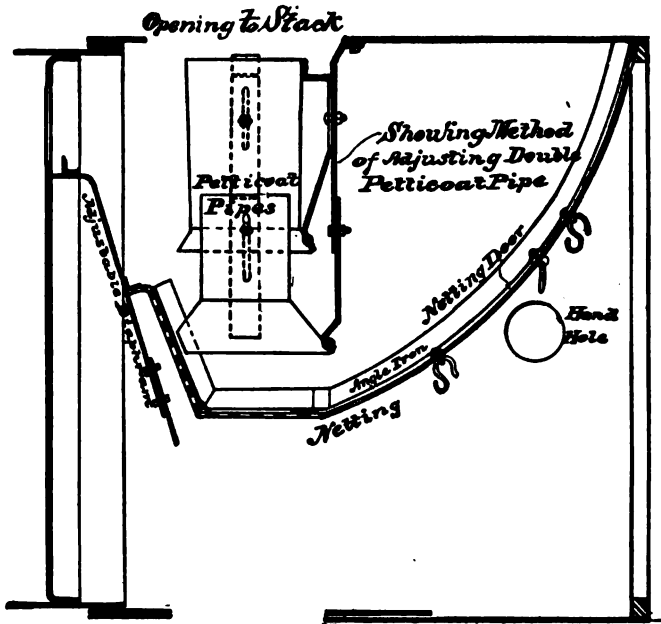


Fig. 4.
Draught Appliances in Smoke Box

It indicates that the greatest amount of draught passes through the top flues.

How can these defects be remedied? By adjusting the draught appliances in the smoke-box of the engine.

What is meant by the "draught appliances" of a locomotive? The diaphragm, the petticoat-pipe or pipes, the exhaust pipe and nozzle, and the netting. (See Fig. 4.)

How often should grates be shaken? They should be shaken as often as is necessary to keep ashes and clinkers from forming on them; it depends very much upon the kind of coal used.

What causes an excessive "pull" on the fire-box door?*

What is the result of opening the fire-box door when the engine is working? The temperature is lowered in the fire-box and flues.

Why is it important that bituminous coal should be broken into the size of an ordinary apple before it is put into the fire-box? Because it increases the exposed surface and can be better spread over the fire.

Why should the coal be wet? To prevent dust and dirt and to give weight to fine coal.

What should be the condition of the fire when a stop is made at a station or when the summit of a long down grade is reached? The fire should be burned down so as to prevent the engine either blowing off or emitting black smoke.

What is the proper method of using dampers? The dampers should be closed when the engine is not working. The back dampers should at all

*A "pull" on the fire-box door is caused by the partial vacuum always existing in the fire-box and smoke-box when there is a forced draught. This draught pulls the door shut, or holds it when it is sought to open it. If the fire-box is not kept free of clinkers and ashes, thus permitting the passage of air through the fire, there will be a stronger pull on the fire-box door.

other times be used solely (if possible) when the engine has a single ash-pan.

If the engineer keeps the injector working after the engine has been shut off, in what condition should the fire be kept? The fire should be kept burning brightly, using the blower lightly (if necessary) in order to keep the boiler at the proper temperature.

Is blowing off at the pop valves wasteful? Yes. It causes a waste of steam, and consequently a waste of fuel.

Describe a blower. It consists of a cock on the boiler-head with a pipe coupled to it, leading to and terminating in the smoke-box, and pointing upward toward the stack near the nozzle. (See Fig. 5, also Plate I.)

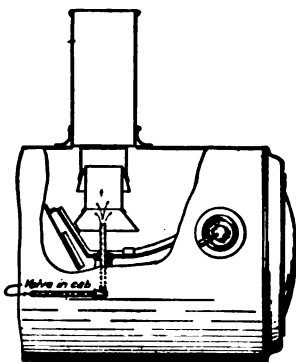


FIG. 5.

What is the use of a blower? Its use is to create a forced draught on the fire when the engine is not working.

Explain how the blower may be used improperly. By using it too strongly while the fire-box

and grates are being freed from ashes and clinkers, or while the door of the fire-box is open, when there is only a light or poor fire, thus forcing cold air through the flues, causing them to contract and leak.

Are you studying the subject of combustion?

In what way are the draught holes in the fire-box door and the deflector inside of the furnace a benefit? By permitting the oxygen to come in contact with the carbon and hydro-carbons, thus creating a more perfect combustion.

Do you, in the interest of the company, and for your own benefit as well, aid and assist the engineer in the performance of his duties whenever you can?

How much coal do you burn per engine mile and per mile per unit of tons hauled?*

What is the comparison in this respect between your record and others in the same service?

How do you account for any differences there may be?

If your engine runs two round trips over a division of 109 miles with one filling of the lubricator, how far are you running to the pint of valve oil, if the lubricator holds 3 pints? $109 \times 2 = 218$, round trip. $218 \times 2 = 436$ miles to 3 pints. $436 \div 3 = 145\frac{1}{3}$ miles run to the pint of valve oil.

If you use 8 pints of engine oil in the same distance what is your mileage per pint of engine oil? 436 (miles) $\div 8 = 54\frac{1}{2}$ miles per pint of engine oil.

*Statistics of companies are sometimes based on the engine mileage and sometimes on the pounds of coal burned per 100-ton-miles, i. e., in hauling 100 tons one mile or one ton 100 miles.

What is your mileage per pint of lubricating oil (both engine and valve oil)? $3+8=11$ pints; 436 (miles) $\div 11=39.64$ miles per pint lubricating oil.

Should you burn 18 tons of coal per round trip, what would be your engine mileage per ton? $218 \div 18=12.11$ (Answer).

If you hauled 1,000 tons each way over the division on this trip, burning 18 tons or 36,000 pounds of coal, how much coal would you burn per *100-ton-miles*? $1,000 \times 218=218,000$ ton miles or 2,180 *100-ton-miles*. $36,000$ (pounds) $\div 2,180=16.52$ pounds coal burned per *100-ton-miles*.

Suppose that you should pull only a caboose car weighing 20 tons and burn 3 tons for the round trip, how many pounds of coal would you burn to the *100-ton miles*, and would this increase or reduce your average for the month? 3 tons = 6,000 pounds. 218 (miles) $\times 20$ (tons) = 4,360 ton-miles or only 43.6 *100-ton-miles*. $6,000 \div 43.6=137.6$ pounds of coal per 100-ton-miles. It is evident by comparison with the preceding example, where a full train was hauled and only 16.52 pounds burned per *100-ton miles*, that this one trip, requiring 137.6 pounds, or over eight times as much, will make your monthly record higher than it would be otherwise. Heavy trains every day in the month make the best showing on the *ton-mileage* basis.

How would this trip affect the records if taken on the *engine mileage basis*? If you made 218 miles with 3 tons of coal that would be 72 2-3 miles run per ton of coal. But, in the former example, as your engine mileage with a full train

was only 12.11 miles per ton of coal, it is evident this trip of over 72 miles per ton would increase your monthly average.

Can you locate the different parts of a locomotive and give their proper names?*

Do you keep the engine which you fire in as clean a condition as circumstances permit?

What are your views regarding the use of fuel, coal, and other supplies and tools? They should be used carefully, with a view to the greatest possible economy consistent with effective service.

Do you comply cheerfully with all orders emanating from your superiors in the service?

What is of supreme importance to an engine or train when on the road? Their right to be there and their due and proper protection.

If you should discover that a fixed signal was missing or imperfectly displayed, what would it be your duty to do? It would be my duty to notify the engineer at once.

The foregoing constitutes the first examination. It is very simple and easily learned. However, it is desired that the student should meanwhile extend his knowledge in other directions. Among other things, he should familiarize him-

*The reader will note that the fine engraving of the locomotive (Plate I.) used in *Railway Equipment*, Vol. I., has been introduced into this volume as well, in order that reference thereto may be the more easily had. This complete chart, naming each and every part of a locomotive, will be found extremely valuable to any one who seeks to familiarize himself with the intricate machinery and the names of the different parts of a locomotive. The reference numbers throughout this manual which are inclosed in brackets, refer to the number of the part designated by Plate I., and should be carefully studied.

self in a practical way with the construction and working of the locomotive.*

*It is proper to repeat here that the inquiries and replies as embodied in this and the succeeding sections will vary more or less on the different roads that take up the system of progressive examinations, but whatever they may be, the knowledge embraced in these inquiries and the replies thereto will not only greatly facilitate the fireman in passing his examination, but will be a benefit to him in all his subsequent career.

DUTIES AND RESPONSIBILITIES OF ENGINEERS.

FIREMEN'S SECOND EXAMINATION.

NOTE.—As indicated in a preceding foot note, the book on *Railway Equipment* of this series, will be found to contain a carefully prepared diagram of the locomotive in which the different parts are numbered. These parts are frequently referred to in the examinations which follow. By reference to the number indicated, the reader will be able to locate the particular thing referred to. This reference, while possibly not necessary in every case, will, nevertheless, make the examination more easily understood.

The questions that suggest themselves in connection with the second examination, and the answers thereto, are as follows:

What has been the average amount of coal (or wood) consumed per mile run, or per mile per unit of tons hauled, by the engine fired by you during the past year?*

How many firemen, if any, have done better than this?

What are your relations with your engineer? (They should be of an amicable nature, so that you may freely and fully discuss with him every matter pertaining to your duties.)

What are your views in reference to the use of intoxicating liquors? (The occasional use of

*Upon many roads statistics of this kind are based upon the miles run by the locomotive. A much better basis, however, when it is practicable, is the tons hauled by the locomotive.

intoxicating liquors, if continued, results finally in their frequent and habitual use. This is not always the case, but as a rule tipping results finally in the participant becoming a drunkard. No one, of course, who indulges in the use of liquor ever believes such will be his case.)

Do you work to the best of your ability for the interests of your employer, and are you economical in the use of tools, fuel and supplies? Yes, I consider the interests of my employer as my own, and therefore economize in the use of supplies as if paid for by myself.

Do you understand the principle of combustion?

What is it? It is the uniting with oxygen of any combustible material that has been heated to the point of ignition.

What is carbon? It is the element which forms the chief part of every kind of solid fuel.

From what is oxygen obtained? From the atmosphere.

What other gas does the atmosphere contain? Nitrogen.

Which element forms the greater portion of the atmosphere? Nitrogen has a volume of four parts to one of oxygen, but by weight is only double the latter.

To cause complete combustion of one pound of coal, how large a volume of air is required with the forced draught of a locomotive? About 300 cubic feet; and as each shovelful of coal contains 15 to 20 pounds, the necessity of free admission of air to the fire is apparent.

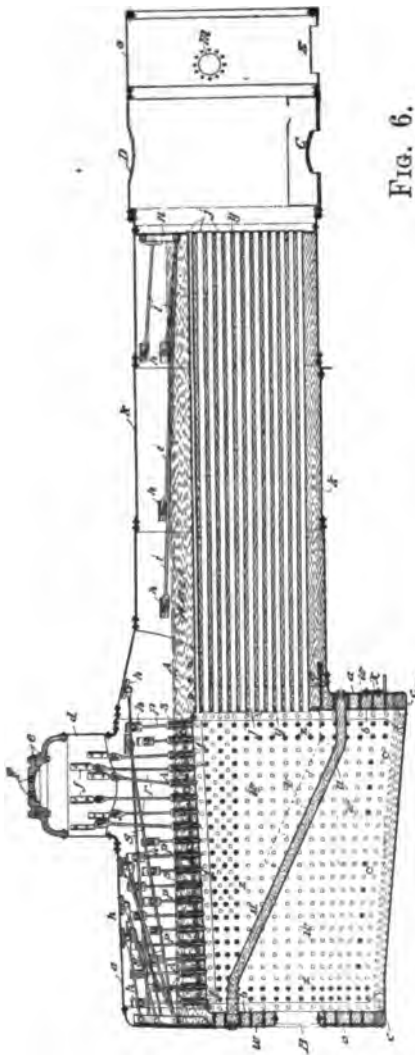


FIG. 6.

Longitudinal Section of Locomotive Boiler Filled With Water.

a Boiler shell. *b* Inside shell of fire box. *c* Mud ring. *d* Dome shell. *e* Dome castings. *f* Dome lugs. *g* Rear longitudinal stays. *h* Shell lugs. *i* Forward longitudinal stays. *j* Flues. *k* Barrel Plates. *l* Hand hole. *m* Dry pipe ring. *n* Extension end. *p* Sling stays. *q* Inside shell brace. *r* Dome sling stays. *s* Crown-bars. *t* Crown-sheet. *u* Water tubes for supporting arch. *v* Brick arch. *w* Stay bolts (solid). *x* Frame tie. *y* Flue sheets. *z* Stay bolts (hollow). *A* Cross stays. *B* Fire door. *C* Saddle opening. *D* Smokestack opening. *E* Cinder chute opening. *F* Safety-valve connections.

Describe the general form of a locomotive boiler? It is cylindrical in form. It has, usually, a rectangular shaped fire-box at one end and a smoke-box at the other end. Flues run through the cylindrical part, which, like the fire-box, are surrounded by water.

Why are these parts surrounded by water? In order that steam may be generated quickly and in as large a quantity as possible, by presenting the greatest practicable surface to the action of the heat.

Describe a locomotive fire-box. The modern form is a rectangular shaped structure located at the back end of the boiler. It has a door and is composed of side-sheets, a crown-sheet, a back-sheet and a flue-sheet from which the flues run to the smoke-box located in the front end of the engine. (See Fig. 6.)

To what kind of a strain is the fire-box subjected? It is subjected to a crushing strain.

How are the sheets of the fire-box supported? They are supported by means of stay-bolts screwed through the inside and outside sheets and are riveted together. (See Fig. 7.)

What is the object of hollow stay-bolts or of "detector holes" in stay-bolts? To immediately indicate by the escape of steam through this small (detector) hole that the stay-bolt is broken.*

*A "detector hole" is a small one-eighth or three-sixteenth inch hole drilled in the center of the outer end of a stay-bolt to a depth somewhat greater than the thickness of the outside sheet of the fire-box. (See Fig. 7.) This practice is based upon the fact that it is at the outer end that a stay-bolt usually breaks.

In what manner is the crown-sheet supported?
By means of crown bars or radial stay-bolts.
(See Fig. 6.)

What annoying feature is there connected with crown bars? They are hard to keep clean, and cause "mud-burnt" crown-sheets.*

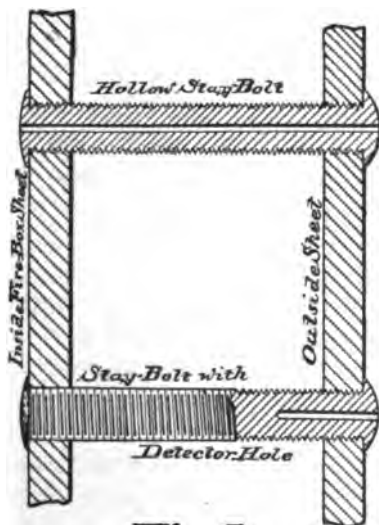


Fig. 7.

What is the advantage of the radial stayed crown-sheet? It is comparatively easy to keep clean and cheaper to repair.

*When crown bars are used, the top of the fire-box is flat and hence offers a considerable surface for the settling of mud and other incrustating matter. With the radial stayed fire-boxes the top of the fire-box is the arc of a circle and consequently less of such matter can settle thereon. If a layer of mud or other poor conductor of heat settles upon the crown-sheet, the water is kept from contact with it and the sheet is overheated and becomes burned.

How are the inside and outside sheets of the fire-box secured at the bottom? They are riveted to a wrought iron ring called the mud-ring. (See Fig. 6.)

What are below this? The grate-frame, ash-pan, grates, lever for shaking grates and dumping the fire. (Nos. 139, 164 and 165 of Plate I.)

Describe the ash-pan and its uses? It is a receptacle secured to the bottom of the fire-box and is provided with two or more dampers designed to regulate the admission of air to the fire. It collects the ashes dropped from the fire-box and thus prevents their setting fire to bridges, cattle-guards and other property elsewhere along the road.

What is the so-called wagon-top boiler? It is a boiler which has the fire-box end made larger than the cylindrical part in order to provide more steam space.

Why are boilers provided with steam domes? In order to furnish more steam space, obtain dryer steam, and provide a place for the steam-pipe (191), throttle valves (195), safety-valves (201) and whistle (202).

What must be the condition of the boiler in order to give satisfactory results? It must have a good circulation and be clean and free from incrustation of any nature, such as scale, mud, etc.

What is meant by the "circulation" of a boiler? The free movement of the water, so that it may come in contact with the heating surfaces, and after being converted into steam, be immediately replaced by fresh supplies of water.

What would be the effect if the leg of the boiler became filled with mud? There would be no water in contact with the heated sheets and they would in consequence quickly become blistered or "mud-burnt."*

What would be the result if the sheets should become overheated? They would be forced off the stay-bolts and an explosion would occur.

What effect is occasioned by the stoppage of one or more flues? The heating surface and draught are decreased by just so much.

Why are the boiler check valves (121 and Fig. 9^A) placed so far away from the fire-box? In order to introduce the water into the boiler as great a distance from the fire as possible. This permits the water to become somewhat heated before coming in contact with the fire-box and also tends to better circulation.

Where is the steam generated, and in what manner is its power transmitted to the locomotive? It is generated where the water comes into contact with the heated surfaces and afterward rises to the top of the boiler. It passes thence through the throttle valve (195) and dry pipe (191) into the steam pipes (33) in the front end (14) and so on to the steam chests (44). From there it passes through the steam ports (56) at each end of the cylinders (57) when uncovered by the valve (47), and coming in contact with the piston (61), pushes it away from the cylinder head (64) until the opposite steam port (56)

*The narrow water space between the inside and outside sheets of the fire-box is termed the "leg" of a boiler.

is uncovered by the valve, and at the end of the stroke the reverse motion is induced by the steam entering the opposite side of the valve (47) and pushing against the piston in the opposite direction. Simultaneously the first steam port is brought into connection with the exhaust opening (54), and thus the steam that has been used escapes into the atmosphere through the exhaust pipe (31 and 32) and smokestack (38). (See Plate I. and Fig. 6.)

What quantity of water ought to be evaporated in a locomotive boiler to a pound of coal? Six to eight pounds, according to circumstances.

What are the advantages of the arch in the locomotive fire-box? It induces a more perfect combustion by retaining the gases in the fire-box until they have reached the igniting point. It thus prevents, partially at least, black smoke by giving the fire time to consume the carbon and gases. It also partially heats the cold air before it enters the flues, and otherwise acts as a deflector on the fire.

What is the advantage of extending the front end (14) of the boiler? (See also Figs. 4 and 6.) It serves as a receptacle for sparks, which, if not confined, would be ejected through the smokestack, thus causing discomfort to the public and danger to property.

What provision is made in this extended front end (14) for the regulation of the draft? It contains the exhaust nozzle (32), the so-called petticoat-pipe (36), and an adjustable deflecting plate or diaphragm (27). (See also Fig. 4.)

What is the purpose of the safety valve (201) and how does it operate? Its purpose is to relieve the boiler of excessive pressure by allowing the steam to escape into the air. The steam, after attaining a certain pressure, pushes up a stem and spring and thereby unseats a valve and thus allows the steam to escape into the atmosphere until the pressure becomes normal, when the spring again seats (closes) the valve.*

Of what use is the second safety valve? It is valuable as a measure of safety, in the event the first valve should stick or otherwise become in-operative.

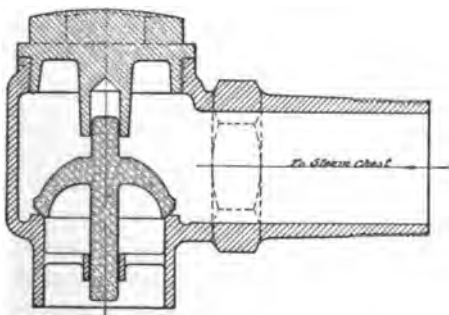


Fig. 8.
—Steam Chest Relief Valve—

Why are suction or air relief valves (45) † placed on the steam chest of many locomotives? In order to admit air into the steam chest and thus prevent a vacuum therein, when the engine is running with steam shut off.

*American locomotives are fitted with two safety valves with the steam pressure usually set at from three to five pounds difference between them.

†Fig. 8 shows one style of steam chest relief valves.

What is the object of safety valves on the steam chest or dry pipe of a locomotive? To prevent bursting the steam chest or knocking out a cylinder head in case the engine were reversed with the throttle closed.

If, upon opening the fire-box door (222) what is called a red fire should be discovered, what would be the probable cause? That the grates had become filled with ashes and clinkers and the fire was not getting sufficient air.

If the fire was not getting air enough through the grates (165), why would you not open the fire door? Because if the door was even partially opened, a large quantity of air would enter and pass directly through the gases without uniting therewith, except to a small extent. Thus, it would pass into the flues (because of the powerful action of the exhaust) thereby cooling the flues and reducing the temperature of the water in the boiler. In order to secure perfect combustion, the air must be mixed with the gases in the proper proportion. This can be best accomplished by admitting the air through the grates and having it pass thence through the fire.

How can the theory of the proper mixing of the air and the gases be demonstrated? By inverting a shovel in the fire door at an angle toward the fire. The air will thus be deflected into the fire in a wide sheet and will be more thoroughly mixed with it, thereby insuring greater combustion as will be shown by the increased brightness of the fire. Under such circumstances, the entire grate area may be seen,

and the fireman can examine all parts of the fire-box to ascertain whether he is distributing the coal to conform to the draught arrangements of the engine.

If a hole is formed in the fire, what will be the result? Heat will be lost, as cold air will enter the fire-box and cool the gases below the point of ignition.

Why is it necessary to keep a "heavier," or deeper fire on one engine than another? Largely because of the influence of the draught appliances upon the fire.

What is the best way to fire a locomotive? The fuel should be applied frequently and in small quantities. It should be distributed evenly over the fire. The coal should be broken into pieces about the size of an apple.

How can too much air be admitted? By opening both dampers when the engine is working lightly and there is only a light thin fire. Air admitted above the amount required for combustion cools the gases below the igniting point.

What constitutes perfect firing? Providing fuel and air in exactly proper proportions.

How can this end be most nearly attained? By observing attentively the results of different methods of firing and being governed by that which is best.

In the case of an engine working hard and using bituminous coal, is it possible to admit too much air through the fire? No, not if the fire is sufficient to consume the gases.

Does the draught from an open cab window or otherwise, affect the working of lubricators (224)? Yes, the cold air chills the oil and thereby retards its flow—causes it to “feed” irregularly.

What else would cause irregularity? Dirt in the lubricator (18). If the choke plugs were too large, such a result would follow.*

If a lubricator feeds faster when the engine throttle is closed than when it is open, what is the trouble? The choke plugs are too large. (See detail cuts and explanation of lubricators. Appendix C of this volume.)

Will bad results be caused by filling a lubricator full of cold oil? Yes, when the oil becomes heated, it will expand. It may thus cause the lubricator to burst or bulge.

How can you clean the sight feeds when they become filled with dirt? By removing the regulating valve and blowing out the nozzle, or by running a fine wire or straw through it.†

How can choke plugs be cleaned? By disconnecting the oil pipes and running a wire through them.

When waiting on sidings, etc., should the feed valve or the water valve be closed? The feed valve, as the water valve may not be tight.

*The choke plug is the nozzle, through the small hole in which the oil feeds in passing from the lubricator (224) to the cylinder supply pipe (123). See also cuts in Appendix C.

†The sight-feed is the nozzle inside of the lubricator feed glasses of what is known as the “Sight Feed Lubricator.” It is thus called because of the fact that the oil that is feeding (i. e., being supplied to the part needing lubrication), is doing so in plain sight of the engineer. See appendix C.

Should oil be used as fast for a speed of fifteen miles per hour as for a speed of thirty miles per hour? No.

Explain how to modify the friction of oil. By making the oil thin by adding kerosene, or other light oil, rather than by heating it. If it is heated, the cold surface congeals it, making it a poor lubricant and occasioning internal friction.

Please describe any new signals introduced since your last examination.

How many changes have been made in the old signals?

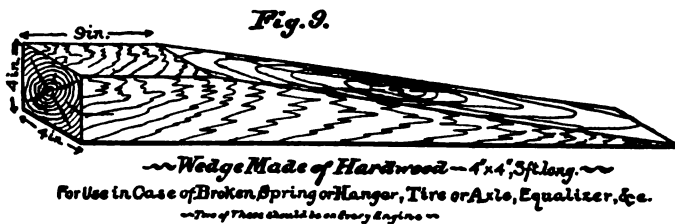
What tools should a locomotive be supplied with? Those that the company's rules and regulations require.*

Besides the ordinary tools, what should be carried for use in case of break-downs on the road? A valve-stem clamp, blocking for the crosshead, two hardwood wedges (as shown in Fig. 9), a few pieces of pine board, a small coil of wire or strong cord, and a miscellaneous assortment of bolts

*These rules and regulations are not, of course, uniform on different roads. Indeed, some roads do not specify what they should embrace. However, generally speaking, the list may be said to include the following items: Axe, pinch bar, flue plugging bar, small steel bar, blocking, bolts and nuts, broom, tallow bucket, water bucket, one gallon oil-can, one quart oil-can, squirt can, engine chain, cape chisels, cold chisels, clinker bar, clinker hook, coal pick, cushions, dipper, green flags, red flags, white flags, frogs, machinist hammer, soft hammer, ash hoe, 9-inch jack, 24-inch jack, jack levers, blizzard lamps, white lanterns, packing hook, packing iron, flue plugs, front-end poker, saw, scoop shovel, tallow pot, torch, torpedoes, 12-inch monkey wrench, 15-inch monkey wrench, eccentric set screw, oil cups, steam chest nut wrench, air-pump spanner, large injector spanner.

and nuts. Many times considerable delay will be avoided if these tools are readily at hand.

What should the engineer do before attaching his engine to a train? He should comply with any regulations there may be in regard to registering; examine the shop book to ascertain whether or no the repairs have been made that have been ordered; look over the engine carefully and remedy any defects there may be; try the gauge cocks (219) and both injectors (179), and see that the engine is supplied with the tools, supplies and blocking it requires. He should also ascertain whether the fireman has attended to his duties or not.



What precaution should be taken if work or repairs, such as having valves faced, brasses filed, etc., have been done to the locomotive? The engineer should examine to see that the work has been properly done and whether the parts require lubrication or not. In any event, they require to be given special attention, as new parts are always liable to run hot and cause rough bearings.

When everything is ready, how should the engine be started? In full gear. The throttle

(195) should be opened slowly and carefully in order to start the train without a jerk. This lessens possible injury to draw bars, and in the case of passengers and freight minimizes the annoyance and danger.

Is the engineer required to see that his entire train is attached? Yes.

Should the bell (132) be rung before starting? Yes, always.

In what manner should water be supplied to the boiler? Continuously, except when starting the train. The quantity should be regulated according to the work the engine has to do.

After the engine is started, what particular thing will especially facilitate its economical working? The use of a full or wide open throttle (195), except when the engine can do the work with less than a six-inch cut-off; also, by regulating the speed by means of the reverse lever (217).

When an engine is to be taken over the road without a train, what should be done before starting? If the rules permit an engine passing over the road without a conductor, it would be necessary to make such entries as the rules require in the train register; also secure running orders; also see that the engine is supplied with necessary lanterns, flags, torpedoes, etc.

If the engine should break down between stations, what should be done? The line should be protected at once by the use of the danger signals prescribed by the company. Afterward the engineer should investigate as to the extent of

the damage and repair same if possible, so that he might at least go forward to the nearest siding, from whence he would report the matter to the proper official.

What is meant by the "total wheel base" of a locomotive? The distance from the center of the front to the center of the back wheel.

What is meant by "rigid wheel-base?" The distance between the centers of the front and back driving wheels.

Why is the top rail of the frame not made straight? (See Plate I. and cuts on pages 62 and 114 of *Railway Equipment*, Vol. I.; also Figs. 22 and 23.) To give slope to shallow fire-boxes, so that the flues will be further above the grate.

Why are the piston rods frequently extended out through the front cylinder head, as shown in Fig. 139? In order to better guide the piston and produce more uniform wear of the cylinders. This is the practice, noticeably, with the large cylinders of compound locomotives.

DUTIES AND RESPONSIBILITIES OF ENGINEERS.

THIRD EXAMINATION OF FIREMEN.

NOTE.—The questions propounded, and the answers thereto, that constitute the third examination are given below. It will be remembered that this is the final examination and the fitness shown by the applicant, together with the general character he has established, determine whether he will be thought competent to be promoted to the position of engineer or not. It will be observed that this examination is much more elaborate than those that have preceded it. However, study and experience will enable the applicant to pass it without difficulty. A perusal of the questions and the responses thereto strengthens the suggestions previously made that many engineers who have never been critically examined in regard to the construction, maintenance and working of the locomotive will greatly strengthen their position by familiarizing themselves with the points this and the other examinations bring out. It will be noticed that the duties indicated are such as belong to the engineer to perform or that he is responsible for. I also wish, in this connection, to again call particular attention to the accompanying diagram of the locomotive; also to the description of the locomotive embraced in the companion volume to this on *Railway Equipment*. The description in question is accompanied by forty-four engravings prepared especially for this work, and representing the main features of the machine, namely: Longitudinal section of boiler; front view of locomotive; rear view of locomotive; sectional views of locomotive through the exhaust chamber and the live steam chamber; side view of American bogie (or pony) truck, supporting forward end of locomotive; sectional views of locomotive through the forward driver and the fire-box; side view of American locomotive truck, supporting forward end of locomotive; evolution of the coal burner smokestack; side view of injector; section of injector; force pump; check valve for preventing water returning; section of boiler fuse plug; section of

safety valve; interior of steam gauge; exterior of steam gauge; section showing action of steam in single-expansion cylinder; end view of cylinder; two and four bar crossheads; section of indicator; side view of eccentrics, straps and reversing gear; end view of reversing gear; engineer's lever in connection with reversing gear; section showing action of steam in compound cylinder; front view of compound cylinder; section of starting valve and relief cock, compound cylinder; application of starting valve and relief cock, compound cylinder; section showing grate and damper; longitudinal section of locomotive boiler filled with water; part section of boiler, showing blower; section showing spark arrester; section showing fire-box and tank arrangement for the use of oil as fuel; fuel oil burner; side view of tender with water scoop dropped; section of tender showing water scoop in track tank; front view of tender with scoop in track tank; rear view of tender; equalizer, side view; sand pipe of locomotive, supplemented by steam or air blast; steam whistle; cylinder relief cocks; side view of locomotive; eight wheel passenger locomotive; chart of standard American locomotive.

Notwithstanding the exceptionally large number of engravings in the volume *Railway Equipment*, I have had many original engravings of a more special character prepared for this edition of the Manual. Hence it is that I feel justified in thinking that, while many so-called catechisms and progressive examinations have been published and are very well in so far as their limited scope permits, the combination of this Manual together with the other volumes comprising the *Science of Railways*, will be of untold advantage to students of railway matters.

The book *Railway Equipment* also contains a technical and exhaustive account of the working of the air brake, illustrated by thirty-two expressly prepared engravings. It also further contains a detailed and scientific account of the practical application of electricity as a motive power to general transportation, illustrated by eighty engravings prepared expressly for the volume in question.

In the event the injector (179) should not work while on the road, what action would you take? If the tank valve was open and the tank con-

tained water, I should look for the stoppage in the hose (237) or strainer. If I found them all right, I should conclude there was something the matter with the injector (179) and act accordingly.

What should be done in regard to the water level meanwhile? It should be watched, and the fire-box door opened so as to prevent the engine blowing off. If the water should get low, I would bank the fire.

To what cause, as a rule, is the failure of the left-hand injector to be attributed? Non-use.

What should be done to obviate this? Both injectors should be used daily.

In what way can both injectors be kept in good order? By their alternate use, say, one used on the out-trip and the other on the return trip, or by using one at terminals and the other while running.

What is the difference between "priming" and "foaming" of a boiler? Priming is caused by contracted steam space or the boiler being too full of water. Foaming is caused by foreign substances, such as oil, soap, etc., getting into the water.

What would you do in the case of foaming? I would shut off the throttle and injectors and ascertain the true level of the water, by allowing it to settle; then I would open the fire door so that the engine would not blow off. If the water should drop too low, I would open the throttle and apply the injectors. If there was a surface cock, I would open it, if there was none I would

handle the engine carefully until reaching a point where the boiler could be washed out.

What would you do if you discovered that the water in the tank contained oil? I would proceed as in the case of foaming, until I reached a water station, when I would flush the tank, using the heaters in the tank to bring the oil to the surface. *

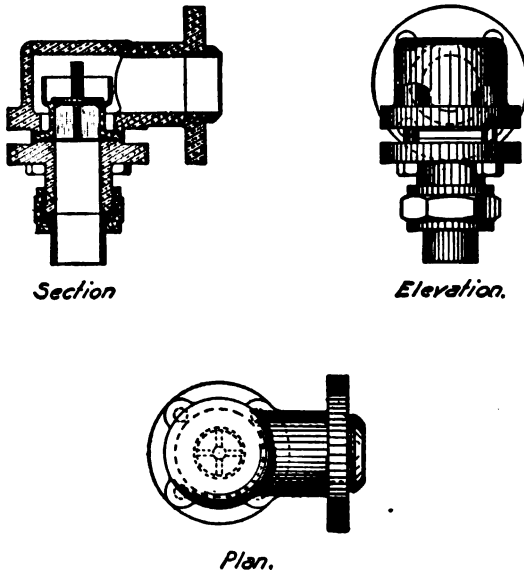


FIG. 9^A

Check valve, for preventing water from running.

What attention should be given to boiler attachments, such as the gauge cock (219), water

*Brown sugar put into the hose and forced into the boiler will generally counteract the effect of the oil.

glass, etc.? They should be looked after to see that they are in good working order and are not clogged or filled up.

What should you do if a wash-out plug (104) was blown out, or a blow-off cock could not be closed or was broken off? I should dump the fire, plug up the hole and re-fill the boiler. If I found it impossible to plug up the hole, I should send for assistance to take the engine to a place where it could be repaired.*

If the check valves (Fig. 9^a) remain open after the injector stops working, how would you proceed to close them? I would tap the valves gently on the top or bottom of the valve case, preferably with a piece of wood, being careful not to hit the sides of the valve if it is made of brass.

If you could not re-fill the boiler, what would you do? I would disconnect the engine and arrange to have it hauled to some place where it could be repaired.

What parts would it be proper to disconnect? It would be proper to disconnect the valve stems (49) and take down the main rods (92).

How can a disconnected tank valve be opened without stopping the engine? By closing the water valve (185) and injector overflow (180) and blowing steam through pipe (236) and hose (237) suddenly.†

*Blow-off cocks are located in parts of the boiler where mud or other incrustating matter is liable to settle. By their means such sediment is ejected from the boiler.

†This will generally blow the tank valve out of its seat, but steam should be shut off quickly to prevent bursting the hose (237).

What would you do if you stopped the engine working and the water in water glass dropped out of sight? I would open the throttle so as to raise the water above the crown sheet, deaden the fire if necessary, and immediately set both injectors to work.

What should be done in the case of a disconnected throttle?*

If the throttle becomes disconnected and remains open, the steam pressure should be reduced so that the engine can be handled with the reverse lever (217). The trainmen should be notified of the mishap and a report made of it at the first telegraph office. If the throttle becomes disconnected and remains closed the engine should be towed in. Disconnect valve rods, pushing the valves forward, uncovering the back ports to allow oil to enter cylinders from the lubricator, leaving the main rods up. The engine should be kept under steam to operate injectors and lubricators and prevent freezing in cold weather.

Fig. 10.



*~Allen Ported Valve~
~Central Position~*

What should be done with a flue-(122) that leaked badly or had burst? It should be plugged,

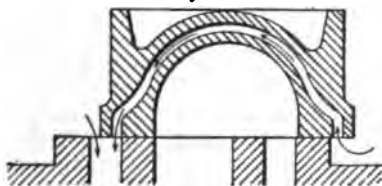
*A disconnected throttle signifies that either the throttle valve (196) has become disconnected from the throttle bell crank (196) or that the latter has become disconnected from the throttle stem (197). It will readily be seen that in either event the movement of the throttle lever (215) will not open or close the throttle valve.

and the engine should be provided with tools suitable for that purpose.

What should be done if the whistle (202) or one of the safety valves (201) blows out? They should be plugged with soft wood, tied or otherwise secured.

What would you do if the engine was stalled in the snow and the water in the tank was low? I would shovel snow into the tank and melt it with the heaters.*

Fig. 11.



~Allen Valve~
~Early Admission Period~

How low would you allow the water in the tank to get before shoveling in the snow? Not lower than one foot.

Can the boiler be filled with water through the injectors by towing the engine with another locomotive? Yes.

How is this done? Close all openings from the boiler except those from the tender, open the engine throttle and both injectors, leaving the

*The term "heater," as usually applied to a locomotive, signifies the supplying of steam to the tank through the feed pipe (286) and hose (287) from the injector (179) after closing the heater valve, as shown in the supply pipe (119) above the overflow (180).

reverse lever in the ordinary position for that direction in which the engine is being towed. The pistons will form a partial vacuum in the boiler, and water from the tender will be drawn in. It is evident that any air suction valves (Fig. 8) on the steam chest must also be closed in some way.

If the throttle was closed and steam still came out of the cylinder cocks (68) what would you do? I would see if the oil pipes (123) from the lubricator (224) were closed, If they were, then I should report that the throttle (195) leaked.

How can you distinguish a leaky throttle (195) from a leaky dry pipe (191)? If the water in the boiler is high enough to submerge the dry pipe, steam issuing from the cylinder cocks (68) would indicate a leaky throttle. Water and steam would indicate a leaky dry pipe. If the dry pipe is not submerged, the location of the leak cannot be determined.

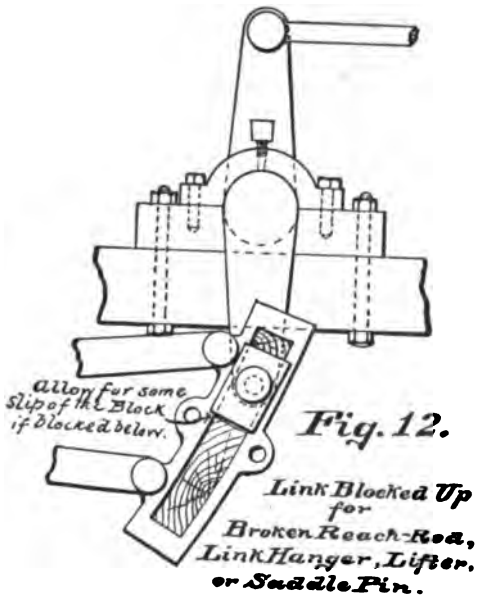
How should a hot bearing be treated? It should be lubricated and packed, and cooled so far as practicable before going ahead.

How would you proceed with a cracked steam chest (44)? I would loosen the steam chest cover (43) and insert iron wedges or nails between the steam chest bolts and sides of the chest, and fasten down the steam chest cover.

How would you disconnect if you had a broken steam chest (44)? I would disconnect the valve stem (49), cover the admission ports (56), take down the main rod (92) and block the cross-head (96).

How are the steam chests and covers usually ruptured? By reversing the engine at high speed without opening the throttle.

With a totally demolished steam chest and cylinder on one side, what would you do? I would put out the fire, disconnect both sides of



the engine and ask to have it hauled to the shop. Repairs might be made by putting a solid gasket in the steam pipe, but as a rule this is not practicable.

What can be done if the lifting shaft (112), reverse lever (217) or reach rod (118) break? The links (105) can be blocked up to the point

at which the engine should cut off, as illustrated in Fig. 12. It must be remembered, however, that it is impossible to reverse until the block is changed.

If the piston (60 and 61), crosshead (96), connecting rod (92) or crank pin were bent or broken, what would you do? I would disconnect the engine. If the crank pin was bent or broken, I would take down both side rods.

What should be done with a hot piston rod (60)? It should be cooled off with oil, the engine being kept moving slowly meanwhile. Water should not be used in cooling a piston rod.

If a piston rod (60) should break and knock out the forward cylinder head (64), how would you disconnect? I would disconnect the valve stem (49) at the connection (51) and cover the ports (56) and remove the broken parts.

Why would you not take down the main rod (92)? Because there would be no harm in leaving it up.

What should be done if one of the glands that holds the piston rod packing (59) in place was blown out, thereby breaking off one lug and one bolt? The piston gland should be blocked or secured, if possible; if not, the engine should be disconnected on that side.

What will indicate that an eccentric (*BB* Fig. 12) has slipped on the axle (*A*)? The irregular sound of the exhaust.

How can you determine which eccentric has been displaced? By running the engine slowly with the link first in full forward motion, then

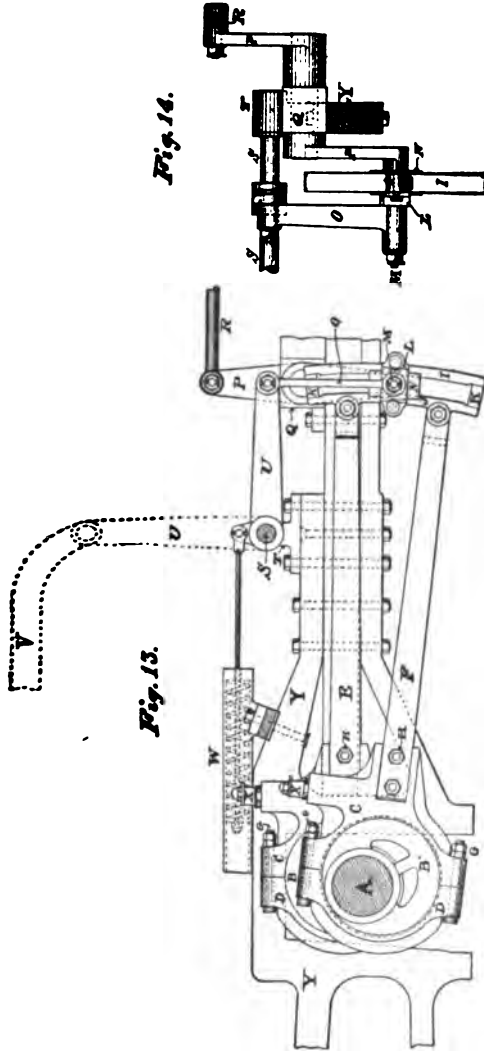


Fig. 14.

Fig. 13.

END VIEW.

SIDE VIEW.

ECCENTRICS, STRAPS AND REVERSING GEAR.

- A—Axle.
- BB—Eccentrics.
- CC—Front half of eccentric-strap.
- DD—Back half of eccentric-strap.
- E—Forward motion eccentric-rod.
- F—Back motion eccentric-rod.
- GG—Eccentric-strap bolts.
- HH—Eccentric-rod bolts.
- I—Reversing-link, front half.
- J—Reversing-link, back half.
- KK—Reversing-link filling pieces.
- L—Reversing-link saddle.
- M—Saddle pin.
- N—Link-block.
- O—Link-lifter.
- PP—Rocker-arms.
- Q—Rocker-shaft box.
- R—Valve rod.
- S—Reversing or tumbling shaft.
- T—Reversing shaft box.
- U—Reversing-arms.
- V—Reach-rod.
- W—Spring counter-balance.
- XX—Eccentric oil-cups.
- Y—Frame of engine.

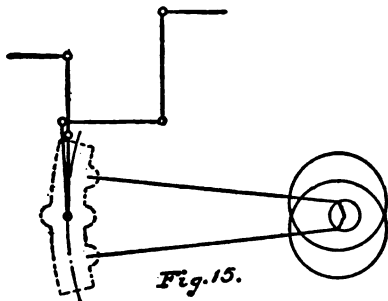
in full backward motion, and observing if the steam is admitted at each end of the cylinder just before the crank pin reaches the dead points. The effect of a slipped eccentric on the valve is either to increase or diminish the lead. If the eccentric has slipped toward the crank pin, the lead will be increased and steam will be admitted to the cylinder sometime before the piston reaches the end of its stroke. If it has slipped away from the crank pin, the lead will be diminished, or taken away entirely, and steam will not be admitted until after the piston has reached the end of its stroke.* The admission of steam is indicated by its escape from the cylinder cocks, which must be left open.

Having determined which eccentric has slipped, how would you proceed to reset it? I would place the engine on the forward center. If the forward motion eccentric (*B* Fig. 13) had slipped, I would put the reverse lever in the back notch of the quadrant (220) and scratch a line on the valve stem (49) close to the packing gland. Then I would place the lever in the forward notch of the quadrant and move the eccentric around by hand until the line on the valve stem appeared; then I would tighten the screws that fasten the eccentric to the axle. If the backward motion eccentric (*B* Fig. 13) had slipped, I would proceed in the opposite manner.

*This applies to indirect valve motion, as shown in Figs. 13, 14 and 15. With direct valve motion, as shown in Fig. 123, the reasoning would be the reverse.

What is the position of the eccentric when the crank pin is on the forward center? With the standard type of rocker arm (*P*), which gives indirect valve motion, the forward motion, (go-ahead) eccentric always follows, and the back-up eccentric always leads the crank pin at right angles, less the amount of lap and lead, when the engine is moving forward, see Skeleton Fig. 15.

INDIRECT VALVE MOTION
WITH ROCKER ARM



In the event of a valve (47), valve yoke (48), or stem (49), becoming broken inside of a steam chest (44), how can the breakage be located? To test one side, place the piston at half-stroke and admit a little steam to the cylinders, then move the reverse lever (217), from full forward to full backward gear. If the steam escapes alternately from both cylinder cocks (68) it may be concluded that the defect is in the opposite steam chest.

Having located the defect, how would you put the engine in safe running order? By taking off the steam chest cover (43), and blocking or fastening the valve (47) centrally as shown in Fig. 16,

or by plugging the ports (56) with soft wood boards if the valve was broken. The defective side should then be disconnected and the crosshead (96) securely blocked.

If the valve seat (52) is broken, what should be done? Take off the steam chest cover, cover both steam ports (56) as shown in Fig. 16 and disconnect the engine.* In some cases the false valve seat may be removed.

Is it necessary when disconnecting to block the crosshead (96)? Yes. It is the safest thing to do in case the ports (56) become uncovered.

How and in what position is it best to block the crosshead? Put the crosshead at one end of the stroke and place a block between it and the guide blocks, securing the blocks by strong cord or wire, to prevent their falling out, as shown in Fig. 17.

Does it make any difference at which end of the stroke you block the crosshead? Yes. On engines where the forward driver is opposite the guides, the crosshead must be blocked clear ahead so that the forward crank pin will not strike it.

If a disabled engine is being handled on one side, what is the best method of stopping so that

*Disconnecting one side of an engine, as in this case, means the removal of the main rod or rods on one side, securing the crosshead (preferably at the back end of the guides (89), as shown in Fig. 17, if it will clear the crank pin in that position) by means of a crosshead clamp or hardwood blocks, well secured, and setting the valve in a central position so as to cover all steam ports, and securing it there by a valve stem clamp or by cocking the valve stem gland and setting the gland nut tight on one side. An engine may still be operated if only one side of it is disconnected.

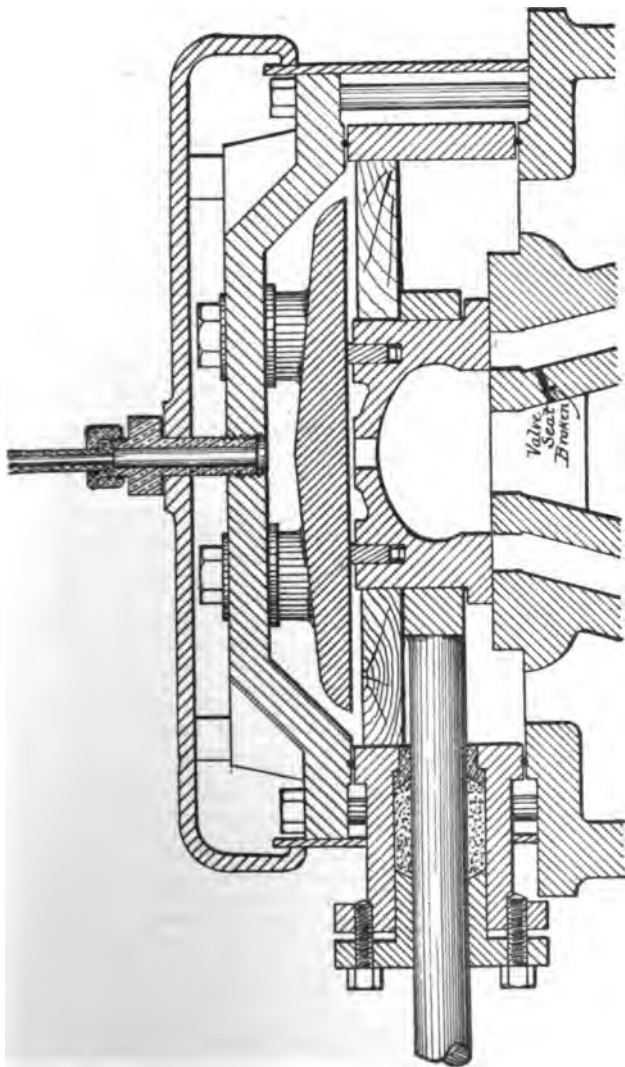


Fig. 16.

*Richardson Balanced Slide Valve
Also showing Method of Blocking any Slide Valve for Broken Valve Seat or
Other Breaks Inside of the Steam Chest ~*

the side that is working will not stand on center? Shortly before coming to a stand, release the brakes, reverse the engine and open the throttle slightly.

Why will this prevent the engine from stopping on center? The final power for stopping comes from the back pressure against the piston and this acts against the rotation of the driving wheels only when the engine is off the center.

How can you distinguish between a valve blow (47) and a cylinder piston packing blow (62)? A valve blow is generally continuous and a cylinder piston packing blow intermittent. If it arises from cylinder packing it will blow the strongest at the commencement of the piston stroke.*

Do you fully understand the difference between piston rod packing (59) and cylinder packing (62)? The piston packing rings (62) are termed "cylinder packing," to avoid confounding them with the piston rod packing (59).

What should be done in the case of a broken eccentric strap or blade (160 and 162)? Take down both eccentric straps and blades on the side where the break was located, and disconnect that side of the engine.

How would you disconnect if a lower rocker arm (116) became broken? I would place the valve central on its seat and clamp it there, leaving the main rod (92) up. In this way the steam ports (56) to cylinder (57) would be covered. If the lower rocker arm (116) did not strike anything, I would leave it up. In case engine stopped on center on good side, the valve on the side on which rocker arm is broken could be moved by hand to open the ports and assist engine off the center.

With the main rod (92) up and valve central on its seat, how would you oil cylinder (57) on that side? I would remove indicator plugs and oil with engine or car oil, or remove front cylinder head.

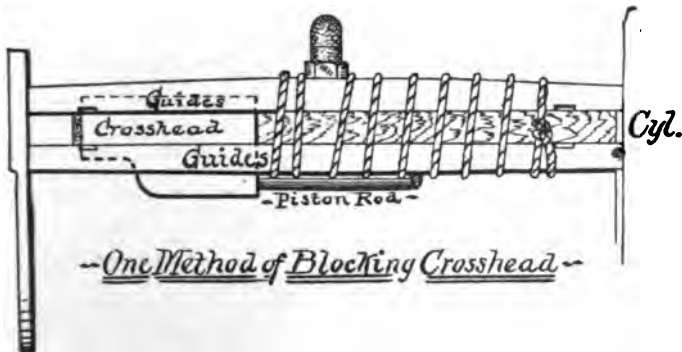
Is there any other method you could employ to prevent cylinder from being cut or damaged when the main rod is left up on disabled side? Yes. In disconnecting a heavy engine I would remove the back cylinder cock or valve from the cock, clamp the valve to admit steam to the back end of the cylinder to produce a good strong blow from the open cylinder cock, leaving the main rod up; the steam thus admitted to the cylinder will prevent it from being cut. In case the engine does stop on the center or dead point on the good side, by replacing the cylinder cock or valve the steam admitted behind the piston will move the engine sufficiently to take the good side

*A wasteful escape of steam through the engine exhaust nozzle is termed a "blow" in contradistinction to the usual "exhaust."

off the center. Then remove the cylinder cock and proceed as before.

What can be done in case a link saddle pin (107) breaks? The hanger (111) can be taken down and the top of the link (105) blocked up with a piece of wood to the point at which you wish to cut off.

Fig. 17.



If the link hanger (111) or lifting arm (112) should break, what would you do? I would do the same as in the case of a broken saddle pin.

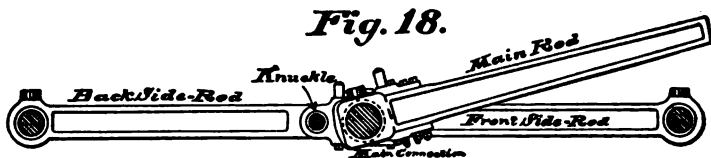
Would you reverse the engine under these conditions? No.

If you should lose a rod key, what would you do? If it was a main rod key, I would substitute a side rod key, if the engine had one, and put a wooden key in its place.

How would you disconnect in the case of a broken crosshead (96)? The same as for a broken cylinder head. I would disconnect the engine on the side on which the break was located.

If the engines have six or more connected driving wheels, what side rods should be taken off, if opposite ones are broken? If the knuckle is back of the pin, as in Fig. 18, and the back section is broken, the corresponding side rods on the opposite side should be taken off. If the forward section is broken, all side rods should be taken off.

How would you disconnect if you broke a main crank pin close to the wheel? I would take off all side rods (152)* and disconnect engine, and fasten the crosshead (96) and valve (47) (with steam ports (56) covered) on the broken side.



—Rods &c.—
For Mogul or Ten-Wheel Engine—

Which are the main drivers of a locomotive? That pair of wheels to which the main rods are attached.

On which axle is it customary to place the eccentrics, and why? On the main axle, so that the engine can be run, even with all the side rods taken down.

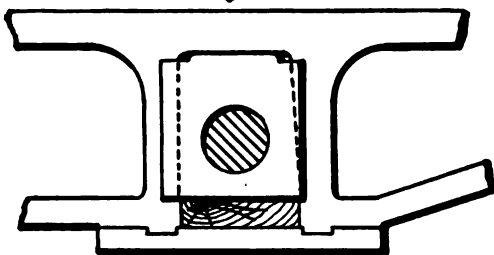
Describe the difference between a standard, mogul, ten-wheel and consolidation engine. A standard engine has four drivers, connected, and a four-wheel truck. A mogul has six drivers, connected, and a "pony" or two-wheel truck. A ten-wheel engine has six drivers, connected, and a

*Some locomotives have the eccentrics placed on the axle forward of the main axle. In case an engine of this design should break a main pin close to the wheel, all the rods on that side should be taken down, but side rods could be left up on the good side. It would be necessary to do this in order to keep the forward wheels, to which the eccentric was attached, in register with the main wheel. If all side rods were taken down and the main wheels would slip, it would be necessary to disconnect the good side and be towed in. The reason for taking down side rods, on opposite sides, is that if one side was on the quarter the other side would be on the center and the wheel connected by one side rod only. If on the center it would be liable to break the pin or rod or start the wheel revolving in the opposite direction, when working steam with both main rods up. When only one main rod is in use, if the side rods are left up on that side and the engine should stop on the center, it would have to be moved or pinched so that the steam admitted to the cylinder would exert a rotative force to the wheel, and all pins on that side being above or below the center, there would be no danger of further damage as in the case of one side rod left up when using both cylinders.

four-wheel truck. A consolidation engine has eight or more drivers, connected, and a "pony" or two-wheel truck.

If one of the forward tires (137) of a ten-wheel engine should break, what would you do? I would run the wheel with broken tire up on wedges (see Fig. 9) placed on the track, so as to raise the tire above the rail and insert in place

Fig. 19.



Wheel Blocked Up

For Broken Tire or Axle

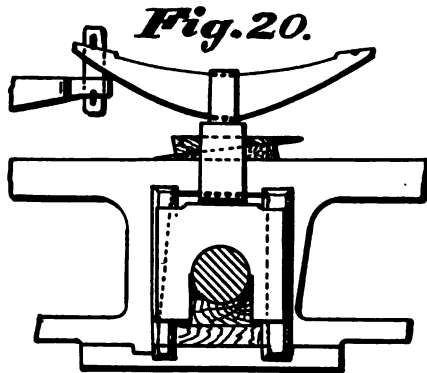
of the cellar a block thick enough to hold the tire off the rail, as shown in Fig. 19. Then, if the rods were not sprung, I would go ahead with the train.

What would you do in the case of the tire on a rear driving wheel breaking? I would proceed as in the case of a broken front tire, running very carefully, especially around curves.

What would you do in the case of a broken main driving wheel tire (137)? I would block up

the wheel to the thickness of the tire, loosen the side rod keys and proceed carefully without the train.

How would you proceed to run a mogul engine with the back tire off? I would remove the cellar and insert a block between the pedestal and



~ Driving Axle Broken Outside the Box ~

journal so as to hold the wheel center off the rail and then take off both back sections of the side rods.*

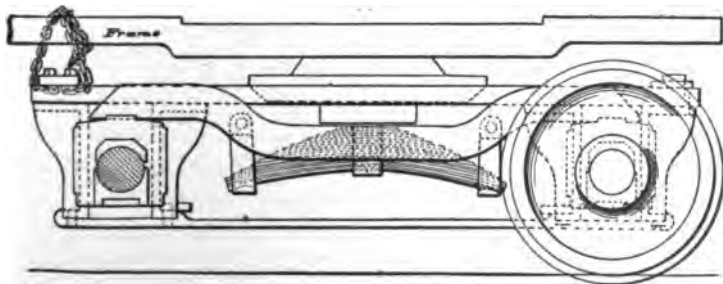
*The cellar of a journal is a hollow, box-like casting placed beneath the journal. In conforming as nearly as possible to that portion of the journal not covered by the brass, it serves a double purpose—to keep dust and dirt from the journal, and, being packed with waste, wool, hair or other similar substance saturated with oil, greatly assists to a proper lubrication of the journal. The bolts or keys that secure it in place are termed cellar bolts.

The pedestals are the jaws of the frame of a locomotive, between which the driving boxes (150) are held.

What would you do under similar circumstances with an eight-wheel standard engine? I would endeavor to run the engine to the shops, by placing wedges between the tank and engine, thereby blocking up the engine so that the weight will be against the flange of the good wheel.

How fast would you run in that condition? Not exceeding five or six miles per hour, and very slowly on curves and switches.

Fig. 21.
—For Broken Eng. Track Wheel or Axle—



If the back tire of an engine were off, how could you fix the engine so as to safely back around curves, if necessity required? With standard (eight-wheel) engines, by blocking as for broken rear tire on a mogul; that is, relieve all possible weight from rear drivers. With a mogul, you would have to block with soft wood between engine and tender on the inside of the curve.

In case the axle of a driving wheel should break, how should the axle be blocked up and part of the weight relieved from that box? Hardwood blocks should be used to block the axle up level; blocking under the spring saddle will take part of the weight from the box, as shown in Fig. 20.

What would you do in the case of a totally demolished tank truck? I would go to the nearest siding and send for help. In case of necessity I would substitute a car truck.

What should be done if an engine truck wheel (71) or axle (73) breaks? Remove the broken wheel or axle and chain the truck frame to the engine frame, as shown in Fig. 21.

How should a broken tank truck, wheel or axle be treated? By removing the broken wheel and axle, placing a cross tie on top of the tank and suspending the truck to it with chains, afterwards proceeding slowly to destination.

What is the object of equalizers and springs? (See Figs. 22, 23 and 24.) To distribute the weight of the locomotive more equally upon all the bearings and to make the engine ride easier, thereby lessening the wear and tear on the machinery as well as affording greater comfort to the enginemen.

When the springs and equalizers are in order, where is the weight of the engine carried? The frame and the boiler resting upon it is supported at the engine truck center in front and at the fulcrums of the equalizers and, from these latter points of suspension, the weight is transferred

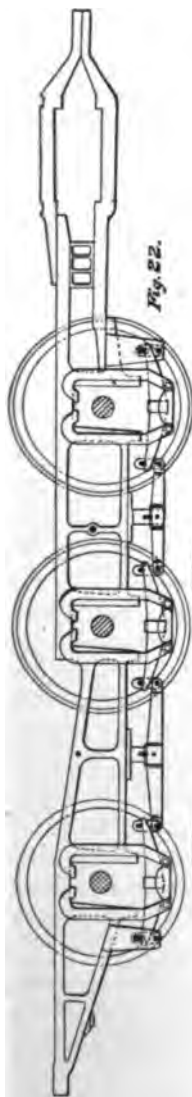


Fig. 22.

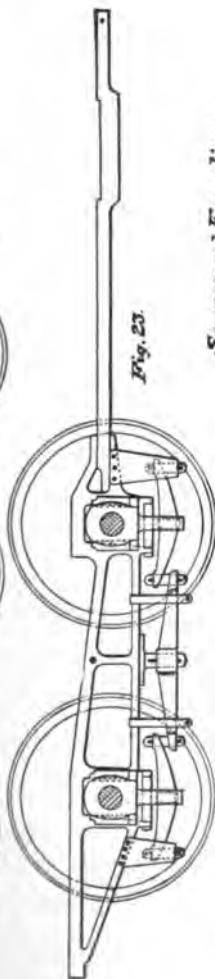


Fig. 23.

Springs and Equalizers

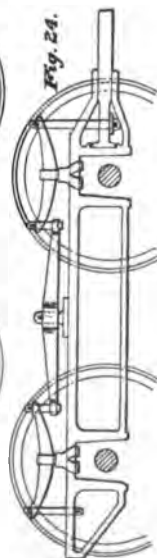


Fig. 24.

through the equalizers and springs to the spring saddles resting directly upon the driving boxes.*

How is the weight carried when an engine is blocked up on top of the boxes? On perfectly smooth track there would be little difference, but on rough track there would be times when the whole weight of one side would come upon the box that is rigidly blocked.

What makes the best blocking for use between the driving boxes and the frame? Good hardwood, because of its greater elasticity than metal and it also remains in place better.

What should be done if a driver spring (141), spring hanger (142) or equalizer (143) breaks? With heavy engines such as those in use, engineers are not expected to jack up the engine. Even if the engine is small, the quickest way is to raise it by placing wedges (see Fig. 9) on the rail, if possible, as time is an important consideration; but this should be done carefully, as other springs or hangers may be broken or the engine may be derailed. If a forward spring or hanger should break on an eight-wheel engine, a fish-plate or other piece of iron should be placed between the top of the back box (150) and the frame (155) on the broken side. This

*Locomotives having the springs above or below the frame are said to be over-hung or under-hung, as the case may be. There is no difference in the principle, but simply in its practical application to the various classes of engines. Plate I. and Figs. 22 and 23 show engines under-hung, Fig. 24 shows springs over-hung, while in the engraving on p. 114 of *Railway Equipment* (Vol. I.) the back springs are shown under-hung and the forward springs over-hung.

will save raising the wheel that much higher and will permit the use of a smaller wedge. Then a wedge should be placed on the rail and the back wheel run up on it. This will take the weight off the forward box. I would then block solid with wood between the top of the forward box and the frame and remove the spring saddle, if necessary, as in Fig. 25; then let the engine down, remove the fish-plate from the back box and run the forward wheel up on to the wedge, which will take the weight off the back box and

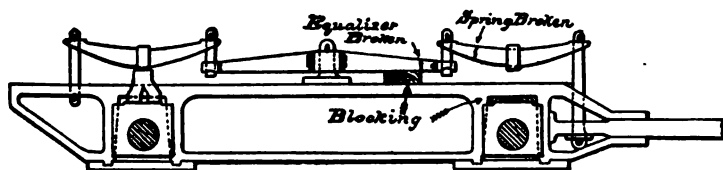
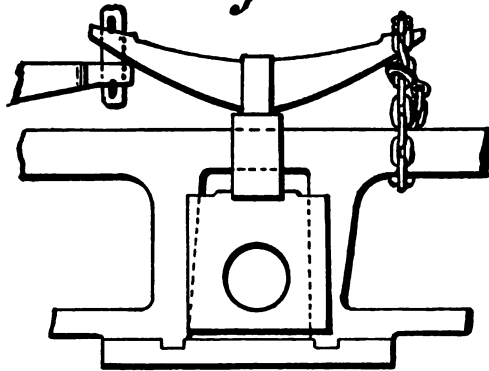


Fig. 25.

relieve the equalizers (149). I would then pry up the front end of the equalizer and block it solid, as in Fig. 25, and let the engine down and remove all loose parts. If the back spring or hanger is broken, the reverse should be done. If it is a mogul or ten-wheel engine, I would run the forward wheel up on the wedge in order to raise the weight off the main wheel, or run the main wheel up in order to raise the weight off the forward wheel. If it is a mogul engine, and a forward spring or hanger breaks, it may be necessary to remove both forward springs and block on top of both forward boxes; but if it is only a

hanger that is broken, a chain may replace it, as in Fig. 26. When both forward driving boxes are blocked, the intermediate equalizer to the truck should also be blocked. When the springs and hangers are below the frame, I would proceed in the same manner, and then block or chain up the equalizer (143) until level and remove or secure the broken springs or hangers. When the spring hangers (142) straddle

Fig. 26.



~Broken Hanger Replaced by a Chain~

the frame (155) it is sometimes possible to block between the hanger and the frame. If the large spring (141) below the frame (155) and between the drivers (138) should break, I would block the top of both boxes (150) or block between both long hangers and the bottom of the frame, securing or removing the broken parts. If the small coil spring back of the rear drivers

breaks, it may be necessary to remove one of the small equalizers which ride the box. If it is necessary to do so, I would block on top of the box. If it is not necessary to do so, and the spring hanger cannot be held in any other way, I would chain the back end of the small equalizers to the frame; otherwise I would let the frame ride the box and run the engine very slowly. With equalizers broken, I would raise the engine the same as in the case of a broken spring or hanger if it is possible to do so. If an equalizer or a stand-

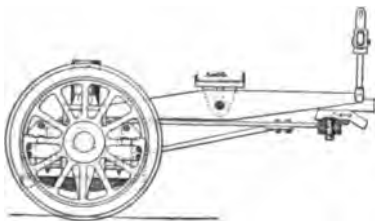


Fig. 26^A

Side View of American Bogie (or Pony) Truck, supporting forward end of locomotive.

ard on an eight-wheeled engine breaks, I would block on top of one box and block up the loose end of the equalizer the same as for a broken spring or hanger, if possible; if not, I would block on top of the driving boxes. If the forward equalizer on a ten-wheeled engine breaks, I would block on top of the forward and main boxes and block up the forward end of the back equalizer.

What should be done if the pony truck center pin or long equalizer of a mogul engine is broken?

If it is the cross equalizer on a mogul, block on top of both forward boxes and block on top of the back end of the long intermediate equalizer that goes to the truck; if it is an intermediate equalizer, block between the boiler and cross equalizer; if it is the cross equalizer on a four-wheeled pony, block on top of both forward boxes. If the equalizer is below or between the frames, it might be possible to block between the hangers and the frames. If it is a small equalizer that rides the back box, block on top of the back box and chain up the back end of the bottom equalizer. If it is the truck equalizer, block on top of the truck boxes between the box and the truck frame. All loose parts should be removed or secured. If a pony truck center pin breaks, replace it, or block between the cross equalizer and the boiler.

If the front end (18) should break, what should be done? Board it up, using the studs (bolts with threads cut on both ends), if possible; otherwise brace it. A wet blanket will do for a short time.

If you lost the smokestack (38) of your engine, what would you do? Substitute something that will create a draught, such as a barrel or long box.

How can you make temporary repairs to a hole punched in the engine tank, so that the engine can run to shops? By stopping the leak with burlaps, waste, or cab curtains used as a gasket, secured by means of boards inside and outside.

Why should the bottom joints (13) of a cinder hopper be kept tight? To prevent the air from

getting into the front end and causing the cinders to ignite; thus cracking or otherwise injuring the front end of the engine and weakening the draught.

If the grates (165) were burnt out or broken, while on the road, how would you manage? I would block them with brick, wood, the water pail, or other available substance, if they were not too badly burnt or broken.

Which is generally considered to be the better direction to move a derailed engine in order to get it back on the track? Retracing the path it took in leaving the rails.

What precautions should be taken to prevent the engine from emitting live sparks from the smokestack? Care should be taken to see that the netting (26) is in good condition, and that the ash-pan and its protecting screens are also in good condition. If an engine throws fire, it should be worked as light as possible and slipping the driving wheels avoided. The matter should be reported to headquarters at once.

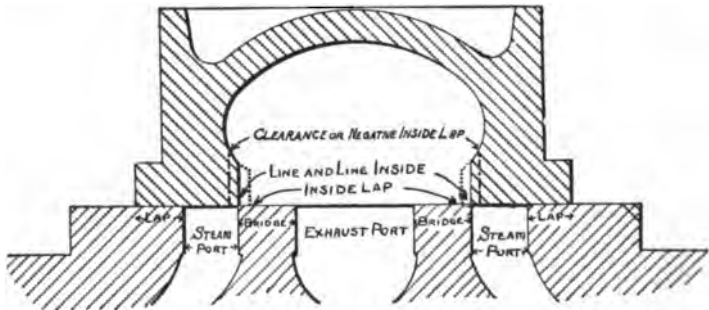
After the train has started, why should the reverse lever (217) be hooked towards the center of the quadrant (220)? To cut off the supply of steam from the boiler to the cylinders at a shorter point of the piston stroke.

What is meant by working steam expansively? Allowing the steam that is in the cylinder (57) when the supply is cut off to perform the remainder of the stroke by its expansion. Saving of fuel is thus effected.

What is meant by the "lead" of a valve (47)? The width of the opening of the steam port (56) when the piston is at the beginning of its stroke. When there is no "lead" an engine is called "blind."

What is meant by "outside lap"? The distance that the valve (47) projects over the outside edge of the steam ports (56) when it is in the center of the seat. See Fig. 27.

Fig. 27.



~Graphic Definitions of Valve Dimensions~

Why are locomotives given lap? For the purpose of enabling the engine to work steam expansively: thus the steam is held in the cylinder and expanded while the valve is traveling the distance of its lap.

What is meant by "inside lap"? The distance that the inside edges of the exhaust cavity of a valve overlap the outside edges of the bridges when the valve is in the center of its seat; negative inside lap is termed "clearance." See Fig. 27.

What effect would be produced on the lap and lead by changing the length of the eccentric blades (161 and 163)? The total lap and lead of both ends would be unchanged: what would be taken from one end would be added to the other.

Why are the eccentric blades (161 and 163) made adjustable? In order to equalize the travel of the valve (47).

Does lead increase by "hooking up" the engine, or shortening the cut-off, when the ordinary link motion is employed? Yes, the earlier the cut-off, the more lead.

How can the total lap of a valve be changed? Only by cutting off or adding to the edges of the valve.

How can lead be changed? Only by moving the eccentrics on the axle.

If lead can only be changed by moving the eccentric on the axle, how does "hooking up" an engine increase the lead, as stated above? Because hooking up throws the whole motion back around the eccentric, which acts the same as throwing the eccentric ahead through the motion.

Is it the engineer's duty to adjust the valve motion of an engine? No, except in case of derangement on the road; at all other times it should be done by shopmen.

What is a by-pass valve* and what are its uses? It is a small valve similar to the check valve and is located on the top and at each end of the steam chest for the purpose of relieving excessive compression. It is connected with the live steam side of valve and a steam port leading to the cylinder. It is held on its seat by steam chest pressure, and unseated when the compression in cylinder is greater than steam chest pressure.

How could you test for a broken or stuck open by-pass valve? I would place valve central on its seat, open cylinder cocks and give engine steam. Steam would show at cylinder cock on that end on which by-pass valve is defective.

What work about the engine should the engineer do before the engine is attached to the train? See that the wedges, nuts and bolts are tight, tighten the rods by means of the wedge keys, see that the journal oil boxes are well packed, see

*See volume "Locomotive Appliances." Piston valves.

that all frictional parts of the engine are properly oiled and look after the headlight.

How would you proceed to tighten the driving box wedges (148)? I would block the tank wheels and place the engine on upper back eighth (see diagram) on the side to be adjusted.* I would then push the lever ahead once or twice, leave the lever forward with the steam behind the pistons and then push the loose wedge up. I would commence at the main drivers.

What are the proper positions in which to key up the main rod? The positions in which the wrist pin is the largest through the length of the main rod.

What is the necessity of keeping the brasses keyed up properly? If they are not thus keyed up, they will become loose in the straps and pos-

*For the purpose of particularizing the various positions of the driving wheel crank (when occasion requires), the 360

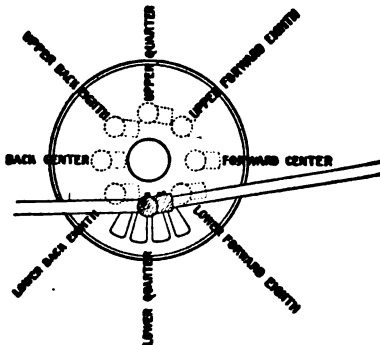


FIG. 28.

upper, lower, forward and back, as shown by diagram.

degrees through which it passes are divided into eight parts; the "upper quarter" represents the crank pin when directly above the main axle; the "lower quarter" when directly below it; the "forward center" locates the crank pin on a straight line between the main axle and the cylinder, the "back center" 180 degrees from there. The "eights" are the up-

sibly break, as well as loosen everything about the engine.

How would you proceed to key up the side rods (152) on a mogul and a consolidation engine? I would first see that the wedges were properly adjusted, then place the engine on forward center on the side to be keyed, loosen all the keys on that side, key the main connection (See Fig. 18) first, and then adjust the front and back ends in the same manner.

Why is it necessary to place the engine on dead center while keying up the side rods? In order to insure the keying of the rods at the proper length and to avoid a strain in passing the dead centers.

Why should the side rods of a six-wheel connected engine be keyed from the main connection first? In order to get the proper length of all the rods.

Can the length of a side rod of an engine be altered by keying in any other position than on the center? Yes, but any other position might throw the engine out of tram.

What provision should be made in the rods for the uneven movement of the boxes on the pedestals? The rods should be made as long as possible, but still remain free on the crank pins during a full revolution.

If an engine pounds when steam is shut off, what does it indicate? That something is wrong—that the drivers are flat; that the main rods are too long or too short, or that the follower bolts (i. e., bolts for holding together the parts

of the piston on the front side of the packing rings) or something in the cylinder is loose.*

Why will engines usually pound worse in full gear than when hooked up? Because in full gear the lead is the least and there is very little cushioning of the pistons.

What are most frequent causes of pounding? (1) Broken or loose driving boxes or (2) driving box brasses; (3) loose or broken main-rod brasses or (4) side-rod brasses; (5) main-rod too long or too short, causing either the crossheads or pistons to strike; (6) worn guides; (7) spider loose on the piston-rod; (8) follower bolts loose; (9) piston rod loose in the crosshead; (10) flat spots in the driving wheel tires.

What would you do in order to locate a "pounding" in the driving box (150), rod-brasses, etc. I would place the engine on the top quarter (see diagram), block the driving wheels on the opposite side, stand down by the side of the engine, and have the fireman work the reverse lever back and forth by the center, with steam in the cylinder. Then I would try the opposite side in the same way.

In what manner would you give an engine a thorough inspection on arrival at your destination? I would inspect the bearings, wheels, eccentrics, springs, hangers, and all parts of the engine that could be seen. If any defects existed I would notify the proper parties of the fact in writing.

*The blow felt on an engine from flat wheels, loose brasses, etc., is termed a "pound."

What is meant by friction? The resistance of two bodies in contact with each other; that which in any way opposes the mechanical motion or sliding of one upon the other.

Upon what does the amount of friction depend? It depends upon the pressure of one body bearing upon another, independent of the area in contact; the nature of the materials brought into

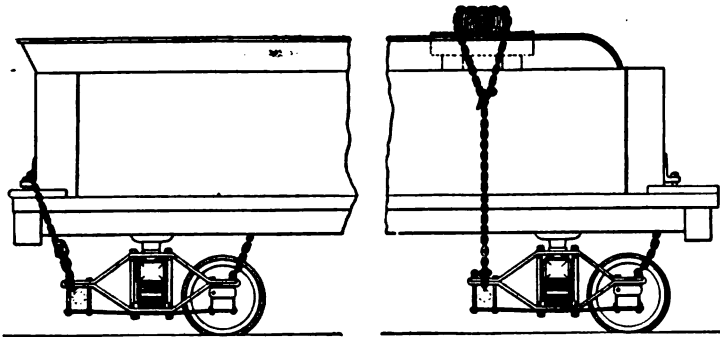


Fig. 29.

Fig. 30.

-- Two Methods of Chaining up Truck for Broken Wheel or Brk --

contact; the efficacy of the lubricant used; speed and temperature.

What is the effect of introducing oil or any other lubricant between frictional surfaces? The generation of heat is prevented, and the surfaces between which there is friction are prevented from coming together, thus minimizing the friction.

What rule should be observed in regard to oiling an engine? All parts requiring it should be oiled, using no more oil than is necessary. The

amount of work the engine has to do, the temperature and the weather must to be taken into consideration.

How great a distance should an engine run to a pint of engine oil, or a pint of valve or cylinder oil, and how should an engine be oiled to effect the greatest economy? The best record made by any engine of a similar class and doing similar service should be equaled or excelled.

Describe the manner in which a sight feed lubricator (224) operates? The steam is condensed into water and flows down into the reservoir, as water is heavier than oil. The oil rises and then passes through a tube down into a cavity in the bottom of the lubricator, and then through the sight feed glasses, which are filled with water. There it is caught by a jet of steam from the equalizing tube and is taken into the oil pipe (123) leading to the cylinder (57).

Describe the principle upon which injectors (179) work? The action of injectors is due to the fact that the velocity of steam escaping from a boiler at a certain pressure greatly exceeds the velocity of water under the same pressure, and consequently, when the water is brought in contact with the steam, the steam imparts its velocity to the water, and, by mixing with it, is condensed.

The following explanation of the accompanying engraving of a rudimentary injector, Fig. 31, will make clear the principle: In Fig. 31 the steam pipe terminates in the nozzle *N*, inside of a cone *C* on the end of the feed pipe. When

steam is admitted through valve *V* to the steam pipe it escapes through the nozzle *N* and the cone *C*, and this current of steam produces a partial vacuum in the latter and in the feed pipe, thus drawing water up from the water tank into this cone *C*, where it encounters the jet of steam

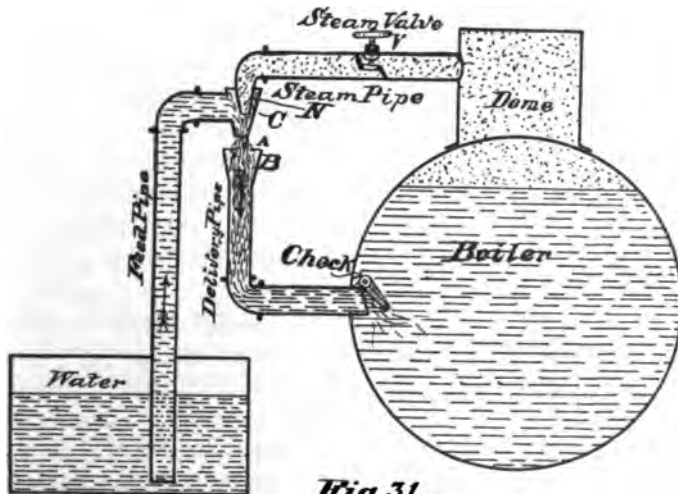


Fig. 31.
Injector Principle

from the nozzle *N*, both escaping at *A*. But when the water mingles with the current of steam in the cone *C* the steam is condensed, imparts its velocity to the water, and the jet escaping from *C* consists of water only. This at first overflows at *A*, but after a few seconds its velocity has become so great that the momentum of the water forces the check valve open and flows into the

boiler against the pressure therein. By closing the steam valve *V*, the injector ceases to work and check is closed by the pressure from within the boiler. The actual construction of an injector is shown in *Railway Equipment*, Vol. I., p. 78.

Will an injector sometimes work better and an engine steam more freely if the injector throttle is partially closed? Yes.

Name some of the principal things considered as an abuse of the engine? Lack of proper care; slipping the driving wheels when it can be avoided; catching the driving wheels on sand while slipping; working the engine harder than is necessary; reversing while running, when it can be avoided, and supplying the boiler with water irregularly.

Why should sand from both sand pipes strike the rail simultaneously? To avoid straining the engine more on one side than on the other; also to prevent the tires from wearing unevenly.

How can you tell when a wedge is stuck? By the way the engine rides. Wedges are placed between the pedestal and the driving box; the box moves up and down on faces of wedges; when it does not, or becomes rigid by being cut, it is termed "stuck."

How would you proceed to pull down a wedge that had become stuck? By running the wheel over a nut on the rail or by causing a downward strain on the wedge bolt. Being wedge shape, by pulling it down it increases the space between the pedestal and driving box and releases the latter.

What is the principle of the compound locomotive? This is fully explained under the chapters on the Compound Locomotive hereinafter contained.

Explain the working and operation of each class of compound locomotive used on this road. (See chapters in this volume referred to.)

Should the fireman conform to your views of what is best while on the engine? Yes, but matters should be talked over and explanations given when necessary.

In case of accidents on a busy main line of the road, what is of first consideration? After protecting the train, to get the main line clear as soon as possible.

What circumstances will govern procedure in such a case? If the engine can be cautiously moved to a nearby siding, there would be the proper place to disconnect and make temporary repairs; if a wreck occurred on double track, one track should be cleared first to permit trains to pass around the wreck and facilitate the work of the wrecking car.

To repeat a former inquiry, what is the proper method of firing? Firing light and often and having the coal broken into fine pieces and evenly distributed over the fire.

AIR BRAKE EXAMINATION.

NOTE.—In the book on *Railway Equipment* great pains have been taken to describe the air brake and how it is worked: It was intended to be exhaustive or at least more complete than anything hitherto written on the subject. What follows is embodied here, because it forms a part of an examination of “would-be” engineers that I am describing for the benefit of those concerned. The account of the air brake in *Railway Equipment*, referred to above, covers nearly a hundred pages and is profusely illustrated. I would recommend it to firemen who seek to be engineers, and all others who wish to post themselves in regard to the construction, maintenance and operation of the air brake.

In regard to the particular air brake referred to (the Westinghouse), I adopt that, not because I have any interest whatever in the brake or its owners, but simply because it is more generally used than others, and is therefore of greater general interest. To understand it thoroughly will enable the student to quickly familiarize himself with other forms, because while details differ in many essential things, yet the object and general means of attainment are the same.

M. M. K.

Can you trace the air through the air brake system? Yes. The air is received from the atmosphere through the air cylinder (169) of the pump; from there it is carried through the discharge pipe (172) to the main drum (99); then through the engineer's valve (218) to the train line (231); through the branch pipe, cut-out cock and triple valve to the auxiliary reservoir (to charge the cars); then through the triple valve to the brake cylinder (to set the brake); then through the

triple valve to the atmosphere (to release the brake). When a retainer is used, the final exhaust has to go through the retainer.

Are Westinghouse air pumps single or double acting? They are double acting.*

Under what circumstances will a pump compress air in but one direction? When any one of the four valves in the air cylinder are fast or broken.

How should an air pump be started and lubricated? It should be started slowly and should be lubricated by putting eight to ten drops of cylinder oil in the steam cylinder (170) as soon as the water has worked out. The harder the pump's service the greater should be the amount of oil supplied thereafter.

At what speed should a pump be run? It should be run at a uniform medium speed not sufficient to cause excessive heating.

What kind of oil, if any, should be used in the air cylinder of a pump and where should it be applied? Valve (cylinder) oil should be used sparingly. Apply it through oil cup which is located on top of the air cylinder. Never oil the air cylinder through the strainer and air passages. Usually a teaspoon of oil will be sufficient for one trip, but if service is heavy, another oiling of same quantity will be necessary before completing the trip. An air cylinder sight-feed-cup, one that would supply about one drop in two minutes to the air cylinder, would work to a better ad-

*See full explanation and illustration of Air Pump, Appendix B.

vantage. Where an air pump has become hot, the best method of cooling it would be to reduce the speed of pump. (As the sensitiveness of all the air parts of an engine depend upon the treatment of the air cylinder, this is a most important subject.)

What harm is there in using kerosene or any oil excessively? Kerosene affords a liability to explosion, while any oil gums up everything if used too freely.

Should a swab be used on a pump rod? Yes, metallic packing should always have a swab.*

What causes water to get into the main drum (99)? Compression of the atmosphere (containing moisture) causes precipitation of water.

How often should the main drum and tender drain cup be drained? Daily in freezing weather; at other times, every few days, according to the weather.

What damage does water do? In summer it rusts the pipes, and the scale falling therefrom stops the strainers and cuts the valves. In winter, if the water freezes, it bursts the pipes, or they are clogged with frost, thus preventing the working of the brakes.

What train-line pressure should be carried on an engine? That which the rules and regulations prescribe. Seventy pounds, ordinarily, is the rule.

*A "swab" is the term applied to the cotton wick or other absorbent material wrapped around a piston rod or valve rod for the purpose of lubricating the rod in its packing gland. This "swab" is kept continually saturated with oil.

The engineer is responsible, although the engine may be in his charge for only one trip.

How is the train-line pressure regulated with an 1889 valve (*D 8*) on an engine? By means of the governor (177).*

How is it regulated with an 1892 (*D 5, E 6* or *F 6*) engineer's valve? By means of the feed valve, when the governor is set above the required train-line pressure.†

What is excess pressure? The amount of pressure in the main drum over the train-line pressure.

When should excess pressure be carried? At all times, except when charging a train at terminals or recharging on heavy grades.

What is the value of excess pressure? It insures prompt and certain release of the brakes, especially on long trains. It is also used to charge cars quickly.

How much excess pressure would you carry with an 1889 valve? Fifteen pounds for a passenger or short train, and twenty pounds for a freight or long train.

*The 1889 valve is so designated to avoid the confusion of letters and numbers. I call it thus because it was introduced in 1889. It is more generally known as *D 8*. In 1892 another valve was introduced, and this is also designated by letters and numbers. I designate one the valve of 1889 and the other the valve of 1892.

†The 1892 valve is variously designated in different catalogues. The reason I designate it as the 1892 valve is because it was introduced in that year, and in order to avoid the confusion that the various numbers and letters cause to railway men. In some cases it is called the 1892 valve in others *D 5, E 6*, or *F 6*. They all refer to one and the same valve.

How much excess pressure would you carry with an 1892 valve? Twenty pounds for a passenger or short train, and twenty-five to forty-five pounds for a freight or long train.

Why would you carry a different amount of excess pressure for a freight than for a passenger train? Because freight cars have a larger train-line piping, and there are usually more cars than in passenger trains. Consequently, to insure prompt release, more excess pressure is necessary. Besides uncharged cars are often introduced (picked up) by freight trains; such trains also frequently break in two, necessitating a large quantity of air to release the brakes.

How do you regulate excess pressure with each kind of engineer's valve? With the 1889 valve in running position, the excess pressure is regulated by the tension of the spring in the excess pressure valve; with the 1892 valve, if the feed valve is properly set, the excess pressure is regulated by adjusting the governor.

What does air blowing out of the little hole in the neck of the top of the new governor indicate? It indicates that the pin valve (or diaphragm valve) is off its seat, either on account of dirt or on account of the tension of the governor spring having been reached.

If the pump stops before the maximum pressure is attained, what should be done first? Shut the pump off entirely for a minute, and then open it quickly; if it then fails to start, it is probable that the main valve is broken and cannot be fixed without protracted delay. If the pump

starts, but stops frequently, remove one of the caps of the pump (the side one preferably) and put in some cylinder oil, replace the cap and start the pump slowly. If this does not suffice, remove the reversing piston (side cap) and ascertain if the packing rings are broken. If they are, remove the broken pieces and wrap with candle wicking and oil. Next remove the center cap, pull out the reversing valve and stem, noticing as you do so that the reversing plate is not loose.

If these parts are found to be all right, put them back (being careful to put the valve in facing the reversing piston), and push the stem completely down, replacing the cap. Then if the pump starts and makes one complete stroke, up and down, the trouble is with the reversing valve plate (to get at which it is necessary to remove the top head of the pump,) or with the air piston—the piston nut has probably worked loose—to remedy which, remove the bottom air head.

NOTE.—If rubber or asbestos gaskets are used instead of copper to connect the pump, pieces of them lodged in the small ports in the top head will stop the pump. When the side cap is off, it is a good plan to turn on some steam in order to test some of these ports.*

Should the conductor be notified if the pump does not work? Yes, at once, even if the engineer expects to get the pump working before the next stopping point is reached.

*The above description only applies to the 9½-inch pump where it has parts in common with the 6-inch or the 8-inch pump. See Appendix B.

What are the essential parts of the automatic brake for cars? The train-line, the triple valve, the auxiliary and the cylinder.

How can you distinguish between the two kinds of triple valves? The plain triple valve has a cut-out cock in the triple valve casting, or has one-half inch piping. The quick action triple valve has no cut-out cock in the triple valve casting; it is in the large one-inch or one and one-quarter-inch branch pipe.

What are these cocks for? They are to cut in or cut out the brake—that is, they are used to let the air enter a particular brake apparatus or to cut out such brake. In the case of the four-way cock in the old style triple valve, it also may be used to cut in to straight air.

Where is the compressed air kept stored for use? For all purposes, in the main drum, train-line and auxiliaries; for applying brakes, in the auxiliary, and (with the quick action triple valve) in the train-line.

How does it get there? The answer to the first question in the air brake examination describes this, also.

How rapidly does an auxiliary charge? At the average rate of about half a pound a second, when the train-line is kept at its maximum.

When should you bear this in mind particularly? When charging uncharged cars, or when recharging on descending grades.

How can you tell the pressure in the auxiliary? In a practical way by lapping the valve (position 3) and noting the black hand of the air gauge

when it stops dropping—i. e., with the brakes not set. When the brakes are applied the train line and auxiliary pressures are equal if an over-reduction has not been made.

Where does the air that enters the brake cylinders come from? It comes from the auxiliary, if service application is used; and from the train-line and auxiliary if emergency application (with quick action triple valve only) is used.

What is the office of the triple valve? It charges the auxiliary and sets and releases the brake.

How is the automatic brake applied and released? By the triple valve, which allows the air to enter and leave the brake cylinder. The triple valve is moved by increasing the train-line pressure above, or decreasing it below the auxiliary pressure.

When the train-line pressure exceeds that of the auxiliary, what is the effect on the brakes? They are released by the triple valve.

When the auxiliary pressure is higher than the train-line pressure, what is the effect on the brakes? The triple valve sets them.

In making a service application with any given pressure, what proportion of it should you reduce to get a fully applied brake? One-fourth of the auxiliary pressure, for the standard piston travel of eight inches. This because the cylinder is at that travel about one-third of the standard auxiliary's capacity.

How much should the first reduction be? From four to eight pounds, according to circumstances.

Up to ten cars of air, four or five pounds; from ten to twenty cars of air, five or six pounds; above thirty cars of air, seven to eight pounds.

Why are there leakage grooves in cylinders? To prevent a slight leak from applying the brakes. Driver brakes have no leakage grooves.

How long are these grooves? They are long enough to allow the piston to move three inches before covering them.

After making a full service application, how much pressure is there in the cylinder? The same as in the auxiliary, i. e., three-fourths of what the auxiliary had before the brake was applied, for standard eight-inch piston travel.

When and how can you obtain greater pressure than this? By using emergency (with quick action triples) before you have made much or any service application.

What is meant by an over-reduction? The further reduction of the train-line pressure after the pressures of the auxiliary and cylinder have equalized (that is, become equal).

What is the result of making an over-reduction? It is a useless waste of air and results in an irregular and oftentimes difficult release of the brakes.

If you do not make an over-reduction, how much air is it necessary to restore to the train-line in order to release all of the brakes? If an over-reduction is not made on any car, the brakes will all release together by a sudden increase of but a pound or two, even though the cars have an unequal piston travel.

How many applications are necessary to make a stop? One, usually, but not more than two.

What is the objection to more? Each application reduces the reserve pressure in the auxiliary reservoir.

When would you make more than one application in making a stop with a passenger train? When at yard limits, draw bridges, railroad crossings, meeting points, or other places of danger; also when a slippery road crossing is reached just before a stop is to be made, or at a place where sand cannot be depended upon.

Why is it dangerous to repeatedly apply and release the brakes? Because each application reduces the auxiliary pressure, and, if there is not sufficient time between the applications to recharge, the braking power is greatly weakened.

How would you handle the engineer's valve in releasing the brakes ordinarily? I would move it to full release (position 1) and bring it immediately to running position (position 2) before removing my hand from the handle.

What separates the main drum from the train-line pressure? The rotary valve of the engineer's valve when the handle is at any place except on full release. Also the feed valve of an 1892 valve or the excess pressure valve of an 1889 valve separates these pressures in running position only.

Explain the effect of a cut or leaky rotary valve or seat? It generally causes a loss of excess in running position and releases the brakes on lap. While a rotary valve might be cut in many ways,

usually the leak is from the main drum to the train-line, as the seat between the two is only a quarter of an inch broad.

How would you do good braking with a leaky rotary? "Good"—the word is comparative. Rough handling of the train or jerking could be avoided if the train-line exhaust was allowed to blow out as much air, or more than the leaky rotary was putting into the train-line.

Is a leaky rotary considered dangerous? Yes, and a proper test before taking the engine out of the house would have determined the defect.

Why is it necessary to keep the rotary, feed and excess pressure valves clean? Because gum or dirt will cause them to open or leak when they should be closed, or will cause them to close when they should be open. Excellent work cannot be done if these valves are not kept clean.

Where are these valves located? The rotary valve is located under the handle key of both engineer's valves. The feed valve is located on the side of the 1892 engineer's valve. The excess pressure valve is located on the side of the 1889 engineer's valve.

What is the purpose of the engineer's brake valve drum? It enlarges the cavity above the equalizing piston without taking up space inside of the cab and making a bulky valve. This space being large, permits a preliminary exhaust opening large enough not to become easily stopped up, and yet a very slight reduction in the pressure can be had.

If this drum should spring a leak on the road, what would you do to accomplish good braking? I would plug the connection to it, plug the train-line exhaust, and use the handle in direct application (position 5), opening it carefully so as to avoid quick action, and closing it slowly so as to prevent the surge of air ahead from releasing the head brakes.

State the different positions of the engineer's valve. Full release (1), running (2), lap (3), service stop (4), and direct application or emergency (5).

What harm is caused by leaving the 1889 engineer's valve on lap a long time and then releasing? With this valve the governor will allow a high main drum pressure to accumulate, if the train-line is below standard when the handle is on lap. Putting this into the train-line upon releasing, a burst hose will result, auxiliaries be overcharged and governor injured.

Would you run a pump fast with an 1889 valve when on a grade? Not unless there was a long train which had to be recharged frequently on account of leakage.

What is the function of the air pump governor? It automatically shuts off the supply of steam to the pump when the maximum air pressure has been obtained and readmits steam to the pump when the air pressure it is regulating falls below the standard amount.

What might prevent the governor from shutting off the steam when the maximum pressure had been obtained? The drain or waste pipe be-

ing stopped or frozen-up; stoppage of the relief port in the spring cap; too long a diaphragm valve; excessive leakage by the governor piston or above it; with new governors; the spring under the diaphragm valve head, broken or missing.

If the governor became inoperative, what would you do to get it in working order? I would try to adjust it by adjusting the spring. Then if it failed to work, I would relieve it of pressure and clean the diaphragm valve and valve seat with soft wood or something that would not scratch or cut them.

What would you do if the governor did not allow you more than thirty or forty pounds of air, although you had adopted the above means of repair? I would disconnect the air pipe leading to the governor and plug it up, using the pump throttle to regulate the pump for the remainder of the trip.

What is the cause of gum or dirt in the governor? Oil from the air cylinder, or the running of the pump over an ash-pit or other dirty or dusty place.

Why should the brakes on a passenger train be released before the train is brought to a full stop? To avoid the disagreeable lurch which is caused by the trucks being tilted when the train stops. The greater the amount of air in the brake cylinder at the instant of release, the longer it will take it to escape, and this must be allowed for in order to get a release at exactly the right time.

Why should you not release the brakes on a freight train before coming to a full stop? It is not necessary to do so, because the brakes on freight cars are generally hung differently from those on passenger cars, and the train may break in two.

When would you use the emergency application of the brake? Only when necessary to prevent the loss of life or property.*

Does the emergency jerk most when going fast or when going slowly? When going slowly.

How should the brakes on a freight train, with only a part of the cars having air brakes, be applied and released? They should be applied lightly at first, increasing the pressure when necessary. They should not be released until the train has stopped.

If necessary to release a part air brake train when moving, how do you handle the engineer's valve? Place the handle in running position (2), and then move it back to lap quickly, repeating this several times until nearly all of the brakes have been released, each time leaving the handle in a running position a little longer than the previous time; finally, throw the handle to full release and then back to running position.

When should the hand brakes be set on the rear of a train? Only upon a call for brakes, or when a part air brake train is backing up. In the latter case, most of the braking should be done

*Reference to Appendix A will show that a locomotive should not be reversed after applying the brakes in emergency.

by using the hand brakes at the rear. When the engineer requires assistance, because of too few air cars, the hand brakes immediately behind the air brake cars should be used.

If you find the brakes dragging, how can you release them? By using excess very quickly, if you have it. If not, by setting the brakes enough to get excess, and then releasing quickly.

Why is it necessary to test the air brake apparatus before starting? To insure the safety and celerity of trains upon the road.

Describe the proper method of testing brakes on a train. Beginning at the rear, the brakeman should couple all the hose, open all the angle cocks except the one at the rear, see that all the cars are cut in (except such as are marked defective), see that all the hand brakes are off, and the retainers open, with the handles pointing down. The engine should be cut in last. While the engine is charging the cars, the brakeman should pass along the train and inspect it carefully to ascertain if there are any leaks. In charging a train, the pump should be run according to the temperature of the weather, in order to charge the train reasonably fast without overheating it. Where there are the average leaks, an eight-inch pump should charge a train in about one-half as many minutes as there are cars; a nine-and-one-half-inch pump twice as quickly. After the train is charged and the engineer is satisfied that it is reasonably free from leaks, the head brakeman (stationed at the head air brake car) should signal the rear brakeman

(stationed at the rear air brake car), who should repeat the signal. After the engineer gets the signal from the rear man, he should apply fifteen to eighteen pounds in service application and place the engineer's valve handle on lap. The brakemen should, now walk toward each other, inspecting each car, to see that it sets and holds—noting the piston travel as well. After this has been done, they should signal the engineer to release. Then the brakemen should pass each to his respective end of the air brake cars to see that all the brakes have been released, and, in winter, see that no shoes are frozen to the wheels. The head brakeman should then advise the engineer as to the number of air cars that are in good working order, and the tonnage or length of the train.

In testing brakes, why is it not advisable to use the emergency application? Because the use of service application is the ordinary method of stopping a train. Some defective brakes will set in an emergency application that will not set in service application.

Why should a full reduction be made, and not five or six pounds? Because some cars may charge five or six pounds faster than others, if charged rapidly. A proper test must insure the setting of every car that is in fair condition.

In making a test with a train standing, if any brake in the train sets quick action, how can it be detected? By noticing the train-line exhaust from the engineer's valve. If it stops suddenly while the brake valve is in service position (it

may start again or not, according to how much reduction is made), it shows that the train-line pressure has suddenly dropped faster and lower than the pressure above the equalizing discharge piston. Emergency does this by venting the train-line pressure directly to the brake cylinder suddenly.

How would you proceed to ascertain in which car the trouble was? One method is to set about five pounds in service application and then find out which cars having the quick action triple valve are not set; have some one watch each car while increasing three to five pounds more in the service application. The car that sets in quick action first is the defective one, but as emergency travels at the rate of about twenty-three cars per second, it is best to cut out one of the cars that did not set at the first reduction, and have the application continued; if this proved not to have been the one thus defective, test the train again, cutting out another car that failed on the first application, until the defective car is located. Another and ordinarily shorter method is as follows: Cut the air cars in two equal sections and repeat the test for trying brakes. This will tell which half of the train is defective. Then take one-quarter or three-quarters, according to whether the defective car is in the front half or back half of the train, and continue in this way (never trying with less than three car lengths of piping) until the defective car is found and cut out. A broken graduating pin in the quick action triple valve will cause a brake to set quick

action, and although this rarely occurs, no train should be taken out of the station until the defective car is located and cut out. It should be done before damage occurs.

If one triple valve goes to emergency, will the others follow? Yes, if it is a quick action triple, all the other triples of either kind will go to emergency. Rare exceptions to this rule may occur where a large number of plain triples or cars having brakes cut out are placed together in a train.

Before starting from a terminal station, or where a change is to be made in a train, is it the engineer's duty to find out how many cars there are in his train with and without air brakes? Yes, it is his duty to find out how many cars there are with air brakes. To know the tonnage of a train is more valuable than to know the number of cars.

In making a careful test, why is it necessary to hold the brakes applied for a minute or longer? Because the longer the brakes can be left applied the more certain it is that they will hold for a long and difficult stop.

Where else, except at starting points, should a terminal test be made? When changing engines, or adding a double header (another engine) after long delays have occurred on the road, and at the summit of very heavy descending grades. When air brake cars are added to a train, a terminal test of such cars should be made by the forward brakeman, while the rear brakeman should see that the rear air brake car can be applied and

released from the engine. When the engine is cut off, or the train cut in two at a crossing, or elsewhere, it should be ascertained that the engineer can set and release the rear air brake car.

When the brakes apply suddenly without the action of the engineer, what is the cause? The train has parted, the hose has broken, or a valve has pulled open.

What should be done in such a case? The engine throttle should be shut off and the air brake handle should be put on lap (position 3) as quickly as possible.*

If you find that the train has broken in two, what would you do so as to be able to get under way again promptly? When the train has been brought to a stop, I would place the handle in running position to see if the train pipe is still open. If I thought it was a burst hose, I would keep the handle moving from lap to running position and back, so that the trainmen could hear the air escaping from the burst hose. If I find that the black hand is gaining in running position, I would know that the trainmen had found the defect and had closed the angle cock ahead of it. I would then release the head brakes and lap the valve so as to pump up excess ready to release the rear cars when the hose had been replaced, or the train recoupled if it has been parted.

*No attempt should be made to get away from the rear portion of the train. Increasing the distance of separation between the parts will only increase the violence of their finally running together.

If, after recoupling, you could not release all the brakes at once, how would you handle the engineer's brake valve in order to do so the most quickly? I would lap the valve and, after getting about twenty pounds of excess, I would try to release with this, repeating the operation until all the brakes were released. I should never leave the engineer's valve handle in release position expecting the action of the pump to release all the brakes.

How should you handle the engineer's valve in backing up a train where a "tail hose" is being used at the rear end?* Leave it in a running position all the time, running the pump a little more slowly than usual. Before backing out of the yard, as a test, the rear man should set the brake while the train is moving, and stop it against the working of the engine.

When two or more engines are coupled together, which engine should do the braking? The forward engine.

What would you do on the other engines? I would close the stop cock in the train-line under the engineer's valve and run the pumps, keeping the engineer's valve handles in running position.

*A "tail hose" or "back up hose" is a long hose to be coupled to the rear air brake hose of the last car, and has on its extreme end a valve by which the trainman operating it may allow air to escape from the train-line to apply brakes. This hose is used where passenger trains are backed any considerable distance. In conjunction with the valve, it frequently has an air whistle with which to sound warnings on approaching street crossings, etc. The free end of the "tail hose" is fastened to the platform hand railing, so as to be readily accessible to the operator from the platform of the rear car.

All the engines should be equipped with such stop cocks.

Would you do any differently in cold weather than you would in warm weather? Yes, in winter the pump on the rear engine must be kept moving, even if it is necessary to break some pipe joint to cause a leak.

What variation is allowable in the brake piston travel on cars, tenders, drivers and engine truck? Generally speaking the piston travel should be kept between one-half to three-fourths the length of all kinds of brake cylinders except drivers. It is advisable, however, that freight cars be taken up to five inches when empty and drivers are best kept between two and four inches. It occurs in the practice of some companies, that engine trucks and ore cars or other cars of special construction have cylinders but eight inches long.

How is the slack taken up in each case? In passenger cars it is taken up by the turn buckles or dead levers. In freight cars and tenders it is taken up by the dead levers, or bottom rods for inside connected brakes. In cam driver brakes, it is taken up by lengthening the arms, and in truck brakes by lengthening the outside arms.*

How can brake shoes be kept from rubbing against the tires continually on eight-wheeled

*The cam driving brake is placed between two adjacent driving wheels--mainly on locomotives having but two pair of drivers. Formerly it was largely applied to the two rear drivers of moguls and ten-wheel engines. The more modern form is "the outside equalized brake" as shown in the chart of the Standard American Locomotive (Plate I.).

engines? By adjusting the screws of supporting rods or by adjusting springs.

How are the outside equalized brakes adjusted? Both the steam and air brakes are adjusted by tightening the adjusting screw located near the rear driver on each side.

How does the variation of piston travel affect the braking power? The braking power is increased by the shortening of the piston travel, and *vice versa*.

With the same piston travel, can loaded and empty cars be stopped alike? No, they will neither hold nor stop alike on account of the variation of weight to be stopped, but the brake itself exerts about the same force in both cases.

Why should the brakes be released before uncoupling from a train? In order that the cars can be switched and car repairers can tap (test) the wheels or jack up a journal box; also to prevent the shoes from freezing to the wheels, and especially because a brake that is applied leaks so rapidly that in changing engines it may be found that much of the air has escaped.

What should be done with the air hose at each end of an engine before coupling to the train? Air should be blown through them, or they should be shaken out by hand to clear them of dirt and dust.*

What is the pressure retaining valve? It is a weighted valve which the triple exhaust has to

*The rules of some roads require that whenever air hose are not coupled together they shall be hung up in dummy couplings provided for that purpose.

raise in order to escape it when the retainer handle is turned up, and has to be turned up before the brake is released.

What is its use? It retards the release and finally holds from fifteen to twenty pounds of air in the brake cylinder while the auxiliary is being recharged.

In descending a grade, what is the best way to keep a train under control? The best way is to apply the air lightly while the train is moving slowly, keep the train at a slow speed, and the train-line pressure as high as possible all the time. To do this, if it is necessary to recharge, reduce the speed below the average just before recharging. To recharge, handle the train as though a flagman had been sent half a mile ahead, i. e., go slow and exercise caution.

In switching with an air brake train and picking up uncharged cars, how should the engineer's valve be handled? As a high main drum pressure will release a low auxiliary pressure, this condition should be obtained before coupling to the uncharged cars. Then the pressure should be released, and the handle left in full release until the pointers of the air gauge commence to rise.

Do you consider a good light on the air gauge as important as on the steam gauge? Yes, more so, as steam is indicated by the working of the engine, while, until ready for its use, there is no certain indication of the amount of air pressure except by the gauge, which must be clearly seen. Clear vision of the air gauge at night is very im-

portant and should be given proper attention; the light from the fire-box when the door is open is not sufficient.

How often should the air gauge be observed? When whistling for road crossings, or similar places, and about two miles from all dangerous places or places where the train is to stop.

Can one tell approximately how many air brake cars are attached to the engine by a five or six pound reduction? Yes, the length of the blow from the train-line exhaust indicates this approximately. It is easy to discern a few from many cars.

How far from important stops, meeting points, railroad crossings, etc., should the first brake application be made? Not less than a mile on freight trains, and on passenger trains the distance should be far enough to insure safety in case the brakes fail to work satisfactorily.*

For what purposes and in what way is air taken from the main drum? For many purposes. It is taken by the train-line, air signal, air bell ringer, air sander, air blow-off cocks, and air flanger.

Will a ten pound reduction from seventy pounds set a brake any harder than a ten pound reduction from fifty pounds initial train-line pressure? No, not with a standard piston travel, or greater than the standard.

If you had but forty pounds of air, how much would you reduce to obtain full power? One-

*Some railroads require a running test at least two miles from all such points and at the summit of heavy grades.

fourth with standard eight-inch piston travel would be a full application.

Why is it important to keep the driver brakes in good order? Because they are the most powerful brakes on the train and the most costly. They keep the tires worn down, prevent the engine from pulling away from the tank, and prevent the train from parting near the head end.

How do you test for leaks in driver breaks? First, apply them. (Emergency application will hold longer than service application and the straight air will supply loss from leakage.) Everything from the triple valve to both cylinders, and all the parts of both cylinders should then be examined with a torch. A gauge screwed into the oil hole of the cylinder also affords an accurate test.

When do wheels generally slide, at high or at low speed? At low speed.

Which is the more likely to slide, a freight or a passenger car? A passenger car, as it has a braking power of ninety per cent of its weight under quick action, while a freight car has seventy per cent or less.

How would you stop a passenger train when the track was slippery? Apply the sand a train length before applying the air, and only shut off the sand when the train had come to a stop. Less air should be used than at other times, as the sand helps the brake shoes to hold as well as the rail.

When is the rail most slippery? When there is a frost, or the rail is lightly sprinkled. When

cinders or coal screenings are used for ballast, the rail is rendered more slippery.

If it is impossible to depend upon sand, as in the case, say, with a side wind, or if the sand pipes should stop up, how should the braking be done? To make a sudden stop, from ten to fifteen pounds should be applied about the same distance from the stopping point as in the case of a good rail. When the train is reduced to a speed of from fifteen to eighteen miles per hour, all the brakes should be released and then five to eight pounds applied, or not enough pressure to make the wheels slide.*

Does the black hand of the air gauge show the train-line pressure at all times? No; only in full release or running position, or on lap at the instant the train-line exhaust starts or stops. It always shows the pressure in the cavity (and little drum connected thereto) above the equalizing discharge piston.

Are the train-line pressure and the auxiliary pressure always the same? No. While releasing or charging, the train-line pressure is greater than the auxiliary pressure. While setting, or after making an over-reduction, the train-line pressure is less.

With an 1889 engineer's brake valve can you supply a leak in the train-line with the handle in running position? Yes, if in releasing after

*The speed curve in Fig. 33 shows clearly that it is the reduction of the high velocity that requires the severest application, while a low speed can easily be overcome by a light application, and it is then that wheels are most liable to slide.

brake applications you move the handle to full release and bring it immediately to running position before letting go of it.

What is the result of leaving the handle of the engineer's valve in full release too long and then returning it to running position? Any leak in the train will set the brake, and the engineer's valve is not ready to overcome it.

What is indicated by noticing the discharge from the train-line exhaust nipple? About the number of cars in the train; also, when applying service application it will indicate whether the brakes will act with emergency application or not. When the handle is placed in release position, a blow from the train-line exhaust indicates few or no cars.

If the air signal whistle blows every time the brakes are released, what is wrong? The pressure reducing valve needs cleaning, as it does not reduce the main drum pressure.

When the weather is cold is it desirable you should examine the tank wheels before starting, to see if the shoes are frozen to them, and, if so, to effect their release? Yes, particularly so, as there is great liability of water dripping from the tank.

Should a passenger train going at high speed be steadied by the brakes while on a curve or rough place? Yes. The brakes should be applied a little before reaching the place, and held on until the whole train has passed.

If short of air, how can you distinguish whether the trouble is with the pump or with the gov-

ernor? By reducing the pressure that the governor regulates or by letting it all out. Then, if the pump works all right, the trouble is probably in the governor. If the pump does not work all right, the trouble is probably in the pump.

Would the air brake on a car work properly with the retainer broken off? Yes, if not plugged up.

How many air-brake cars should be operated by one engine? To the extent of the train-limit. If the brakes leak, complaint should be made forthwith and the defects remedied.

With an independent brake on the engine, if you were backing up, which would you apply first, the automatic brake, or the independent brake? The automatic train brakes.

How often should you report defects in the engine, that need repairs? Daily, and at every roundhouse your engine enters.

Do you appreciate the fact that the proper handling of the air brake on trains is one of the most difficult tasks that an engineer has to perform, and that its proper handling so as to secure the comfort of passengers and the safety of life and property requires close attention and the exercise of good judgment? Yes.

Is it not a fact that the failure of the air brakes to work is almost invariably due to the neglect of some one to do the right thing at the right time? Yes.

Is it the duty of an engineer to observe and study with painstaking care any and all new fixtures and appurtenances introduced from time to

time in connection with the air brake or other features of the engine? Yes; his imperative duty.*

*In closing this examination the attention of the reader is again respectfully called to the detailed description of the locomotive and the air brake, together with the numerous engravings illustrating the same, to be found in the book on *Railway Equipment*. The information in question will prove of value to all students of the subject treated on.

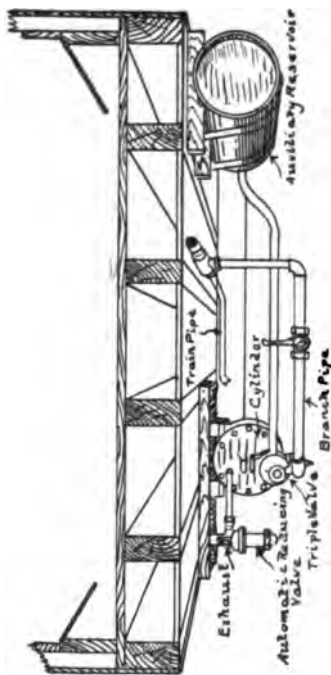


Fig. 32.

~ Passenger Car Equipped ~
~ with ~
~ HIGH SPEED BRAKE ~

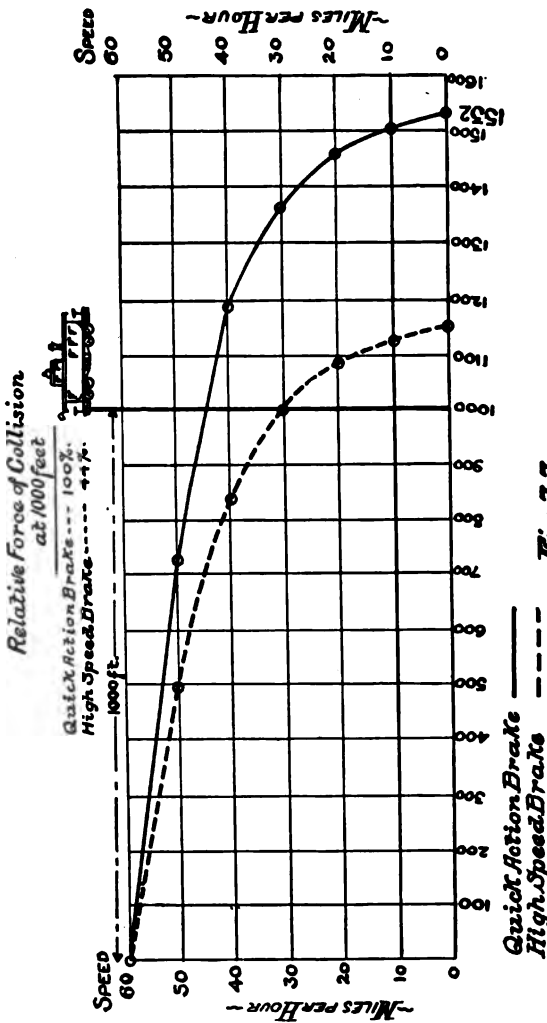


Fig. 33. Speed Curves for Stopping with Quick Action and High Speed Brakes

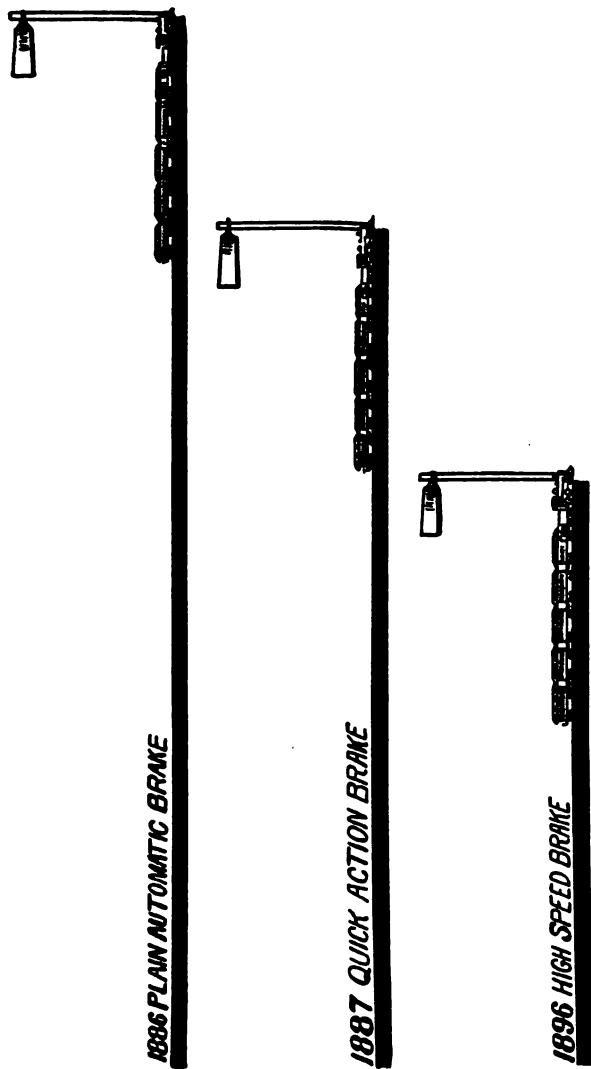


Fig. 34.
Progress in Train Stopping During a Period of Ten Years



OTHER MATTERS RELATING TO THE DUTIES AND RESPONSIBILITIES OF ENGINEERS.

The foregoing examinations, with what follows, prepared with a view to ascertaining the fitness of firemen to become engineers, treat of things that it is desirable engineers should know—should have at their fingers' ends—in order to fill their places to the best advantage. If they are not familiar with them they should lose no time in becoming so. They are primary in their nature.*

The vast resources at the engineer's disposal, the result of experience, while much of it may be particularized in print, much of it cannot be. The beginner does not possess this fund of information and it is not expected of him. He is,

*While we must believe that it is desirable that the engineer should not only understand his own duties perfectly, but those of the fireman as well, it is nevertheless true that this universality of knowledge is not possessed by all engineers. This renders manuals all the more necessary. One reason why engineers do not possess the knowledge in question is that methods change after they cease to be firemen; thus we will say, the kind of fuel may have changed, from wood to coal. Whatever the occasion of the lack of knowledge, the lack exists and is recognized by railroad companies and excused because unavoidable, but in so far as engineers are deficient in the knowledge of the duties of firemen, manuals that throw light on the duties of the fireman are not only of value to the latter but to the engineer as well.

however, expected to attain it as quickly as possible. If he is ambitious and adaptable he will soon acquire it. The time required will be dependent upon the thought that he gives the subject and his ability to learn. Nothing connected with his business will be too small to escape his observation; nothing too trifling if it affords him information; he will avail himself of the literature, however scant, that dwells upon his duties or that has any relation to the train service; he will observe and study the actions of those about him; question with untiring zeal, all from whom he can gain light. He will not be satisfied with the fact that he has been found worthy to have charge of an engine; he will not stop until he understands the anatomy of his machine and its working as the surgeon does that of his patient.

After his examinations he will go on with even greater zeal than before, because his ambition will by this time have led him to aspire to even higher things. For these and other reasons I have thought it well to supplement what I have said with other things that relate to the responsibilities of engineers, and that must be known to firemen in order to enable them to run an engine. What I add is not new nor especially ingenious. It is, however, useful to engineers and a help to others. I cannot claim to be more than the compiler and editor, for others before me have given it expression in one form or another. It is of the common sense kind, and

partakes, like all corporate regulations, of a practical nature. I shall try to avoid as much as possible repeating anything concerning the duties and responsibilities of engineers already given.*

With this explanation, I proceed to enumerate such things as occur to me at this time as forming a part of the subject.

To begin, then, it may be said of engineers, that amiability, quickness of perception, skill and promptness of action mark those of the highest attainments. The fireman who hopes to become a good engineer must possess similar characteristics.

It is also a characteristic of such engineers that they are stirred by an ambition to excel in every way.

While the fireman is the subordinate of the engineer, the latter should seek to further his advancement by teaching him everything connected with the construction, maintenance and operation of the locomotive that his time and capacity for learning permits of.

The fireman on his part should show his appreciation of the kindness and interest of the engineer by his industry, amiability and willingness to obey orders.

The engineer and fireman must work together, each recognizing his dependence upon the other, if the best results are to be attained.

*I shall, however, be only partially successful in this, but while there will be more or less going over ground already traversed, it will be in connection with new ideas and a fuller development of old ones.

In reference to details, it is becoming more and more the practice for the engineer to have charge of both injectors. This notwithstanding the efficiency of the fireman in this direction. If, however, the fireman miscalculates in regard to the requirements of the engine, and, in consequence, finds his fire too low, and the steam pressure dropping unduly because of it, he must call the engineer's attention to the fact, that the injector may be shut off and the supply of water reduced so that the pressure may be the more quickly regained.

It is a truism that economical firing is impossible where the engine and injector are started simultaneously, or both shut off at the same time on approaching stations.

A fact to be remembered is that the cause of leaky boilers is not necessarily the result of overworking the engines, but too often due to poor management of the fire and injectors, combined with injudicious use of the throttle.*

It has been estimated that when steam escapes at the safety valves, the loss amounts to about one-fourth of a pound of coal each second, or a shovelful of coal per minute, or, as an authority ingeniously puts it, "It is the same, or worse, than an engineer allowing the fireman to throw

* In relation to the promotion of a fireman to the position of engineer, it is claimed by many experts that a fireman who has been out of freight service for several years should not be promoted to the position of engineer without again firing a freight engine for three or four months.

a shovelful of coal off the engine each minute without taking steps to stop the waste." Severe critics claim they have seen engineers sit calmly by on such occasions and hear the escape of steam from the safety valves with indifference.

In reference to the art of firing, there are two systems of supplying coal to the engine. One is the banking system, used principally with certain grades of coal having few or no clinkers; the other is the spreading system, which is followed where anthracite coal and some grades of bituminous coal, having more or less clinkers, are used. Where the banking system is followed, a large quantity of coal is placed in the rear of the fire-box until the gases and hydro-carbons have been expelled and it becomes a coke. Then it is pushed forward onto the incandescent coals by a slash bar or rake and a fresh supply of coal placed near the door. This method is little used and does not require much skill. Where the spreading system is used the coal is broken into pieces not larger than an apple. While many companies require that the coal shall be thus broken before being placed on the tender, it is, perhaps, more generally the custom to have it broken by the fireman. However this may be, he is expected to see that it is so prepared before being placed in the fire-box.

Coal broken into pieces of the proper size offers greater surface area to the heat and permits of being scattered more uniformly over the fire

Except in very cold weather coal should be wet to prevent dust and dirt. This gives increased weight to the fine particles which otherwise would be drawn directly into the flues, causing not only a waste of fuel, but stoppage of the flues.

At starting, the fire should be sufficient to carry the train out of the yard, so as to permit the fireman to give his attention wholly to the signals and switches.

If the locomotive is supplied with a smoke burner, it should be carefully looked after, and if there are any flues in the sides or rear of the fire-box for admitting air above the fire, they should be kept open, as it will tend to more perfect combustion and help to abate the smoke nuisance.

When the train is under way and normal pressure of steam has been attained, two or three shovelfuls of coal should be placed in the fire-box at a time, but in doing this the fire-box door should be kept open only so long as may be absolutely necessary. The coal having been broken in advance, the shovel should be filled and drawn forward within reach ready for the coal to be placed on the fire; this before the fire-box door is opened.

In firing, coal should be placed along the sides of the box and in the corners thereof, so as to exclude the cold air, which has a tendency to lower the temperature and chill the flues and fire-box.

Care should be taken not to throw the coal so that it will strike the flues or fall on top of the arch, if the engine has one.

A fire requires to be frequently replenished with small quantities of fuel in order to keep it bright. Heat is greatest when there is a rapid state of combustion. If there are clouds of smoke in the fire-box, heat will not readily penetrate them, and so poor results will be attained.

In case it is found necessary to maintain a very heavy fire in order to generate sufficient steam, it indicates that there is something wrong with the front end of the engine; either the nozzle is too small or may have become choked, or the draft appliances are not properly adjusted.

The temperature required to ignite carbon (of which coal is chiefly composed) is about eighteen hundred degrees. If, therefore, a large amount of coal is placed on the fire at one time, the temperature is reduced until the coal supplied can be brought up to the required temperature. The result is, first, contraction of the metal surrounding the fire-box, followed by expansion, thus subjecting the boiler to a great and unnecessary strain.

The importance of making proper use of the dampers is not always appreciated. With single part ash-pans, one damper, and that ordinarily the rear one, will be found most economical. By opening both dampers when the engine is working lightly with a thin fire, too much air will be admitted, and as air drawn through a fire

in excess of the amount required for combustion tends to cool the gases below the point of ignition, waste of fuel results. Closing the dampers prevents the admission of air through the fire. This stops combustion and leaves the fire-box and flue sheets to gradually cool off. Opening wide the fire-box door will only partially prevent the draft through the fire, while it admits cold air directly onto the flues and sheets surrounding the fire-box, thereby cooling them so suddenly as to cause leaks.

In firing, the requirements of the service should be anticipated. A heavy fire should not be maintained when steam is to be shut off wholly or partially. A hard pull, on the other hand, should be anticipated.

In starting, the coal should be well ignited so that there will be no occasion for opening the fire-box door until the train has gained considerable headway and the lever has been hooked up, with consequent lighter pull from the exhaust.

On approaching a stopping point, the dampers should be shut down, and if bituminous coal is used, but little, if any, fresh fuel supplied to the fire. If, however, fresh coal has been applied through misjudgment or otherwise, the blower should be opened and the fire-box door left slightly ajar to prevent smoke and injurious gases escaping.

Choking volumes of coal smoke and gases often find their way into passenger cars, causing

great discomfort, when careless or unskillful firing is exercised.

It should be borne in mind, in approaching a stopping place, that a saving of fuel will result from letting the steam drop back a few pounds, rather than to allow it to escape through the safety valves. When it is found necessary to reduce the steam pressure, the dampers should be closed, rather than the fire-box door opened. The injector may also be started if the boiler is not already too full; if it is, the steam may, in many cases, be utilized by turning it into the tank to warm the water therein.*

The ash-pan (139) and the front end (14) should be cleaned whenever opportunity presents itself. A set rule cannot be laid down as to the frequency with which these duties should be performed. No great amount of labor will be required in cleaning the front end of cinders if the draft appliances are good and there are no steam leaks.

In regard to the ash-pan, it will fill up more or less quickly according to the grade of coal and the amount used. With a poor grade of coal, it may become necessary to clean the ash-pan on the road. The better steaming of the engine will more than compensate for time thus lost, and it may result that failure to perform this duty will necessitate the consumption of two or three additional tons of coal on a trip.

When sufficient air is not admitted through the body of the fire, there is a loss through the smoke-stack of about two-thirds, or more, of the

*Practical experiment has demonstrated that every 11 degrees (Fahr.) increase in the temperature of the feed water produces

heating properties of coal. This shows the importance of keeping as thin a fire as is consistent with the working of the engine.

While it is possible for a man to become an adept without having studied the laws of combustion, it is nevertheless true that if he be thus skilled, he is obeying those laws. To such a one the study of combustion may be more interesting than beneficial, but to others study will open up an avenue to the knowledge they should possess if they would serve their employer acceptably. Men ignorant of the laws of combustion, who stumble into the right path, would attain it much easier and more quickly by study. All, therefore, should study the subject, and this both practically and scientifically.

Extended observation leads to the knowledge that lack of steam-making power in the engine is too often the result of over-firing. Especially is this true in the case of new firemen, or where the engine has a reputation of making steam poorly.

As already pointed out, perfect firing means the admission of fuel and air in exactly proper proportions, but as no fixed rule can be accurately followed, the fireman may hope to approximate it by watching closely the results of different methods of firing, remembering that, in many cases, by saving the shovelfuls of coal, the ton is saved.*

* While the foregoing instructions in regard to firing apply in the main to all classes of fuel, yet it is true they refer par-

Among many other things appertaining to engineers, the study of friction and the knowledge of what is dependent thereon is essential. Economical and effective use of oil cannot be attained without it.

Aside from information relative to more practical things, the engineer and fireman must know what clothing to wear, and the food best suited to their requirements.

They must study particularly the best methods of doing repair work: packing glands, cellars and boxes; removing brasses; keying rods; setting wedges, and work of a like nature about the engine and tender.

No one is qualified, it may be said, to operate an engine, who does not know in advance what to do in every emergency of train service. He must be able to act quickly and in the light of the best practices. In the cases of delays and mishaps, there is no time to study up questions or situations. The man in charge must be able to act instantly. There are, in the generality of cases, preferred methods of procedure in the case of break-downs and other mishaps. With these the engineer should be familiar. He is also

ticularly, in several instances, to bituminous coal. Where anthracite coal or wood is used therefor, modifications will be required according to the nature of the fuel and the class of fire-box and engine. However, the general rule requiring that the fuel shall be so used as to burn most freely and create the maximum intensity of heat with the least fuel possible, applies in every case. This is also true in regard to keeping the grates free of clinkers and ashes.

expected to be able to make such repairs on the road as are possible under the circumstances; to be able to temporarily adjust eccentrics or the front-end appliances, set wedges, and disconnect the engine; to be skillful in the treatment of hot journals or bearings, and have an ear so trained as to be able to detect and locate a blow or a pound that may cause a break-down.

The faculty of observation is to be cultivated by engineers and firemen. Some men, without apparent effort, are ever conscious of what is going on about them, while others see nothing. It is necessary that the defect of the latter should be corrected if they would become valuable in their places. Everyone ambitious of preferment should seek information from the better informed men about them, and should not be rebuffed or discouraged if replies to their questions are not always courteous or direct. Practice and reading will do the rest.

In the operation of railroads, men engaged for years on a particular class of engine, have been known to remain in ignorance of other classes about them. This may be remedied by study and observation. Certainly any engineer thus handicapped labors under great possible disadvantages.

As it is becoming the custom of many well managed roads to keep a record of the fuel and other supplies used by each engineer and fireman, questions of economy on such roads, it will be seen, have a personal application not known elsewhere.

It is a duty required of engineers, in many cases, that they shall reach the engine-house while their engine is over the pit, that they may thus be enabled to examine it from underneath, to better advantage. They are also expected to inspect the packing of truck cellars, see that the bolts and nuts are tight, look after the eccentrics and see that the oil holes are clear and oil cups filled. As the engineer is responsible for the fulfillment of the fireman's duties, he is also required to see that they are not neglected.

When the engineer does not know in advance the engine he is to run (that is, when the engines are pooled or worked in common), he must, upon taking charge, exercise greater care than he would otherwise, to see that it is provided with necessary tools, blocking and other appliances. He should also examine the work-book in such cases, to see what repairs were last reported as being necessary and what has actually been done. Parts that have been repaired always require more attention than others, because of the friction that intervenes in such cases. The inspection of the engine and tender by the engineer, it is apparent, is the first thing to be done on taking charge. The work should be systematic and thorough. In those instances where the roundhouse force looks after the packing of the driving boxes, tank boxes, truck cellars, and so on, the engineer must still see that the work has been done properly. Many engineers insist on doing it themselves, as they feel greater confi-

dence that they will get over the road promptly and without mishap than they would if the work was performed by an employe of the roundhouse.

Among the further duties of the engineer these may be briefly summarized: To see that the water supply in the boiler is ample—this he does by trying the gauge cocks and noting the indication in the water glass; to try the gauge cocks frequently when on the road, using the water glass as an auxiliary or indicator merely; to look from time to time into the fire-box for leaks, and if the engine has an arch, to see that it is in place; to inspect the air pump and its lubricator, the guides, guide bolts, crosshead and piston rod packing, bearings, rods and rod bolts, keys and set screws, wedges and wedge bolts; to see in filling oil cups that the amount of oil required indicates that there is no stoppage of the feed or oil hole; to examine the wheels and flanges for breaks, chips or cracks, and the driving wheel centers and tires to see that they are not working loose; to see that the sand pipes are open, that the headlight is filled and trimmed and the reflector cleaned, that the cinder hopper is tight and that no leaks appear in the front end; to blow out the steam heating pipes in winter lest they be clogged with ice; to ring the bell a sufficient length of time before starting to enable any one who may be working under or about the machine to escape;* to see before leaving the

*Numerous accidents to life and limb have resulted from a neglect to observe this precaution.

engine house that the cylinder cock is opened; to start the engine slowly and under no circumstances to slip the engine for the purpose of throwing the water out of the cylinders; in backing the engine to the train, to see that the lubricator is started and all parts of the engine working in good order; to lubricate all parts of the engine before starting a train; to place the reverse lever in starting in the "corner" and open the throttle slowly and carefully so as to avoid jerking the train or slipping the wheels; to be particular if the rails are slippery or the load requires it; to sand the track before the wheels begin to slip; to be careful not to "catch" the engine when slipping on sand, as it is a severe strain to the machinery, and pins and rods frequently break under such circumstances; to use in sanding the rail only so much sand as is necessary to keep the wheels from slipping, as a train pulls harder on a sanded rail; to see when headway is attained that the reverse lever is pulled back to prevent unnecessary waste of steam and undue disturbance of the fire by too strong a draft; in starting (and also at other times) to look back and exchange such signals with the rear end of the train as may be necessary to be assured that the train is intact and in proper working order; to use full opening of the throttle except where a simple engine can do the work required with less than one-fourth cut-off, in which latter event it is economical to leave the cut-off at one-fourth and regulate the steam by the

throttle;* to see that water is supplied the boilers in as nearly a continuous flow as possible, to see that the water is, so far as practicable, kept at a uniform height, not losing sight of the fact that water in the boiler at a high temperature (or indeed warm water in the tank) represents so much heat energy available when the normal capacity of the boiler is inadequate to supply the demand;† to remember that the time to favor an engine by reducing or entirely stopping the supply of water to the boiler is when moving rapidly towards an ascent or heavy grade;‡ to see, when approaching dangerous places, drawbridges, railroad crossings, interlocking switches, yards, etc., that the train is under such control that a stop may be made, if necessary, before reaching the

*To illustrate: It would not be economical to use one-half to two-thirds cut-off and throttle the steam pressure when the work could be done with one-fourth or one-third cut-off with a full throttle opening, while one-eighth cut-off with full throttle is less economical than one-fourth throttled, due to increased cylinder condensation, where the temperature of the cylinder has too wide a range.

†The capacity of water for storing heat is great, and this fact should be taken advantage of. When it is not, engines will too often be found standing at stations or descending grades with light throttle, and with steam blowing off; or blowing off when the water in the tank is cold, or there is but half a glass of water in the boiler. At such times the injector should be at work or the surplus heat should be used to warm the water in the tank.

‡After speed has been reduced (even though the reverse lever has been dropped down), the engine is using a less amount of steam and the injector may then be started.

danger point;* to see, in stopping, that steam is shut off a sufficient distance to permit slowing down easily; to see that the link is hooked down to give the valves more travel and keep the valve seats in better condition.†

It is the duty of the engineer to see that the air brake is used with care, bearing in mind that it requires the nicest judgment and skill at all times to prevent mishap or jarring of the train. In the event the water in the boiler gets low (through failure of the pumps, or otherwise) the fire must be banked or drawn.‡ It may be necessary in some instances to detach an engine and proceed to the nearest station for water when the supply is exhausted. It can, however, sometimes be dipped from pools or streams along the track, or, in winter, snow may be shoveled into the tank and melted. Everything should be done in such cases that is consistent with safety to

*The speed limit in such cases is usually placed at six miles an hour, or as fast as a man can walk a short distance.

†This will also prevent the raising of the valves by compression from the cylinders, and where there are no relief valves on the steam chest, it will partially prevent the drawing of the smoke and hot gases from the front end into the cylinder. With some engines, having very long eccentric blades, it is unsafe to hook the links down to the lowest point while running fast, as in such cases a broken eccentric strap might follow.

‡“Banking” a fire usually means covering it with fine coal, well wet down, but sometimes it is advisable to cover with ashes or sand, which will practically extinguish it. “Drawing” or “dumping” the fire means knocking it through the grates and extinguishing it entirely.

keep the engine alive, but it is considered highly discreditable to "burn" an engine.

If the engine is priming or foaming, the cause thereof must be ascertained and the necessary remedies applied.*

In the care of the locomotive it must be remembered, among other things, that water projected from the smoke stack injures the paint on both the engine and cars. It looks bad moreover. In summer, after filling the tank with cold water, the heater should be applied long enough to prevent the tank sweating. Failure to observe this simple precaution may greatly injure the paint on the tank.

An important duty of the engineer is to see that the safety valves are regulated according to the steam pressure allowed the engine. Many companies undertake to make periodical tests of safety valves, gauges and air governors independently of the engineer. It should be a duty of the latter, however, to order a special test made

* Priming is generally caused by keeping the boiler too full of water. This can, as a rule, be prevented. Foaming is due to foreign matter in the boiler and may be relieved by a surface cock, or a blow-off cock, with which most engines are supplied. If the water used is of poor quality, the tank may be cleansed by flushing at the water station. In cases of priming or foaming, the true water level can only be determined by shutting off the engine and letting the water supply in the boiler settle. This should be done frequently under such circumstances. From an economical standpoint, the effect of working water into the cylinders (aside from the liability of knocking out a cylinder head and cutting the valves) may be appreciated by remembering that a cubic inch of water (which is not expansive) will make one cubic foot of steam, which is expansive.

whenever he may have reason to believe there is anything defective therewith.

At water and coaling stations, the engineer should utilize the time to inspect the bearings and running gear of the engine and tender and supply needed lubrication.

It is a duty of engineers to carefully inspect their engines at terminals, and notify the official at the engine-house what work is required to fit them for economical and effective use. Hot bearings should also be reported so that they may be examined at the shop, and in the event another person is put in charge of the engine, that he may be notified of the same.

Returns giving an account of delays, overtime, accidents, and for other purposes, should be made and transmitted to the proper officer as soon after arrival at the terminal station as possible.

In order that there may be no unnecessary loss of time in communicating with engineers and firemen when off duty, their addresses should be left with the foremen of engine-houses, or other designated officials.

In closing these instructions, it will be proper to again call attention to the necessity of wise and economical use of tools and supplies. Engineers and firemen cannot hope to make satisfactory records otherwise. Questions affecting the use of tools and supplies grow more and more important every year because measures for ascertaining the care exercised are becoming more and more effective each year. The subject is therefore, it will be

seen, one of supreme importance to the employe as well as to the employer.

The foregoing account of the duties and responsibilities of engineers and firemen, while complete so far as it goes, is, as I have already explained, necessarily limited. At least two of my books treat almost wholly of matters with which the engineer must be more or less familiar in order to perform his work intelligently. It has been my particular endeavor here to group certain specific things that master mechanics and superintendents of motive power consider especially important to the safe and economical working of engines. The account, however, as already intimated, is incomplete, because the duties of engineers and firemen cannot in many things be treated apart from those of other train and station men. It was this universality of duty and interest running through the whole railroad world, that led me to take up the subject in its entirety in the "*Science of Railways*" as I have already explained.

What I have written in regard to engine men, while applying particularly to American railroads, refers in the main, it is apparent, to the railroads of the whole world, for the reason that construction, maintenance and operation are substantially the same everywhere.

A CHAPTER OF DON'TS FOR ENGINEERS AND FIREMEN.

FIRST. *Don't* think because you are only one engineer or fireman, that what you do does not amount to much. It is the little drops of water that make the mighty ocean, and the little grains of sand that make up this earth of ours; so each individual, in the aggregate, can do a great deal. If each engine crew saves one-quarter of a ton or five hundred pounds of coal, this on a thousand locomotives would result in a daily saving of two hundred and fifty tons, or in round figures \$157,000 a year.

SECOND. *Don't* neglect being at roundhouse in ample time to examine the firing tools on the engine before leaving the roundhouse. See that your ashpan, grates and flue-sheets are in good condition to make the run.

THIRD. *Don't* fill the boiler full of water as soon as you get out of the house. Leave a space so the injector can be worked to prevent popping while air pump exhaust is fanning the fire, pumping air to make the terminal air brake test. If you do this your fire will be in better condition to pull out with. The noise of open pop prevents trainmen from locating leaks.

Don't forget to start the lubricator a few minutes before leaving a terminal. Set it to feed

regularly. The proper lubrication of valves and cylinders saves coal.

"FOURTH. *Don't* forget, when starting trains, to do so carefully, thus preventing damage to drawbars and draft rigging. By so doing you will save serious delays to your own as well as other trains. All delays mean extra fuel consumption to make up time lost.

"*Don't* neglect using the blow-off cock, as it keeps the boiler clean and water in good condition, and insures better circulation in boiler. Result: Better steaming engine and a saving in coal.

"FIFTH. *Don't* allow the engine to slip. This is an unnecessary waste of coal, wears out tires and rails, causes great damage to pins, axles and running gear, and generally results in spoiling a fire.

"SIXTH. *Don't* pull out of a station with a train (after engine has stood for a while, and fire was allowed to get low) without first giving the fireman a chance to build up the fire. The time lost waiting to do this will save coal, and can better be made up before reaching the next station. Remember this when you get a time order.

"SEVENTH. *Don't* leave the reverse lever down in corner longer than necessary when pulling out of stations. No rule can be made to govern how the throttle and reverse lever should be used. This must be acquired by practice and observing the performance of the engine. Bring the lever up gradually as speed is acquired. The lever hooked well towards center of quadrant, with

throttle well open, usually gives better results than using the throttle to govern the speed. Up to five years ago we considered it good practice with our smaller power to run with wide open throttle, and as short a point of cut-off as possible consistent with weight of train; but in our heavier and larger engines we find that it is better at many times to throttle the engine. Particular attention is called to all wide fire-box type of locomotives. The engineer can permit the reverse lever in these engines to remain low in the quadrant when starting from a station for a greater length of time than with the other types of locomotives without pulling the fire or losing steam. When you are running on short time, it would be good judgment for the engineer to take advantage of this when pulling out from a station. In this engineers will use their best judgment.

"EIGHTH. *Don't* put four or five or more shovelfuls of coal into the fire at once. One or two shovelfuls will give better results, and these two should not be thrown in the same spot. It is good practice to fire on one side of the box at one time, and the next time on the other side of the box, in order that the bright fire on one side may take up the gases from the fresh coal on the other side. This will reduce the smoke and give more steam.

"Always fire as light as possible consistent with your work. Very heavy firing will make your flues and staybolts leak, and in time will crack your fire-box sheets. The reason for this is that

when you have a very heavy fire the air will not pass up through it readily, and the gases pass off, because there is not sufficient oxygen to unite with them to produce combustion, and as the gases must get air from somewhere, the air is then pulled through the fire-door, causing the chilling of flues and sheets as referred to above.

"NINTH. *Don't* allow steam to escape at pops unnecessarily. Frequent blowing off at pops shows improper judgment, and implies that the engine crew is not practicing economy. Tests have demonstrated that $\frac{1}{4}$ lb. per second, or 15 lbs. per minute, is wasted. This amounts to about one ordinary scoopful, and in most cases may as well have been thrown on the ground as into the firebox. There are only 133 scoopfuls in a ton of coal, so you can see that you would only have to have your pops open one hundred and thirty-three minutes in a whole day in order to throw a ton of coal away.

"TENTH. *Don't* open the firebox door to prevent steam blowing off at pops when engine is working; dropping dampers is a better practice. The supply of air is cut off, and combustion is partially suspended. When engine stops blowing off, open dampers again before putting in coal. This method keeps fire in better condition and saves coal. You have no doubt noticed that on a certain class of locomotives, when working hard on a hill, you have to shut your dampers in order to keep your fire from turning over. This is because the exhaust pulls too much air up through the grates, and causes your coal to be too active,

and to prevent this activity of coal, as well as increased combustion which follows, we consider it a good thing to drop your dampers, as per above.

“ELEVENTH. *Don't* insist upon having the maximum steam pressure with pops opening occasionally when handling light trains, when less pressure will handle the train on time, thus avoiding the opening of pops.

“TWELFTH. *Don't* forget, when engine is shut off for stations, to drop your dampers, opening the firebox door slightly, if necessary, and using the blower to carry off the black smoke.

“THIRTEENTH. *Don't* blame the engine or coal if engine is not steaming properly, before you have ascertained whether or not both of you are doing your duty. Talk it over; see if injector is not supplying more water than is being used, or that fireman is not firing too light or too heavy. Heavy firing is responsible for more poor steaming engines than the lighter method. You all know some engine crews have better success than others, with same engines and conditions. Think a little; there must be some cause for this.

“*Don't* wait until you get the signal to pull out before building up the fire. This should be done gradually until the proper thickness has been reached. A good fire to start with is essential to maintain the proper steam pressure, while engine is working hard getting train under way. Afterwards distribute the coal evenly on sides, ends and corners. Do this systematically, keeping in mind where you have placed the last

shovelful, thus avoiding getting holes in fire, and prevent piling up coal all in one place. Endeavor to keep the steam pressure uniform, with as little black smoke as possible. Experience has taught that engines with draft appliances properly adjusted require very little coal in center of firebox.

"FOURTEENTH. *Don't* permit the water to get so high in boiler that it is carried over into the valves and cylinders. This usually occurs when pulling out of stations, and the water carries off the oil, which not only results in cut valves and cylinders, but the extra friction damages the entire valve motion, to the detriment of the power of engine and the coal record.

"*Don't* gauge the amount of water an engine will safely carry by water coming out of stack. Keep it low enough to insure dry steam being used, because moist steam has the same effect as water. Usually one-half glass or two gauges give best results. Be careful, however, that when ascending a grade, and you are about to pitch over the other side, that you have sufficient water to keep your crown-sheet thoroughly covered. If your custom has been to carry high water, try less and note results in better handling of tonnage, also saving in coal and oil.

"FIFTEENTH. *Don't* neglect to take advantage of your excess steam before your engine is about to pop off, by making a heater of your injector, blowing steam back into the tank to warm the cold water, but avoid getting it so hot that the injector will not lift the water. By doing this

you will keep your engine from blowing off at pops when standing at stations after the boiler is filled up. You have all tried warming the water in the tank to help a poor steaming engine, with good results. What is good for a poor steaming engine will surely help a good steaming engine do better. Try it and you will find that it will not only save work for the fireman, but will make a better coal record for the engine crew, besides keeping the tank from sweating, which you are aware spoils paint.

"SIXTEENTH. *Don't* think the fireman alone to blame for your coal record. The best and most economical fireman cannot make a showing with an engineer who supplies more water to boiler than is being used, and who shuts injector off only when boiler is pumped full. The proper handling of the injector is one of the most important matters in saving coal. Feed water to boiler according to demands. If on through train keep water level as possible. If on way freight or switch trains, lose a little water between stations. Fill up again while drifting into, standing or switching at station. The advantages of supplying less water than is being used between stations are: It requires less coal to keep up steam pressure when running; also leaves a space so injector can be worked to avoid pops opening, and heavier fire can also be maintained to do switching, without the possibility of the fire being pulled.

"*Don't* pull out after making a stop with injectors working. The cool water introduced during

period throttle was shut off is put in circulation throughout the boiler, and pointer on gauge drops back from five to twenty-five pounds. The fireman must then fire heavier to regain the lost steam, and naturally will use more coal. This condition exists also when engine has gone down grade with throttle shut or slightly open. Shut the injector off before opening the throttle. If this is not your practice, try it and note the difference.

“SEVENTEENTH. *Don't* wait for the pops to open, and use this as a signal to put on the injector. Keep an eye on the air gauge, steam gauge and water glass. You all know this can be done without distracting your attention from the track ahead. A look for an instant every mile or two will keep you informed, and is a good habit. Doing this will also keep you posted on air pressure, and may avoid difficulties should the air pump stop. The fireman should also keep an eye on the water glass, as the engineer is sometimes compelled to keep the injector at work to prevent the engine blowing off. When glass is full, the fireman should fire lighter, to give the engineer a chance to shut off the injector, and not have engine blow off. However, this condition should only exist when injector cannot be worked fine enough to just supply amount used. This sometimes occurs when card time is slow, or on down grade, or when running with light train.

“EIGHTEENTH. *Don't* put too much coal under the arch of engines with sloping fireboxes, because these engines naturally pull the coal ahead,

which results in forward section of grates becoming stuck and clinkered over, and fire is pulled in back end of firebox. Experience and observation will teach you to put most of the coal in back end of firebox.

“NINETEENTH. *Don't* think engine having two firebox doors requires twice the quantity of coal it would if engine had but one. The extra door is for the purpose of distributing the coal more evenly over the grate surface, with less effort on the part of the fireman.

“TWENTIETH. *Don't* shovel large chunks of coal into firebox, because you find them on the tank. The coal house men have instructions to break it the size of an apple. If not properly broken, report it to Road Foreman of Engines or to Master Mechanic, instead of fellow engineers or firemen, but don't think it a hardship to break some occasionally. Better break it than to throw in large chunks. They are foundations for clinkers.

“TWENTY-FIRST. *Don't* expect the fireman to fire the engine with one or two scoops to each fire, and also ring the bell for highway crossings and stations. Some engineers expect this. If engine is equipped with an air bell-ringer, get into the habit of starting the bell-ringer when blowing the whistle. By so doing, the habit will become as fixed as whistling for crossings and stations. Besides, it is just as important. Remember the engineer is responsible.

“TWENTY-SECOND. *Don't* put in a heavy fire about the time the engine is shut off for a station or down-grade. The heavy cloud of black smoke

is evidence the engine crew is not working in harmony or practicing economy. If on train that stops at all stations, the fireman should guard against it and learn when to stop firing. He will be governed by grade, service and weather conditions. If train does not make all station stops, the engineer should keep the fireman informed of intended stops.

"TWENTY-THIRD. *Don't* forget that different qualities of coal and different make of grate used, govern the shaking of grates. Coal that fills up and clinkers, requires more attention than the better grade. The object is to keep the grates free, so the proper amount of air can be admitted,

"TWENTY-FOURTH. *Don't* neglect cleaning your fire on trains that are long hours on the road. Make use of the first opportunity. You will get better results with less labor and coal, and avoid leaky flues. Better clean out a small amount two or three times than not clean it at all.

"*Don't* take coal or water oftener than necessary, as it requires an extra amount of coal to again get a heavy train in motion, especially on a grade. Good judgment is required, in order not to run short before getting to next coal chute or water tank. Where possible take water only from tank containing good water, and as little as you can from tanks containing poor water.

"TWENTY-FIFTH *Don't* forget that leaks in the air pressure are being kept up by an equal amount of steam pressure. As it takes coal to make steam, air leakage means a waste of coal. Keep apparatus on your engine tight, and insist on trainmen doing their part.

"TWENTY-SIXTH. *Don't* try to put more coal on tank than will lay on it securely. All coal dropped off by overloading is wasted. Also keep coal from falling out of gangway when running. This may be only a little each day, but it all counts against your coal records besides it looks badly when strewn along the tracks. You can not save coal by the ton; it must be in pounds, which in time makes tons.

"TWENTY-SEVENTH. *Don't* forget to make an intelligent report on your work slip on arrival at Round House. Consult your fireman in regard to any defect that has come to his notice, especially with grates, dampers or firing tools.

"TWENTY-EIGHTH. *Don't* neglect reporting the pop valves ground in when leaking or when they blow back eight or ten pounds before seating. Also report leaky piston rod and valve stem packings, or if cylinder packing or valves are blowing. All these leaks draw on the coal pile unnecessarily; it takes coal to generate the wasted steam. This also applies to leaky steam heat appliances, cylinder cocks, etc.

"TWENTY-NINTH. *Don't* neglect looking at coal report each month to see how you stand in relation to others in same service with whom you are comparable. The other crews get the same pay you do, and it should be your aim to be as economical with both fuel and supplies as they are, other things being equal. Keep posted and be with the average. It will be to your credit and interest some time; therefore aim to be at the top.

“THIRTIETH. *Don't* think when coal report shows you using only two pounds more per 100 ton mile than other crews in same service, it is close enough. This means two pounds more used for every mile you hauled 100 tons—or another way, two pounds for every 100 tons hauled one mile. Figure this up and you will find in hauling 1,000 tons 100 miles, a difference of 2,000 pounds or one ton. This method of showing up the individual record is more equitable to all than on basis of mile run per ton of coal.

“THIRTY-FIRST. *Don't* think, after reading over this chapter of “*Don'ts*” you should save coal to the detriment of the service. The actual amount required to make up time, keep on time, or handle tonnage, is not what we are trying to save ; it is the waste.”*

* R. Quayle.

BOOK II.

COMPOUND LOCOMOTIVES.

**FORMING A PART OF THE
ENGINEERS' AND FIREMEN'S MANUAL.**

CONTENTS.

BOOK II.

COMPOUND LOCOMOTIVES.

	PAGE
Introductory,	155
General description—comparison with simple locomotives, .	159
Classes of compound locomotives and their general construction	171
Questions and answers on the operation of compound locomotives in general,	181

Description and operation of compound locomotives:

	PAGE		PAGE
Baldwin four cylinder,	186	Schenectady, design of 1896, .	222
Baldwin two cylinder,	202	Pittsburg,	238
Schenectady (McQueen),	209	Richmond,	246
Schenectady, original type,	209	Rogers,	258
Schenectady, design of 1892,	210	Brooks four cylinder tandem, .	278
Schenectady, design of 1892, with Southern Pacific modification,	221	Cooke,	286
		Dickson,	292
		Rhode Island,	297

Accidents to compound locomotives:

	PAGE		PAGE
Baldwin four cylinder,	198	Pittsburg,	243
Baldwin two cylinder,	208	Richmond,	255
Schenectady (McQueen),	231	Rogers,	289
Schenectady, original type,	231	Brooks four cylinder tandem, .	283
Schenectady, design of 1892, with Southern Pacific modification,	234	Cooke,	291
Schenectady, design of 1896,	235	Dickson,	296
		Rhode Island,	300

CHAPTER I.

ENGINEERS' AND FIREMEN'S MANUAL, CONTINUED— COMPOUND LOCOMOTIVES—INTRODUCTORY.

NOTE—In regard to the merits of the compound cylinder as compared with the single-expansion, I do not desire nor profess to express any opinion. I merely wish to describe the compound cylinder in what follows, and, if in some places preference seems to be expressed, it is the claim of builders and not mine. Those who use locomotives must themselves be the judges of the respective merits of single-expansion and compound cylinders and of the particular pattern they want.

M. M. K.

In view of the fact that the Compound Locomotive is of comparatively recent introduction as compared with the single-expansion cylinder, its construction and working are less understood by those connected with the equipment department of railroads. These particulars I have, for that reason, thought it best to embody here in connection with the "ENGINEERS' AND FIREMEN'S MANUAL." More and more attention is being given to the expansive use of steam in connection with the locomotive. It is claimed not to be unreasonable in view of the triple and the quadruple expansion of steam (expansion in three and four cylinders) in the most approved stationary and marine engines that it should be possible to devise practical means of obtaining double expan-

sion, at least, in a locomotive. Because of the more or less general introduction of compound cylinders, some account of the working of the compound locomotive is becoming every day more and more necessary to those connected with the machinery and equipment of railroads. Indeed, practical familiarity with the working of compound engines may be said to have become, in a measure, a necessary part of the knowledge of every engineer and fireman, for the reason that their duties may at any time, through promotion or otherwise, take them to roads where some form of compound locomotive is extensively used. Moreover, it is well that their attention be especially directed to the subject in order that it may have the consideration and scrutiny at their hands which its growing importance justifies and their practical knowledge is likely to render so valuable.

It is not surprising, inasmuch as the opinions of engineers and firemen respecting the operation of simple engines differ so widely, that there should be much controversy among them in regard to the operation of compound locomotives. Experience on the part of those operating the compound locomotive will tend to its better service and consequently greater development. Many prejudices against it are due to lack of acquaintance with its operation. This is true of every new thing. Especially is it true in the case of compounds where a railway has few locomotives of this kind. The feeling is but natural, if we remember, as we should, that in the handling

of their engine the reputation of the engineer and fireman is at stake. The opportunity afforded them for handling and studying any odd engine, compound or otherwise, is necessarily limited. Moreover, in the operation of such locomotive, it is possible they may be impressed with the unhandy, because unusual, cab arrangements. Naturally, they are filled with apprehension, lest some accident might occur and they be found ignorant of what should be done to temporarily repair the engine and bring it in. If a considerable number of the locomotives of a railroad are compounds of similar class, the men handling them become accustomed to their operation and this fear disappears. It is with a view to the practical usefulness these pages may have for engineers, firemen, and others interested in the operation of compounds, that the descriptions herein are elaborated to the extent they are.

The plan followed with each class of compound locomotives is, first, to give a general description of its operation, succeeded by a detailed description of its technical parts. This is done that the reader may, in the first instance, if he desires, learn of the general arrangement of each class without the details, and afterwards, at his leisure, he may apply himself to the particular class or classes that most interest him. Following the description of each class of compounds will be found, in catechetical form, information relating to its operation in case of any ordinary derangement of its parts when the methods of procedure will differ from those in case of similar accidents

to simple locomotives, as outlined in the manual. It is said that reforms must pass through three stages: ridicule, argument, and adoption. The compound has been subjected to the first and second of these epochs, and it may be assumed to have reached the last stage mentioned. Like every part of a railroad, it is still in a state of evolution. I know of no preference in regard to compounds that is proper to express here. The order of description has, therefore, no significance. In the description of the various types I have endeavored to eliminate all matter that does not pertain directly to the practical application of the principle of compounding, as descriptions relating to other parts of the locomotive are to be found elsewhere in "THE SCIENCE OF RAILWAYS." In relation to the descriptions of the compound, I wish to say that I am indebted in a marked manner to Mr. E. W. Pratt, whose familiarity with the construction and working of locomotives and the appliances of the latter makes him an authority of the highest order in regard to all such matters. I am indebted to him in many other ways and it affords me much gratification to be able to acknowledge it thus conspicuously.

CHAPTER II.

ENGINEERS' AND FIREMEN'S MANUAL — COMPOUND LOCOMOTIVES — GENERAL DESCRIPTION — COM- PARISON WITH SIMPLE LOCOMOTIVES.

A compound locomotive is one in which the exhaust from one or more cylinders is passed into one or more other cylinders and made to do more work by further expansion before it is allowed to escape to the atmosphere. In stationary and marine service the principle of compounding has long since passed its experimental stage and, following the replacement of the single-expansion engine by the double-expansion type, came the era of high boiler pressures with triple and even quadruple-expansion engines in marine service. It was long thought by many, and is still held by some, that, although compounding of steam in marine and stationary engines was a great economy due to the use of the condenser,* on locomotives where condensers were impracticable, the compound locomotive would not be able to gain sufficient advantage over the simple engine to warrant their general use.

Without any attempt to pass judgment upon the relative value of the points put forward for and against compound locomotives, I will out-

*A condenser is a chamber into which the final exhaust of an engine takes place and in which the steam is cooled and condensed, either by a jet of water or by contact with sheets or tubes having cold water circulation on their opposite sides. These two forms of condensers are termed "jet condenser" and "surface condenser," respectively.

line some of the claims made by their advocates and also some of the practical objections met with in their use, many of which objections have been largely overcome in the later designs.

It should be remembered that the locomotive is not a steam engine merely, but consists of a boiler as well, and must also carry water and fuel for its own demands.

The first advantage of the compound over the simple locomotive comes from its greater economy in fuel, resulting primarily from the saving in steam. There is, however, a secondary saving, produced by the less violent effect of the exhaust upon the fire and also the economical use of high boiler pressures in compound engines.

Experiments have shown that high boiler pressures, say above 180 pounds, which have been found very economical (especially in the space occupied per horse power developed) in stationary and marine engines, are not a source of economy with the type of single-expansion locomotives in use in this country, due to the extreme ranges of temperature within a single cylinder and the consequent condensation. Also, locomotive cylinders and their steam ports are not well protected, and compounding the cylinders renders the variations of temperature in each cylinder less wide, and thus makes practicable the use of higher pressure. With the use of steel in place of iron for boiler construction, and also on account of the excellent care and inspection given all locomotive boilers, there is no material increase of first

cost or for maintenance of high-pressure boilers. In simple locomotives the exhaust produces such a violent draft upon the fire that great quantities of unconsumed fuel are drawn from the fire-box and thrown from the stack. This is not alone a waste of fuel, but cinders entering the open car windows are a source of great annoyance to passengers, while, before the use of the compound locomotive in the service of suburban railways, the noise of the exhaust had to be overcome by means of mufflers, which became quickly choked up and produced a high back-pressure on the pistons, resulting in the loss of from 15 to 20 per cent. of the power.

The throwing of sparks from the stack is not only a source of annoyance, but frequently results in heavy losses from damage by fire in timber and agricultural districts, and this is largely, if not entirely, overcome by the compound locomotive.

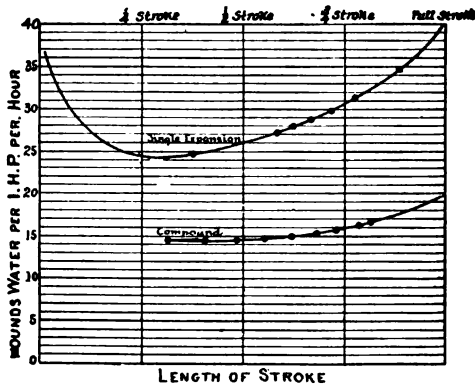
The heating surfaces of any given boiler absorb heat from the fire and deliver it to the water at a certain rate. If the rate at which the products of combustion are carried away exceeds this rate of absorption, there will be a continual waste that can only be overcome by reducing the velocity of the products of combustion. In the compound locomotive this is effected by the milder exhaust. It has been clearly demonstrated by experiment, that a milder exhaust and consequently a slower rate of combustion produces a greater evaporation of water per pound of fuel.

The milder exhaust is, of course, the result of a

lower back-pressure and thereby permits a greater effective power on the piston.

There is also found to be considerable reduction in cylinder condensation, owing to the relatively small variation of temperatures in each cylinder as compared with single-expansion engines. In any engine the walls of the cylinder, one cylinder-head, and one side of the piston are cooled to the temperature of the exhaust steam during each stroke, and the live steam, again entering, must

Fig. 100.



reheat them to its own temperature, thus condensing and requiring additional steam to flow in and take its place. In the compound this total range of temperature is divided between the high and the low-pressure cylinders, and thus the variation and consequent condensation in each cylinder is less.

The saving of steam results in the saving of

both water and fuel. The economy in fuel can be directly reduced to dollars and cents, while that resulting from the saving of water is more indirect. In bad water districts, the reduction of from 15 to 20 per cent. in the amount of water used, necessitates less frequent washings-out of the boiler and must result in greater life and diminished repairs to boiler and flues. Moreover, as its carrying capacity of water limits the distance that a locomotive can run without stopping (or slowing up, where track-tanks are used), it is evident that the compound locomotive would have an advantage in this respect. Fig. 100, besides showing the most economical point of cut-off for simple and compound engines, as far as the use of water is concerned, clearly shows the relatively smaller amount of water used by the compound per indicated horse power.

No locomotive can haul more than its adhesion to the rails will permit, and hence the tractive power of an engine is based upon whatever the adhesion to the rails may be. This is determined by practical experiment. With a fairly dry rail, a turning force of more than one-fifth, or 20 per cent., of the weight of the drivers on the rails, will cause the wheels to slip; a perfectly dry rail will permit of a tractive power of about one-fourth, or 25 per cent., of the weight on the drivers; a well sanded dry rail will allow one-third, or 33 $\frac{1}{3}$ per cent., while a bad frosty rail will permit less than half this last amount. Where all the driving wheels are connected, it matters not, of course, whether this force is ap-

plied by one or many cylinders, but, if the power is not uniformly distributed throughout the revolution and becomes sufficiently excessive at any one point to cause the wheels to slip, a very much less power will thereafter keep them slipping. It is a well known fact that adhesion, and consequently the tractive power of a locomotive, is very much reduced after the wheels begin to slip.*

It is claimed for the compound, that, as the average cut-off is later in both cylinders than for simple engines, the turning power is more uniform throughout the revolution, and hence heavier trains can be hauled than with the single-expansion engine. Then, too, while it would be uneconomical at other times to design a simple engine with cylinders sufficiently large to develop so high a tractive power as $33\frac{1}{2}$ per cent. at slow speeds, this can be done with compound locomotives of the "convertible" type without loss in economy under ordinary speeds of service, when working compound.

A saving of oil has been one of the minor economies claimed to be incidental to the use of compound locomotives. It is generally thought that from six to ten drops of valve oil per minute are required to be supplied with the steam in order to properly lubricate a valve and cylinder. This

*Every engineer knows this and puts his knowledge into practice when on a very slippery rail by opening the throttle very slightly and leaving the valve in full gear, thus distributing the pressure more uniformly throughout the stroke than would be the case with a shorter cut-off.

oil is supplied to the high-pressure cylinder only, and hence, in the two-cylinder class of compounds, a saving has been effected in many cases.

Comparative tests of greater or less duration have been made by various railways, between compound and simple locomotives of otherwise similar construction, and the results obtained by the different experimenters are widely at variance. In general, it may be said that the reported saving in fuel with the compound is about ten per cent. in fast passenger and 20 per cent. in heavy freight service, although figures double the latter have frequently been given.*

Later designs of compound locomotives, arranged to be worked simple at the will of the engineer, will temporarily pull a heavier train than a simple engine of otherwise like design. When it is considered that the ruling grade on a division is the governing factor for the maximum rating of through trains over the whole division, it will be seen that a locomotive capable of enough greater power to haul an additional car or two up that grade, produces more economical service for the whole division.

Leaky valves and cylinder packing are less wasteful in a compound than in a simple engine. Steam leaking by the valve or packing of the high-pressure cylinder is still worked expansively

*Fast freight service will more nearly compare with express passenger service and the saving will be less than in heavy slow freight service, on account of the simple engine using steam more expansively in the former service than in the latter. This is more fully brought out elsewhere.

in the low-pressure cylinder. Then, too, the difference of pressure between the two sides of the valves and pistons is less than for simple engines, and the wear should be consequently less.

On the other hand many serious practical objections have been raised. The large cylinders greatly increased the weight of the reciprocating parts.* This must be followed by heavier counter-balance† weights and their accompanying evils.‡ Also larger ports and consequently larger valves must be provided for the large cylinders. Inasmuch as considerable difficulty was formerly experienced in obtaining admission and exhaust ports of sufficient size for the cylinders of large high-speed single-expansion engines, it is not remarkable that there should have been considerable trouble experienced from this source in designing ports for the much larger cylinders of the compound locomotive.

In connection with these last two points, the weight of reciprocating parts and the port re-

*By the reciprocating parts is meant those parts that have a forward and back (or reciprocating) motion. This includes the pistons and piston-rods, the cross-heads and a certain part of the main rods.

†The counter-balance is the balance weight placed in the wheel at a point opposite the crank pin. (See No. 240, Plate I.)

‡The counter-balance weights act at all points of the revolution, having an outward or centrifugal tendency from the center of the wheel that is great at high speeds, and is only counteracted when the engine is passing the front and back centers. At other points it produces an upward tendency upon the engine when moving up and a downward blow upon the rails when moving down.

quirements, let us see for one moment what the requirements for high speed are. Take an engine with a five foot driving wheel and a twenty-four inch stroke, traveling at the not unusual rate of a mile a minute. This requires 336 revolutions per minute, and means that the piston starts and stops 672 times, and with all its stopping and starting travels 1344 feet per minute. At mid-stroke the piston speed is about 35 feet per second or 24 miles per hour. To the average railway man high speeds are so common that I can think of no better way to show the full meaning of these figures than to compare them with those of a falling body acted upon by gravity. A falling body at the end of the first second is traveling at the rate of 32 feet per second, or about 22 miles per hour, and in gaining this speed the body has fallen some 16 feet, through which distance the continued action of gravity has produced this not inconsiderable acceleration, while in the case of the piston of the locomotive in question, the still greater speed of 24 miles per hour must not only be attained by the time the piston has reached the middle of its stroke, or in one foot, but also it must be exerting great additional propelling power on the crank pins. The steam in front of this rapidly moving piston must be exhausted freely or there would be no effective power to maintain the speed. Where the reciprocating parts weigh nearly a thousand pounds, it will be seen what enormous power is required to stop and start them without jar or shock to the locomotive, and also the size of ports required to

freely exhaust the pressure ahead of and freely supply steam behind the very large pistons of compound locomotives. With any of the several types of valve gear used in locomotive practice to-day, it goes without saying that no compound can be relatively so efficient, in comparison with single-expansion engines, in express passenger as in freight service, for the reasons hereinbefore described. When many single-expansion locomotives with moderately large ports require a velocity of steam through their ports of over 1,000 feet per second, it can better be imagined than told what the port requirements are for the large low-pressure cylinder on a compound. It is generally considered that for express passenger service the low-pressure cylinders should not be so large in proportion to the high-pressure cylinders as for freight service.

Many of the earlier compounds in this country suffered in comparative tests with simple engines of otherwise similar design, by having cylinders of too small a size to do the same work as the simple engine. While they did their work with economy, they would not haul the heavy trains of the simple engines, and their supposed capacity had to be reduced, to the annoyance of those engaged in the operating of trains. Since then, with the advent of larger cylinders and the "convertible" class of compounds, the conditions have become altered.

With any locomotive, when steam is shut off, as in running down grade, the pistons act as air compressors, causing thumping, rough riding, and

cooling of the cylinders, as well as a strong draft in the stack at a time when no steam and little draft are required, and thus produce a waste of fuel. The large low-pressure cylinders of the compound have greatly magnified this evil, and several builders have overcome it by the use of automatic valves on the low-pressure cylinder, by which the two sides of the low-pressure piston are connected whenever the locomotive is drifting.

After closing the throttle, an engine working compound will make several strokes before all steam is finally exhausted. This delay in clearing the cylinders of steam, placed compound locomotives to considerable disadvantage in switching or like service; also, in such service, accustomed to gauge the speed by the exhaust of the engine, trainmen were often deceived by the less frequent exhaust of the two-cylinder compound. The employment of the separate high-pressure exhaust, whereby the engine can be run simple at the will of the engineer, it appears, has overcome these objections from an operating standpoint.

Many of the earlier forms of intercepting valves were of the poppet type and hammered badly in opening or closing. It will be noticed that these valves in the later designs are of the piston type and are almost invariably cushioned by dash-pots connected thereto, or some other equally effective means.

It is also claimed that the breakage and loosening of the large low-pressure cylinders have been considerably done away with by the use of proper

reducing valves and a better attachment of cylinders to the frame, the use of double front rails for the latter being particularly noticeable in modern construction of large locomotives.

Thus it is that improvements in design and construction are continually taking place, and the upholders of the great principle of compounding will certainly witness their more extensive adaptation to all classes of service.

CHAPTER III.

ENGINEERS' AND FIREMEN'S MANUAL—CLASSES OF COMPOUND LOCOMOTIVES AND THEIR GENERAL CONSTRUCTION.

There are many classes of compound locomotives in use. First, the *strictly plain compound*, where no live steam is admitted to the low-pressure cylinder, even in starting. The Webb three-cylinder compounds (with cylinders arranged as outlined in Fig. 106,) which are usually without connecting rods—the two high-pressure cylinders turning the rear pair of driving wheels by

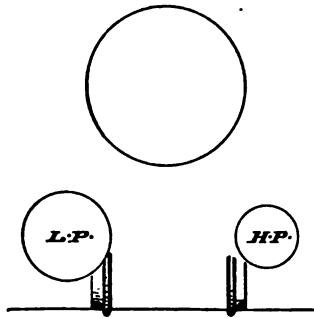


Fig. 101.

two outside cranks while the low-pressure cylinder turns the forward drivers by means of an inside crank—belong to this class and are used in considerable numbers on the London & North-Western of England. They are not powerful in starting, as the driving wheels acted upon by the high-pressure cylinders must turn, either by slipping or moving the train, before steam enters the low-pressure cylinder.

Second, *automatic compounds*—those using live steam in the low-pressure cylinder in starting only, automatically changing to compound with the first stroke, and thereafter cannot be run except as compounds.

The third class can be run simple or compound at any time at the will of the engineer and will be termed *convertible compounds*.

Each of these principal classes may have two, three, or four cylinders. The two-cylinder or "cross-compound" always has an intermediate receptacle, called a receiver,* between the high and low-

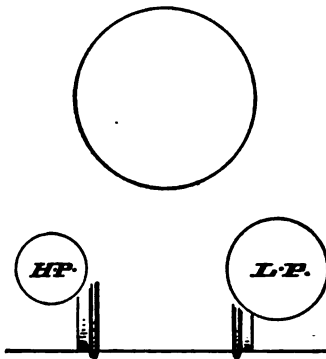


Fig. 102.

pressure cylinders, while the four-cylinder engines may or may not have receivers—those with both pistons attached to the same crosshead generally have not. The three systems of four-cylinder compounds used in this country are the Baldwin (Vauclain), the Brooks (Player), and the John-

stone. Of these, the Brooks has receivers, while the remaining two are of the continuous expansion† type and have no receivers.‡

*The receiver is for the purpose of receiving the exhaust from the high-pressure cylinder and holding it until the engine gets to the point in the revolution where it is admitted against the low-pressure piston. Incidentally, the receiver may act as a reheater, if located in the smoke-box, as is usually the practice.

†Meaning expansion without any pause or interruption as is the case when a receiver is interposed between the high and the low-pressure cylinders.

‡In Europe the Hurgarian State Railways employ four-cylinder tandem compounds with one receiver into which both high-pressure cylinders exhaust and from which both low-pressure cylinders receive their supply.

The arrangement of cylinders is quite varied, as shown by the several skeleton cuts. There may be two cylinders, one high-pressure and one

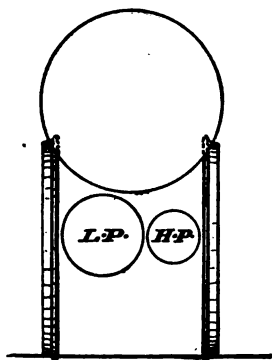


Fig. 103.

low-pressure, as outlined in Figs. 101, 102 and 103; one high and two low-pressure, as in Figs. 104 and 105; two high-pressure and one low into which they both exhaust, as in Fig. 106; two high, each exhausting independently into a low-pressure cylinder on the same side of the engine, shown in Figs. 107, 108, 109 and 110; or two high ex-

hausting into a common receiver from which both low-pressure cylinders draw their supply, as in Figs. 111 and 112. Aside from the varied ar-

range of cylinders, many of the European designs employ three and four cranks and use no side rods. Some French constructions, retaining the use of side rods, employ for the high-pressure cylinders two inside cranks on one driving axle at an angle with the low-pressure cranks on a

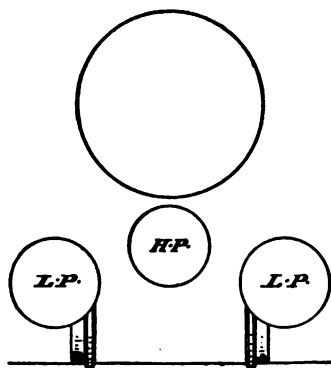
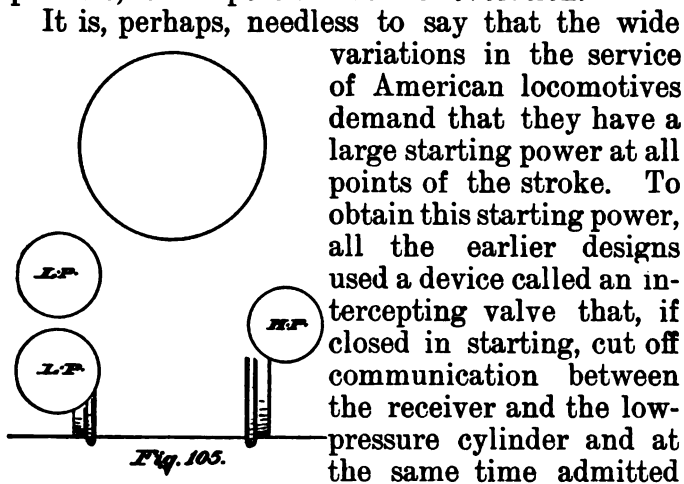


Fig. 104.

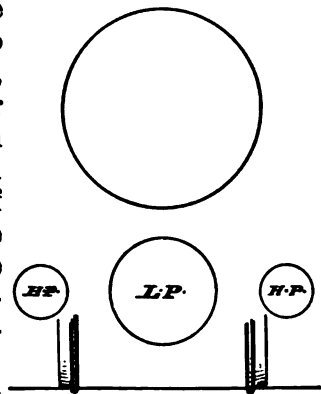
second driving axle, the angle between the cranks

being such as to give as large a turning power as possible, for all portions of the revolution.



live steam to the low-pressure side, but after the first exhaust from the high-pressure cylinder to the receiver took place, the pressure in the latter automatically shoved open the intercepting valve and simultaneously shut off the further supply of live steam to the low-pressure cylinder. Hence these engines belong to the automatic class of compounds.

Mr. Anatole Mallet, who was the designer of the first practical compound locomotives in Europe



The diagram shows a large circle representing the receiver at the top. Below it, in the center, is a circle labeled 'L.P.' (low-pressure). On either side of the 'L.P.' circle are two vertical lines representing valves, each topped with a smaller circle labeled 'H.P.' (high-pressure). A horizontal line at the bottom represents the cylinder bed.

Fig. 106.

in 1876, was also the first to devise a means by which a compound could be worked as a simple locomotive for any desired period at the will of the engineer. This was accomplished by adding a separate exhaust valve through which the exhaust from the high-pressure cylinder could escape to the atmosphere without accumulating in the receiver. This relieved all back pressure on the high-pressure piston and admitted of greater power at slow speed than was otherwise obtained.*

Many objections were raised to placing the operation of the engine either as a simple or as a compound in the hands of the engineer, and the fear was freely expressed that the average engineer would run the locomotive to its disadvantage in simple position more than enough to offset the saving when operated as a compound. However, one prominent railroad officer,

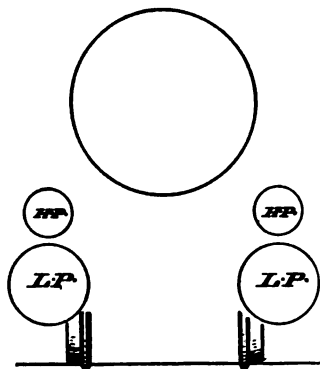


Fig. 107.

in placing the operation of the valves at the will of the engineer, seemed to express the now settled conviction of all, when he said: "To argue that an

*It should also be stated that not only were the automatic compounds less powerful, at slow speeds after starting, than simple engines, but, except in the case of four-cylinder engines having one high and one low-pressure cylinder on the same side they were practically helpless in case of a broken steam chest on either side. The use of the separate exhaust valve has greatly altered the conditions in these cases.

engineer is likely to work simple any longer than absolutely necessary, is about the same as saying that an engineer with the ordinary engine cannot be trusted to pull the reverse lever up as soon as possible."

Later practice interposed, within or near the intercepting valve, a reducing valve, which is used to admit live steam, at a reduced pressure only, into the low-pressure cylinder when starting or when working simple. This reduced the

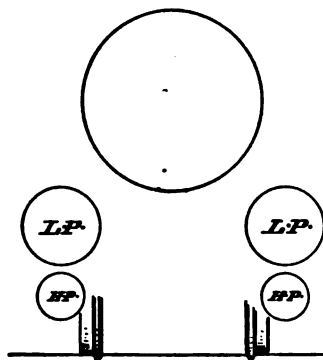


Fig. 106.

abnormal shocks that were produced when starting large compounds of earlier design. The reducing valve, the intercepting valve, and the separate exhaust valve were so closely combined in many cases and so dependent, one upon the other, in their operation, that it became the tendency among railway and me-

chanical men to refer to the whole mechanism simply as the "intercepting valve."

While the limit to the size of the ordinary locomotive may be considered to have been reached when the largest practical boiler that can be placed on a given gauge track has been attained, the limit to the American two-cylinder, or cross-compound, with outside cranks will be the maximum width allowable for locomotives. However, again Mr. Mallet, the father of the present era

of compound locomotives, has seemingly solved the problem by dividing the low-pressure cylinder into two cylinders, as shown in Fig. 105, of smaller size attached to the same crosshead. With such a construction it would appear that the boiler would still be the limiting feature of the size of the compound as well as the simple locomotive.

The proper cylinder ratio of compounds for all varieties of service is still somewhat undetermined. By the cylinder ratio is meant the proportion between the volumes of the high and the low-pressure cylinders, not including the clearance

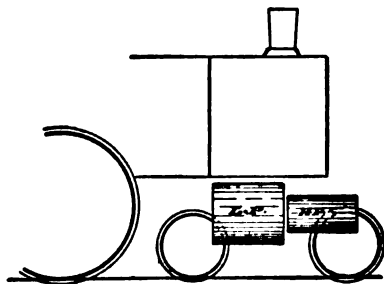


Fig. 105.

spaces. In American practice where the length of stroke is the same, the cylinder ratio would be as the areas of the two pistons, and it can readily be found by multiplying the diameter of each cylinder by itself and comparing the two products. For instance, to find the cylinder ratio of an engine with a 20 inch high and a 30 inch low-pressure cylinder, multiply 20×20 equals 400; 30×30 equals 900; 400 goes in 900 two and one-fourth times, which is the cylinder ratio.

The early practice in this country with two cylinder compounds gave a ratio of two to one or even less; but extended experiment has demonstrated that a greater proportion than this is advisable and many compounds of this class have a low-pressure cylinder from two and one-half to two and three-quarters times larger than their high-pressure cylinder. The Baldwin works used a ratio of 3 to 1 in their Vaucrain four-cylinder compounds for both passenger and freight service for a number of years and consider the results eminently satisfactory, while the builders of the Brooks tandem four-cylinder compound advise a ratio of between 2.8 and 3 to 1. However, the whole problem of cylinder ratios for compound locomotives is based upon the desirability of dividing the work as equally as possible between the high and the low-pressure cylinders, and without going into details, it is apparent that no given ratio will keep the work equally divided

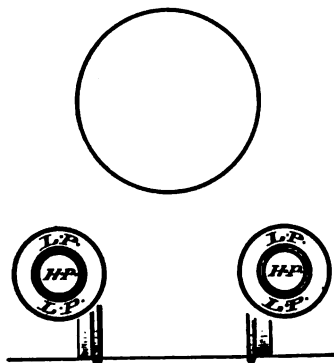


Fig. 110.

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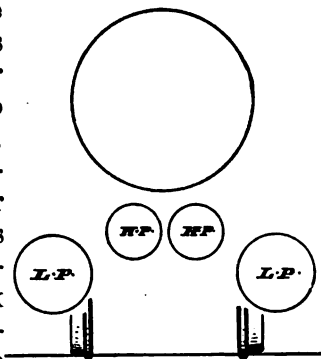
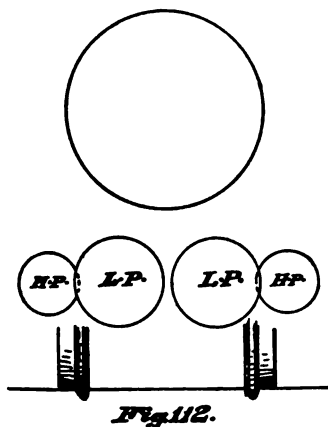


Fig. 111.

it is apparent that no given ratio will keep the work equally divided

for different service and different points of cut-off, nor should this equal division of power between the cylinders be given anything but secondary consideration in comparison with the total economy of the locomotive. To partially equalize the power of compounds, the amounts of lap and lead are not the same for both cylinders; one builder uses a separate lever in the cab for independently adjusting the travel of the low-pressure valve, as fully described elsewhere.

There seems to be no general rule followed by



builders in this country as to which cylinder of a two-cylinder compound should be placed on the right-hand or engineer's side of the engine. Generally the intercepting valves are located on the engineer's side to make their connections as simple as possible, and hence, according as the design contemplates the plac-

ing of this valve adjacent to the high or the low-pressure cylinder, that one is placed on the right-hand side. But even this rule is not without exception.*

*It would seem as though the intercepting valve, if placed between the high-pressure cylinder and the receiver, would cause less wire-drawing of steam to the low-pressure cylinder than if located between the latter and the receiver.

Some compounds have cylinder casings both of the same size, but with the advent of the thirty-four or thirty-five inch low-pressure cylinder it seemed to many advisable to place it on the engineer's side with the thought of its better protection from damage if within his vision, and, furthermore, that the high-pressure cylinder casing be made no larger than necessary for reason of its better protection from accident.

It is becoming the general practice on compounds of any size to place combination safety and relief valves on the receiver and the low-pressure chest and cylinder heads to avoid damage in case of broken reducing valve or other accident that might produce unsafe pressure on that side.

CHAPTER IV.

ENGINEERS' AND FIREMEN'S MANUAL — QUESTIONS AND ANSWERS ON THE OPERATION OF COM- POUND LOCOMOTIVES IN GENERAL.

In what respects should the instructions for firing compound locomotives differ from those for single-expansion engines, as described in the Manual? On account of the effect of the milder exhaust on the fire, the fireman should carry the fire as light as possible and yet keep a thin layer of coal in a well ignited state over the entire surface of the grates.

Should the engineer observe any difference between the operation of a compound and a simple locomotive? Perhaps the most important thing is that the engineer must accustom himself to use the reverse lever for what it is intended, not hesitating to increase the valve travel whenever necessary, and converting the engine to "simple" only at low speeds and after the maximum power of the engine working compound is found insufficient. There will be no such waste of steam from lack of expansion (see Fig. 100) nor such serious injury to the fire by working the valves full gear as is the result with single-expansion engines. Do not expect to find the best running position of the reverse lever as near the center of the quadrant as with a simple engine. The engine will do better work with the lever nearer

full gear, just how far depending, of course, on the varying conditions of train, grade, and speed; but, in general, do not cut the lever back too far. The engine throttle should usually be run as wide open as possible, but judgment must be used in this respect according to the existing circumstances. An engine designed for heavy freight service may do better under very light work or in passenger service, if throttled.

In order to move and stop engines quickly when desired, as for engine-house or turn-table work, how is it advisable that compound engines be handled? Their valves should be kept in simple or starting position whenever their construction will permit, in order that the engines may be moved with the least necessary opening of the throttle and that, when the throttle is closed, the pressure remaining in the pipes will the sooner escape.

In starting, why are compounds more likely to slip than other engines? If they are started working simple, their power temporarily is considerably greater than that of simple engines of the same weight, hence great care should be exercised by the engineer to avoid slipping; but at any rate the cylinder cocks should be left open as long as there is any liability of water being in the cylinders.

Why is it, that, under these circumstances, compound locomotives frequently slip only a part of a turn instead of spinning around, as many simple engines will do unless steam is immediately shut off? Because, while they are more

powerful at slow piston speeds, the ports used for starting are generally so small that a rapid movement of the piston will so greatly reduce the effective pressure on the piston as to cause the slipping to cease, many times without closing the throttle.

What harm results from frequent slipping for only a part of a revolution? This will occur each time at that part of the stroke where the turning power is the greatest and finally wear the tires out of round, so that the wheels will pound badly at high speeds, thus causing damage to the machinery and track besides making the engine ride hard.

Wherein does the lubrication of their cylinders differ from that of simple engines? Oil need only be supplied to the high-pressure cylinder or cylinders, when the engine is working compound. Hence a four-cylinder compound would be lubricated, as usual, on both sides of the engine, but a two-cylinder, or cross-compound, would require oil only in the one high-pressure cylinder when working in compound position. In this latter class, valve oil should be supplied to the low-pressure cylinder, however, when the engine is starting or running simple, but immediately shut off as soon as the change is made to compound working.

What are apt to be the injurious consequences of feeding oil to the low-pressure side when the engine is working compound? There being then no supply of live steam through the reducing and the intercepting valves, the oil would settle there

and gum these valves so as to cause them to stick and, possibly, become inoperative.

When is it advisable to work the compound as a simple engine? In starting very heavy trains, and also on heavy grades when it is seen that the power as a compound with the valve in full gear is insufficient.

When the engine can be run simple for any period at the will of the engineer, above what speed is it impracticable to do so? Above a speed exceeding six or eight miles an hour.

What is the reason for this? Because, as outlined elsewhere, the special ports for use when the compound locomotive is working simple are usually purposely designed too small to permit of much speed.

If special valves for use when the engine is drifting are not provided, what is it advisable to do? Work a little steam all the time in order to keep the large valves and pistons somewhat lubricated.

Why is it more difficult to detect leaky valves and cylinder packing in compound than in simple engines? In the first place it does not so seriously affect the good working of the engine, and, in the second place, because the high-pressure cylinder does not exhaust to the atmosphere where a blow could be heard, and also the pressure behind the low-pressure piston is very much lower than with a simple engine and, consequently, a blow does not sound as loud.

What general rule will apply to compound as well as simple locomotives where one side has to

be disconnected in cases of accident? On the disabled side, always block securely at both ends of the crosshead and firmly secure the valve, under all ordinary circumstances, in the center of its seat?

What is usually the cut-off in the high-pressure cylinder with the reverse lever hooked up? Some builders cut no notches higher up in the quadrant than would give a cut-off at one-half stroke, while others notch the quadrant all the way up to the center.

Why is it not necessary to have notches in the quadrant for shorter cut-off than one-half? A shorter cut-off than one-half for a compound locomotive is generally inadvisable for reasons analogous to those hereinbefore urged against a shorter cut-off than one-fourth for a simple locomotive; also it prevents damage that might ensue from excessive compression. With a ratio of 2 to 1 between the sizes of the low and the high-pressure cylinders, one-half cut-off gives practically four expansions, a three-fourths cut-off gives two and two-thirds expansions; with a cylinder ratio of 3 to 1, one-half cut-off gives about six, and three-fourths cut-off about four expansions. Fig. 100 clearly shows, that, while the most economical cut-off (as far as the amount of steam used is concerned) is about one-quarter of the stroke for single-expansion engines, it is about one-half stroke for compounds. Lighter work than is produced by full throttle and one-half cut-off in the high-pressure cylinder can best be obtained by throttling the engine.

In what way does the use of a separate exhaust valve give greater power to the two-cylinder compound at slow speeds? Assuming 200 pounds boiler pressure and a cylinder ratio of $2\frac{1}{2}$ to 1, the high-pressure exhaust reaches about 57 pounds when the engine is working compound. This pressure is the receiver pressure and becomes the initial pressure (at slow speeds) in the low-pressure cylinder. When working simple, the reducing valve permits about 80 pounds of live steam to pass into the low-pressure cylinder, thus considerably increasing the power in that cylinder. The high-pressure piston also exerts an equally increased power when working simple, as the back pressure of 57 pounds is removed by the separate exhaust valve.

THE BALDWIN FOUR-CYLINDER COMPOUND.

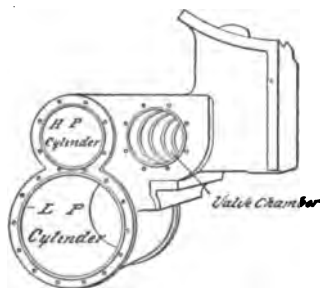
The builders of the "Vauclain" four-cylinder compound locomotives claim a design productive of the greatest efficiency with the utmost simplicity of parts and the least possible deviation from existing practice; that they also develop equal power on each side of the locomotive, thereby preventing the racking of the machinery resulting from an unequal distribution of power; and that, in their method of handling by the engineer, there is but slight departure from that of single-expansion or non-compound locomotives. They may be started, and run for any desired length of time, either simple or compound, at the will of the engineer, and can be changed from the one to the other at his discretion by the

movement of a small lever in the cab which also operates the cylinder cocks.

The principal features of construction are as follows:

The cylinders consist of one high-pressure and one low-pressure cylinder for each side, the ratio of their volumes being as nearly 3 to 1 as the employment of convenient measurements will allow. They are cast in one piece with the cylindrical valve chamber and the saddle, the cylin-

Fig. 113

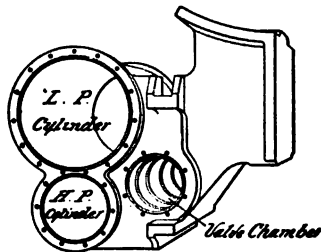


*Baldwin Four-Cylinder Compound.
Cylinder Arrangement.*

ders being placed one directly above the other and as close together as they can be with adequate walls between them. Figs. 113 and 114 show the proximity of the two cylinders, while in Fig. 115, which shows the arrangement of the cylinders in relation to the valve, the actual construction is distorted for illustrative purposes.

The valve used to distribute the steam to the cylinders is of the piston type, working in a cylindrical steam chest located in the saddle of

the cylinder casting as close to the cylinders as possible and between them and the smoke-box, as shown in the figures. This chest, having steam passages cast larger than required, is bored out enough larger than the diameter of the piston valve to permit the use of a hard cast iron bushing. Fig. 122 shows this bushing and one method of forcing it into place so that steam tight joints will be had between all ports; it

Fig. 114.

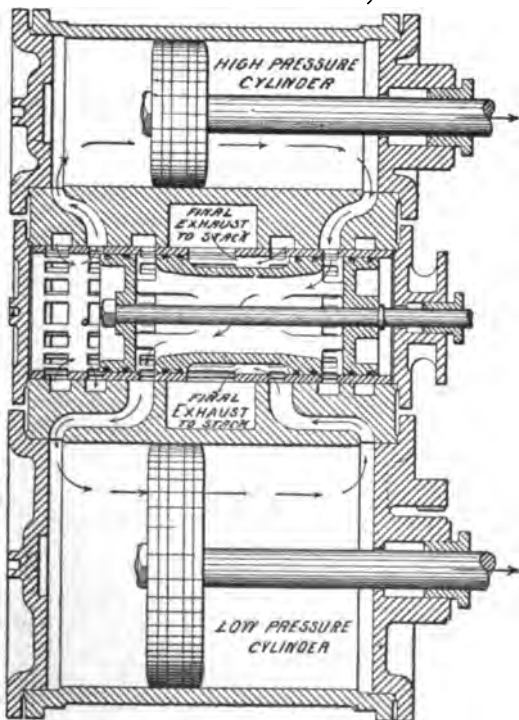
*Baldwin Four-Cylinder Compound.
Cylinder Arrangement*

also shows the narrow bridges across the steam ports which prevent the eight packing rings of the valve (shown in Fig. 116) from entering the ports. These cast iron packing rings form the edges of the valve.

The valve is of the piston type—double, and hollow between the two inside pistons—but having two solid ends, as shown by Fig. 116, and controls the admission and exhaust of both cylinders. The exhaust steam from the high-pressure

cylinder becomes the supply steam for the low-pressure cylinder and is transmitted from one side of the high-pressure cylinder to the opposite

Fig. 115.



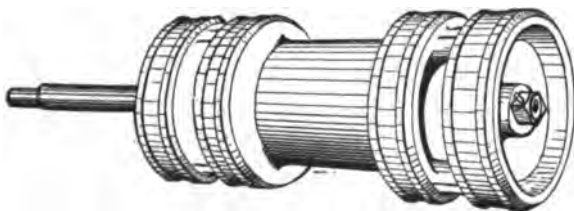
*Baldwin Four-Cylinder Compound.
Steam Distribution with Piston Valve*

side of the low-pressure cylinder through the hollow portion of the valve, as indicated by arrows, Fig. 115. The supply steam for the high-pressure

cylinder enters the steam chest at both ends, thus balancing the valve with the exception of the area of the valve-stem at the back end.

The more common slide valve action being so much better understood by the average railroad man than the piston valve, I will liken this four-piston valve to one slide valve within another having external admission and internal exhaust in both cases. Thus it will be seen that the outside

Fig. 116.



Baldwin Four-Cylinder Compound.

Piston Valve.

edges of the two outer pistons govern admission and their inside edges the exhaust of high-pressure cylinder, while the two inner pistons similarly regulate the flow of steam to and from the low-pressure cylinder, all of which will be evident by a reference to the arrows in Fig. 115.

Where the front rails of the frame are single bars, the high-pressure cylinder is usually put on top, as shown in Fig. 113, and in that event, with

the usual rocker-arm, indirect valve motion is used.* When the low-pressure cylinder is put above (Fig. 114) on account of the double front rails of the frame, they also prevent the use of the rocker-shaft and box and the valve motion is then termed direct-acting, which necessitates a different location of the eccentrics on the axle.*

Engineers and those employed in shops and round-houses for setting valves and eccentrics should thoroughly understand the difference between the position of the eccentrics with relation

Fig. 117

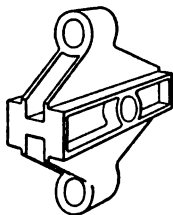
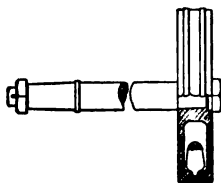
Baldwin Four-Cylinder Compound
Cross-Head

Fig 118

Baldwin Four-Cylinder Compound
Hollow Steel Piston

to the crank-pins for direct and indirect valve motion, as given fully elsewhere in the Manual, and further brought out in the Catechism on Accidents to Baldwin Four-Cylinder Compounds hereinafter contained.

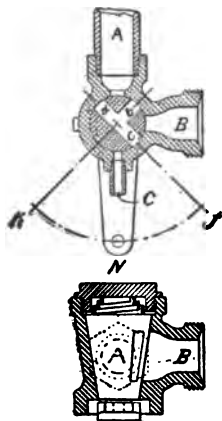
The style of crosshead is shown in Fig. 117. It is made of cast steel, to insure the greatest strength with a minimum weight, the wearing surface being lined with tin. The piston, shown

*Direct and indirect valve motion will be found fully illustrated and explained in the earlier chapters of the Manual.

in Fig. 118, is also preferably made with cast steel heads, the object in both cases being to reduce the weight of the reciprocating parts to a minimum.

It is obvious, that, in starting these locomotives from a state of rest with heavy trains, it is necessary to obtain a greater power than that exerted by the high-pressure piston alone, for there would

Fig. 119



*Baldwin Four-Cylinder Compound.
Combined Starting Valve and Drip Cock.*

be no pressure on the low-pressure piston until the high-pressure cylinder had made one exhaust; hence it is necessary to admit steam to the low-pressure as well as the high-pressure cylinders. This is accomplished by the use of the starting

valve (Fig. 119).* This is simply a plug-cock which is opened by the engineer by means of suitable levers from the cab, to admit steam from one end of the high-pressure cylinder to the other, and thence, as if it were the ordinary high-pressure exhaust, into the low-pressure cylinder. This same valve acts as a cylinder cock for both ends of the high-pressure cylinder and is operated by the same lever that actuates the ordinary cylinder cocks, which are in this case on the low-pressure cylinder, thus making, probably, the most simple starting device used on any compound locomotive and one not easily deranged. The operation of the starting valve in conjunction with the cylinder cocks is clearly shown in Fig. 120. The starting valve should be kept closed (position *N*) as much as possible, as its indiscriminate use reduces the economy and makes the locomotive "logy."†

Air valves, to prevent a vacuum, are placed in the steam passages of the high-pressure cylinder,

*This is sometimes called the "By-Pass" valve, as it connects the two sides of the high-pressure piston, but for an entirely different purpose than that to which the by-pass valves are put in connection with the low-pressure cylinder as described herein—after under the Richmond and the Rogers compound, and for that reason I have not called it a "by-pass" valve. Two earlier forms of starting valves have been used with Vauclain compounds, but, inasmuch as they have been superseded by this form of valve, it is not deemed necessary to illustrate and describe them herein.

†An engine which should be capable of high speed but is not, and in which the pressures work against themselves in the cylinders, is said to be "logy."

a practice now generally followed on all locomotives, either simple or compound. Additional air valves, marked *C* and *C'* in Fig. 120, are placed in connection with the ports in the valve chamber leading to the low-pressure cylinders. Air valves of somewhat different shape have been described and shown in detail heretofore in the *Manual*.

Water relief valves *W W*, Figs. 120 and 121, which are nothing more nor less than pop valves, are applied to the low-pressure cylinders and attached to the front and back cylinder heads to relieve excessive pressure of any kind, steam or water. The spring in the water relief valves on these engines is made to carry a pressure enough greater than the boiler pressure to prevent their discharging steam and water ordinarily in starting the engine simple.

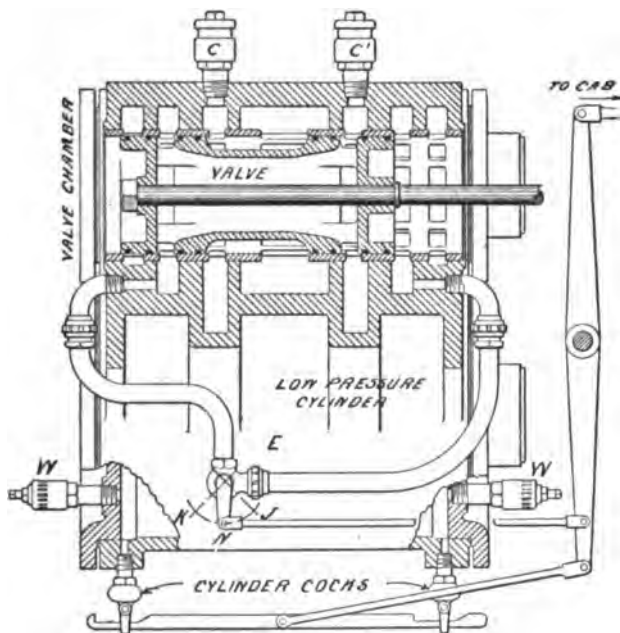
In all other respects the locomotive is the same as the ordinary single expansion locomotive.

Operation of the Baldwin Four-Cylinder Compound.—When starting the locomotive, the engineer should, ordinarily, pull the cylinder cock lever way back and thus open the cylinder cocks in order to relieve the cylinders of condensation, and, as the starting valve is opened by the same movement, steam is thus admitted to the low-pressure cylinder and the locomotive started quickly and freely.

In case the locomotive is at a platform of a crowded station, or in any other place where it is

undesirable to open the cylinder cocks, the engineer should move the starting lever in the opposite direction from that usually given it,

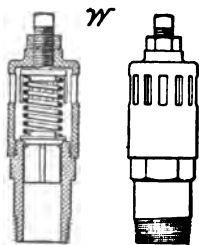
Fig.120.



*Baldwin Four-Cylinder Compound.
Showing operation of Starting Valve and
Cylinder Cocks.*

placing the starting valve handle in position *J*, Figs. 119 and 120; that is, he should push forward the lever in the cab, thus allowing steam to pass

through the starting valve without opening either the low-pressure cylinder cocks or the drip *C* of the starting valves. By further reference to Fig. 119, it will be seen how, when the handle is in position *K*, ports *A*, *B*, and drip *C* are all connected by the ports *a*, *b*, and *c* of the plug; but if the handle is in the opposite position *J*, ports *A* and *B* only are connected, as *b* is now at *a* and *c* is opposite *B*; in its central position *N* (normal position for compound working), it will be seen that all ports are closed as in the figure.

Fig. 121.

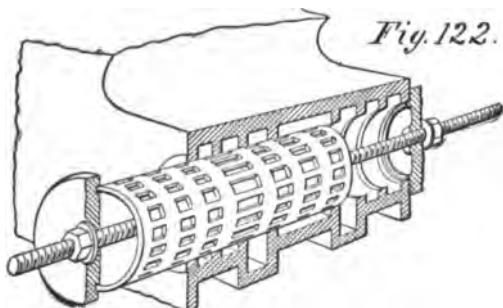
*Baldwin Four-Cylinder Compound.
Cylinder Relief Valve.*

After a few revolutions have been made and the cylinders are free from water caused by condensation or priming, the engineer should move the cylinder cock lever into the central position, *N*, causing the engine to work compound entirely. This should be done before the reverse lever is disturbed from its full gear position.

Ordinarily, the reverse lever should not be "hooked up," thereby shortening the travel of

the valve, until after the cylinder cock lever has been placed in its central position, but it is often necessary to open the cylinder cocks when at full speed to allow water caused by priming or foaming to escape from the cylinders, and in such cases no disadvantage is experienced, and the reverse lever need not be disturbed.

The starting device is simply designed for use in the starting of the train and should not be used at any other time unless there is imminent danger of stalling and the lever has been previously dropped to full gear. In other respects,



*Baldwin Four-Cylinder Compound
Valve Bushing, Showing Method of Pressing in*

aside from these here noted, the rules governing the operation of compound locomotives in general should be clearly understood by any engineer who is liable to be called upon to run a compound locomotive of this or other design.

REPAIRS.

The builders of the Vaucrain four-cylinder compound claim an advantage in it over the

two-cylinder or "cross-compound" locomotive in simplicity of parts, there being no intercepting valve,* and a similarity to all the parts of a single-expansion locomotive. Thus its repairs will be similar to those of simple locomotives. To carry out this simplicity of parts, the piston rods of the high and low-pressure cylinders are of the same diameter and designed strong enough to withstand the severest strains of service.

The packing rings in the valves are easily replaced and the valve chest bushing can be cheaply and easily renewed. In extracting old bushings it is best to split them between the ports with a narrow chisel. The new bushings can be pressed in by some such handy device as that shown in Fig. 122.

Accidents to Baldwin Four-Cylinder ("Vauclain") Compounds.—For all ordinary accidents, such as broken main rod or pin, or a broken valve stem, what should be done? The same as for non-compound or simple locomotives, as described fully in the earlier chapters of the *Manual*.

With a low-pressure cylinder head knocked out, would it be necessary to disconnect that side? Not for a short distance.

In that event, how many exhausts would there be during one revolution? There would be three

*The intercepting valve is the valve which prevents the live steam which is admitted from the boiler to the low-pressure cylinder at certain times, from passing through the receiver to the high-pressure cylinder where it would produce back pressure on the piston.

in the stack and one through the open cylinder head and the latter exhaust might obstruct the engineer's view, if on his side, and render the procedure inadvisable.

With the Vaucrain Compound, at what position of the reverse lever is work of the two cylinders most nearly equalized? At a cut-off of about one-half the stroke in the high-pressure cylinder.

When is the work most unequal and the strains on the crosshead consequently the greatest? In starting with the engine working simple, as then the high-pressure piston is nearly balanced by live steam on both sides and the low-pressure cylinder obtains approximately boiler pressure.

What results would be likely should the rigging of the cylinder cocks and starting valve become bent or disconnected? Should one starting valve fail to properly close, the exhausts would be of unequal intensity. If one of them failed to open when required in starting, the engine would be weak on that side as it would have to start compound, that is with steam for the first stroke in the small high-pressure cylinder only.

In this latter event, when would the first exhaust from that side take place? Not until the completion of the return stroke.

If the cylinder cocks open and close with the same rigging as the by-pass valve, why would not the engineer know thereby that the by-pass valve was in position desired? From the previous

description of this rigging, shown in Figs. 119 and 120, it should be remembered that the cab lever pushed clear ahead opens the by-pass valve, but not its drip nor the cylinder cocks.

Before altering the valve motion, what else should be examined if the exhausts were of unequal intensity? Examine for broken packing rings in the piston valve or the low-pressure cylinder.*

In case a valve-stem broke off inside the chest or the valve itself broke, would it be certain of discovery at once, as with an ordinary slide valve? Possibly it would not. Instances have been cited where compound locomotives of this system have hauled passenger trains long distances with broken valve-stems and broken valves. The two ends of the valve being unbalanced by the area of the valve-stem (see Figs. 115 and 116) accounts for the first possibility, while live steam from the induction ports acting on each end of the valve would explain the case of an undetected broken valve.

How can it be found if the cylinder packing in the high-pressure cylinder is blowing? Put the engine on the quarter, block the wheels, and test as usual for leaky slide valve; then, with the starting valve closed (in compound position) and the low-pressure cylinder cocks blocked open,

*A case is cited by the builders where an engineer ran his locomotive two days without any piston head at all in one of the high-pressure cylinders, and even then could not tell what was the matter except that the intensity of the exhausts were unequal and the engine did not make good time. Machinists put to work to locate the trouble, found it to the great surprise of the engineer.

drop the reverse lever into full gear. Steam passing the high-pressure piston will appear at the open cylinder cock of the low-pressure cylinder, but at the opposite end that would be expected with a simple engine.

How can it be found if the packing in the low-pressure cylinder is blowing? Put the engine on the quarter and open the starting valve and cylinder cocks and look for any escape of steam from the low-pressure cylinder cock on the end that should be in exhaust, as with a simple engine.

*DIRECT VALVE MOTION
WITHOUT ROCKER ARM.*

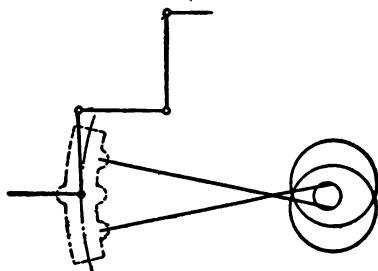
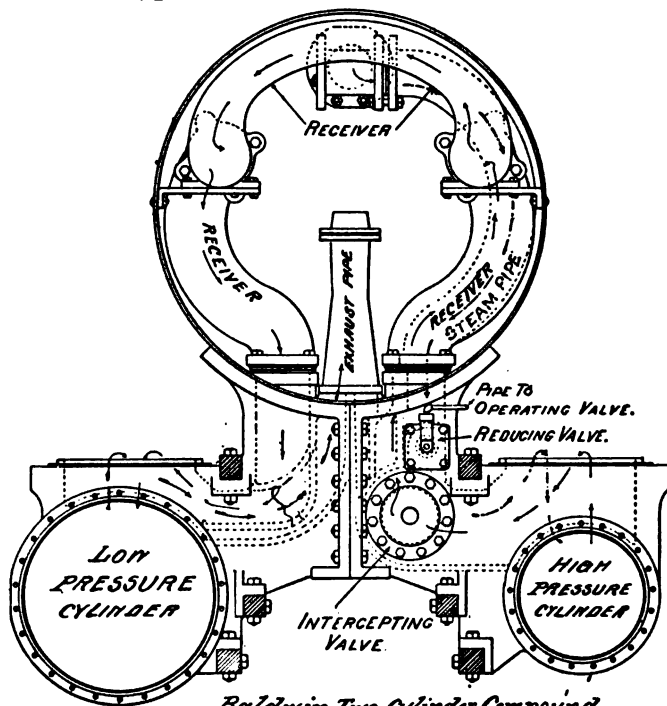


Fig. 123.

With the four-cylinder type, where the large low-pressure cylinder is placed on top, as in Fig. 114, and direct valve motion is employed, how should the eccentric rods on one side stand with the same side of the engine on the forward center? They should be crossed, as shown in skeleton Fig. 123. A slipped eccentric should be set the same as for similar valve motion on a simple engine, as fully described heretofore in the Manual under "Third Examination of Firemen."

THE BALDWIN TWO-CYLINDER COMPOUND.

The original Baldwin two-cylinder compound, built in the year 1892, was of the cross-compound receiver type and, after the first stroke or two,



Baldwin Two-Cylinder Compound

Fig. 124

or as soon as the receiver had attained a pressure of 100 lbs., the engine automatically changed to compound and could not be operated otherwise. It belonged, therefore, to the automatic class of compounds. The reducing and the starting valve

then employed were changed materially in the later design of the two-cylinder compound here-with illustrated and described.

Their later two-cylinder compound locomotives belong to the class of convertible compounds, as they can be operated either simple or compound for any length of time by the movement of a small valve in the cab, as shown by Fig. 128.

Fig. 124 shows a front view, giving the general arrangement of cylinders, steam, exhaust and receiver pipes in the front end, and the location of the intercepting and reducing valve in the saddle of the high-pressure cylinder. The low-pressure cylinder derives all its pressure from the receiver when running compound, as is usual in two-cylinder compounds.

The office of the intercepting valve is two-fold. It acts as an intercepting valve by opening and closing communication between the two cylinders, and also as a separate exhaust valve, by connecting the low-pressure cylinder with the exhaust to the stack. This it does by diverting the exhaust from the high-pressure cylinder either into the atmosphere, when working single-expansion, or into the receiver, when working compound, and is operated at the will of the engineer.

The office of the reducing valve is to admit live steam at a reduced pressure into the receiver and thence to the low-pressure cylinder, when the engine is working single-expansion, and also to close simultaneously with the changing of the intercepting valve to the position which causes

the engine to work compound, so that the receiver will obtain no live steam from boiler when taking the exhaust from high-pressure cylinder. The performance of the first above-mentioned function—that of reducing the pressure of live steam delivered to the receiver—is necessary in order

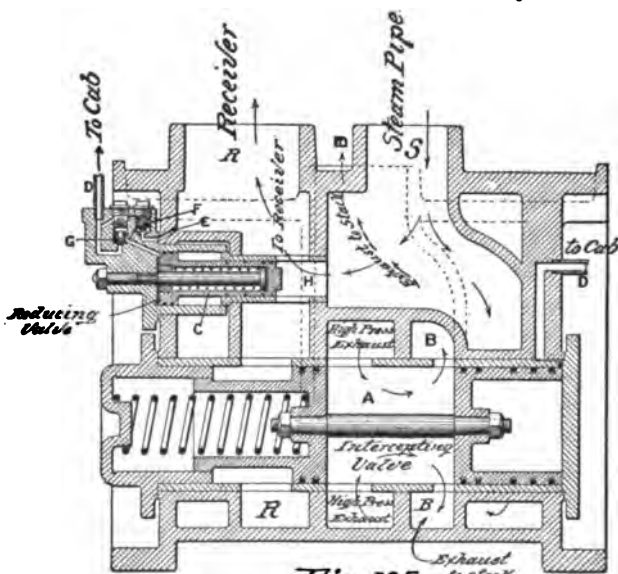


Fig. 125.

*Baldwin Iron-Cylinder Compound
Engine Working Simple*

that the total pressure on the large low-pressure piston shall not be greater than that on the high-pressure piston, and thus the low-pressure side kept from jerking the train and producing unequal strains on the two sides of the locomotive when working as a simple engine.

Operation of the intercepting and reduction valves.—In Figs. 125 and 126 the intercepting valve is marked *A* and the reducing valve *C*. It will be seen that they are both cylindrical

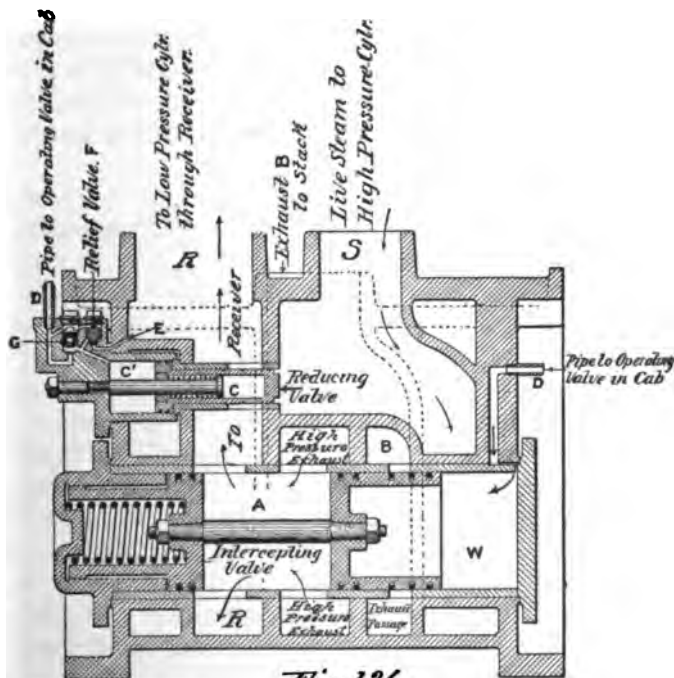


Fig. 126

*Baldwin Two-Cylinder Compound
Engine Working Compound.*

form, are placed in bushings having suitable ports, and that coil springs hold them in their normal positions when no pressure is acting against them to overcome these springs.

In the cab of the locomotive is placed an operating valve, shown in Figs. 127 and 128, having two positions, marked "SIMPLE" and "COMPOUND." Through this operating valve a pressure of air or live steam is admitted to one side of the reducing and the intercepting valves through two pipes marked *DD*, and, acting against the right end of valve *A* and against the left end of valve *C*, moves both from their normal positions shown in Fig. 125 to those of Fig. 126.

The reducing valve *C*, when it is not closed permanently by live steam from the operating pipe *D*, is automatically closed when the pressure in the receiver *R* is great enough to produce as much power in the large low-pressure cylinder as is obtained in the smaller high-pressure cylinder. For this purpose steam from the receiver *R* can pass through a port *E*, raising the poppet valve *F* (which remains open as long as the engine is not working compound) and bears upon the larger end of the reducing valve *C*, causing it to move to the right and close the live steam passage *H* (shown in Fig. 125) leading to the receiver *R*, whenever the receiver pressure becomes excessive. Thus it will be seen that when the engine is working simple there must be a close balance between the left-hand larger end of the reducing valve, being acted upon by receiver pressure, and the right-hand smaller end of the reducing valve, being acted upon by live steam from the main steam pipe *S*. In this way is the receiver pressure kept as much lower than the boiler pressure as the large end of the reducing valve is greater than

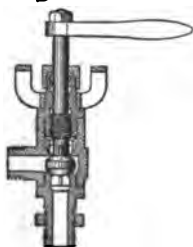
the small end. This proportion is relative to the respective sizes of the high and the low-pressure cylinders and hence equal cylinder power will be given both sides of the engine in working simple. When the engine is standing, the lever of the small operating valve, Figs. 127 and 128, in the cab should be placed at position marked "SIMPLE," and the valves are then in position for the engine to work as a single-expansion locomotive, as the

Fig. 127.



Dial

Fig. 128.



Operating Valve

Bellevue Live Cylinder Compound.

steam pressure is relieved through this cab valve from the large end of the reducing valve and the right-hand end of the intercepting valve, allowing these valves to assume (by the action of their springs) their respective positions shown in Fig. 125. The arrows in this figure illustrate clearly how the steam can pass from the high-pressure exhaust through the intercepting valve *A* to the independent exhaust *B* leading to the stack (see dotted lines and arrows). At the same time the passage of live steam to the receiver—from which the low-pressure cylinder receives its supply—takes place through ports *H*, as shown by other arrows. The receiver pressure is governed by the automatic action of the reducing valve, as previously explained.

Thus the engine can be used as a single-expansion locomotive in making up and starting trains,

and then, at the will of the engineer, the operating valve, Figs. 127 and 128, in the cab can be moved to the position marked "COMPOUND." This will admit live steam through the two supply pipes *D*, thence to the cylinders marked *W* and *C'*, Fig. 126, changing the intercepting and the reducing valves quickly, and, as the ports are small, noiselessly, to the position shown in the latter figure. With the intercepting valve in this position it will be seen that the independent exhaust *B* is closed and steam from the high-pressure exhaust must follow the course of the arrows to the receiver, passing around the small reducing valve bushing and its valve *C* which is kept closed by the live steam from pipe *D*.

At any time the engineer may desire to increase the power of the engine as, for instance, when in danger of stalling, by moving the lever of the operating valve in the cab to position marked "SIMPLE" the engine is again changed at once to a single-expansion locomotive.

Accidents to Baldwin Two-Cylinder Compounds.
—With one side disabled, what should be done in order to safely run the engine in? Disconnect the disabled side, as advised for simple engines, place the intercepting valve in position for working simple so as to open the separate exhaust port, and run in with one side.

Should the small pipes *DD* leading to the reducing valve *C* and the intercepting valve piston be broken off, how could the engine be worked? With single-expansion only, unless the back head of the separate exhaust chamber *W* were removed

and the piston blocked in the position shown in Fig. 126; then the engine would become an automatic compound, that is, would start simple but automatically go to compound after a revolution or so.

What would it be advisable to do in case of a broken reducing valve? Use very light throttle at slow speeds, or run with a reduced boiler pressure.

Should the small valves *F* and *G* be frequently inspected and cleaned? Yes. These valves and the reducing and the intercepting valves become gummed by the injudicious use of cylinder oil on the low-pressure side.

THE SCHENECTADY COMPOUND.

Locomotives built by the Schenectady Locomotive Works are oftentimes styled by the older railway men as "McQueen" engines, although the name of the builders has been as at present for many years.

These builders have constructed many compound locomotives, and, including the original valve design, have employed three styles of compound mechanisms, but all engines built have been of the two-cylinder variety of compounds.

Original Schenectady Type.—The original design by their then superintendent, Mr. A. J. Pitkin, consisted of an intercepting valve and a reducing valve. The stem of the intercepting valve was connected by levers to an index in the cab, which showed its position to the engineer. These engines belonged to the class of automatic compounds.

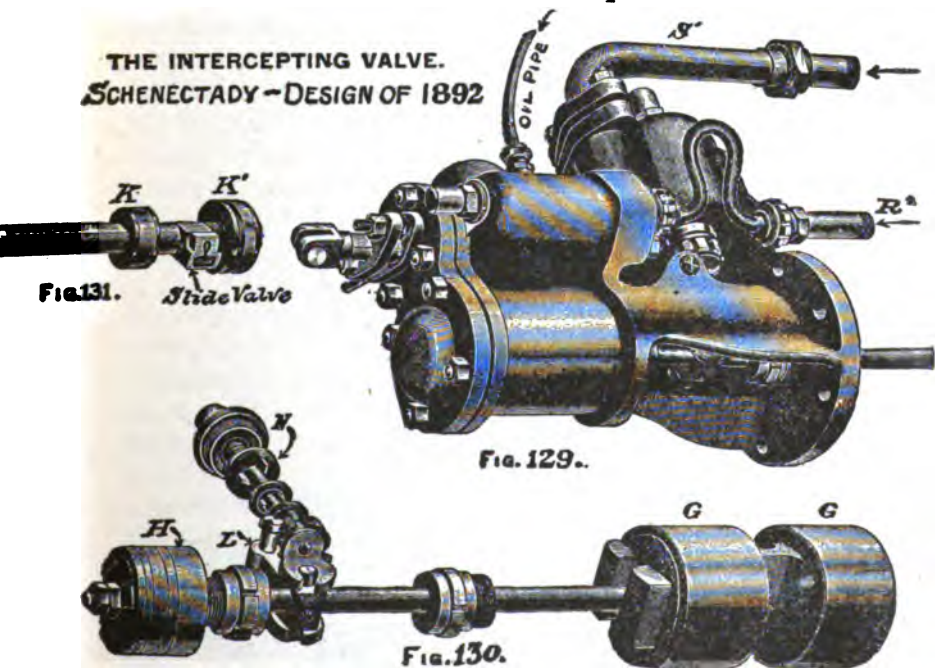
In starting the engine, a small pipe from the boiler through a reducing valve supplied steam to the low-pressure cylinder at a reduced pressure. When the receiver had accumulated sufficient pressure by the exhaust into it from the high-pressure cylinder, the intercepting valve would automatically be thrown to its normal position for working compound; then the supply of live steam to the low-pressure cylinder was cut off and the receiver pressure admitted, and thus the engine worked compound.

The following modification of this valve arrangement was afterwards made by Mr. Pitkin and applied to many locomotives by the Schenectady Locomotive Works.

Design of 1892.—With this construction of 1892, the opening of the throttle admits live steam at the same time to both the high and the low-pressure cylinders, closes the intercepting valve and allows the engine to start with its full power as a simple engine. After a few strokes the receiver pressure automatically opens the intercepting valve and cuts off the passage of live steam to the low-pressure cylinder and the engine works compound. The special valves are located in and behind the saddle on the low-pressure side and are operated automatically and beyond the will of the engineer. Fig. 129 shows the general appearance of that portion of the intercepting valve projecting back of the saddle; Figs. 130 and 131 show the valves and pistons removed from their encasing chambers. Upon opening the throttle, a small connection from the

steam pipe admits live steam through suitable valves to an actuating piston, the movement of which opens a poppet valve, supplying live steam to the low-pressure cylinder, and also places the intercepting valve so as to close connection between the receiver and the low-pressure steam

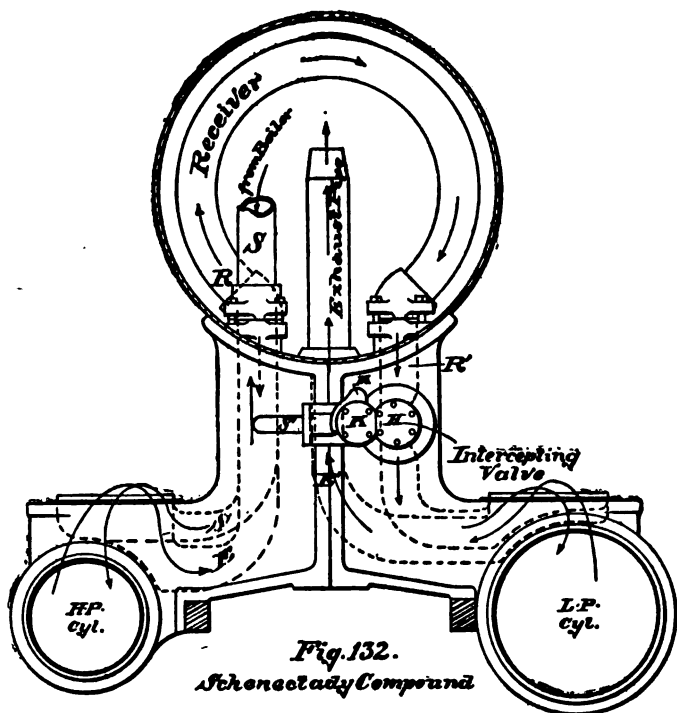
THE INTERCEPTING VALVE.
SCHENECTADY—DESIGN OF 1892



chest. Thus the low-pressure cylinder exhausts to the atmosphere, and the high-pressure cylinder into a closed receiver. Sufficient pressure will accumulate in the receiver after a few strokes to move the small valves, thereby moving the actuating piston and with it the intercepting valve. to

such position as will close off live steam to the low-pressure cylinder, and instead admit the receiver pressure, thus working the engine compound.

For the benefit of those interested in the details of this device, a more thorough description of the accompanying figures follows:



The front view, Fig. 132, shows the general arrangement of cylinders, steam passages, and the intercepting valve. Figs. 133 and 134 both

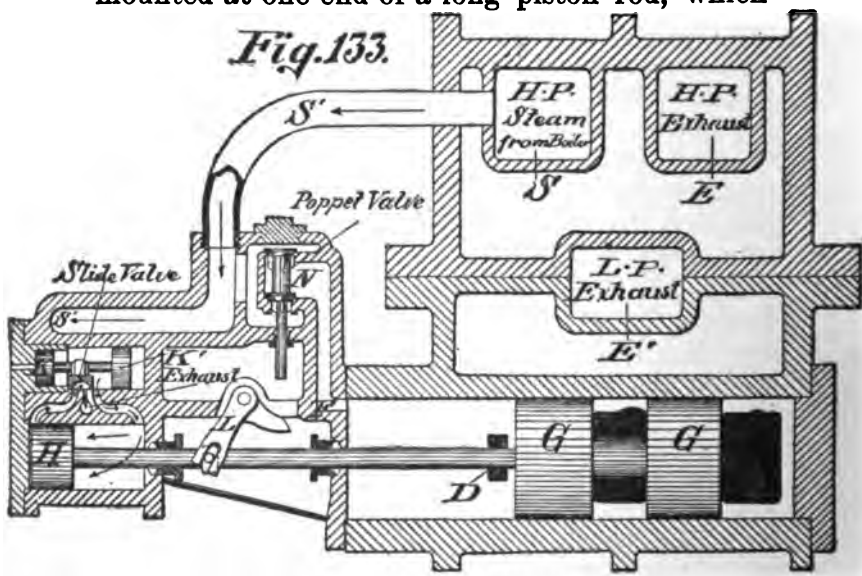
show the same horizontal section through the saddles and show the intercepting valve and the actuating valves, Fig. 133 showing them in position for working compound, and Fig. 134 for starting. Fig. 135 gives a vertical section, better showing the passages between the receiver and the low-pressure steam chest, which passages are opened and closed by the double pistons GG which form the intercepting valve. Of the remaining figures, 136 and 137 show details of the regulating valve, and Fig. 138 an end view of the intercepting pistons GG . The arrows in Figs. 133 and 134 indicate the direction of the steam in passing through the apparatus.

Fig. 132 shows a smoke-box mounted on saddles connected with the high and low-pressure cylinders located on opposite sides of the engine and having the necessary admission and exhaust ports. The exhaust port of the high-pressure cylinder is connected by a passage E (see dotted lines in Fig. 132 and full section of port in Figs. 133 and 134) with the receiver at R , Fig. 132. The other end of the receiver connects with the inlet passage R^1 (shown also in Fig. 135) leading to the low-pressure steam chest, and in this passage the intercepting valve GG is located and travels across it to open or close this passage.

The intercepting valve and the mechanism for operating it are mounted on the saddle of low-pressure cylinder, as before stated, while the live steam pipe S and the high-pressure exhaust passage E are situated in the high-pressure saddle. The low-pressure exhaust passage E^1 is formed

by the two saddles being bolted together, see Figs. 133 and 134.

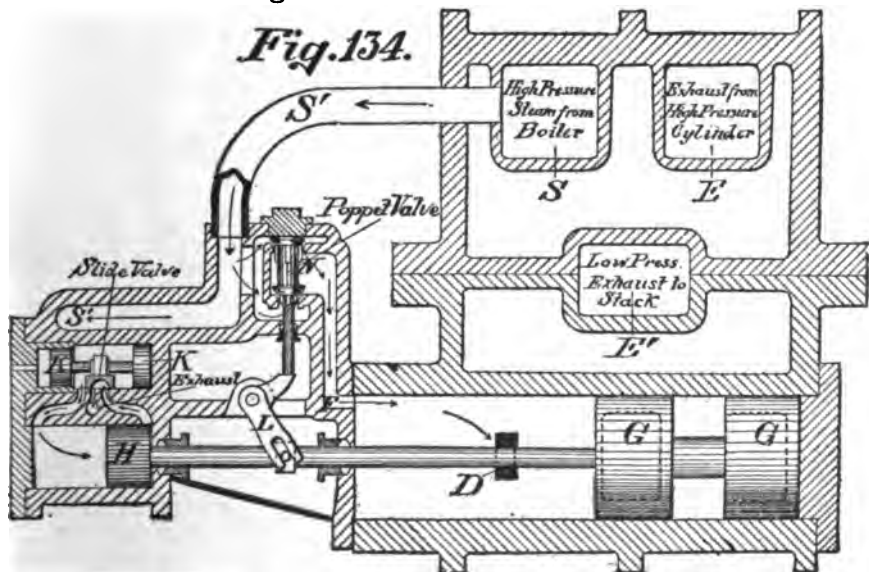
The intercepting valve consists of two pistons *GG* (having several small holes *g* through them in order to balance them, see Figs. 135 and 138) mounted at one end of a long piston rod, which



Intercepting Valve Open
Engine Working Compound

moves to and fro in a cylinder having four openings. The two large openings shown lead from the receiver to the low-pressure steam chest (see Fig. 135) and are closed by the two intercepting pistons *GG* when the engine is to be started, so that live steam may be admitted to the low-

pressure cylinder without producing a back pressure in the high-pressure cylinder through the receiver. Of the two remaining openings in the valve cylinder, port *D* leads to the low-pressure steam-chest and port *F* admits steam from the boiler when the apparatus stands in position as shown in Fig. 134.



Intercepting Valve Closed
Engine Working Simple

The back end of the intercepting piston-rod passes through suitable stuffing boxes to a small cylinder provided with a piston *H*, which actuates the intercepting valve. This cylinder has a small steam chest, slide valve and admission and exhaust

ports so similar to those of an ordinary locomotive cylinder, that its operation will be made plain by referring to the Figs. 133 and 134, if the movements of its slide valve are explained. This

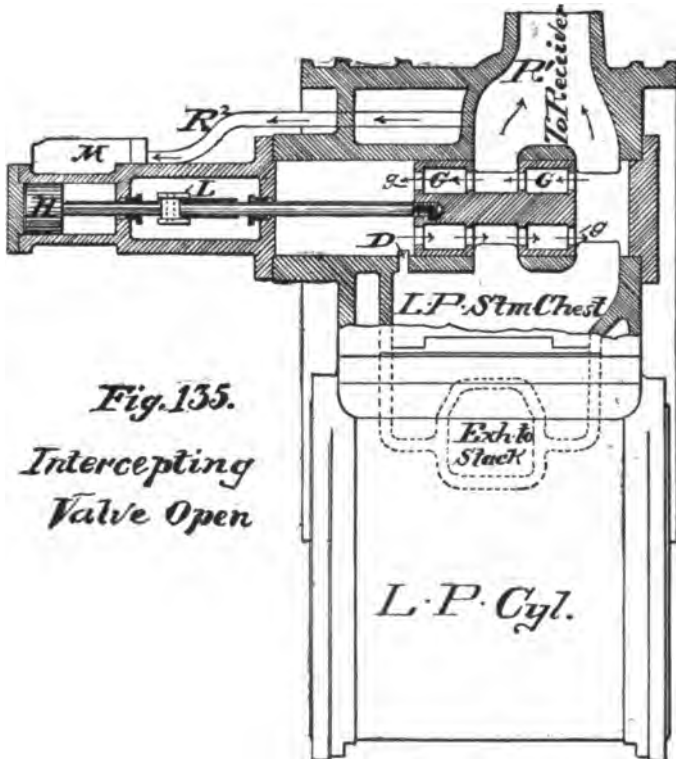
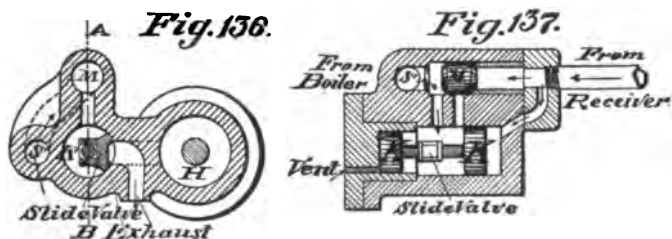


Fig. 135.
Intercepting
Valve Open

small slide valve, Fig. 131, is moved by a stem connecting two pistons, K and K^1 , of unequal diameter in order to insure their movement in the proper direction at the proper time. The actuation of these pistons, and with them the slide

valve, will be made clear by the figures. From Fig. 135 it will be seen that a small pipe R^2 leads from the receiver connection R^1 to this valve mechanism, and from Figs. 133 and 134, that a pipe S^1 comes from the live steam passage in the saddle and has a small port leading to the actuating valves as well as to the poppet valve N . These live steam and receiver connections come to opposite sides of a small piston valve M (Fig. 137), which is called the "regulating valve" and travels across two ports leading to the slide valve beneath it, as shown.



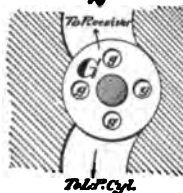
The remainder of this mechanism consists of a balanced poppet valve N , which, when open, admits live steam from pipe S^1 through the intercepting valve to the low-pressure cylinder in starting. This poppet valve N has a projecting stem on the lower side and is opened and allowed to close by a rocker-arm or bell-crank L , its two positions being shown in Figs. 133 and 134, respectively.

The operation of the apparatus is as follows: The normal position of the parts when the engine is working compound is shown in Fig. 133, in which position steam for the low-pressure

cylinder comes entirely from the high-pressure exhaust through the receiver. To start the train, the engine throttle is opened as usual. This permits steam to pass to the high-pressure side and also through the pipe S^1 (Figs. 133 and 136) to the left side of piston valve M (Fig. 137) and down through the adjacent port (as indicated by arrows) to the slide valve chamber, there acting between the two pistons K and K^1 (Figs. 131, 133 and 137). The right-hand piston, being the larger, causes a movement of the slide valve from its position shown in Fig. 133 to that shown in Fig. 134, thereby uncovering the steam port to the left of piston H , which it forces with the intercepting valve GG to the right. In this position,

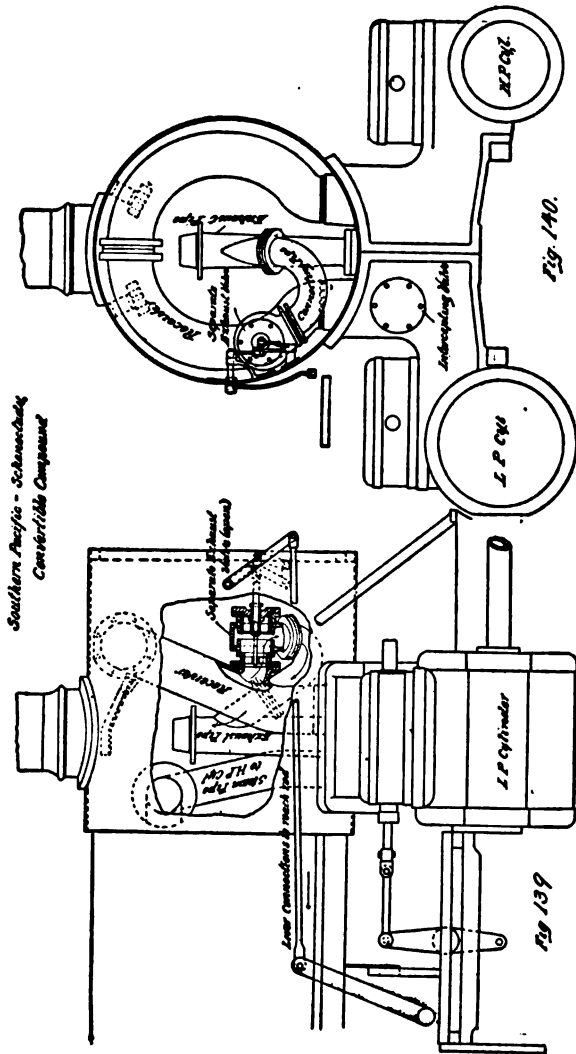
Fig. 138. as shown in Fig. 134, the receiver openings are closed by the pistons GG and the poppet valve N has been opened by the bell-crank L , thus admitting live steam through the intercepting valve cylinder and port D to the low-pressure steam chest, as indicated by the arrows. Hence it is possible to obtain the full pressure of live steam in the low-pressure cylinder in starting.

After one or two revolutions the pressure in the receiver, passing down through the small connecting port to the right of the larger piston K^1 (Fig. 137) overbalances the pressures between the pistons, thus moving the slide valve to the left, the position shown in Figs. 133 and 137. According to the ordinary action of a slide valve this reverses the pressures on the actuating piston H , forcing it



to the left and opening the intercepting valve. This return movement of the actuating piston *H* detaches the bell-crank *L* from the poppet valve *N* and allows the latter to close before the intercepting valve opens. After this the locomotive works compound, the passage of steam being through the high-pressure cylinder to the receiver and thence through the intercepting valve and low-pressure cylinder to the atmosphere, as previously described.

A difficulty met with in many of the earlier forms of compound mechanism, and to which the reader's attention was called at the beginning of this chapter, namely, the accumulation of dangerously high pressure in the receiver when running with the throttle closed, was overcome in this device by an automatic action of the piston valve *M* and the differential pistons *K* and *K*¹ (Fig. 137), as follows: When the engine is using steam the regulating valve *M* is always against the right-hand seat, as shown, and this valve only comes into use when running without working steam, as down a long grade. In this case, if the intercepting valve happened to be closed, the action of the engine would cause air-pressure to accumulate in a closed receiver as there would then be no live steam available to cause the actuating device to open the intercepting valve. Hence it is arranged so that air-pressure in the receiver will force the valve *M* to the left and itself take the place of live steam by passing to the slide valve chamber and down to the right side of the actuating piston *H*, moving it to the



left and opening the intercepting valve, as shown in Fig. 133. Thus the small valve *M* acts as a safety valve, insuring the opening of the intercepting valve when live steam is not being used, and preventing the danger of excessive receiver pressure or the lifting of the high-pressure slide valve off its seat when the engine is running with steam shut off.

**SCHENECTADY 1892 DESIGN, WITH SOUTHERN PACIFIC
MODIFICATION.**

To render it possible to run the engine "simple" for any desired period in starting, or to obtain a maximum power in case a train were stalling on a heavy grade, the Southern Pacific Co. in 1893 added to many of their Schenectady compounds of the 1892 design, a separate exhaust valve located in the smoke-box, as shown in Figs. 139 and 140. The reverse lever in the cab, when placed in either of its extreme positions, caused this valve to open and thereby connect the receiver directly with the main exhaust pipe, thus permitting the high-pressure cylinder to exhaust through the receiver directly to the atmosphere, as indicated by arrows in Fig. 139. As the receiver pressure was thus kept down it will be readily understood from the preceding description of the intercepting valve that the latter will remain in starting position as in Fig. 134, and hence the locomotive will work as a simple engine until such time as the engineer pulls the reverse lever higher up on the quadrant and thereby closes the separate exhaust valve. Then the

intercepting valve automatically assumes the compound position, as in Fig. 133, for reasons hereinbefore explained.

This modification of the two-cylinder or cross-compound is of especial note inasmuch as it was one of the first in this country which permitted the working of the locomotive as a simple engine for any desired length of time, at the will of the engineer. Its results in practical operation were to greatly reduce the jerking of trains in starting (then a very serious objection to many compounds); it gave a greater maximum power at critical periods, and was withal so eminently satisfactory that the reader will notice the majority of the builders of two-cylinder compounds in this country have embodied a separate exhaust valve in their later designs.

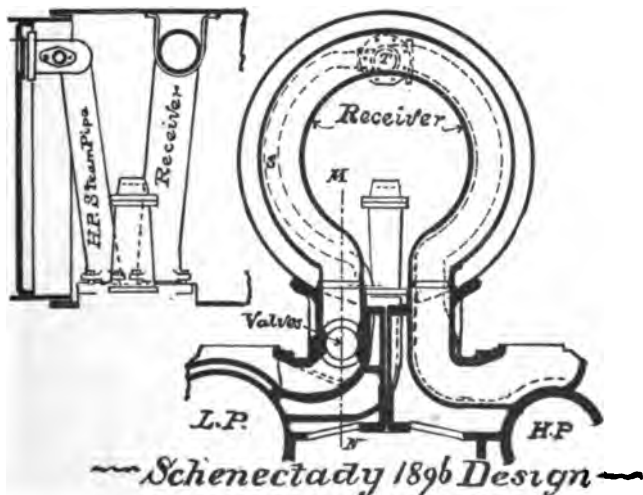
SCHENECTADY COMPOUND—DESIGN OF 1896.*

The valve arrangement designed in 1896 by Messrs. A. J. Pitkin, Vice-President and General Manager, and J. E. Sague, Mechanical Engineer of the Schenectady Locomotive Works, and used as their standard construction for two-cylinder compound locomotives, will be made clear by what follows.

In general it may be said that this so-called "intercepting valve" consists of four separate parts, namely: (1) An intercepting valve proper, which allows steam to pass to the low-pressure cylinder from either the receiver or the boiler, according to its position. (2) A reducing valve allowing live steam at only a reduced pressure

* This design is the "Schenectady" standard in 1903.

to enter the low-pressure cylinder when working simple. (3) An independent or separate exhaust valve which, when open, vents the exhaust from the high-pressure cylinder to the atmosphere through the exhaust pipe and stack. (4) A small valve *K* inside of the separate exhaust valve, by the use of which the latter can be opened more easily and gradually.

*Fig. 141.**Fig. 142.*

By the arrangement of these valves the engine can be started and run either compound or simple and can be changed from compound to simple, or the reverse, at the will of the engineer, with the throttle and the reverse lever in any position; the engineer has only to move a small three-way cock in the cab and the working of the engine changes very smoothly and without jerking the train.

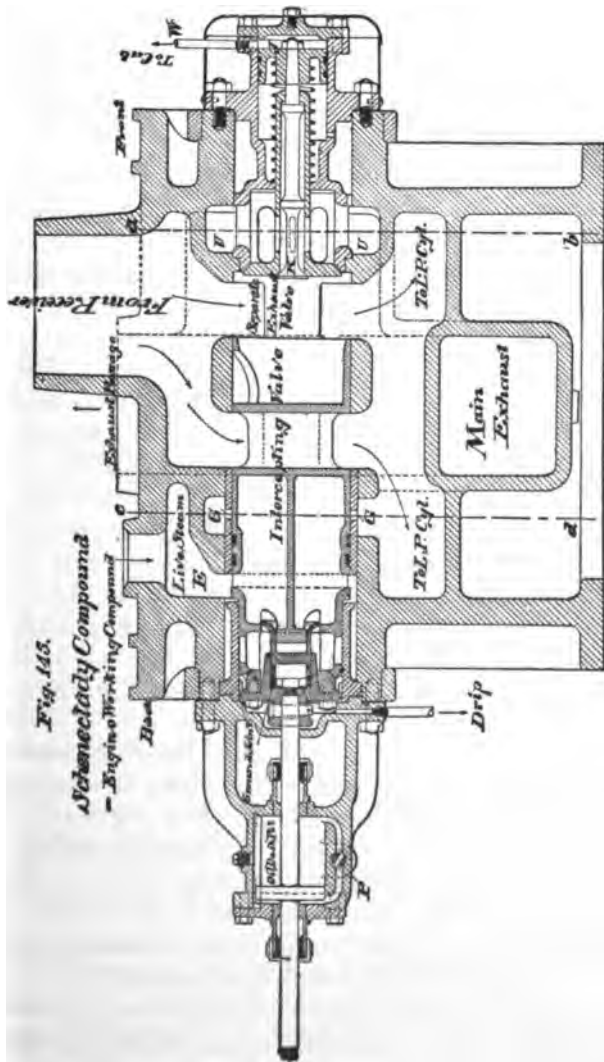


Fig. 143.

Scheme of Compound

Engine Working Compound

Figs. 141 and 142 give sections of smoke arch and cylinder saddles and show the steam passages, the receiver and the location of the intercepting valve in the saddle of the low-pressure cylinder on the right-hand side of the engine.

It will be noticed by the dotted lines behind the receiver pipe that there are two steam pipes as in a simple engine, but the one (*S*) leading to the intercepting valve on the low-pressure side is much smaller than usual, as it will only be required for use at low speeds.

Fig. 143 shows a vertical section lengthwise through the low-pressure cylinder saddle and the intercepting valve (as if they were cut through at *MN* of Fig. 142) and shows the intercepting and the separate exhaust valves in the position taken when the engine is working simple and receiving live steam in both cylinders. Fig. 144 is a section through the dash-pot of Fig. 143.

Fig. 145 gives the same section as Fig. 143, but shows the intercepting and the separate exhaust valves in the position taken when the engine is working compound.

Figs. 146 and 147 show two sections crosswise of the intercepting valve at points indicated respectively by the lines *cd* and *ab* of Fig. 145. Section *cd* shows the passages *G* for admitting live steam into the low-pressure cylinder, and section *ab* shows the outlet passage *U* from the separate exhaust valve to the main exhaust pipe.

The part which each portion of the valve arrangement performs is as follows: The separate exhaust valve, when open, allows the steam

to exhaust from the high-pressure cylinder to the atmosphere without going through the low-pressure cylinder, thus working the engine simple; when it is closed, the high-pressure exhaust must pass through the low-pressure cylinder, thus working the engine com-

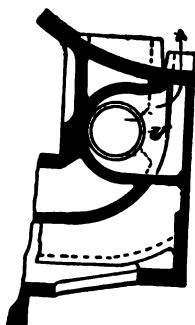
Fig.146

Section c-d



Fig.147.

Section a-b



-Intercepting Valve Passages-

pound. The intercepting valve closes the passage between the two cylinders when the separate exhaust valve is open, so that steam cannot go from the high-pressure cylinder to the low-pressure cylinder; thus doing away with back pressure on the high-pressure piston when the engine is working simple; it also admits live steam direct from the dry-pipe through the reducing valve to the low-pressure cylinder. When the separate exhaust valve closes, the intercepting valve automatically opens the pas-

sage between the two cylinders and cuts off the supply of live steam from the dry pipe to the low-pressure cylinder. The reducing valve works only when the engine is working simple and throttles the steam passing through it, so that the pressure of steam going to the low-pressure cylinder is about one-half (or, less, according to the proportionate sizes of the two cylinders) of that admitted from the boiler to the high-pressure cylinder.

The reducing valve is quite heavily cross-sectioned, while the long, intercepting valve appears next lighter, in order to render their outlines in Figs. 143 and 145 readily distinguishable. Examining the two ends of the intercepting valve, it will be seen that the left end, exposed to the pressure of the atmosphere through the drip, is only about three-fourths as large as the right end (between the bridges *RR*, Fig. 143), exposed to the receiver; hence, if the receiver has little or no pressure, the boiler pressure on the shoulder of the intercepting valve automatically carries it to the right, as shown in Fig. 143. The reducing valve is automatically opened because of the difference in area of its two ends also. The movement of each of these valves is cushioned by dash-pots, as shown. The separate exhaust valve is operated by the engineer by means of a three-way cock in the cab. To open the separate exhaust valve the handle of the three-way cock is thrown so as to admit a pressure of steam or air through the pipe *W* against the piston *J*. Pulling the handle back relieves the pressure

against piston *J* and the spring shuts the valve, as in Fig. 145. All the engineer has to do in connection with the operation of the valves is to pull the handle of the three-way cock in the cab one way or the other, according as he wishes the engine to run simple or compound. The engineer uses the handle under the following conditions:

To Start Simple.—Under ordinary conditions this is not necessary, but if the maximum power of the engine is needed to start a heavy train, the engineer pulls the handle of the three-way cock so as to admit pressure from the cab through pipe *W* against the piston *J*, Fig. 145. This will force piston *J* into the position shown in Fig. 143, opening the separate exhaust valve and holding it open. The engine throttle now being opened, live steam at boiler pressure enters the chamber *E* from the small steam pipe *S* before mentioned and forces the intercepting valve to the right against the seat *FF'*, as shown in Fig. 143. The exhaust steam from the high-pressure cylinder now passes through the receiver and is exhausted through the separate exhaust valve to an annular chamber *U* connected with the main exhaust to the stack, as indicated by the arrow in Fig. 143. (See also Fig. 147.) Steam also enters the low-pressure cylinder from chamber *E* through the reducing valve and the annular ports *G* in the intercepting valve (See Figs. 143 and 146), and is exhausted in the usual way. The reducing valve prevents the full boiler pressure from reaching the low-pressure cylinder. As will be seen from

Figs. 143 and 145, the reducing valve is partly balanced by its smaller left end being open to the atmosphere through a small groove leading to the chamber having an open drip, and thus the boiler pressure acting on the unbalanced area throws the valve open—to the right. When the pressure in the intercepting valve cavity on the right of the reducing valve becomes high enough, it will throw the valve to the left, because it acts on the whole area of the valve; the result is that the steam is throttled to the proper pressure desired for the low-pressure cylinder.

To Work Compound.—Having started the train, when the engineer wishes to change the engine from simple working to compound, he pushes the handle of the three-way cock to its first position which, relieving the pressure on piston *J* through pipe *W*, allows the spring to act to the right and close the separate exhaust valve, as in Fig. 145. As soon as this valve is closed the pressure in the receiver, having no outlet, rises and presses the intercepting valve to the left against the pressure from chamber *E*, which acts only, as stated, upon the shoulder of the intercepting valve. The receiver pressure holds the intercepting valve to the left, as shown in Fig. 145, thereby closing the ports *G* and opening a free passage from the receiver to the low-pressure cylinder as indicated by the arrows, and the engine works compound. While working compound, which is the usual way of working the engine, both the reducing and the intercepting valves are held to the left against ground joint seats. This should prevent any

steam which might leak by the packing rings from constantly escaping at the drip.

To Change from Compound to Simple.—With the engine running compound, if the engineer wishes to change to simple because of a very heavy grade, he has only to pull the three-way cock handle to the same position as for starting simple. Then piston *J* first opens the small valve *K* and then the separate exhaust valve. The small valve *K* relieves the pressure more gradually than if the larger valve were opened at once. As soon as the separate exhaust valve is opened the pressure in the receiver escapes through it and becomes so low that the intercepting valve is again forced to the right (as in Fig. 143) against its seat *F* by the steam pressure from chamber *E*, and the engine works simple as in starting.

To Start as an Automatic Compound.—If the separate exhaust valve is left closed, as in Fig. 145, the engine will start as an automatic compound when the throttle is opened, for the pressure from chamber *E* will force the intercepting valve to the right, as in Fig. 143, thus admitting live steam through the reducing valve and ports *G* to the low-pressure cylinder, while at the same time the high-pressure cylinder exhausts into a closed receiver for a few strokes. This pressure, accumulating in the receiver, will then automatically close the ports *G* by moving the intercepting valve to the left, as in Fig. 145, and the engine thereafter runs compound.

Accidents to Schenectady Compounds—the Automatic Compound of 1892. What should be done

in case of a break-down on the road, necessitating the disconnecting of the high-pressure side? If but a short distance to go and a slow speed would suffice, clamp the high-pressure slide valve in center and permit the engine to run by the admission of live steam through the small pipe S^1 and the poppet valve N to the high-pressure cylinder (Figs. 133 and 134). If the intercepting valve is out of order, block the poppet valve N open, that is, up. If it were required to run at considerable speed, this small pipe S^1 would give insufficient supply, in which case the high-pressure slide valve should be blocked clear back (much farther than its ordinary travel carries it), so as to uncover the exhaust port, thus admitting live steam direct to the receiver. If the steam chest is large enough to place the high-pressure valve as described, and the intercepting valve is not deranged, the engine would run at full speed with the low-pressure side. If out of order, the intercepting valve should be held open (in the position as shown in Fig. 133) by clamping the stem between the stuffing boxes. In all cases the throttle should be handled easily to prevent a too rapid flow of boiler pressure to the large low-pressure cylinder and the consequent liability of jerking the train or causing damage to this cylinder.

What should be done if it becomes necessary to take down the low-pressure side of the engine? The engine could be moved a short distance with the cylinder cocks open or the indicator plugs removed on the high-pressure side, but as most en-

gines of this class have either a large steam chest or an "Allen"* ported slide valve, the valve can be clamped back far enough to uncover the low-pressure exhaust port, and thus run at full speed. If this cannot be done, block both the low-pressure crosshead and valve clear back and unscrew the relief valves or take off the front cylinder head on that side to make an exhaust opening from the receiver. If the intercepting valve is out of order, it must be securely clamped open, as in Fig. 133, otherwise the opening between the receiver and the low-pressure steam chest would be closed.

In this last procedure, with the exhaust other than through the stack, would the engine steam with much of a train? No; but a limited amount of steam could be maintained by the use of the blower for creating draught.

What would be the effect of the removal of the slide valve on the disabled side? This would give a free port opening under all circumstances, but would generally consume too much time to be practicable.

What prevents the leakage of live steam into the receiver when the intercepting valve is closed, as in Fig. 134, there being no packing rings in the two pistons *GG*? The live steam pressure acts from below when starting, so as to hold these pistons tight against ports of the receiver. Fig. 135 illustrates this clearly, if the intercepting

*See illustrations in Part First of the Manual, showing the "Allen" slide valve.

valve were there shown closed, as live steam would then be below pistons *GG*.

What would be the result if the wiper *L* would strike the poppet valve *N* (Figs. 133 and 134) before the intercepting valve pistons *GG* closed their ports? Live steam would blow through to the receiver and produce a back pressure on the high-pressure side.

How can this be prevented? Pistons *GG* have sufficient lap to allow of their closing before the wiper *L* strikes the poppet valve *N*, and the adjustable tappet on the intercepting valve stem should be set so as to cause this. If the tappet is set too far back, valve *N* would not be opened at all and, as a consequence, no live steam would be admitted to the low-pressure cylinder in starting.

If the operating piston *H* should break, what position would the intercepting valve probably take? On account of the unbalanced area of the stem, it would probably move open to the left as for compound working, Fig. 133.

Accidents to Schenectady design of 1892, with Southern Pacific Modifications.—If it became necessary to disconnect the high-pressure side of the engine, what should be done? The same as with the 1892 Schenectady system.

Would there be any difference in case the low-pressure side broke down? Yes; disconnect the broken side as usual (see instructions for simple engines in Part First of the Manual) and run with reverse lever in full gear, if for a short distance or a low speed only is required. If it is necessary to run for a considerable distance at a good speed, it

would be advisable to disconnect the separate exhaust valve levers from their connection to the reach-rod and properly secure them in either extreme position, so as to hold the valve open. The engine can then be "hooked-up," that is, the reverse lever pulled up toward its central position, to correspond to the demands of the service.

Accidents to Schenectady Compounds—design of 1896.—What should be done in case the high-pressure side had to be disconnected? Ordinarily, open the separate exhaust valve * and do nothing different than with a simple engine; but to obtain greater speed than the supply of live steam to the low-pressure cylinder through its small steam pipe would permit, the high-pressure valve should be secured in such a position, if possible, as will uncover its exhaust port, thereby admitting live steam to the receiver and thence to the low-pressure cylinder. In this case leave the separate exhaust valve closed and handle the throttle easily so as not to cause constant opening of the safety valves on the low-pressure side.

What is necessary with the low-pressure side disconnected? Open the separate exhaust valve and allow the high-pressure cylinder to exhaust to the stack through its connection. While considerable train could thus be handled, it would not be done at anything but a slow speed, unless the low-pressure slide valve were placed so as to

* While not absolutely necessary to open the separate exhaust valve for this case, it is best to do so that there may be no accumulation of pressure in the receiver should the high-pressure valve leak.

uncover its exhaust port and the separate exhaust valve left closed.

What is done to prevent full boiler pressure from reaching the low-pressure cylinder in case the reducing valve becomes defective or broken? Pop or safety valves are placed on the chest and both heads of the low-pressure cylinder and they are set at about one hundred pounds, the highest pressure deemed advisable in so large a cylinder.

In case of a broken intercepting valve what precautions should be taken? Run the engine compound only and do not stop the engine with the low-pressure side on center.

Why must the oil dash-pot be kept filled with oil? The flow of oil from one side of the dash-pot piston to the other prevents sudden movements of and serious jars to the intercepting valve.

How can the rapidity of this movement be regulated? By a greater or less opening of the valve *P*, Figs. 143 and 144, as this valve regulates the flow of oil from one side of the dash-pot piston to the other. A slight opening causes a slow movement, while a wide opening makes possible a too rapid movement.

What would be most liable to cause breakage to the intercepting valve? Allowing the oil dash-pot to become partially or wholly empty.

What kind of oil should be used in this dash-pot? Only mineral oil, thinner, if anything, than ordinary engine oil.

What is the purpose of the key shown in the dash-pot (Fig. 144)? To prevent the intercepting valve from turning around.

With this compound, what pressure from the cab is used to operate the separate exhaust valve? Either air or steam.

Why is air pressure generally considered preferable? On account of the absence of moisture therein. As the separate exhaust valve piston *J* and its cylinder (Figs. 143 and 145) project from the front of the cylinder saddle and are exposed to currents of cold air, the use of steam therein and a lack of proper drainage might cause them to freeze in cold weather.

What objection is there to the use of air? Should the air pump stop or the pressure otherwise become exhausted, as in switching and picking up a large number of air-brake cars, there might be insufficient pressure to hold the valve open against the receiver pressure.

How is this objection overcome when air is used for this purpose? Besides the air connection to the three-way cock in the cab, there is a steam connection; closing the one and opening the other, quickly furnishes an alternative pressure for operation.

What would be the result if both the steam and the air connections were left open? There would be no effect upon the engine itself, but the steam would fill the whole air-brake system with water and seriously affect the operation of the brakes.

THE PITTSBURG COMPOUND.

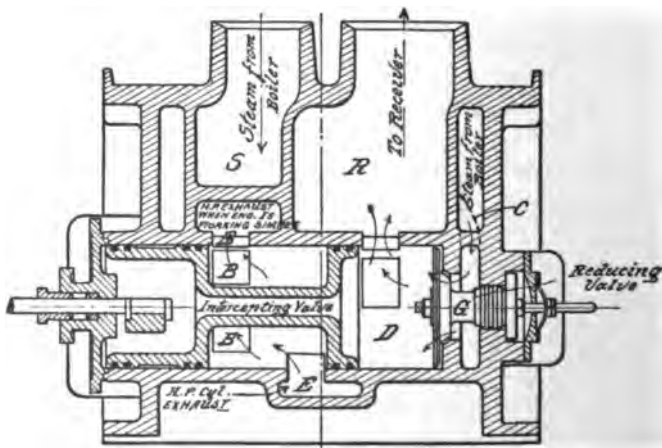
The Pittsburg Locomotive Works have been one of the largest builders of two-cylinder or cross-compound locomotives in this country. Their location of the intercepting valve in the saddle of the high-pressure cylinder instead of the low-pressure cylinder is an arrangement which obviates the necessity of a second steam pipe for admitting live steam to the intercepting valve and low-pressure cylinder when it is desired to work the engine non-compound.

With the valve mechanism which will be shown and described in what follows, when the reverse lever is either in full forward or back-up gear and the throttle opened, the engine starts by the admission of live steam into both cylinders and with an open exhaust passage from each cylinder to the stack. The live steam admitted to the low-pressure cylinder is sufficiently reduced in pressure by passing through a reducing valve to cause the engine to have the same power that a simple locomotive would have with two cylinders the size of the high-pressure cylinder. When the reverse lever is "hooked-up," or drawn toward the center, one or more notches, it mechanically works an operating valve and piston near the cab, which throws the intercepting valve into position for compound working. There is a hand lever in the cab, as shown in Fig. 148, which can be used to move the inter-

cepting valve in case of derangement of the operating device, or other necessity. However, the engine will only start simple when the intercepting valve is placed in proper position, as this valve does not automatically assume simple position of its own volition. Fig. 148 gives the

Fig. 149.

Pittsburg Compound.



*Position of Valves when Engine
is working simple.*

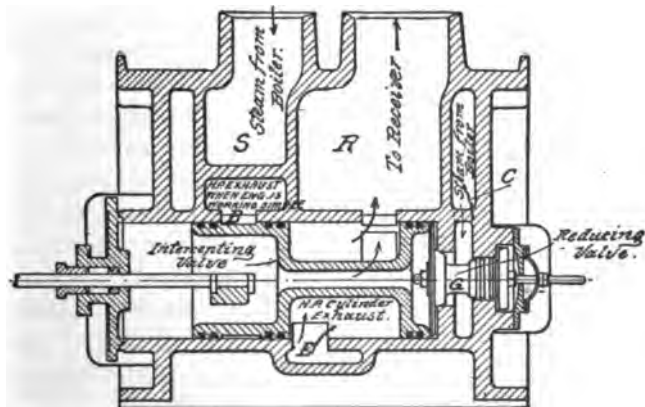
general arrangement and shows the position of the intercepting and reducing valves in the saddle of the high-pressure cylinder on the right-hand side of the engine, the lever connections between the intercepting valve and the operating cylinder near the cab, and the means of moving

the operating valve by its attachment to the reach-rod. The operating piston can be actuated either by air or steam pressure, the former being preferable, especially in cold climates.

Figs. 149 and 150 show on a larger scale the same section through the valves in the saddle.

Fig. 150.

Pittsburg Compound



*Position of Valves when Engine
is working compound.*

In Fig. 149 the intercepting and the reducing valves are in position for working simple, while in Fig. 150 they are shown in compound position.

Port *S* is the passage from the steam pipe to the high-pressure steam chest, and port *E* the exhaust passage from the high-pressure cylinder; port *R* is the opening into the receiver; port *B* leads to the atmosphere through the stack, being

an independent exhaust for the high-pressure cylinder. Port *C* is a branch from the main steam port *S*, and carries live steam to the reducing valve *G* for use in the low-pressure cylinder when needed.

When the intercepting valve is moved to the left in position for working simple, as shown in Fig. 149, steam from the high-pressure exhaust *E* passes through the intercepting valve (between its two piston ends) and to the atmosphere through the independent exhaust *B*. At the same time live steam from *C* opens the reducing valve *G*, as the valve is then unbalanced by its left end being larger than its right, and passes through the intercepting valve chamber *D* and the receiver *R* to the low-pressure cylinder. The engine is thus made a simple engine with live steam admission and independent exhausts for each cylinder, as indicated by the arrows in Fig. 149.

The reducing valve *G*, when in use, only allows a portion of the full pressure to pass into the receiver, for, when the pressure in the intercepting valve chamber *D* (Fig. 149) becomes equal to about half that of the boiler, it acts against the larger left-hand end of the reducing valve and forces it closed—to the right—thereby throttling the steam.

The intercepting valve moved ahead, or in compound position, as in Fig. 150, holds closed the reducing valve *G*, thus shutting off the live steam supply to the low-pressure cylinder. At the same time it closes the independent exhaust opening *B*, instead opening the ports to the receiver *R* and con-

necting the high-pressure exhaust *E* therewith around the stem of the intercepting valve. As the other end of the receiver leads to the low-pressure steam chest, the high-pressure exhaust thus becomes the supply steam for the low-pressure cylinder and the engine works as a compound, the flow being indicated by the arrows, Fig. 150.

From the above description it will be observed that the office of the intercepting valve is to convert the locomotive from simple to compound, or the reverse. The duty of the reducing valve is, when the engine is working single-expansion, to reduce the live steam from the boiler to a pressure inversely proportional to the ratios of the two cylinders before delivering it to the receiver and low-pressure cylinder, thus making the crosshead loads equal on each side of the engine.

Accidents to Pittsburg Compounds.—If the engine broke down and it became necessary to disconnect either side, could the engine be run successfully on one side? Yes, it would be more powerful than a simple engine under similar circumstances and could develop good speed, inasmuch as the independent exhaust ports *B* (Fig. 149) are of considerable size.

With the high-pressure side disconnected, how should the engine be run? The intercepting valve should be placed in simple position (as in Fig. 149) by leaving the reverse lever in full gear. Live steam would then pass through the reducing valve to the low-pressure cylinder and exhaust in the usual way. The high-pressure valve should, of course, be clamped in the center.

If the low-pressure side were disconnected, how could the engine be run? Clamp the low-pressure valve in the center so as to cover all ports and work simple, with engine in full gear. Steam would then be admitted as usual through the steam pipe to the high-pressure cylinder and exhausted through the intercepting valve cavity and the independent exhaust *B*, Fig. 149.

In both of these cases what would be necessary in order to run at considerable speed? To close the small valve which supplies steam to the operating device. The hand lever can then be used for operating and thus the reverse lever hooked up to a shorter cut-off. The intercepting valve levers should be securely fastened in simple position.

With a demolished steam chest on the low-pressure side, could the engine be fixed to run in any way different from such an accident to a simple locomotive? Yes. Proceed the same as before described when the low-pressure side is disconnected, except that the reducing valve must now be held closed. This could be done by tightening up the nuts on the outside stem of the reducing valve, or by inserting washers or a block under them. This same procedure could be followed for broken valve yoke, or valve stem broken off inside of steam chest, under which circumstances it is difficult to cover ports without taking up the steam chest cover.

What should be done if the reducing valve became broken? Endeavor to start compound, that is, with the lever hooked up three or four

notches, but if necessary to run simple, use very light throttle or reduce the amount of boiler pressure carried.

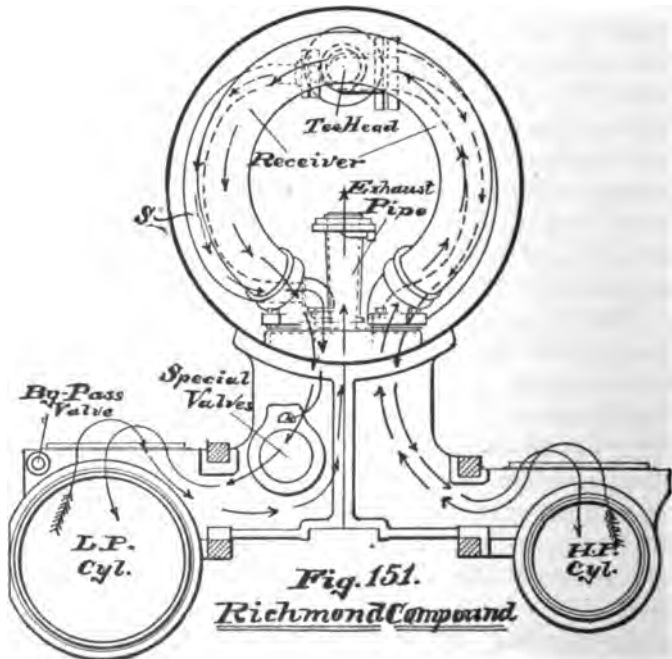
If the packing rings in the intercepting valve blew badly, how could it be detected? First see that the slide valves are tight, then shut off the supply of air or steam from the operating cylinder by closing the small globe valve in the cab, pull the intercepting valve clear back (by means of the hand operating lever) into simple position, as in Fig. 149, and open the throttle, still leaving the valves in the center. The blow would show in the stack. However, it is an easy matter to remove the intercepting valve, by taking off the back cap, and examine the packing rings, and this should be done frequently, that no broken pieces may catch in the ports.

With this design of compound, is it necessary to caution the engineer against the bad practice of operating the engine in simple position for too great a length of time, or at high speeds? No; for, if the small valve in the cab which supplies pressure to the operating device be open, to run the engine simple, requires that the reverse lever be at full stroke, and no competent man would work the engine thus longer than necessary.

In starting, where should the reverse lever be placed? In full motion to allow the intercepting valve to close and the reducing valve to open and admit live steam to the low-pressure cylinder.

RICHMOND COMPOUND.

The Richmond compound locomotive (sometimes termed the "Mellin" system, as it is built under those patents) is also of the two-cylinder or cross-compound type and belongs to the class of



convertible compounds. The large low-pressure cylinder is placed on the right-hand side of the engine, and within its saddle, as shown in Fig. 151, is located the special valve mechanism by which

the engine starts with the admission of live steam to both cylinders and thereafter automatically changes to compound, or may be converted back to simple any time at the will of the engineer. Without any movement of valves by the engineer, the locomotive is an "automatic" compound, that is, changes to working compound after the first stroke or two; but the movement by him of a three-way cock in the cab, causes the opening of a separate exhaust valve (sometimes called the "emergency valve") for the high-pressure cylinder, and thus the engine can be run simple as long as he thinks it advisable, or, if disabled, can be brought in with one side like a single-expansion locomotive.

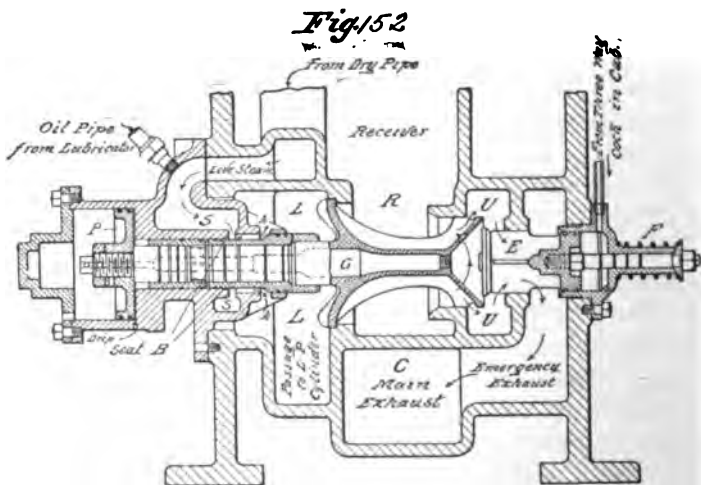
The device called the intercepting valve really consists of three separate and distinct valves, as shown in Figs. 152 and 153.

The intercepting valve proper is marked *G* and is a double poppet valve with its two seats of unequal areas, and has a stem extending back and connecting with the piston *P* of an air dash-pot. The intercepting valve moved, or opened, as in Fig. 153, connects the receiver *R* with the low-pressure steam-chest port *L*, while if closed, as in Fig. 152, it cuts off this communication and opens the receiver *R* to the cavity *U*.

The reducing valve is a long annular valve surrounding the intercepting valve stem and closes by moving to the left. When open, it admits live steam from chamber *S* to the low-pressure steam chest cavity *L*; when closed, it cuts off this communication.

The separate exhaust or "emergency" valve *E* is

an ordinary bevel-seated wing-valve with its right-hand end in the form of a piston. Steam pressure from a three-way cock in the cab, if admitted against this piston, forces the separate exhaust valve open, thereby connecting the cavity *U* with the main exhaust cavity *C*; without pressure on this piston, the spring *F*' again seats the valve.

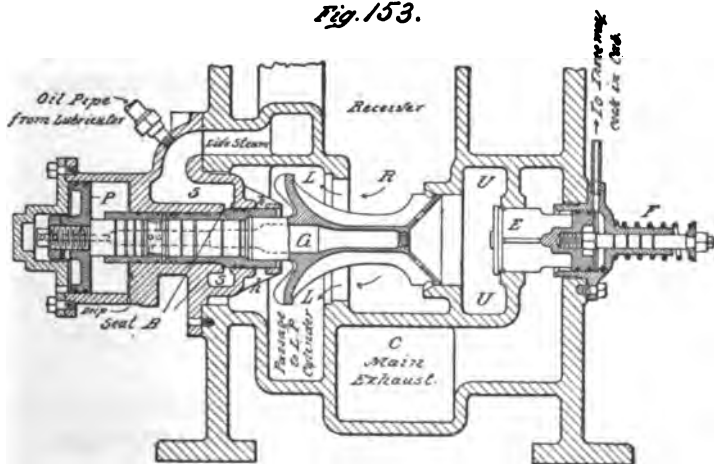


The reducing valve is shown heavily cross-sectioned, the intercepting valve is next as dark.

The operation of the valves is as follows: Suppose the engine to be at rest after running compound with the valves in position as shown in Fig. 153. Upon opening the engine throttle, steam passes not only to the high-pressure side in the

usual manner, but also through a branch steam pipe *S* (Fig. 151) to the annular cavity *SS* (Fig. 153), bears against the shoulder *e* of the reducing valve at the seat *B* (Figs. 153 and 154) and forces the latter valve to the right, and with it the intercepting valve, to the position in which they are shown in Fig. 152. As soon as the enlarged end of the reducing valve passes the edge *h* of the

Fig. 153.

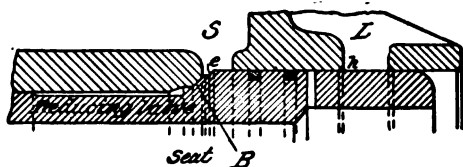


*Richmond Compound
Valve Positions, Engine working Compound.*

port *L* (see also Fig. 154), live steam is admitted to *L* and thence to the low-pressure cylinder, as indicated by the arrows. As we assumed the engineer had not opened the separate exhaust valve, it will remain closed instead of open, as Fig. 152 shows it; otherwise that figure would show the valve positions at this stage. Thus, while the receiver *R* is in

communication with the cavity *U*, there is no outlet from the latter, and one or two exhausts from the high-pressure cylinder into the closed receiver *R* will produce sufficient pressure to act against the larger left-hand face of the intercepting valve *G* and cause it to move to the left, shoving with it and closing the reducing valve, as shown in Fig. 153. Now the receiver pressure becomes the supply for the low-pressure cylinder as shown by the arrows, and the engine works compound thereafter. The engine will start all ordinary trains in this manner but if the train

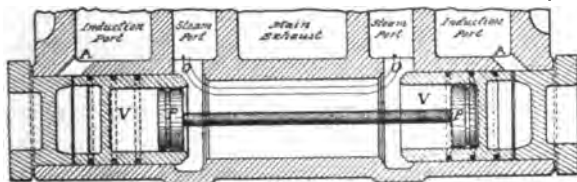
Fig. 154



to be started is a very heavy one, or such a train is threatened with stalling while ascending a heavy grade, the handle of the three-way cock in the cab should be turned to open the separate exhaust valve *E*. This would vent the pressure in chamber *U* to the main exhaust *C*, as indicated by the arrows in Fig. 152. If the engine were starting, no pressure could accumulate in the receiver *R* on account of this vent to the atmosphere, and hence all valves would remain as in Fig. 152 and the engine would continue to work simple until such time as the engineer closed the separate

exhaust valve *E* by means of his cab valve. If, however, the engine were stalling working compound (Fig. 153) and the engineer opened the

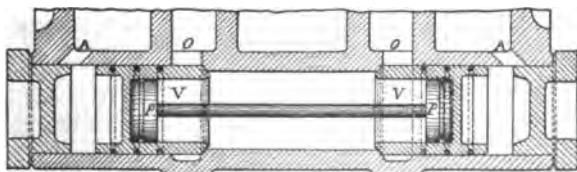
Fig. 155.
The Richmond Compound
By Pass Valve



Position when Running
Steam shut off

separate exhaust valve *E*, the removal of pressure from chamber *U* would cause the intercepting valve to close, assisted by the live steam pressure on the reducing valve shoulder, and thus all valves

Fig. 156.
The Richmond Compound
By Pass Valve



Position when Running
Under Steam

would remain as in Fig. 152 until the engineer desired to work compound again. Then he would simply close the separate exhaust valve *E*

and permit the valves to automatically assume compound working by the accumulation of pressure in the receiver *R*.

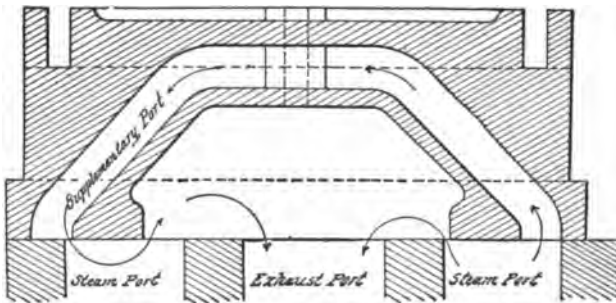
The annular shaped reducing valve appears so much like an inoperative sleeve around the intercepting valve stem that the separate sketch is made on a larger scale in Fig. 154, in order to illustrate its principle the more clearly. Live steam from *S* bearing against the shoulder *e* would force the reducing valve from the position in the cut to the right until shoulder *e* had passed the edge *h* of the chamber *L* and live steam thus be admitted to *L* and the low-pressure cylinder. As soon as the pressure in *L* became sufficiently great, say about half that in *S*, the valve would close partly so that only the desired proportion of the full boiler pressure would be admitted to the low-pressure cylinder.

The injurious action of large pistons in pumping air when the engines are shut off, as previously mentioned under "Classes of Compound Locomotives and their General Construction," is prevented in compound engines of the Richmond type by the use of "by-pass" valves located in the casting of low-pressure cylinder, as shown in Fig. 151, and further shown in detail in their two positions by Figs. 155 and 156. They work automatically by the opening and closing of the engine throttle, their construction and operation being as follows: The outer ends of the two piston valves *VV* are connected by the passages *AA* with the induction ports of the low-pressure cylinder and their inner ends are connected by the passages *OO* with the

motives and it was there stated that auxiliary ported valves of the "Allen" type were used to give a double port opening to the cylinders in the early part of the admission period.

One Richmond design of slide valve employs this auxiliary port not only for double early admission, but also to give a double opening in the early exhaust period. Fig. 157 shows the design and gives the dimensions. It will be noticed that

Fig. 158.



Early Exhaust Period

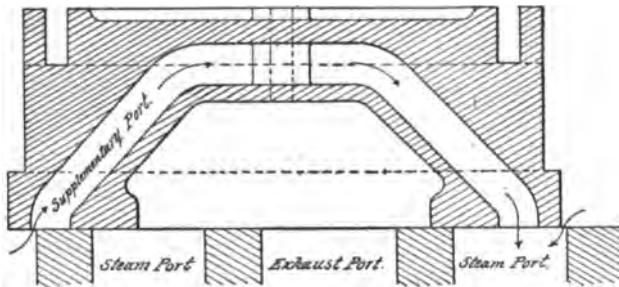
the "Allen," or supplementary, port is much wider at the seat than usual.*

To clearly show the features of novelty in this valve over the ordinary slide valve, Figs. 158 and 159 are given. The arrows in Fig. 158 indicate the double exhaust from the right-hand end of the cylinder during the early exhaust period. In Fig. 159 the arrows indicate similarly the ordinary

*Letters patent have been granted for this valve.

action of an "Allen" ported valve in giving double admission to the same end of the cylinder during the early steam period. This style of slide valve has been in use on locomotives and given only a six-inch extreme travel of valve and has proven very successful in keeping down the back pressure, especially at high speeds.

Fig. 159.



Early Admission Period

Accidents to Richmond Compounds.—In case of accident on the road requiring the engine to be run in with one cylinder, what should be done? Ordinarily, open the separate exhaust or "emergency" valve and do nothing otherwise differently than with a simple engine.

In case the engine was running with the low-pressure side only, why do you instruct to open the separate exhaust valve? So that there shall be no accumulation of pressure in the receiver which might occur in case of a leaky slide valve or balance strips leaking on the high-pressure side.

As the emergency port openings are small, what could be done in order to obtain considerable speed in case the break-down occurred in passenger service? Try to block the slide valve on the disabled side in an extreme position so as to uncover the exhaust port.

What should be done in case the reducing valve stuck open or became broken? Care should be used in starting by opening the throttle very

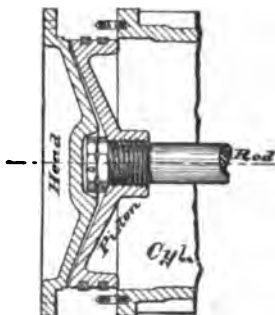


Fig. 160.

-Piston for Lightness & Strength-

slightly and the engine should be run as a compound only. If it had to be run simple, the boiler pressure should be reduced about one-half.

What might cause the reducing valve to stick? Feeding valve oil to the low-pressure side when the engine is working compound and there is consequently no flow of steam through this valve.

What precaution would it be advisable to observe in case the intercepting valve became broken? The engine should be run compound

only and it would be safer not to stop with the low-pressure side on center. If this latter precaution were not observed, the high-pressure piston might have considerable back pressure upon it from the receiver, should the intercepting valve break in such a way as to permit live steam from the reducing valve to enter the receiver in starting.

What prevents slamming of the intercepting valve? The air dash-pot connected thereto.

In this class of compounds, why are the cylinder heads sometimes dished, or not flat, as is usually the case? In order to give a maximum strength with a minimum weight of piston, these builders frequently use a piston such as is shown in Fig. 160; hence the cylinder heads conform to the shape of the piston.

ROGERS COMPOUND.

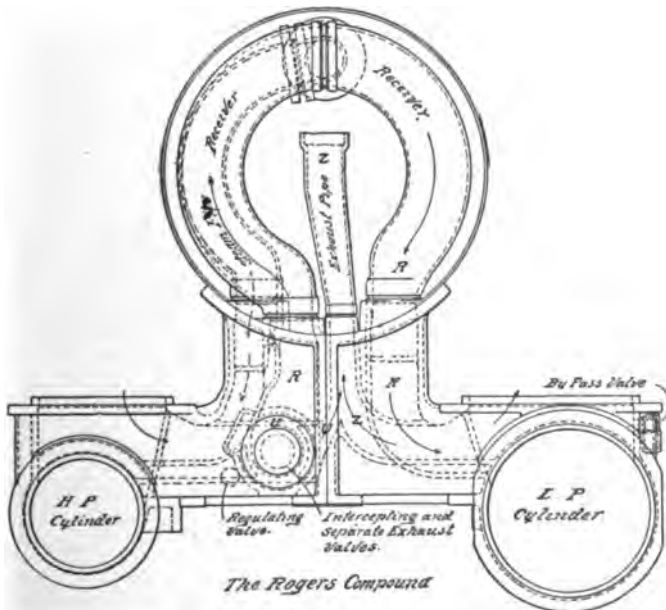
The intercepting valve originally employed by the Rogers Locomotive Works for their system of two-cylinder compound, was placed in the smoke-box and was controlled automatically and beyond the will of the engineer. In starting, by placing the reverse lever in either extreme position, a separate reach-rod with suitable levers was made to open the reducing valve and admit live steam from the boiler to the low-pressure cylinder, and close communication between the latter and the receiver, so that the high-pressure cylinder exhausted into a closed reservoir or receiver. After one or two strokes sufficient pressure accumulated in the receiver to automatically throw the intercepting valve into position for working compound and the hooking up of the reverse lever closed the reducing valve.

The succeeding arrangement used by these builders is fully described and illustrated in what follows. The device is for a two-cylinder or cross-compound locomotive, and is placed in the high-pressure saddle on the right side and connected to a lever in the cab having three notches, and is operated by the engineer at will. As long as this lever remains in the forward notch the engine works as a single expansion locomotive; the back notch places the intercepting valve in compound position, while the middle notch makes an automatic compound, that is, the inter-

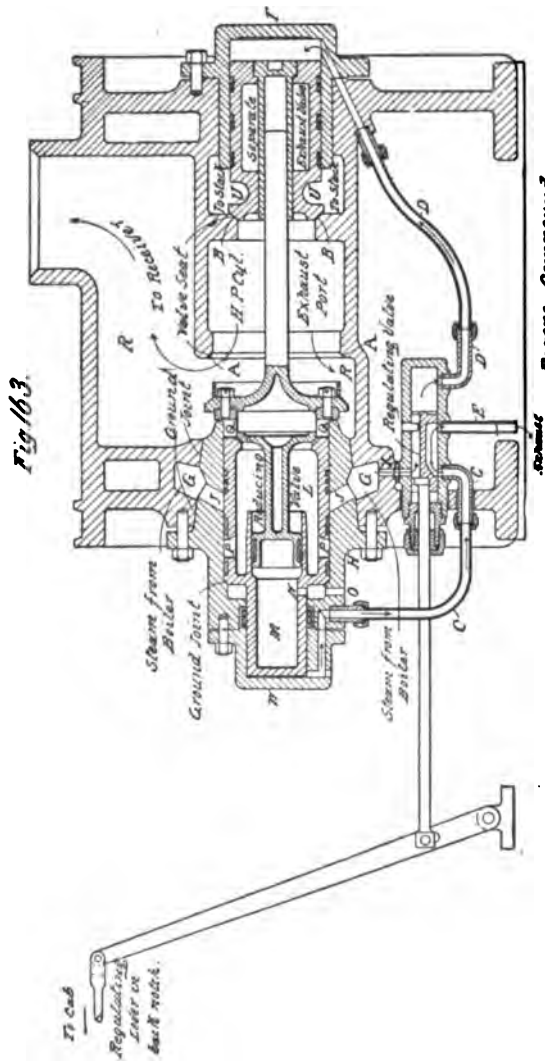
cepting valve works the engine simple for a few strokes and then the valves automatically assume the compound position. Thus this engine belongs to the class of convertible compounds.

The component parts of the device are: A regulating valve (positively controlled by the cab

Fig. 161.



lever above mentioned), an intercepting and a reducing valve (controlled either positively by the regulating valve or at times automatically by the pressure in the receiver), and a separate exhaust valve (controlled by the operating valve). The



Rogers Compound
Position of intercepting valve when running compound

intercepting valve has two positions, one for working compound and one for working simple. In the former position, as shown in Fig. 163, the high-pressure cylinder exhaust is connected to the receiver and thence to the low-pressure side, while in the simple position, as shown in Fig. 162, this communication is closed and the high-pressure exhaust directed through the separate exhaust valve to the stack, live steam at the same time being admitted to the low-pressure steam chest through the reducing and the intercepting valves.

To somewhat reduce the high compression that takes place in the large low-pressure cylinder when running at high speeds without steam—as, for instance, down grades—a by-pass arrangement similar in some respects to “La Chatalier” brake is employed. This consists of an automatic device for connecting the two sides of the low-pressure piston when steam is shut off, and will be fully described hereafter.

Fig. 161 is a view from the front, showing the high-pressure cylinder to be on the right-hand side of the engine. In the saddle on that side are shown the positions of the regulating valve and the intercepting and separate exhaust valves. The location of the by-pass valve on the low-pressure cylinder is also shown.

Figs. 162 and 163 are sectional views of the special valve mechanism. For simplicity in explaining their working, the regulating valve is shown as though it were located directly underneath the intercepting valve which is not its actual position shown in Fig. 161. The intercepting

valve is composed of two parts bolted together and is shown cross-sectioned more heavily than its casing while the reducing valve *L* within it is distinguishable by its still darker appearance. Its principal port openings to the receiver and from the high-pressure cylinder exhaust are lettered and the direction of flow through them is indicated by arrows, that an understanding may be the more easily arrived at. Port *G* is an annular chamber around the intercepting valve cylinder *H* and is connected with the high-pressure steam pipe in the saddle and therefore has live steam pressure when the engine throttle is open. Between *G* and the intercepting valve is a series of holes marked *J*. The intercepting valve is hollow and has two series of holes through its shell at *P* and *Q*, the latter being to the right of the reducing valve seat.

Fig. 162 shows the intercepting valve closed (to the right) on its seat *A*, and the reducing valve off its seat (open), as it is when working simple except that the reducing valve *L* is then brought near enough to its seat to the left, to prevent more than about one-half the boiler pressure from passing through it. As usual, the reducing is accomplished by the two ends of the reducing valve *L* being of different diameters, the smaller end having its outer left-hand side always connected to the atmosphere through small ports marked *N* and *O*, while the outside of the larger right-hand end is exposed to the receiver pressure when in operation, as in Fig. 162. The left-hand smaller end *M* of the intercepting valve works in a cylinder *W*, while the right-hand

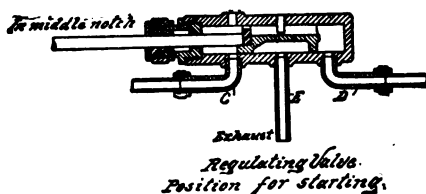
larger area of the intercepting valve is exposed either to the receiver or the high-pressure exhaust cavity, according to the position of the valve. The separate exhaust valve is located in a chamber *U* directly connected to the main exhaust pipe *Z*. (See Figs. 161 and 163.) The right-hand end of the separate exhaust valve is in the form of a piston and works in a cylinder *T*. The outer ends of these two cylinders, *W* and *T*, are connected by small pipes *C* and *D* with the regulating valve, as shown in Figs. 162 and 163. The stem of the intercepting valve extends over into separate exhaust valve and forms a guide to keep both valves central, and also serves as a dash-pot, but allows each valve to act independently of the other. All pistons are fitted with packing rings, as shown, and the valve seats and ground joints are so indicated.

The regulating valve receives steam from *G* through a small port *X* and therefore has live steam whenever the engine throttle is open. The regulating valve consists of a slide valve of the well-known "*D*" type and moves on a seat having two steam ports and one exhaust opening, as usual with a slide valve. Steam admitted through the right steam port and pipes *DD* to chamber *T* would bear against the separate exhaust valve and close it, as in Fig. 163. Steam through the left port and pipes *CC* to chamber *W* would force the intercepting closed, as in Fig. 162. If the engineer places the regulating valve lever in the forward notch, as in Fig. 162, live steam entering the regulating valve chamber from ports *G* and *X*

finds the left hand port uncovered and passes through the small pipe *CC* to the cylinder *W* (as indicated by arrows), moving the intercepting valve to the right against its seat *A* and thereby closing communication between the high-pressure cylinder exhaust port and the receiver *R*. In this position live steam pressure from *G* passes through ports *JJ* and *PP* to the interior of the intercepting valve, automatically opening the reducing valve and flowing through ports *QQ*, enters the receiver *R*, the other end of which is connected to the low-pressure steam chest, as shown in Fig. 161. Thus the low-pressure cylinder has received live steam at a reduced pressure and can work independently of the high-pressure cylinder, as its exhaust is as always to the stack. The intercepting valve now being closed, the exhaust from the high-pressure cylinder (its communication to the receiver being thereby shut off) forces the separate exhaust valve off its seat, as in Fig. 162, and escapes to the stack and the engine works simple, or with a live steam admission and an exhaust to the atmosphere on both sides. The separate exhaust valve remains open, as shown in Fig. 162, because chamber *T* is connected to the atmosphere through pipe *DD*, the under side of the regulating slide valve, and pipe *E*—as indicated by arrows.

If the regulating lever in the cab be moved to the back notch, the regulating valve takes the position shown in Fig. 163 and will then admit steam through the right-hand pipe *DD*, into

chamber *T*, pushing and holding the separate exhaust valve against its seat *B*, and at the same time chamber *W* will be in exhaust through pipes *CC* and *E*, as indicated by arrows. The separate exhaust valve being now closed, a slight pressure in the cavity marked "high-pressure cylinder exhaust" will open the intercepting valve, that is, move it off its seat *A* into the position shown in Fig. 163. Then the high-pressure cylinder exhausts through the intercepting valve into the receiver and thence to the low-pressure steam

*Fig. 164**Rogers Compound*

chest, and the engine works compound. No live steam from ports *GG* can get to the receiver in this position as the ports *PP* are not in register with those at *JJ*.

It will be noticed that there is an extended flange on the face of the intercepting valve, that enters the seat of the latter enough before closing and leaves it sufficiently late in opening, to prevent live steam from flowing through ports *PP*, *QQ*, and *R* to the high-pressure cylinder exhaust port when

the intercepting valve is opening or closing. If the engine is standing and the regulating valve is moved to its central position, as shown in Fig. 164, when the throttle is opened steam will pass through both pipes *CC* and *DD* to the outer ends of the intercepting and the separate exhaust valves respectively, and they will both be instantly closed against their respective seats *A* and *B*, Figs. 162 and 163. The receiver would then be filled with steam through the hollow intercepting valve and the reducing valve, as indicated by the arrows in Fig. 162; but as soon as the pressure at the high-pressure exhaust port became about twenty per cent. of the pressure in the dry pipe at the time, the intercepting valve would be opened and thereafter held open by the receiver pressure acting toward the left on the large right-hand end of the intercepting valve; thus a slight pressure on the large area of this valve overbalances the higher pressure on the smaller left-hand end *M* in chamber *W*, and the engine automatically changes to compound after two or three strokes, the main ports being opened as in Fig. 163.

If the engine had been working simple, with the valves as in Fig. 162, and the operating valve lever were placed in either the center or back notch, the working would automatically be changed to compound; if in the center notch, it would take a slight accumulation of pressure at the high-pressure exhaust port, as just explained; if in the back notch the intercepting valve opens with almost no pressure from the high-pressure exhaust port as then chamber *W* is in exhaust through pipe *CC*

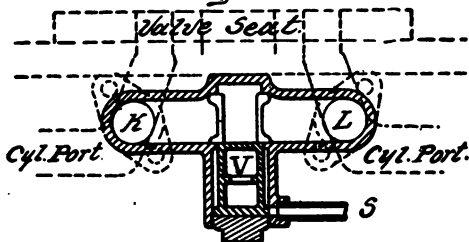
and the regulating valve. Subsequently to working simple, it is best to move the regulating lever to its middle position (Fig. 164) for a few seconds without closing the engine throttle; after that it can be moved to its back notch, as in Fig. 163, and left there until it is desired to again start simple or go from compound to single-ex-

Fig 165.

Rogers Compound



Fig. 166.



pansion in order to prevent stalling on a heavy grade.

Figs. 165 and 166 show two views of the bypass arrangement which is placed on the low-pressure cylinder in the position shown in Fig. 161. It consists of a valve *V* which automatically opens

and closes the port in a hollow casting bolted to the cylinder and connected below the valve seat at *K* and *L* with the steam ports of the low-pressure cylinder, as illustrated in Figs. 165 and 166. The hole through this by-pass casting is two inches in diameter. In Fig. 166 the valve *V* is shown dropped down in its chamber, thus leaving a two-inch open communication between the steam ports and hence the two sides of the low-pressure piston. A small pipe from the live steam port in the saddle of the high-pressure cylinder leads through the pipe *S* to the under side of this cylindrical valve *V*, as shown, so that when the engine throttle is opened the valve *V* raises to the top of its chamber and shuts off all communication between the ports *K* and *L*, remaining there as long as the high-pressure cylinder is receiving steam; but when the throttle is closed, it falls again by gravity and is thus an automatic valve.

Accidents to Rogers' Compounds.—In case of break-down on one side of this engine, can it be run in with the other side? Yes. The reducing valve would furnish a live steam supply for the low-pressure cylinder, or the separate exhaust valve would give an exhaust opening for the use of the high-pressure cylinder, according to which side was to be used; hence, in either case, general instructions would be to place the regulating valve in its extreme forward position, as for working simple, Fig. 162.

Under such circumstances would the engine be as powerful as a simple engine on one side? Yes, considerably more so at low speed, but the

smaller port openings than usual would not permit of as great speed.

As there are three notches in the cab for the regulating valve lever, how should this be handled when it is desired to change from simple to compound, or the reverse? It is not advisable to throw it from forward to back notch, or the opposite, without pausing a second or two in the middle notch and thereby producing a more gradual movement and causing a cushioning of the intercepting and separate exhaust valves.

Under ordinary circumstances, in what position is it best to keep the regulating valve? In the back notch, or compound position.

How should a light train be started? With the regulating valve lever in the center notch. The engine starts thus as an automatic compound.

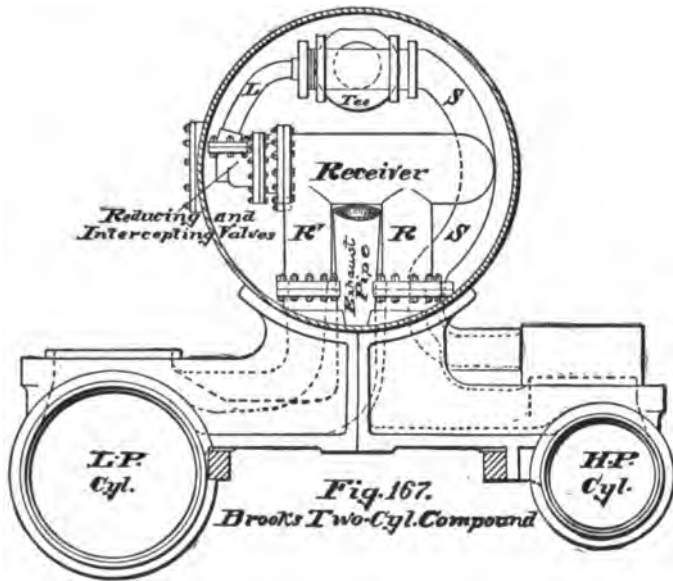
If the engine actually works compound in the center position, why is that not advisable? Because in that position the opening and closing of the throttle while running and the wide variations of pressure in the steam pipe and receiver when running, would cause more or less unnecessary movements of the intercepting valve.

When running the engine with one side, in what position will the "by-pass" valves (Figs. 165 and 166) be found? No matter which side is in use, live steam from the high-pressure steam pipe acts to keep them closed.

What kind of oil should be used in the oil cups shown in Fig. 162? Nothing but valve oil and that regularly but not too often, as it has a

tendency to gum the valves where there is not a constant flow of steam.

If the high-pressure side were on the center, why would not the engine move with the operating lever in compound position (back notch)? Because then the valves would be as in Fig. 163 and no live steam could be admitted to the low-



pressure cylinder. This would not be the case in starting with the regulating lever in either of the other two notches.

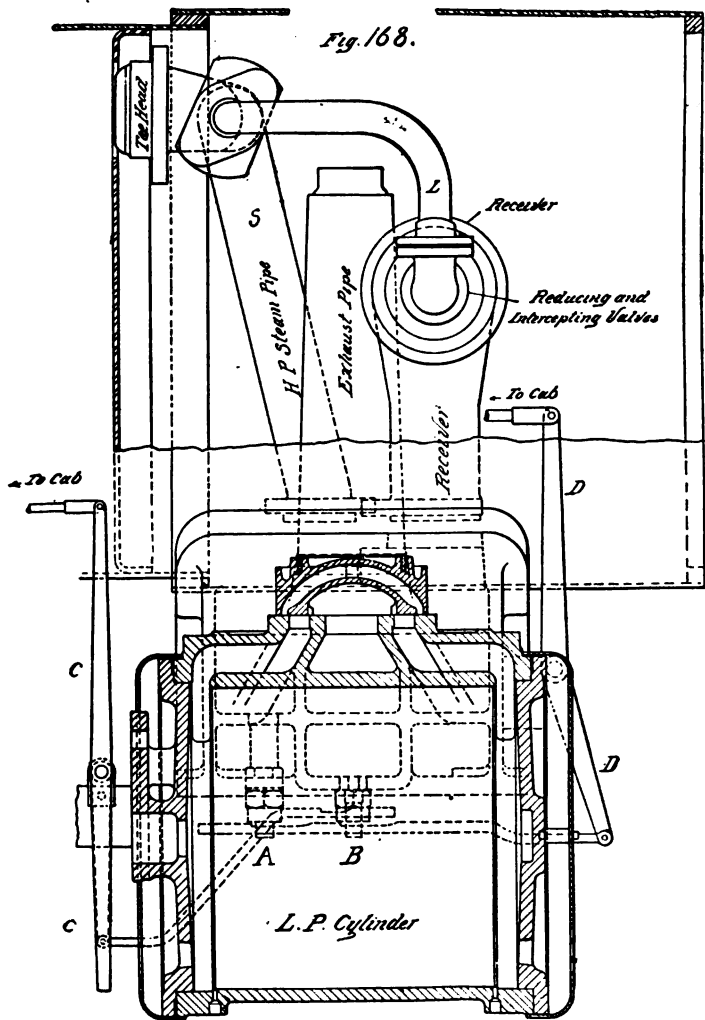
BROOKS TWO-CYLINDER COMPOUND.

This design is of the two-cylinder or cross-compound type, built under the Player patents, having

the high-pressure cylinder on the left side and a receiver in the smoke-box between the two cylinders, as shown in Fig. 167.

There is a combined admission, pressure-regulating and intercepting valve located either on the receiver in the smoke-box as shown, or in the cylinder saddle, which valve upon opening the engine throttle admits live steam at a reduced pressure to the low-pressure cylinder; at the same time the intercepting valve automatically closes, preventing the live-steam pressure from working against the high-pressure piston. The reducing valve remains open until the pressure in the receiver, accumulating from the high-pressure exhaust, becomes equal to or slightly greater than that on the low-pressure side, when the valve automatically closes, thereby shutting off the admission of live steam, and the intercepting valve simultaneously opens the receiver to the low-pressure steam chest, and the engine works compound thereafter as long as the throttle remains open.

In order to give the engineer control of the locomotive at all times, controlling valves are provided on the low pressure side. In the illustration (Fig. 168) these valves, *A* and *B*, are shown located in the bottom of the receiver and are connected to the cab by suitable levers *C* and *D*. They are sometimes made larger, connected higher up with the exhaust pipe, and arranged as to work automatically in combination with the intercepting valve, so that the engine can be run simple as long as desired and the exhaust take

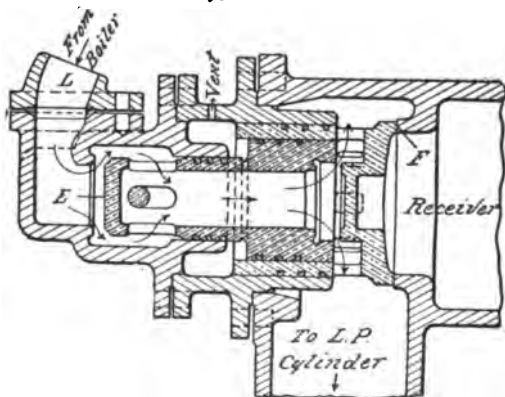


BROOKS TWO-CYLINDER COMPOUND.

place through the stack; however, its builders have claimed the design here shown to be "all that is necessary to give the engine its maximum power."

The operation of the locomotive is as follows: When the engine throttle is opened, live steam is

Fig. 169.

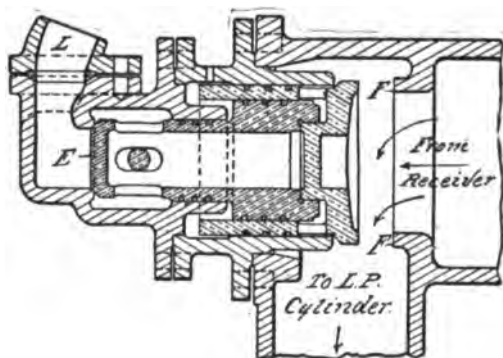


*Brooks Two-Cylinder Compound
Starting Position
Reducing Valve Open, Intercepting Valve Closed.*

admitted to the high-pressure steam chest through the steam pipe *S* (Figs. 167 and 168) and operates upon the high-pressure piston in the usual manner. At the same time, through the small steam pipe *L*, steam acts against the seat *E* of the reducing valve, then closed as in Fig. 170,

causing this valve to open, passing through the hollow portion of the valve, automatically closing the intercepting valve against its seat *F* on the receiver, as in Fig. 169. Steam then flows through the passages in the intercepting valve and down to the low-pressure steam chest, as in-

Fig. 170.



*Brooks Two-Cylinder Compound
Compound Position*

Reducing Valve Closed, Intercepting Valve Open.

dicated by the arrows. To render them readily distinguishable, the reducing or regulating valve is cross-sectioned very heavily, while the intercepting valve is less dark in appearance.

From Figs. 169 and 170, it will be seen that the right-hand end of the reducing valve is of larger area than that acted upon by live steam at

its seat on the left-hand end *E*. It is this difference that causes the partial closing of the valve, thereby throttling the steam passing through it to a reduced pressure. These areas being about two to one, the reducing valve, in order to equalize the work of the two cylinders in starting, prevents more than about one-half the pressure in the dry pipe from passing to the low-pressure cylinder.

As soon as the high-pressure cylinder has exhausted sufficient steam into the receiver to overbalance the reduced live steam pressure holding the intercepting valve closed, this valve opens automatically, at the same time locking the regulating valve against its seat as shown in Fig. 170. Exhaust steam from the high-pressure cylinder then flows through the receiver to the low-pressure steam chest, as indicated by the arrows and the engine works compound. The receiver pressure can become considerably reduced and still, through the action of the combined valves, keep the pressure regulating valve closed.

Accidents to Brooks Two-Cylinder Compounds.—What should be done in case of an accident necessitating the removal of the main rod on the low-pressure side? Disconnect that side, block the crosshead and clamp the valve in center, as with a simple engine. Open wide the controlling valves underneath the saddle and run in with one side. The exhaust will take place through these valves. To obtain a larger exhaust opening than the controlling valves furnish and thus permit of more speed and better steaming qualities,

attempt should be made to place the slide valve on the disabled side so as to uncover the exhaust port and thus give an exhaust through the stack

What should be done for a similar accident to the high-pressure side? Just the same as for a simple engine. There being then no exhaust into the receiver, the intercepting and reducing valve would admit live steam to the low-pressure cylinder upon opening the engine throttle.

What mode of procedure should be followed in case of a broken valve stem or rocker arm? Proceed as above, according to which side was broken.

What should be done if the intercepting valve became broken so as to leave an opening between both ends of the receiver? The proper method would be to disconnect the small steam pipe *L* (Figs. 167 and 168) and insert a blind gasket. The engine could then be started and worked only as a "strictly plain" compound and should not be stopped with the high-pressure side on center, as no live steam could be given the low-pressure cylinder for starting. Without disconnecting the steam pipe the engine could be run in with part of a train by reducing the boiler pressure or by using a slightly open throttle, in which case live steam from the reducing valve would pass through the receiver and work against the high-pressure piston in starting, and hence the engine should not then be stopped with the low-pressure side on center.

What should be done for a broken reducing valve? The same as for a broken intercepting valve.

Should the controlling valves fail to open, where would you look for the cause of the trouble? They operate very similarly to cylinder cocks and their levers becoming disconnected or bent may cause them to either fail to open, or remain continually open, as the case may be. The remedy is obvious.

BROOKS FOUR-CYLINDER TANDEM COMPOUND.

The Brooks (Player System) of four-cylinder compound is of the tandem type, that is, two cylinders on each side, one ahead of the other, as shown in Fig. 109. With this system the two low-pressure cylinders and their saddles are placed similarly to ordinary single-expansion cylinders, with which they can always be made interchangeable. They are of course larger, have a different style of steam chest and, bolted preferably to their forward ends, as shown in Figs. 109 and 171, are the two high-pressure cylinders which have steam chests communicating with the steam chests of the low-pressure cylinders with an enlargement between, all together forming a receiver. There are no devices in the smoke-box except those usual to single-expansion locomotives.

The steam is supplied to the high-pressure valve chest through suitable pipes connecting with the usual steam pipes in the smoke-box, and the exhaust from the low-pressure cylinder is through the usual cavity in the saddle.

As shown in Fig. 171, the low-pressure cylinders are fitted with the usual balanced slide

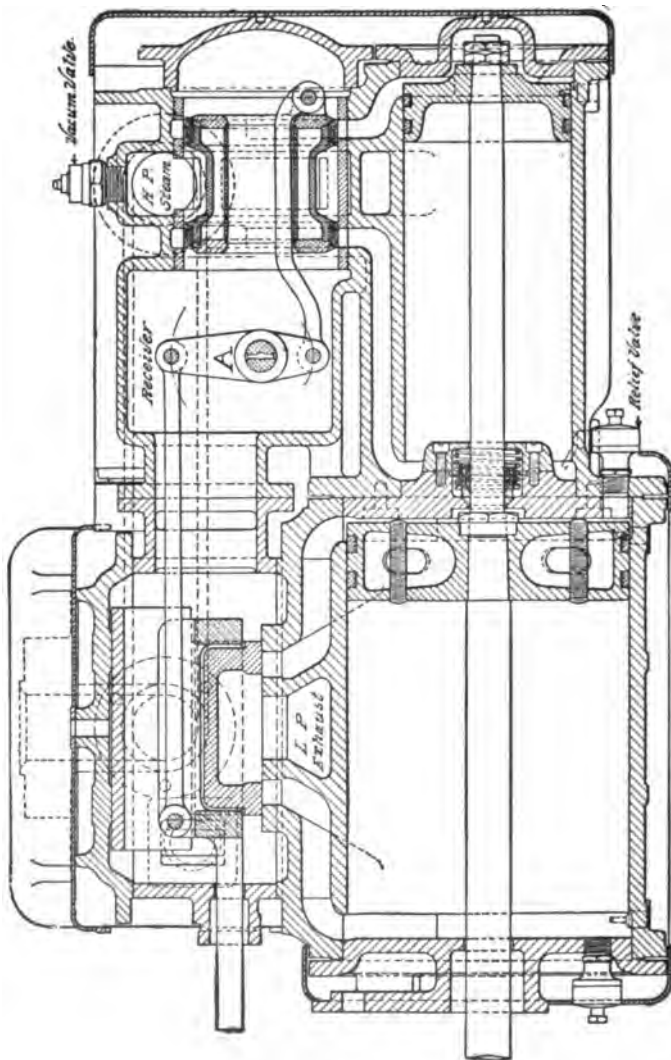
valves, while the valves for the high-pressure cylinders are of the piston type and hollow, having internal admission and external exhaust edges. The low-pressure valve is controlled by the usual eccentric and rocker arms, as ordinary with simple engines. It is rendered advisable to have an internal admission with the high-pressure valve in order to lessen the cooling of the steam from the boiler as well as for constructive reasons.

On account of the high-pressure valve having internal admission and the low-pressure valve having external admission (the latter being usual with ordinary slide valves) it is necessary that these valves should travel in opposite directions. This is accomplished by placing in the receiver (as shown in Fig. 171) an intermediate rocker arm *A* which is connected by rods to both valves and has arms of the desired ratio to give a relatively less travel to the high than to the low-pressure valve. These valves are so proportioned that when running in nearly full gear, the high-pressure cut-off takes place later in the stroke than the low-pressure cut-off, but when the engine is hooked up the relative time of cut-offs changes.

The pistons of both the high and the low-pressure cylinder are fitted upon the same piston rod, the intermediate head between the two cylinders having suitable metallic packing, as shown in the illustration.

On the low-pressure steam chest is fitted a reducing and starting valve which is connected with the high-pressure steam pipe, as shown with the

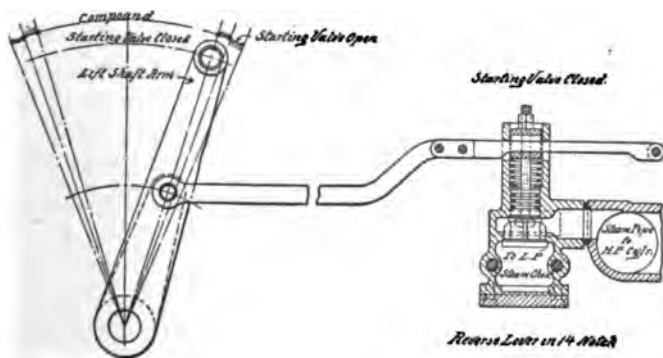
Fig. 171.



Brooks' Tandem Four-Cylinder Compound.

reducing valve in closed position by Fig. 172. By the connection of a rod with the arm of the lift shaft, this reducing valve is automatically opened whenever the reverse lever is placed either in full forward or full back gear. In the intermediate positions of the reverse lever, this reducing valve is locked to its seat by a suitable spring, so that it is rendered inoperative and the engine must necessarily work compound at all

Fig. 172



*Brooks Tandem Compound
Operation of Starting Valve*

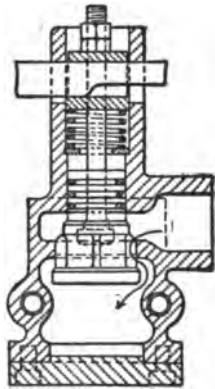
times and under all conditions of steam pressure when the reverse lever is in any other position than full gear. Fig. 172 shows the range of the lift shaft arm for the starting valve to be either open or closed. This combined starting and reducing valve, when open, permits live steam to enter the low-pressure cylinder at a pressure equivalent to the maximum pressure obtained in

this cylinder when the engine is working compound. As soon as the engine has made one complete revolution, the receiver becomes charged sufficiently by the exhaust from the high-pressure cylinder to close the reducing valve against its spring, thus automatically rendering the starting

Fig. 173.

Brooks Tandem Compound.

Starting Valve Open.



Reverse Lever in full Gear, 17 Notch.

valve inoperative and thereby necessitates the compound working of the engine. The reducing valve on a larger scale is shown in open or starting position by Fig. 173.

The engine operates in the following manner: Steam is admitted to the high-pressure steam

chest through suitable pipes, into the annular steam admission cavity surrounding the high-pressure piston valve, thence to the high-pressure cylinder, and exhausts into the receiver—the exhaust from the forward end of the cylinder passing through the inside of the hollow piston valve. The low-pressure steam chest, being also of large size, somewhat increases the receiver capacity, so that practically uniform pressure is maintained therein, steam from the receiver being admitted to and exhausted from the low-pressure cylinder by an ordinary slide valve which gives a distribution in that cylinder in the same manner as for simple engines.

This style of compound has been in operation for several years and, the builders state, shows an excellent economy in fuel, water, and repairs.

Accidents to Brooks Four-Cylinder Tandem Compound.—What would you do if it became necessary to disconnect one side of the engine? The same as with a simple engine of similar design in other respects.

In case the front head of the high-pressure cylinder became broken, how would you proceed in order to run the engine in with a full train? Remove the front steam chest head, place the reverse lever so as to throw the high-pressure valve clear ahead, disconnect the high-pressure valve and its intermediate rocker-arm rod (Fig. 171) and block this valve securely in the center so as to cover all ports; then block the starting valve open on that side, thereby allowing live steam at a reduced pressure to enter the low-

pressure cylinder. This will enable the engineer to slowly handle a full train, but should not be so run for any distance or the high-pressure cylinder will be badly cut. In the lighter service of passenger trains, the engine would be capable of greater speed by disconnecting the broken side, blocking the valves in the center of their seats, and running with one side, as would be done with a simple engine.

If the intermediate rocker arm or the valve rod should break what should be done? Broken at some certain points, the engine might be treated as for broken high-pressure cylinder head; but the preferable procedure, all things considered, would be to disconnect on that side and be sure to block both valves over ports, to do which it may be necessary to remove front steam chest head and block the high-pressure valve inside.

In disconnecting one side of these engines, should it be imperative to securely block the crosshead? It should, because of the difficulty of securely holding the high-pressure valve in its central position.

How could it be determined if the metallic piston-rod packing between the two cylinders were blowing badly? Place the engine with one side on the upper quarter and the reverse lever in the center, block open the starting valves, and open the cylinder cocks and the throttle. If no steam escapes from either the high or low-pressure cylinder cocks, it has been determined that the valves are not leaking. Now close the throttle and remove blocks from reducing valve,

put the reverse lever in about half forward gear and allow all steam previously admitted to the pipes to escape from the open cylinder cocks. Again open the throttle and, as steam will then be admitted behind the high-pressure piston only, a blow through the forward low-pressure cylinder cock would indicate that this packing was blowing. The same operation should be repeated for testing the other side.

Should the engine fail to develop its proper starting power in full gear, what might be wrong? Open the cylinder cocks, with the throttle open and the engine standing, and if steam at no considerable pressure escapes from the low-pressure cylinder, examine the attachments connecting the reverse lever with the starting valves; they operate similarly to the ordinary cylinder cock arrangement and may likewise become defective and thus fail to open the reducing valve.

COOKE COMPOUND.

The compound arrangement for two-cylinder locomotives built by the Cooke Locomotive Works is such that, by means of a small steam

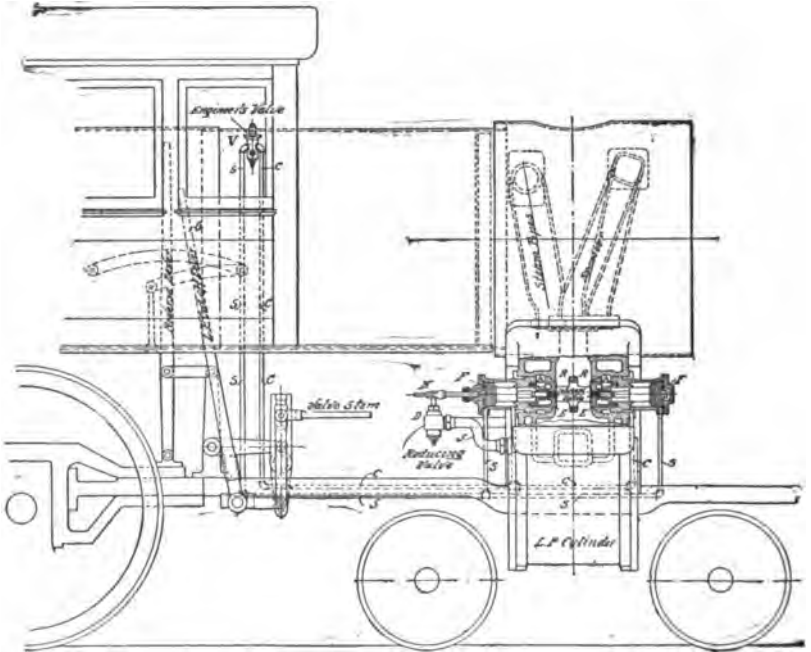
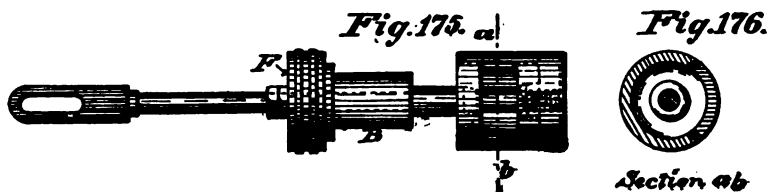


FIG. 174. COOKE COMPOUND.

operating valve in the cab, the engine can be run either simple or compound as the engineer may desire, and is, therefore, a convertible compound. This operating valve admits steam to suitable pistons which open and close the inter-

cepting valve and operate the reducing valve by a suitable lever connection. The intercepting valve is placed on the right-hand side of the engine within the saddle of the low-pressure cylinder and in the passages *RE*, leading from the receiver to the low-pressure cylinder, as shown in Fig. 174; it also has two connecting ports *AA*, leading into the main exhaust to the stack. By the movement of this valve, steam from the high-pressure cylinder, coming through the receiver, can be thrown out to the atmosphere instead of being allowed to pass to the low-pressure cyl-



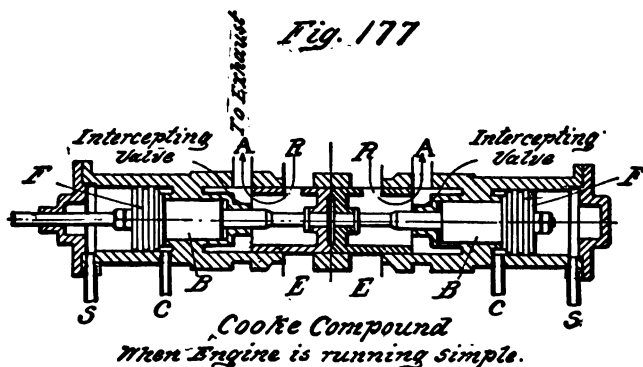
Cooke Compound

~Back Half of Intersecting Valve~

inder for compound expansion. This movement makes an independent engine of the high-pressure side and at the same time opens a reducing valve *D*, Fig. 174, which supplies, at a reduced pressure, live steam from the boiler to the low-pressure steam chest. The high-pressure cylinder always exhausts into the receiver, and the exhaust from the low-pressure cylinder is direct to the stack with either simple or compound working.

The reader will notice a novelty in the shape

of an additional low-pressure cut-off lever *G*, located in the cab, as shown in Fig. 174. This lever is sometimes applied to Cooke engines of this class and is used to increase or decrease the travel of the slide valve on the low-pressure side independently of the valve on the high-pressure side, in order to equalize the power developed on opposite sides of the engine under variable conditions of steam pressure and different positions of the reverse lever.

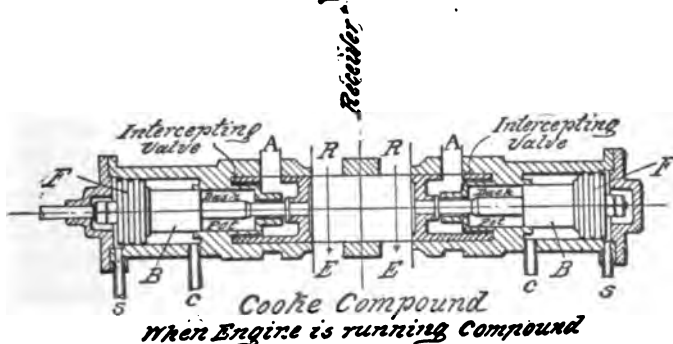


The intercepting valve is composed of two pistons in duplicate, as shown in Figs. 174, 177 and 178, each part being moved by a piston *F'* in a separate chamber. Figs. 175 and 176 show one-half of the valve removed from its chamber. It will readily be seen from Fig. 174, that live steam from the engineer's valve *V* in the cab can be supplied through two small pipes *S* and *C* to either the outer or the inner sides, respectively, of these two pistons *FF*. Ports *RR* are passages

from the receiver and ports *EE* lead to the low-pressure steam chest.

To start the engine with single expansion or to run it thus at any time, the engineer pulls the handle of his engineer's valve *V* in the cab to the back notch. This admits live steam through the small pipe *S* (Fig. 174) to outside ends of the two pistons *FF*, thereby moving them and their attached intercepting valve pistons until the two latter come together, the position in which they

Fig. 178



are shown on a larger scale in Fig. 177. In this position the intercepting valve has closed the ports *EE* to the low-pressure cylinder, and the high-pressure exhaust into the receiver can pass out from ports *RR*, through the hollow intercepting valves and escape to the atmosphere by exhaust ports *AA* leading to the main exhaust, as indicated by arrows. The extended and slotted stem of the left-hand intercepting valve piston *F* (shown in Figs. 174 and 175) in moving to the right has

pulled with it the crank lever *K* (Fig. 174) and opened the reducing valve *D* which, by a connecting pipe tapped into the main steam passage of the high-pressure side, admits live steam to the low-pressure steam chest through pipe *J*.

When the engineer desires to work compound, he pushes the handle of the engineer's valve *V* in the cab to the forward notch, thereby admitting steam through pipe *C* (Fig. 174) to the inner sides of the two intercepting valve pistons *FF* and forcing them and their valves outward, as shown in Fig. 178. In this position the passage is opened from the receiver through the intercepting valve ports *RR* and *EE* to the low-pressure steam chest (See Fig. 174). The outward movement of the pistons *FF* has shut off the admission of live steam to the low-pressure cylinder by closing the reducing valve *D*, and the steam must now pass from the high-pressure cylinder through the receiver and the low-pressure cylinder to the exhaust or, in other words, the engine works compound.

Each stem between the operating pistons *FF* and the intercepting valve pistons has an enlargement *B* (Figs. 175, 177 and 178) which fits loosely into a chamber of the intercepting valve bushing and thus forms an air dash-pot, thereby preventing the slamming of the valves when their positions are changed.

The stem of the piston *F* which extends back to operate the reducing valve *D* is slotted out, as shown in Fig. 175, so as not to engage the valve crank *K* (Fig. 174) until after the intercepting

valve has closed the ports *EE*. Thus the live steam used in the low-pressure cylinder in starting cannot reach the high-pressure side through the receiver and produce a back pressure on the high-pressure piston.

The builders state that in case of accident to either side of the engine, the opposite side may be run for any length of time as a simple engine by disconnecting and blocking the injured side in the same manner as for single-expansion locomotives.

DICKSON COMPOUND.

The Dickson Locomotive Works' compound is built under the Dean patents which cover special valves both for automatic and for convertible compounds, but, inasmuch as the practical information is based on the mechanism for the former class only, the detailed description will be confined to the automatic compound.

The starting and intercepting valves are placed on top of the high-pressure steam chest on the right side of the engine. Upon opening the throttle for starting, live steam is admitted to both cylinders, but, after a stroke or two, the intercepting valve automatically opens and the engine works compound thereafter.

The high-pressure exhaust port Q (Fig. 179) is in the balance shield of a Richardson balanced valve P , having its top removed, and thus the exhaust steam from the high-pressure cylinder passes up through it and the intercepting valve G to the receiver and low-pressure cylinder, when the intercepting valve G is open. Beneath the seat R , intercepting valve G , is a port E^1 leading to the chamber E .

The receiver, as usual with cross-compounds, is located in the smoke-box, but its shape is out of the ordinary. It is made very large and, between its connections with the high and the low-pressure saddles, branches into two forks, each of which is oval and has metal ribs lengthwise with the pipes. Fig. 180 shows a section through this

double portion of the receiver. The object of the designer has been to obtain a very large heating surface, so as to re-evaporate some of the water

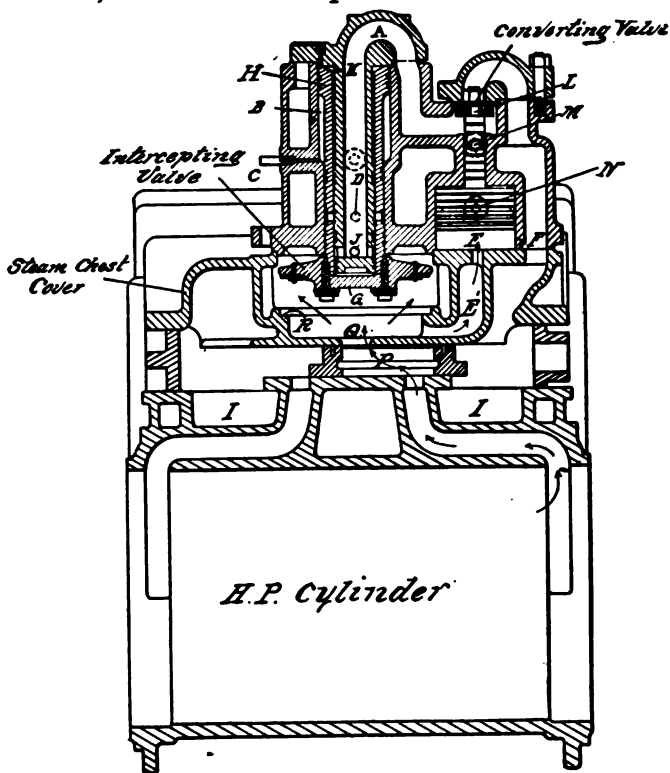


Fig. 179.

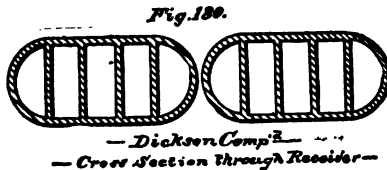
Dickson Compound.

condensed in the high-pressure cylinder as it passes with the exhaust steam through the receiver to the low-pressure side. From the re-

ported economy of these engines, it would seem that the object has been largely attained.

Referring to Figs. 179 and 181, it will be seen that the intercepting valve *G* is fastened to the annular stem *H* having an enlarged top above the space *B* which is constantly filled with air pressure or live steam from the pipe *C* when the engine throttle is open, and hence sleeve *H* will be found at the top of its travel, as illustrated, after the engine has started.

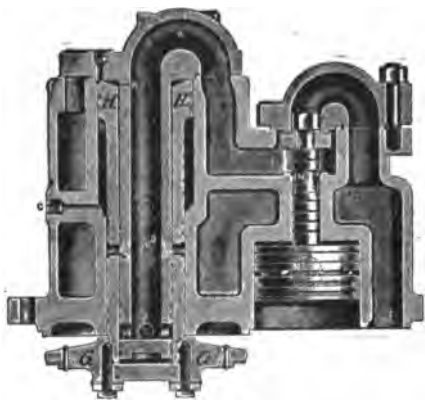
The operation is as follows: Open the throttle for starting and live steam enters the high-pressure steam chest from the induction ports *I*



(Fig. 179) as usual and besides has a connection to *F* through the top of the steam chest, as shown. There being no pressure in the receiver (to which chamber *E* is connected through the open intercepting valve *G*), the weight of *N* will have caused the converting valve *L* to drop down, and thus the live steam passes through valve *L* into the tube *AJ*. Port *K* admits steam to the enlarged top of the annular stem *H*, forcing the intercepting valve *G* down on its seat *R* and bringing the ports *D* in the stem *H* opposite the ports *J* of the central steam tube *A*, thus admitting live steam through them to the

receiver and low-pressure steam chest. With the intercepting valve *G* closed (down), the first high-pressure exhaust, acting in chamber *E* through the port *E*¹, causes piston *N* to lift and close the converting valve *L* (as shown in Figs. 179 and 181), thereby shutting off the supply of steam from *F* to the central tube *AJ*. What

Fig. 181.



Dickson Compound
Starting Valve in position, working Compound

steam remains in this tube escapes through the relief port *M* and allows the intercepting valve *G* to move up (open) by live steam pressure from the pipe *C* acting in the annular cavity *B*, as hereinbefore described, assisted by the high-pressure exhaust below *G*. The engine then works compound, as live steam is shut off from

the low-pressure cylinder and the exhaust from the high-pressure cylinder takes its place.

The engine above described is an automatic compound, that is, starts with live steam in both cylinders but after the first stroke changes automatically to compound.

The inventor of this system, in a design not shown, introduces a reducing valve in the central tube *A* and adds a separate exhaust valve operated by live steam from a three-way cock in the cab, thus making a compound of the convertible class, but at the same time he does not advise convertible construction in compounds.

Accidents to Dickson Compounds.—What should be done in order to run the engine in with the low-pressure side only? Nothing different from a simple engine, but the boiler pressure carried should be reduced about one-half or else the engine throttle opened very slightly.

How could the engine run with the high-pressure side only? There being no means of exhaust except into the receiver, the low-pressure valve would have to be placed so as to uncover the exhaust port or, if that were found to be impossible, the valve entirely removed.

RHODE ISLAND COMPOUND.

The type of compound locomotive built by the Rhode Island Locomotive Works is sometimes known as the "Batchellor" system, that being the name of the inventor of the device.

In the saddle of the low-pressure cylinder on the left side of the locomotive is located an intercepting and a reducing valve and in the smoke-box a separate high-pressure exhaust valve. When the throttle is opened, the engine starts with live steam in both cylinders. With the separate exhaust valve closed the engine automatically changes to compound in the course of a complete revolution; with it open, the engine continues to work as a simple engine as long as desired. This separate exhaust valve is operated at the will of the engineer by means of a three-way cock in the cab; and thus the engine belongs to the class of convertible compounds.

Fig. 182 shows a vertical section lengthwise through the intercepting valve, with the latter in the position when the engine is either starting or being run as a single-expansion locomotive. Fig. 183 shows the same section with the intercepting valve in compound position. *R* is the receiver port; *S* is a connection from the main steam pipe; *L* is a port leading to the low-pressure steam chest, and *B* is a reducing valve. The intercepting valve is composed of the four pistons, 1, 2, 3 and 4, of which the last works in an oil dash-pot *C*.

If the engine had stopped after running compound with the valve, as in Fig. 183, and the engine throttle were then opened, live steam from the pipe *S* would force the intercepting valve into simple position as shown in Fig. 182, because piston 2 is larger than piston 1. In this latter position small port *D* is open and steam from *S* passes through it and the reducing valve *B* to the low-pressure side. Piston 3 has now closed the communication with the receiver *R* in which one

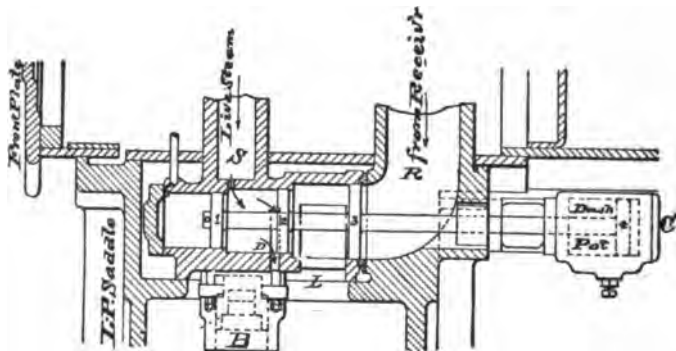


Fig. 182.

*Rhode Island Compound
Engine Working Simple.*

or two exhausts from the high-pressure cylinder soon produces sufficient pressure to react on this piston 3, bearing the intercepting valve to the left against the differential pressures on pistons 1 and 2 acting in the opposite direction, and the valve is shifted to compound position, as in Fig. 183, in which position no more live steam can pass through port *D* to the low-pressure side, and

the receiver *R* is connected through port *L* with the low-pressure steam chest, for which it forms the supply thereafter, as indicated by the arrows.

The port leading from the live steam supply *S* into the intercepting valve, is larger than it appears from the illustrations, as it extends partly around the circumference of the valve.

The separate exhaust valve shown in Figs. 184 and 185 is placed on the receiver in the smoke-

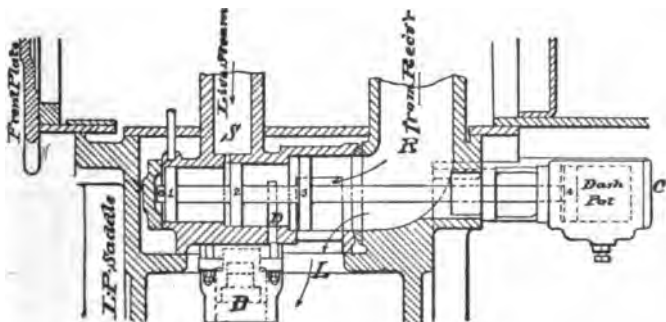


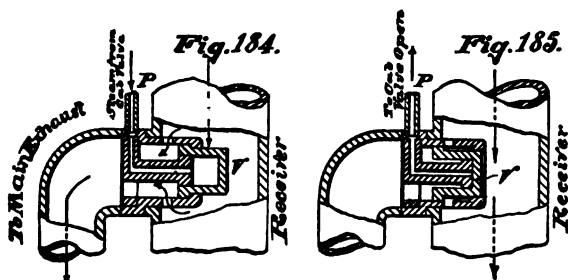
Fig. 183.

Rhode Island Compound
- *Engine Working Compound* -

box and, when opened by pressure through pipe *P* leading from a three-way cock located in the cab and under the control of the engineer, connects the receiver with the main exhaust pipe. The opening of this valve will thus permit the high-pressure exhaust to escape and there will be no accumulation of pressure in the receiver. Hence, from the previous explanation, it will be seen that the intercepting valve remains in sim-

ple position (Fig. 182) until such time as the engineer closes the separate exhaust valve, when a stroke of the engine automatically changes the mechanism to compound position, as before described when starting.

The operation of the separate exhaust valve, shown in Figs. 184 and 185, is very simple. Pressure admitted from the cab through pipe *P*, moves the valve *V* from its closed position (Fig. 185) to the right and vents the receiver pressure direct to the exhaust pipe, as indicated by the



Open-Engine Working Simple. Closed-Engine Compound.
Rhode Island-Separate Exhaust Valve

arrows, Fig. 184. Withdrawing the pressure from the pipe *P*, allows the receiver pressure to automatically move and hold closed the valve *V*, as in Fig. 185.

Accidents to Rhode Island Compound.—If it became necessary to disconnect either side, how should the engine be run? Disconnect properly, observing the same precautions advised for simple engines, then open the separate exhaust

valve so that no pressure can accumulate in the receiver.*

What would you do with a broken intercepting or reducing valve? Open the separate exhaust valve and run with very light throttle, or, preferably, carry a reduced boiler pressure.

Would the working of the engine be affected if the separate exhaust valve *V* were broken? Probably not; but, if it left an opening between the receiver and the exhaust, the engine would run as a simple locomotive only.

*As remarked elsewhere in relation to designs having a separate exhaust valve, if it were the high-pressure side that was disconnected, it would not be necessary to open the separate exhaust valve unless there was some leakage of steam into the receiver.



APPENDIXES.



APPENDIX A.

AIR BRAKE TESTS.

The following tests made by the general manager of a large railroad in the south, clearly demonstrate that the air brake used alone is better than the brakes with the reverse lever, or than the reverse lever alone.

The table of these tests here produced is taken from the published reports of the *Air Brake-men's Association Proceedings for 1895*:

Conditions of the test were as follows:

Driving brake power, seventy per cent; tender, one hundred per cent; N. C. & St. L. coaches, ninety per cent; Pullman Sleeper, forty to one hundred and one per cent.

Boyer speed recorder was used and tests were made: first, brakes applied; second, engine reversed; third, sand lever opened. Track was level, in best possible condition, and all circumstances favorable.

From the record of tests the following valuable information was derived:

First. Best stops are made with braking power not quite strong enough to skid wheels.

Second. Length of stop is the same in reversing the engine whether cylinder cocks are opened or closed.

Third. The wheels did not lock rigidly when the engine would reverse without the brakes being used.

Fourth. The tests demonstrated that the brakes used alone are better than with the engine being reversed. The stop is quicker, and there are no flat spots obtained.

Fifth. Enough sand is much better than too much.

Sixth. Sand should be used before wheels start skidding, as its use will not start the wheels revolving when once skidding; it will simply increase the flat spots.

Seventh. Sand being used on a straight track, the drivers did not lock when the engine was reversed, but on a curve they would. On a curve the engine rocks, and sand is not so likely to strike the rail.

Eighth. In expected emergencies, the drivers did not lock when sand was used before brakes were applied and engine reversed, but it took so long to get the sand running first, that, in the end, the stop was not made as quickly as with unexpected emergencies where the engine was not reversed.

Ninth. The unexpected emergencies are the ones that bear the most weight, as expected emergencies are practically unheard of.

WESTINGHOUSE QUICK-ACTION AUTOMATIC BRAKE.

SUMMARY OF RESULTS OF TESTS, WITH 50 CAR TRAIN, IN OCTOBER, NOVEMBER AND DECEMBER, 1937.

PLACE OF TEST.	FIRST.		SECOND.		FOURTH.		SIXTH.		SEVENTH.		EIGHTH.		NINTH.		TENTH.							
	Down Grades.	Feet per mile.	Miles speed.	Feet distance.	Sec'da time.	Miles speed.	Feet distance.	Sec'da time.	Miles speed.	Feet distance.	Sec'da time.	Miles speed.	Feet distance.	Sec'da time.	Miles speed.	Feet distance.	Sec'da time.					
St. Paul . . .	13.6	19,172	736	490	15	{ 20,200 . . . } { 37,583 . . . }	19	1,200	62	20	59	20	109	37	337	11	1,204	27				
Chicago . . .	22	184	1037	480	15	{ 34,470 } { 35,502 } { 37,573 } { 38,636 } { 39,648 } { 40,679 } { 41,718 } { 42,757 } { 43,796 } { 44,835 } { 45,874 } { 46,913 } { 47,952 } { 48,991 } { 49,030 } { 50,069 } { 51,108 } { 52,147 } { 53,186 } { 54,225 } { 55,264 } { 56,303 } { 57,342 } { 58,381 } { 59,420 } { 60,459 } { 61,498 } { 62,537 } { 63,576 } { 64,615 } { 65,654 } { 66,693 } { 67,732 } { 68,771 } { 69,810 } { 70,849 } { 71,888 } { 72,927 } { 73,966 } { 75,005 } { 76,044 } { 77,083 } { 78,122 } { 79,161 } { 80,200 } { 81,239 } { 82,278 } { 83,317 } { 84,356 } { 85,395 } { 86,434 } { 87,473 } { 88,512 } { 89,551 } { 90,590 } { 91,629 } { 92,668 } { 93,707 } { 94,746 } { 95,785 } { 96,824 } { 97,863 } { 98,902 } { 99,941 } { 100,980 }	21	2,115	128	23	61	20	1,009	25	100	30	109	37	337	11	1,204	27
St. Louis . . .	52.8	20,176	1136	507	18	35,502	17	2,115	128	23	61	20	109	37	337	11	1,204	27				
Cincinnati . . .	50.0	25,284	1235	542	17	37,573	17	2,115	128	23	61	20	109	37	337	11	1,204	27				
Cleveland . . .	40.0	26,265	1243	718	20	38,636	17	2,115	128	23	61	20	109	37	337	11	1,204	27				
Buffalo . . .	32.2	21,214	1240	679	19	39,648	19	2,115	128	23	61	20	109	37	337	11	1,204	27				
Albany . . .	35.0	20,158	1036	500	18	37,580	19	2,115	128	23	61	20	109	37	337	11	1,204	27				
Boston . . .	40.0	19,123	1032	406	16	34,483	17	2,115	128	23	61	20	109	37	337	11	1,204	27				
New York . . .	53.0	23,203	1241	674	20	41,672	20	2,137	85	22	43	22	91	6	45	319	12					
Philadelphia . . .	44.0	23,264	1436	593	19	36,579	18	1,889	75	22	35	20	87	6	49	547	17					
Washington . . .	52.0	19,159	1042	694	21	42,718	21	1,643	67	23	58	21	81	6	40	493	13					
Pittsburgh . . .	47.0	20,194	1140	649	21	40,673	20	1,720	72	22	30	95	6	45	647	19						
																		494				
																		890				

• Passenger train only. Compare with freight train in Test No. 9.
THIRD TEST.—In all cases the brakes went fully on within two seconds.
FIFTH TEST.—The brakes were released in all cases in four seconds.

DESCRIPTION OF TESTS.

1. Emergency stops, train running at *twenty miles per hour.
2. Emergency stops, train running at *forty miles per hour.
3. Applying brakes, while train was standing still to show rapidity of application.
4. Emergency stops, train running at *forty miles an hour.
5. Service stops, and time of release. Exhibition of smoothness of ordinary stop and time of release.
6. Hand brake stops at *twenty miles per hour with five brakemen at their posts. At Buffalo there were seven brakemen.
7. Breaking train in two.
8. Emergency at *twenty miles per hour, the brake leverage having been increased to give the quickest stop possible. In the seven previous tests the usual safe-braking power was used.
9. Emergency stop at *forty miles per hour, same leverage was test 8.
10. A train of twenty freight cars and a train of twelve ordinary passenger coaches, run along beside each other on parallel tracks, each being about the same weight and length of trains, and the brakes applied at the same time. This shows the relative stopping power of the old and the new brakes.

*Speed attempted; actual speeds attained are given in statement and as read from speed gauge on engine. Fractions of miles and sections are omitted. Two engines were used in making tests at St. Paul, and one in other tests.

APPENDIX B.

PRINCIPLE OF THE AIR PUMP.

NOTE.—In Volume I. *Railway Equipment* the air pump is referred to, but not minutely. For that reason it has been thought well to embody a particular description of it here in connection with the *Engineers' and Firemen's Manual*, as it in every case forms a part of their examinations in regard to fitness, or in the absence of such examinations is of value to them as explaining a part of their work. The information is, therefore, embodied here for the purpose of making a more thorough exposition of the subject.

M. M. K.

SUPPLEMENTARY REMARKS.

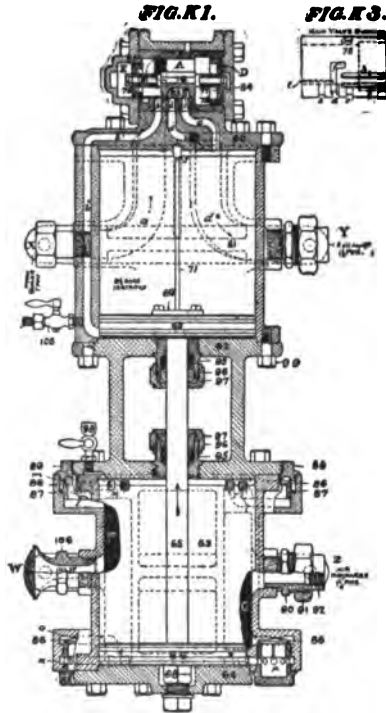
The air pump used in compressing the air for the use of the automatic air brake is placed on the locomotive, usually on the engineer's side of the boiler and immediately in front of the cab, although it is occasionally located similarly on the left-hand side. It is, however, becoming more and more the practice to place a pump on each side of the locomotive, so that there will be one in reserve should the other fail.

When we consider the many efforts made to reduce engine failures and understand that an air pump failure almost invariably results in a delay which is charged up against the locomotive department as an engine failure, it seems as though it would be advisable to place two pumps on all locomotives or employ some such device as the Sweeney Brake, illustrated and described elsewhere.

The air pump is a vertical compressor, consisting of two main cylinders, the upper one being the steam cylinder and the lower one the air cylinder. They are connected by a center casting, through which, in properly designed stuffing boxes, runs the piston rod connecting the main steam piston above with the air piston below. On top of the steam cylinder is the steam head which contains practically all of the valve motion of the nine and one-half inch pump; it will be evident from this last fact alone that this form of pump is superior to the former six-inch and eight-inch pumps not only because of its larger size, but also because these smaller pumps have a portion of their valve mechanism in the main steam cylinder casting of the pump; thus it will be seen that, by the removal of the top head of the nine and one-half inch pump, an entire change of the valve mechanism is effected, and it is this portion of a pump that is most likely to become defective.

These two smaller sizes of pumps (six and eight inches in diameter, respectively,) are being so generally supplanted by the larger (nine and one-half inch size) that it is not considered necessary herein to describe their operation, although it differs but slightly from that of the latter.

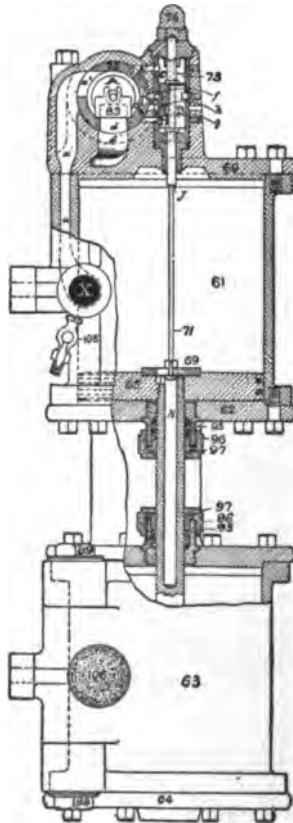
To those not wishing to go into the details of an explanation of the complete cycle of the movement of the nine and one-half inch pump, the following brief exposition of its principle is given:



NINE AND ONE-HALF INCH AIR PUMP.

- | | |
|------------------------------------|-------------------------------------|
| 60.—Top Head, complete. | 81.—Main Valve Stem. |
| 61.—Steam Cylinder, complete. | 83.—Main Slide Valve. |
| 62.—Center-piece, complete. | 84.—Right Main Valve Cylinder Head. |
| 63.—Air Cylinder, complete. | 85.—Left Main Valve Cylinder Head. |
| 64.—Lower Head. | 86.—Air Valves. |
| 65.—Steam Piston and Rod. | 87.—Air Valve Seats. |
| 66.—Air Piston, complete. | 88.—Air Valve Cages. |
| 68.—Piston Rod Nut. | 89.—Valve Chamber Caps. |
| 69.—Reversing Valve Plate. | 95.—Stuffing Boxes. |
| 71.—Reversing Valve Rod. | 96.—Stuffing Box Nuts. |
| 75.—Main Valve Bushing. | 97.—Stuffing Box Glands. |
| 76.—Main Piston Valve, complete. | 98.—Air Cylinder Oil-cup. |
| 77.—Main Valve Piston, Large Head. | 105.—Drain Cocks. |
| 79.—Main Valve Piston, Small Head. | 106.—Air Strainer. |

FIG. K 2.



NINE AND ONE-HALF INCH AIR PUMP.

- | | |
|--------------------------------------|----------------------------------|
| 60.—Top Head, complete. | 74.—Reversing Valve Chamber Cap. |
| 61.—Steam Cylinder, complete. | 75.—Main Valve Bushing. |
| 62.—Center-piece, complete. | 83.—Main Slide Valve. |
| 63.—Air Cylinder, complete. | 88.—Air Valve Cages. |
| 64.—Lower Head. | 89.—Valve Chamber Caps. |
| 65.—Steam Piston and Rod. | 95.—Stuffing Boxes. |
| 69.—Reversing Valve Plate. | 96.—Stuffing Box Nuts. |
| 71.—Reversing Valve Rod | 97.—Stuffing Box Glands. |
| 72.—Reversing Valve. | 105.—Drain Cocks. |
| 73.—Reversing Valve Chamber Bushing. | 106.—Air Strainer. |

Each upward and each downward stroke of the steam piston causes a corresponding movement of the air piston in the lower cylinder. In this air cylinder are two sets of valves that lift whenever the pressure below them is greater than that above; thus both the top and the bottom sides of the air piston have valves to admit air from the atmosphere when the piston is receding, and this valve closes as soon as the piston reverses; the air that is drawn in on the previous stroke is then compressed until the pressure in the air cylinder is greater than the pressure in the main reservoir, when the discharge valve is lifted from its seat and this compressed air discharged to the main reservoir. There is one upper and one lower discharge valve. The pump is double acting, discharging and drawing in air at one or the other side of the air piston on both the up and the down stroke.

To move the air piston the steam must be alternately admitted first to one side and then to the other of the steam piston in the upper cylinder. This admission is regulated by the valve motion of the upper head which consists of a slide valve covering two steam ports leading to either side of the steam piston and an exhaust port leading to the atmosphere. On top of this slide valve is always steam pressure when the pump is working; but this downward pressure of the steam on the slide valve would effect no change of its position without some form of valve motion, so there are two small pistons, one on either side of the slide valve, attached to the ends

of a stem having two collars between which this small slide valve is held and thus shifted back and forth in the same manner as an eccentric would reverse the positions of its ordinary "D" slide valve on a steam engine. These two pistons that operate the slide valve are of different diameter and consequently when the same pressure per square inch is bearing on their inside surfaces the greater piston is going to overcome the smaller and pull the slide valve in its direction thereby uncovering a port and admitting steam to the under side of the main steam piston and forcing it upward while at the same time, by means of the cavity underneath the slide valve, the upper side of the steam piston is connected with the atmosphere through an exhaust port. When the main piston approaches its upper termination it engages with a stem which moves a very small slide valve in the upper head and allows steam to pass to the outside of the larger main-valve piston. This pressure on the outside of the larger piston just balances the pressure on its inside and leaves the pressure on the smaller piston to effect the movement of the stem and slide valve in its direction, thereby reversing the pump by permitting live steam to enter the steam cylinder above the piston and allowing the exhaust steam from below the piston to escape to the atmosphere through the under side of the slide valve. We have now completed a revolution of the pump and only have to place the valve motion in the position in which they were found when starting the pump (as in Fig. K¹.) This

is done by the engaging of the main piston with the same reversing stem that it struck on approaching its upper limit, only now it is at the approach to its downward termination that it pulls down this stem, thereby drawing its small slide valve with it, which valve permits the steam previously admitted to the outer side of the larger slide-valve piston to escape to the atmosphere through suitable ports. Hence the situation is as at first found—with a larger and a smaller piston acted upon from the inside in opposite directions and no pressure on their outside surfaces; the larger one overcomes the smaller and draws the slide valve to the position as at the outset. (See Fig. K^1 .)

As these ports are not large, it is easy to see how small an object it would take to obstruct the passage of steam and consequently cause the pump to stop the same as though some part were broken. That is the reason that the use of nothing but metallic gaskets is advised in the steam connections to the air pump.

THE NINE AND ONE-HALF INCH IMPROVED AIR PUMP.

As will be seen by reference to Figs. K^1 and K^2 of the accompanying cut, the valve motion of the pump consists of two pistons, 77 and 79, of unequal diameter, mounted on the rod 81, while a slide valve 83, of the "D" type, held in position between them provides for the distribution of steam to the upper and lower sides of the main steam piston 65, as required. Steam enters

the pump at *X*, where a suitable stud and nut admits of direct attachment to the pump governor, and by means of passages *a* and *a*¹, and port *a*² is admitted to the slide valve chamber *A* between the two pistons 77 and 79 which (by reason of the greater area of the former) it forces to the right to the position in which the valve is shown in Fig. 1, thus admitting steam through ports *b* and passages *b*¹ and *b*² to the under side of the main piston 65 and forcing it upward, while the steam previously used on the opposite side in forcing the main piston 65 downward is exhausted to the atmosphere through passage *c*, port *c*¹, and cavity *B* of the slide valve 83, port *d* and passage *d*¹ and *d*² at the connection *Y*, from whence it is conveyed by a suitable pipe to the smoke-box of the locomotive.

In Fig. *K*³ is shown the outside view of the main valve bushing 75 giving the several ports and steam passages therein, of which port *t* communicates between chamber *E* in the main valve head 85 and the exhaust passage *f*¹, and hence is in constant communication with the outside atmosphere, relieving the pressure on the surface of the main valve piston 79 exposed to chamber *E*. A reversing valve 72 operates in chamber *C* in the center of the steam cylinder head (Fig. *K*²), steam being supplied thereto from slide valve chamber *A* through ports *e* and *e*¹, and which is given motion through the medium of a rod 71 extending into the space *k* of the hollow main piston rod. The duty of this valve is that of admitting steam to and exhausting it from

space D between main valve piston 77 and the head 84, and is shown in Fig. 2 in position to exhaust the steam previously used, from the space D through port h (Fig. K^3), port h^1 (Fig. K^2), reversing valve cavity H and ports f and f^1 to the main exhaust ports d and d^1 and d^2 .

It will at once be apparent, having described how the surfaces of main valve pistons 77 and 79, exposed in chambers D and E , respectively, are free from pressure other than the atmosphere, that the steam on the insides of these pistons in chamber A is exerting a force against both pistons, but the total force to the right is the greater on account of the greater area of the larger piston 77. This effect, however, is reversed when the main piston 65, approaching the upward termination of its stroke, strikes the shoulder, j , of the reversing valve rod 71, forcing the rod and its valve 72 upward, causing the admission of steam from chamber C to chamber D through ports g and g^1 (Fig. K^3), thus balancing the pressure on both sides of the main valve piston 77, so that the steam in chamber A , acting upon the effective inside area of the main valve piston 79, forces it to the left and live steam is again admitted to the upper side of the main steam piston 65 (while the steam below piston 65 is allowed to exhaust), and thus forcing it downward until at the lower termination of its stroke the button head on the lower end of the reversing valve stem 71 comes in contact with the reversing valve plate 69, again moving reversing valve 72 to the position shown in Fig. K^2 ,

thereby completing the cycle of its movement.

Coincident with the reciprocal movements of the main steam piston 65, the air piston 66 is moved by means of the main piston rod (also lettered 65) and air from the outside atmosphere is drawn alternately into the respective ends of the air cylinder 63 through the screened inlet 106 at *W*, chamber *F*, and receiving valves 86 to the left, Fig. *K*¹, and from thence discharged under pressure through discharge valves 86 to the right, Fig. *K*¹ to chamber *G* and the main reservoir to which the pump should be connected by one and one-fourth inch pipe at *Z*. The lift of the receiving and discharge valves 86 should be three thirty-seconds of an inch.

This pump should receive as great care as that recommended for all previously designed pumps. The admonition, however, to use *only a very small amount of oil in the air cylinder* will bear repeating. Ample provision is made for drainage by means of two cocks, Figs. 105, *K*¹ and *K*², located in the steam passages *a* and *b*², which should be left open in starting the pump and in winter at all times when the pump is not working.

APPENDIX C.

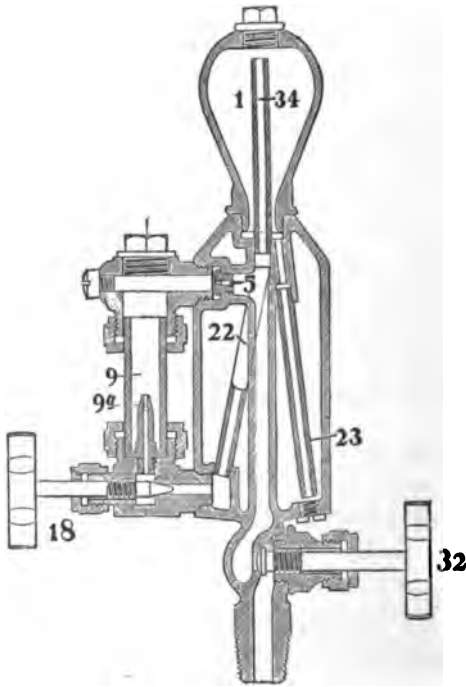
THE LOCOMOTIVE LUBRICATOR.

Although many engines (notably marine engines using distilled feed water) have been run successfully without cylinder lubrication other than that of the steam that is condensed about the walls of the chamber, as higher boiler pressure became used in locomotive practice it was found advisable to employ oil in the lubrication of the cylinders.

The boiler of a locomotive is probably forced more at times and more steam is taken from it in a given time than from that of any other boiler of the same size. This causes priming and more or less of the water is carried with the steam into the cylinders. Hence, if the water has much of any incrustating matter in solution, much of it reaches the valves and valve seats, the pistons and cylinders, and results in cutting these surfaces to a considerable extent, even with the most approved methods of lubrication.

The original method employed for oiling the valves and cylinders was by means of an oil cup located on top of the steam chest through which cup oil could be supplied to the valves and cylinders below whenever steam was shut off.

FIG. 38.



AIR BRAKE LUBRICATOR—SECTIONAL VIEW. (NATHAN.)

- 1.—Condenser.
- 5.—Reducing or Choke Plug.
- 9.—Sight-Feed Glass.
- 9a.—Sight-Feed Nozzle.
- 18.—Regulating Valve.
- 22.—Oil Pipe.
- 23.—Water Pipe.
- 32.—Steam Valve.
- 34.—Condenser Tube.

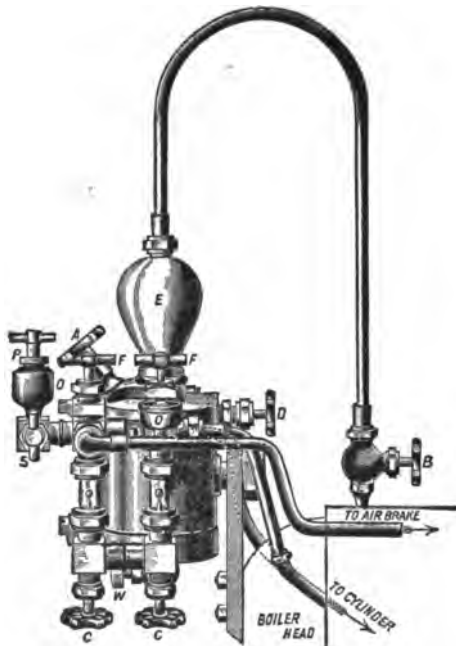
This necessitated the engineer or fireman going to the front end of the engine and pouring oil in these two cups—one or either side. This was neither convenient nor always safe. About the year 1864 the next improvement made was in the placing of these oil cups in the cab and connecting them by sloping pipes to either steam chest. Thus the oil could be supplied by the enginemen without their leaving the cab.

After many designs of hand oilers had been used, the necessity for an even flow of oil to valves and cylinders of locomotives was met in the year 1872 by the introduction of the steam-chest oiler that could be filled and an adjustment made whereby a constant and controllable flow of oil was had.

In 1883 the first *down drop-feed* lubricator made its appearance, one being provided for each cylinder. These lubricators were located in the cab with pipes leading to each steam chest.

In 1885 this was changed to the *up drop-feed*, one lubricator for each cylinder being used, however, until 1886, when the *double sight feed* lubricator was put in use. From the time of the introduction of the air brake and consequent use of the air pump up to 1888, a separate lubricator was used for air pump lubrication. In that year, however, another feed was added to the cylinder lubricator making it a *triple sight feed* lubricator, as at present used.

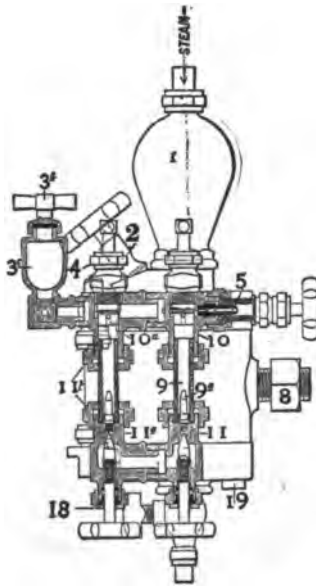
FIG. 89.



**TRIPLE SIGHT-FEED LOCOMOTIVE CYLINDER AND AIR BRAKE
LUBRICATOR. (NATHAN.)**

- A—Filling Plug.
- B—Steam Valve.
- C, C, C—Regulating Valves.
- D—Water Valve.
- E—Condenser.
- F, F, F—Safety Valves.
- O, O, O—Auxiliary Oilers.
- W—Waste Cock.

FIG. 40.



TRIPLE SIGHT-FEED LOCOMOTIVE CYLINDER AND AIR BRAKE
LUBRICATOR—SECTIONAL VIEW. (NATHAN.)

- 1.—Condenser.
- 2.—Filling Plug.
- 3.—Auxiliary Oiler.
- 4.—Safety Oiler.
- 5.—Reducing or Choke Plug.
- 8.—Stud Nut.
- 9.—Sight-Feed Glass.
- 9a.—Sight-Feed Nozzle.
- 10.—Upper Sight Bracket (for cylinder)
- 10a.—Upper Sight Bracket (for air brake)
- 11.—Lower Sight Bracket (for cylinder.)
- 11a.—Lower Sight Bracket (for air brake.)
- 18.—Regulating Valve.
- 19.—Bottom Plug.

FIG. 41.



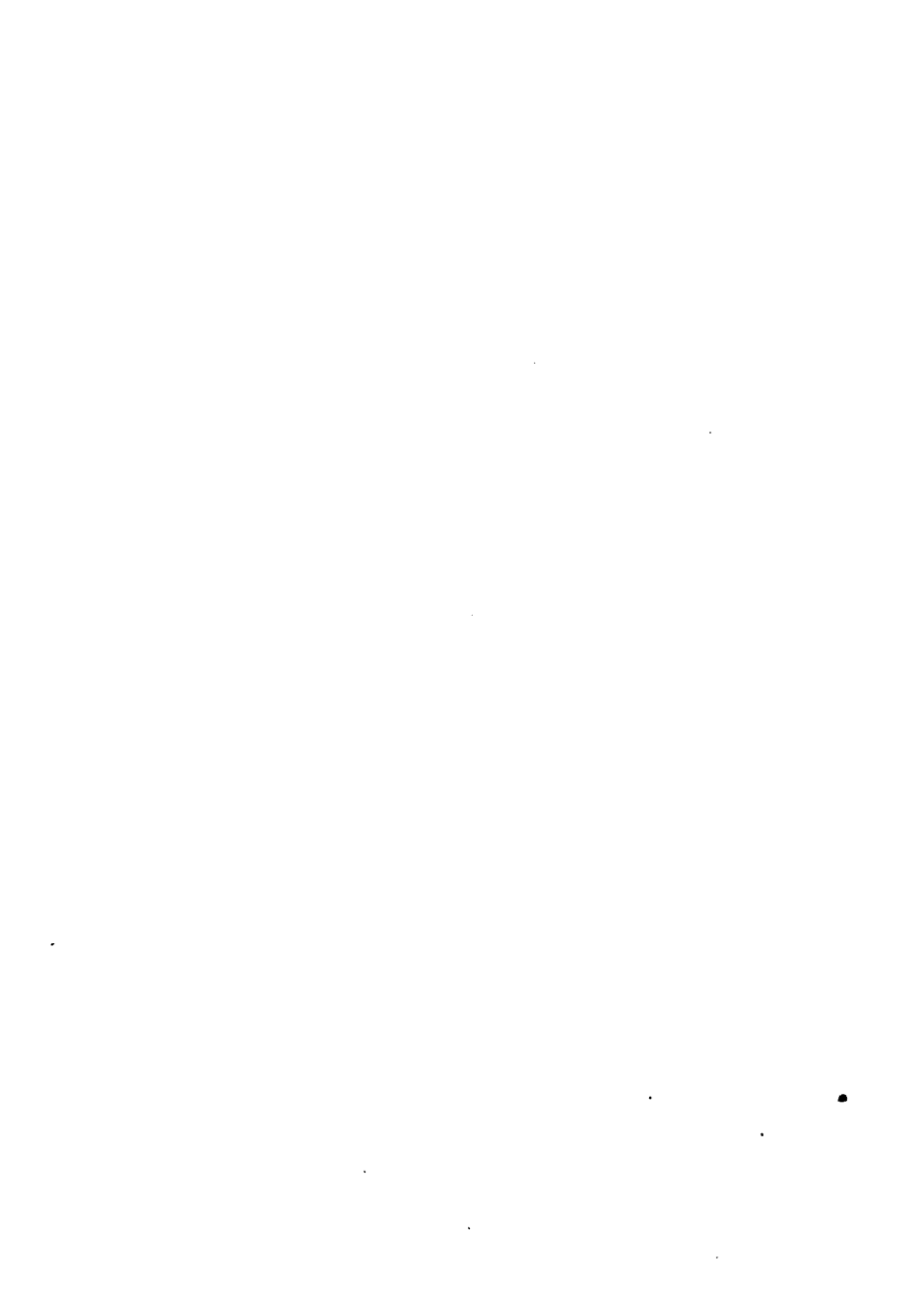
TRIPLE SIGHT-FEED LOCOMOTIVE CYLINDER AND AIR BRAKE LUBRICATOR. (DETROIT.)

- A—Oil Reservoir.
- BB—Auxiliary Oilers.
- C—Connection for Boiler Pressure.
- D—Water Valve.
- EE—Regulating Valves.
- F—Condenser.
- G—Drain Valve.
- HH—Sight-Feed Glasses.
- I—Regulating Valve for Air Pump.
- K—Sight-Feed Glass for Air Pump.
- M—Steam Valve for Boiler Pressure.
- O—Filler Plug.
- R—Steam Connection to Air Pump.
- S—Tallow Pipe Connection to Cylinder.



BOOK III
GENERAL INDEX
TO THE
"SCIENCE OF RAILWAYS."

BOOK III
GENERAL INDEX
TO THE
"SCIENCE OF RAILWAYS."



GENERAL INDEX.

INTRODUCTION.

What follows, while seemingly uninviting, represents long continued labor and, taken in connection with what precedes it, completes the subject of railway carriage. It is at once an Index and, in many respects, an Encyclopedia or key to the door of railway knowledge. By its aid the student may pick out from the woven fabric the particular thread he seeks and follow its devious windings through the different divisions of the railway service with which it is connected and thus obtain a connected view of every subject, no matter how trivial it may seem.

I do not, of course, claim that I have exhausted the subject. If a man could do this, there would never be but one book written on a subject; but, fortunately, what one man writes only serves to stimulate the ambition and broaden the minds of others. I have discovered this in my own experience. Some of my books have been rewritten many times. What they represent today

is an evolution, not only in railway affairs but in my own life and experience as a writer. In my early experience I called in from the publishers and burned many hundreds of books because I became dissatisfied with them. What seemed at first worthy of being printed, I discovered upon reflection and further investigation to be grossly deficient, hence the books called in and burned, to be re-written and burned again and again. However, they served as a guide until, finally, I have been able to write something that seems to me worthy of being read. I hope that I may not be alone in this belief, but that my readers may feel that after many years of effort I have written something worthy of their perusal.

GENERAL INDEX.

[EXPLANATORY NOTE.—In consulting this general index the reader will note that following each subject are Roman numerals; these refer to the particular volume of the series to which reference is made; the Arabic figures following denote the page. Thus an item as follows;

Accidents.....I, 267; II, 250; V, 570; IX, 127; XI, 67
 would mean that the subject of Accidents is referred to in Volume I, at page 267; Volume II, at page 250; Volume V, at page 570; Volume IX, at page 127; Volume XI, at page 67.]

	PAGE
Abbreviations, Avoidance of—in Ordering Material.....	VII, 60
“ “ Use of.....	VI, 94, 111, 123
“ “ —in Telegraphic Orders.....	IV, 392
Ability, Administrative.....	II, 124
Abraham, Carriage in Time of.....	XI, 153
Absolute Block System.....	IV, 293
“ “ English—Rules Governing...IV,	456-463
Absolutism.....	II, 18, 19
Abstracts, Daily Traffic.....	X, 53, 54, 57
“ Errors in.....	VI, 195
“ Freight.....	IX, 45
“ “ —Comparison of, with Way Bills.....	X, 111
“ “ —English.....	VI, 324
“ Notices of Errors and Omissions in—Rules Governing.....	VI, 195
“ of Freight Received.....	VI, 210
“ “ Interline Way Bills Forwarded. VI, 227, 228, 230,	234
“ “ “ Received.....	VI, 228-230, 235
“ “ Local Way Bills Forwarded....VI, 223-226, 230,	232
“ “ “ Received.....	VI, 227, 230, 233
“ “ Way Bills.....	IX, 44, 45
“ Rules Governing.....	VI, 230-232
“ Traveling Auditors’.....	IX, 149
Acadians, The.....	II, 130
Accident, Amelioration of the Condition of Railway Men and Their Families in Cases of.....	X, 291-353
“ Insurance Funds, in Germany.....	X, 345-347
Accidents.....	II, 199, 234; III, 261, 293, 332, 430; IV, 403, 404
“ Assistance at.....	IV, 363, 381, 382
“ at Crossings.....	IV, 130, 131

	PAGE
Accidents Caused by Color Blindness	IV, 242, 243
" " Lighting Cars	IV, 181-183
" Causes of	I, 380; IV, 124, 125
" Due to Defective Equipment	IV, 60
" Information in Regard to	IV, 123
" Judicial Notice of	IV, 127
" Legislation to Prevent	VIII, 316
" Obstruction of Main Track by	IV, 377, 378
" Prevention of—at Stations	IV, 121
" Railway—in Early Days	III, 121
" Relation of Discipline to	IV, 125-127
" " Speed to	IV, 125
" Remissness of Laws Relating to	IV, 127, 128
" Reporting	IV, 361, 331, 415, 428, 435; V, 177
" to Baggage	V, 327, 328
" " Employes	IV, 122, 123
" Train	I, 333; IV, 81
" Writings on	IV, 107-109
Accommodations, Interior—of Cars	V, 28,
" Passenger	V, 25
—in America	V, 31, 32
Accordion Car	I, 204
Accountant	II, 63
" Car	IV, 58; VI, 49, 63, 67, 68; X, 67
Accountants, Car—International Association of	VI, 54
" Characteristics of	IX, 153-157
" Devices of	II, 276, 277; V, 74; IX, 154
" Different Methods of	IX, 43, 44
" Duties of	V, 71, 72; X, 27
" Freight	II, 248
" Methods of ..	V, 69
" Railway	IX, 303, 304; X, 24
" Skilled—Employment of	IX, 37, 38
" Ticket	II, 248
Accounting, Baggage	V, 479
" Carelessness in	X, 262
" Cheap Systems of	VII, 235, 236; X, 25, 26
" Corporate	V, 68
" " —Purpose of	IX, 330
" Cost of	II, 304; X, 25, 26
" " —Upon What Dependent	VII, 235
" Department	I, 288; II, 137, 139,
272-305; V, 69; IX, 300, 304; X, 41	
" " —A Safeguard	II, 282
" " Chief of	II, 285
" " Duty of	V, 70
" " English	VI, 329
" " in Early Times	II, 279, 283
" " Management of	X, 36, 37
" " Organization of	II, 248

	PAGE
Accounting, Details of—in Connection with Construction	
Work.....	VII, 469-471
Effective.....	X, 24
Effect on Cost of—by Charging for Transportation of Railway Material.....	VII, 202
Expenses of.....	II, 279
Expensive Systems of.....	X, 26
Extravagance in.....	VII, 238
for Excess Baggage Revenue.....	V, 506-514
Forms Used in.....	V, 71
Freight.....	VI, 79, 82-85
Knowledge Possessed by.....	X, 64
Necessity of Clearness and Accuracy in.....	IX, 297-306
Officer, Assistants of.....	II, 283, 284
Authority of.....	II, 291
Discretion of.....	II, 289
Duties of.....	II, 272-305
—His Relation to Other Officers.....	II, 291, 298
—Meaning of Title.....	II, 141
Office of.....	V, 69, 70
Relation of—to Manager.....	II, 299-301
“ —to Treasurer.....	II, 192, 193
Requirements of.....	V, 72-74
Title of.....	VII, 249
Officers.....	V, 507; VI, 18; X, 48, 49
Association of American Railway.....	II, 278; V, 13; VI, 92, 125
English.....	II, 274
Presumption of Errors in.....	IX, 37, 39
Railway—Diversity in Methods of.....	VII, 236
“ —Needs of.....	VI, 87-90
Systems of.....	IX, 85, 86
The Author's Method of.....	VI, 89, 90
Transition State of.....	X, 26, 27
Use of Carbon Sheets in.....	VI, 89, 90
Accounts.....	I, 267
Access to—by Treasurer.....	II, 192
Advantages of Efficient System of.....	IX, 219, 220
Against Persons for Material and Labor.....	VII, 414-429
Agents'—Auditing.....	V, 84, 85; IX, 307
—Principles Governing.....	IX, 35-64
—Transferring.....	IX, 256-261, 411, 412
and Cash, Concentration of.....	II, 285, 286
Appliances of.....	V, 72
Arrangement of—in Distribution of Material Book.....	VII, 319
Auditing.....	II, 285, 286, 291, 300; X, 24, 68, 91, 199
Authentication of.....	II, 283
Baggage—Auditing.....	X, 134
Balancing.....	IX, 407-411

	PAGE
Accounts, Bank—Auditing.....	X, 266
“ Books of—Necessity of.....	X, 28
“ Certifying.....	X, 92
“ Changes in.....	X, 49
“ —Channels Through Which They Pass.....	X, 86-90
“ Cheapening.....	II, 279
“ Collection of.....	V, 519, 537
“ Complication of.....	II, 282
“ Conductors’—Auditing.....	V, 84, 85; IX, 307
“ Construction.....	VII, 197, 198
“ —Classification of.....	VII, 456-469
“ Corporate.....	IX, 219-221
“ —On What Based.....	X, 49
“ Correction of Errors in... VI, 187, 189; IX, 40, 361-366	
“ Correspondence in Regard to.....	V, 173
“ Covering Up Deficiencies in.....	IX, 136, 137, 139, 140
“ Current, Agents’.....	IX, 262-270
“ Different Methods of Keeping.....	X, 64, 65
“ Dining Car Service.....	VII, 301, 302
“ Disbursement.....	II, 290
“ “ Method of Keeping.....	VII, 243
“ “ Necessity of Accuracy and Definiteness in.....	VII, iv
“ “ Summarizing.....	X, 83, 89
“ Disposition of Supplies in.....	VII, 28, 29
“ Division of.....	X, 60-62
“ Elaboration of.....	X, 55
“ Errors in.....	IX, 39
“ Examination of.....	VI, 189; VII, 432
“ —English System.....	X, 23
“ Express.....	V, 541
“ Extent of Devices in.....	II, 278
“ Facilitating.....	II, 279
“ Freight.....	II, 248; V, 75, 76
“ —Auditing.....	X, 109-120
“ —Their Complexity.....	VI, i
“ Fuel.....	VII, 323, 330-336
“ in Early Days.....	II, 272-274
“ Indexing.....	X, 75
“ Joint Freight.....	X, 112-118
“ Keeping.....	X, 38
“ Labor.....	VII, 349-413, 430
“ —Certification of.....	VII, 354, 355
“ —Methods of Keeping.....	VII, 240, 244
“ Ledger.....	X, 70-76
“ Material.....	VII, 42-44, 252-272, 312-316, 430
“ —Methods of Keeping.....	VII, 240, 244
“ —What They Represent.....	VII, 273
“ Multiplex System of.....	
“ VI, 90, 120, 175, 181, 187, 226, 254, 293; IX, 86	

	PAGE
Accounts, Necessity of Accurate.....	I, 281
“ Object of.....	X, 21-34, 49
“ of Railways.....	V, 72; VIII, 296-298
“ Omissions from.....	IX, 39
“ —On What Based.....	VI, 81, 82
“ Operating.....	III, 404
“ —Charges Against.....	VII, 64
“ Organization of.....	IX, 26, 46; X, 35-59
“ Passenger.....	II, 248
“ —Auditing.....	IX, 117; X, 121-134
“ —Auditor of.....	V, v, 81
“ Pay.....	VII, 353, 354
“ —Access to.....	VII, 369
“ Paying.....	X, 199, 275
“ Paymasters'.....	X, 238
“ Payment of—by Agents.....	IX, 180, 181
“ Purpose of.....	V, 190
“ Railway.....	X, 21-34
“ —Appliances of.....	X, 40, 41
“ —Auditing.....	II, 258, 259
“ —Classified Schedule of.....	X, 357-361
“ —Different Methods of Keeping.....	IX, x
“ —Difficulty of Handling.....	X, 35
“ —Necessity of.....	VI, 77
“ —Uniformity in.....	VII, 237
“ Recapitulations of.....	VII, 538-541
“ Revenue.....	II, 290
“ Rules for Handling.....	VI, 84, 85
“ Should Be Impersonal.....	II, 305
“ Special.....	VII, 414-429
“ Spreading—on General Books.....	X, 63-69
“ Station.....	IX, 124-157
“ —Auditing.....	IX, 77-97
“ —Examination of.....	IX, 136-138, 140, 141, 226-231, 236-240, 248
“ Statistical.....	X, 28, 29
“ Supervision of.....	II, 285, 292
“ Suppression of.....	IX, 55, 96; X, 58
“ Systems of.....	II, 296
“ —Their Effect Upon the Care and Repair of Locomotives and Cars.....	I, 281, 282
“ Theory of.....	X, 63-69
“ Ticket.....	V, 75; IX, 108, 109
“ —Bureau of.....	V, 17
“ —Communications Referring to.....	V, 175
“ —Handling, in America.....	V, 81
“ Track.....	III, 206, 284; VII, 111
“ Traffic.....	IX, 341
“ —Auditing.....	II, 248, 249
“ —Posting.....	X, 68

	PAGE
Africa—Its Primitive Associations and Means of Carriage.....	XI, 219-230
“ Primitive Carriage in— <i>Illustrations</i>	XI, 219-230
Agencies, Car Service.....	IV, 58
“ Collecting—for Freight Charges.....	IX, 71-74
“ Express—Classification of.....	V, 541
“ New—Opening.....	IX, 261
“ Transferring.....	IX, 286
Agent, Claim.....	II, 224, 234, 236; VI, 287
“ Division Freight.....	II, 139
“ Foreign.....	II, 139
“ General Baggage.....	II, 139
“ “ Freight.....	II, 138
“ “ “ —Correspondence of.....	II, 244, 245
“ “ “ —Duties of.....	II, 241-249
“ “ “ —Knowledge of.....	II, 246, 247
“ “ Passenger.....	II, 139, 249-259
“ “ “ —Characteristics of.....	II, 256, 257
“ “ Ticket.....	II, 139, 249, 259
“ “ “ —Characteristics of.....	II, 254
“ Goods—English.....	II, 208
“ Local Freight.....	II, 139
“ “ Passenger.....	II, 139
“ —Meaning of Title.....	II, 142
“ Purchasing.....	II, 138
“ “ and Sales.....	II, 260-271
“ “ “ —Character of.....	II, 261, 262, 268
“ “ “ —Opportunities of.....	II, 263
“ “ “ —Selection of.....	II, 266
“ Station.....	II, 58
“ Title of.....	VII, 250
“ Traveling Freight.....	II, 139
“ “ Passenger.....	II, 139
Agents, Accounts of—Auditing.....	V, 84, 85; IX, 307
“ “ “ —Principles Governing.....	IX, 35-64
“ Advances on Freight by.....	IX, 87
“ Age of.....	IX, 30, 31
“ and Conductors, Fiscal Duties of.....	IX, 293-324
“ Appointment of.....	IX, 25-28
“ Authority Over.....	II, 199
“ Baggage—Accounts of, Rules Governing.....	V, 506-514
“ “ “ —Miscellaneous Instructions to.....	V, 443-445
“ “ “ —Responsibility of.....	V, 433
“ “ “ —Returns of.....	V, 434, 435
“ Cash Transactions of.....	IX, 304, 305
“ Claim.....	V, 319
“ Commercial.....	V, 474
“ Difference Between Efficient and Poor.....	V, 114
“ Disbursements Made by.....	IX, 358-361
“ Drafts Drawn by.....	IX, 358-361

	PAGE
Agents, Duties of—in Procuring Business.....	V, 112-115
“ Fiscal Duties of.....	IX, 307-434
“ Foreign—Apportionment of Cost of.....	VII, 508
“ Forwarding.....	VI, 109
“ “ —Instructions to.....	VI, 138
“ General Baggage—Association of.....	V, 488, 491
“ “ Claim—Relief Vouchers Made by.....	IX, 372
“ “ Instructions to.....	V, 169-176; VI, 313
“ “ Passenger.....	V, 80, 81
“ “ Ticket.....	V, 79, 80
“ Information Afforded by.....	VI, 105, 316
“ Intermediate—Instructions to.....	VI, 163
“ Irresponsible—Employment of.....	II, 110
“ Junction—Instructions to.....	VI, 163
“ Leaving Service, Retaining Wages of.....	VII, 404, 405
“ Liability of—for Tickets.....	V, 129, 135
“ Money Collected by—Account Various Persons.....	VII, 421, 422
“ “ Deposited with.....	IX, 311
“ News.....	V, 419
“ Orders of—for Money.....	V, 146-150
“ “ Tickets.....	V, 146-150
“ Pay Checks Cashied by.....	X, 248-250
“ Payment of Bills by—Before Audit.....	VII, 441, 442
“ “ Time Tickets by.....	VII, 406-409
“ Payments Made by.....	IX, 326, 327
“ Purchasing—Relief Vouchers Made by.....	IX, 371
“ “ —Requirements of.....	VII, 49
“ Receiving.....	VI, 109
“ “ —Instructions to.....	VI, 168-173
“ Relation of—to Subordinates.....	IX, 351, 352
“ Relief Claims.....	VI, 295, 296
“ Remittances of.....	V, 174; IX, 412-419; X, 135-139, 266
“ Responsibility of—for Subordinates.....	V, 174
“ Returns of.....	V, 156-158
“ “ —English.....	VI, 324-326
“ “ —for Tickets Sold.....	V, 81
“ “ Required of.....	VI, 83
“ Route—Express.....	V, 539
“ Rules Governing.....	V, 112
“ Selection of.....	IX, 20, 32
“ Source from Which Drawn.....	IX, 27
“ Station.....	VI, 13, 14, 16, 17
“ “ —Bank Accounts of.....	IX, 289
“ “ —Bonding.....	IX, 242-244, 353-358
“ “ —Care of Cash by.....	IX, 167
“ “ —Claims of.....	IX, 369-374
“ “ —Credit Extended by.....	IX, 68, 69
“ “ —Defaulting.....	IX, 193-218
“ “ —Dismissal of.....	IX, 222-224, 244, 245

GENERAL INDEX.

19

	PAGE
Agents, Station—Duties of.....	IX, 75
“ “ —Express, Telegraph, Insurance and Other Moneys Collected by.....	IX, 142, 143
“ “ —Fiscal Affairs of.....	IX, 219-249
“ “ —Frauds by.....	IX, 245-249
“ “ —Incompetent.....	IX, 220, 221, 252, 253
“ “ —Indemnifying for Uncollectible Charges...	IX, 132, 133
“ “ —Inefficient.....	IX, 220, 253, 289
“ “ —Installing.....	IX, 250-261
“ “ —Joint.....	IX, 234-236
“ “ —Overcharges Collected by.....	IX, 366
“ “ —Payment of Bills by.....	X, 98, 99
“ “ “ “ Vouchers by. VII, 438; IX, 374-378	
“ “ —Qualities of.....	IX, 75, 76
“ “ —Relieving of Amounts Charged to.....	IX, 129-131, 369-374
“ “ —Remittances of.....	IX, 135, 179-181, 291
“ “ —Removal of, by Traveling Auditors... IX, 288	
“ “ —Responsibility of.....	VI, 107; IX, 347-349
“ “ —Returns of.....	IX, 45; X, 67
“ “ —Their Check Upon Each Other... IX, 52	
“ “ “ “ Influence on Patrons.....	IX, 76
“ “ —Transferring Accounts of... IX, 250-261, 411, 412	
“ Supervision Over.....	IX, 32
“ Ticket—Defaulting.....	IX, 216
“ “ —Fraudulent Collusion with Conductors	IX, 214-216
“ Train.....	V, 17
“ Transfer—Traffic Returns of.....	IX, 53, 56
“ Vouchers Paid by.....	X, 278
“ Working Funds of.....	IX, 329, 332-334
Agitators.....	II, 18
Agrarianism.....	XI, 44
Agreements.....	III, 80
“ Authentication of.....	II, 182
“ Drawing.....	II, 137, 232
“ Making.....	III, 425
Agricultural Implements, Advances on.....	IX, 89
Ahead of Time—Meaning of Term.....	IV, 316
Air, Application of—at Atmospheric Pressure.....	I, 292
“ Brake.....	I, 110, 204; IV, 114, 115
“ “ Apparatus.....	I, 315
“ “ Application of—in Service—Instructions to En- glnemen.....	I, 317, 318
“ “ Construction and Operation of.....	I, 291
“ “ Coupling, Extra.....	I, 321
“ “ Explanation of a Popular Form of Automatic... I, 538	
“ “ Failures, Cause of.....	I, 375, 376
“ “ Hose.....	I, 321

	PAGE
Air Brake—How to Use It.....	I, 314-333
“ “ Invention of.....	I, 308
“ “ Mechanism, Armored— <i>Illustration, Plate II.</i>	I, 116-117
“ “ “ Coupling— <i>Illustrations, Plate II.</i>	I, 116-117, 309
“ “ “ Extra.....	I, 321
“ “ “ —Release or Charging Position— <i>Illustration.</i>	I, 337
“ “ “ —Set Position— <i>Illustration.</i>	I, 338
“ “ Number of Men Required to Manufacture.....	I, 133
“ “ Straight.....	I, 305
“ “ —The First Form Successfully Used.....	I, 305
“ “ “ Perfected.....	I, 333-363
“ Braked Cars, Hand Brakes on—Instructions to Trainmen.....	I, 374
“ “ “ Setting Out.....	I, 374
“ Brakes, Automatic.....	I, 300, 334-336
“ “ for Motor Cars.....	I, 485
“ “ Introduction of.....	I, 294
“ “ Jerking with.....	I, 368
“ “ Kinds of.....	I, 334
“ “ “Straight”.....	I, 334, 335
“ “ Testing.....	I, 269
“ “ Use of.....	IV, 416, 423
“ Carbureted—Use of, for Lighting Cars.....	IV, 175
“ Cocks—Instructions to Trainmen.....	I, 372
“ Compressed.....	I, 110, 244, 262, 269, 274, 305, 307, 334
“ “ —for Shop Purposes.....	I, 384
“ “ —Locomotives Propelled by.....	I, 223
“ “ —Use of, for Protecting Trains Automatically.....	IV, 299-301
“ Compressor.....	I, 244, 262, 485
“ “ The Sweeney— <i>Illustration.</i>	I, 383
“ Cylinder Brake Pump— <i>Illustration, Plate I.</i>	I, 58-59
“ Delivery Pipe, from Pump to Main Reservoir— <i>Illustration.</i>	I, 539
“ Drum— <i>Illustration, Plate I.</i>	I, 58-59
“ “ Bracket— <i>Illustration, Plate I.</i>	I, 58-59
“ Gauge.....	I, 315, 336
“ “ — <i>Illustration, Plate I.</i>	I, 58-59
“ “ Duplex.....	I, 349
“ “ “ — <i>Illustration.</i>	I, 316
“ Heated—Circulation of.....	I, 261
“ Hoists.....	I, 248
“ Hot—Use of, for Heating Cars.....	IV, 155, 156
“ “ “ “ “ in Europe.....	V, 235
“ Jacks.....	I, 269
“ “ Portable.....	I, 275
“ Operations of—Through Automatic Brake System....	I, 336
“ Pipe, Check Valve in— <i>Illustration, Plate II.</i>	I, 116-117

	PAGE
Air Pipe from Main Reservoir to Engineer's Valve— <i>Illustration</i>	I, 539
" Pipes, for Testing Purposes.....	I, 382
" " in Engine House.....	I, 328
" Piston.....	I, 352, 353
" Pressure	I, 302
" " Gauge— <i>Illustration</i>	I, 539
" " Governor— <i>Illustration, Plate II</i>	I, 116-117
" " Maintaining	I, 320
" " Train Line, Standard.....	I, 312
" Pump.....	I, 292, 308, 315, 320, 334, 336, 485, also Vol. XII
" — <i>Illustration</i>	I, 539, also Vol. XII
" " Exhaust Pipe— <i>Illustration, Plate I</i>	I, 58-59
" " —Instructions to Enginehouse Foremen and Inspectors.....	I, 328
" " Testing.....	I, 328
" " Throttle— <i>Illustration, Plate I</i>	I, 58-59
" " Westinghouse.....	I, 538
" Pumps	I, 384
" " Location of.....	I, 381
" " Lubricator— <i>Illustration, Plate I</i>	I, 58-59
" " Steam Unions of.....	I, 381
" —Quantity Conveyed to Fire Box.....	I, 70
" Reservoir	I, 292
" Resistance of	IV, 97, 98
" Signal	I, 321; IV, 250
" " Care of	I, 382
" " Couplings	I, 375
" " Hose— <i>Illustration, Plate I</i>	I, 58-59
" " " Extra.....	I, 328
" " —Instructions to Engineers	I, 366
" " Train	I, 317, 322, 330
" " " —Operations of.....	I, 362
" Signaling Apparatus, Train— <i>Illustrations</i>	I, 385, 386
" Storage Reservoir.....	I, 244, 262
" Strainer— <i>Illustrations</i> , { <i>Plate I</i>	I, 58-59
" " { <i>Plate II</i>	I, 116-117
" Superheated.....	I, 104
" Tank— <i>Illustration, Plate II</i>	I, 116-117
" " Drip Cock in— <i>Illustration, Plate II</i>	I, 116-117
" Valves	I, 95
" Vent from Water Tank— <i>Illustration, Plate II</i>	I, 116-117
" Whistle.....	IV, 115
Akron, Bedford & Cleveland Railway—Use of Electricity on	I, 489, 490
Alabama, Railway Taxation in.....	III, 451
Alcinous.....	XI, 152
Alexander the Great.....	X, 48; XI, 105, 124
Alexandria.....	I, 17

	PAGE
Algeria—Its Primitive Associations and Means of Carriage.....	XI, 231-236
" Primitive Carriage in— <i>Illustrations</i>	XI, 231-236
Alignment.....	III, 301
" Effect of—on Cost of Operation.....	III, 393
" Imperfect.....	III, 430
" Improving.....	II, 221
Allen, Horatio.....	I, 28
Alphabet.....	XI, 118, 119
Alternating Current.....	I, 407, 408, 421-426
" " and Direct Current.....	I, 426
" " —Direct Current System.....	I, 430, 440, 451, 487, 488
" " Generation and Transmission of.....	I, 487
" " Generator (650 Kilowatt), Two-Phase— <i>Illustration</i>	I, 500
" " Generators.....	I, 440, 449, 452
" " Induction Motor, Complete— <i>Illustration</i>	I, 444
" " Modifications.....	I, 486
" " Motor, Evolution of the.....	I, 445
" " Motors.....	I, 412, 426, 441, 442
" " System.....	I, 430, 441-449, 452, 453, 488, 489
" " System, Supplying Polyphase Current by Two Trolleys and Rail Return to Alternating Current Motors on the Cars— <i>Illustration</i>	I, 441
" " System, Supplying Rotary Trans- formers Which Deliver Direct Current to the Trolley System— <i>Illustration</i>	I, 426
" " Transformation of—into Direct Cur- rent.....	I, 426
" " Transformer.....	I, 423, 424
" " " Windings of.....	I, 422, 423
" Magnetism.....	I, 422
Amber.....	XI, 135
Ambrosovics, M. Bela.....	X, 42
Amelioration of the Condition of Railway Men and Their Families in Cases of Accident, Sickness, Disability and Death.....	X, 291-353
Amenophis III.....	XI, 109
America, Association for Handling Claims in.....	VI, 20
" Box Car In.....	I, 207
" Capitalization in.....	III, 142
" " of Railways in.....	III, 69
" Car Adopted in.....	I, 171
" Carriage of Parcels in.....	V, 517, 518
" Checking Baggage in.....	V, 377-383
" Construction of Railways in.....	III, 143, 149-151

	PAGE
America, Construction of Tunnels in	III, 188, 189
“ Cost of Operating in	III, 146
“ Decorations of Passenger Cars in	I, 147
“ Distances Traversed in	I, 189
“ Duties of Trainmen in	IV, 17
“ Early Railways in	III, 116-117
“ Efficiency of Handling Passengers in	I, 287, 288
“ Financial Conditions in	I, 50
“ First Four-Wheeled Bogie in	I, 50
“ “ Headlight in	I, 57
“ “ Rail Rolled in—Baltimore & Ohio Railroad— <i>Illustration</i>	III, 233
“ Form of Cylinders in General Use in	I, 88
“ Freight Carload in	I, 205
“ “ Traffic in	VI, 9, 10
“ High-Class Passenger Cars in	I, 181, 182
“ Improvident Use of Freight Cars in	VI, 55, 56
“ Inauguration of Railway Operations in	I, 28
“ Kinds of Tickets Used in	V, 88-111
“ Loads Hauled by Engines in	I, 206
“America” Locomotive, 1829	I, 28
America, Locomotives in	I, 111
“ Low Rates in	III, 146
“ Passenger Accommodations in	V, 31, 32
“ Popularity of Parlor Car in	I, 195
“ Practice of Locomotive Builders in	I, 64
“ Railway Operations in	I, 152
“ “ Taxation in	III, 435-453
“ “ Travel in	I, 202
“ Rivalry Among Travelers in	I, 202
“ Scarcity of Money in	I, 50
“ Speed of Freight Trains in	I, 31
“ Use of Brakes in	I, 314
“ “ Crude Oil in	I, 54
“ “ “ Headlights in	I, 57
“ “ “ Private Cars in	VI, 69, 70, 73, 74
“ “ “ the Bogie in	I, 50
American Accounting Company	IX, 86, 97
“ Apartment Car— <i>Illustration</i>	I, 227
“ Association of Railway Superintendents	IV, 28
“ Bogie (or Pony) Truck, Side View of— <i>Illustration</i>	I, 66
“ Buffet Smoking Car, Interior of— <i>Illustration</i>	I, 212
“ Car, Smoking Compartment in— <i>Illustration</i>	I, 213
“ Coach	I, 203
“ “ —How Looked Upon by English People	I, 184
“ Designers and Mechanics	I, 139
“ Dining Car— <i>Illustration</i>	I, 219
“ Drawing Room or Parlor Car	I, 200
“ Flat Cars, Standard— <i>Illustration</i>	I, 153

	PAGE
American Four-Wheeled Saddle Tank Engine— <i>Illustration</i>I,	105
“ Gondola Car, Standard— <i>Illustration</i>	I, 160
“ Horse Car— <i>Illustration</i>	I, 196
“ Institute of Electrical Engineers.....	I, 391
“ Locomotive	I, 150
“ “ Standard— <i>Illustration, Plate I</i>	I, 58-59
“ “ Superior Qualities of ..	I, 44, 151, 152
“ Logging Truck— <i>Illustration</i>	I, 154
“ Manufacturers	I, 152
“ “ of Electrical Apparatus Relating to Carriage.....	I, 139
“ Master Car Builders' Association.....	I, 203
“ Observation Car— <i>Illustration</i>	I, 228
“ Palace Car, Apartments in— <i>Illustration</i>	I, 223
“ “ “ for Day and Night Use— <i>Illustration</i>	I, 224
“ Parlor Car— <i>Illustration</i>	I, 219
“ Passenger and Sleeping Car, Standard— <i>Illustration, Plate II</i>	I, 116-117
“ Plate Girder Overhead Bridge— <i>Illustrations</i>	III, 379, 381
“ Postal Car, Interior of— <i>Illustration</i>	I, 206
“ Railway Accounting Officers, Association of.....	V, 550; VII, 348, 468, 465, 467, 535
“ “ Association.....	IV, 76, 276, 327, 341, 498, 499, 509; VI, 65
“ “ Managers.....	III, 141
“ Railways, Construction of.....	II, 26
“ “ Earning Capacity of.....	I, 166
“ “ Efficiency of.....	V, 357
“ “ Operation of.....	II, 26
“ “ Safety of.....	II, 26
“ “ Train Service of.....	IV, 10
“ Reclining Chairs— <i>Illustration</i>	I, 218
“ Reversible Seat— <i>Illustrations</i>	I, 217
“ Sleeping Car.....	I, 200
“ Standard Baggage and Buffet Smoking Car— <i>Illustration</i>	I, 211
“ “ “ Car— <i>Illustration</i>	I, 209
“ “ Box Freight Car.....	I, 167
“ “ “ “ and Truck — <i>Illustration, Plate III</i>	I, 170-171
“ “ “ “ Cross Section of— <i>Illustration</i>	I, 169
“ “ “ “ End Elevation of— <i>Illustration</i>	I, 168
“ “ “ “ Sectional View— <i>Illustration</i>	I, 167
“ “ Freight Car.....	I, 207-214
“ “ “ Coupler— <i>Illustrations</i>	I, 175

	PAGE
American Standard Freight Car—End Elevation and Section Through Journal Box of Truck— <i>Illustration</i> I, 178	178
“ “ “ “ Plan of Truck of— <i>Illustration</i> I, 180	180
“ “ “ “ —Side Elevation and Section at Center Bearings of Truck— <i>Illustration</i> I, 177	177
“ “ “ “ Truck—Section Showing Body and Truck Bolsters — <i>Illustration</i> I, 179	179
“ “ Gauge I, 402	402
“ “ Passenger Coach— <i>Illustration</i> I, 216	216
“ “ Postal Car— <i>Illustration</i> I, 205	205
“ “ Railway Passenger Car— <i>Illustration</i> I, 215	215
“ “ Sleeping and High-Class Passenger Car — <i>Illustration</i> I, 223	223
“ “ Stock Car— <i>Illustration</i> I, 192	192
“ “ Suburban Milk Car— <i>Illustration</i> I, 209	209
“ Steel Flat Car— <i>Illustration</i> I, 153	153
“ “ “ “ —View of Under Side— <i>Illustration</i> I, 154	154
“ Vestibule Car— <i>Illustration</i> I, 221	221
Americans, Habits of—on Trains I, 176	176
Ammeter I, 461	461
Ampere, Definition of I, 401	401
Amyntas XI, 105	105
Anchor Iron, Truss Rod— <i>Illustration, Plate II</i> I, 116-117	116-117
Ancient Devices of Business VII, 229-231	229-231
“ Primitive Associations and Means of Carriage, XI, 489-509	489-509
“ “ Carriage— <i>Illustrations</i> XI, 489-509	489-509
“ Wheel— <i>Illustration</i> IV, 191	191
Ancients, Horses of XI, 86	86
“ Ideas of—Regarding Light IV, 169	169
“ The XI, 154	154
“ Writings of—Reference to Use of Air Brake in I, 293	293
Angle Cock I, 326, 372, 373, 375, 377	326, 372, 373, 375, 377
“ — <i>Illustrations, Plate II</i> I, 116-117, 320, 321, 372	116-117, 320, 321, 372
“ “ Train Pipe— <i>Illustration, Plate III</i> I, 170-171	170-171
“ Cocks, for Closing Train Pipe— <i>Illustrations</i> I, 540, 541	540, 541
“ Drip Valve— <i>Illustration, Plate II</i> I, 116-117	116-117
“ Fitting— <i>Illustration, Plate II</i> I, 116-117	116-117
“ Plates III, 335-340	335-340
“ Splice Bar, A. D. 1875— <i>Illustration</i> III, 293	293
“ “ “ A. D. 1879— <i>Illustration</i> III, 296	296
“ “ “ A. D. 1880— <i>Illustration</i> III, 298	298
“ “ “ A. D. 1885— <i>Illustration</i> III, 303	303
“ Valve— <i>Illustration, Plate II</i> I, 116-117	116-117
Animal Power, Use of I, 394	394
Animals, Transportation of Portable Railroads by I, 223	223

	PAGE
Animals, Valuable—Carriage of	V, 519
Annealing Furnace.....	I, 266
" Pit.....	IV, 204
Annuities.....	II, 60
Apartment Car, American— <i>Illustration</i>	I, 227
" Cars, American—Capacity of.....	I, 199
" in a Palace Car— <i>Illustration</i>	I, 222
Apartments in an American Palace Car— <i>Illustration</i>	I, 223
Apparatus, Air Brake.....	I, 315
" " Signaling.....	I, 362
" Automatic Electric Block System.....	IV, 280
" Brake—Inspection of.....	I, 330
" Electrical—Development of.....	I, 521, 522
" " —Engravings of.....	I, 391
" " —Limitations of.....	I, 427-430
" " —Manufacturers of.....	I, 139
" " —Upon What Based.....	I, 523
" Signal.....	I, 378
" Telegraphic.....	I, 401
" Train Air Signaling— <i>Illustrations</i>	I, 385, 386
Applan Way.....	VII, 217
Appliances, Car.....	V, 37-39
" Electrical—of Railways.....	VII, 213
" for the Care and Maintenance of Rolling Stock.....	I, 238
" Heating—of Shops.....	I, 261
" Improvements in.....	IV, 27, 69, 70
" Mechanical—Use of, by Carriers.....	VIII, 7, 28
" of the Car Accountant's Office.....	VI, 67
" Railway.....	I, 281; III, 168; VII, 257; X, 40
" Safety.....	IV, 106-145
" " —Adoption of.....	II, 26; IV, 134, 135, 137, 138
" " —Power of State to Enforce.....	IV, 138
" Sanding—Automatic.....	I, 313
" Signal—on Trains.....	IV, 403, 404
" Station.....	V, 37-39
" Surgical.....	II, 232
" Track.....	II, 212
" " —Evolution of.....	III, 174, 199, 200
Applicants for Indemnity Bonds.....	IX, 165, 166, 170, 171
" Passing Upon.....	IX, 28, 29
Application of Brakes from an Unknown Cause—Instruc- tions to Enginemen.....	I, 319
" " the Air Brake in Service—Instructions to Enginemen.....	I, 317, 318
" " Automatic Brake and Brake Shoe to the Driving Wheels— <i>Illustration</i>	I, 542
" " Brake in Emergency—Instructions to Enginemen.....	I, 319
Applying Brakes.....	I, 326, 334-336, 348
Appointments, Investigations Preceding.....	IX, 28, 29

	PAGE
Armature, Surface-Wound.....	I, 473
" Toothed.....	I, 473
" Weight of.....	I, 469
" Wires.....	I, 410
" with Coils in Place— <i>Illustration</i>	I, 413
Armies, of Corporations.....	IX, 12
Armenia—Its Primitive Associations and Means of Carriage.....	XI, 316-327
" Primitive Carriage in— <i>Illustrations</i>	XI, 316-317
Armored Air Brake Hose— <i>Illustration, Plate II</i>	I, 116-117
" Signal Hose— <i>Illustration, Plate II</i>	I, 116-117
Army Life, Discipline of.....	II, 19
" The Railway.....	II, 13
" " —Action of.....	II, 13
" " —Freedom in.....	II, 13
" " —Obedience in.....	II, 13
" " —Organization of.....	II, 13
" " —Purpose of.....	II, 13
" United States.....	II, 120, 121
" " —Purchase and Care of Material in.....	II, 270
Articles, Damaged—Provision for Storing.....	I, 272
" Manufactured by a Company, Charging... VII, 321-324	
Articles Manufactured by the Company".....	VII, 324
Articles, Number of—Used by Railways.....	VII, 207-215
" of Common Use, Care of.....	VII, 202
" Old—Return of.....	VII, 259-262
" —Railways Manufacture.....	VII, 126, 129
Artificial Limbs.....	II, 232
Arrangement of Railroad Shops and Roundhouses.....	I, 230
" " Shop Labor.....	I, 283
" " Shops.....	I, 283
" " and Shop Work.....	I, 288
Aryans.....	I, 159, 160; XI, 10, 54-57, 61-63, 75
" Perfection of Carriage Among.....	XI, 47
" Vehicles of.....	XI, 53
" Wheels Made by.....	IV, 188
Ashbel Welch Rail, A. D. 1866— <i>Illustrations</i>	III, 279-281
Ashes, Air Holets for Handling.....	I, 246
" Disposition of.....	I, 246
" Handling.....	I, 259
Ashley, O. D.....	II, 95
Ash Pan.....	I, 96, 246
" " — <i>Illustration, Plate I</i>	I, 58-59, 60
" " Damper Handle— <i>Illustration, Plate I</i>	I, 58-59
" " Dampers.....	I, 69
" Pans, Cleaning.....	IV, 427
" Pit— <i>Illustration, Plate II</i>	I, 116-117
" " Bottom— <i>Illustration, Plate II</i>	I, 116-117
" " Door— <i>Illustration, Plate II</i>	I, 116-117
" " " Handle— <i>Illustration, Plate II</i>	I, 116-117

GENERAL INDEX.

29

	PAGE
Asia.....	I, 217
" Central.....	XI, 54
" " —Use of Portable Railroads in.....	I, 223
Asphaltum, Use of—by Railways.....	VII, 213
Aspirations of Railway Employes.....	II, 63
Ass, Ancient Use of—as a Carrier.....	XI, 109
Assets, Custody of.....	II, 186
" Description of.....	X, 183
" —What They Consist of.....	X, 62
Asshurbanipal.....	XI, 103
Assistance Funds, Italian.....	X, 349, 350
Assistant General Superintendent, Scope of.....	II, 174, 175
Association, American Railway.....	IV, 76, 276, 327, 341, 498, 499; VI, 65
" Car Accountants'.....	VI, 57
" General Ticket Agents'.....	V, 79
" Master Mechanics'.....	I, 64
" of American Railway Accounting Officers, II, 278; V, 13, 550; VI, 92, 125; VII, 348, 458, 465, 467, 535	
" " General Baggage Agents.....	V, 488, 491
" Southern Railway and Steamship—Demurrage Rules of.....	VI, 337, 338
Associations, Advocates of.....	I, 225, 226
" Artificial—of Labor.....	II, 35
" Benefits of.....	I, 229
" Car Service.....	VI, 57, 58
" for Inspecting and Weighing Goods.....	VI, 24
" Growth of—Among Railway Employes.....	II, 59
" Labor.....	II, 32, 33, 36, 59, 60
" of Officers and Employes.....	I, 225
" Protective.....	II, 95
" Railway.....	II, 108
Assyrian Chariot Wheel, 600 B. C.— <i>Illustration</i>	IV, 190
Assyrians, Wheels of.....	IV, 193, 194
Astigmatism.....	IV, 225
Atchison, Topeka & Santa Fe Railroad.....	III, 361
Atkinson, Edward.....	III, 35
"Atlantic Type" Locomotive, Baldwin— <i>Illustration</i>	I, 143
"Atlas" Locomotive, 1834.....	I, 31
Atmosphere, Resistance of.....	IV, 97, 98
Atmospheric Engines.....	III, 120
" Pressure, Application of Air at.....	I, 292
Atomizer.....	I, 104
Attendants, Expenses for.....	II, 232
Attorney.....	II, 138
Attorneys, Staff of.....	II, 224
Audible Signals.....	IV, 272, 273
Audit Office, Goods and Mineral—English.....	VI, 329-331
Auditor.....	II, 139, 285
" English.....	II, 274, 275

	PAGE
Auditor, Freight.....	II, 139; X, 67
“ “ —Duties of.....	VI, 109
“ “ —Meaning of the Term.....	II, 291
“ “ of Disbursements.....	II, 139
“ “ Passenger Accounts.....	V, v
“ “ the Treasury.....	II, 292
“ “ Public—English.....	II, 275
“ “ Ticket.....	II, 139; V, 81; X, 67
“ “ —Duties of.....	II, 258
Auditors, Freight—Relief Vouchers Made by.....	IX, 371, 372
“ “ General Traveling—Duties of.....	IX, 276, 277
“ “ Railway—English.....	X, 23, 24
“ “ Ticket—Relief Vouchers Made by.....	IX, 372
“ “ Traveling.....	IX, 271-292
“ “ —Authority of.....	VI, 316
“ “ —Communications of.....	IX, 222, 223
“ “ —Co-operation of.....	IX, 240, 241, 247
“ “ —Duties of.....	VII, 433; IX, 37, 42, 43, 54, 56, 57, 61, 62, 63, 77, 86, 90, 93, 99, 116, 120-123, 125, 127, 133, 136, 143, 144, 146, 147, 152, 153, 166, 168, 173, 186, 190, 191, 195, 197, 200-204, 211, 224, 225, 236-240, 246, 251, 253-261, 271-292, 432
“ “ —Examinations of.....	IX, 284-286
“ “ —Influence of.....	IX, 223, 224
“ “ —Qualifications of.....	IX, 147, 148
“ “ —Reports of.....	IX, 277-283, 287, 288
“ “ —Their Duty in Regard to Old Papers.....	VII, 142
Australasia—Its Primitive Associations and Means of Carriage.....	XI, 347-352
“ “ Primitive Carriage in— <i>Illustrations</i>	XI, 342-352
Australia, Baggage Allowed in.....	V, 290
“ “ Government Management in.....	VIII, 240
“ “ Status of Railways in.....	VIII, 331
Austria, Baggage Allowed in.....	V, 289
“ “ in.....	V, 285
“ “ Storage Charges in.....	V, 425, 426
“ “ Coaches in.....	I, 203
“ “ Method of Handling Baggage in.....	V, 385
“ “ Passenger Service in.....	V, 223-229
“ “ Responsibility for Baggage in.....	V, 312, 313
“ “ Status of Railways in.....	III, 49, 50; VIII, 338
“ “ Use of Metal Ties in.....	III, 378, 379
“ “ Vestibule Car in.....	I, 204
Austria-Hungary—Its Primitive Associations and Means of Carriage.....	XI, 437-440
“ “ Primitive Carriage in— <i>Illustrations</i>	XI, 437-440

	PAGE
Austrian Box Car for Transportation of Glass— <i>Illustration</i>	I, 185
“ Car— <i>Illustration</i>	I, 155
“ “ for Creosoting or Impregnating Wood— <i>Illustration</i>	I, 197
“ “ “ Liquids— <i>Illustration</i>	I, 165
“ Compartment Sleeping Car— <i>Illustration</i>	I, 226
“ Excess Baggage Way Bills	V, 493
“ Goods Car— <i>Illustration</i>	I, 184
“ Horse Car— <i>Illustration</i>	I, 195
“ Imperial Saloon Car— <i>Illustration</i>	I, 220
“ “ Train Engine, Tender of— <i>Illustration</i>	I, 118
“ Locomotive— <i>Illustration</i>	I, 117, 135, 137
“ Postal Car— <i>Illustration</i>	I, 207
“ “ Interior View of— <i>Illustration</i>	I, 208
Austro-Hungary, Heating Cars in	V, 234, 235
Author—An Executive Railway Officer	II, v
“ Early Railway Experience of the	IV, 436
“ First Books of the	V, iv
“ Writings of the	VII, 15-17
Author's Previous Books, Shortcomings of	II, vi
Authors, Railway Men as	II, vii
Authority, Concentration of	I, 284
“ Concurrent	II, 125
“ Division of	II, 113, 294
“ Exercise of	II, 193
Autocracy in Corporate Government	II, 132, 148
Autocratic Government	II, 124, 134; XI, 43
Automatic Air Brake, Explanation of a Popular Form of	I, 538
“ Brakes	I, 300, 334-336
“ “ Sanding Appliances	I, 313
“ Bellringer	I, 58
“ Block Signals— <i>Illustrations</i>	IV, 602-604
“ “ System	IV, 276-290
“ Brake Freight Car Equipment— <i>Illustration</i>	I, 541
“ “ Locomotive Equipment— <i>Illustration</i>	I, 539
“ “ Passenger Car Equipment— <i>Illustration</i>	I, 540
“ “ Plain	I, 325
“ “ System	I, 336
“ Brakes	I, 308, 309; IV, 15, 114, 115
“ “ Application of—to Long Trains of Cars	I, 309, 310
“ Coupler	I, 204; IV, 15, 117-120
“ “ — <i>Illustrations</i>	I, 60, 176
“ “ Air Brake	I, 308
“ Electric Block Signals— <i>Illustrations</i>	IV, 280, 282-285
“ “ System	IV, 279-301
“ Feeds	I, 259
“ Governor	I, 485
“ Graduated Relief Valve	I, 312, 313

	PAGE
Automatic Regulator.....	IV, 164
“ Relief Valve.....	I, 810
“ Safety Switch Stand— <i>Illustration</i>	III, 336
“ Signals.....	IV, 15
“ Slack Adjusters.....	I, 361, 362
“ Switches.....	IV, 15
“ Triple Valve, Plain— <i>Illustration</i>	I, 325
“ Vacuum Brake.....	I, 292
“ Whistles.....	I, 112
Auxiliary Compression Beam Brace— <i>Illustration, Plate II</i>	I, 116-117
“ Reservoir.....	I, 306-308, 324, 325, 335, 336, 356-361
“ “ — <i>Illustrations, { Plate II, I, 116-117, 540, 541</i>	I, 170-171
“ “ — <i>Illustrations, { Plate III, I, 170-171</i>	I, 170-171
“ “ Band— <i>Illustration, Plate II</i>	I, 116-117
“ “ Beams— <i>Illustration, Plate II</i>	I, 116-117
“ “ Charging.....	I, 371
“ “ for Driver Brakes— <i>Illustration</i>	I, 539
“ “ Pressure, Reduction of.....	I, 368
“ “ Ratio of—to Brake Cylinder— <i>Illustrations</i>	I, 357-359
“ “ Release Valve— <i>Illustration, Plate III,</i>	I, 170-171
“ Reservoirs, Draining.....	I, 332
“ “ Exhausting Pressure from.....	I, 377
“ “ Recharging.....	I, 327
Avoiding Over-Reductions—Instructions to Engineers....	I, 368
Awards.....	II, 29-31; III, 324, 325
Axle— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ — <i>Plate III</i>	I, 170-171
“ and Wheel, The First Form of— <i>Illustration</i>	IV, 188
“ Boxes, Construction of.....	IV, 210
“ Collar— <i>Illustration, Plate III</i>	I, 170-171
“ “ Truck— <i>Illustration</i>	I, 65
“ Driving— <i>Illustration, Plate I</i>	I, 58-59
“ Dust Guard Seat— <i>Illustration, Plate III</i>	I, 170-171
“ Engine Truck— <i>Illustration, Plate I</i>	I, 58-59
“ Journal— <i>Illustration, Plate III</i>	I, 170-171
“ “ Bearing— <i>Illustration, Plate III</i>	I, 170-171
“ Safety Bearing— <i>Illustration, Plate II</i>	I, 116-117
“ “ Strap— <i>Illustration, Plate II</i>	I, 116-117
“ Wheel Seat— <i>Illustration, Plate III</i>	I, 170-171
Axles.....	I, 213, 293
“ — <i>Illustration</i>	I, 60
“ Car.....	IV, 186-223
“ “ —Manufacture of.....	IV, 221, 222
“ Cost of.....	III, 403
“ Defective.....	III, 430
“ Driver—Weight Placed on.....	I, 64
“ Driving—Manufacture of.....	IV, 222, 223

	PAGE
Axles, Facilities for Storing.....	I, 269
“ Handling.....	I, 275
“ Inspection of.....	I, 278
“ of Car Trucks.....	I, 468
“ “ Motor Car Trucks.....	I, 468
Babbit Metal. (See also “Brasses”)	
“ “ Care of.....	VII, 184-138
“ “ Inspection of.....	VII, 184-138
“ “ Loss of.....	VII, 137
“ “ Use of.....	VII, 184-138
“ “ “ —by Railways.....	VII, 209
Babylon.....	XI, 125, 129
Babylonia, Ancient.....	XI, 99
Babylonians, The.....	XI, 126, 127, 130-132
Back Band— <i>Illustration, Plate II</i>	I, 116-117
“ Cylinder Head— <i>Illustration, Plate I</i>	I, 58-59
“ Gravity Bar— <i>Illustration, Plate II</i>	I, 116-117
“ of Seat— <i>Illustration, Plate II</i>	I, 116-117
“ Up Eccentric— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Connection— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Rod— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Strap— <i>Illustration, Plate I</i>	I, 58-59
affle-Plate.....	I, 54
Bagdad, Means of Conveyance In.....	XI, 153
Baggage.....	II, 259; V, 275-514
“ Access to.....	V, 329, 330, 433
“ Accidents to.....	V, 327, 328
“ Accounts, Auditing—by Traveling Auditors...IX,	286
“ Advances on.....	IX, 88
“ Agents, Accounts of—Rules Governing.....	V, 506-514
“ “ Miscellaneous Instructions to.....	V, 443-445
“ and Buffet Smoking Car, American Standard— <i>Illustration</i>	I, 211
“ “ Compartment Passenger Car, Victoria— <i>Illustration</i>	I, 210
“ Anxiety of Passengers Concerning Their....	V, 415-417
“ Articles Constituting.....	V, 283, 284
“ Bad Order.....	V, 335, 336, 444
“ Billing.....	V, 347-352
“ “ —European Methods.....	V, 56-58, 369-376, 492, 493
“ “ Through—in Europe.....	V, 386, 387
“ Blanks.....	V, 409
“ Bulky.....	V, 324
“ Business, Beginnings of.....	XI, 151
“ “ Cost of Doing.....	V, 353
“ Car, American Standard— <i>Illustration</i>	I, 209

	PAGE
Baggage Car and Electric Lighting Plant, Austrian Imperial Train— <i>Illustration</i>	I, 211
“ “ the—and its Associations.....	V, 396-403
“ Cars.....	I, 183, 198
“ Care of.....	V, 329-333
“ Caring for.....	V, 52
“ Carriage of—in Great Britain.....	I, 171
“ Changing Destination of.....	V, 499
“ Checking.....	V, 52, 436-439, 494
“ “ —American System of.....	V, 377-383
“ “ —Inconvenience of, to Passengers.....	V, 347-350
“ “ —in United States.....	V, 53-58
“ “ —Systems of.....	V, 53-58
“ Checks.....	V, 53-54
“ “ —Care of.....	V, 436-439
“ “ —Cost of.....	V, 378
“ “ —Exchange of.....	V, 333
“ “ —Lost.....	V, 330, 331, 440, 441
“ “ “ —Rules Governing.....	V, 503, 504
“ “ —Metal.....	V, 55, 57, 58
“ “ “ —Merits of.....	V, 375
“ “ “ —Objections to....	V, 372-375, 377, 378
“ “ Mismatching.....	V, 331-333
“ “ Reversible.....	V, 55
“ “ Shell.....	V, 55, 56
“ “ “ Strap.....	V, 490
“ “ Use of.....	V, 380-383
“ Claims for Damage to.....	II, 232; V, 59-62
“ “ Settlement of.....	V, 315-322
“ Coupons.....	V, 475, 476, 495
“ “ Auditors’.....	V, 473, 477
“ “ Damage to—Causes of.....	V, 325-328
“ Damaged—Claims for.....	V, 337, 340
“ “ —Collections for.....	VII, 422
“ Definition of.....	V, 277, 278
“ Delivered by Train Baggage-men to Agents.....	V, 435, 436
“ Delivering.....	V, 52
“ Delivery of—by Train Baggage-men.....	V, 447-449
“ Department, Attaches of.....	V, 390, 391
“ “ Duties of.....	V, 295
“ “ Experiences of.....	V, 339
“ “ Interest of Public in.....	V, 353
“ “ Officials of.....	V, 525
“ “ Operations of—How Governed.....	V, 353
“ “ Rules Governing.....	V, 431-453
“ Depositories.....	V, 427-430
“ Dispatching—American System of.....	V, 377-383
“ “ —European “ “.....	V, 369-376
“ “ —Facilities for.....	V, 353-368
“ Estray.....	V, 52

	PAGE
Baggage, Estray—Tracing for	V, 342-346
Excess. (See also "Excess Baggage.") ..	V, 371, 442, 443
" " —Billing	V, 478-493, 495
" " —Charges for	V, 62, 63
" " —Devices of Passengers to Escape Charges for	V, 460, 461
" " —Difficulty of Collecting Charges on, ..	V, 458, 459
" " —Forwarded by Freight Trains—Rules Governing	V, 501, 502
" " —Forwarding	V, 494-502
" " —Receiving	V, 502, 503
" " —Rules Governing	V, 494-505
Extra—Charges for	IX, 62
Facilities for	V, 323, 324
Forms, Explanation of	V, 491-493
Forwarding	V, 52, 347-352
Found	V, 434
Franks	V, 466, 467, 495
Free Transportation of	V, 305
Handling	V, 59, 80, 323-328
" " —American System of	V, 357-360
" " —In Austria	V, 385
" " " Italy	V, 385, 386
" " " the United Kingdom	V, 384
" " —Principles Governing	V, 367, 368
" " —Suggested Change in Method of, ..	V, 298, 299
Hypothecated	V, 450-452
Identification of	V, 441, 445
Inspection of	V, 334-336
Interline—Checking	V, 55, 438
Joint—Settlements for	X, 133, 134
Legal Definition of	V, 280-282
Loading	V, 436
Local—Checking	V, 54
Lost	V, 59, 60, 309, 310
" " —Claims for	V, 337, 340
" " —Rules Governing	V, 439-440
" " —Tracing for	V, 342-346
Manipulation of	IX, 36
Marking	V, 53, 54, 439
Meaning of the Term	V, 227, 228
Method of Charging for Carriage of	V, 299, 300
Methods of Handling	V, 51-65
of the Poor	V, 413
" " Rich	V, 413
Owners of	V, 400-403
Permits	V, 466, 467, 495
Protection of	V, 329, 330
Provision for	V, 323, 324
Punches	V, 485

	PAGE
Baggage, Quality of—Carried on Local Trains.....	V, 411, 412
“ Quantity Carried by Passengers.....	V, 456
“ “ on Trains	V, 409
“ “ of—Restrictions in	V, 62, 63
“ “ Transported Without Extra Charge.....	V, 287-294
“ Rates	V, 296
“ Receipt of—by Train Baggage-men.....	V, 447-449
“ Receipts for.....	V, 53, 56, 57, 386
“ Receiving.....	V, 52
“ Rechecking En Route.....	V, 351, 352, 415-417
“ Records.....	V, 337-341
“ Relation of—to Express Business.....	V, 304
“ Responsibility for Damage to.....	V, 53
“ “ Loss of.....	V, 53
“ “ of Carriers for.....	V, 60, 61, 307-314, 335, 336
“ Restriction of Quantity of.....	V, 298
“ Returns.....	V, 337-341, 432, 434, 435
“ Revenue, Collection of	V, 462-477
“ “ for Handling.....	V, 63-65
“ Robbery of.....	V, 329
“ Service.....	V, 275-514
“ “ —Its Relation to Passenger Service..	V, 295-306
“ “ Needs of.....	V, 63-65
“ Shipment of—in England.....	V, 299, 300
“ “Smasher,” the.....	V, 328
“ Stamps.....	V, 486
“ Station Records of.....	IX, 93, 94
“ Storage Charges, Collection of.....	V, 504, 505
“ “ of.....	V, 424-430
“ “ Charges for.....	V, 424-427
“ Traffic.....	V, 51, 65
“ “ Classification of.....	V, 462
“ “ Comparison of—with Freight Traffic..	V, 480, 481
“ “ Handling.....	V, 79
“ Transferring.....	V, 332
“ Transportation of—in Cities and at Transfer Points	V, 296
“ Unchecked.....	V, 432
“ Unclaimed.....	V, 60, 441, 442
“ “ —Collections for.....	VII, 422; IX, 427
“ “ —Disposition of	V, 342-346
“ Way Bills.....	V, 369, 370, 372-376
“ “ C. O. D.....	V, 484
“ “ Colored Paper for.....	V, 491
“ “ Use of.....	V, 436
“ Weighing.....	V, 57, 360, 370, 371, 479
“ —What Constitutes It.....	V, 277-286
Baggage-men	IV, 33

	PAGE
Baggagemen, American	V, 379
" Duties of	V, 334
" Peculiarities of	V, 393, 394, 406, 407
" Responsibility of	V, 433
" Station	V, 388-391
" " —Duties of	V, 498, 409
" Train	V, 404-408
" " —Delivery of Baggage by	V, 447-449
" " —Receipt of Baggage by	V, 447-449
" " —Returns of	V, 446, 447, 514
" " —Rules Governing	V, 452, 453-499, 501
" " —Special Directions to	V, 449, 450
Bags, Soot	I, 170
Bahrein Islands	XI, 120
Bailey, George	V, 80
Baker, George H.	IV, 41
Baker Heater— <i>Illustration, Plate II</i>	I, 116-117
Balance Plate— <i>Illustration, Plate I</i>	I, 58-59
" Sheets, Agents', VI, 313, 314; IX, 262-270, 285, 291, 404-407	
" " —Covering Up Shortages in	IX, 140
" " Conductors'	IX, 423
" " General	X, 38, 29, 61, 182-184
" " Station—Making	IX, 145, 146
" " Transfer	IX, 267
" Spring, Center-Brake— <i>Illustration, Plate II</i>	I, 116-117
" " Lower— <i>Illustration, Plate II</i>	I, 116-117
" " Upper— <i>Illustration, Plate II</i>	I, 116-117
" " Rod— <i>Illustration, Plate II</i>	I, 116-117
" " " Center Brake— <i>Illustration, Plate II</i>	I, 116-117
Balanced Valve— <i>Illustration, Plate I</i>	I, 58-69
Balances, Interline Freight—Settling	X, 114, 115
" " —Settling	IX, 358-361
" " Ticket	X, 133
" " Traffic	IX, 367
Balancing Accounts	IX, 407-411
Baldwin Locomotive, "Atlantic Type"— <i>Illustration</i>	I, 143
" " "Pioneer," 1836— <i>Illustration</i>	I, 39
" " Works	I, 32, 49, 50
" Locomotives— <i>Illustration</i>	I, 145
" Matthias W.—First Locomotive Built by— <i>Illustration</i>	I, 50
" Single-Driver Passenger Locomotive— <i>Illustration</i> , I 142	
Ballast	III, 221, 222, 252, 253, 328
" Cinder	III, 221
" Description of—on Various Railways	III, 183, 184
" Devices for Unloading— <i>Illustration</i>	I, 151
" Effect of—on Rails	III, 328
" " " Ties	III, 280-282
" Gravel	III, 221

	PAGE
Ballast, Gravel—Chicago & North-Western Railway— <i>Illustration</i>	III, 353
“ Influence of—on Cost of Maintenance.....	III, 353
“ Manner of Applying.....	III, 183
“ Materials Used for.....	III, 182-184
“ Object of.....	III, 182, 280
“ Sand.....	III, 373
“ Slag.....	III, 221
“ Stone.....	III, 221
“ Trains.....	IV, 374
“ Unloaders, Steam.....	III, 258
“ Use of.....	VII, 219
“ Value of Different Kinds of.....	VII, 220
“ Ballasting”.....	VII, 457
Ballasting, Imperfect.....	III, 490
Ball Signals.....	IV, 252, 254
Baltimore & Ohio Railroad.....	I, 464; III, 148
“ “ “ “ Pension Fund of.....	X, 321-323
“ “ “ “ Relief Department of.....	X, 296, 298, 307-309
“ “ “ “ Reward Offered by.....	I, 32
“ “ “ “ Savings Fund of.....	X, 313
“ “ “ “ Tunnel—Use of Electricity in...	I, 464, 496-498
“ Chronicle.....	I, 190, 195
Bancroft.....	XI, 28
Band, Auxiliary Reservoir— <i>Illustration, Plate II</i>	I, 116-117
“ Back— <i>Illustration, Plate II</i>	I, 116-117
“ Hose— <i>Illustration, Plate II</i>	I, 116-117
“ Spring— <i>Illustration, Plate II</i>	I, 116-117
Bands, Jacket— <i>Illustration, Plate I</i>	I, 58-59
Bank Check, Invention of.....	XI, 128
“ Deposit Books.....	X, 266
“ Draft, Invention of.....	XI, 128
“ Notes, Transportation of.....	V, 519
Banks, Accounts with—by Agents.....	IX, 183-289
“ Exchanging Currency for Drafts of.....	X, 192
“ Guaranteeing Drafts of.....	IX, 187
“ Local—Drafts of.....	IX, 184-187
“ Pay Checks Cashied by.....	X, 248-250
“ Protection of.....	III, 264
Bankers, Railways Acting as.....	V, 139-144
Banking System of Locomotive Firing.....	I, 97
Bar, Arch— <i>Illustration, Plate III</i>	I, 170-171
“ —Center Bearing— <i>Illustration, Plate II</i>	I, 116-117
“ Back Gravity— <i>Illustration, Plate II</i>	I, 116-117
“ Bottom—of Shade— <i>Illustration, Plate II</i>	I, 116-117
“ Center Bearing Arch—Body— <i>Illustration, Plate II</i>	I, 116-117
“ Draw— <i>Illustration, Plate III</i>	I, 170-171
“ Equalizing— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
"Bar" Frame.....	I, 53
Bar, Guide.....	I, 87
" Inverted Arch—Center Bearing— <i>Illustration, Plate II</i>	I, 116-117
.....	I, 116-117
" Pressure— <i>Illustration, Plate II</i>	I, 116-117
" Stop—Lower Berth— <i>Illustration, Plate II</i>	I, 116-117
" Tie— <i>Illustration, Plate III</i>	I, 170-171
" " —Pedestal— <i>Illustration, Plate II</i>	I, 116-117
Bars, Bonding and Splice—Automatic Electric Block Signals	
— <i>Illustrations</i>	IV, 283
" Bus.....	I, 431, 438, 460, 461
" Crown.....	I, 75
" " — <i>Illustration</i>	I, 98
Barbarism, Relation of Property to.....	XI, 9
Barbed Wire Fence— <i>Illustration</i>	III, 341
Barclay, Dr. Robert.....	IV, 18
Barker, Mr. J. H.....	I, 209
Barlow Wheel, Invention of.....	I, 519
Barlow's "Saddle Back" Rail, A. D. 1856— <i>Illustration</i>	III, 264
Barnard, W. T.....	X, 298
Barrel Plates— <i>Illustration</i>	I, 98
Barry, John Wolfe.....	I, 86; III, 189
Barter, Early Practice of.....	XI, 71
" Influence of—on Rates.....	VIII, 79
" Woman as a Subject of.....	XI, 14
Base Casting— <i>Illustration, Plate II</i>	I, 116-117
" Pilaster— <i>Illustration, Plate II</i>	I, 116-117
" Smoke Flue— <i>Illustration, Plate II</i>	I, 116-117
" Stack— <i>Illustration, Plate I</i>	I, 58-59
" Washer for Railing Post— <i>Illustration, Plate II</i>	I, 116-117
Basin Coupling— <i>Illustration, Plate II</i>	I, 116-117
" Valve— <i>Illustration, Plate II</i>	I, 116-117
" Waste Pipe— <i>Illustration, Plate II</i>	I, 116-117
Basis, for Ascertaining the Relative Economy of Railways	
in the Employment of Labor.....	II, 27
" of Capitalization.....	III, 28-40
" " Railway Taxation.....	III, 433-457
Basket Rack Brackets— <i>Illustration, Plate II</i>	I, 116-117
" " Continuous— <i>Illustration, Plate II</i>	I, 116-117
" " Netting— <i>Illustration, Plate II</i>	I, 116-117
" " Rod— <i>Illustration, Plate II</i>	I, 116-117
Battens, Grain Door— <i>Illustration, Plate III</i>	I, 170-171
" " Leaf— <i>Illustration, Plate III</i>	I, 170-171
Batteries, Storage.....	I, 438-440
" " —Use of.....	IV, 178, 180
" Thermal.....	I, 397
Battery.....	I, 397
" Chemical Energy in a.....	I, 402
" Elements in—Automatic Electric Block Signals—	
<i>Illustrations</i>	IV, 282

	PAGE
Battery, Galvanic—Production of Light from.....	IV, 175
Gravity—Electro-Motive Force of a Cell of.....	I, 401
Terminals in.....	I, 397
Battle of the Gauges.....	I, 36, 37; III, 192
Baume-Marpent's Iron Car— <i>Illustration</i>	I, 162
Bavaria, Heating Cars in.....	V, 234
Beaconsfield.....	IX, 17
Beam Brace, Auxiliary Compression— <i>Illustration, Plate II</i>	I, 116-117
" " Compression— <i>Illustration, Plate II</i>	I, 116-117
" Brake— <i>Illustrations, { Plate II... Plate III</i>	I, 116-117
" " —Hollow— <i>Illustration, Plate II</i>	I, 116-117
" Buffer— <i>Illustration, Plate I</i>	I, 58-59
" Center Bearing— <i>Illustration, Plate II</i>	I, 116-117
" " Brake — <i>Illustration, Plate II</i>	I, 116-117
" Compression— <i>Illustration, Plate II</i>	I, 116-117
" Safety— <i>Illustration, Plate II</i>	I, 116-117
" " Middle— <i>Illustration, Plate II</i>	I, 116-117
" Spring— <i>Illustration, Plate II</i>	I, 116-117
Beams, Auxiliary Reservoir— <i>Illustration, Plate II</i>	I, 116-117
" Brake.....	I, 298, 304, 379, 381
" " —Springs on.....	I, 334
" Steel—Trough of.....	I, 464
Bearing.....	IV, 199
— <i>Illustration</i>	IV, 198
" Journal— <i>Illustration, Plate II</i>	I, 116-117
" Pivot—Swing Hanger— <i>Illustration, Plate II</i>	I, 116-117
" Safety—Axle— <i>Illustration, Plate II</i>	I, 116-117
" Side—Truck— <i>Illustration, Plate II</i>	I, 116-117
" Spring Plank— <i>Illustration, Plate II</i>	I, 116-117
Bearings, Side.....	I, 214
" Spring.....	I, 213
Beckman.....	XI, 107
Bedding, Facilities for Repairing.....	I, 274
Beer Car, German— <i>Illustration</i>	I, 187
Beginning and Growth of Transportation.....	XI, III, IV
Behind Time—Meaning of Term.....	IV, 316
Belgian Car for Transportation of Casks— <i>Illustration</i>	I, 151
" Locomotive and Tender Combined— <i>Illustration</i>	I, 126
" " Tender, for Pushing Trains— <i>Illustration</i>	I, 126
" Passenger Locomotive and Tender— <i>Illustration</i>	I, 136
" Railroad Half Box Car— <i>Illustration</i>	I, 158
" State Railroad Horse Car— <i>Illustration</i>	I, 194
" " Railways.....	III, 178, 183
Belgians, Cars of.....	I, 171
Belgium, Baggage Allowed in.....	V, 288
" Builders of.....	I, 152
" Gauge Used in.....	III, 194

	PAGE
Belgium, Government Supervision in.....	III, 50
" Heating Cars in.....	V, 234, 235
" Lighting Cars in.....	IV, 173
" Railway Taxation in.....	III, 433, 444
" State Management of Railroads in.....	VIII, 238
" Status of Railways in.....	VIII, 342
" Use of Metal Ties in.....	III, 377
Bell.....	I, 58, 111, 112
" — <i>Illustrations, Plate I</i>	I, 58-59, 60
" Cord.....	I, 362
" " First Use of—as Signal.....	IV, 250, 251
" " Hanger— <i>Illustration, Plate II</i>	I, 116-117
" " Signals—Rules Governing.....	IV, 347, 348
" " Train.....	I, 112
" Crank, Throttle— <i>Illustration, Plate I</i>	I, 58-59
" Engine—Use of.....	IV, 350
Bell-Ringer, Automatic.....	I, 58
" Steam— <i>Illustration, Plate I</i>	I, 58-59
Bell Stand— <i>Illustration, Plate I</i>	I, 58-59
" Use of.....	IV, 268
Bells, Electric.....	I, 401
Bellerophon.....	XI, 86
" Belpaire" Fire Box.....	I, 75
Belt Rail— <i>Illustration, Plate II</i>	I, 116-117
" " Cap— <i>Illustration, Plate II</i>	I, 116-117
Benches for Working in Metals and Wood.....	I, 269
" Work.....	I, 243
Bend, Return— <i>Illustration, Plate II</i>	I, 116-117
Benefits Derived from Interchange of Views Between Rail- way Officials.....	I, 289
Bentley & Knight.....	I, 520
Benzole, Handling.....	VI, 99
Berbers.....	XI, 25, 56
Berlin-Hamburg Railroad, Locomotive and Tender Com- bined— <i>Illustration</i>	I, 130
Berne.....	III, 251
Berth Catch Handle— <i>Illustration, Plate II</i>	I, 116-117
" Chain Pulley— <i>Illustration, Plate II</i>	I, 116-117
" Curtains— <i>Illustration, Plate II</i>	I, 116-117
" Front, Lower Part— <i>Illustration, Plate II</i>	I, 116-117
" " Panel— <i>Illustration, Plate II</i>	I, 116-117
" " Upper Part— <i>Illustration, Plate II</i>	I, 116-117
" Lower— <i>Illustration, Plate II</i>	I, 116-117
" Mattresses— <i>Illustration, Plate II</i>	I, 116-117
" Upper—Down— <i>Illustration, Plate II</i>	I, 116-117
" " —Up— <i>Illustration, Plate II</i>	I, 116-117
" Partition— <i>Illustration, Plate II</i>	I, 116-117
" Pillows— <i>Illustration, Plate II</i>	I, 116-117
" Safety Rope— <i>Illustration, Plate II</i>	I, 116-117
" Spiral Spring— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Berth, Spring Chain— <i>Illustration, Plate II</i>	I, 116-117
“ “ Frame— <i>Illustration, Plate II</i>	I, 116-117
“Best Friend” Locomotive, 1830— <i>Illustration</i>	I, 33
Bethlehem Iron Company’s Rail, “Meat Yard” Pattern— A. D. 1884— <i>Illustration</i>	III, 302
Betterments—Charging to Construction.....	VII, 455
Beveled Grain Strips— <i>Illustration, Plate III</i>	I, 170-171
Bidder, I. P.....	X, 164
Biddle System of Lighting.....	IV, 179
Bids, for Ties.....	VII, 97, 98
“ “ Wood.....	VII, 98, 99
“ Solicitation of.....	VII, 51-53
Bill Clerks.....	VI, 133
“ of Lading.....	VI, 94, 114, 118
“ “ Importance of.....	VI, 119
“ “ Limitations of.....	VI, 121
“ “ Rules Governing.....	VI, 126
“ Special Journal—Freight Auditor’s Advice of.....	VI, 307, 308
Bills, Approval of.....	II, 285, 291
“ Auditing.....	II, 285; X, 69, 91-99
“ Bank—Redemption of.....	III, 16
“ Care of.....	X, 271, 272
“ Doctors’.....	II, 232
“ Examination of.....	VII, 432
“ Freight.....	IX, 84
“ “ —List of Uncollected.....	IX, 66, 266, 406
“ “ —Necessity for Details on.....	IX, 62-64
“ “ —Payment of.....	IX, 309
“ “ —Received Ahead of the Goods.....	IX, 54
“ “ —Remitting.....	IX, 425
“ “ —Uncollected.....	IX, 77, 78
“ Fuel.....	VII, 85
“ Gas.....	X, 285
“ “ —Payment of.....	VII, 441; IX, 403
“ “ —Remitting.....	IX, 425
“ of Lading, Use of.....	IX, 89, 90
“ Payment of.....	II, 285, 291; X, 91-99
“ “ —Before Approval.....	IX, 403, 404
“ “ “ “ Audit.....	VII, 441, 442
“ “ “ —by Agents.....	IX, 180; X, 98, 99
“ Register of.....	X, 68, 85
“ Registered—Collections for.....	IX, 427
“ Shipping.....	VI, 109-114
“ Unpaid.....	X, 84, 85
“ Various Persons.....	VII, 414-429
“ “ —Cancellation of.....	VII, 428, 429
Billing Baggage, in Europe.....	V, 56-58, 369-376
Bimetallicism.....	III, 13
“ Definition of.....	III, 11
Bins.....	I, 259

	PAGE
Bins for Storing Damaged Articles.....	I, 272
Birds, Carriage of.....	V, 519
Birkenshaw's Wrought-Iron Rail, A. D. 1820— <i>Illustration</i> ..	III, 190
Black Pointer.....	I, 319
Blackett.....	I, 23
Blackett's Locomotive.....	I, 23
" Second Locomotive.....	I, 23
Blacksmith, Ability of—in the Early Ages of Mankind, I, 131,	132
" Shop, Car Department—End Elevation— <i>Illustration</i>	I, 264
" " Car Department—Side Elevation— <i>Illustration</i>	I, 263
" " Cross Section— <i>Illustration</i>	I, 265
" " Locomotive Department— <i>Illustrations</i>	I, 249
" Shops..... I, 130-132, 251, 256, 262, 263, 271, 272,	275
Blacksmiths.....	I, 230
Blade, Eccentric.....	I, 90
Blanks, Baggage.....	V, 469
" Train Statistic.....	IV, 62-67
" Use of.....	VI, 315
" Writing on.....	IX, 433
Blanche, M.....	V, 223
Blast, Intensity of—How Controlled.....	I, 69
" Steam.....	I, 30
"Bleeder".....	I, 377
"Bleeding" a Car.....	I, 346
" a Train—Instructions to Switchmen and Yardmen.....	I, 376, 377
Bleeding Cock— <i>Illustration, Plate II</i>	I, 116-117
Blenkinsop, John.....	I, 21; III, 125; XI, 511
Blenkinsop's Locomotive, Details of.....	I, 41
" Rack Rail Locomotive, 1811— <i>Illustration</i> , I, 21	
Block, Center Plate— <i>Illustration, Plate II</i>	I, 116-117
" Cylinder— <i>Illustration, Plate III</i>	I, 170-171
" Guide— <i>Illustration, Plate I</i>	I, 58-59
" Link.....	I, 90, 94
" " — <i>Illustration, Plate I</i>	I, 58-59
" Pin Link— <i>Illustration, Plate I</i>	I, 58-59
" Reservoir— <i>Illustration, Plate III</i>	I, 170-171
" Scotch—Meaning of Term.....	IV, 315
"Block Signals".....	VII, 457
Block Signals.....	IV, 276-301
" " Automatic— <i>Illustrations</i>	IV, 502-504
" " Electric— <i>Illustrations</i>	IV, 280, 282-285
" " Systems of.....	IV, 276, 277
" Spring— <i>Illustration, Plate I</i>	I, 58-59
" System.....	III, 38; IV, 115-117
" " Absolute.....	IV, 293
" " Cost of.....	IV, 294, 295

	PAGE
Block System, Cost of—in England.....	IV, 141
“ “ Electric Automatic.....	IV, 279-301
“ “ English—Rules Governing.....	IV, 456-463
“ “ —Meaning of Term.....	IV, 316
“ “ Permissive.....	IV, 293
“ “ Signals of.....	I, 311
“ “ Use of—in England.....	VIII, 323
“ Turnbuckle— <i>Illustration, Plate III</i>	I, 170-171
Blocking.....	III, 247, 248, 332
Blocks, Insulating.....	I, 464
Blotter, Labor.....	VII, 362, 379
Blow-Off for Steam— <i>Illustration, Plate II</i>	I, 116-117
“ “ Water— <i>Illustration, Plate II</i>	I, 116-117
“ “ to Clear Strainer— <i>Illustration, Plate II</i>	I, 116-117
Blow-Out Hose—Instructions to Trainmen.....	I, 369
Blow Pipe.....	I, 104
“ Triple Valve—Stopping.....	I, 374, 375
Blower— <i>Illustrations, Plate I</i>	I, 58-59, 99
“ Lock— <i>Illustration, Plate I</i>	I, 58-59
Blowing, Triple Valve—Instructions to Trainmen....	I, 374, 375
“ Blucher” Locomotive—Stephenson’s—Details of.....	I, 42
“ “ Stephenson’s First Locomotive— <i>Illustration</i> ... I,	25
Blue Printing Office.....	I, 278
“ Signification of.....	IV, 341
Board, Chairman of the.....	II, 131, 138, 143
“ Cornice—Window Sill— <i>Illustration, Plate II</i> ... I,	116-117
“ Fascia— <i>Illustration, Plate II</i>	I, 116-117
“ Head— <i>Illustration, Plate II</i>	I, 116-117
“ Inside Cornice Fascia— <i>Illustration, Plate II</i> I,	116-117
“ Board of Construction Force”.....	VII, 457
Board of Directors.....	II, 128
“ “ Trade (England), Duties of.....	VIII, 319
“ Running.....	I, 381
“ — <i>Illustration, Plate I</i>	I, 58-59
“ Tread— <i>Illustration, Plate II</i>	I, 116-117
Boards of Arbitration.....	VI, 21
“ Roof— <i>Illustration, Plate II</i>	I, 116-117
Boat or Stem, Tail— <i>Illustration, Plate II</i>	I, 116-117
Boats, Early Use of—in Egypt.....	XI, 112
“ Egyptian, Size of.....	XI, 113
“ —Various Classes of.....	XI, 112
“ on the Euphrates.....	XI, 81
Boatmen, Ionian.....	XI, 83
Body Bolster— <i>Illustration, Plate II</i>	I, 116-117
“ “ Bottom Plate— <i>Illustration, Plate III</i> I,	170-171
“ “ Center Filling— <i>Illustration, Plate III</i> I,	170-171
“ “ Top Plate— <i>Illustration, Plate III</i>	I, 170-171
“ “ Wedge Filling— <i>Illustration, Plate III</i> I,	170-171
“ Bolsters.....	I, 210
“ Casting— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Body Center Bearing Arch Bar— <i>Illustration, Plate II</i>	I, 116-117
“ “ Plate— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>{ Plate III</i>	I, 170-171
“ End or Grab Rail— <i>Illustration, Plate II</i>	I, 116-117
“ “ Plate— <i>Illustration, Plate II</i>	I, 116-117
“ Queen Post— <i>Illustration, Plate II</i>	I, 116-117
“ “ Brace— <i>Illustration, Plate II</i>	I, 116-117
“ Side Bearing— <i>Illustration, Plate III</i>	I, 170-171
“ “ Bridge— <i>Illustration, Plate II</i>	I, 116-117
“ “ Pillar— <i>Illustration, Plate II</i>	I, 116-117
“ Transom Center Bearing Pillar— <i>Illustration, Plate II</i>	I, 116-117
“ “ Pillar, Intermediate— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Truss Rod— <i>Illustration, Plate II</i>	I, 116-117
Bogart, John	III, 298
Bogie	I, 24, 50
“ Cars, in Germany	I, 171
“ Engine, Coupled Passenger— <i>Illustration</i>	I, 132
“ Four-Wheeled—The First in America	I, 50
“ —Its Value in America	I, 50
“ Truck	III, 145, 149
“ “ Advantages of	III, 114
“ “ American—Side View of— <i>Illustration</i>	I, 66
“ “ Steel— <i>Illustration</i>	I, 229
Boller	I, 92, 244
“ Cylindrical Part of	I, 75
“ Difficulties Attending the Construction of	I, 38
“ Dome of	I, 75
“ Evaporation of	I, 73
“ Extension End of— <i>Illustration</i>	I, 98
“ Flues of	I, 97
“ Fuse Plug, Section of— <i>Illustration</i>	I, 81
“ Hanger to Frame— <i>Illustration</i>	I, 60
“ Height of Water in—How Ascertained	I, 80, 81
“ —How Supplied with Water	I, 76, 77, 79
“ Inside Shell Brace of— <i>Illustration</i>	I, 98
“ Jacket— <i>Illustration, Plate I</i>	I, 58-59
“ Lagging	I, 74
“ — <i>Illustration, Plate I</i>	I, 58-59
“ Length of	I, 38
“ Locomotive—Effect of Impure Water Upon	I, 248
“ “ —Generation of Steam in	I, 72
“ “ —American	I, 44
“ “ —Longitudinal Section of— <i>Illustration</i>	I, 62, 98
“ Main Barrel of— <i>Illustration</i>	I, 60
“ Means of Fastening to Frame— <i>Illustration</i>	I, 62

	PAGE
Boiler, Method of Supplying Water to.....	I, 105, 106
“ Multitubular—The First.....	I, 18
“ “ “ “ on a Railway Locomotive— Seguin's, 1928.....	I, 26
“ Plate, Inspection of.....	I, 278
“ “ Material Used for.....	I, 74
“ Quantity of Water in.....	I, 76
“ Room, Ventilation of.....	I, 259
“ Safety of—Methods of Securing.....	I, 75, 76
“ Seam, Horizontal— <i>Illustration, Plate I</i>	I, 58-59
“ Section of—Showing Blower— <i>Illustration</i>	I, 99
“ Sheets.....	I, 248
“ Shell— <i>Illustration</i>	I, 98
“ Shop.....	I, 251, 255, 262
“ Size of.....	I, 71
“ Steam Generating Capacity of.....	I, 68
“ Strain on.....	I, 75
“ Supply of Steam Required from.....	I, 70
“ Tin, Flue, Wood and Blacksmith Shops; Locomotive Department— <i>Illustrations</i>	I, 249
“ Trimming Gang.....	I, 286
“ Trimmings.....	I, 285
“ Tubes.....	I, 97
“ “ Machinery for Cleaning.....	I, 261
“ “ Number of.....	I, 73
“ “ Size of.....	I, 73
“ Wagon-Top of.....	I, 75
Boilers.....	I, 252, 259
“ Early Locomotive.....	I, 52
“ Locomotive—Construction of.....	I, 74
“ Shop.....	I, 255
Boilermakers.....	I, 247
Boilerwashers.....	I, 247
Bolster, Body— <i>Illustration, Plate II</i>	I, 116-117
“ False.....	I, 172
“ Spring— <i>Illustration, Plate II</i>	I, 116-117
“ “ Cap— <i>Illustration, Plate II</i>	I, 116-117
“ “ Seat— <i>Illustration, Plate II</i>	I, 116-117
“ Truck— <i>Illustrations, { Plate II.....</i>	I, 116-117
“ “ “ “ <i>{ Plate III.....</i>	I, 170-171
Bolsters, Body.....	I, 210
“ Truck.....	I, 213
Bolt, Carline Strap— <i>Illustration, Plate III</i>	I, 170-171
“ Column— <i>Illustration, Plate III</i>	I, 170-171
“ Eye—Check Chain— <i>Illustration, Plate II</i>	I, 116-117
“ Gravity Bar Fulcrum— <i>Illustration, Plate II</i>	I, 116-117
“ Journal Box— <i>Illustration, Plate III</i>	I, 170-171
“ “ “ “ Cover— <i>Illustration, Plate II</i>	I, 116-117
“ King— <i>Illustration, Plate III</i>	I, 170-171
“ Track— <i>Illustration</i>	III, 323

	PAGE
Bolt, Wedge— <i>Illustration, Plate I</i>	I, 58-59
Boits.....	I, 75, 272; III, 285
" Cost of	III, 403
" Fang	III, 197, 198
" Interlocking.....	III, 330
" Radial Stay— <i>Illustration, Plate I</i>	I, 58-59
" Stay.....	I, 75
" "— <i>Illustrations, Plate I</i>	I, 58-59, 98
" "—Drilling Out and Replacing	I, 243
" Strap— <i>Illustration, Plate II</i>	I, 116-117
Bonded Debt—A Basis for Taxation.....	III, 446
Bondholders	III, 92, 94
" Waiving Interest by	III, 462
Bonding and Splice Bars, Automatic Electric Block Signals — <i>Illustrations</i>	IV, 283
Bonds,	III, 65, 80
" Coupon	III, 96
" Details of	III, 92-100
" Draymen's	IX, 318
" Duplication of	III, 75
" Guaranteeing Payment of Freight Charges.....	IX, 312
" Guaranty	IX, 158-177
" Income	III, 93
" Indemnity	VI, 116; IX, 158-177, 288, 353-358
" "—Applications for.....	IX, 165, 166, 170, 171
" "—Collection of.....	IX, 164
" "—Details of.....	IX, 162
" "—Fixing Amount of	IX, 162, 163
" "—for Lost Checks.....	X, 98
" " " Documents.....	X, 269
" "—of Public Companies.....	IX, 158, 160, 161
" "—on Loss of Time Tickets.....	VII, 409
" "—Paymasters'	X, 232
" "—Private.....	IX, 172, 353, 358
" "—Register of	IX, 175
" "—Renewal of	IX, 174
" "—Signatures on.....	IX, 172, 173
" "—Transfer of	IX, 175, 176
" "—Treasurer's Staff.....	X, 259, 260
" Interest on.....	III, 96
" "—Accounting for, VII, 434, 447-449; X, 178, 180	
" "—Disbursements for	III, 422
" Issue of.....	III, 65, 76
" "—in England.....	III, 73
" " " the United States.....	III, 73
" Mortgage	III, 42, 64, 86, 88, 158
" Negotiation and Sale of	II, 137
" Payment of	III, 101
" Registered	III, 97
" Sale of.....	III, 92

	PAGE
Bonds, Spurious.....	II, 194
" Town.....	III, 16
Bondsmen, Guaranty.....	IX, 172, 173
" Investigation of—by Traveling Auditors.....	IX, 288
" Private.....	IX, 175
Bonuses.....	III, 74, 75
" Payment of.....	III, 78
Book, Bridge and Building Time (and Distribution).VII,	375, 376
" Distribution of Material—Track Foremen's.....	VII, 325
" General Distribution of Labor.....	VII, 382-385
" " " Material.....	VII, 315-320
" " Time.....	VII, 372, 373
" Material Received.....	VII, 289-291
" " —Use of.....	VII, 100, 101
" Track Time (and Distribution).....	VII, 373-375
Tickets.....	V, 95-97
Books, Carriage of.....	V, 520
" Distribution.....	VII, 314
" " —Entering Various Persons Accounts in.....	VII, 433-428
" " —Use of.....	VII, 381
" Memorandum—Agents'.....	V, 512-514
" of Reference, Necessity and Value of.....	II, 111
" Old—Disposition of.....	VII, 305, 432; IX, 291, 431-433
" Overcharge.....	IX, 364, 365
" Preparatory—Material.....	VII, 62
" Preservation of.....	IX, 42, 43
" Purpose of.....	I, 118
" Receipt—Substitutes for.....	IX, 95
" Record—Access to.....	V, 173
" " —Use of.....	V, 173
" Stock—Closing.....	III, 89-91
" The Author's.....	IV, 9, 10; VII, 15-17, 237, 241, 242, 245
" Ticket Record.....	X, 128
" Time.....	VII, 357, 364, 365, 368-372
" " —Certification of.....	VII, 371
" Value of.....	V, 190, 191
" Writing in.....	IX, 433
" Written by Engineers.....	I, 235
Booking Office—Meaning of Term.....	IV, 315
Bookkeeper, General.....	X, 80
Bookkeepers.....	II, 273; X, 77
Bookkeeping.....	X, 27, 70, 73
" Uniformity in.....	X, 41
Booster (300 Kilowatt) Driven by Motor— <i>Illustration</i>	I, 434
" Dynamos.....	I, 451
" Load Upon.....	I, 437
" on Long Feeder— <i>Illustration</i>	I, 433
" System, The.....	I, 434-437, 450, 451
Booth, W. H.....	III, 151; VI, 87

	PAGE
Boxes, Driving.....	I, 285, 286
“ of Motor Car Trucks.....	I, 468
“ Oil.....	I, 213
Brace— <i>Illustration, Plate II</i>	I, 116-117
“ Arch— <i>Illustration, Plate I</i>	I, 58-59
“ Auxiliary Compression Beam— <i>Illustration, Plate II</i>	I, 116-117
“ Body Queen Post— <i>Illustration, Plate II</i>	I, 116-117
“ Compression Beam— <i>Illustration, Plate II</i>	I, 116-117
“ Driver Spring Hanger— <i>Illustration, Plate I</i>	I, 58-59
“ Floor Timber— <i>Illustration, Plate II</i>	I, 116-117
“ Forward— <i>Illustration</i>	I, 60
“ Frame— <i>Illustration, Plate I</i>	I, 58-59
“ Hand Wheel— <i>Illustration, Plate II</i>	I, 116-117
“ Inside Shell— <i>Illustration</i>	I, 98
“ Pedestal— <i>Illustration, Plate I</i>	I, 58-59
“ “ — <i>Illustration, Plate II</i>	I, 116-117
“ Rod Straining— <i>Illustration, Plate II</i>	I, 116-117
“ “ Washer— <i>Illustration, Plate II</i>	I, 116-117
“ Step Hanger— <i>Illustration, Plate II</i>	I, 116-117
Braces.....	I, 75
“ End— <i>Illustration, Plate III</i>	I, 170-171
“ Intermediate and Door Post— <i>Illustration, Plate III</i>	I, 170-171
“ Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ Transom and Corner— <i>Illustration, Plate III</i>	I, 170-171
“ “ Intermediate— <i>Illustration, Plate III</i>	I, 170-171
Bracket, Air Drum— <i>Illustration, Plate I</i>	I, 58-59
“ Brake Platform— <i>Illustration, Plate III</i>	I, 170-171
“ Cab— <i>Illustration, Plate I</i>	I, 58-59
“ Chain Sheave— <i>Illustration, Plate II</i>	I, 116-117
“ Curtain Rod— <i>Illustration, Plate II</i>	I, 116-117
“ End Door— <i>Illustration, Plate III</i>	I, 170-171
“ Gas Lamp— <i>Illustration, Plate II</i>	I, 116-117
“ Headlight— <i>Illustration, Plate I</i>	I, 58-59
“ Pilot— <i>Illustration, Plate I</i>	I, 58-59
“ Pin Lifter—Deadwood— <i>Illustration, Plate III</i>	I, 170-171
“ “ —End Sill— <i>Illustration, Plate III</i>	I, 170-171
“ Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ “ Lamp— <i>Illustration, Plate II</i>	I, 116-117
“ Towel Holder— <i>Illustration, Plate II</i>	I, 116-117
“ Wedge End Door— <i>Illustration, Plate III</i>	I, 170-171
“ “ Side Door— <i>Illustration, Plate III</i>	I, 170-171
Brackets, Basket Rack— <i>Illustration, Plate II</i>	I, 116-117
“ Hand Rail— <i>Illustration, Plate I</i>	I, 58-59
“ Wheel— <i>Illustration, Plate III</i>	I, 170-171
Brahma.....	XI, 97
Brake, Adoption and Use of.....	I, 294
“ Air.....	I, 110, 204

	PAGE
Brake, Air—Automatic	I, 300
“ “ —Construction and Operation of	I, 291
“ “ —Explanation of a Popular Form of Automatic, I, 538	
“ “ —First Form Successfully Used.....	I, 305
“ “ —How to Use It.....	I, 314-333
“ “ —Invention of.....	I, 306
“ “ —Number of Men Required to Manufacture....	I, 133
“ “ —The Perfected.....	I, 333-363
“ Apparatus, Inspection of.....	I, 330
“ Application of, in Emergency—Instructions to Enginemen.....	I, 319
“ “ “ “ Service—Instructions to Enginemen.....	I, 317, 318
“ “ “ “ —Inventions for Hastening.....	I, 310
“ Automatic.....	I, 308, 309
“ “ Freight Car Equipment— <i>Illustration</i>	I, 541
“ “ Locomotive Equipment— <i>Illustration</i>	I, 539
“ “ Passenger Car Equipment— <i>Illustration</i>	I, 540
“ Beam— <i>Illustrations</i> , { <i>Plate II</i>	I, 116-117
“ “ { <i>Plate III</i>	I, 170-171
“ “ Adjusting Hanger Carrier— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ “ Compression Members of.....	I, 214
“ “ Hollow— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ “ Truss Rod— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
“ Beams	I, 298, 304, 379, 381
“ “ Springs on.....	I, 334
“ Cam.....	I, 329
“ Car—Operated by Steam, 1839— <i>Illustration</i>	I, 299
“ Chain.....	I, 292, 298, 306
“ “ Hand.....	I, 297
“ “ Shaft— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Compressed Air.....	I, 292, 299
“ Continuous.....	I, 298
“ Coupling, Vacuum— <i>Illustration</i>	I, 308
“ Couplings	I, 321, 330
“ Cut-Out Cock— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Cutting Out, on a Car—Instructions to Trainmen	I, 324-326
“ Cylinder	I, 297, 305-308, 334-336, 356-361, 377, 378, 380
“ “ — <i>Illustration</i> , <i>Plate III</i>	I, 170-171
“ “ Piston	I, 332
“ “ Pressure.....	I, 356-361
“ “ Quick Action.....	I, 312
“ “ Ratio of Auxiliary Reservoir to— <i>Illustrations</i>	I, 357-359
“ “ “Reinforce”.....	I, 312
“ “ Retaining Pressure in	I, 327
“ Cylinders— <i>Illustrations</i> , <i>Plate II</i>	I, 116-117, 540, 541
“ “ Driver— <i>Illustration</i>	I, 539

	PAGE
Brake Cylinders—Instructions to Engine-House Foremen and Inspectors.....	I, 329
“ “ Repairs to.....	I, 382
“ Discovery of.....	I, 291
“ Driver.....	I, 382
“ Early Form of— <i>Illustration</i>	I, 296
“ “ Lever, 1630— <i>Illustration</i>	I, 291
“ Emergency Applications of.....	I, 311-313
“ Engine-Truck.....	I, 329
“ Evolution of.....	I, 291-314
“ Hand—Modern— <i>Illustration</i>	I, 300
“ “ —on Freight Cars.....	I, 378
“ Hanger— <i>Illustration, Plate II</i>	I, 116-117
“ “ Arm— <i>Illustration, Plate III</i>	I, 170-171
“ “ Carrier— <i>Illustration, Plate II</i>	I, 116-117
“ “ Hook— <i>Illustration, Plate III</i>	I, 170-171
“ “ Pin— <i>Illustrations, { Plate II.....</i>	I, 116-117
“ “ “ <i>{ Plate III.....</i>	I, 170-171
“ Hangers.....	I, 379
“ Head— <i>Illustrations, { Plate II.....</i>	I, 116-117
“ “ “ <i>{ Plate III.....</i>	I, 170-171
“ Heads.....	I, 214
“ “High Speed”.....	I, 310-312, 354, 356
“ High Speed—Safety Valve for— <i>Illustration</i>	I, 362
“ History of.....	I, 291-314
“ Hose, Air—Armored— <i>Illustration, Plate II</i>	I, 116-117
“ Hydraulic.....	I, 292, 298
“ Importance of—in the Operation of Railroads.....	I, 295
“ Inspectors.....	I, 322
“ “Le Caan”.....	I, 292
“ “ —1796— <i>Illustration</i>	I, 293
“ Lever.....	I, 291
“ “ 1825— <i>Illustration</i>	I, 295
“ “ 1832— <i>Illustration</i>	I, 297
“ “ Connecting Rod— <i>Illustration, Plate III</i>	I, 170-171
“ “ Equalizing— <i>Illustration, Plate II</i>	I, 116-117
“ “ Fulcrum— <i>Illustration, Plate III</i>	I, 170-171
“ “ Guide— <i>Illustration, Plate III</i>	I, 170-171
“ “ Safety Loop— <i>Illustration, Plate III</i>	I, 170-171
“ “ Stop— <i>Illustration, Plate II</i>	I, 116-117
“ “ Truck— <i>Illustration, Plate II</i>	I, 116-117
“ Levers.....	I, 214, 334
“ Machinery of.....	I, 294
“ —Meaning of Term.....	IV, 316
“ New-Castle-on-Tyne—1630— <i>Illustration</i>	I, 292
“ Operated by Steam, Gearing of— France, 1840— <i>Illustration</i>	I, 300
“ Origin of.....	I, 291
“ Piston, Power Exerted by.....	I, 377
“ Pistons.....	I, 315, 334

	PAGE
Brake, Plain Automatic	I, 325
“ Platform Bracket— <i>Illustration, Plate III</i>	I, 170-171
“ Power, Cause of Loss in	I, 378
“ Primitive—Forms of	I, 291
“ Pump, Air Cylinder— <i>Illustration, Plate I</i>	I, 58-59
“ “ Steam Cylinder— <i>Illustration, Plate I</i>	I, 58-59
“ Quick Action	I, 310, 311, 324, 373
“ Railway—Evolution of	I, 294
“ Ratchet— <i>Illustration, Plate II</i>	I, 116-117
“ “ Wheel— <i>Illustration, Plate II</i>	I, 116-117
“ Reference to Use of—in Writings of the Ancients ..	I, 293
“ Reinforce	I, 312
“ Rigging, Stiff	I, 378
“ Rules and Regulations Governing the Use of ..	I, 314-333
“ Safety Strap— <i>Illustration, Plate II</i>	I, 116-117
“ Sectional	I, 298
“ Shaft	I, 298
“ Shoe	I, 291, 292, 301-305
“ “ — <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>{ Plate III</i>	I, 170-171
“ “ and Its Application to the Driver— <i>Illustration,</i>	I, 304
“ “ Clogging	I, 299
“ “ Friction	I, 379
“ “ Key— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>{ Plate III</i>	I, 170-171
“ “ Pressure of—Against the Wheel	I, 311
“ Shoes	I, 314, 334
“ “ —Slack of	I, 332
“ “Sprag”— <i>Illustration</i>	I, 294
“ Steam	I, 292, 305, 380
“ “ —for Driving Wheels—Stephenson’s, 1833— <i>Il-</i>	lustration
“ “ “ Tender, 1832— <i>Illustration</i>	I, 298
“ “ —Robert Stephenson’s	I, 297
“ Straight Air	I, 305
“ Style of	I, 379
“ System, Automatic	I, 336
“ Tender	I, 381
“ Tests, Upon Motor	I, 476
“ The Sweeney	I, 333
“ Truck— <i>Illustration, Plate I</i>	I, 58-59
“ Vacuum	I, 299-301
“ “ — <i>Illustration</i>	I, 306
“ “ —Automatic	I, 292
“ “ —Plain	I, 292
“ Valve, Conductors’	I, 319
“ “ Emergency Position of	I, 319
“ “ Engineer’s	I, 309, 315, 317, 319, 320, 538
“ “ — <i>Illustrations, Plate I</i>	I, 58-59, 349
“ “ —Operations of	I, 349-352

	PAGE
Brake Valve, Engineer's—with Feed Valve Attachment and Duplex Air Gauge— <i>Illustration</i>	I, 318
“ “ Handle.	I, 318
“ “ Reservoir— <i>Illustration, Plate I.</i>	I, 58-53
“ Valves, Conductors'	I, 330
Brakes.	I, 214
“ Adjustment of—Instructions to Car Inspectors.	I, 332
“ “ “ “ “ Engine-House Foremen and Inspectors.	I, 329
“ Air.	IV, 114, 115
“ —Automatic.	I, 334-336
“ —for Motor Cars.	I, 485
“ —Introduction of	I, 294
“ —Kinds of.	I, 334
“ —Jerking with	I, 368
“ —“Straight”.	I, 334, 335
“ —Testing.	I, 269
“ —Use of.	IV, 416, 423
“ Application of, from an Unknown Cause—Instructions to Enginemen.	I, 319
“ Applying	I, 334-336, 348
“ and Releasing.	I, 308, 309
“ “ from the Train.	I, 326
“ “ in Emergency.	I, 373
“ Automatic	IV, 15, 114, 115
“ —Application of, to Long Trains of Cars	I, 309, 310
“ Call for—Instructions to Trainmen	I, 326
“ (Continuous Automatic) Use of—in England.	VIII, 323
“ Cutting Out—Instructions to Enginemen	I, 320
“ Defective	I, 330, 331
“ Driver	I, 286
“ — <i>Illustration, Plate I.</i>	I, 58-59
“ Effect of Gravity on.	I, 334
“ “ —on Chilled Wheels.	IV, 205, 206
“ “ Repeated Applications of	I, 327
“ Emergency Applications of	I, 343
“ “ Electric	I, 485, 486
“ Engine	I, 380
“ Examination of—for Defects.	I, 322, 323
“ Hand	I, 332
“ —on Air-Braked Cars—Instructions to Trainmen	I, 374
“ “ Use of—Instructions to Trainmen	I, 323
“ Holding Power of	I, 364
“ Management of.	IV, 416, 417
“ Not in Use—Instructions to Trainmen	I, 326
“ —Number Used.	I, 313, 314
“ Railway—One of the First.	I, 296

	PAGE
Brakes, Releasing	I, 305, 334-336, 348, 365
“ “ —Instructions to Trainmen.....	I, 374
“ “ —on Freight Trains.....	I, 367
“ Running Tests of.....	I, 363, 364
“ Setting.....	I, 348
“ Sticking—Instructions to Trainmen.....	I, 324
“ Storage of Pressure for Applying.....	I, 334
“ Testing.....	I, 375
“ “ —Instructions to Car Inspectors.....	I, 330, 331
“ “ “ Engineers.....	I, 363, 364
“ “ “ Enginemen.....	I, 317
“ “ “ Trainmen.....	I, 321-323
“ The First.....	I, 293
“ Train	I, 380
“ Use of—on Cars.....	I, 297
Brakeman, The.....	IV, 54-56
Brakemen, Duties of.....	IV, 401
“ Early Duties of.....	I, 171, 172
“ Freight—Rules Governing.....	IV, 420
“ General Instructions to.....	IV, 418-420
“ Passenger—Rules Governing.....	IV, 417, 418
“ Responsibility of.....	IV, 123, 124, 417
“ Trustworthiness of.....	IV, 54
Braking, by Hand—Instructions to Enginemen.....	I, 319, 320
“ Power.....	I, 311, 378-380
“ “ —Effect of Piston Travel on.....	I, 358-361
“ “ —Instructions to Car Inspectors.....	I, 332
“ Uniform.....	I, 361
Branch Pipe— <i>Illustrations, Plate I</i>	I, 58-59, 541
“ “ Signal, to Car Discharge Valve— <i>Illustration, Plate II</i>	I, 116-117
“ “ to Conductor's Valve— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Train Pipe— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Triple Valve— <i>Illustration</i>	I, 540
“ “ Triple Valve to Auxillary Reservoir— <i>Illustration</i>	I, 540
“ Pipes.....	I, 336
Branches, Construction of.....	II, 211
Brass, Engine Truck— <i>Illustration, Plate I</i>	I, 58-59
“ Foundry.....	I, 257, 258
“ Journal— <i>Illustration, Plate II</i>	I, 116-117
“ Melting Furnaces.....	I, 257
“ Scrap, Care of.....	VII, 303
“ Use of—by Railways.....	VII, 209
Brasses.....	I, 213, 258
“ Accounting for.....	VII, 135, 137
“ Care of.....	VII, 134-138, 259, 261, 297
“ Disbursement of.....	VII, 136, 298
“ Examination of—on Locomotives.....	I, 244

	PAGE
Brasses, Inspection of.....	VII, 134-138
“ Inventorying	VII, 346, 347
“ Loss of	VII, 135, 137
“ Old—Return of.....	VII, 135, 262
“ Ordering	VII, 83, 137
“ Requisitions for.....	VII, 134
“ Returns for.....	VII, 298, 299
“ Shipping.....	VII, 134
“ Storing.....	VII, 298
“ Use of.....	VII, 134-138
Brazilian Cattle Car— <i>Illustration</i>	I, 191
“ Dynamite Car— <i>Illustration</i>	I, 186
“ Flat Car— <i>Illustration</i>	I, 152
Breda Engine, of Milan	I, 151
Brick Arch— <i>Illustration</i>	I, 98
“ Cars for Handling	I, 224
“ Use of—by Railways.....	VII, 213
Bridge, American Plate Girder Overhead— <i>Illustrations</i>	III, 379, 381
“ and Building Time (and Distribution) Book.....	VII, 375, 376
“ Bent Trestle— <i>Illustration</i>	III, 375
“ Cantilever— <i>Illustration</i>	III, 378
“ Guard— <i>Illustration</i>	III, 343
“ Material, Shipping	VII, 191
“ Plate Girder— <i>Illustration</i>	III, 376
“ Rail	III, 200
“ Side Bearing— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Body— <i>Illustration, Plate II</i>	I, 116-117
“ Steel Truss— <i>Illustration</i>	III, 372
Bridges.....	III, 354
— <i>Illustration, Plate I</i>	I, 58-59
“ Construction of	II, 211
“ “ and Maintenance of.....	III, 296-299
“ —Cost of Keeping in Order	III, 422, 423
“ “ Maintenance of.....	III, 292
“ Deterioration of.....	III, 292
“ Duration of.....	III, 293
“ Effect of Climate on.....	III, 294, 295
“ “ Traffic on.....	III, 292, 295
“ Guard Rails for.....	III, 223, 224
“ Influence of—on Cost of Maintenance.....	III, 383, 389
“ Life of.....	III, 294
“ Poor—Expensiveness of.....	III, 401
“ Precautions Against Fire on.....	IV, 427
“ Protection of.....	III, 325-327
“ Rebuilding.....	II, 221
“ Repairing.....	III, 398
“ Requisitions for Material for.....	VII, 78
“ Supplies for.....	VII, 111, 112
Bridges, Trestles and Culverts”.....	VII, 457, 458

	PAGE
Bridges, Unsafe.....	III, 430
Bridging.....	I, 213
— <i>Illustration, Plate II.</i>	I, 116-117
Briquettes, Use of—for Heating Trains.....	V, 233, 234
British Guiana.....	III, 15
" Isles—Their Primitive Associations and Means of Carriage.....	XI, 441-447
" " Primitive Carriage in— <i>Illustrations</i>	XI, 441-447
" Mint.....	III, 11
Bronze.....	XI, 73
" Manufacture of—by the Phœnicians.....	XI, 134
" Use of—by Railways.....	VII, 209
" Wheels, Ancient— <i>Illustration</i>	IV, 193
"Brother Jonathan"—First Truck Engine, 1832— <i>Illustration</i>	I, 34
Brotherhood of Locomotive Engineers.....	II, 53
Brown & Sharp Gauge.....	I, 402
Bruce.....	XI, 28
Brunel.....	I, 35; IV, 35
" Gauge Adopted by.....	III, 191
Brush, Cutting.....	III, 240
" Removing.....	III, 285
Brushes.....	I, 457
" Access to.....	I, 471
" Burning at the.....	I, 439
" for Conducting Current.....	I, 407, 408
Brushholders.....	I, 457
Brute Force, Domination of.....	XI, 26
Buck, L. L.....	III, 360
Buckles, Turn.....	I, 332
Buffer Beam— <i>Illustration, Plate I.</i>	I, 58-59
" Plate, Short— <i>Illustration, Plate II.</i>	I, 116-117
Buffers, Carriage.....	I, 170
" Face Plate— <i>Illustration, Plate II.</i>	I, 116-117
Buffet.....	I, 200
" Car.....	I, 196
" Smoking and Baggage Car, American Standard— <i>Illustration</i>	I, 211
" " Car.....	I, 148, 182, 196
" " American—Interior of— <i>Illustration</i>	I, 212
Builder, Car—Master.....	I, 284
" Carriage—The First.....	I, 132
" Problem of.....	I, 149
Builders, Administrative Talent of.....	I, 126
" Benefits of Consultation Among.....	I, 126
" Car.....	II, 277
" Early Railway.....	I, 36
" Experience and Talent of.....	I, 121
" General Practice of—in America.....	I, 64
" of Cars and Locomotives.....	I, 124

	PAGE
Builders of Organizations.....	II, 126
" Private.....	I, 141-143
Building, Foundry.....	I, 257
" Laboratory.....	I, 278
" Material, Shipping.....	VII, 191
" Power House.....	I, 259
Buildings, Care and Maintenance of.....	III, 299, 300
" Construction of.....	II, 211
" Cost of Keeping in Order.....	III, 422, 423
" Deterioration of.....	III, 300
" Disbursements for Rent of.....	III, 422
" Extending.....	II, 221
" for Care and Maintenance of Rolling Stock.....	I, 238
" " Making Repairs.....	I, 239
" " Sheltering Locomotives.....	I, 238, 239
" Buildings, Furniture and Fixtures".....	VII, 458
Buildings, Improving.....	II, 221
" Influence of—on Cost of Maintenance.....	III, 383
" Removal of.....	II, 233
" Repair of.....	II, 233
" Requisitions for Material for.....	VII, 78
" Shop—Design for.....	I, 253
" Supplies for.....	VII, 111, 112
Bulgaria.....	IV, 195
Bulgarian Wheel— <i>Illustration</i>	IV, 195
Bulk—an Element in Classifying Rates.....	VI, 26
Bulldozer.....	I, 263
Bulletins, Posting.....	III, 425
Bull-Headed Rail, A. D. 1858— <i>Illustrations</i>	III, 270, 271, 273
" " London & Northwestern Railway, A. D. 1889— <i>Illustration</i>	III, 309
Bullion.....	II, 242; III, 10, 18
" Transportation of.....	V, 519
Bumper.....	I, 109
Bumping Post— <i>Illustration</i>	III, 349
Bunk Apron— <i>Illustration, Plate II</i>	I, 116-117
" Panel— <i>Illustration, Plate II</i>	I, 116-117
Bureau, Advertising.....	II, 139
" Claim.....	II, 138, 245
" Land.....	II, 138
" Tax.....	II, 138
Bureaus, for Adjusting Claims.....	VI, 18, 19
Burlington & Mt. Holly Branch of Pennsylvania Railroad, Use of Electricity on.....	I, 490-492
Burma—Its Primitive Associations and Means of Carriage.....	XI, 237-253
" —Primitive Carriage in— <i>Illustrations</i>	XI, 237-253
Burner Cock— <i>Illustration, Plate II</i>	I, 116-117
" Fuel Oil.....	I, 101
" " — <i>Illustration</i>	I, 102

	PAGE
Burner, Headlight— <i>Illustration, Plate I</i>	I, 58-59
" Tips— <i>Illustration, Plate II</i>	I, 116-117
Burnettizing Process.....	III, 359-362
Burst Hose—Instructions to Trainmen.....	I, 326
Burt, H. G.....	VII, 304
Bury & Company.....	I, 32, 37
Bus Bars.....	I, 431, 436, 460, 461
Bush, Rod— <i>Illustration, Plate I</i>	I, 58-59
Business, Ancient and Modern Devices of.....	VII, 229-231
" Car.....	VII, 225, 226
" Competitive.....	II, 237, 238
" Freight.....	VI
" Methods.....	X, 11-15
" " Uniformity in.....	VII, 237
" Passenger—Procurement of.....	V, 112-116
" Supervision of.....	II, 201
Butter, Loading.....	VI, 103
Butting Timber— <i>Illustration, Plate III</i>	I, 170-171
Button, Push—Electric— <i>Illustration, Plate II</i>	I, 116-117
Buttresses.....	I, 253
Cab.....	I, 55, 112
— <i>Illustrations, Plate I</i>	I, 58-59, 60
" American Style of—Its Introduction into England....	I, 56
" Bracket— <i>Illustration, Plate I</i>	I, 58-59
" The First—on a Locomotive.....	I, 55, 56
" Trimnings.....	I, 286
" Whistle in.....	I, 362
Cabinet Makers.....	I, 274
Cable.....	I, 393, 394
" Road.....	I, 393
" Transfer.....	I, 254
Cadiz.....	XI, 133
Cadmium, Use of—by Railways.....	VII, 209
Cage, Draw Bar Spring— <i>Illustration, Plate III</i>	I, 170-171
Caledonian Railway Passenger Locomotive, Scotland— <i>Illustration</i>	I, 122
California, Use of Petroleum in.....	I, 104
Calking.....	I, 74
" Implements.....	I, 262
Call for Brakes—Instructions to Trainmen.....	I, 326
Cam Brake.....	I, 329
"Camel" Locomotive, 1848—Built by Ross Winans— <i>Illustration</i>	I, 42
Camels, Carriage of Railroads by.....	I, 223
Camden & Amboy Railroad.....	III, 176
Campbell, Henry R.....	I, 51
"Campbell," 1837—The First Standard American Eight-Wheel Locomotive— <i>Illustration</i>	I, 52

	PAGE
Cams, Adjustment of.....	I, 329
Canada, Baggage Allowed in.....	V, 290
" —Its Primitive Associations and Means of Carriage	XI, 379-403
" Primitive Carriage in— <i>Illustrations</i>	XI, 379-403
" Status of Railways in.....	VIII, 325
" Superannuation Funds in.....	II, 60
" Transportation of Freight in.....	III, 125
Cancellation of Vouchers.....	VII, 442-444
Candaules.....	XI, 100
Candles, Tallow—Use of, for Light.....	IV, 168
" Use of—as Signals.....	IV, 248
" —for Lighting Cars.....	I, 204; IV, 170, 171
Cannibals.....	XI, 11
Cantilever Bridge— <i>Illustration</i>	III, 378
Cap Belt Rail— <i>Illustration, Plate II</i>	I, 116-117
" Dome— <i>Illustration, Plate I</i>	I, 58-59
" Pilaster— <i>Illustration, Plate II</i>	I, 116-117
" Spring—Bolster— <i>Illustration, Plate II</i>	I, 116-117
" —Equalizing Bar— <i>Illustration, Plate II</i>	I, 116-117
" Truss Lark— <i>Illustration, Plate II</i>	I, 116-117
Capacity, Carrying—of Equipment.....	VI, 51, 52
" of Cars.....	I, 164, 165
Cape Colony, Governmental Management in.....	VIII, 241, 243
Capital.....	II, 33-36, 40, 44, 68, 69
" Acquisition of—for Railway Investments.....	VII, 18-27
" —Amount Invested in Railways.....	III, 62
" Coercion of.....	II, 52
" " —by Labor.....	II, 33
" Concentration of.....	III, 459
" Confidence of—Necessary to Commerce.....	VIII, 20
" Domination of.....	II, 36
" Effect of a Fluctuating Currency on.....	III, 21, 22
" Foreign—Investments Made by.....	III, 15, 16
" " —Margin Afforded by.....	III, 23
" —How Represented.....	VII, 21, 22
" Increase of—Per Mile of Road.....	III, 30
" —Its Ability to Find Safe and Profitable Employ-	II, 34
" " Relation to Net Income.....	III, 56
" of Railways.....	III, 154
" Railway—Precautions for Investors.....	III, 79-84
" Relation of—to Earnings.....	III, 35, 70, 71
" Requirements of.....	VIII, 20
" Return on—Relation to Rates.....	VIII, 43
" Secret Power of.....	III, 460
" Status of—Toward Labor.....	II, 50
" Stock.....	III, 42, 80, 85-91, 158
" " —a Basis for Taxation.....	III, 446
" " Form of Certificate of.....	III, 87

	PAGE
Capital Stock—Meaning of the Term.....	III, 86
“ “ Voting.....	II, 129
“ Strife of—to Find Profitable Use.....	II, 34
“ Wisdom and Moderation of.....	II, 53
Capitalists.....	III, 26
Capitalization.....	III, 7-105
“ Basis of.....	III, 30
“ Criticism of Methods of.....	III, 28
“ —Effect on Rates.....	VIII, 293
“ in America.....	III, 69, 142
“ “ England.....	III, 65-71, 85, 86
“ “ Europe.....	III, 142
“ Influences Affecting.....	III, 53-58
“ Methods of—in Different Countries.....	III, 41-52
“ “ “ Great Britain.....	III, 487-490
“ of Railroads.....	VIII, 293
“ Proper Basis of.....	III, 86
“ “ Limit of.....	VIII, 193
Capitalizing Construction Expenditures.....	II, 187, 188
Captains, Receipts Given by.....	VI, 220, 221
Capstans.....	I, 173
Car. (See also “Cars” and “Coaches”).....	I, 159
“ Accountant.....	IV, 58; VI, 49, 63, 67, 68; X, 67
“ Accountants' Association.....	VI, 57
“ Accountants, International Association of.....	VI, 54
“ American Palace—Apartments in— <i>Illustration</i>	I, 223
“ “ —Smoking Compartment in— <i>Illustration</i>	I, 213
“ “ Standard Box Freight and Truck — <i>Illustration, Plate III</i>	I, 170-171
“ “ “ “ “ —Sectional View— <i>Illustration</i>	I, 167
“ “ “ “ “ —Cross Section of— <i>Illustration</i>	I, 169
“ “ “ “ “ —End Elevation of— <i>Illustration</i>	I, 168
“ “ “ Freight—End Elevation and Section Through Journal Box of Truck— <i>Illustration</i>	I, 173
“ “ “ “ —Plan of Truck of— <i>Illustration</i>	I, 180
“ “ “ “ —Side Elevation and Section at Center Bearings of Truck— <i>Illustration</i>	I, 177
“ “ Steel Flat— <i>Illustration</i>	I, 153
“ “ “ “ —View of Under Side— <i>Illustration</i>	I, 154
“ Apartment—American— <i>Illustration</i>	I, 227
“ Appliances.....	V 37-39

	PAGE
Car, Austrian— <i>Illustration</i>	I, 165
" " Box—for Transportation of Glass— <i>Illustration</i>	I, 185
" " —for Creosoting or Impregnating Wood— <i>Illustration</i>	I, 197
" " " Liquids— <i>Illustration</i>	I, 165
" Axles.....	IV, 186-223
" " Manufacture of.....	IV, 221, 222
" Baggage—American Standard— <i>Illustration</i>	I, 209
" " and Buffet Smoking—American Standard— <i>Illustration</i>	I, 211
" " " Compartment Passenger—Victorian— <i>Illustration</i>	I, 210
" " " Electric Lighting Plant—Austrian Imperial Train— <i>Illustration</i>	I, 211
" " " Its Associations.....	V, 396-403
" Beer—German— <i>Illustration</i>	I, 187
" Belgian—for Transportation of Casks— <i>Illustration</i>	I, 161
" "Bleeding" a.....	I, 346
" Box—German— <i>Illustration</i>	I, 184
" " —in America.....	I, 207
" " —Turkish— <i>Illustration</i>	I, 182
" " —Victorian— <i>Illustration</i>	I, 183
" Brake Operated by Steam, 1839— <i>Illustration</i>	I, 299
" Brazilian Flat— <i>Illustration</i>	I, 152
" Buffet.....	I, 196
" " Smoking.....	I, 148, 182, 196
" " " —American—Interior of— <i>Illustration</i>	I, 212
" Builder, Master.....	I, 281
" Builders.....	II, 277
" Business.....	VII, 225, 226
" Caboose.....	I, 199
" Cattle—Brazilian— <i>Illustration</i>	I, 191
" " —Italian— <i>Illustration</i>	I, 190
" " —Victorian Railway— <i>Illustration</i>	I, 191
" Coal.....	I, 207
" " —Victorian Railway— <i>Illustration</i>	I, 163
" Companies, Palace.....	I, 196-199
" Compartment.....	I, 177
" " —Bosnian Railway— <i>Illustration</i>	I, 214
" " —New South Wales— <i>Illustration</i>	I, 225
" Construction.....	I, 147
" " Details of.....	I, 180
" " Differences in.....	I, 131
" " Standard Details of.....	I, 270
" Cutting Out the Brake on a —Instructions to Trainmen.....	I, 324-326
" Decoration.....	I, 147
" Defective—Instructions to Engineers.....	I, 365
" Department.....	I, 277

	PAGE
Car Design	I, 377-381
“ Dining	I, 148, 195, 196
“ “ —American— <i>Illustration</i>	I, 219
“ Discharge Valve— <i>Illustration</i>	I, 386
“ “ “ Signal Branch Pipe to— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Door— <i>Illustration, Plate II</i>	I, 116-117
“ Double Truck—Frame of	I, 467
“ Drawing Room	I, 148, 194, 195
“ “ “ or Parlor—American	I, 200
“ Dynamite—Brazilian— <i>Illustration</i>	I, 186
“ Early Sleeping	I, 165
“ Electric—Its Effect Upon Street Railway Service	I, 394
“ “ “ Motor	I, 467-469
“ English Compartment—Origin of	I, 183, 184
“ First Class Passenger—German— <i>Illustration</i>	I, 214
“ Flat—in Great Britain	I, 207
“ Floor— <i>Illustration, Plate II</i>	I, 116-117
“ for Carriage of Sugar Cane— <i>Illustration</i>	I, 161
“ “ Small Cattle, Peloponnesus Railroad— <i>Illustration</i> , I, 190	
“ Freight—American Standard	I, 207-214
“ “ —Development of	VI, 49
“ “ —in Great Britain	I, 31
“ “ —The First	I, 204
“ Initials	VI, 143
“ French Dumping— <i>Illustration</i>	I, 150
“ “ Reservoir—for Liquids— <i>Illustration</i>	I, 164
“ Goods—Austrian— <i>Illustration</i>	I, 184
“ “ —in Great Britain	I, 31
“ Gondola	I, 207
“ “ —Victorian Railway— <i>Illustration</i>	I, 158
“ Half-Box—Belgian Railroad— <i>Illustration</i>	I, 158
“ “ —Italian— <i>Illustration</i>	I, 160
“ “ —with Tubular Frame—Belgium— <i>Illustration</i>	I, 158
“ Hand— <i>Illustration</i>	I, 148
“ Horse—American— <i>Illustration</i>	I, 196
“ “ —Austrian— <i>Illustration</i>	I, 195
“ “ —Belgian State Railroad— <i>Illustration</i>	I, 194
“ “ —Victorian Railways— <i>Illustration</i>	I, 195
“ Hot Water Pipe to— <i>Illustration, Plate II</i>	I, 116-117
“ Inspectors—General Instructions to	I, 330-333
“ Insulated—for Dairy Products—Victorian Railways— <i>Il-</i> <i>lustration</i>	I, 188
“ Iron— <i>Illustration</i>	I, 159
“ “ —Baume-Marpent’s— <i>Illustration</i>	I, 162
“ Joint Service Compartment and Passenger— <i>Illustration</i> ,	I, 221
“ Light Push— <i>Illustration</i>	I, 147
“ Load, Freight	I, 205, 206

	PAGE
Car Load, Freight—The Maximum.....	I, 164, 165
“ Manager’s.....	VII, 225, 226
“ Manufactories, Number of.....	I, 138
“ “ Specialists Among.....	I, 214
“ Manufacturers, in United States.....	I, 196
“Car Mileage, Balance”.....	VII, 490, 521
Car Mileage Rates.....	VI, 63, 64
“ Motor—Mt. Holly Road— <i>Illustration</i>	I, 491
“ Neptune’s.....	XI, 96
“ Numbers.....	VI, 143
“ Observation—American— <i>Illustration</i>	I, 228
“ Open—in America.....	I, 171
“ Ore— <i>Illustration</i>	I, 163
“ Palace.....	I, 148
“ “ —An Apartment In— <i>Illustration</i>	I, 223
“ “ —For Day and Night Use— <i>Illustration</i>	I, 224
“ “ —Popularity of.....	I, 201
“ Parlor.....	I, 194, 195
“ “ —American— <i>Illustration</i>	I, 219
“ Passenger.....	I, 197
“ “ —American Standard— <i>Illustration</i>	I, 215
“ “ and Sleeping—American Standard— <i>Illustration, Plate II</i>	I, 116–117
“ “ —for Suburban Traffic.....	I, 177, 178
“ “ —Important Details of Construction and Maintenance.....	I, 178, 179
“ “ —Requirements of.....	I, 181
“ Perishable Goods—New South Wales— <i>Illustration</i>	I, 188
“ Postal—American Standard— <i>Illustration</i>	I, 205
“ “ —Austrian— <i>Illustration</i>	I, 207
“ “ “ —Interior View of— <i>Illustration</i>	I, 208
“ “ —Interior of American— <i>Illustration</i>	I, 206
“ Poultry— <i>Illustration</i>	I, 189
“ Railway—Substitute for Peddler’s Wagon.....	I, 168
“ Refrigerator—Capacity of.....	I, 165
“ “ —New South Wales— <i>Illustration</i>	I, 187
“ Repairers.....	I, 270, 271
“ Repair Shop, Section and End Elevation— <i>Illustration</i>	I, 255
“ “ “ Side Elevation— <i>Illustration</i>	I, 252
“ “ Shops, Plan for— <i>Illustration</i>	I, 242
“ Roumanian State— <i>Illustration</i>	I, 220
“ Saloon—Austrian Imperial— <i>Illustration</i>	I, 220
“ Seals.....	VI, 49–51, 103
“ “ Breaking.....	VI, 104
“ “ Inspection of.....	VI, 104
“ Seat, Evolution of.....	I, 186, 187
“ Service (See also “Demurrage”).....	VI, 49, 53–57
“ “ Agencies.....	IV, 58
“ “ Associations.....	VI, 57, 58
“ “ Charges for.....	IX, 61

	PAGE
Car Service Record of Amounts Charged, Collected and Re-	
funded for	VI, 219, 220
" Superintendent of	VI, 57
" Sheep—Victorian— <i>Illustration</i>	I, 193
" Shop, Passenger	I, 274
" Signal Valve— <i>Illustration, Plate II</i>	I, 116-117
" Sleeping—American	I, 200
" " and High Class Passenger—American Standard	
— <i>Illustration</i>	I, 223
" " —Austrian Compartment— <i>Illustration</i>	I, 226
" " —"Pioneer"	I, 194, 197
" Standard American Gondola— <i>Illustration</i>	I, 160
" Steam Shovel— <i>Illustration</i>	I, 200
" " Framework of— <i>Illustration</i>	I, 199
" " Wrecking— <i>Illustration</i>	I, 201
" Stock—American Standard— <i>Illustration</i>	I, 192
" Storage Battery on a	I, 439
" Suburban Milk—American Standard— <i>Illustration</i>	I, 209
" Swinging or Dumping— <i>Illustration</i>	I, 149
" The Accordion	I, 204
" " Compartment	IV, 123
" " Harmonica	I, 204
" " Vestibuled	IV, 119, 120
" Track Inspection— <i>Illustration</i>	I, 148
" Truck, American Standard Freight—Section Showing	
Body and Truck Bolsters— <i>Illustration</i>	I, 179
" Varsovie-Vienne Railroad— <i>Illustration</i>	I, 157
" Velocipede Hand— <i>Illustration</i>	I, 149
" Vestibule—American— <i>Illustration</i>	I, 221
" " —in Austria	I, 204
" " " Germany	I, 204
" Wheel, English— <i>Illustration</i>	IV, 215
" " Number of Men Required to Manufacture a	I, 133
" Wheels	I, 178; IV, 186-223
" " —How They Differ from Other Wheels	IV, 196
" " Inspection of	I, 278
" " Kinds of	IV, 198
" " Storing	I, 272
" Wrecking— <i>Illustration</i>	I, 200
" Wurtemberg— <i>Illustration</i>	I, 152
" " Railroad— <i>Illustration</i>	I, 158
(cars. (See also "Car" and "Coaches")	I, 159
" Adaptability in Construction of	I, 155, 156
" " of—to Locomotives and Curves	III, 114
" " " Needs	I, 201
" Air-Braked	I, 343
" " —Hand Brakes on—Instructions to Train-	
men	I, 374
" " —Setting Out	I, 374
" American Apartment—Capacity of	I, 199

	PAGE
Cars, Appliances for Renewing or Rebuilding	I, 237
“ Apportionment of—to the Different Classes of Travel, I, 203	I, 203
“ “ “ Wear and Tear of.....	VII, 509
“ —Average Number Per Train.	I, 165
“ Baggage	I, 183, 198
“ Belgian	I, 171
“ Bogie—in Germany.....	I, 171
“ Box	I, 121
“ Builders of	I, 124
“ Box—in England.....	I, 172, 173
“ Capacity of.....	I, 164, 165
“ Care and Maintenance of.....	I, 230, 237, 283, 284
“ “ of.....	I, 231, 268-271
“ Carrying Capacity of—in Europe	VI, 51, 52
“ “ “ the United States.....	VI, 51, 52
“ Chair.....	V, 221
“ Cleaning.....	I, 269; IV, 434
“ Coal	I, 121
“ Coke	I, 121
“ Comparison of American and European	V, 27-29
“ Compartment.....	I, 201, 203; V, 28, 29
“ Coupling.....	I, 120
“ “ —by Chains.....	I, 204
“ Cut Out—Instructions to Trainmen.....	I, 372, 373
“ Delays in Unloading—How Lessened.....	VI, 57, 58
“ Demand for	I, 138
“ Derailment of.....	IV, 60
“ Designs for.....	I, 277
“ Detaching—Instructions to Trainmen	I, 323
“ Detention of—Demurrage Charges for	VI, 58-63
“ Differences in	I, 119, 120
“ “ —To What Due.....	I, 183
“ Dining	I, 191
“ “ —Superintendent of.....	II, 138
“ Disabled—Instructions to Trainmen.....	I, 373, 374
“ Discrimination in the Use of.....	VI, 74
“ Distribution of.....	IV, 59
“ “ Mails in	V, 561, 562
“ Double Truck	I, 467
“ Drawing Room.....	I, 174; V, 212, 221
“ Drinking Water on.....	I, 181
“ Duties of Conductors in Relation to.....	IV, 406, 406
“ “ “ Yardmasters in Relation to.....	IV, 432-435
“ Effective Use of	IV, 57-61; V, 27, 49, 57, 58
“ “ “ —Divergence in.....	VI, 51, 52
“ Empty—Supervision of	II, 201
“ Entrances to Passenger.....	I, 176
“ European	IV, 316, 317
“ Evolution of.....	I, 166
“ Fastening.....	VI, 103

	PAGE
Cars, First Class—English.....	I, 170
“ Fitness of	I, 233
“ Flat.....	I, 121
“ Foreign	VI, 54
“ “ —Rules Governing the Use of... ..	VI, 65, 66
“ Freight.....	I, 121, 156; III, 406
“ “ —Brake Hangers on	I, 379
“ “ —Carrying Capacity of	VI, 49, 50
“ “ —Daily Performance of	VI, 53
“ “ —Disabled En Route.....	VI, 106
“ “ —Effective Use of.....	VI, 5-26, 42, 49
“ “ —English.....	I, 172; III, 147
“ “ —Hand Brake on	I, 378
“ “ —Improvident Use of, in America.....	VI, 55, 56
“ “ —Inspection of.....	VI, 100
“ “ —Kinds of.....	I, 207; VI, 49
“ “ —Loading.....	VI, 97-100
“ “ —Overloading.....	VI, 98, 99
“ “ —Private—Charges for Use of.....	VI, 159
“ “ —Receipting for	VI, 104
“ “ —Repair Shed for—End Elevation— <i>Illustration</i>	I, 258
“ “ “ “ “ —Longitudinal — <i>Illustration</i>	I, 255
“ “ —Repairs to.....	VI, 106
“ “ —Return of, to Owners.....	VI, 101
“ “ —Transferring.....	VI, 222, 223
“ “ —Unloading.....	VI, 97
“ “ —Weighing.....	VI, 222, 223
“ Half Box.....	I, 207
“ Heating.....	IV, 146-165
“ “ —by Steam.....	I, 269
“ “ —in Early Days.....	III, 120
“ High Class Passenger—in America.....	I, 181, 182
“ Higher Forms of.....	I, 119
“ Idleness of.....	IV, 58
“ Increased Strength of.....	IV, 120, 121
“ Inspection of.....	II, 47, 242; IV, 60, 61, 434; VI, 12, 13
“ Interchange of.....	IV, 59, 60; VI, 63
“ Interior Accommodations of.....	V, 28
“ Iron.....	I, 167, 168
“ Joint Use of.....	X, 119
“ Knocking Together in Coupling.....	I, 376
“ Lighting.....	I, 204; IV, 166-185; V, 36, 37
“ “ —Cost of	IV, 184, 185
“ “ —in Early Days.....	III, 120
“ “ —Systems of.....	IV, 171
“ Liverpool & Manchester Railway.....	I, 171
“ Loading—by Gravity	I, 246
“ Locking.....	II, 242

	PAGE
Cars, Machinery for Constructing and Repairing	I, 131
“ Mail	I, 183
“ Manufactories of	I, 130
“ Manufacturers of	I, 116, 141
“ Method of Heating—in England	I, 173
“ Military	I, 224
“ Motor—Air Brakes for	I, 485
“ —Heating	I, 486
“ —Lighting	I, 486
“ —Tests on	I, 480—482
“ Number of Brakes Used on	I, 313, 314
“ of Portable Railroads	I, 223, 224
“ Operated by a Generator	I, 458
“ Operation of—in the Direct Feeding System	I, 431—434
“ Organization for the Care of	I, 270
“ Overloading	I, 205; VI, 23, 24
“ Owners of—in the United States	I, 45
“ Palace	I, 182
“ Stock—Charges for Use of	VI, 159
“ Parlor	I, 174; V, 212, 221
“ Passenger	I, 156, 269
“ —Decorations of, in America	I, 147
“ —English	III, 147
“ —First Design of	I, 174
“ —Joint Use of	V, 26
“ —of France	I, 174
“ Pay—Appliances of	X, 220
“ —Care of	X, 221, 222
“ —Protection of	X, 223—227, 231
“ Piped	I, 373
“ Piping	I, 379
“ Postal	I, 198; V, 562
“ Postoffice	V, 557
“ Private	VI, 49, 69—74
“ —Collections for Use of	IX, 427, 428
“ —Freight—in England	II, 45
“ —Owners of	II, 46
“ —Use of, in England	II, 45
“ Procuring Tickets Before Entering	V, 117—119
“ Push	I, 261, 262, 275
“ Records of Movements of	VI, 56, 57
“ Refrigerator	VI, 102
“ —Icing	VI, 102
“ —Loading	VI, 103
“ Repair and Renewal of	I, 232
“ Tracks for	I, 268
“ Repairs of	I, 271—279, 382; IV, 434
“ Reports of	X, 67
“ Routing	VI, 54
“ Sealing	II, 242; VI, 103; VII, 310

	PAGE
Cars, Searching	IV, 409, 435
“ Second Class—in England	I, 170
“ Securing Piping to	I, 379
“ Signal Pipes on	I, 362
“ Sills of	I, 179
“ Sleeping	I, 188-194; V, 221
“ —in England	I, 201
“ —Rules Governing Use of	V, 212
“ Special—Charges for	VI, 124
“ Stable Stock—Charges for Use of	VI, 159
“ Standard American Flat— <i>Illustration</i>	I, 153
“ Steel	I, 157
“ Street—Current Taken by	I, 401
“ Superintendent of	I, 233, 270, 271, 277
“ Switching	IV, 94-96
“ —in Great Britain	I, 173
“ Telescoping of	I, 179
“ —Their Development and Uses	VI, 49
“ Third Class—in England	I, 170
“ Tool	I, 379
“ Uniformity in Construction of	VI, 50
“ Upholstery of—Number of Men Required to Manu- facture	I, 133
“ Use of—as Stores	I, 168
“ “ “ Temporary Warehouses	VI, 54, 55
“ “ “ Brake on	I, 297
“ “ “ Iron and Steel in Building	I, 157
“ “ “ Wood in Constructing	I, 158
“ Used Jointly by Railroads	VI, 49, 63-68
“ Utilization of	IV, 58
“ Various Patterns of	I, 159
“ Ventilation of	V, 33-36
“ Wrecking	I, 378
Carbon Sheets, Use of	VI, 89, 90, 120, 202
Carbureted Air, Use of—for Lighting Cars	IV, 175
“ Gas, Use of—for Lighting Cars	IV, 173
Carbureter— <i>Illustration</i>	IV, 175
“ Description of	IV, 175
Carbureters, Gasoline—Use of, for Lighting Cars	IV, 183
Carcasses, Charges Collected for	VII, 414, 421, 422; IX, 428
Card, James T.	III, 364, 365
Card Tickets	V, 93-95
“ “ English	V, 238
“ “ Excursion	V, 95
“ “ Local—Auditing	X, 124, 125
“ “ Origin of	V, 92
“ “ Round Trip	V, 94, 95
Cards, Excess Baggage. (See “Way Bills.”)	
“ Postal—Accounting for	X, 287, 288
Care of Cars and Locomotives	I, 230-232, 235

	PAGE
Care of Locomotives.....	I, 238-247
“ “ Rolling Stock.....	I, 238
“ “ Track.....	III, 206-271
Carey Iron, Drawbar— <i>Illustration, Plate II</i>	I, 116-117
“ “ Inner Drawbar— <i>Illustration, Plate II</i>	I, 116-117
Carhart, Professor.....	III, 274, 279
Carline, Compound— <i>Illustration, Plate II</i>	I, 116-117
“ Platform Roof— <i>Illustration, Plate II</i>	I, 116-117
“ “ End— <i>Illustration, Plate II</i>	I, 116-117
“ Strap Bolt— <i>Illustration, Plate III</i>	I, 170-171
“ Tie Rod— <i>Illustration, Plate III</i>	I, 170-171
“ Upper Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Vestibule End— <i>Illustration, Plate II</i>	I, 116-117
Carlines— <i>Illustration, Plate II</i>	I, 170-171
Carlisle's Wrought-Iron Rail, A. D. 1811— <i>Illustration</i>	III, 188
Carpenter, A. V. H.....	V, 80
Carpenters, Master.....	I, 230
Carpets, Cleaning.....	I, 269
“ Renovating.....	I, 274
Carriage. (See also “Transportation.”)	
“ Among the Chaldeans.....	XI, 75
“ Builder, The First.....	I, 132
“ Culmination of.....	XI, 523
“ Development of.....	XI, 53
“ Effect of Environment on.....	XI, 53
“ “ the Introduction of Steam Upon.....	I, 16
“ Electrical Apparatus Relating to.....	I, 139
“ First Mention of.....	XI, 104
“ Idea of—Its Conception.....	I, 160, 161
“ Land.....	XI, 149
“ —Dangers of.....	XI, 101
“ —Origin of.....	XI, 52, 151
“ Manufacture of Rude Appliances of.....	I, 131
“ Origin of Ancient Forms of.....	XI, 49
“ Portrayal of Primitive Forms of.....	XI, 156
“ Primitive—Among the Egyptians.....	XI, 95
“ “ —Comparison of Past and Present.....	XI, 149
“ “ —Evolution of.....	XI, 95
“ “ —Methods of.....	XI, 109
“ Railway—Development of.....	I, 149
“ “ —Need of Facilities for Studying the Sub- ject.....	II, vii
“ “ —Theory of.....	I, 392
“ Steam—Cugnot's, 1769— <i>Illustration</i>	I, 18
“ “ —Read's, 1791—First Multitubular Boiler— <i>Illustration</i>	I, 19
“ Various Methods of.....	XI, 47
“ Water.....	XI, 151
“ “ —Origin of.....	XI, 151
Carriages, Covered—First in Europe.....	XI, 105

	PAGE
Carriages, Third Class, in England.....	I, 170
" Use of, by the Ancients.....	XI, 105
Carrier, Brake Beam Adjusting Hanger— <i>Illustration, Plate</i>	
<i>II</i>	I, 116-117
" " Hanger— <i>Illustration, Plate II</i>	I, 116-117
" Common—Duties of.....	V, 356
" " —Meaning of the Term.....	VI, 5-7
" " —the First.....	XI, 83
" Hodge— <i>Illustration, Plate II</i>	I, 116-117
" the First.....	XI, 47, 101
" the Horse as a Favorite.....	XI, 85
Carriers. (See also "Railways.")	
" Arts of.....	XI, 98
" Duties of.....	II, 242; VI, 116
" Ethics of Their Trade.....	VIII, 19
" Exemptions of.....	VI, 283-293
" Individual.....	II, 41, 42
" Liability of.....	II, 242; V, 14
" Losses Incurred by.....	VI, 19
" Methods of Defrauding.....	VI, 22, 23
" Oppression of the Public by.....	II, 48, 49
" Prehlotoric.....	XI, 9
" Primitive—the Carthaginians.....	XI, 137
" Private—Use of Railroads by.....	II, 47
" Profits of—Upon What Dependent.....	IV, 57
" Responsibilities of.....	V, 307-314; VI, 288-293
" Responsibility of—for Baggage.....	V, 61
" Signals of.....	IV, 244
Cart.....	I, 293; XI, 67
" Introduction of.....	XI, 51
" Use of—as a House.....	XI, 95
" Uses of—in Ancient Times.....	XI, 96
Carts, Primitive—of Mesopotamia.....	I, 132
" Railway—The First.....	III, 110
" Rude—of Primitive Ages.....	I, 293
Cartage, Charges for.....	VI, 9, 10
Carthage, Carriage in.....	XI, 137
" Carrying Trade of.....	XI, 146
" Circulating Medium of.....	XI, 146
" Destruction of.....	XI, 98, 147
" Government of.....	XI, 142, 144
" Power of.....	XI, 147
" Revenue of.....	XI, 146
Carthaginians.....	XI, 137-141, 143
" Voyages of.....	XI, 146
Case, Check Valve— <i>Illustration, Plate II</i>	I, 116-117
" Headlight— <i>Illustration, Plate I</i>	I, 58-59
" Pump Valve— <i>Illustration, Plate I</i>	I, 58-59
" Raising Transformer— <i>Illustration</i>	I, 423
Cases, Ticket.....	IX, 180, 191

	PAGE
Cases, Ticket—English.....	V, 240
“ “ —Rules Governing Use of.....	V, 123, 129
Cash. (See also “Money.”).....	X
“ Access to.....	IX, 340, 341
“ “ —at Stations.....	IX, 183
“ and Accounts, Concentration of.....	II, 285, 286
“ Balancing.....	IX, 230, 231, 407-411
“ Book.....	II, 273
“ “ Agents’.....	IX, 330-332
“ “ “ and Conductors’—at Headquarters.....	X, 138, 139
“ “ “ —Auditing, by Traveling Auditor.....	IX, 285, 286
“ “ Audited Accounts.....	X, 140, 141
“ “ Entries in.....	IX, 141, 142, 144, 332
“ “ Falsifying.....	IX, 144
“ “ General.....	X, 60-62, 139-141
“ “ Station—Balancing.....	VI, 206
“ “ “ Entries in.....	VI, 205
“ Care of.....	IX, 133-135, 167, 242-245
“ Collections of—Account Various Persons.....	VII, 417
“ Counting.....	IX, 331
“ “ —by Traveling Auditors.....	IX, 285, 341
“ Differences.....	IX, 349-351
“ Disbursements.....	X, 92-94
“ Drawers.....	IX, 190, 191, 287, 337, 338, 341
“ Fare Collections.....	V, 192, 194
“ “ Receipts, Conductors’.....	IX, 83, 84, 113, 114, 421
“ “ Record.....	V, 195
“ “ Returns, Rules Governing.....	V, 218-221
“ Fares, Collection of.....	V, 181, 182
“ “ “ —Rules Governing.....	V, 194-198
“ Handling.....	V, 191; IX, 133-135, 289, 304, 434; X, 288, 289
“ Receipt of.....	II, 285
“ Receipting for.....	IX, 81-85
“ Remittance of.....	V, 222; IX, 135, 138, 139, 261; X, 69
“ “ “ —in England.....	V, 251, 252
“ “ “ —Various Persons Accounts.....	VII, 417-419
“ Responsibility for.....	IX, 350, 351
“ Supervision Over.....	II, 285
“ Vault, Care of.....	X, 270, 271
Cashier, General.....	X, 260, 261
Cashiers, Appointment of.....	II, 261
“ Assistant.....	X, 260
“ Duties of.....	IX, 351, 352
“ Duties of—at Large Stations.....	IX, 232-234
“ Transfer of.....	IX, 260
Casing Dome— <i>Illustration, Plate I</i>	I, 58-59
“ Inside— <i>Illustration, Plate II</i>	I, 116-117
“ Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Window— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Casks, Handling	VI, 98
Caspian Sea	I, 103
Casting, Base— <i>Illustration, Plate II</i>	I, 116-117
" Body— <i>Illustration, Plate II</i>	I, 116-117
" Roof— <i>Illustration, Plate II</i>	I, 116-117
" Staple—Swing Hanger— <i>Illustration, Plate II</i> ..	I, 116-117
" Truck Center— <i>Illustration, Plate I</i>	I, 58-59
Castings, Brass. (See also "Brasses")	VII, 136
" Dome— <i>Illustration</i>	I, 98
" Draw Bar Check— <i>Illustration, Plate III</i>	I, 170-171
" Driving Wheel— <i>Illustration</i>	I, 67
" Storage of	I, 252
Cast-Iron Car Wheel with Steel Tire— <i>Illustration</i>	IV, 209
" Use of—for Car Wheels	IV, 215, 216
" Wheels	IV, 206
Cast-Steel Wheels	IV, 198
Catch, Doorholder— <i>Illustration, Plate II</i>	I, 116-117
" Spring— <i>Illustration, Plate II</i>	I, 116-117
Catches for Doors	I, 243
Cattle Car, Peloponnesus Railroad— <i>Illustration</i>	I, 190
" Guard, American— <i>Illustration</i>	III, 342
" Guards	III, 225, 256
" —Cost of Maintenance of	III, 292
" Trucks, Use of—for Passengers	I, 169
Cavanaugh, J. A.	VI, 57
Cedar Ties	III, 350
Ceiling— <i>Illustration, Plate II</i>	I, 116-117
" Deafening— <i>Illustration, Plate II</i>	I, 116-117
" Lower Deck— <i>Illustration, Plate II</i>	I, 116-117
Cement	I, 273
" Use of—by Railways	VII, 219
Centaur	XI, 84
Centennial Exposition, Locomotive exhibited at—The First Passenger Mogul, 1876— <i>Illustration</i>	I, 46
Center Bearing Arch Bar— <i>Illustration, Plate II</i>	I, 116-117
" " " Body— <i>Illustration, Plate II</i> ..	I, 116-117
" " " Beam— <i>Illustration, Plate II</i>	I, 116-117
" " " Plates— <i>Illustration, Plate II</i> ..	I, 116-117
" " " Strip— <i>Illustration, Plate II</i> ..	I, 116-117
" " " Inverted Arch Bar— <i>Illustration, Plate II</i> ..	I, 116-117
" " " Pillar, Body Transom— <i>Illustration, Plate II</i> ,	I, 116-117
" " " Stool— <i>Illustration, Plate II</i>	I, 116-117
" Bound Track	III, 217
" Brake Balance Spring— <i>Illustration, Plate II</i> ..	I, 116-117
" " " Rod— <i>Illustration, Plate II</i> ..	I, 116-117
" " " Beam— <i>Illustration, Plate II</i>	I, 116-117
" " " Fulcrum— <i>Illustration, Plate II</i> ..	I, 116-117

	PAGE
Center Brake Hanger— <i>Illustration, Plate II</i>	I, 116-117
“ “ Release Spring— <i>Illustration, Plate II</i> ..	I, 116-117
“ “ Safety Hanger— <i>Illustration, Plate II</i> ..	I, 116-117
“ “ Shoe— <i>Illustration, Plate II</i>	I, 116-117
“ “ Transom— <i>Illustration, Plate II</i>	I, 116-117
“ Casting Truck— <i>Illustration, Plate I</i>	I, 58-59
“ Cross Tie— <i>Illustration, Plate III</i>	I, 170-171
“ Filling, Body Bolster— <i>Illustration, Plate III</i> ..	I, 170-171
“ Nailing Strip— <i>Illustration, Plate III</i>	I, 170-171
“ Pin— <i>Illustration, Plate II</i>	I, 116-117
“ “ Truck— <i>Illustration</i> ..	I, 65
“ Plate Block— <i>Illustration, Plate II</i>	I, 116-117
“ “ Body— <i>Illustrations</i> , { <i>Plate II</i>	I, 116-117
“ “ “ { <i>Plate III</i>	I, 170-171.
“ “ Truck— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Bolster— <i>Illustration, Plate III</i> ..	I, 170-171
“ Plates	I, 214
“ Stem— <i>Illustration, Plate II</i>	I, 116-117
“ “ Follower— <i>Illustration, Plate II</i>	I, 116-117
“ “ Inner Guide— <i>Illustration, Plate II</i>	I, 116-117
“ “ Pin— <i>Illustration, Plate II</i>	I, 116-117
“ “ Spring— <i>Illustration, Plate II</i>	I, 116-117
“ Suspension Lamp— <i>Illustration, Plate II</i> ..	I, 116-117
Centers, Driving Wheel— <i>Illustration, Plate I</i> ..	I, 58-59
Central America—Its Primitive Associations and Means of Carriage	XI, 407-417
“ “ —Primitive Carriage in— <i>Illustrations</i> ..	XI, 404-417
“ Asia	XI, 54
“ “ —Carriage in	XI, 153
“ “ —Its Primitive Associations and Means of Car- riage	XI, 362-365
“ “ —Primitive Carriage in— <i>Illustrations</i> ..	XI, 362-365
“ “ —Use of Portable Railroads in	I, 223
“ Pacific Railroad	III, 163; V, 287, 439
“ Railroad of Georgia	VI, 20
“ “ of New Jersey	III, 363
Centrifugal Force, Counteraction of—on Curved Track ..	III, 187, 188
Certificate Watch—Form of	IV, 336
Certificates, Convention	V, 171
“ of Stock, Sale of	III, 90
“ “ Wages. (See also “Time Tickets”)	IX, 380-390; X, 271
“ “ “ —Payment of	IX, 390-397; X, 286
Ceylon—Its Primitive Associations and Means of Carriage ..	XI, 353-358
“ —Primitive Carriage in— <i>Illustrations</i> ..	XI, 353-358
Chafe Thimble, Draw Bar— <i>Illustration, Plate III</i> ..	I, 170-171
Chafing Plate, Check Chain— <i>Illustration, Plate II</i> ..	I, 116-117

	PAGE
Chafing Plate, Spring Beam— <i>Illustration, Plate II</i>	I, 116-117
“ “ Transom— <i>Illustration, Plate II</i>	I, 116-117
“ “ Truck Bolster— <i>Illustration, Plate II</i>	I, 116-117
“ Strip, Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ Strips, End Door— <i>Illustration, Plate III</i>	I, 170-171
Chain Brake	I, 292, 298, 308
“ “ Hand	I, 297
“ Check— <i>Illustration, Plate II</i>	I, 116-117
“ Face Plate Retaining— <i>Illustration, Plate II</i>	I, 116-117
“ Hand Brake— <i>Illustration, Plate III</i>	I, 170-171
“ Pin Lifter— <i>Illustration, Plate III</i>	I, 170-171
“ Platform Railing— <i>Illustration, Plate II</i>	I, 116-117
“ Pulley, Berth— <i>Illustration, Plate II</i>	I, 116-117
“ Safety Coupling— <i>Illustration, Plate II</i>	I, 116-117
“ Shaft, Brake— <i>Illustration, Plate II</i>	I, 116-117
“ Sheave— <i>Illustration, Plate II</i>	I, 116-117
“ “ Bracket— <i>Illustration, Plate II</i>	I, 116-117
“ Spring—Berth— <i>Illustration, Plate II</i>	I, 116-117
Chains, Coupling Cars by	I, 204
Chair Cars	V, 221
“ Rail—Invention of	III, 177
“ “ —the First, New-Castle-on-Tyne, A. D. 1797— <i>Illustration</i>	III, 177
Chairs, Rail	III, 332, 341
“ “ —Use of	III, 374
“ Reclining—American— <i>Illustration</i>	I, 218
Chairman of the Board	II, 131, 138, 143
Chaldeans, Building Among	XI, 81
“ Carriage Among	XI, 75
“ Home of the	XI, 79
Change, Indisposition to—Danger of	X, 46, 47
Changes in Railway Force	II, 67
“ “ the Railway Service, Due to the Introduction of Electricity	I, 392
Channel Carrying Exhaust Steam from Cylinder to Smoke-stack— <i>Illustration</i>	I, 65
“ Live Steam— <i>Illustration</i>	I, 65
Characteristics, General—of the Alternating Current System	I, 441-443
“ of Men	II, 17
“ “ Railway Service	II, 63, 64
Charges, Advanced—Verifying	IX, 91, 92
“ Baggage—Interline Excess	V, 509
“ “ —Local Excess	V, 508, 509
“ “ Storage	V, 509, 510
“ “ —Unpaid	V, 509
“ Car Service	VI, 219, 220
“ Demurrage	VI, 49, 53-63
“ Excess Baggage—Collection of	V, 462-477
“ Express—Collection of	V, 523

	PAGE
Charges, Fixed—Meaning of the Term.....	III, 413
“ for Cartage.....	VI, 9, 10
“ “ Transferring Cars.....	VI, 222, 223
“ “ Weighing Cars.....	VI, 222, 223
“ Freight.....	VI, 105
“ “ —Accruing en Route.....	VI, 213-215
“ “ —Accumulation of Unpaid.....	IX, 75
“ “ —Advanced.....	VI, 113, 125, 158; IX, 320-323
“ “ —Rules Governing.....	VI, 160
“ “ —Collection of.....	IX, 65-74, 290, 308-316
“ “ —Extending Credit for.....	IX, 65-74
“ “ —for Special Cars.....	VI, 124
“ “ —Guaranteeing.....	VI, 95, 96
“ “ —Interline, Prepaid.....	VI, 156; IX, 126
“ “ —Rules Governing.....	VI, 161, 162
“ “ —Miscellaneous.....	VI, 158, 215-217
“ “ “ —Prepaid.....	VI, 156, 214
“ “ “ —Receipt for.....	VI, 217, 218
“ “ “ —Unpaid.....	VI, 158, 214
“ “ —not Specified on Way Bills.....	VI, 215-217
“ “ “ Waybilled.....	VI, 214
“ “ —Payment of.....	VI, 209
“ “ —Prepaid.....	VI, 113, 125, 152-157; IX, 315
“ “ —Prepayment of.....	VI, 96; IX, 126-129
“ “ —Receipt for.....	VI, 197-210
“ “ —Receipts Given Shippers for.....	IX, 114
“ “ —Uncollectible.....	IX, 132, 133
“ “ —Unpaid.....	VI, 152
“ “ —Verifying Uncollected.....	IX, 77
“ Government Freight.....	VI, 279
“ Local—on Way Bills.....	VI, 129, 130
“ Miscellaneous—Accounting for.....	IX, 62-64
“ Special—Way Bill for.....	VI, 131
“ Stockyard—Waybilling.....	VII, 340
“ Storage.....	VI, 107
“ “ for Baggage.....	V, 424-427
“ Switching.....	VI, 252-255
“ “ —Collectible.....	VI, 260, 261
“ “ —Due Other Companies.....	VI, 258, 259
“ “ —Receipt for.....	VI, 255-258
“ “ —Record of.....	VI, 255-258
“ Terminal.....	III, 408, 409
“ Transportation—on Material.....	VII, 276-278
“ Unrefunded—Monthly Return of.....	VI, 265, 266
“ “ —Receipt for.....	VI, 263, 264
“ “ —Record of.....	VI, 263, 264
Charging Floor.....	I, 258
“ —Instructions to Trainmen.....	I, 371
Chariot, First Use of.....	XI, 102
“ of Nausicaa.....	XI, 152

	PAGE
Chariot, Use of—in Battle.....	XI, 103
“ “ —in Primitive Times.....	XI, 104
Chariots.....	I, 293
“ Bronze.....	XI, 102, 106
“ Egyptian.....	XI, 110, 111
“ of Antiquity.....	XI, 103
“ Reference to—by Homer.....	XI, 103
“ War—Wheels of.....	IV, 180-183
Charles I.....	XI, 106
Charleston & Hamburg Railroad, Train of— <i>Illustration</i>	I, 33
Charlton, James.....	V, 80
Chart, Ticket—Interline.....	V, 136-138
“ Time.....	IV, 71-75
“ “ Table—Form of.....	IV, 505
Charts.....	II, 213
Charter, Cost of.....	III, 156
“ Procurement of.....	III, 156
Charters, Drawing.....	II, 232
“ Grant of.....	VIII, 179
Check, Bank—Invention of.....	XI, 128
“ Chain— <i>Illustration, Plate II</i>	I, 116-117
“ “ Chafing Plate— <i>Illustration, Plate II</i>	I, 116-117
“ “ Eye Bolt— <i>Illustration, Plate II</i>	I, 116-117
“ “ Hook— <i>Illustration, Plate II</i>	I, 116-117
“ “ Loop— <i>Illustration, Plate II</i>	I, 116-117
“ Metal.....	I, 266
“ Room.....	I, 266
“ Screws for Cluster— <i>Illustration, Plate II</i>	I, 116-117
“Check” System of Keeping Time.....	I, 265, 266; VII, 361-363
Check Valve— <i>Illustrations, Plate I</i>	I, 58-59, 60, 79, 344
“ “ Case— <i>Illustrations, { Plate I.....</i>	I, 58-59
“ “ “ { <i>Plate II.....</i>	I, 116-117
“ “ in Air Pipe— <i>Illustration, Plate II</i>	I, 116-117
“ “ Spring— <i>Illustration</i>	I, 344
Checks, Accepted by Agents.....	IX, 345, 346
“ Baggage. (See also “Way Bills.”).....	V, 53, 54
“ “ —Access to.....	V, 433
“ “ —Care of.....	V, 436-439
“ “ —Cost of.....	V, 378
“ “ —Exchange of.....	V, 333
“ “ —Lost.....	V, 330, 331, 440, 441, 503, 504
“ “ —Merits of Metal.....	V, 375
“ “ —Mismatching.....	V, 331-333
“ “ —Objections to Metal.....	V, 372-375, 377, 378
“ “ —Reversible.....	V, 55
“ “ —Shell.....	V, 55, 56
“ “ —“Shell” Strap.....	V, 490
“ “ —Use of.....	V, 380-383
“ Indorsements on.....	IX, 344-346
“ Mileage Exchange.....	V, 211

	PAGE
Checks, Money—Accepting.....	X, 262
“ “ —Care of.....	X, 271
“ “ —Drawing.....	VII, 445
“ “ —Effect of Paying Wages in.....	X, 190
“ “ —Forgery of.....	X, 188
“ “ —Indorsing.....	VII, 444, 445
“ “ —Issuing.....	X, 267, 268
“ “ —Lost.....	VII, 440; X, 98, 268
“ “ —Payment of Wages by.....	X, 188-215, 235-252
“ “ —Spoiled.....	X, 268
“ “ —Stolen.....	X, 268
“ “ —Writing on.....	IX, 433
“ Pay—Cashing.....	X, 193, 194, 202, 203
“ “ —Cost of Payment by.....	X, 212, 215
“ “ —Delivery.....	X, 240, 244
“ “ —Differences in.....	X, 208
“ “ —Distribution of.....	X, 208, 212, 213, 244-247
“ “ —Funds for Cashing.....	X, 248-250
“ “ —Issuing.....	X, 236-244
“ “ —Rules Governing.....	X, 235-252
“ “ —Uncalled for.....	X, 251
“ Receiving.....	IX, 188
“ Stop-over.....	V, 213-216; X, 127, 128
“ Time.....	VII, 361-363
“ <i>versus</i> Currency.....	X, 211-215
Checking Baggage.....	V, 436-439
“ —American System of.....	V, 377-383
“ Speed of Trains.....	I, 317, 318
Chemical Energy—Its Conversion Into Electrical Energy..	I, 402
“ “ —Production of Electricity by.....	I, 397
“ “ “ Heat by.....	I, 397
“ “ —Transformation of, into Mechanical En- ergy.....	I, 393
“ Tests.....	I, 277
Chemins de fer De L'Etat Belge, Locomotive of.....	I, 150
Chest, Steam.....	I, 286
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ —How Kept Free from Cinders.....	I, 95
Chestnut Ties.....	III, 350
Chewsures.....	XI, 72
Chicago & North-Western Railway.....	III, 89, 183, 184
“ Milwaukee & St. Paul Railway.....	III, 88
“ Rock Island & Pacific Railroad.....	III, 360
Chief Engineer.....	II, 138
“ —Duties of.....	II, 210-223
“ Executive “ “.....	II, 143
“ “ —Influence of.....	II, 81
“ “ —Titles of ..	II, 143
“ Manager. (See also “General Manager.”).....	II, 134
Chiefs, Barbaric—Power of.....	XI, 32, 35

	PAGE
Children, Property Rights of.....	XI, 14
" Value of.....	XI, 17
" Recognition of.....	XI, 26
Chilled Iron— <i>Illustration</i>	IV, 202
" Wheel, for Passenger Cars— <i>Illustration</i>	IV, 201
" Wheels.....	I, 302; IV, 198
" " —Manufacture of.....	IV, 200-207
" " —Patterns of.....	IV, 207
Chilling, Process of.....	IV, 201, 202
Chime Whistles— <i>Illustration, Plate I</i>	I, 58-59
Chimney, Side Lamp— <i>Illustration, Plate II</i>	I, 116-117
" Ventilating— <i>Illustration, Plate II</i>	I, 116-117
Chimneys, Destruction of—How Overcome.....	I, 53
China.....	XI, 16-69
" Carriage of.....	V, 519
" —Its Primitive Associations and Means of Carriage...	XI, 254-272
" —Primitive Carriage in— <i>Illustrations</i>	XI, 254-272
" Railway Locomotive— <i>Illustration</i>	I, 121
Chinese Vehicles, Wheels of.....	IV, 191
Chios.....	XI, 106
Christ, Teachings of.....	XI, 20, 41
Christianity, First Teachings of.....	XI, 70
Chronicle, The Baltimore.....	I, 190, 195
Chronometers, Use of—by Railways.....	VII, 209
Churchward, James.....	III, 328, 332, 334, 338
Chute, Cinder— <i>Illustration, Plate I</i>	I, 58-59
" Coal.....	I, 108
Cinder Ballast.....	III, 221, 222
" Chute— <i>Illustration, Plate I</i>	I, 58-59
" " Slide— <i>Illustration, Plate I</i>	I, 58-59
" Gondola— <i>Illustration</i>	I, 60
Cinders.....	I, 96
" Handling—at Roundhouse.....	I, 260
" —How Kept from the Steam Chest and Cylinders.....	I, 95
" In the Air Brake.....	I, 369
" Removal of.....	I, 246
Circuit Breaker.....	I, 460, 461
" Current in a—How Found.....	I, 402
" for the Flow of Electrical Current.....	I, 397
" Resistance of.....	I, 415, 416, 432, 433, 475, 476
" Street Railway—Electro-Motive Force on.....	I, 401
" Transmission.....	I, 396, 449
Circuits, Employed in the Control and Operation of a Block System— <i>Illustration</i>	IV, 285
" High Tension.....	I, 452
" Losses in.....	I, 415-419
Circulars.....	IX, 41, 42
Circulating Drum— <i>Illustration, Plate II</i>	I, 116-117
" Pipe, Hot Water— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Circulating Pipe, Steam— <i>Illustration, Plate II</i>	I, 116-117
Circulation of Heated Air.....	I, 261
Circumferential Seam— <i>Illustration, Plate I</i>	I, 53-59
Circus Trains, Waybilling.....	VI, 138
Cities, Vouchers in Favor of.....	VII, 435
City & South London Railway—Use of Electricity on....	I, 505
Civil Engineer.....	II, 175, 176, 198; III, 131-133, 311, 312
" " Characteristics of.....	II, 210, 211, 213
" " Functions of.....	II, 211
" Engineers, Requisitions of.....	VII, 72
" Liberty—How Maintained.....	XI, 45
" Service of Railways.....	II, 143, 163, 204
Civilization.....	II, 36
" Complex.....	I, 136
" Organized.....	I, 136
" Relation of Property to.....	XI, 9
" —To What Due.....	II, 34
Claim Agent.....	II, 224, 234-236; V, 319; VI, 287
" Bureau.....	II, 138, 245
" Department Scope of.....	VI, 19
Claims.....	VI, 18-22
" Adjustment of.....	VI, 283-295
" " —in England.....	VI, 21
" Against the Government.....	VI, 276-279
" Agents'—for Relief.....	VI, 295, 296;
" 	IX, 129-131, 259, 267-269, 369-374
" Baggage.....	V, 337, 339, 340
" " —Settlement of.....	V, 315-322
" Damage—Interline.....	VI, 300-306
" Delays in Settlement of.....	VI, 21
" Department Having Charge of.....	II, 233
" Freight—English.....	VI, 332, 333
" Interline—Rules Governing.....	VI, 297
" " —Settlement of.....	VI, 21
" Joint—Auditing.....	VI, 20
" Loss—Interline.....	VI, 300-306
" Overcharge—Interline.....	VI, 298-300
" Settlement of, II, 137, 232, 235; VI, 19, 20, 283-295; IX, 63	
" Unjust—Efforts to Enforce.....	II, 17
Clamp, Hose— <i>Illustration, Plate II</i>	I, 116-117
Clan.....	XI, 67
" Origin of.....	XI, 27
" Religion of.....	XI, 41
Clapperton.....	XI, 28
Clark, Thomas C.....	III, 318
Classification Adopted by Association of American Railway	
Accounting Officers.....	VII, 468, 469
" Common.....	VI, 30
" of Construction Accounts.....	VII, 456-469
" " Freight.....	VI, 27-29

	PAGE
Classification of Labor.....	VII, 379-382
" " Operating Expenses.....	VII, 472-499
" " " Value of.....	X, 142-147
" " Passenger Traffic, English.....	V, 244
" " Railway Officers and Employes.....	II, 806
" " Trains.....	IV, 352, 353
" Purpose of.....	VI, 26
" Railway.....	VII, 453-471
" Table, the.....	VI, 26
" The Western.....	VI, 444
" Uniform—Its Effect on Commercial Interests.....	VI, 34
" " " Impracticability.....	VI, 35-37
" Uniformity in.....	VI, 26, 80-37
Classifications.....	VIII, 53
" for Different Sections of the United States.....	VI, 34
" Relation of Discrimination to.....	VIII, 56
" Study of—by Agents.....	IX, 57
Clean Valves—Instructions to Engineers.....	I, 365
Cleaners.....	I, 270
Cleaning Brake Cylinders.....	I, 329
" Cars.....	I, 269
" Cylinders and Triple Valves—Instructions to Car Inspectors.....	I, 331, 332
" Door— <i>Illustration, Plate I.</i>	I, 58-59
" Freight in Transit.....	VI, 267
" Triple Valves.....	I, 329
Cleanliness.....	II, 21
" Necessity of.....	IV, 68, 69
" of Paint and Oil Stock Rooms.....	I, 274
Clear Story— <i>Illustration, Plate II.</i>	I, 116-117
Clearance Posts.....	III, 238
Clearing a Train—Meaning of Term.....	IV, 817
"Clearing and Grubbing,".....	VII, 460
Clearing House Half Yearly Parcel Settlement.....	V, 269, 270
" " Passenger Credit Statement, English.....	V, 262-265
" " " Debit Statement, English.....	V, 261
" " " Station Debit Returns, English.....	V, 267-269
"Clearing Wrecks,".....	VII, 491, 522
Clearness, Necessity of—in Accounting.....	IX, 297-306
Clerical Force, Skill of.....	III, 468, 469
" Work.....	II, 282
" " Cost of.....	II, 288
Clerks, Bill.....	VI, 183
" Billing—Duties of.....	IX, 49, 50
" English.....	IV, 447-450
" Tally, Duties of.....	IX, 50
" Time.....	X, 67
" Value of.....	II, 282
Clevis, Pin Lifter— <i>Illustration, Plate III.</i>	I, 170-171

	PAGE
Climate, Effect of—on Bridges.....	III, 294, 295
" " " " Property.....	III, 477-478
" " " " Rails.....	III, 272-277
" " " " Ties.....	III, 282
" " " " Track.....	III, 287, 288
" Influence of—on Cost of Maintenance.....	III, 383, 391
Clinker Pit.....	I, 246
Cloak Rooms, English.....	V, 249, 250
Clock System of Timekeeping.....	I, 266
Clocks, Rules Governing.....	IV, 335-338
Closed Clasp, Side Door— <i>Illustration, Plate III</i>	I, 170-171
" Conduit System.....	I, 466
" Stop, End Door— <i>Illustration, Plate III</i>	I, 170-171
" " Side Door— <i>Illustration, Plate III</i>	I, 170-171
" Switch, Meaning of Term.....	IV, 312
Cloth, Emery—Use of, by Railways.....	VII, 212
Clothing, Origin of the Use of.....	XI, 63
Cloths, Furnishers of.....	I, 182
Club—the First Weapon.....	XI, 62
Cluster— <i>Illustration, Plate II</i>	I, 116-117
" Checks Screws for— <i>Illustration, Plate II</i>	I, 116-117
" " Stem— <i>Illustration, Plate II</i>	I, 116-117
" " Lock Nut— <i>Illustration, Plate II</i>	I, 116-117
Coach, American Form of.....	I, 203
" " " " —How Looked Upon by English People.....	I, 184
" Covered.....	XI, 106
" First Class Passenger.....	I, 174
" Passenger—American Standard— <i>Illustration</i>	I, 216
" Wheels, Steel Tired.....	I, 302, 303
Coaches. (See also "Car" and "Cars.")	
" Day—Weight of.....	I, 165
" First Let for Hire.....	XI, 106
" Passenger.....	I, 203
" Various Classes of.....	I, 202
Coaching Returns, English.....	V, 252-259
" Traffic—in England.....	V, 237
Coal Accounting for.....	VII, 315
" Anthracite—Composition of.....	VII, 167
" " —Deterioration of.....	VII, 168-170
" " —Grates for.....	I, 96
" As a Source of Power.....	I, 393
" Bituminous—Composition of.....	VII, 167
" " —Deterioration of.....	VII, 164-167
" Box— <i>Illustration, Plate II</i>	I, 116-117
" Car, Victorian Railway— <i>Illustration</i>	I, 163
" Cars.....	I, 121, 207
" Chute.....	I, 108
" Combustion of.....	IV, 41, 42, 44-48
" Comparative Cost of.....	I, 103

	PAGE
Coal, Consumption of—by Locomotives.....	I, 71, 72
“ Cost of.....	VII, 175
“ Deterioration of.....	VII, 327
“ Differences in Quality of.....	VII, 170
“ Effect of—on Fire Boxes.....	VII, 171
“ Experiments Regarding the Use of.....	I, 54
“ Heat Produced by Burning.....	I, 402
“ Heating Capacity of.....	VII, 162
“ House.....	I, 246
“ Invoices of.....	VII, 328
“ Moisture in.....	VII, 164
“ Oil, Handling.....	VI, 98, 99
“ Receiving.....	VII, 329
Coat Hook— <i>Illustration, Plate II</i>	I, 116-117
Cock, Angle.....	I, 326, 372, 373, 376, 377
“ “ — <i>Illustrations, Plate II</i>	I, 116-117, 320, 321, 372
“ Bleed	I, 320
“ Bleeding— <i>Illustration, Plate II</i>	I, 116-117
“ Blower— <i>Illustration, Plate I</i>	I, 58-59
“ Burner— <i>Illustration, Plate II</i>	I, 116-117
“ Cut Out.....	I, 336, 538
“ “ — <i>Illustration, Plate III</i>	I, 170-171
“ “ “ — <i>Brake—Illustration, Plate II</i>	I, 116-117
“ “ “ — <i>In Air Pipe Under Engineer's Valve—Illustration</i>	I, 539
“ “ “ “ — <i>Branch Pipe—Illustrations</i>	I, 540, 541
“ “ “ “ — <i>Signal Branch Pipe—Illustration, Plate II</i>	I, 116-117
“ Cylinder Relief— <i>Illustrations</i>	I, 113
“ Drip— <i>Illustration, Plate I</i>	I, 58-59
“ Four-Way.....	I, 320
“ Hose.....	I, 363
“ Hot and Cold Water— <i>Illustration, Plate II</i>	I, 116-117
“ Lever Cylinder— <i>Illustration, Plate I</i>	I, 58-59
“ Reservoir.....	I, 324
“ Stem of Three-Way— <i>Illustration, Plate II</i>	I, 116-117
“ Stop— <i>Train Signal—Illustration, Plate II</i>	I, 116-117
“ Straight-Way.....	I, 372
“ “ — <i>Plain—Illustrations</i>	I, 322, 372
“ Three-Way.....	I, 347
“ “ — <i>Illustrations, Plate II</i>	I, 116-117, 348
“ Train Pipe.....	I, 326
Cocks.....	I, 330
“ Air— <i>Instructions to Trainmen</i>	I, 372
“ Angle— <i>for Closing Train Pipe—Illustrations</i>	I, 540, 541
“ Cylinder.....	I, 94
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ — <i>Closing</i>	IV, 352
“ Drip.....	I, 315
“ Gauge.....	I, 80

	PAGE
Cocks, Gauge or Water— <i>Illustrations, Plate I</i>	I, 58-59, 64
“ in Train Pipes.....	I, 321, 323, 324
Coil, Expanding Generator— <i>Illustration, Plate II</i>	I, 116-117
Coils.....	I, 407, 408
“ Armature.....	I, 472, 473
“ “ for Railway Motor— <i>Illustration</i>	I, 411
“ Insulation of.....	I, 457
Coin, Remitting.....	IX, 417
“ Transportation of.....	V, 519
Coins, Mutilated.....	IX, 327
“ Receiving.....	IX, 327
Coinage.....	III, 10
“ Free.....	III, 11
Coke, Accounting for.....	VII, 315
“ Cars.....	I, 121
Cold Water Pipe— <i>Illustration, Plate II</i>	I, 116-117
“ “ to Bowl— <i>Illustration, Plate II</i>	I, 116-117
Colebrookdale.....	III, 176
Collar, Axle— <i>Illustration, Plate III</i>	I, 170-171
Collaterals.....	III, 16
“ Custody of.....	II, 186
Collecting Agencies, for Freight Charges.....	IX, 71-74
Collection of Freight.....	VI, 9, 10
“ “ Railway Revenue.....	IX, 72-92
“ “ Way Bills.....	IX, 92, 93, 310, 311
“ “ —Rules Governing.....	VI, 211-213
Collections, Cash Fare.....	V, 192-194
“ “ —Rules Governing.....	V, 194-198
“ Conductors’.....	IX, 419, 420
“ Ferry—Record of.....	VI, 221, 222
“ Freight—Accounting for.....	VI, 206
“ “ —at Stations.....	IX, 65-74
“ “ —Discrepancies in.....	VI, 206
“ Miscellaneous.....	IX, 60-62, 282
“ “ —Remitting.....	IX, 424-427
“ Special—Accounting for.....	VII, 414-429
“ Station—Remittance of.....	IX, 352
“ Stockyard.....	VII, 340, 341
“ Suppressing.....	X, 58
“ Suppression of—by Agents.....	IX, 206
“ Ticket—Auditing.....	X, 123
“ “ —Conductors’.....	X, 123, 124
Collectors, Ticket.....	V, 16, 17, 83
Colleges, Railway—Establishment of.....	II, 222
Collieries, Proprietors of—in Great Britain.....	II, 45
Colliery, The Wylam.....	I, 23
Collisions, Prevention of.....	IV, 122
“ Protection of Trains from.....	IV, 293-301
“ Rear.....	IV, 81, 123, 124
Color Blindness.....	IV, 224-243

	PAGE
Color Blindness—Cause of.....	IV, 224
“ “ Prevalence of—in Railway Service.....	IV, 18
“ “ Testing for.....	IV, 232-239
“ “ Writings on.....	IV, 228
Colors, Meaning of—as Signals.....	IV, 340, 341
“ Use of—for Signals.....	IV, 263
Columbia & Maryland Railway—Use of Electricity on.....	I, 504, 505
Columbus.....	XI, 122
Column Bolt— <i>Illustration, Plate III</i>	I, 170-171
Columns.....	I, 214
Combination Coupling.....	I, 374
“ Drip Cock— <i>Illustration, Plate II</i>	I, 116-117
Combinations, Causes of.....	VIII, 64
“ Effect of.....	VIII, 61
Combustion, Explanation of.....	IV, 41, 42, 44-48
“ Maximum Amount Per Hour.....	I, 72
“ Production of Heat by.....	I, 397
“ Rapid.....	I, 71
“Comet” Locomotive.....	I, 33
Commerce, Conditions of—in Ancient Times.....	XI, 97
“ Equities of.....	VI, 52
“ Fluctuations of.....	II, 243
“ Natural Laws Governing.....	VIII, 21, 22
“ Origin of.....	XI, 72
“ Relation of Special Rates to.....	VIII, 129
“ Requirements of.....	XI, 144
Commercial Agents.....	V, 474
“ Travelers, Baggage Tickets for.....	V, 471
Commission, Characteristics of a Valuable.....	VIII, 194
“ Description of a Desirable.....	VIII, 197
“ Value of an Impartial.....	VIII, 194
“Commissions”.....	VII, 493, 522
Commissions, Payment of—to Agents of Other Lines.....	V, 49, 50
“ Ticket.....	V, 49, 50
Commissioners, Government.....	III, 46
Committee, Arbitration—English.....	VI, 333
Committees of Directors.....	II, 130, 131
Commodity Statement.....	VI, 271
Common Carrier—Meaning of the Term.....	VI, 5-7
“ “ The First.....	XI, 83, 88
“ Carriers, The First Reference to.....	XI, 83
“ Stock.....	III, 65-69, 88
Communal Period, Close of.....	XI, 38
Communism.....	XI, 24, 34
“ Age of.....	XI, 30
“ Existence of.....	XI, 31
Communitic Period, The.....	XI, 28, 43
Community Effect of Over-construction on.....	VIII, 171
“ “ Unnecessary Railroads on.....	VIII, 200
“ Injury to—by Unwise Legislation.....	VIII, 22

	PAGE
Community, Interest of—In Construction Expenditures..III,	166
" " " " Railway Construction.....	VIII, 172, 173, 285, 292
" Prosperity of—Dependent Upon Railroads.VIII,	20
" Protection of—Against Excessive Rates...VIII,	101
" Relation of Carriers to.....VIII,	84
" " —to Railroads.....VIII,	20, 188
" Rights of.....II,	15
" Rules Governing.....XI,	29
Commutation Tickets.....V,	93, 99-101
Commutator.....I,	407, 408, 411, 426, 457, 471
" Construction of.....I,	421
" Effects of Sparking on.....I,	473
" Flashing at the.....I,	415
" Segment of a—Showing Grooves at Top of Neck for Attaching Wires from Armature — <i>Illustration</i>I,	407
" Showing Segments to Which Armature Wires are Connected— <i>Illustration</i>I,	408
Companies, Limited.....II,	41, 42
Comparison of Cost.....I,	283
Comparisons of Freight Rates of Different Countries...VI,	37-41
" " Traffic—in Different Countries.VI,	8-11
" " Outlay.....I,	287
" " Work.....I,	287
" Result of.....I,	289, 290
Compartment and Passenger Car, Joint Service— <i>Illustration</i>I,	221
" Car, Bosnian Railway— <i>Illustration</i>I,	214
" " English—Origin of.....I,	183, 184
" " New South Wales— <i>Illustration</i>I,	225
" Cars.....I,	177, 201, 203; IV, 122; V, 28, 29
" Sleeping Car, Austrian— <i>Illustration</i>I,	226
" Smoking—in an American Car— <i>Illustration</i> , I,	213
Compass Needle.....I,	400
Compensation, for Labor.....II,	34
Competency, Necessity of—in Railway Service.....III,	415, 416
Competition.....II,	110
" Advantages of.....III,	147
" Effect of...I,	145, 166; VIII, 8, 9, 34, 62, 80, 93, 108, 126, 136, 163, 169, 172, 174, 180, 181
" " "—on Credits.....IX,	71
" " " Pools on.....VIII,	10, 155
" Extent of.....VIII,	9, 176
" for Preferment.....X,	63
" Fruits of.....VIII,	9, 35
" in America.....VIII,	10, 83
" in Germany.....VIII,	83
" Influence on Rates.....VIII,	45, 46
" —Its Effect on Labor.....II,	104

GENERAL INDEX.

87

	PAGE
Competition, Processes of.....	VIII, 146
" Railway	V, 30
" Result of	V, 32
" Universality of.....	VIII, 8, 10, 62
" Wastage of	VIII, 34
Competitive Business	II, 237, 238
Competitors, Advertising Matter of.....	V, 116
" Advice to Officials of Movements of.....	V, 113
" Deviation from Rates by.....	V, 114
" Reporting Irregular Practices of	V, 114
Complications, Cause of.....	II, 16
Compound Carline— <i>Illustration, Plate II</i>	I, 116-117
" Locomotives—While there are numerous refer- ences to the Compound Locomotive in Vol- ume I, and also a number of illustrations, yet the reader is referred for a full account of the Compound Locomotive, fully and practically illustrated, to Volume XII.	
" Rail, New York Central Railroad—A. D. 1855— <i>Illustrations</i>	III, 252, 253, 255
" " Troy Union Railroad—A. D. 1855— <i>Illus- trations</i>	III, 254, 257
" Wound Dynamo	I, 409
" " Two Field Windings— <i>Illustra- tion</i>	I, 409
" " Generators.....	I, 459
Compressed Air,	I, 244, 262, 269, 274, 305, 307, 334
" " Brake	I, 292, 299
" " for Shop Purposes.....	I, 384
" " Locomotives Propelled by.....	I, 223
" " Use of—for Protecting Trains Automati- cally.....	IV, 299-301
Compression Beam— <i>Illustration, Plate II</i>	I, 116-117
" " Brace— <i>Illustration, Plate II</i>	I, 116-117
" " " Auxiliary— <i>Illustration, Plate II</i>	I, 116-117
" " Members of Brake Beam.....	I, 214
Compressor, Air.....	I, 244, 485
" " —The Sweeney— <i>Illustration</i>	I, 383
Comptroller.....	II, 139, 285
Concentration of Authority.....	I, 284
" " Responsibility.....	I, 284

	PAGE
Concentration of Shops.....	I, 283
Concessions.....	II, 350
" —Injudicious.....	II, 110
Conclusions, General—Regarding Pressure, Distance, Cost and Loss in Circuit.....	I, 419, 420
Conducting Transportation.....	VII, 485-495, 518-528
Conductor, The.....	IV, 52-54
Conductors.....	VI, 16
" Accounts of—Auditing.....	V, 84, 85; IX, 307
" Appliances of—for Collecting Fares.....	V, 119
" Authority Over.....	II, 199
Conductors' Brake Valves.....	I, 319, 330
Conductors, Cash Collections of.....	V, 192-194; IX, 112, 113
" " Fare Receipts.....	IX, 83, 84
" Collections of.....	IX, 419-424
" " —Auditing.....	V, 86
" —Defrauding.....	IX, 214-216
" Dining Car—Responsibility of.....	VII, 300
" Duties of.....	IV, 401; V, 190, 217; VII, 367
" " —on Construction Trains.....	IV, 373, 375
" Electrical.....	I, 398, 399, 431, 432, 435, 439, 450, 462
" " —Copper.....	I, 451, 452, 457
" " —Cost of.....	I, 422, 533-537
" " " Copper in.....	I, 420
" " —Overheating.....	I, 429
" " —Power Lost in.....	I, 451
" " —Pressure Between.....	I, 437
" " Surface—For Collecting Current.....	I, 464, 465
" English.....	IV, 441
" Evasion of Rules by.....	V, 182
" Examination of Car Seals by.....	VI, 104
" Fares Collected by.....	IX, 118, 119
" Fiscal Duties of.....	IX, 307-437
" Freight—Instructions to.....	VI, 308-310
" " —Returns of.....	IX, 52, 53, 55, 56
" " —Rules Governing.....	IV, 409-415
" " —Waybilling Instructions of.....	VI, 114
" General Instructions to.....	IV, 402-415; V, 172-179
" Leaving Service, Retaining Wages of.....	VII, 404, 405
" Licensing.....	II, 47
" List of Supplies Required by.....	V, 593
" Passenger.....	VI, 14
" " —Rules Governing.....	IV, 406-409
" Payment of Fares to.....	V, 118
" Remittances of.....	V, 174; IX, 291, 419-424; X, 135-139
" Reporting at Night Telegraph Stations.....	IV, 380
" Responsibility of.....	IV, 52, 359, 374, 377, 402, 403
" " —for Subordinates.....	V, 174
" Returns of.....	V, 156-158, 216-222
" " —for Fares Collected.....	V, 81

	PAGE
Conductors, Returns of Freight Hauled	VI, 179, 180
" " Required of.....	VI, 83
" Rules Governing.....	V, 112
" Tickets Collected by.....	X, 67
Conductor's Valve— <i>Illustration, Plate II</i>	I, 116-117
" " Branch Pipe to— <i>Illustration, Plate II</i>	I, 116-117
" " for Applying Brakes— <i>Illustration</i>	I, 540
" " —Instructions to Trainmen.....	I, 326
Conductors, Withholding Wages of.....	IX, 389
Conduits, Water-tight	I, 466
Connecticut Railroad Commission.....	III, 164
Connecting Lines, Operation of—Where the Gauges Are	
Differant.....	III, 194, 195
" Rod.....	I, 92, 334
" " Brake Lever— <i>Illustration, Plate III</i>	I, 170-171
" " Cylinder Lever— <i>Illustration, Plate II</i>	I, 116-117
" " Hand Brake— <i>Illustration, Plate II</i>	I, 116-117
" " Hodge Lever— <i>Illustration, Plate II</i>	I, 116-117
" " Locomotive.....	I, 87
" " Lower Brake— <i>Illustration, Plate II</i>	I, 116-117
" " to Truck Gear— <i>Illustration, Plate II</i>	I, 116-117
" " Upper Brake— <i>Illustration, Plate II</i>	I, 116-117
Connection, Cylinder Lever and Floating Lever— <i>Illustration</i>	
<i>Plate III</i>	I, 170-171
" " " " Hand Brake— <i>Illustration</i>	
<i>Plate III</i>	I, 170-171
" Floating Lever and Live Truck Lever— <i>Illustration,</i>	
<i>Plate III</i>	I, 170-171
" Main Rod— <i>Illustration, Plate I</i>	I, 58-59
" Pump— <i>Illustration, Plate I</i>	I, 58-59
" " Exhaust— <i>Illustration, Plate I</i>	I, 58-59
" " Steam— <i>Illustration, Plate I</i>	I, 58-59
Connections Between Dynamo and Feeders in Switchboard	
— <i>Illustration</i>	I, 461
" Mechanical—for Carrying Current.....	I, 430
"Conscience" Funds.....	IX, 286, 287
" Money, Accounting for	VII, 423
"Consequent Pole" Motor	I, 472, 473
Consignee, Authority of—Over Freight	VI, 116
" Changing Name of	VI, 116
" Receipt to—for Charges	VI, 197-210
Consignees, Delivery of Freight to.....	IX, 316-318
" Deposits of—to Cover Freight Charges... ..	IX, 311, 312
" Inquisitiveness of.....	IX, 95
" Notice to—of Arrival of Freight . . .	VI, 60, 61, 196
" Property Refused by.....	IX, 131
" Visiting—by Traveling Auditors.....	IX, 80, 285
Consignment Notes.....	VI, 818
Consolidation, Effect of.....	VIII, 61

	PAGE
Consolidation, Freight Locomotive, Brooks'— <i>Illustration</i> ..	I, 138
“ “ or Goods Locomotive, New South Wales— <i>Illustration</i>	I, 128
“ “ of Properties.....	II, 27
“ “ Progress of.....	VIII, 203, 205
Constables	II, 195
Constant Potential Dynamo	I, 408
“ “ Motors.....	I, 415
“ “ Speed Motor.....	I, 445
Constitutional Right, Questions of.....	II, 229
Constructing and Maintaining.....	III, 107-483
Construction.....	III, 109-271
“Construction” Account.....	VII, 525
Construction, Accounting for.....	VIII, 297, 302
“ “ Accounts, Classification of.....	VII, 456-469
“ “ Authority for.....	VIII, 166
“ “ Benefits Following.....	VIII, 182
“ “ Car.....	I, 147
“ “ —Differences in.....	I, 121
“ “ —Standard Details of.....	I, 270
“ “ Causes.....	VIII, 172
“ “ Charges to.....	VII, 454, 455
“ “ Companies.....	III, 30
“ “ Cost of.....	VII, 206; VIII, 51
“ “ —How Lessened.....	III, 152
“ “ —Upon What Dependent.....	III, 167
“ “ Differences in.....	III, 137, 138
“ “ Disbursements for.....	III, 156-166
“ “ Elements of.....	III, 167-176
“ “ Excessive.....	VIII, 169
“ “ Expenditures.....	II, 187, 188; III, 137; VIII, 293
“ “ “ Capitalization of.....	III, 73
“ “ “ Interest of the Community in...	III, 166
“ “ Extravagance in.....	III, 151
“ “ Foremen.....	III, 209
“ “ Free.....	II, 237; VIII, 162, 180, 183
“ “ Indiscriminate.....	VIII, 178, 211
“ “ Influences Attending.....	III, 56
“ “ In India.....	III, 157
“ “ Items Included in.....	III, 132
“ “ —Meaning of the Term.....	III, 137
“ “ Methods of.....	III, 137-151
“ “ “ Raising Money for.....	III, 158
“ “ of Cars and Locomotives.....	I, 232
“ “ “ Equipment.....	I, 238
“ “ “ Locomotives, Improvements in.....	I, 43
“ “ “ Track.....	III, 206-238
“ “ Outlay for—How Governed.....	III, 173
“ “ Particulars of.....	III, 152-166

	PAGE
Contracts, Live Stock.....	V, 204; VI, 101
" Material.....	VII, 89, 288, 289
" Special.....	V, 169
Control, Government. (See also "Government Control.")	
" —Objections to.....	VII, 11, 12
" Private <i>versus</i> Government—of Railroads....	VIII.
Controlled Manual Block System.....	IV, 276
Controller, the.....	I, 483-485
" for Electric Motors; Open, Showing Drum and Fixed Contacts— <i>Illustration</i>	I, 486
" " Two Fifty-Horsepower Motors— <i>Illustration</i>	I, 484
" " Railway Motors— <i>Illustration</i>	I, 485
Convention Certificates.....	V, 171
" Tickets.....	V, 92, 107
Conventions, Notice of—to Officials.....	V, 113
Converter, or Transformer.....	I, 422
" Rotary.....	I, 427
Conveyance, Exhaust Process of.....	I, 274
Conveyances, Execution of.....	V, 519
Cook.....	XI, 28
Cooley, L. E.....	III, 133
Cooler, Water— <i>Illustration, Plate II</i>	I, 116-117
Cooper, Peter—Locomotive Built by— <i>Illustration</i>	I, 27
Cooperation, Charges for.....	VI, 94; IX, 61
Co-operation, Among Railroads.....	I, 287
" —How Obtained by Managers.....	VII, 71
" Necessity of in Commerce.....	VIII, 39
" Systematic.....	I, 284
" Value of.....	II, 290; IX, 433, 434
" " —in Railway Management....	III, 386, 387
Co-operative Effort—How Obtained.....	II, 58
Copper.....	I, 416-420; III, 8; XI, 73
" and Tin Shop— <i>Illustration</i>	I, 251
" Conductors.....	I, 457
" Use of—by Railways.....	VII, 209
" Wire.....	I, 397
Copying Press, Introduction of.....	VI, 85, 86
" Presses, Use of.....	VI, 180, 181
Cord, Bell.....	I, 112, 362
" —Use of, as Signal.....	IV, 250, 251
" Signal.....	I, 362
" — <i>Illustration, Plate II</i>	I, 116-117
Core, Armature—1500 Kilowatt Generator— <i>Illustration</i>	I, 393
" Iron.....	I, 400
" Ovens.....	I, 257
" Rooms.....	I, 257
Corea—Its Primitive Associations and Means of Carriage...	
" 	XI, 293-305
" —Primitive Carriage in— <i>Illustrations</i>	XI, 293-305

	PAGE
Cork, Use of—for Brake Shoes.....	I, 302
Corner Iron, Girt— <i>Illustration, Plate III</i>	I, 170-171
“ “ Plate— <i>Illustration, Plate III</i>	I, 170-171
“ “ Sill— <i>Illustration, Plate III</i>	I, 170-171
“ Plate, End Sill— <i>Illustration, Plate II</i>	I, 116-117
“ Transom— <i>Illustration, Plate II</i>	I, 116-117
“ Post— <i>Illustration, Plate III</i>	I, 170-171
“ Rods— <i>Illustration, Plate III</i>	I, 170-171
Cornico Board, Window Sill— <i>Illustration, Plate II</i>	I, 116-117
“ Fascia Board, Inside— <i>Illustration, Plate II</i>	I, 116-117
“ Inside Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Rafter— <i>Illustration, Plate II</i>	I, 116-117
Coroners, Fees of.....	II, 232; III, 398
Corporate Accounting.....	V, 68
“ Accounts—On What Based.....	VI, 81 82
“ Life, Discipline of.....	II, 19
“ Property, Organization of.....	II, 58-59
“ Seal, Care of.....	II, 182
“ Service, Talent Required in.....	II, 156
“ Vicissitudes of.....	II, 60
Corporations, Accounts of.....	IX, 297
“ Administration of.....	XI, 129
“ Affairs of.....	II, 17
“ Armies of.....	IX, 12
“ Characteristics of.....	IX, 110, 111
“ Directors of.....	II, 128
“ Diversity in Organization of Different.....	II, 125
“ Documents in Favor of.....	VII, 444
“ Downfall of.....	II, 59
“ Economical Operation of.....	II, 85 86
“ Efficiency of.....	II, 79, 80
“ Employees of.....	IX, 110, 111
“ Government of.....	II, 281
“ Great—Characteristics of.....	II, 122, 123
“ —How Their Interest in Their Employees Is Manifested.....	II, 60
“ Interests of.....	II, 16
“ Judgment of.....	II, 67
“ Life of.....	IX, 16
“ Management of—by Private Owners.....	III, 57, 58
“ Managers of.....	II, 73
“ Managing and Working Forces of.....	II, 70
“ Methods of.....	II, iv
“ Operating Force of.....	II, 83
“ Principles Governing the Organization of the Forces of.....	II, 108-121
“ Private—Efficient Service of.....	II, v
“ “ —Growth of.....	II, 135
“ Problems of.....	II, iv
“ Public.....	II, vi

	PAGE
Corporations, Railway—as Manufacturers	VII, 125-133
“ “ —Civil Service of	IX, 17
“ “ —Organization of	X, 36
“ “ —Rights of	VII, 27
“ “ —Safeguards Enforced by	V, 321, 322
“ Safety of—Upon What Dependent	VII, 93
“ Service of	II, 100
“ Vouchers in Favor of	VII, 435
“ Wages Paid by	II, 103
Corpses, Tickets for	V, 97, 139
“ Transportation of	V, 138, 139, 444, 519
Corrections, Making	IX, 361-366
Correspondence, Conduct of	VI, 314
Corrosion, Prevention of	III, 368
Corrugated Iron Roofing— <i>Illustration, Plate III</i>	I, 170-171
Cortez, Conquest of Mexico by	XI, 85
Cost, Comparison of	I, 283
“ “ —Between the Use of Coal and Oil	I, 103
“ Influences Affecting	III, 383-413
“ of Electrical Conductors	I, 422, 533-537
“ “ Operating Railroads	II, 50
“ “ “ “ by Steam Locomotives and by Electricity	I, 514-516
“ “ Power, at Main Stations	I, 440
“ “ Transmission	I, 430
“ Ratio of—to Gross Earnings	III, 144, 145
“ Specifications of—for Construction	III, 131
Counsel	II, 224-234
“ Characteristics of	II, 230, 231
“ Duties of	II, 224-226
“ Experiences of	II, 230
“ General	II, 138
“ Jurisdiction of	II, 224
“ —Meaning of Title	II, 142
“ Records of	II, 230
“ Staff of	II, 226, 227
“ Title of	VII, 250
Counselors, Business Men as	XI, 145
Counter Balance Spring and Rig— <i>Illustration, Plate I</i>	I, 58-59
“ “ Weight— <i>Illustration, Plate I</i>	I, 58-59
Counterbrace— <i>Illustration, Plate II</i>	I, 116-117
“ Rods— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ “ <i>{ Plate III</i>	I, 170-171
Counties, Vouchers in Favor of	VII, 435
Coupled Passenger Bogie Engine, Scotland— <i>Illustration</i>	I, 132
Coupler, Automatic— <i>Illustration</i>	I, 60, 176
“ “ —Air Brake	I, 308
“ Freight Car—American Standard— <i>Illustrations</i>	I, 175
Couplers, Automatic	I, 204; IV, 15, 117-120
Coupling, Air Brake—Extra	I, 321

	PAGE
Coupling and Uncoupling—Instructions to Trainmen	I, 370
Basin— <i>Illustration, Plate II</i>	I, 116-117
Between Dynamo Shaft and Driving Shaft	I, 466
Cars, by Chains	I, 204
Chain, Safety— <i>Illustration, Plate II</i>	I, 116-117
Combination	I, 374
Five-Link	I, 172
Hose, Air Brake	I, 308
“ “ “ — <i>Illustrations, Plate II</i>	I, 116-117, 309
“ “ Keeping Pressure in	I, 373
“ “ Signal— <i>Illustration, Plate II</i>	I, 116-117
“ “ Standard— <i>Illustration</i>	I, 370
“ “ Train Pipe— <i>Illustration, Plate III</i>	I, 170-171
Lugs	I, 371
Pin, Draw Bar— <i>Illustration, Plate III</i>	I, 170-171
Rod— <i>Illustration</i>	I, 60
Steam Hose (Gibbs)— <i>Illustration, Plate II</i>	I, 116-117
“ “ (Sewall)— <i>Illustration, Plate II</i>	I, 116-117
Three-Link	I, 172
Train Pipe— <i>Illustration, Plate III</i>	I, 170-171
Vacuum Brake— <i>Illustration</i>	I, 308
Couplings	I, 299, 336
Air Signal	I, 375
Brake	I, 321, 330
Cleaning	I, 369
Dummy	I, 321, 326, 330, 333
for Train Pipe— <i>Illustrations</i>	I, 539-541
Frozen—Instructions to Trainmen	I, 323, 324
Thawing Out	I, 323, 324
Train Line	I, 375
Coupon, Bond—Form of	III, 96
Mileage Tickets	V, 471, 474, 475, 495
Orders, English	V, 239
Tickets	V, 88, 102
Local	V, 99
Coupons	III, 96
Baggage	V, 475, 476, 495
—Auditors'	V, 473, 477
Bond—Authentication of	II, 182
Detached	V, 205
Mileage	V, 209, 210
Paid—Accounting for	VII, 447-449
Payment of	II, 193
Ticket	V, 175
Court Costs	III, 160, 161
Courtesy, Necessity of—In Agents	V, 113
Courts, Customs of	II, 229
Precedents of	II, 229
Cove Molding, Window— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Cover for Iron Hopper— <i>Illustration Plate II</i>	I, 116-117
“ Journal Box— <i>Illustration, Plate II</i>	I, 116-117
“ Steam Chest— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Casing— <i>Illustration, Plate I</i>	I, 58-59
Covetousness.....	VII, 18, 19
Cow—The Unit of Value.....	XI, 73
Cowcatcher.....	I, 56, 57, 109
Cranes.....	I, 106, 172, 254
“ Power.....	I, 260
“ Sand.....	I, 247
“ Swinging.....	I, 260
“ Traveling.....	I, 253, 255, 257, 260, 261, 264
“ Water.....	I, 247
Crank.....	I, 83
“ Bell—Throttle— <i>Illustration, Plate I</i>	I, 58-59
“ Pin.....	I, 83, 85, 87
“ “— <i>Illustration</i>	I, 60
“ Shaft.....	I, 85, 87
Credit, Extending.....	X, 266, 267
“ “ —for Freight Charges.....	IX, 65-74, 313-315
“ Loss of.....	III, 25
“ of Carriers, Injury to—Effect on Other Industries.....	VIII, 12, 19
Credits.....	III, 7
“ Effect of Competition on.....	IX, 71
“ Investigating—by Traveling Auditors.....	IX, 296
Creosote, Effect of—on Wood.....	III, 352
“ Use of.....	III, 358-360, 363, 364
“ Value of.....	III, 358-361
Creosoting, Description of.....	III, 354, 355
Crescent Link— <i>Illustration, Plate II</i>	I, 116-117
“ “ Hanger— <i>Illustration, Plate II</i>	I, 116-117
Crete, Island of.....	XI, 134
Crews, Different Methods of Handling.....	IV, 20-23
Criticism, Benefits of.....	I, 227; VIII, 41
“ Effect of.....	VII, 16, 17
Critics, Statements of.....	III, 73
Crops, Claims for Injury to.....	II, 233
“ Failure of—Effect of.....	VIII, 19
“ Movement of.....	VIII, 38
Cross Arms, Painting.....	IV, 351
Crosshead.....	I, 86, 286
“ — <i>Illustrations, Plate I</i>	I, 58-59, 60, 87
“ Pin— <i>Illustration, Plate I</i>	I, 58-59
“ Piston (or Push) Rod— <i>Illustrations, Plate II</i>	I, 116-117, 540
Crossing, Forty-five Degree— <i>Illustration</i>	III, 263
“ Frogs.....	III, 236, 237
Crossings.....	III, 235

	PAGE
Crossings, Accidents at.....	IV, 130, 181
“ Abolishment of.....	IV, 131, 132
“ —Cost of Keeping in Order.....	III, 422, 423
“ Early Signals at.....	IV, 254, 255
“ Grade—in Germany.....	IV, 132, 133
“ “ —Trains Approaching.....	IV, 355
“ Railway.....	IV, 133
“ “ —Damages Arising from.....	II, 232
“ Road.....	III, 256, 257
“ “ —Duties of Conductors in Relation to.....	IV, 404
“ “ —Effect of, on Cost of Operation.....	III, 394
“ “ —Maintenance of.....	III, 300
Crossover Pipe.....	I, 324
Crossovers, Double.....	III, 234, 235
“ on Curves.....	III, 234
“ “ Straight Lines.....	III, 234
Cross Section of a Railway Motor— <i>Illustration</i>	I, 403
“ Stays— <i>Illustration</i>	I, 98
“ Tie, Center— <i>Illustration, Plate III</i>	I, 170-171
“ “ Split Half Log— <i>Illustration</i>	III, 213
“ “ “ Quarter Log— <i>Illustration</i>	III, 212
“ “ Timber— <i>Illustration, Plate II</i>	I, 116-117
“ “ Whole Log, Hewn Both Sides— <i>Illustration</i>	III, 214
“ Ties.....	III, 179, 209
“ Transoms.....	I, 213
Crown Bar— <i>Illustration</i>	I, 67
“ “ Fire Box.....	I, 97
“ “ Bars.....	I, 75
“ “ — <i>Illustration</i>	I, 98
“ Plate.....	I, 96
“ Sheet.....	I, 71, 75, 76, 81, 96, 97
“ “ — <i>Illustrations</i>	I, 67, 98
Crude Oil.....	I, 103
Cugnot, Vehicle Invented by.....	I, 18
Cugnot's Steam Carriage, 1769— <i>Illustration</i>	I, 18
Culmination of Carriage.....	XI, 523
Culvert, Pipe— <i>Illustration</i>	III, 368
“ Stone Arch— <i>Illustration</i>	III, 369
“ Street.....	III, 222, 223
Culverts, Construction and Maintenance of.....	III, 296-299
“ “ of.....	II, 211
“ “ —Cost of Keeping in Order.....	III, 422, 423
“ “ “ Maintenance of.....	III, 292
“ Effect of Traffic on.....	III, 293
“ Influence of—on Cost of Maintenance.....	III, 383, 389
“ Insecure.....	III, 430
“ Protection of.....	III, 325-327
“ Repairing.....	III, 398
“ Supplies for.....	VII, 111, 112

	PAGE
Cumberland Valley Railroad, Introduction of Sleeping Car on.....	I, 189
Cunards.....	XI, 81
Cuneiform Writing.....	XI, 118
" " Invention of.....	XI, 130
Cup, Drain.....	I, 329
" " — <i>Illustration, Plate III</i>	I, 170-171
" " Oil—for Pump— <i>Illustration</i>	I, 539
Cups, Drain.....	I, 315
Cupolas.....	I, 257, 268
Currency, Debased—Its Effect Upon Railways and Other Property.....	III, 7-27
" " " " " Those Who Work for Wages, III, 7, 20	
" Effect of—on Labor.....	III, 19
" " " Wages.....	III, 19
" Exchanging—for Drafts.....	IX, 184-187; X, 287
" Fluctuating—Its Effect.....	III, 7
" Mutilated.....	IX, 328
" Payment of Wages in.....	X, 189, 191, 192, 198, 213-234
" Receiving.....	IX, 327
" Remitting.....	IX, 418
" Sound—Its Effect.....	III, 7
" The First.....	XI, 13
" Transportation of.....	V, 519
Current, Electric.....	I, 475, 476
" " —Alternating.....	I, 407, 408, 421-426
" " " and Direct.....	I, 426
" " " —Generation and Transmission of.....	I, 487
" " —Alternation of.....	I, 413
" " —Brushes for Conducting.....	I, 407, 408
" " —Conditions Necessary for the Flow of.....	I, 397
" " —Continuous or Direct.....	I, 420, 421
" " —Devices for Transmitting.....	I, 463
" " —Direct—How Secured.....	I, 407, 408
" " —Effect of Excessive.....	I, 429
" " —Effects of.....	I, 398
" " " " Speed on.....	I, 429
" " " " Increase of.....	I, 428, 429
" " —for Heavy Trains.....	I, 463
" " " Operating Electric Brake Attachment.....	I, 486
" " —How Produced in the Dynamo.....	I, 406-410
" " —in a Circuit—How Found.....	I, 402
" " —Measure of.....	I, 401
" " —Mechanical Connections for Carrying.....	I, 430
" " —Primary.....	I, 423
" " —Secondary.....	I, 423

	PAGE
Current, Electric—Strength of	I, 397, 398, 415, 416
“ “ —Surface Conductors for Collecting ..	I, 464, 465
“ “ —Transformation of Alternating into Direct ..	I, 426
“ “ —Transmission of Power by	I, 425
“ “ —Underground Systems for Collecting ..	I, 466
“ “ —Variation of	I, 414
Currents, Electric	I, 397
“ “ —Energy of	I, 402-405
“ “ —Source of	I, 397, 398
“ for Operating the Induction Motor	I, 444
“ Magnetic Effects of—Where Utilized	I, 401
“ Polyphase	I, 425, 426
Curtain Rings— <i>Illustration, Plate II</i>	I, 116-117
“ Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Bracket— <i>Illustration, Plate II</i>	I, 116-117
“ Window— <i>Illustration, Plate II</i>	I, 116-117
Curtains, Berth— <i>Illustration, Plate II</i>	I, 116-117
“ Facilities for Repairing	I, 274
“ Renovating	I, 274
Curves, Avoidance of—in Great Britain	I, 24
“ Crossovers on	III, 234
“ Effect of—on Cost of Operation	III, 393
“ Elevation of	III, 218-220
“ Motor	I, 476-480
“ Resistance of	IV, 99
“ Switches on Outside of	III, 237
“ Turnouts on	III, 234
Cushion— <i>Illustration, Plate II</i>	I, 116-117
Cushions, Renovating	I, 274
Custom, Force of	XI, 29
Customs, Differences in	I, 148, 149
Cut Off and Relief Valve	I, 310
“ Out Cock	I, 336, 538
“ “ — <i>Illustration, Plate III</i>	I, 170-171
“ “ “ Brake— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ in Air Pipe Under Engineer's Valve— <i>Illustration</i> ..	I, 539
“ “ “ “ Branch Pipe— <i>Illustrations</i>	I, 540, 541
“ “ “ Signal Branch Pipe— <i>Illustration, Plate II</i> ..	I, 116-117
“ “ “ Valve— <i>Illustration, Plate I</i>	I, 58-59
Cuts, Cost of Keeping in Order	III, 422, 423
“ Deepening	II, 221
“ Rock	III, 226
“ Sodding	III, 226
“ Widening	II, 221
Cutting Off Machinery	I, 262
“ Out Brakes—Instructions to Enginemen	I, 320

	PAGE
Cutting Out the Brake on a Car—Instructions to Trainmen.....	I, 324-326
Cylinder— <i>Illustrations, Plate I</i>	I, 58-59, 60, 84a
“ Action of Steam in	I, 84, 85
“ Back Head— <i>Illustration, Plate II</i>	I, 116-117
“ Block— <i>Illustration, Plate III</i>	I, 170-171
“ Boring Bars.....	I, 262
“ Brake.....	I, 297, 305-308, 334-336, 356-361
“ “ — <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>Plate III</i>	I, 170-171
“ “ “	I, 540, 541
“ “ Pump, Air— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Steam— <i>Illustration, Plate I</i>	I, 58-59
“ “ Quick Action	I, 312, 313
“ “ Ratio of Auxiliary Reservoir to— <i>Illustrations</i>	I, 357-359
“ “ —“Reinforce”.....	I, 312
“ “ —Retaining Pressure in	I, 327
“ Casing— <i>Illustration, Plate I</i>	I, 58-59
“ Casting, Saddle of	I, 93
“ Cock Lever— <i>Illustration, Plate I</i>	I, 58-59
“ “ Reach Rod— <i>Illustration</i>	I, 60
“ Cocks.....	I, 94
“ “ — <i>Illustrations, { Plate I</i>	I, 58-59
“ “ “	I, 60
“ “ Closing	IV, 352
“ “ Rigging— <i>Illustration, Plate I</i>	I, 58-59
“ Compound—Action of Steam in.....	I, 93
“ “ —Application of Starting Valve and Relief Cock— <i>Illustration</i>	I, 95
“ “ —Front View of— <i>Illustration</i>	I, 93
“ Construction of	I, 89
“ End View of— <i>Illustration</i>	I, 84
“ Expansion of Steam in.....	I, 91
“ Front—Head— <i>Illustration, Plate II</i>	I, 116-117
“ Head Casing— <i>Illustration, Plate I</i>	I, 58-59
“ “ Front— <i>Illustration, Plate I</i>	I, 58-59
“ “ of.....	I, 89
“ Heads.....	I, 95
“ High Pressure.....	I, 93
“ Lagging— <i>Illustration, Plate I</i>	I, 58-59
“ Lever.....	I, 332
“ “ — <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>Plate III</i>	I, 170-171
“ “ and Floating Lever Connection— <i>Illustration, Plate III</i>	I, 170-171
“ “ “ Hand Brake Connection— <i>Illustration, Plate III</i>	I, 170-171
“ “ Connecting Rod— <i>Illustration, Plate II</i> , 116-117	

	PAGE
Cylinder, Lever Guide— <i>Illustration, Plate II</i>	I, 116-117
“ Low Pressure	I, 93
“ “ —Admission Ports of	I, 95
“ Lubricator— <i>Illustration, Plate I</i>	I, 58-59
“ Mechanical Energy in	I, 403
“ Movement of Piston in	I, 85, 86
“ Oil	I, 366
“ Packing	I, 89
“ Port— <i>Illustration</i>	I, 341
“ Power, Locomotive	I, 64
“ Pressure, Brake	I, 313
“ Relief Cock— <i>Illustration</i>	I, 113
“ Saddle— <i>Illustration, Plate I</i>	I, 58-59
“ (Standard Freight), Reservoir and Triple Valve— — <i>Illustration</i>	I, 373
“ Single Expansion—Section Showing Action of Steam in— <i>Illustration</i>	I, 83
“ Steam Pressure in—How Ascertained	I, 88, 89
“ Trevithick's Locomotive	I, 45
“ Vacuum	I, 292
Cylinders	I, 45-48, 92, 286, 305
“ Admission of Steam into	I, 83, 91
“ Auxilliary—Compound Locomotive— <i>Illustration</i> ,	I, 146
“ Boring	I, 243
“ Brake	I, 336, 377, 378, 380
“ “ —Driver— <i>Illustration</i>	I, 539
“ “ —Repairs to	I, 382
“ Cleaning—Instructions to Car Inspectors ..	I, 331, 332
“ Compound	I, 46, 47
“ Diameter and Stroke of—Statement of.	I, 39
“ Effect of Quick Action on	I, 369
“ for Applying Brake Force	I, 298
“ —Form Used in America	I, 88
“ “ “ “ England	I, 88
“ Horizontal	I, 46
“ —How Kept Free from Cinders	I, 95
“ Inclined	I, 46
“ Inside	I, 30, 31, 46, 87
“ Mechanism of	I, 85
“ Oiling	I, 329, 331
“ Outside	I, 46, 87
“ “ Versus Inside	I, 87, 88
“ Shutting Off Steam from	I, 83
“ Steam	I, 82, 83
Cypress Ties	III, 350
Cyprus, Ancient Wheel from— <i>Illustration</i>	IV, 194
“ Island of	IV, 194
Cyrus	XI, 87, 105, 115

	PAGE
Dabney, W. B.....	V, 531
Dairy Products, Insulated Car for—Victorian Railways— <i>Illustration</i>	II, 188
Dakota, Railway Taxation in.....	III, 452
Daltonism. (See also "Color Blindness").....	IV, 228
Damaged Articles, Provision for Storing.....	I, 272
Damages, Apportionment of.....	VII, 511, 512
" Baggage.....	V, 315-322
" Claims for.....	II, 232, 235, 242; VI, 18
" " —on Baggage.....	V, 59-62
" Settlement of Claims for.....	VI, 283
Damper— <i>Illustrations</i> , {	I, 64
" and Grate, Section Showing— <i>Illustration</i>	I, 96
" Handle, Ash Pan— <i>Illustration</i> , <i>Plate I</i>	I, 58-59
Dampers.....	I, 96
" Ash Pan.....	I, 69
D'Andellarre, Marquis.....	I, 218
Danger—Its Effect on Wages.....	II, 101
" Signals, Permanent.....	IV, 367
Dares.....	XI, 91
Darius.....	XI, 104, 105
" Baggage of.....	V, 278
Darwin.....	XI, 234
Data, Fiscal—Value of.....	VII, 233, 234
Davenport, Thomas—Electric Car Constructed by.....	I, 520
Davidson, G. M.....	VII, 167
Davis & Gartner.....	I, 32
Davis, Phineas—Locomotive Built by, 1832— <i>Illustration</i>	I, 38
Davy, Sir Humphrey.....	IV, 175
Day Book.....	II, 273
" Coaches, Weight of.....	I, 165
" Labor.....	I, 125
Dead Brake Lever— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
" " " Guide— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
" " " Hook— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
" Levers.....	I, 379
" Truck Lever— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
" " Levers.....	I, 329, 332
Deadheads.....	V, 44
Deadwood— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
" Angle Iron— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
Deafening Ceiling— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
Deafness, Prevalence of—In Railway Service.....	IV, 18
Death, Amelioration of the Condition of Railway Men and Their Families in Cases of.....	X, 291-353
Debenture Stock.....	III, 42, 95
Debentures.....	III, 65
Debt, Floating.....	III, 80
" Funded.....	III, 92

	PAGE
Debts and Freight Claims Committee.....	II, 131
" Collection of.....	II, 195; IX, 433
" Railway—Guaranties of.....	III, 39
Decauville, M. Paul.....	I, 215-218
Deceased Employees, Paying Wages of.....	VII, 403, 407
" " Wages of.....	IX, 394
Decimal System.....	XI, 74
Deck Cornice, Inside— <i>Illustration, Plate II</i>	I, 116-117
" Eaves Molding— <i>Illustration, Plate II</i>	I, 116-117
" End Sill— <i>Illustration, Plate II</i>	I, 116-117
" Outside Window Sash— <i>Illustration, Plate II</i> ...	I, 116-117
" Panels— <i>Illustration, Plate II</i>	I, 116-117
" Plate— <i>Illustration, Plate II</i>	I, 116-117
" Post— <i>Illustration, Plate II</i>	I, 116-117
" Sash— <i>Illustration, Plate II</i>	I, 116-117
" " Lintel— <i>Illustration, Plate II</i>	I, 116-117
" " Pivot— <i>Illustration, Plate II</i>	I, 116-117
" " Pull— <i>Illustration, Plate II</i>	I, 116-117
" " Opener— <i>Illustration, Plate II</i>	I, 116-117
" " Screen Post— <i>Illustration, Plate II</i>	I, 116-117
" Sill— <i>Illustration, Plate II</i>	I, 116-117
" " Facing— <i>Illustration, Plate II</i>	I, 116-117
" Window Screens— <i>Illustration, Plate II</i>	I, 116-117
Decoration of Cars.....	I, 147
" " Vehicles.....	I, 197
Deductions from Pay of Employes.....	VII, 386-387, 392
" " Mail Service.....	V, 557-559
Deeds, Custody of.....	II, 213
" Execution of.....	V, 519
" Recorder of.....	III, 96
" Transportation of.....	V, 519
Defalcations. (See also "Shortages.")	
" 	II, 290; IX, 21,
23, 25, 32, 149, 167, 168, 193-218, 233, 271; X,	58
" Covering Up.....	IX, 136, 137, 139, 140, 267
" Information Regarding.....	IX, 167
" Prelude of.....	IX, 302
" Record of.....	X, 199
" Reporting.....	IX, 197
Defaulters.....	IX, 193-218, 244
Defective Brakes.....	I, 330, 331
" Car—Instructions to Engineers.....	I, 365
" Slide Valves.....	I, 382
" Triple Valves.....	I, 371
Defect Tag.....	I, 325
Defects, Discovering—In Air Brakes.....	I, 322
" Reporting—to Inspectors—Instructions to Train-	men..... I, 327
Definiteness, Necessity of—In Disbursement Accounts....	VII, iv
Definition of Electricity.....	I, 393, 394

	PAGE
Deflector	I, 54
" Plate— <i>Illustration, Plate I</i>	I, 58-59
" " Adjuster— <i>Illustration, Plate I</i>	I, 58-59
Delano, F. A.	III, 342
Delaware & Hudson Canal Company, Locomotives Purchased by	I, 28
Delay, Prevention of—in Loading and Unloading Cars	VI, 49, 58-63
Delays, Claims for	II, 232, 242; VI, 18
" in Settlement of Claims	VI, 21
" " Unloading Cars—How Lessened	VI, 57, 58
" Settlement of Claims for	VI, 283
Delivery of Freight	VI, 9, 10
" to Drum— <i>Illustration, Plate I</i>	I, 58-59
Demand for Locomotives and Cars	I, 138
Demurrage (See also "Car Service")	VI, 99
" Charge, in Great Britain	I, 173
" Charges for	III, 406, 407; VI, 49, 58-63
" Rates for	II, 242
" Rules and Regulations Governing Demurrage Storage Charges, etc.	VI, 337, 338
Denton, Professor	VII, 123
Department, Accounting	I, 289; II, 137, 139, 272-305; V, 69, IX, 300, 304; X, 41
" " —a Safeguard	II, 282
" " —Chief of	II, 285
" " —Duty of	V, 70
" " —English	VI, 329
" " —in Early Times	II, 279, 293
" " —Management of	X, 36, 37
" " —Organization of	II, 248
" Administrative	II, 136
" Baggage—Attaches of	V, 390, 391
" " —Duties of	V, 295
" " —Experiences of	V, 339
" " —How Its Operations Are Governed, V,	353
" " —Interest of Public in	V, 353
" " —Officials of	V, 525
" " —Rules Governing	V, 431-453
" Car	I, 277
" Claim—Scope of	VI, 19
" Engineering	II, 136-138
" " —Recognition of	I, 234
" Equipment	II, 176, 305a-305r
" Executive	II, 138
" Financial	II, 137
" " —Discipline in	IX, 33
" Freight—Methods of	V, 480, 481
" Goods—English	VI, 318-323
" Hygienic	IV, 68

	PAGE
Department, Law	II, 137, 138, 224-234
“ Machinery.....	I, 230, 240, 277; II, 176; IV, 25
“ “ —Duties and Responsibilities of Officials in.....	I, 230, 231
“ “ —How Saving Is Effected in.....	I, 284
“ “ —Importance of.....	I, 233
“ “ —Intelligence and Skill Displayed in.....	I, 234
“ “ —Rank of Men in Charge.....	I, 230, 231
“ “ —Status of, in Early Days.....	I, 234
“ “ —Value of Information Regarding.....	I, 232, 233
“ Material—English.....	VII, 105
“ Mechanical.....	I, 277
“ Operating.....	II, 136, 138; IV, 28; IX, 233
“ “ —Duty of.....	V, 70
“ “ —Its Relation to the Accounting Department.....	II, 290, 305
“ “ —Organization of.....	II, 173-176
“ Passenger—Attaches of.....	V, 17, 18
“ “ —Authority of.....	II, 252
“ “ —Machinery of.....	II, 252
“ Postoffice.....	V, 554, 558, 559, 561
“ Relief.....	X, 291-353
“ Roadway—Organization of.....	III, 268-260
“ “ —Rules Governing.....	III, 260-271
“ Supply—Organization of.....	VII, 70
“ Ticket—Duties of.....	II, 250, 251
“ Traffic.....	II, 137-139, 237, 239
“ “ —Duty of.....	V, 70
“ Treasury—Conduct of.....	II, 193
Departmental Foremen.....	I, 277
“ Officers.....	II, 200
“ “ Methods of.....	II, 139
Departments, Division of the Railway Force into.....	II, 19, 20
“ of a Railway.....	II, 136, 137
“ Subdivision of.....	II, 138
Depositories, Baggage.....	V, 427-430
Deposits, Bank.....	X, 265, 266
“ Guaranty.....	IX, 323, 324
Depot Grounds, Claims for.....	II, 233
Depots, Supply. (See also “Storehouses.”)	
“ “ —Arrangement of.....	VII, 189, 198
“ “ —Inspectors of.....	VII, 77
Depressed Pits.....	I, 246
“ Track.....	I, 246
Derailing Switches.....	III, 237, 238
Derails, Use of.....	IV, 112, 113
Derrick, Steam.....	III, 258
Descending Grades.....	I, 327

GENERAL INDEX.

107

	PAGE
Dies.....	I, 263
Diligence, Necessity of—in Handling Requisitions.....	VII, 71
Dining Car.....	I, 148, 196, 196
" " American— <i>Illustration</i>	I, 219
"Dining Car Service".....	VII, 301
Dining Car Service Accounts.....	VII, 301, 302
"Dining Car Supplies".....	VII, 302
Dining Car Supplies.....	VII, 87
" " " Accounting for.....	VII, 300
" " " Care of.....	VII, 299
" " " Inventorying.....	VII, 346
" " " Orders for.....	VII, 300
" " " Returns for.....	VII, 300
" " Cars.....	I, 191
" " Repairs of.....	VII, 301
" " Superintendent of.....	II, 138
Diodorus.....	XI, 28, 113
Direct Current—Direct Fed System.....	I, 451
" " Dynamo.....	I, 411
" " Feeder Systems— <i>Illustrations</i>	I, 433
" " Generator.....	I, 426, 440, 452
" " —How Secured.....	I, 407, 408
" " Lighting System.....	IV, 176-180
" " Motor.....	I, 411
" " Systems.....	I, 430-440, 454
" " Transmission of Power by.....	I, 425
" Dynamo System.....	IV, 176
" Feeding.....	I, 431-434
" Steam Heating, Floor Valves— <i>Illustration, Plate II</i> ,.....	I, 116-117
" System of Steam Heating.....	IV, 157, 158
Directors, Action of—in Filling Offices.....	II, 133, 134
" Acts of.....	II, 130
" Adviser of.....	II, 229
" Authority of.....	II, 131
" Board of.....	II, 128
" " —English.....	II, 130, 131
" Committees of.....	II, 130, 131
" Counselor of.....	II, 229
" Election of.....	II, 128, 129; III, 87
" English.....	III, 140
" Meetings of.....	II, 129, 130
" Number of—on Different Railways.....	II, 128
" Responsibilities of.....	II, 130
" Tenure of Office of.....	II, 128, 129
Dirt, Hauling—Railroads for.....	I, 217
" in the Air Brake.....	I, 369
" Preventing Accumulation of—in Air Signal.....	I, 366
Disability, Amelioration of the Condition of Railway Men and Their Families in Cases of.....	X, 291-353

	PAGE
Disabled Cars—Instructions to Trainmen.....	I, 373, 374
Disasters, Financial	IX, 300, 301
Disbursement Accounts, Method of Keeping	VII, 243
Disbursements	II, 283
" Accounting for.....	X, 86-89
" Accounts Relating to	II, 283, 290
" Auditor of.....	II, 139
" Cash	X, 92-94
" Duty of Accounting Officer in Relation to, II,	287
" for Construction	III, 156-166
" Officer in Charge of	II, 186
" of Railways.....	VII
" Railway	II, 109
" —How Influenced.....	III, 388, 389
" Reports of.....	X, 67, 68
" Statistics of.....	X, 31
" Summarizing	X, 88, 89
" Summary of.....	VII, 525-527
Disc, Armature—Showing Slots, Diagram of Commutator and One Coll in Place Connected to the Commuta- tor— <i>Illustration</i>	I, 414
" Signals, Automatic Block— <i>Illustrations</i>	IV, 504
" " Early	IV, 243, 249
" Valve, Rotary.....	I, 329
Discharge Valve, Car— <i>Illustration</i>	I, 386
" " —Signal Branch Pipe to— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
Disciplinary Practices	II, 16
Discipline, Lack of—Its Result... ..	II, 19
" Laxity of—Its Effect.....	IV, 125-127
" Maintenance of.....	IV, 28-31
" of Army Life.....	II, 19
" " Corporate Life.....	II, 19
" " Railway Forces.....	II, 18
" Preservation of—in Financial Department... ..	IX, 33
" Relation of—to Accidents.....	IV, 125-127
Discount.....	III, 74, 75
"Discount".....	VII, 461
Discounts, Accounting for	X, 180
Discovering Leaks—Instructions to Trainmen.....	I, 370, 371
Discovery of the Brake.....	I, 291
Discrimination	VIII, 8, 107
" Basis of.....	VIII, 43
" Definition of.....	VIII, 108
" Elimination of.....	VIII, 34
" English Laws Regarding.....	VIII, 137
" —French Experiences.....	VIII, 138
" in Railway Taxation.....	III, 436, 444
" " the Use of Cars.....	VI, 74
" —Investigations in Europe.....	VIII, 107

	PAGE
Discrimination, Limitation of.....	VIII, 63
" Practice of.....	VIII, 36
" —Relation to Classifications.....	VIII, 56
" Result of Preventing.....	VIII, 55
Discussion, Associations for.....	I, 229
" Results of—Among Railway Officials.....	I, 288
" Value of—Among Employes of Shops.....	I, 289, 290
Discussions.....	I, 225
" Value of.....	I, 289, 290
Diseases, Contagious—Passengers Afflicted with.....	IV, 69
Disinfection.....	IV, 68, 69
Dismissal.....	IV, 30, 31
Disobedience.....	II, 14
Dispatcher, Train.....	II, 199
" —Meaning of Term.....	IV, 322
Dispatching Baggage, American System of.....	V, 377-383
" European System of.....	V, 369-376
" Trains by Telegraph—Forms Used.....	IV, 465-478
Dissemination of Knowledge.....	I, 226
Distance, Effect of—on Cost of Transmission.....	I, 430
Distances.....	I, 419
Distress Funds.....	II, 60
Distribution Book, Labor—General.....	VII, 537
" " Material—General.....	VII, 315-320
" " Books.....	VII, 314
" " —Entering Various Persons Accounts in.....	VII, 423-428
" " Use of.....	VII, 381
" of Electrical Energy.....	I, 414
" Labor Book, General.....	VII, 382-385
" Material Book, Track Foremen's.....	VII, 325
" Pay Roll.....	I, 290
" Shop Labor.....	I, 285
" Work.....	I, 267
" Relation of Carriers to.....	VIII, 82
" —Use of the Word.....	VII, 373
District Goods Managers, English.....	II, 208
" Superintendent, English.....	II, 207
Ditchers, Steam.....	III, 258
Ditches.....	III, 251, 252
" —Cost of Keeping in Order.....	III, 422, 423
Ditching.....	III, 285
Dividends.....	III, 86, 87
" Declaration of.....	II, 187; III, 55, 89, 90
" Expenditures of Railways for.....	VIII, 24
" Fluctuations in.....	III, 41
"Dividends on Stock" Account.....	VII, 537
Dividends on Stock, Accounting for.....	X, 179, 180
" Payment of.....	II, 137, 189, 191; III, 89, 90
" " —in America.....	III, 42

	PAGE
Door Handle, Feed— <i>Illustration, Plate II</i>	I, 116-117
“ Hinge— <i>Illustration, Plate II</i>	I, 116-117
“ Hinges, Vestibule— <i>Illustration, Plate II</i>	I, 116-117
“ Holder— <i>Illustration, Plate II</i>	I, 116-117
“ “ Catch— <i>Illustration, Plate II</i>	I, 116-117
“ Knob— <i>Illustration, Plate II</i>	I, 116-117
“ Lintel— <i>Illustration, Plate II</i>	I, 116-117
“ Locker— <i>Illustration, Plate II</i>	I, 116-117
“ Lock, Vestibule— <i>Illustration, Plate II</i>	I, 116-117
“ Panels, Lower— <i>Illustration, Plate II</i>	I, 116-117
“ “ Middle— <i>Illustration, Plate II</i>	I, 116-117
“ Post— <i>Illustration, Plate III</i>	I, 170-171
“ “ Rods— <i>Illustration, Plate III</i>	I, 170-171
“ Rail, Bottom— <i>Illustration, Plate II</i>	I, 116-117
“ “ Middle— <i>Illustration, Plate II</i>	I, 116-117
“ “ Top— <i>Illustration, Plate II</i>	I, 116-117
“ Sash Lift— <i>Illustration, Plate II</i>	I, 116-117
“ “ Lock— <i>Illustration, Plate II</i>	I, 116-117
“ “ Lower— <i>Illustration, Plate II</i>	I, 116-117
“ “ Upper— <i>Illustration, Plate II</i>	I, 116-117
“ Smoke Arch— <i>Illustration, Plate I</i>	I, 58-59
“ Vestibule— <i>Illustration, Plate II</i>	I, 116-117
Doors, Car.....	I, 214
“ of Roundhouses.....	I, 243
“ Storehouse.....	I, 259
Dorian Invasion.....	XI, 90
Dorsey, Edward Bates.....	III, 145, 149; V, 26, 28; VI, 11
Double Cross-Overs.....	III, 234, 235
“ Electro Magnet— <i>Illustration</i>	I, 400
“ Governors.....	I, 313
“ Headed Rail.....	III, 200
“ Header Locomotive, Scottish— <i>Illustration</i>	I, 135
“ Headers—Instructions to Enginemen.....	I, 320
“ Magnet.....	I, 400
“ Plate Wheel— <i>Illustration</i>	IV, 207
“ “ “ —Master Car Builders' Washburn Pat- tern— <i>Illustration, Plate III</i>	I, 170-171
“ Poppet Valve.....	I, 308
“ Trolley Line.....	I, 445
“ Truck Car, Frame of.....	I, 467
“ “ Cars.....	I, 467
Draft, Bank—Invention of.....	XI, 128
“ Pipe or Petticoat— <i>Illustration, Plate I</i>	I, 58-59
“ Rigging.....	I, 210
“ “ Continuous— <i>Illustration</i>	I, 176
“ Spring— <i>Illustration, Plate II</i>	I, 116-117
“ “ Followers— <i>Illustration, Plate II</i>	I, 116-117
“ “ Strap— <i>Illustration, Plate II</i>	I, 116-117
“ Timber— <i>Illustration, Plate III</i>	I, 170-171
“ “ Filling Block— <i>Illustration, Plate III</i>	I, 170-171

	PAGE
Draft, Timber Keys— <i>Illustration, Plate III</i>	I, 170-171
“ Timbers.....	I, 209
Drafts, Accepted by Agents.....	IX, 345, 346
“ Agents’.....	IX, 358-361
“ Bank—Guaranteeing.....	IX, 187
“ “ —Exchanging Currency for.....	IX, 416, 417; X, 193, 287
“ Care of.....	X, 271
“ Collection of.....	V, 519, 537
“ Drawing.....	VII, 445
“ Drawn on Treasurer.....	X, 272-275
“ for Traffic Balances.....	X, 267
“ Indorsements on.....	IX, 345, 346
“ Indorsing.....	VII, 444, 445
“ of Local Banks.....	IX, 184-187
“ Paying.....	X, 275
“ Receiving.....	IX, 188; X, 262
“ Spoiled.....	X, 268
“ Use of—in Paying Freight Charges.....	IX, 309, 310
“ Vouchers Used as.....	X, 279
“ Writing on.....	IX, 433
Dragging Brakes.....	I, 365
“Dragon” Locomotive, 1848—The First Engine Built for Burning Cumberland Coal, and the First to Have a Rocking Grate— <i>Illustration</i>	I, 43
Drain Cup— <i>Illustration, Plate III</i>	I, 170-171
“ Cups.....	I, 315, 329
Drainage.....	I, 273; III, 225, 251-255, 285, 372
“ Influence of—on Cost of Maintenance, III, 383, 390, 391	
“ Slope.....	III, 226
“ Tunnel.....	III, 226, 227
Draining Auxillary Reservoirs.....	I, 332
“ —Instructions to Enginehouse Foremen and In- spectors.....	I, 329, 330
“ Triple Valves.....	I, 332
Drapanum.....	XI, 91
Drapery, Window— <i>Illustration, Plate II</i>	I, 116-117
Draught, Creation of.....	I, 71
“ Device for Creating—When Locomotive Is Stand- ing Still.....	I, 99, 100
Draughting Office.....	I, 278
Draughtsmen.....	I, 277
Drawbar— <i>Illustrations</i> , { <i>Plate I</i>	I, 58-59
“ { <i>Plate III</i>	I, 170-171
“ Carey Iron— <i>Illustration, Plate II</i>	I, 116-117
“ Carrier and Brake Step— <i>Illustration, Plate III</i>	I, 170-171
“ Chafe Thimble— <i>Illustration, Plate III</i>	I, 170-171
“ Check Castings— <i>Illustration, Plate III</i>	I, 170-171
“ Coupling Pin— <i>Illustration, Plate III</i>	I, 170-171

	PAGE
Drawbar, Follower Straps— <i>Illustration, Plate III</i>	I, 170-171
“ Followers— <i>Illustration, Plate III</i>	I, 170-171
“ Knuckle— <i>Illustration, Plate III</i>	I, 170-171
“ “ Pin— <i>Illustration, Plate III</i>	I, 170-171
“ Loop— <i>Illustration, Plate III</i>	I, 170-171
“ Pull, Motor Rated in.....	I, 473
“ Spring Cage— <i>Illustration, Plate III</i>	I, 170-171
“ Springs— <i>Illustration, Plate III</i>	I, 170-171
“ Timbers— <i>Illustration, Plate II</i>	I, 116-117
Drawbars, Tracks for Handling—on Push Cars.....	I, 276
“ Uncoupling.....	I, 370
Draw Bridges, Trains Approaching.....	IV, 355
“ Head— <i>Illustrations, { Plate I</i>	I, 58-59
“ “ <i>{ Plate II</i>	I, 116-117
Drawing Room Car, American.....	I, 200
“ “ Cars.....	I, 148, 174, 194, 195; V, 212, 221
Draymen, Bonds Required of.....	IX, 318
“ Delivery of Freight to.....	IX, 318
Dress, Cultivation of.....	XI, 65
Drill, Track— <i>Illustration</i>	III, 330
Drilling, Tools for.....	I, 243
Drills.....	I, 262
Drinking Water, on Cars.....	I, 181
Drip Cock— <i>Illustration, Plate I</i>	I, 58-59
“ “ Combination— <i>Illustration, Plate II</i>	I, 116-117
“ “ in Air Tank— <i>Illustration, Plate II</i>	I, 116-117
“ Cocks.....	I, 315
“ Tray— <i>Illustration, Plate II</i>	I, 116-117
“ Valve Angle— <i>Illustration, Plate II</i>	I, 116-117
“ Water— <i>Illustration, Plate II</i>	I, 116-117
Driver Brake.....	I, 382
“ “ Cylinders— <i>Illustration</i>	I, 539
“ Brakes.....	I, 286
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ Adjustment of.....	I, 329
“ Springs— <i>Illustration, Plate I</i>	I, 58-59
“ “ Equalizers— <i>Illustration, Plate I</i>	I, 58-59
“ “ Hangers— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Brace— <i>Illustration, Plate I</i>	I, 58-59
“ The.....	IV, 33-40
Drivers, Pile.....	I, 378
“ Weight Upon.....	I, 429
Driving Axle— <i>Illustration, Plate I</i>	I, 58-59
“ Axles, Manufacture of.....	IV, 222, 223
“ Box— <i>Illustration, Plate I</i>	I, 58-59
“ “ Gang.....	I, 286
“ “ Journals and Brasses, Examination of.....	I, 244
“ “ Shoe— <i>Illustration, Plate I</i>	I, 58-59
“ “ Wedge— <i>Illustration, Plate I</i>	I, 58-59
“ Boxes.....	I, 285, 286

	PAGE
Driving Shaft	I, 456
“ Wheel Castings— <i>Illustration</i>	I, 67
“ “ Centers— <i>Illustration, Plate I</i>	I, 58-59
“ “ —Its Ability to Carry a Load	I, 64
“ “ —The Largest Ever Known	I, 35
“ “ Tire— <i>Illustrations, Plate I</i>	I, 58-59, 67
“ Wheels	I, 87, 286
“ “ — <i>Illustration</i>	I, 60
“ “ Application of Flanged Brake Shoe to	I, 304
“ “ French	IV, 210
“ “ Load on	III, 195
“ “ Locomotive—Brake Used on	I, 297
“ “ —Number Required	I, 66
“ “ Removing	I, 244
“ “ Steam Brake for—Stephenson's, 1833— <i>Illustration</i>	I, 299
“ “ Steel-Tired	I, 302
“ “ Theory of the Application of the Automatic Brake and Brake Shoe to the— <i>Illustration</i>	I, 542
“ “ Use of Brakes on	I, 314
Drop Hammer	I, 263
“ Handle, Vestibule Door— <i>Illustration, Plate II</i>	I, 116-117
“ Off Flagman—Meaning of Term	IV, 317
“ Pits	I, 244
“ “ Pneumatic	I, 244
“ Table	I, 261
Drum, Air— <i>Illustration, Plate I</i>	I, 58-59
“ Circulating— <i>Illustration, Plate II</i>	I, 116-117
“ Delivery to <i>Illustration, Plate I</i>	I, 58-59
Dry Goods. Use of—by Railways	VII, 211
“ Kiln	I, 272
“ Pipe	I, 286
“ “ — <i>Illustrations, { Plate I</i>	I, 58-59
“ “	I, 62
“ “ Hangers— <i>Illustration, Plate I</i>	I, 58-59
“ “ Joint— <i>Illustration, Plate I</i>	I, 58-59
“ “ Ring— <i>Illustration</i>	I, 98
Du Chailu	XI, 28
Dudley, Dr	I, 100
Dummy Couplings	I, 321, 326, 330, 333
Dumping Car— <i>Illustration</i>	I, 149
“ French— <i>Illustration</i>	I, 150
Dump Pan— <i>Illustration, Plate II</i>	I, 116-117
Duplex Air Gauge	I, 349
“ — <i>Illustration</i>	I, 316
“ Pump Governor— <i>Illustration</i>	I, 355
Duplicate Order System of Telegraphic Dispatching	IV, 83, 84
“ Way Bills	VI, 180, 181
Duplication of Railroads—How Lessened	II, 46

	PAGE
Dust, Avoidance of—in Air Pump.....	I, 381
" Guard, Journal Box— <i>Illustration, Plate III</i>	I, 170-171
" in the Air Brake.....	I, 369
Duties of Executive Officers.....	II, 132
" " the Common Carrier.....	VI, 6
Duty, Neglect of.....	IV, 329
Dwarf Signals— <i>Illustrations</i>	IV, 501
Dyeing, Facilities for.....	I, 274
Dynamite Car, Brazilian— <i>Illustration</i>	I, 186
Dynamo.....	I, 396, 397, 401, 455, 488
" and Storage Battery System.....	IV, 178
" Compound Wound.....	I, 409
" " " —Two Field Windings— <i>Illustration</i>	I, 409
" Connection of—to the Engine.....	I, 456
" Constant Potential.....	I, 408
" Direct Current.....	I, 411
" Electric Horsepower Delivered by a—How Found, I, 404	I, 404
" Electro-Motive Force—How Determined.....	I, 409
" Energy of Steam in.....	I, 403
" How Current is Produced in the.....	I, 405-410
" Invention and Development of.....	I, 520
" Limitations of.....	I, 427-429
" Loading the.....	I, 429
" Magnetic Field in a.....	I, 405
" Mechanical Energy in a.....	I, 402
" Output of.....	I, 427, 428
" Power Delivered by a.....	I, 404
" Section of a—Showing Electro-Magnets or Fields and the Armature Within— <i>Illustration</i>	I, 406
" Self-Excited.....	I, 409
" Separately Excited.....	I, 409
" Shaft.....	I, 456
" Speed of.....	I, 407
" Terminals in.....	I, 397
Dynamos.....	I, 253, 259, 460, 461
" Belt-Driven.....	I, 456
" Booster.....	I, 451
" Design of.....	I, 408, 409
Ea	XI, 97
Early Form of Brake— <i>Illustration</i>	I, 296
" Lever Brake, 1630— <i>Illustration</i>	I, 291
Earning Capacity of American Railroads.....	I, 166
Earnings, Baggage.....	V, 63-65
" Classes of.....	X, 81
" Divisions of—Between Portions of a Line...X, 149-153	X, 149-153
" Effect on—of Charging for Transportation of Rail- way Material.....	VII, 201, 202, 204

	PAGE
Earnings, Express—Definition of.....	X, 178
“ “ Traffic.....	V, 548-551
“ Freight—Daily Returns of.....	VI, 243-247
“ “ —Definition of.....	X, 177
“ Gross—A Basis for Taxation.....	III, 441-446
“ “ —Ratio of Cost to.....	III, 144, 145
“ “ —Unit of.....	II, 27
“ Joint—Apportioning.....	X, 131, 132
“ “ —Divisions of.....	X, 151, 152
“ Locomotive—How Increased.....	I, 166
“ Mail—Definition of.....	X, 178
“ Miscellaneous.....	X, 149
“ “ —Definition of.....	X, 178
“ “ —English.....	VI, 327-329
“ Passenger—Daily Exhibits of.....	V, 156-158
“ “ —Definition of.....	X, 177
“ Percentage of—Paid for Labor.....	VIII, 24
“ Relation of Cost of Operating to.....	II, 109, 110
“ “ “ Speed to.....	IV, 104
“ “ “ —to Capital.....	III, 35, 70, 71
“ “ “ Expenses.....	III, 57
Earth, Cars for Handling.....	I, 224
Eason, Charles, Jr.....	III, 65
East Indian Railway.....	III, 178
“ “ Freight Cars of.....	I, 121
Eastern Railway of France.....	III, 178, 183
“ “ “ Cars Used on.....	I, 121
Eastwich & Harrison.....	I, 51
Eaves, Molding— <i>Illustration, Plate II</i>	I, 116-117
“ “ Deck— <i>Illustration, Plate II</i>	I, 116-117
Eccentric, Back Up— <i>Illustration, Plate I</i>	I, 58-59
“ “ Blade.....	I, 90
“ “ Connection, Back Up— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Go Ahead— <i>Illustration, Plate I</i>	I, 58-59
“ “ Go Ahead— <i>Illustration, Plate I</i>	I, 58-59
“ “ Rod— <i>Illustration</i>	I, 60
“ “ “ Back Up— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Go Ahead— <i>Illustration, Plate I</i>	I, 58-59
“ “ Rods.....	I, 89
“ “ Stephenson's Locomotive.....	I, 48
“ “ Strap, Back Up— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Go Ahead— <i>Illustration, Plate I</i>	I, 58-59
“ “ Straps.....	I, 89
Eccentrics.....	I, 89, 286
“ — <i>Illustration</i>	I, 67
“ Location of.....	I, 94
“ Straps and Reversing Gear—Side View of— <i>Illustration</i>	I, 90
Economic Laws.....	II, 33
“ “ Influence of—on Railways.....	IV, 8

GENERAL INDEX.

117

	PAGE
Economic Theory of Rates.....	VIII
Economical Purchase, Care and Use of Material	VII, 9-226
Economists	III, 14
Economy, Awards for	II, 29, 30
" in the Employment of Labor.....	II, 27
Edmonson, Thomas	V, 80, 92
Educated Men, Advantage of... ..	I, 130
Education, Effect of—on Railway Officers.....	III, 139
" Necessity of	IV, 35
" Systematic—Value of.	II, 297
" Value of—in Railway Service.....	IX, 17
" " —to Trade	I, 129
Effect, Heating—of Electric Current.....	I, 398, 399
" Magnetic—of Electric Current.....	I, 399, 400, 401
Effects of Electric Current	I, 398
Efficiency of Engine-type Railway Generators.....	I, 459, 460
" the Induction Motor.....	I, 446, 447
" Recognition of.....	IV, 24-27
" The Highest—How Secured.....	IX, 36
Efficient Service.....	VI, 5, 11-18
Effort, Co-operative—How Obtained.....	II, 58
Eggs, Loading.....	VI, 103
Egibi & Son.....	XI, 126-128
Egypt, Common Carriers of	XI, 109
" Inscriptions of	XI, 112
" —Its Primitive Associations and Means of Carriage.....	XI, 283-292
" Position of Women in.....	XI, 24
" Primitive Carriage in— <i>Illustrations</i>	XI, 283-292
Egyptian Chariot Wheel, Ancient— <i>Illustration</i>	IV, 190
" Locomotive— <i>Illustration</i>	I, 120
" Wheel, Ancient— <i>Illustration</i>	IV, 191
Egyptians.....	XI, 109, 113, 114, 119
" Chariots of.....	XI, 110, 111
" Primitive Carriage Among.....	XI, 95
Ejector.....	I, 110, 111, 292, 299, 300
" — <i>Illustration</i>	I, 111
Elasticity of Track.....	III, 179
Elbow, Reducing— <i>Illustration, Plate II</i>	I, 116-117
Elections, Notices of.....	III, 425
Electric Bells.....	I, 401
" Block Signals, Automatic— <i>Illustrations</i>	IV, 280, 282-285
" " System, Automatic.....	IV, 279-301
" Brakes.....	I, 485, 486
" Car—Its Effect Upon Street Railway Service.....	I, 394
" Current, Effects of.....	I, 398
" " Strength of.....	I, 397, 398
" Currents.....	I, 397
" " Energy of.....	I, 402-405

	PAGE
Electric Currents, Source of.....	I, 397, 398
“ Emergency Brakes.....	I, 485, 486
“ Generator.....	I, 396
“ Heaters.....	I, 402, 486
“ Horsepower, Delivered by a Dynamo—How Found.....	I, 404
“Electric Light Plants”.....	VII, 461
Electric Lighting Plant and Baggage Car, Austrian Imperial Train— <i>Illustration</i>	I, 211
“ Lights, Development of.....	I, 520
“ Locomotive.....	I, 467-469
“ “ — <i>Illustration</i>	I, 521
“ “ —Baltimore & Ohio Railroad Tunnel— <i>Illustration</i>	I, 388
“ “ The Heilmann.....	I, 516-519
“ “ Truck— <i>Illustration</i>	I, 513
“ Locomotives of the Baltimore & Ohio Railroad...I,	464
“ Machines.....	I, 405-412
“Electric Motive Power Plants”.....	VII, 461, 462
Electric Motor Car.....	I, 467-479
“ “ —The Place It Shall Occupy.....	I, 394, 395
“ Motors.....	I, 260, 264, 394, 396
“ “ Controller for; Open, Showing Drum and Fixed Contacts— <i>Illustration</i>	I, 486
“ Power, Delivered by a Dynamo.....	I, 404
“ Problem, the.....	I, 394, 395
“ Push Button— <i>Illustration, Plate II</i>	I, 116-117
“ Railway, Elements of an.....	I, 453-485
“ “ The First.....	I, 520
“ “ Track.....	I, 462, 463
“ Roads.....	I, 489-506
“ System—The First Practically Operated.....	I, 520
“ Traction, for General Railway Purposes.....	I, 507-514
“ “ History of.....	I, 519-522
“ “ Possibilities and Limitations of.....	I, 395
Electrical Apparatus, Development of.....	I, 521, 522
“ “ Engravings of.....	I, 391
“ “ Limitations of.....	I, 427-430
“ “ Manufacturers of.....	I, 139
“ “ —Upon what Based.....	I, 523
“ Appliances, of Railways.....	VII, 213
“ Conductors.....	I, 398, 399
“ “ Cost of.....	I, 533-537
“ Current, Conditions Necessary for the Flow of...I,	397
“ Energy, Conversion of Chemical and Mechanical Energy Into.....	I, 402
“ “ Distribution of.....	I, 414
“ “ Production of Heat by.....	I, 397
“ “ Transmission of.....	I, 412, 413
“ Engineers, American Institute of.....	I, 391

GENERAL INDEX.

119

	PAGE
Electrical Force	I, 253
“ Limits	I, 429
“ Power—How Measured	I, 403
“ “ System	I, 402
“ Principles and Laws	I, 396-405
“ Progress	I, 522-525
“ Science	I, 390
“ System, Elements of	I, 396
“ “ Storage Battery in an	I, 438, 439
“ Systems, Comparison of	I, 450-453
“ “ for Railway Service	I, 430-453
“ “ Variety of	I, 413
“ Units	I, 401, 402
Electricity	I, 58, 223, 262; III, 347
“ Application of—to Railway Work	I, 454
“ As a Motive Power for Railways	I, 387-526
“ Definition of	I, 393, 394
“ Effect of—on Watches	IV, 337
“ Extension of—Upon What Dependent	I, 523, 524
“ Function of—in the Operation of Railways	I, 396
“ Influence of	IV, 7
“ Practicability of—for General Railway Purposes	I, 507-514
“ Present and Future of	I, 519-525
“ “ Status of	I, 390-392
“ Production of	I, 397
“ “ Light by	IV, 176
“ Relation of—to Transportation	I, 392-396
“ Use of—by the Lowell & Suburban Street Rail- way Company	I, 495, 499
“ “ “ “ Niagara Falls Power Company	I, 500-504
“ “ “ “ Utah Power Company	I, 499, 500
“ “ “ for Freight Service	I, 513
“ “ “ Heating Cars	IV, 164, 176-180
“ “ “ Lighting Coaches	I, 204
“ “ “ Local Passenger Service	I, 507-509
“ “ “ Protecting Trains Automatically	IV, 299-301
“ “ “ Through Passenger Service	I, 509-513
“ “ —in the Baltimore & Ohio Railroad Tun- nel	I, 496-498
“ “ —on the Akron, Bedford & Cleveland Railway	I, 489, 490
“ “ “ “ Burlington & Mt. Holly Branch of Pennsylvania Railroad	I, 490-492
“ “ “ “ City & South London Railway	I, 505

	PAGE
Electricity, Use of—on the Columbia & Maryland Railway	I, 504, 505
“ “ “ “ “ Lugano, Switzerland, Electric Tramway.....	I, 505, 506
“ “ “ “ “ Metropolitan Elevated Railway, Chicago.....	I, 495, 496
“ “ “ “ “ Nantasket Beach Branch of The New York, New Haven & Hartford Railroad.....	I, 492-495
“ “ “ “ “ Union Passenger Railway, I,	520, 521
“ “ “ Under Special Conditions.....	I, 514
“ —What It Does	I, 396
Electro-Magnet— <i>Illustration</i>	I, 400
“ Double— <i>Illustration</i>	I, 400
Electro-Magnets	I, 410, 486
Electro-Motive Force	I, 397, 411, 419, 420, 422, 423, 429, 431-433, 436, 445, 446, 460, 475, 476
“ “ Measure of.....	I, 401
“ “ Production of.....	I, 406
Electroplating	I, 374
“ Chemical Energy in.....	I, 402
Elements in Battery, Automatic Electric Block Signals— <i>Illustrations</i>	IV, 282
“ Induction Motor.....	I, 443
“ of an Electric Railway.....	I, 453-485
“ “ Construction	III, 167-173
“ “ the Electrical System.....	I, 396
Elephants, Carriage of Railroads by.....	I, 223
Elevators.....	I, 259, 259
Ellis, William F.....	III, 814
Elphinstone.....	XI, 28
Embankments	III, 129
“ Construction of	VII, 218, 219
“ Cost of Keeping in Order.....	III, 422, 423
“ Enlarging.....	II, 221
“ Slope of.....	III, 251
“ Sodding.....	III, 226
Emergency, Application of the Brake in—Instructions to Enginemen.....	I, 319
“ Applications of Brake.....	I, 311-313, 343, 373
“ Brakes, Electric.....	I, 485, 486
“ or Direct Application Position, of Engineer's Brake and Equalizing Discharge Valve ...	I, 352
“ Piston— <i>Illustration</i>	I, 344
“ Stopping a Train in.....	I, 326
“ Valve— <i>Illustration</i>	I, 344
“ When Service is Intended—Instructions to Trainmen.....	I, 371
Emery Cloth, Use of—by Railways.....	VII, 212

	PAGE
Emery, Storing	VII, 293
" Use of—by Railways.....	VII, 212
" Wheels, Use of—by Railways.....	VII, 212
Emigrants, Effect of American Customs on.....	I, 202
Eminent Domain, Value of Right to Carriers.....	VIII, 58
Employe, Interest of Employer in.....	II, 31, 32, 61
" Relations of—to Employer.....	II, 91-95
" Welfare of.....	II, 15
Employes, Acceptance of Political Offices by.....	IX, 204, 205
" Accidents to.....	IV, 122, 123
" and Officers, Relations Between.....	II, 27, 28
" Arbitrary Dismissal of.....	II, 205, 206
" Associations of.....	I, 227-229
" " with Officers.....	I, 225
" at Headquarters.....	III, 418, 419
" Average Amount Paid—in America, Europe and India.....	II, 25
" Behavior of.....	IV, 332, 334
" Bonding.....	IX, 158-177
" Classification of.....	II, 306
" Co-operation of—with Employers.....	X, 293-295
" Deceased—Wages of.....	VII, 403, 407; IX, 394
" Deductions from Pay of....	VII, 385-387, 392
" Discharged—Payment of.....	VII, 408
" —Re-employment of.....	IV, 330
" Dishonest.....	II, 199
" Disposition of Property Found by.....	IV, 331, 332
" Dissatisfaction Among.....	II, 18
" Duties of—on Way Freight Trains.....	IV, 323
" Earnings Capacity of—in the United States.....	II, 25, 26
" Faithful.....	II, 92
" Faithfulness of.....	V, 326
" Fitness of.....	II, 103
" " —Test of.....	IV, 331
" Government.....	V, 320
" Granting Passes to.....	VII, 138
" Grievances of.....	III, 473
" Guaranty Funds.....	IX, 170
" Identification of.....	VII, 397
" " —to Paymasters.....	X, 230
" Increase in Number of.....	III, 419-421
" Inefficient.....	IX, 289
" Inexperienced.....	IX, 38, 39
" Information Regarding the Character of.....	IX, 167
" Intercourse of—With Officers.....	II, 17
" Interest of Managers in.....	IV, 24
" " —Methods of Heightening.....	II, 13, 28, 29
" Investments by—in the Stock of the Employer.....	II, 28
" Keeping Time of.....	I, 279, 280
" " —in England.....	VII, 531, 532

	PAGE
Employee, Taking Time of.....	VII, 360-368
" Tipping.....	V, 391-395
" Track—Rules Governing.....	III, 260-271
" Training of.....	II, 103
" Transferred, Wages of.....	VII, 403
" Uncalled for Amounts Due.....	X, 197
" Unfaithful.....	II, 92
" Unskillful.....	IX, 38, 39
" Use of Intoxicants by.....	IV, 330
" " Stationery by.....	VII, 137, 138
" Value of Experienced.....	II, 20
" " —to Employers.....	IX, 15, 16
" Withholding Wages of.....	IX, 388, 389
" Worn Out—Provision for.....	II, 95
" Young—Necessity of Especial Supervision Over.....	IX, 29, 30
Employer, Condition of—How Improved.....	II, 35
" —His Knowledge of Labor Performed.....	I, 281
" Interest of—In Employee.....	II, 31, 32, 61
" Loyalty of Employee to.....	II, 31, 32
" Relations of—to Employee.....	II, 91-95
Employers, Co-operation of—With Employees.....	X, 293-295
" Observation of Contracts by.....	II, 38
" Value of Employees to.....	IX, 15, 16
Employment, Ability of Capital to Find Safe and Profitable.....	II, 34
" Railway—Opportunities to Find.....	IX, 14
Emulation, Spirit of.....	I, 226
End Braces— <i>Illustration, Plate III</i>	I, 170-171
" Carline, Platform Roof— <i>Illustration, Plate II</i>	I, 116-117
" " Vestibule— <i>Illustration, Plate II</i>	I, 116-117
" Door— <i>Illustration, Plate III</i>	I, 170-171
" " Bracket— <i>Illustration, Plate III</i>	I, 170-171
" " " Wedge— <i>Illustration, Plate III</i>	I, 170-171
" " Chafing Strips— <i>Illustration, Plate III</i>	I, 170-171
" " Closed Stop— <i>Illustration, Plate III</i>	I, 170-171
" " Hangers— <i>Illustration, Plate III</i>	I, 170-171
" " Hasp— <i>Illustration, Plate III</i>	I, 170-171
" " Hood— <i>Illustration, Plate III</i>	I, 170-171
" " Open Clasp— <i>Illustration, Plate III</i>	I, 170-171
" " " Stop— <i>Illustration, Plate III</i>	I, 170-171
" " Seal Pin— <i>Illustration, Plate III</i>	I, 170-171
" " Staple— <i>Illustration, Plate III</i>	I, 170-171
" " Threshold Plate— <i>Illustration, Plate III</i>	I, 170-171
" Fascia— <i>Illustration, Plate III</i>	I, 170-171
" Girts— <i>Illustration, Plate III</i>	I, 170-171
" Grab Iron— <i>Illustration, Plate III</i>	I, 170-171
" of Car. Observation— <i>Illustration, Plate II</i>	I, 116-117
" Piece Plate— <i>Illustration, Plate II</i>	I, 116-117
" Plate— <i>Illustration, Plate III</i>	I, 170-171

	PAGE
End Plate, Body— <i>Illustration, Plate II</i>	I, 116-117
“ “ Tie Rod— <i>Illustration, Plate III</i>	I, 170-171
“ Post— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>{ Plate III</i>	I, 170-171
“ Rail, Seat— <i>Illustration, Plate II</i>	I, 116-117
“ Rest, Seat— <i>Illustration, Plate II</i>	I, 116-117
“ Seat— <i>Illustration, Plate II</i>	I, 116-117
“ Sill— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>{ Plate III</i>	I, 170-171
“ “ Corner Plate— <i>Illustration, Plate II</i>	I, 116-117
“ “ Platform— <i>Illustration, Plate II</i>	I, 116-117
“ “ Tie Rod— <i>Illustration, Plate II</i>	I, 116-117
Energy, Chemical—Production of Electricity by.....	I, 397
“ “ “ Heat by.....	I, 397
“ Electrical—Conversion of Chemical and Mechanical Energy into.....	I, 402
“ “ —Distribution of.....	I, 414
“ “ —Production of Heat by.....	I, 397
“ “ —Transmission of.....	I, 412, 413
“ Heat—Production of Electricity by.....	I, 397
“ Loss of.....	I, 398
“ Mechanical—How Measured.....	I, 403
“ “ —Production of Electricity by.....	I, 397
“ “ “ Heat by.....	I, 397
“ of Electric Currents.....	I, 402-405
“ Transformation of Chemical into Mechanical.....	I, 393
Engine. (See also “Locomotive.”)	
“ American—Superiority of.....	I, 44
“ Engine and Roundhouse Men”.....	VII, 485, 486, 518, 519
Engine Brakes.....	I, 380
“ Breda—of Milan.....	I, 151
“ Compound.....	I, 95, also Vol. XII
“ Connection of the Dynamo to.....	I, 456
“ Coupled Passenger Bogie— <i>Illustration</i>	I, 132
“ Detaching—Instructions to Trainmen.....	I, 323
“ Donkey.....	I, 77
“ Evaporating Power of—How Increased.....	I, 26
“ Finishing of the.....	I, 286
“ First Ten-Wheeled Passenger—“Thatcher Perkins,” 1863— <i>Illustration</i>	I, 45
“ “ Truck—“Brother Jonathan,” 1832— <i>Illustration</i>	I, 34
“ Frame.....	I, 380
“ “ Clamping of.....	I, 286
“ Freight—The First, 1832— <i>Illustration</i>	I, 38
“ “Hercules,” 1837—The First Having Equalizing Levers— <i>Illustration</i>	I, 51
“ House, Air Pipes in.....	I, 328
“ “ Foremen, General Instructions to.....	I, 328, 329

	PAGE
Engine "Kodak," Direct Connected to Generator, Fitchburg and Leominster Street Railway— <i>Illustration</i> . . . I,	453
" Length of Time kept in Service I,	247, 248
" Madras Railway— <i>Illustration</i> I,	133
" Mineral Tank—Scotland— <i>Illustration</i> I,	123
" Neilson's Twin Goods—Scotland— <i>Illustration</i> I,	125
" Newton's Experimental, 1680— <i>Illustration</i> I,	17
" North Midland Company's I,	48
" Operation of I,	83, 84
" Passenger—Description I,	66
" " —Suburban I,	303
" " —Through I,	303
" "Pioneer," 1836—Baldwin's— <i>Illustration</i> I,	39
" Saddle Tank—American Four-Wheeled— <i>Illustration</i> I,	105
" Stationary I,	108
" Steam I,	453, 454
" Superintendent I,	27
" Testing—for Leaks I,	370
" —The First Built for Burning Cumberland Coal— <i>Illustration</i> I,	43
" " " in America with a Four-Wheeled Bogie — <i>Illustration</i> I,	50
" " " to Draw a Car on the American Conti- nent—Cooper's "Tom Thumb," 1829 — <i>Illustration</i> I,	27
" " " with a Double Fire Box I,	49
" " " " " " Rocking Grate— <i>Illustration</i> I,	43
" " " " " " Equalizing Levers I,	51
" Tank I,	106
" Trimmings I,	286
" Truck— <i>Illustration, Plate I</i> I,	58-59
" " Axle— <i>Illustration, Plate I</i> I,	58-59
" " Box— <i>Illustration, Plate I</i> I,	58-59
" " Brake I,	329
" " Brass— <i>Illustration, Plate I</i> I,	58-59
" " Equalizer— <i>Illustration, Plate I</i> I,	58-59
" " Frame— <i>Illustration, Plate I</i> I,	58-59
" " " Brace— <i>Illustration, Plate I</i> I,	58-59
" " Pedestal— <i>Illustration, Plate I</i> I,	58-59
" " " Brace— <i>Illustration, Plate I</i> I,	58-59
" " Spring— <i>Illustration, Plate I</i> I,	58-59
" " " Band— <i>Illustration, Plate I</i> I,	58-59
" " " Hanger— <i>Illustration, Plate I</i> I,	58-59
" " Tire— <i>Illustration, Plate I</i> I,	58-59
" " Wheels— <i>Illustration, Plate I</i> I,	58-59
" Trucks I,	286
" Type Railway Generator I,	456-458
" " " Armature of—Showing Winding Connected to Commutator— <i>Illustration</i> I,	458

	PAGE
Engineers' and Firemen's Time Book.....	VII, 366, 376-379
“ Books and Essays Written by.....	I, 235
“ Brake and Equalizing Discharge Valve, with Feed Valve Attachment— <i>Illustration</i>	I, 351
“ “ Valve.....	I, 309, 315, 317, 319, 320, 538
“ “ “ — <i>Illustrations, Plate I</i>	I, 58-59, 349
“ “ “ —Instructions to Enginehouse Fore- men and Inspectors.....	I, 328
“ “ “ —Operations of.....	I, 349-352
“ “ “ with Feed Valve Attachment and Duplex Air Gauge— <i>Illustra- tion</i>	I, 316
“ Characteristics of.....	IV, 34, 38
“ Civil—Requisitions of.....	VII, 72
“ Electrical—American Institute of.....	I, 391
“ Equalizing Brake Valve— <i>Illustration</i>	I, 539
“ Fuel Delivered to.....	VII, 334, 335
“ Influence of—on Consumption of Fuel.....	VII, 173
“ Instructions to.....	I, 315-321, 363-369
“ Lever in Connection with Reversing Gear— <i>Illus- tration</i>	I, 91
“ Licensing.....	II, 47
“ Locomotive—Brotherhood of.....	II, 53
“ Practical Knowledge of Fuel of.....	VII, 170
“ Rules Governing.....	IV, 420-428
“ Stakes, Care of.....	III, 244
“ Valves.....	I, 305, 306, 313, 334, 347-349, 353, 354
“ Wages of.....	VII, 365
“Engineering”.....	VII, 462
Engineering Department.....	II, 136-138
“ “ of the Navy.....	I, 234
“ “ Recognition of.....	I, 234
“ Profession.....	II, 223
Engineer. (See also “Engineer.”)	
“ —Meaning of Term.....	IV, 335
Engineemen. (See also “Engineers.”)	
“ Dangers to—How Minimized.....	I, 198
“ General Instructions to.....	I, 315-321
“ Responsibility of.....	IV, 359
England, Accounting for Material and Fuel in.....	VII, 528-530
“ Adjustment of Claims in.....	VI, 21
“ Capitalization of Railways in.....	III, 65-71, 85, 86
“ Carriage of Parcels in.....	V, 517, 520, 521
“ Collection of Fares in.....	V, 182-188
“ Construction of Locomotives in.....	I, 28
“ Cost of Block System in.....	IV, 141
“ “ “ Operating in.....	III, 145, 146
“ Early Signals in.....	IV, 247-249
“ Experience of in Connection with Compartment Car.....	I, 177

	PAGE
England, Fog Signaling in.....	IV, 271, 272
“ Form of Cylinders in General Use in.....	I, 88
“ Gauge Used in.....	III, 184
“ Great Northern Railway of.....	III, 267-270; IV, 331-334, 343, 344, 349, 360, 363, 378, 402, 405, 407-409, 411, 414, 418, 419, 432; V, 225, 540
“ “ Western Railway of.....	III, 179, 191, 192; IV, 341, 349, 350, 382, 407, 410, 425, 433; V, 227, 229
“ Heating Cars in.....	V, 234, 235
“ Introduction of Link Motion in.....	I, 48
“ “ the Cab in.....	I, 56
“ Keeping Time of Employes in.....	VII, 531, 532
“ Labor Unions in.....	II, 37
“ Lighting Cars in.....	IV, 173
“ Mail Service in.....	V, 560
“ Maintenance of Track in.....	III, 307-309
“ Maximum Rates in.....	VIII, 135
“ Method of Heating Passenger Cars in.....	I, 173
“ Opening Railroads for Business in.....	VIII, 300
“ Opposition to Railways in.....	III, 117
“ Payment of Wages in.....	X, 233, 234
“ Perfection of Safety Appliances in.....	IV, 141
“ Pooling in.....	VIII, 76
“ Practices in.....	VIII, 64
“ “ —of Handling Supplies.....	VII, 104, 105
“ Private Freight Cars in.....	II, 45
“ Prohibitive Rates in.....	VI, 37
“ Railway Accidents in.....	IV, 128, 129
“ “ Laws of.....	VIII, 265
“ Responsibility for Baggage in.....	V, 308
“ Royal Commission of.....	VI, 69-71
“ Safeguards Adopted in.....	IV, 138
“ Scholarship in.....	IX, 17
“ Second Class Cars in.....	I, 170
“ Shipment of Baggage in.....	V, 299, 300
“ Sleeping Cars in.....	I, 201
“ Status of Railroads in.....	VIII, 14, 318
“ Third Class Travel in.....	I, 169, 170
“ Use of Headlights in.....	I, 57
“ “ Metal Ties in.....	III, 376
“ “ “ Parcel Tickets in.....	V, 476
“ “ “ Private Cars in.....	II, 45
“ “ “ Rigid Wheel-Base in.....	I, 24
“ “ “ Teak Wood for Passenger Car Wheels in.....	IV, 215
English Car Wheel— <i>Illustration</i>	IV, 215
“ Cars, First Class.....	I, 170
“ Compartment Car, Origin of.....	I, 183, 184
“ Directors.....	III, 140

	PAGE
English Fish Belly Rail, New Jersey Railroad—A. D. 1832— <i>Illustration</i>	III, 203
“ Freight Cars.....	I, 172
“ Permanent Way, Section of— <i>Illustration</i>	III, 313
“ Railways.....	I, 50
“ “ Cost of.....	III, 148
“ “ Fiscal Affairs of.....	VI, 318-333
“ Time Tables.....	IV, 78, 79
“ Train Rules.....	IV, 331, 334, 340, 343-345, 348-350, 357, 360-364, 366, 367, 374, 377- 382, 402, 403, 405-419, 421, 424, 425, 431-435, 441, 461
“ Use of Portable Railroads by.....	I, 222
Englishman, Personality of the.....	I, 150
Engraving.....	III, 158
Engravings of Electrical Apparatus.....	I, 391
Enlargements, Charging to Construction.....	VII, 455
Enlightenment, Associations of Employes for.....	I, 229
Entellus.....	XI, 91
Enterprise.....	III, 79
Enterprises, Great—Requirements of.....	II, 33
Entrances, Passenger Car.....	I, 176
Envelopes, Remittance.....	X, 263
Environment, Influence of.....	II, vii
Epaminondas.....	XI, 87
Epeus.....	XI, 91
Equalization of Pressure.....	I, 342, 356, 360, 361
Equalizer— <i>Illustration</i>	I, 60
“ Engine Truck— <i>Illustration, Plate I</i>	I, 58-59
“ Fulcrum to— <i>Illustration</i>	I, 60
“ Side View of— <i>Illustration</i>	I, 110
Equalizers, Driver Spring— <i>Illustration, Plate I</i>	I, 58-59
Equalizing Bar— <i>Illustration, Plate II</i>	I, 116-117
“ “ Spring— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Cap— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Seat— <i>Illustration, Plate II</i>	I, 116-117
“ Brake Lever— <i>Illustration, Plate II</i>	I, 116-117
“ “ Valve, Engineer's— <i>Illustration</i>	I, 539
“ Discharge Valve, Operations of.....	I, 349-352
“ Lever, Effect of.....	I, 52
“ Levers.....	I, 51, 110
“ Piston.....	I, 328
“ Reservoir for Engineer's Valve— <i>Illustration</i>	I, 539
Equipment, Adaptation of, to Traffic.....	III, 168, 169
“ Air Brake—Inspection of.....	I, 328, 329
“ Apportionment of Wear and Tear of.....	VII, 507
“ Carrying Capacity of—On What Based.....	VI, 51
“ Comparison of English and American.....	III, 147-149
“ Construction and Maintenance of.....	I, 288
“ Cost of Keeping in Repair.....	III, 478, 479
“ Defective.....	IV, 60

	PAGE
Equipment Department.....	II, 176, 305a-305r
“ Difference in.....	I, 119
“ Discussions of Matters Relating to.....	I, 289, 290
“ Duration of.....	III, 424
“ Effective Use of—Upon What Dependent....	VI, 52
“ Expenses of Inadequate.....	III, 427
“ “ Superabundant.....	III, 428
“ Freight—of English Railways.....	I, 172
“ Handling—of the Planing Mill and Car Shops..	I, 274, 275
“ Inspection of.....	IV, 60
“ Limitations of.....	VI, 49, 51-53
“ Maintenance of.....	VII, 479-485, 516-518
“ Motor Car.....	I, 488
“ of Electric Roads.....	I, 489-506
“ “ Repair Shops.....	I, 237
“ “ Roundhouses.....	I, 243
“ “ Shops.....	I, 259
“ Passenger—Advance in.....	I, 165
“ Purchase of.....	VII, 84
“ Railway.....	I
“ “ Construction of.....	I, 138
“ “ “ in the United States...I,	141
“ “ Manufacturers of.....	I, 126
“ “ —of Great Britain.....	III, 129
“ “ Strife of Manufacturers of.....	I, 140
“ Renewals of.....	III, 399
“ Road—Electrical.....	I, 462-469
“ Successful Manufacturers of.....	I, 145
“ Superabundant.....	VI, 52
“ Supply of—Furnished by Railroads.....	VI, 54, 55
“ Utilization of.....	IV, 57; V, 26-29; VII, 180
Erecting and Machine Shop.....	I, 254, 264, 265
“ Room.....	I, 261
“ Shop.....	I, 273, 274
“ “ for Freight Cars.....	I, 271
“ “ “ Passenger Cars.....	I, 271
“ “ —Locomotive Department—(Cross Section—	Illustration, I, 248
“ “ “ “ —End Elevation—	Illustration, I, 246
“ “ “ “ —Side Elevation	—Illustration
“ “ —Tracks in.....	I, 245
“ “ —Tracks in.....	I, 261, 262
“ Shops.....	I, 272
“ “ —Distribution of Material to.....	I, 272
“ Tracks.....	I, 265
Erie Rail, A. D. 1857—Illustration.....	III, 268
Errors, Claims for.....	II, 242

	PAGE
Errors, Correcting	IX, 361-366
" in Footing Way Bills	IX, 59
" " Way Bills	VI, 183, 186
" Settlement of Claims for	VI, 293, 294
Eryax	XI, 91
Erythraean Sea	XI, 111
Escutcheon— <i>Illustration, Plate II</i>	I, 116-117
Edraelon, Plain of	XI, 104
Essays—Written by Engineers	I, 235
Estimates, for Railway Construction Work	II, 168
" of Cost of Constructing Railways	III, 31
Estray Baggage, Tracing for	V, 342-346
" Freight	VI, 165-168
Etiquette, in Corporate Life	II, 83
Euphrates, Boats Used on	XI, 81
Europe Baggage Allowed in	V, 288, 289
" in	V, 284-286
" Billing Baggage in	V, 369-376
" Business Methods of	VIII, 233
" Capitalization in	III, 142
" Carrying Capacity of Cars in	VI, 51, 52
" Cars of	IV, 316, 317
" Central	XI, 54
" Charges for Storing Freight in	IX, 81
" Electric Railways in	I, 505, 506
" Freight Traffic of	VI, 8-11
" Gauge Used in	III, 194
" Government Management in	VIII, 251
" Lighting Cars in	IV, 173
" Methods of Heating Trains in	V, 232-236
" Miscellaneous—Its Primitive Associations and Means of Carriage	XI, 477-488
" " —Primitive Carriage in— <i>Illustration</i>	XI, 477-488
" Passenger Rates in	V, 25
" Practices in	VIII, 55
" Railway Travel in	I, 202
" Use of Private Cars in	VI, 73
" " the Air Brake in	I, 204
European Railways, Construction of	II, 26
" " Cost of	III, 163, 164
" " Operation of	II, 26
" " Safety of	II, 26
Euryalus	XI, 91
Evaporation in Locomotive Boilers	I, 73
Evolution, Man's—How Shown	I, 296
" of Cars	I, 166
" " Labor	II, 32-56
" " Man	XI, 9, 10, 39
" " Money	XI, 13

	PAGE
Evolution of Property	XI, 9
“ “ Railroads	I, 230; III, 109-122
“ “ the Alternating Current Motor	I, 445
“ “ “ Brake	I, 291-314
“ “ “ Car Seat	I, 186, 187
“ “ “ Coal Burner Smokestack— <i>Illustration</i> ..	I, 69
“ “ “ Locomotive	I, 15, 45, 529
“ “ “ Rail	I, 163-164; II, 212; III, 126, 175-178, 204
“ “ “ Railway Motor	I, 472
“ “ “ Wheel	IV, 187-195
“ “ Track	III, 174-205
“ “ Transportation	I, 159; III, 109
“ “ Vehicles	I, 156
Examination of Engineers	IV, 50, 51
“ “ Station Accounts	IX, 80, 81
“ “ Trainmen	IV, 304, 305
Examinations for Color Blindness	IV, 240-243
“ “ Necessity of—in Train Service	IV, 19
“ “ Station—by Traveling Auditors	IX, 226-231, 236-240, 248, 284-286
Examiners, Medical—Relief Department	X, 301, 312
Excess Baggage	V, 371
“ “ Billing	V, 478-493, 495
“ “ Charges for	V, 62, 63
“ “ Checking	V, 442, 443
“ “ Coupons	V, 475, 476, 495
“ “ Devices of Passengers to Escape Charges for	V, 460, 461
“ “ Difficulty of Collecting Charges on ..	V, 458, 459
“ “ Forwarded by Freight Trains—Rules Gov- erning	V, 501, 502
“ “ Forwarding	V, 494-502
“ “ Interline Returns of	V, 482
“ “ Money Coupon Tickets ..	V, 471, 472, 476, 477, 495
“ “ Monthly Returns of—Rules Governing	V, 507-512
“ “ Rates	V, 458
“ “ Receiving	V, 502, 503
“ “ Revenue	V, 455, 457, 460
“ “ “ Accounting for	V, 506-514
“ “ “ Collection of	V, 462-477
“ “ Rules Governing	V, 494-505
“ “ Tickets	V, 509
“ “ “ Use of	V, 471-477
“ “ Traffic	V, 454-461
“ “ “ Form of Release for	V, 443
“ “ “ —Interline	V, 465
“ “ “ “ —in the United States ..	V, 487, 488
“ “ “ Local ..	V, 465, 466

	PAGE
Expenditures, Permanent.....	VII, 525
" Relation of—to Capitalization.....	VIII, 193
" " " Traffic to.....	III, 413-426
" Temporary.....	VII, 525
Expense, Between Dynamo and Car.....	I, 451
" Bill (See also "Freight Bill").....	VI, 197
Expenses, Classification of.....	VII, 381
" Common—Apportioning.....	VII, 502, 511
" Comparison of.....	II, 109
" Current—Charging.....	X, 29, 30
" Division of.....	X, 30
" Fixed—Meaning of the Term.....	III, 413
" " Operating.....	III, 413-428
" General.....	VII, 495-497, 523, 524
" Influences of Traffic on.....	III, 419-421
" Notarial—Cost of.....	III, 156
" Operating.....	II, 109; VIII, 293
" " —Apportionment of, as Between Passenger and Freight Business....	X, 154-175
" " —Apportionment of, to Divisions.....	VII, 500-524
" " —Charges to.....	VII, 456
" " —Definition of.....	X, 179
" " —Official Classification of.....	VII, 472-499
" " —Reduction of.....	II, 27
" " —Relative Cost for Steam and for Electricity.....	I, 515
" " —Value of Classification of.....	X, 142-147
" " —What They Include.....	X, 62
" Relation of—to Earnings.....	III, 57
" Separation of Natural and Traffic.....	III, 292
" Terminal.....	III, 409-411
" Track—Chargeable to Traffic.....	III, 285-292
" " —Classification of.....	III, 287, 288
" " —Relation Various Items Bear to the Total.....	III, 491
" Train.....	III, 414, 415
" Vouchers for.....	VIII, 435; IX, 368
Expensing, Express Traffic.....	V, 544, 545
Experience, Information Afforded by.....	I, 283
" Necessity of.....	II, 20; IV, 50; IX, 30
" of the Author in Electrical Matters.....	I, 389
" Practical.....	I, 117
" Value of.....	II, 91
" Want of.....	II, 110
" Wisdom Acquired by.....	III, 63, 64
"Experiment," Locomotive.....	I, 45, 50
" 1832. The First Engine in America with a Four-Wheeled Bogie— <i>Illustration</i>	I, 50
Experiments—During Early History of Railroads.....	I, 163

	PAGE
Experts, Expenses of.....	III, 161
Explanation of a Popular Form of Automatic Air Brake...I,	538
Explosives, Use of—by Railways.....	VII, 214
Express Accounts.....	V, 541
" Agencies, Classification of.....	V, 541
" and Mail Service.....	V, 515-563
" Business, Relation of—to Baggage.....	V, 304
" " Revenue From.....	V, 304
" Cars, in Passenger Trains.....	IV, 379
" Charges, Collection of.....	V, 523
" Companies, Advantages of.....	V, 527, 528
" " Methods of.....	V, 537-551
" " Rates Exacted of—in United States..	V, 521
" " " of.....	V, 533-536
" " Relation of—to Community....	V, 530, 531
" Earnings, Definition of.....	X, 178
" Locomotive, Italian— <i>Illustration</i>	I, 129
" " of Chemins de fer de l'Etat Belge— <i>Illustration</i>	I, 128
" Messengers.....	V, 518, 519, 539, 540
" Packages, Unclaimed.....	V, 346
" Sending Money by.....	X, 265
" Service, Beginning of.....	XI, 151
" " in United States.....	V, 537-551
" Settlements.....	V, 550, 551
" Traffic.....	V, 468, 517-536; VI, 9
" " Expenses Attending.....	V, 526, 527
" Way Bills.....	V, 543, 544
Extension End of Boiler— <i>Illustration</i>	I, 98
" Front— <i>Illustration, Plate I</i>	I, 58-59
Extensions, Construction of.....	II, 211
Extra Hose—Instructions to Enginemmen.....	I, 321
" " " Trainmen.....	I, 328
" Train—Meaning of Term.....	IV, 317
" Trains.....	IV, 352, 353
Extras Book, English.....	V, 249
Extravagance, Effect of.....	III, 124
" in Construction.....	III, 151
Eye Bolt, Check Chain— <i>Illustration, Plate II</i>	I, 116-117
Eyesight, Defective.....	IV, 224-243
Face Plate Buffers— <i>Illustration, Plate II</i>	I, 116-117
" " Diaphragm— <i>Illustration, Plate II</i>	I, 116-117
" " Inner— <i>Illustration Plate II</i>	I, 116-117
" " Retaining Chain— <i>Illustration, Plate II</i> ...I,	116-117
Facilities, Conformity of—to Public Needs.....	I, 201
" Effect of—on Cost of Operating.....	III, 427-432
" for Care and Maintenance of Rolling Stock....	I, 238
" Natural—Differences in.....	I, 121

	PAGE
Facilities of Shops.....	I, 235
" Power	I, 262
" Station	III, 410, 411
" Terminal—Cost of	III, 409
Facing, Deck Sill— <i>Illustration, Plate II</i>	I, 116-117
" Machines.....	I, 262
Faculties, Decay of.....	II, 23
Failures, Air Brake—Cause of	I, 375, 376
Fair, Institution of.....	XI, 72
" Tickets.....	V, 92, 107
Fairs, Ancient	XI, 132
" Notice of—to Officials	V, 113
Faithfulness, Recognition of—in Corporate Life.....	II, 19
Falling Water.....	I, 393
Fang Bolts.....	III, 197, 198
Faraday.....	IV, 176
Fare, Third Class—in England.....	I, 169
Fares, Cash—Collection of.....	V, 181, 182
" " Rules Governing.....	V, 194, 198
" Collecting on Waybills.....	V, 153-156
" Collection of—by Conductors.....	IX, 118, 119
" " —in England.....	V, 182-188
" " —on Freight Trains.....	V, 151-156
" Excess—Collection of.....	V, 192, 193, 196
" " —Refunds of	V, 196
" Passenger—Collected on Freight Trains.....	VI, 317
" Payment of—to Conductors.....	V, 118
" Schedules of—Regulations Governing.....	VI, 42-48
Fascia Board— <i>Illustration, Plate II</i>	I, 116-117
" " Inside Cornice— <i>Illustration, Plate II</i>	I, 116-117
" " End— <i>Illustration, Plate III</i>	I, 170-171
" " Side— <i>Illustration, Plate III</i>	I, 170-171
Fast Freight Lines.....	VI, 49, 75, 76
Fastening, Freight Car Door— <i>Illustrations</i>	I, 181
Fastenings, Rail.....	III, 197, 198
" Track.....	III, 328-334, 341
Faucet, Water Cooler— <i>Illustration, Plate II</i>	I, 116-117
Favoritism.....	II, 31; VI, 72
Fawcett, Professor Henry.....	VII, 12
Feed Door— <i>Illustration, Plate II</i>	I, 116-117
" " Handle— <i>Illustration, Plate II</i>	I, 116-117
" " Pipe— <i>Illustration, Plate I</i>	I, 58-59
" " Hanger— <i>Illustration, Plate I</i>	I, 58-59
" " Hose— <i>Illustration, Plate I</i>	I, 58-59
" " Injector— <i>Illustration</i>	I, 60
" Ports— <i>Illustrations</i>	I, 341, 344
" Purchase of.....	VII, 337, 338
" Valve Attachment.....	I, 349
" " — <i>Illustration</i>	I, 351
" Valves.....	I, 313, 365

GENERAL INDEX.

187

	PAGE
Feeder, Booster on Long— <i>Illustration</i>	I, 433
Feeder, Panel.....	I, 461
Feeders.....	I, 431-433, 435, 436, 462, 463, 488
" Trolley Circuit Supplied by— <i>Illustration</i>	I, 433
Feeding, Direct.....	I, 431-434
Feeds, Automatic.....	I, 269
Fence, Barbed Wire— <i>Illustration</i>	III, 341
Fences.....	III, 256, 352
"Fences".....	VII, 462
Fences Between Tracks.....	IV, 121
" Cost of Keeping in Order.....	III, 422, 423
" Effect of—on Cost of Operation.....	III, 392
" Maintenance of.....	III, 300
" Snow—Use of.....	III, 302-305
" Supplies for.....	VII, 111, 112
Fenton, Murray & Company.....	I, 32
Fernow, B. E.....	III, 350, 370, 373-375
Ferriage, Record of Cash Collected for.....	VI, 220, 221
Fertilizing Matter, Cars for Handling.....	I, 224
Fetes, Notice of—to Officials.....	V, 113
Fever, Typhoid.....	I, 181
"Flat" Money.....	III, 17
Fidelity of Officers and Employes—Its Value.....	II, 63
Field Coil for Railway Motor— <i>Illustration</i>	I, 472
" Magnetic.....	I, 399, 405-407
" —Increasing the Strength of.....	I, 400
" Poles.....	I, 406, 408
" Strength—How Limited.....	I, 427, 428
" Winding, in Booster System.....	I, 435
Filament, Lamp.....	I, 399
Fillings, Iron.....	I, 399, 400
Filler, Water Tank— <i>Illustration, Plate II</i>	I, 116-117
Filling Funnel— <i>Illustration, Plate II</i>	I, 116-117
" Pipe— <i>Illustration, Plate II</i>	I, 116-117
" Valve Cover— <i>Illustration, Plate II</i>	I, 116-117
Fills.....	III, 225
Finance Committee.....	II, 131
Finances, Local.....	II, 285
" Management of.....	III, 7
Financial Department.....	II, 137
" Discipline in.....	IX, 33
Financing.....	III, 5-105
Findlay, Colonel..II, 15, 207, 209; III, 139, 307; IV, 78, 79, 87, 94	
Fines.....	IV, 24, 30-32
" Enforcement of.....	VII, 368
" for Misrepresenting Freight.....	VI, 25
" Mail Service.....	V, 557-559
Fire, Agents' Reputed Losses by.....	IX, 245
" Basket, Early English— <i>Illustration</i>	I, 57
" —The First Headlight.....	I, 57

	PAGE
Fire Box.....	I, 71, 96, 97
“ “ — <i>Illustrations</i> , { <i>Plate I</i>	I, 58-59
“ “ and Tank Arrangement for the Use of Oil as Fuel, Section Showing— <i>Illustration</i>	I, 60
“ “ Area of.....	I, 68
“ “ “Belpaire”.....	I, 75
“ “ Consumption of Gases in.....	I, 99
“ “ Crown Bar.....	I, 75, 97
“ “ Double—The First on a Locomotive.....	I, 49
“ “ Inside Shell of— <i>Illustrations</i>	I, 67, 98
“ “ Outside Shell of— <i>Illustration</i>	I, 87
“ “ Radial Stay Type of.....	I, 75
“ “ Severity of Oil on.....	I, 104
“ Claims for Damage by.....	II, 232
“ Destruction of Offices by.....	IX, 342
“ Door— <i>Illustrations</i> , { <i>Plate I</i>	I, 58-59
“ “.....	I, 64, 98
“ First Use of.....	IV, 150, 151
“ Locomotive—How Regulated.....	I, 70
“ Origin of.....	IV, 146
“ Pot— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Precautions Against—at Construction Depots. . .	VII, 194
“ “ —in Oil Houses.....	VII, 124
“ Protection of Trains from.....	IV, 363
“ Sacredness of—to Primitive Peoples.....	IV, 146-149
“ Worship of.....	I, 104
Fires.....	III, 271
“ Damage Caused by.....	III, 300
“ Precautions Against.....	VII, 294
Firearms, Use of—by Railways.....	VII, 214
Fireman, The.....	IV, 40-51
Firemen.....	II, 200
“ A Concise and Specific Account of the Duties of Engineers and Firemen in Connection with the Operation of Locomotives, see.....	Vol. XII
“ Influence of—on Consumption of Fuel.....	VII, 173
“ Practical Knowledge of Fuel of.....	VII, 170
“ Requirements of.....	IV, 49, 50
“ Rules Governing.....	IV, 428-430
“ Wages of.....	VII, 363
Firing a Locomotive, Systems of.....	I, 97, also Vol. XII
“ —Banking System.....	IV, 43
“ Scientific.....	I, 70
“ —Spreading System.....	I, 99; IV, 43
Firms, Vouchers in Favor of.....	VII, 435
First Carriage Builder, the.....	I, 132
“ Distinctive Freight Engine. The “Traveler,” 1832— <i>Illustration</i>	I, 38

	PAGE
First Electric Railway.....	I, 520
“ Freight Car.....	I, 204
“ Passenger Mogul, 1876—An Engine with Six Drivers and a Bogie Truck— <i>Illustration</i>	I, 46
“ Rail Rolled in America, Baltimore & Ohio Railroad— <i>Illustration</i>	III, 233
“ Railway Train in the World—Trevithick’s Engine, 1803 — <i>Illustration</i>	I, 20
“ Ten-Wheeled Passenger Engine, “Thatcher Perkins,” 1863— <i>Illustration</i>	I, 45
“ Truck Engine, “Brother Jonathan,” 1832— <i>Illustration</i>	I, 34
Fiscal Affairs, Collection of Revenue.....	IX
“ “ Expenditures.....	VII, 227-532
“ “ General—Methods of Handling.....	X, 60
“ “ of Agents.....	IX, 219-249
“ “ “ English Railways.....	VI, 318-333
“ “ Principles and Methods Governing.....	VI, 77-92
“ Data, Value of.....	VII, 233, 234
“ Duties of Agents and Conductors.....	IX, 293-434
Fish Bolts.....	III, 181
“ Carriage of.....	V, 519
“ Commission, Transportation for.....	V, 144
“ Plates, Introduction of.....	III, 181
“ “ Styles of.....	III, 182
Fitness, Employer—Test of.....	IV, 331
Fitting, Angle— <i>Illustration, Plate II</i>	I, 116-117
“ Tee— <i>Illustration, Plate II</i>	I, 116-117
Fixed Charges—Meaning of the Term.....	III, 413
“ Expenses—Meaning of the Term.....	III, 413
“ Operating Expenses.....	III, 413-426
“ Signals, at Train Order Offices.....	IV, 391
“ “ First Forms of.....	IV, 246
“ “ Rules Governing.....	IV, 349, 350
Fixtures, Locomotive—Number of.....	I, 89
“ Wear and Tear of.....	III, 299
Flag and Lamp Holder— <i>Illustration, Plate II</i>	I, 116-117
“ Signals, Early.....	IV, 248, 253, 255
“ Size of—American Standard.....	IV, 481
Flags, Use of.....	IV, 340, 342
“ “ —on Trains.....	IV, 344-346
Flagmen.....	IV, 253
“ —Protection of Trains by.....	IV, 355, 356, 359
“ —Tools of.....	IV, 433
Flagstaff— <i>Illustration, Plate I</i>	I, 58-59
Flame, Flat.....	I, 102
Flange Grooves.....	I, 304
“ of Wheel— <i>Illustration, Plate II</i>	I, 116-117
“ V-Shaped.....	I, 304
“ Wear, Cause of.....	I, 379

	PAGE
Force, Station—Rules and Regulations Governing.....	II, 14
“ Supervisory—for the Care and Maintenance of Rolling Stock.....	I, 238
“ “ “ “ “ of Cars.....	I, 271
“ Technical.....	III, 470
“ Track—Rules and Regulations Governing.....	II, 14
“ Train.....	II, 200; III, 470; IV, 33-56
“ “ and Station—Characteristics of.....	IV, 12
“ “ English.....	IV, 442
“ “ —Hours of Work of.....	IV, 19
“ “ —Qualifications of.....	IV, 13, 14
“ “ —Selection of.....	IV, 27, 28
Forces, Elemental—of Labor and Capital.....	II, 35
“ Engineering and Mechanical.....	I, 289, 290
“ Railway—Discipline of.....	II, 18
“ “ Necessity of Courage in.....	II, 19
“ “ “ “ Esprit de Corps in.....	II, 19
“ “ “ “ Intelligence in.....	II, 19
“ “ “ “ Interest in.....	II, 19
“ Regulation of—in Shops.....	I, 232
Foreclosure.....	III, 87
Foreclosures, Mortgage.....	III, 95
Foreign Agent.....	II, 139
“ Agents, Apportionment of Cost of.....	VII, 508
“ Cars.....	VI, 54
“ “ Rules Governing the Use of.....	VI, 65, 66
“ Coupon Tickets.....	V, 88
“ Investors.....	III, 82-84
“ Tickets.....	V, 88, 102
Foreman, General.....	I, 264, 271, 277
Foremen.....	I, 270
“ Assistant.....	I, 264
“ Certification of Pay Rolls by.....	X, 205
“ Construction.....	III, 209; VII, 194
“ Departmental.....	I, 277
“ Engine House—General Instructions to.....	I, 323, 329
“ Gang.....	I, 265, 276; III, 259
“ Roundhouse.....	I, 247, 316
“ Section—Facilities of.....	VII, 106, 109, 110
“ “ —Returns of.....	VII, 108, 109
“ Shop.....	I, 264, 265
“ Skill of.....	III, 468
“ Stockyard—Records of.....	VII, 337, 340
“ “ —Returns of.....	VII, 339, 340
“ Track.....	III, 310, 311
“ “ —Returns of.....	VII, 324, 325
“ “ —Use of Signals by.....	IV, 342
Forest Products, Hauling—Railroads for.....	I, 217
Forge, Primitive.....	I, 131
“ Shop.....	I, 251, 256, 271, 272

	PAGE
Forms, Bridge and Building Time (and Distribution) Book..	VII, 552
“ Card Way Bill.....	VI, 441
“ Certificate of Bondsman.....	IX, 457
“ Clearance Card.....	IV, 478
“ C. O. D. Advice to Destination Line of Baggage Forwarded Unpaid.....	V, 609
“ Conductor's Balance Sheet.....	V, 570
“ “ Exchange Check.....	V, 594
“ “ Record of Freight Loaded at Stations where there are no Agents.....	VI, 344
“ “ Report of Time of Train Crew.....	VII, 561
“ “ Return for Freight Carried in Their Trains... ..	VI, 437
“ “ “ “ Freight Loaded at Stations where there are no Agents.....	VI, 342
“ “ Ticket Journal.....	X, 369
“ “ Waybilling Directions for Freight Loaded at Stations where there are no Agents	VI, 343
“ Daily Record of Closing Numbers and Monthly Summary of Local Tickets on Hand, Received, Sold, Spoiled and Returned	V, 577
“ “ “ “ Oil, Waste and Tallow Delivered to Locomotives.....	VII, 587
“ “ Return of Freight Earnings.....	VI, 401
“ “ Statement of Interline Way Bills Forwarded, ..	VI, 442
“ “ Train Return of Milk Shipped.....	VI, 398
“ Diagram Showing Inside Arrangement of Station Cash Drawers	IX, 467
“ Dining Car Conductor's Trip Report	VII, 580, 581
“ Disbursement Ledger	X, 367
“ Distribution Book for Vouchers and Bills Registers, ..	X, 366
“ “ of Track Material.....	VII, 544
“ Draft That May Be Used in Paying Freight Charges.	IX, 465
“ Duplicate Freight (Expense) Bill.....	VI, 364
“ “ of Special Remittance Notice to Be Used by Agents and Others when Remitting to Treasurer.....	IX, 464
“ Engine Fuel Ticket	VII, 593
“ Engine-House Register.....	VII, 560
“ Engineers' and Firemen's Time Book (for Running Time)	VII, 553
“ Excess Baggage Checks (Way Bills).....	V, 599-604
“ Form of Envelope in Which Conductors Are Required to Return to the Ticket Auditor the Record of Stop-over Checks Issued by Them.....	V, 593

GENERAL INDEX.

145

	PAGE
Forms, Form of Request for Voucher.....	VI, 430
" " to Be Used by Agents When Tickets Are Issued in Exchange for the Tickets or Orders of Other Companies; Also for Government Requests, Etc.....	V, 576
" " Used in Waybilling (Checking) Baggage in Europe, as Amended.....	V, 596
Freight Auditor's Notice to Agents of Errors and Omissions in Abstracts and Summaries, Freight Forwarded.....	VI, 424
Freight Auditor's Notice to Agents of Errors and Omissions in Abstracts and Summaries, Freight Received.....	VI, 422, 423
Freight Auditor's Notice of Errors and Omissions in Interline Way Bills.....	VI, 372
Freight Auditor's Notice of Errors and Omissions in Local Way Bills.....	VI, 371
Freight Bill.....	VI, 440
(Expense) Bill.....	VI, 362
General Balance Sheet.....	X, 183
Cash Book.....	X, 377, 378
Distribution of Labor Book.....	VII, 586
" " Material Book.....	VII, 563
Fuel Report.....	VII, 592
Ledger.....	X, 362
" Journal.....	X, 363
Time Book.....	VII, 550
Guaranty for Freight Charges.....	VI, 436
Inspector's Report of Ties Inspected.....	VII, 577
Interline Baggage Check.....	V, 598
Way Bill.....	VI, 438, 439
Invoice and Receipt for Tickets.....	V, 568
" " of Material.....	VII, 576
" " " Purchased.....	VII, 579
Junction Returns of Interline Way Bills.....	VI, 402, 403
Kirkman's Bank Check and Record Thereof.....	X, 386
Late Slip.....	VII, 555
Letter of Advice to Paymaster Identifying Employee.....	VII, 569, 570
List of Uncollected Bills.....	IX, 446
" " " " Transferred to Incoming Agent.....	IX, 452
Loaded Car Ticket.....	VI, 353
Local Baggage Check.....	V, 597
Locomotive Engineer's Trip Report of Time Worked.....	VII, 557
" " Report.....	X, 381
Material Shipped Away by Section Foreman.....	VII, 547
" " Used by Section Foreman for Repairs of Roadway and Track.....	VII, 545, 546

	PAGE
Forms, Mileage Exchange Check	V, 589
" Modern	VII, 229, 230
" Monthly Abstract of Interline Way Bills Forwarded	VI, 410
" " " " " " " " Received	VI, 412
" " " " Local Way Bills Forwarded, VI,	406
" " " " " " Received... VI,	408
" " Report of Car Brasses.....	VII, 579
" " " Stockyard Charges	VII, 598
" " " Supplies Received and Expenses Incurred at Stockyards .	VII, 596
" " Return and Apportionment Detail of Interline Ticket Sales	X, 382
" " " of Commodities (in Tonnage) for Freight Forwarded.....	VI, 420
" " " " Commodities (in Tonnage) Way-billed Through from Stations on Other Railroads, VI,	421
" " " " Excess Baggage	V, 605
" " " " Interline Ticket Sales.....	V, 584
" " " " Local Ticket Sales.....	V, 580-582
" " " " Milk Ticket Sales.....	VI, 399
" " " " Scrap on Hand.....	VII, 582
" " " " Unrefunded Charges.....	VI, 359
" " Statement—Various Persons.....	VII, 600
" " Summary of Interline Way Bills... VI,	416, 417
" " " Local Way Bills.....	VI, 414
" Notice of no Business to Report	VI, 341
" Order for Switching.....	VI, 385
" " on Paymaster.....	VII, 571
" " " Storekeeper for Supplies.....	VII, 574
" " " to Deliver Freight to Drayman, etc.....	IX, 458
" " " Load Material.....	VII, 585
" " " Sell a Ticket to a Particular Person at a Particular Rate.....	V, 575
" " " " Excursion Tickets at Special Rates, Account of Fairs, Fourth of July Celebrations, Grand Army Reunions, etc	V, 572
" Orders Annulling a Schedule Train.....	IV, 473
" " " or Superseding an Order.....	IV, 474
" " Authorizing a Train to Pass or Run Ahead of Another Train Running in the Same Direction.....	IV, 467, 468
" " Changing the Schedule Time of a Train Between the Points Mentioned.....	IV, 469, 470
" " Fixing a Schedule for an Extra Train..	IV, 470, 471
" " " Meeting Point for Opposing Trains... ..	IV, 467

GENERAL INDEX.

147

	PAGE
Forms, Orders for a Train to Run or Work as an Extra Train.....	IV, 471, 472
“ “ Giving all Regular Trains the Right of Track Over a Given Train.....	IV, 469
“ “ “ an Inferior Train the Right of Track Over an Opposing Train of Superior Grade.....	IV, 468, 469
“ “ to Hold a Train.....	IV, 473
“ “ Regarding Sections of Regular Trains....	IV, 470
“ Passenger Tariff, Turkish Railroad, Jaffa to Jerusalem.....	V, 595
“ Paymaster's Check, Payable to Bearer When Indorsed by Paymaster.....	X, 387
“ “ “ “ “ Order.....	X, 386
“ Pay Roll.....	VII, 564, 565
“ Railroad and Transportation Companies' Car Mileage Journal.....	X, 373
“ “ “ “ Companies' Freight Journal.....	X, 372
“ “ “ “ Companies' Ledger, Embracing All Accounts with Other Companies Except Miscellaneous Account.....	X, 374
“ “ “ “ Companies' Ledger of Miscellaneous Accounts.....	X, 375
“ “ “ “ Companies' Ticket Journal.....	X, 371
“ Recapitulation of Labor.....	VII, 543
“ “ “ Material.....	VII, 542, 543
“ Receipt for Cash Collected.....	VI, 380
“ “ “ Dockage or Terminal Charges.....	VI, 378
“ “ “ Feed Furnished Stockyards.....	VII, 595
“ “ “ Freight Received.....	VI, 339
“ “ “ Miscellaneous Charges.....	VI, 375
“ “ “ Overcharge—Original.....	VI, 433
“ “ “ Prepaid Freight Charges.....	VI, 345, 347
“ “ “ Switching Charges.....	VI, 386
“ “ “ Given to Passengers for Cash Fares Paid to Conductors.....	V, 585
“ “ “ “ Passengers for Property Pledged for Fare or Other Purpose... V,	571
“ “ “ “ Persons Attending Conventions for Tickets Bought by Them; also, Certificate of the Convention in Regard to Attendance Thereat.	V, 574

	PAGE
Forms, Receipt for Excess Baggage Charges.....	V, 607
“ Reconsigning Ticket.....	VI, 365
“ Record Book of Advanced Charge Checks or Drafts	
Drawn on the Treasurer.....	X, 376
“ “ of Amounts Charged, Collected and Re-	
funded for Car Service.....	VI, 426
“ “ “ and Receipt for Advanced Charges...VI,	349
“ “ “ “ “ “ Interline Charges Pre-	
paid.....	VI, 395
“ “ “ Bulk Freight Weighed at Destination....	
.....	VI, 357
“ “ “ Business Done.....	VII, 594
“ “ “ Cash Collected.....	VI, 381
“ “ “ “ Received from Agents and Con-	
ductors.....	X, 379
“ “ “ Coal Received.....	VII, 589
“ “ “ C. O. D. Advice to Destination Line of Bag-	
gage Forwarded Unpaid.....	V, 609
“ “ “ Construction Work.....	VII, 602
“ “ “ Ferry Collections.....	VI, 384
“ “ “ Freight Manipulated in Transit.....	VI, 429
“ “ “ Freight Received Subject to Terminal	
Charge Only.....	VI, 379
“ “ “ “ “ and Agent’s Balance	
Thereof.....	VI, 363
“ “ “ “ Transferred.....	VI, 358
“ “ “ “ Weighed En Route.....	VI, 374
“ “ “ Interline Tickets Received by Agent...V,	578
“ “ “ “ Sold, Spoiled and Re-	
turned by Agent.V,	578
“ “ “ “ Way Bills.....	VI, 404, 405
“ “ “ Loaded Car Ticket.....	VI, 355
“ “ “ Miles Run.....	VII, 558
“ “ “ Miscellaneous Charges Collected.....	VI, 376
“ “ “ Moneys Collected at Stockyards.....	VII, 597
“ “ “ Monthly Abstract of Interline Way Bills	
Forwarded..	VI, 411
“ “ “ “ “ Interline Way Bills	
Received....	VI, 413
“ “ “ “ “ Local Way Bills For-	
warded.....	VI, 407
“ “ “ “ “ Local Way Bills Re-	
ceived,....	VI, 409
“ “ “ “ Return of Excess Baggage...V,	606
“ “ “ “ “ Milk Ticket Sales..VI,	400
“ “ “ “ Summary of Interline Way Bills	
.....	VI, 418, 419
“ “ “ “ “ Local Way Bills...	
.....	VI, 415
“ “ “ Old Rail Delivered to Rolling Mills...VII,	584

	PAGE
Forms, Record of Old Rail Received at General Storehouse	VII, 583
“ “ “ Overcharge Refunded	VI, 434
“ “ “ Overtime	VII, 556
“ “ “ Prepaid Freight Charges	VI, 346, 348
“ “ “ Rails on Hand	VII, 578
“ “ “ Reconsigning Ticket	VI, 367
“ “ “ Switching	VI, 387
“ “ “ “ Charges Collectible	VI, 391
“ “ “ “ “ Due Other Companies	VI, 394
“ “ “ Traveling Auditor	VII, 603-605
“ “ “ Unrefunded Charges	VI, 396
“ “ “ Weights of Iron Ore	VI, 370
“ “ “ Wood Measured	VII, 590
Remittance Notice, to Be Used by Agents When Remitting to Banks	IX, 463
“ “ “ “ “ “ “ “ “ “ “ “ Conductors	IX, 466
Report to Be Made by Traveling Auditor for Each Agency Examined by Him	IX, 437-443
Request for Time Ticket	VII, 566
Requisition for Material	VII, 573
“ “ “ Tickets	V, 567
Return for Bulk Freight Weighed at Destination, VI.,	356
“ “ “ Freight Forwarded After Having Been Manipulated in Transit ..	VI, 428
“ “ “ “ Received to Be Manipulated in Transit	VI, 427
“ “ “ Loaded Car Ticket	VI, 354
“ “ “ Reconsigning Ticket	VI, 366
“ “ “ of Cash Fares Collected	V, 586
“ “ “ Freight Conductors Who Have Not Issued any Cash Fare Receipts During the Week	V, 587
“ “ “ Interline Ticket Sales	V, 583
Returns for Switching Charges Collectible	VI, 389
“ “ “ “ “ Due Other Companies	VI, 392
“ “ “ of Ferry Collections	VI, 382
“ “ “ “ Miscellaneous Freight Collections Not Waybilled	VI, 377
“ “ “ “ Weights of Iron Ore Received	VI, 368
Section Foreman's Report of Material and Tools on Hand at End of Month	VII, 548, 549
Shipping Bill for Freight	VI, 340
Special Form to Be Used in Receipting for Money Paid for Tickets Bought of Agents, or Fares Paid to Conductors	V, 569
“ “ “ Remittance Notice	IX, 463

	PAGE
Forrester & Company	I, 32
Forwarding Agent.	VI, 109
" Agents, Instructions to	VI, 138
Foundations of Shop Buildings	I, 253
Foundries, Accounts with	VII, 309
" Delivery of Material to	VII, 309
Foundry	I, 252
" Brass	I, 257, 258
" Building	I, 257
Four-arm Lamp— <i>Illustration, Plate II</i>	I, 116-117
Four-pole Motor	I, 472
Four-way Cock	I, 320
" " Handle— <i>Illustration</i>	I, 341
" " Key— <i>Illustration</i>	I, 341
Frame, "Bar"	I, 53
" Bent Trestle Bridge— <i>Illustration</i>	III, 375
" Boiler Hanger to— <i>Illustration</i>	I, 60
" Brace— <i>Illustration, Plate I</i>	I, 58-59
" " Engine Truck— <i>Illustration, Plate I</i>	I, 58-59
" Engine	I, 380
" " —Clamping of	I, 286
" " —Development of	I, 53
" " Truck— <i>Illustration, Plate I</i>	I, 58-59
" Front— <i>Illustration, Plate I</i>	I, 58-59
" " Section of— <i>Illustration</i>	I, 60
" Legs	I, 109
" Locomotive	I, 108, 109, 380
" Main— <i>Illustration, Plate I</i>	I, 58-59
" Means of Fastening Boiler to— <i>Illustration</i>	I, 62
" of Electric Motor Car	I, 467, 468
" "Plate"	I, 53
" Rear Section of— <i>Illustration</i>	I, 60
" Splice— <i>Illustration, Plate I</i>	I, 58-59
" Spring—Berth— <i>Illustration, Plate II</i>	I, 116-117
" Tie— <i>Illustrations</i>	I, 64, 98
" Truck— <i>Illustration</i>	I, 60
" " End Piece of— <i>Illustration, Plate II</i>	I, 116-117
Frames	I, 286
" Cost of	III, 403
" of Motor Car Trucks	I, 469
France	I, 215
" Baggage Allowed in	V, 288
" " in	V, 285
" " Storage Charges in	V, 425
" Builders of	I, 152
" Eastern Railway of	III, 178, 183
" " —Cars Used on	I, 121
" Gauge Used in	III, 194
" Government Management in	VIII, 251-253
" " Supervision in	III, 46, 47

	PAGE
France, Heating Cars in.....	IV, 162; V, 235, 236
“ Influences Governing Rates in.....	VIII, 98
“ —Its Primitive Associations and Means of Carriage	XI, 463-467
“ Maintenance of Track in.....	III, 309, 310
“ Passenger Cars of.....	I, 174
“ —Primitive Carriage in— <i>Illustrations</i>	XI, 463-467
“ Relation of Railroads to Government in.....	VIII, 237
“ Relief Departments in.....	X, 329-345
“ Responsibility for Baggage in.....	V, 310, 311
“ Status of Railways in.....	III, 46, 47; VIII, 334
“ Treatment of Ties in.....	III, 355, 356
“ Use of Metal Ties in.....	III, 376
Franks, Baggage.....	V, 466, 467, 495
Fraud, Prevention of.....	V, 329, 330
Frederick the Great, Baggage of.....	V, 279
Freedom, Individual.....	XI, 26
Freight. (See also “Goods” and “Property.”)	
“ Abstracts.....	IX, 45
“ “ Daily System of.....	X, 57
“ Accountants.....	II, 248
“ Accounting.....	VI, 79, 82-85
“ Accounts.....	II, 248; V, 75, 76
“ “ Joint.....	X, 112-118
“ “ —Their Complexity.....	VI, 1
“ Advanced Charges on.....	VI, 97
“ Advances on.....	IX, 87, 318-320
“ and Passenger Car Repair Shop, Section and End Elevation— <i>Il-</i> <i>lustration</i> ...I,	255
“ “ “ “ “ “ Side Elevation— <i>Illustration</i> , I,	252
“ Associations for Inspecting and Weighing.....	VI, 24
“ Auditor.....	II, 139; X, 67
“ “ Duties of.....	VI, 109
“ Auditors, Relief Vouchers Made by.....	IX, 371, 372
“ Bad Order.....	VI, 97
“ Bills. (See also “Expense Bills”.).....	
“ “.....	VI, 197, 201, 211; IX, 84
“ “ List of Uncollected.....	IX, 66, 266, 406
“ “ Necessity for Details on.....	IX, 62-64
“ “ Remitting.....	IX, 425
“ “ Uncollected.....	IX, 77, 78
“ Billing.....	IX, 46-52
“ “ Through.....	IX, 50, 51
“ Bonded—Inspection of.....	VI, 101
“ Boxing.....	VI, 95
“ Broken Packages of.....	VI, 96
“ Brakemen, Rules Governing.....	IV, 420
“ Bulk—Handling.....	VI, 99

	PAGE
Freight, Bulk—Waybilling.....	VI, 148
“ “ Weighing at Destination—Rules Governing,	VI, 150
“ Business and Affairs.....	VI.
“ “ Beginning of.....	XI, 151
“ “ —Its Complexity.....	VI, 1
“ “ Receipts From.....	V, 172
“ Car. See also “Goods Car.”)	
“ “ American Standard.....	I, 207-214
“ “ “ “ “ Box— <i>Illustration, Plate III</i>	
“ “ “ “ “ “ “	I, 170-171
“ “ “ “ “ “ —Cross Section of— <i>Il-</i>	
“ “ “ “ “ “ <i>lustration</i>	I, 169
“ “ “ “ “ “ —End Elevation of—	
“ “ “ “ “ “ <i>Illustration</i>	I, 168
“ “ “ “ “ “ —Sectional View— <i>Il-</i>	
“ “ “ “ “ “ <i>lustration</i>	I, 167
“ “ “ “ “ “ —End Elevation and Section	
“ “ “ “ “ “ Through Journal	
“ “ “ “ “ “ Box of Truck— <i>Ilus-</i>	
“ “ “ “ “ “ <i>tration</i>	I, 178
“ “ “ “ “ “ —Plan of Truck of— <i>Ilus-</i>	
“ “ “ “ “ “ <i>tration</i>	I, 180
“ “ “ “ “ “ —Side Elevation and Section	
“ “ “ “ “ “ of Center Bearings	
“ “ “ “ “ “ of Truck— <i>Illustration</i>	
“ “ “ “ “ “	I, 177
“ “ “ Coupler, American Standard— <i>Illustrations</i>	I, 175
“ “ “ Development of.....	VI, 49
“ “ “ Door Fastening— <i>Illustrations</i>	I, 181
“ “ “ In Great Britain.....	I, 31
“ “ “ Load	I, 205, 206
“ “ “ “ The Maximum.....	I, 164, 165
“ “ “ Paint Shop.....	I, 271
“ “ “ The First.....	I, 204
“ “ “ Truck, American Standard— <i>Illustration, Plate</i>	
“ “ “ “ “ “ <i>III</i>	I, 170-171
“ “ “ “ “ “ —Section—Showing	
“ “ “ “ “ “ Body and Truck	
“ “ “ “ “ “ Bolsters— <i>Ilus-</i>	
“ “ “ “ “ “ <i>tration</i>	I, 179
“ “ “ Wheel, Cast Iron— <i>Illustration</i>	IV, 198
“ Cars.....	I, 121, 156
“ “ Brake Hangers on.....	I, 379
“ “ Carrying Capacity of.....	VI, 49, 50
“ “ Daily Performance of.....	VI, 53
“ “ Effective Use of.....	VI, 5-26, 42, 49
“ “ English.....	I, 172; III, 147
“ “ Erecting Shop for.....	I, 271
“ “ Hand Brakes on.....	I, 378
“ “ Improvident Use of—in America.....	VI, 55, 56

	PAGE
Freight Cars in Passenger Trains	IV, 379
" " Kinds of.....	I, 207; VI, 49
" " Private—in England..	II, 45
" " Repair Shed for—End Elevation— <i>Illustration</i>	I, 258
" " " " " " —Longitudinal Section— <i>Illustration</i>	I, 255
" Carload—Waybilling.....	VI, 138
" Changing Destination of.....	VI, 145
" Charges Accruing on—En Route.....	VI, 213-215
" " Advanced.....	VI, 158
" " " by Shippers.....	IX, 320-323
" " Collection of	IX, 65-74, 290, 308-316
" " for Storing.....	VI, 107
" " " —in Europe.....	IX, 81
" " Guaranteeing.....	VI, 95, 96
" " Interline Prepaid.....	VI, 156
" " " " " —Rules Governing.....	VI, 161, 162
" " Miscellaneous	VI, 158, 215-217
" " " —Prepaid.....	VI, 156, 158, 214
" " " Receipt for.....	VI, 217, 218
" " " —Unpaid	VI, 158, 214
" " Not Waybilled.....	VI, 214
" " Payment of.....	VI, 209
" " Prepaid.....	VI, 152-157; IX, 315
" " Prepayment of.....	VI, 96; IX, 126-129
" " Receipt for.....	VI, 197-210
" " Receipts Given Shippers for.....	IX, 114
" " Uncollectible.....	IX, 132, 133
" " Unpaid.....	VI, 152
" Checking	VI, 99, 113
" Claim Association.....	VI, 20
" Claims, Adjustment of..	VI, 283-295
" " English	VI, 332, 333
" " for Damage to.....	II, 232
" " " Loss of	II, 232
" Classification and Rates.....	VI, 26, 27
" " of.....	VI, 27-29
" Collection and Delivery of.....	III, 406-408
" " of.....	VI, 9, 10
" Combustible	VI, 105
" " —Handling.....	VI, 99
" Commodity—Returns for.....	VI, 272-276
" Company's—Shipping Bill for.....	VI, 111
" " —Waybilling.....	VI, 139
" Comparing—With Way Bills.....	IX, 98, 102, 290
" Conductors, Instructions to.....	VI, 308-310
" " Returns of.....	IX, 52, 53, 55, 56
" " Rules Governing.....	IV, 409-415

	PAGE
Freight, Cooperaage of.....	VI, 94
Cylinder (Standard), Reservoir and Triple Valve— <i>Illustration</i>	I, 373
" Damaged.....	IX, 103, 106
" —Collections for.....	VII, 422
" Delivered from Other Transportation Companies.....	VI, 128
" Delivering.....	II, 242; VI, 121
" Delivery of.....	VI, 9, 10; IX, 75, 76, 94, 316-318
" —in Great Britain.....	I, 173
" —to Consignee.....	VI, 116, 117
" " " Teamsters.....	VI, 107
" Department, Methods of.....	V, 480, 481
" Description of—on Way Bills.....	VI, 145
" Dividing Consignments of.....	VI, 139, 140
" Earnings, Definition of.....	X, 177
" Engines, Weight on Drivers of.....	I, 64
" Estray.....	VI, 165-168
" Explosive—Receipt of.....	VI, 95
" Forwarding.....	II, 242; VI, 96
" Government.....	VI, 279-283
" Guaranteeing.....	VI, 126
" Handling.....	II, 242; VI, 98; IX, 36
" —at Stations.....	IX, 98-107
" —by Trainmen.....	IX, 101
" —Miscellaneous—Rules Governing.....	VI, 105-108
" —Routine Connected With.....	VI, 82, 83
" Holding—to Issue Way Bill.....	VI, 131
" Houses, Guarding.....	VI, 107
" Inflammable—Receipt of.....	VI, 95
" In Open Cars.....	VI, 97
" Inspecting.....	II, 242
" Inspection of.....	VI, 94-96, 100, 101, 145
" Loading.....	II, 242
" and Unloading—Charges for.....	III, 406-408
" —at Stations Without Agents.....	VI, 135
" —Regulations of English Roads....	VI, 97, 98
" Locomotive, Brooks' Consolidation— <i>Illustration</i>	I, 138
" Consolidation—New South Wales— <i>Il-</i> <i>lustration</i>	I, 128
" Italian—Inside Connected— <i>Il-</i> <i>lustration</i>	I, 120
" Russian— <i>Illustration</i>	I, 124
" Lost.....	IX, 102, 103, 131
" Manipulation of—in Transit.....	VI, 268-270
" Marking.....	VI, 94, 111
" Mineral—Waybilling.....	VI, 136
" Missent.....	IX, 104
" Notice to Consignee of Arrival of....	VI, 196; IX, 80, 81
" "Over".....	V, 344

	PAGE
Freight, Over—Reports of.....	IX, 104, 105
“ Overcharges.....	IX, 124-126
“ Packing.....	VI, 94
“ Perishable.....	VI, 106, 129; IX, 106
“ “ —Waybilling.....	VI, 136, 138
“ Persons Accompanying.....	V, 150-156
“ Precautions Against Damaging.....	VI, 98
“ Protection of—from Loss.....	IX, 104
“ Rates, Errors in.....	X, 110
“ “ —in England.....	III, 407
“ “ —How Formulated.....	VI, 26, 27
“ “ of Different Countries.....	VI, 37-41
“ Rebilling—at Junction Stations.....	VI, 317
“ Receipt.....	VI, 94, 114, 115
“ “ Purpose of.....	VI, 117, 118
“ Receipts for.....	VI, 97, 126
“ “ “ —Delivery of.....	IX, 317, 318
“ “ “ —Rules Governing.....	VI, 122-126
“ “ “ —Signatures to.....	VII, 446
“ Receipting for.....	VI, 96, 97
“ Received from Connecting Lines.....	VI, 114
“ “ “ Other Transportation Companies.....	VI, 128
“ “ Record of.....	VI, 197-211
“ “ Subject to Terminal Charge—Record of.....	VI, 211
“ Receiving.....	II, 242; VI, 93, 110, 121, 168
“ “ —At Prepaid Stations.....	VI, 157
“ “ —For Shipment to Prepaid Stations.....	VI, 153
“ Reconsigning.....	VI, 173
“ Refused.....	IX, 131, 132
“ Refusing.....	VI, 94
“ Releases for.....	VI, 96
“ Reloading en route.....	VI, 101
“ Removal of.....	IX, 80, 81, 99
“ Repacking.....	VI, 112
“ Returns, Auditing.....	X, 109-120
“ Revenues, Protection of.....	VI, 25
“ Re-waybilling.....	VI, 144
“ Routing.....	II, 242
“ Service, Difference of—from Passenger Service.....	IV, 17
“ “ Organization of.....	VI, 11, 12, 22
“ “ Use of Electricity for.....	I, 513
“ Shipping Directions for.....	VI, 94
“ “Short”.....	V, 344
“ Short—Reports of.....	IX, 104, 105
“ Station Records of.....	IX, 94-96
“ Stolen.....	IX, 102, 103
“ Storage of.....	IX, 81
“ Traffic.....	V, 354
“ “ Interline.....	VI, 7

	PAGE
Freight Traffic, Kinds of.....	VI, 7
“ “ Local	VI, 7
“ “ —Meaning of the Term	VI, 7
“ “ Necessities of—in 1831.....	I, 31
“ “ —of Different Countries	VI, 8-11
“ “ Principles and Methods Governing ...	VI, 93-108
“ “ Returns of.....	X, 67
“ Trains, Baggage Carried on—Charges for	V, 511
“ “ Charging	I, 371
“ “ Collection of Fares on.....	V, 151-156
“ “ Forwarding Excess Baggage by—Rules Gov- erning.....	V, 501, 502
“ “ in Great Britain.....	I, 63
“ “ Operation of	IX, 100
“ “ Passengers on	V, 150-156
“ “ Releasing Brakes on.....	I, 367
“ “ Speed of	I, 31; VI, 10, 11
“ “ Testing Brakes on.....	I, 363
“ Transferring	VI, 168
“ Transportation of—at Night.....	I, 58
“ “ —Rules Governing.....	II, 241
“ Unclaimed.....	V, 344, 346; IX, 131, 132
“ “ —Collections for.....	VII, 422; IX, 427
“ “ —Reports of.....	IX, 106
“ Unloading.....	II, 242; IX, 101
“ “ —at Stations Without Agents... ..	VI, 105, 125
“ “ En Route	VI, 101
“ Way.....	IV, 413
“ “ —Loading.....	VI, 98, 99
“ Weighing.....	II, 242; VI, 111, 146
“ “ En Route—Rules Governing.....	VI, 148
“ Worthless—Charges on.....	VI, 95
Freights, Cheap—Rates on.....	VIII, 110
French Dumping Car— <i>Illustration</i>	I, 150
“ Locomotive and Tender for Switching Purposes— <i>Illustration</i>	I, 123
“ “ Tender— <i>Illustrations</i>	I, 127, 131
“ Reservoir Car for Liquids— <i>Illustration</i>	I, 164
Freshet Repairs.....	III, 285
Freshets, Damage Caused by.....	III, 294
Friction.....	I, 293, 301, 302, 308
“ Brake Shoe.....	I, 379
“ Coefficient of	I, 311, 429
“ Effect of—on Rails	III, 274
“ Energy of Steam Lost in	I, 403
“ Production of Electricity by.....	I, 397
“ “ Heat by.....	I, 397
Friend, Railways Acting as a	V, 139-144
Frieze, or Letter Board— <i>Illustration, Plate II</i>	I, 116-117
Fringe, Shade— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Frog—An Early Pattern— <i>Illustration</i>	III, 192
“ Guard Rails.....	III, 232, 233
“ Movable—Slip Switch— <i>Illustration</i>	III, 367
“ Old Portage Railroad, A. D. 1835— <i>Illustration</i>	III, 210
“ Staple Iron Used as a Makeshift for a—Camden & Am- boy Railroad, A. D. 1831— <i>Illustration</i>	III, 201
“ Turn-Out— <i>Illustration</i>	III, 366
“ Wood’s—New Jersey, A. D. 1859— <i>Illustration</i>	III, 276
Frogs.....	III, 228, 229
“Frogs and Switches”.....	VII, 462
Frogs Colliery Railroads of England, A. D. 1825— <i>Illustra- tions</i>	III, 193
“ Crossing.....	III, 236, 237
Front Berth—Lower Part— <i>Illustration, Plate II</i>	I, 116-117
“ “—Upper Part— <i>Illustration, Plate II</i>	I, 116-117
“ Cylinder Head— <i>Illustration, Plate I</i>	I, 58-59
“ Extension— <i>Illustration, Plate I</i>	I, 58-59
“ Face Plate Gravity Bar— <i>Illustration, Plate II</i>	I, 116-117
“ Frame— <i>Illustration, Plate I</i>	I, 58-59
“ Panel Berth— <i>Illustration, Plate II</i>	I, 116-117
“ Smoke Arch— <i>Illustration, Plate I</i>	I, 58-59
“ Strap, Main Rod— <i>Illustration, Plate I</i>	I, 58-59
Frost, Action of—on Track.....	VII, 220
Frozen Couplings—Instructions to Trainmen.....	I, 323, 324
Fruits, Delicate—Carriage of.....	V, 519
Fuel.....	I, 63
“ Accounting for.....	VII, 327, 328, 330-336; X, 88
“ “—Practices of English Railways.....	VII, 528-530
“ Acquisition of.....	VII, 162-176
“ Bills for.....	VII, 85
“ Care of.....	VII, 162-176, 326, 327
“ Charging.....	VII, 275, 326-336
“ Comparisons of Consumption of.....	VII, 175
“ Consumption of—Effect of the Fireman on.....	VII, 171
“ “—How Heightened.....	I, 70
“ Cost of.....	III, 396, 424; IV, 44; VII, 175
“ Custodianship of.....	VII, 176
“ Deterioration of.....	VII, 327
“ Enforced Consumption of.....	I, 68
“ Expenditures for.....	III, 399
“ for Early Locomotives.....	III, 120
“Fuel for Locomotives”.....	VII, 486, 519
Fuel, Handling.....	I, 259; VII, 176
“ How Supplied to Locomotives.....	I, 108
“ Influence of—On Cost of Operation.....	III, 394
“ Inspectors of.....	VII, 94
“ “—Returns of.....	VII, 330
“ Inventories.....	VII, 347, 348
“ Kinds of.....	VII, 162-176

	PAGE
Fuel, Liabilities for.....	X, 61
“ Liquid—Its Advantages Over Other Forms.....	I, 102, 103
“ Loading Locomotives With	IV, 428
“ Locomotive—Use of Oil as.....	I, 104, 105
“ Loss of.....	VII, 174
“ Oil Burner— <i>Illustration</i>	I, 102
“ Purchase of.....	VII, 84, 176
“ Quantity Carried in Tender.....	I, 106
“ Records of.....	VII, 330, 331
“ Report, General.....	VII, 333, 334
“ Requisitions for.....	VII, 85, 176
“ Returns for.....	VII, 332-336
“ —of Receipts and Disbursements of.....	VII, 84
“ Sale of.....	VII, 418
“Fuel Stations”.....	VII, 459
Fuel, Stock of.....	VII, 85, 176
“ Supplies	I, 273
“ Tickets	VII, 334, 335
“ Train—Meaning of Term.....	IV, 324
“ Trains.....	IV, 374
“ Use of.....	VII, 162-176
“ “ —In Compound Engines.....	I, 46, 47
“ “ Wood for.....	VII, 163
“ Utility of Different Kinds of.....	VII, 162-176
“ Vouchers for.....	X, 84, 92
“ Waste of....	VII, 172, 173
“ Waybillng.....	VII, 329
Fulcrum	I, 110
“ Bolt, Gravity Bar— <i>Illustration, Plate II</i>	I, 116-117
“ Brake Lever— <i>Illustration, Plate III</i>	I, 170-171
“ Center Brake Beam— <i>Illustration, Plate II</i>	I, 116-117
“ Floating Lever— <i>Illustration, Plate III</i>	I, 170-171
“ Inside Brake Beam— <i>Illustration, Plate II</i>	I, 116-117
“ Outside Brake Beam— <i>Illustration, Plate II</i>	I, 116-117
“ to Equalizer— <i>Illustration</i>	I, 60
“ Truck Lever— <i>Illustration, Plate II</i>	I, 116-117
Fulton, Robert.....	XI, 511
Function of Electricity.....	I, 396
Fund, Reserve	III, 461, 462
“ Working	II, 189
Funds, Accident Insurance—In Germany	X, 345-347
“ Assistance—Italian.....	X, 349, 350
“ “Conscience”.....	IX, 286, 287
“ Custodian of.....	X, 258
“ Custody of.....	II, 186
“ Distress.....	II, 60
“ Employes’ Guaranty.....	IX, 170, 353-355
“ Hospital	X, 312, 313
“ Pension.....	X, 321-323
“ “ —French.....	X, 329-345

	PAGE
Funds, Pension—In Great Britain	X, 326-328
“ “ “ India	X, 350-352
“ “ —Italian	X, 347-349
“ Relief—Sickness, Accident and Death	X, 298-309
“ Safeguarding	IX, 298
“ Savings	X, 313-320
“ Sinking	II, 137, 191
“ “ —Accounting for	VII, 434, 449-452
“ “ —Particulars of	III, 101-105
“ Superannuation	II, 60; X, 326
“ Working—Agents'	IX, 180, 265, 329, 332-334
“ “ —Conductors'	IX, 182
Funded Debt	III, 92
Funnel, Filling— <i>Illustration, Plate II</i>	I 116-117
“ Sand	I, 103
Funnels	I, 243
Furnace	I, 255
“ Oil—for Annealing	I, 256
Furnaces, Brass Melting	I, 257
“ Heating	I, 258, 263
“ Scrap	I, 255
Furniture, Wear and Tear of	III, 299
Furring, Sheathing— <i>Illustration, Plate II</i>	I, 116-117
“ Side Door— <i>Illustration, Plate III</i>	I, 170-171
Furs, Carriage of	V, 519
Fuses, Use of	IV, 342, 352, 360, 403
Gadsden, J. S.	IV, 28
Galloway & Company	I, 33
Galvanic Battery, Production of Light from	IV, 175
Game, Carriage of	V, 519
Gang, Boiler Trimming	I, 286
“ Driving Box	I, 286
“ for Changing Rails on Sunday	III, 343
“ Foremen	I, 265, 276; III, 259
“ Guide	I, 286
“ Steam Pipe	I, 286
“ Valve—Work in Charge of	I, 285, 286
“ Wheel	I, 286
Gangs, Section	III, 238
“ Track Laying	III, 209
Ganger—Meaning of Term	IV, 315
Ganges	XI, 54
Garden Truck, Cars for Handling	I, 224
Garnishments	VII, 385, 387, 388, 403, 409; IX, 401-403
Gas Bills	X, 285
“ “ Payment of	VII, 441; IX, 403
“ “ Remitting	IX, 425
“ Cock, Main— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Gas Holder— <i>Illustration, Plate II</i>	I, 116-117
“ “ Supports— <i>Illustration, Plate II</i>	I, 116-117
“ “ Lamp, Bracket— <i>Illustration, Plate II</i>	I, 116-117
“ Gas Making Plants”	VII, 462
Gas Pipe Hangers— <i>Illustration, Plate II</i>	I, 116-117
“ “ Plant, Reservoir in a	I, 438
“ “ “ for Heating Cars in Europe	V, 235
“ “ “ Lighting Cars	IV, 173, 174, 181
“ “ “ Way— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Wells	I, 104
Gases, Consumption of—In Fire Box	I, 99
Gaskets	I, 324
“ “ Metallic	I, 381
“ “ Paper	I, 371
“ “ Work	I, 371, 375
Gasoline Carbureters, Use of—for Lighting Cars	IV, 183
“ “ Use of—for Lighting Cars	IV, 181
Gate Platform— <i>Illustration, Plate II</i>	I, 116-117
“ “ Signals	IV, 254
Gates, Cost of Keeping in Order	III, 422, 423
“ “ on Car Platforms	IV, 121
Gate-men, English—Wages of	IV, 453
Gauge, Adopted in India	III, 193
“ “ Air	I, 315, 336
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ —Duplex	I, 349
“ “ “ — <i>Illustration</i>	I, 316
“ “ Pressure— <i>Illustration</i>	I, 539
“ “ American Standard	I, 402
“ “ Brown & Sharpe	I, 402
“ “ Car— <i>Illustration, Plate II</i>	I, 116-117
“ “ Cocks	I, 80
“ “ — <i>Illustrations, Plate I</i>	I, 58-59 64
“ “ Device for Changing Trucks from Narrow to Wide, and vice versa— <i>Illustration</i>	I, 203
“ “ Lamp— <i>Illustration, Plate I</i>	I, 58-59
“ “ Measurement of	III, 194
“ “ of Primitive Vehicles	III, 190
“ “ “ the Line	III, 190
“ “ Railroad—Controversy over	I, 35, 36, 37
“ “ Steam	I, 82
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ —Exterior of— <i>Illustration</i>	I, 83
“ “ —Interior of— <i>Illustration</i>	I, 82
“ “ the Narrowest	III, 191, 192
“ “ Standard	I, 36, 38; III, 190, 193, 194
“ “ Widest Ever Used	III, 191
“ “ Track	IV, 211
“ “ — <i>Illustration</i>	III, 331
“ “ Water	I, 80

	PAGE
Gauge, Water— <i>Illustration</i>	I, 64
" Wheel	IV, 211
Gauges, Battle of.....	I, 36, 37; III, 192
" of Different Countries	III, 194
" Railway—That Have Been Used in Different Countries	III, 494
" Uniformity in.....	III, 193
Gauging.....	III, 211
Gear, Reversing.....	I, 49
" " —End View of— <i>Illustration</i>	I, 90
" " —Engineer's Lever in Connection with— <i>Illustration</i>	I, 91
" " —Side View of— <i>Illustration</i>	I, 90
Geared Motors.....	I, 470, 471
Gearing of Brake Operated by Steam, France, 1840— <i>Illustration</i>	I, 300
" " Motors.....	I, 474
Gearless Motors.....	I, 470, 471
Gears, Efficiency of.....	I, 480
General Baggage Agent.....	II, 139
" " Agents, Association of.....	V, 488, 491
" " Balance Sheet, the.....	X, 28, 29, 182-184
" " Bookkeeper.....	X, 80
" " Books, Spreading Accounts on.....	X, 63-69
" " Cash Book.....	X, 139-141
" " Cashier, the.....	X, 260, 261
" " Characteristics of the Alternating Current System.....	I, 441-443
" " —Transmission.....	I, 412, 413, 414
" " Claim Agents, Relief Vouchers Made by.....	IX, 372
" " Counsel.....	II, 138
" " Distribution of Labor Book.....	VII, 382-385, 537
" " " Material Book.....	VII, 315-320
" " Expenses.....	VII, 495-497, 523, 524
" " Fiscal Affairs.....	X, 9-184
" " " and Other Affairs.....	X
" " Fuel Report.....	VII, 333, 334
" " Foreman.....	I, 264, 271, 277
" " Freight Agent.....	II, 138
" " " Correspondence of.....	II, 244
" " " Duties of.....	II, 241-249
" " " Knowledge of.....	II, 246, 247
" " Instructions to Car Inspectors.....	I, 330-333
" " " Engine House Foremen and Inspectors.....	I, 328, 329
" " " Trainmen.....	I, 321-323
" " Journals.....	X, 77-79, 81
" " Laborers.....	I, 286
" " Land Office, Transportation for.....	V, 144
" " Ledger.....	X, 70-76

	PAGE
General Manager. (See also "Chief Manager")	II, 58, 153-176
" " Advisers of	II, 155
" " Characteristics of	II, 153, 154
" " Coadjutors of	II, 155
" " Correspondence of	II, 158-161
" " Duties of	II, 157, 158, 161, 164
" " Forbearance of	II, 202
" " Meaning of Title	II, 142
" " Motives of	II, 154
" " Relation "—to Construction Work	II, 166-172
" " " " " Directors and Owners	II, 155
" " " " " Division Superintendent	II, 199
" " " " " Subordinates	II, 155, 156, 162
" " Scope of	II, 173, 174
" " Titles of	II, 153; VII, 250
" Master Mechanic	I, 277
" Meetings	I, 228
"General Office Expenses and Supplies"	VII, 496, 524
General Officers	II, 65, 117
" Orders, Issuing	IX, 41
" Passenger Agent	II, 139; V, 80, 81
" " Characteristics of	II, 256, 257
" Repair Shops	I, 248, 270
" Storehouse	I, 252
" Storekeeper	VII, 76
" " Duties of	VII, 88
" " Inspections by	VII, 82
" " Requisitions on	VII, 79
" Superintendent	II, 138
" " Scope of	II, 174, 175
" Ticket Agent	II, 139; V, 79, 80
" " and Passenger Agents	II, 249-259
" " Agent, Characteristics of	II, 254
" " Agents' Association	V, 79
" Time Book	VII, 372, 373
" Traffic Manager	II, 138
" Traveling Auditors, Duties of	IX, 276, 277
Generation of Power, in Booster System	I, 435
Generator, The	I, 424, 456-462
" Alternating Current	I, 440, 452
" Baltimore & Ohio Railroad, (500 Kilowatt)— <i>Illustration</i>	I, 497
" Coll, Expanding— <i>Illustrations, Plate II</i>	I, 116-117
" Direct Connected to Vertical Engine. Brooklyn Bridge Power Plant, (400 Kilowatt)— <i>Illustration</i>	I, 456

	PAGE
Generator, Direct Current	I, 426, 440, 452
“ Driven by a Vertical Engine—Metropolitan West Side Railway, Chicago, (1500 Kilowatt)— <i>Illustration</i>	I, 394
“ Electric	I, 396
“ Engine Type Railway—Armature of, Showing Winding Connected to Commutator— <i>Illustration</i>	I, 458
“ Hestonville, Mantau & Fairmount Passenger Railroad, (400 Kilowatt)— <i>Illustration</i>	I, 506
“ in Motion, (800 Kilowatt)— <i>Illustration</i>	I, 459
“ Panel	I, 460
“ Railway, (800 Kilowatt)— <i>Illustration</i>	I, 508
“ Railway—Engine Type	I, 456-458
“ Two-Phase Alternating Current, (650 Kilowatt)— <i>Illustration</i>	I, 500
Generators Alternating Current	I, 449
“ Connected to Horizontal Engines North and West Chicago Railway, (800 Kilowatt)— <i>Illustration</i>	I, 428
“ Current Supplied by	I, 431
“ Railway— <i>Illustration</i>	I, 522
“ Station	I, 431
“George W. Johnson” Locomotive 1830—The First with a Double Fire Box	I, 49
“George W. Johnson” Locomotive, 1830—The First with a Double Fire Box— <i>Illustration</i>	I, 49
Georgia, Central Railroad of	VI, 20
“ Railway Taxation in	III, 450, 451
German Beer Car— <i>Illustration</i>	I, 186
“ Box Car— <i>Illustration</i>	I, 184
“ First Class Passenger Car— <i>Illustration</i>	I, 214
“ Rapid Transit Passenger Locomotive, with Belpaire Type of Fire Box—Warschau-Wien Railroad— <i>Illustration</i>	I, 131
Germans, Influence of—on Manufactures	I, 128
Germany, Baggage Allowed in	V, 288
“ Bogie Cars in	I, 171
“ Breakage of Wheels in	IV, 221
“ Builders of	I, 153
“ Coaches in	I, 203
“ Fourth Class Passengers in	V, 25
“ Gauge Used in	III, 194
“ Government Management in	VIII, 247, 261
“ “ Supervision in	III, 48, 49
“ Grade Crossings in	IV, 132, 133
“ Heating Cars in	V, 233-235
“ —Its Primitive Associations and Means of Carriage	XI, 459-462
“ Manufacturers of	I, 128, 129

	PAGE
Germany, Passenger Service in.....	V, 229-232
“ Practices in.....	VIII, 83, 85
“ —Primitive Carriage in— <i>Illustrations</i>	XI, 459-462
“ Primitive Wheel from— <i>Illustration</i>	IV, 192
“ Railway Accidents in.....	IV, 129
“ Relief Departments in.....	X, 345-347
“ Saxon State Railways of—Freight Cars of.....	I, 121
“ Status of Railways in.....	III, 48, 49; VII, 332
“ Use of Metal Ties in.....	III, 377, 378
“ Vestibule Car in.....	I, 204
Gibbs, George.....	IV, 178
Giffard, H. J.....	I, 54
Girder Rail.....	I, 462
Girls, Destruction of.....	XI, 69
Girt Corner Iron— <i>Illustration, Plate III</i>	I, 170-171
Girts, End— <i>Illustration, Plate III</i>	I, 170-171
“ Side— <i>Illustration, Plate III</i>	I, 170 171
Glacial Epoch, the.....	XI, 58
Gladstone.....	IX, 17
Glasgow.....	I, 44
“ & Garnkirk Railway—Opening of.....	I, 31
Glass, Austrian Box Car for Transportation of— <i>Illustration</i> ,	I, 185
“ Bowl— <i>Illustration, Plate II</i>	I, 116-117
“ Dome— <i>Illustration, Plate II</i>	I, 116-117
“ in Door, Vestibule— <i>Illustration, Plate II</i>	I, 116-117
“ or Tumbler, Water— <i>Illustration, Plate II</i>	I, 116-117
“ Stained—Carriage of.....	X, 519
“ Window— <i>Illustration, Plate II</i>	I, 116-117
Globe— <i>Illustration, Plate II</i>	I, 116-117
“ Holder— <i>Illustration, Plate II</i>	I, 116-117
Glue, Use of—by Railways.....	VII, 212
Go Ahead Eccentric— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Connection— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Rod— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Strap— <i>Illustration, Plate I</i>	I, 58-59
Gold.....	III, 7, 8
“ Early Use of—for Money.....	XI, 128
“ Existence of.....	XI, 73
“ Leaf, Use of—by Railways.....	VII, 209
“ Ratio of—to Silver.....	III, 12, 13
“ —the Standard of Money.....	XI, 13
“ Transportation of.....	V, 519
“Goliath” Locomotive.....	I, 31
Gondola Car.....	I, 207
“ Standard American— <i>Illustration</i>	I, 160
“ “ Victorian Railway— <i>Illustration</i>	I, 156
“ Opening— <i>Illustration</i>	I, 98
Gong.....	I, 111, 112
Gooch, Sir Daniel M.....	X, 164

	PAGE
Goods (See also "Freight.")	
" Agent, English.....	II, 208
" and Mineral Audit Office—English.....	VI, 329-331
" Associations for Inspecting and Weighing.....	VI, 24
" Car. (See also "Freight Car.")	
" Austrian— <i>Illustration</i>	I, 184
" in Great Britain.....	I, 31
" Perishable—New South Wales— <i>Illustration</i>	I, 188
" Classification of.....	II, 241
" Department—English Railways.....	VI, 318-323
" Engine, Twin—Neilson's—Scotland— <i>Illustration</i>	I, 125
" Locomotive, Consolidation—New South Wales— <i>Illustration</i>	I, 128
" Manager, English.....	II, 246
" Managers, District—English.....	II, 208
" Miscellaneous—Manufacture of.....	I, 138
" Protection of—On Freight Cars.....	I, 204
" Sale of.....	I, 125
" Train—Meaning of Term.....	IV, 447
" Trains in Great Britain.....	I, 63
Government, Absence of.....	XI, 130
" Autocratic.....	II, 38, 124, 134; XI, 43
" Carthaginian—Basis of.....	XI, 145
" Civilized.....	XI, 130
" Claims Against the.....	VI, 276-279
" Commissioners.....	III, 46
" Control.....	VIII, 12, 161, 217, 227
" Cost of.....	III, 57, 58
" Effect of.....	VIII, 12, 13, 217, 256
" Objections to.....	VII, 11, 12
" Practices of—in England.....	VIII, 227
" Reasons for.....	VIII, 249
" Scope of.....	VIII, 70
" —When Necessary.....	VIII, 255
" Corporate—Autocracy in.....	II, 132, 148
" Duty of—Toward Railways.....	VIII, 195
" Effect of Interference of.....	VIII, 12, 210
" Employes.....	V, 320
" Characteristics of.....	VIII, 218
" Forms of.....	II, 44
" Freight.....	VI, 279-283
" French—Its Attitude Toward Railways.....	III, 46, 47
" Good—Upon What Dependent.....	II, 122-127
" Interest of—in Transportation Matters.....	II, 238
" Interference.....	VIII, 56, 57, 65, 101, 133, 218, 229, 239
" Advocates of.....	VIII, 222
" Grounds for.....	VIII, 67
" in the United States.....	III, 45
" Result of.....	VIII, 72
" With Rates.....	VIII, 193

	PAGE
Government, Local.....	XI, 29
" Management, Advocates of.....	VIII, 222
" " Basis of.....	VIII, 235
" " Characteristics of.....	VIII, 12, 219, 241, 242, 244
" " Effect on Rates.....	VIII, 242
" " Experiences of.....	VIII, 235
" " Objections to.....	VIII, 221
" " Reasons for.....	VIII, 236
" New Forms of.....	XI, 34
" of Corporate Property.....	II, v
" " Corporations.....	II, 281
" " Labor Unions.....	II, 88
" " Railways.....	II, 136; IV, 8
" " Shops.....	I, 283
" " the United States—on What Based.....	II, 44
" Officials.....	V, 361, 362
" Operation of Railways by the.....	II, 49
" Ownership.....	III, 45
" " Characteristics of.....	VIII, 12, 223
" " Disadvantages of.....	VIII, 253
" " Effect of.....	V, 355
" " Experiences of.....	VIII, 246
" " in United States.....	VIII, 248
" " Reasons for.....	VIII, 230, 253, 259
" " —When Advisable.....	VIII, 249, 250
" Paternal Form of.....	II, 60
" Prescribing Accounts by the.....	X, 38
" Prevention of Unnecessary Roads by....	VIII, 200
" Principles of.....	II, 128-140
" Proper—How Secured.....	II, iv
" Relation of—to Railway Mail Service....	V, 552-563
" Requests for Transportation.....	V, 144-146
" Servants, Peculiarities of.....	VI, 276-279
" Service, Characteristics of.....	VIII, 238
" " Organization of—Compared with Rail- way Service.....	II, 122
" Stamp.....	III, 10
" Supervision.....	VIII, 65, 227, 253
" " Advisability of.....	VIII, 194
" " Best Form of.....	VIII, 228
" " Effect of.....	V, 363-365
" " Scope of.....	VIII, 161, 183, 185, 193
" " Value of.....	VIII, 194, 225
" The Basis of.....	XI, 137
" Transportation by.....	VIII, 60
" Weak—Its Effect.....	VIII, 7
Governmental Interference.....	X, 39, 41
" " —Its Effect, on Railways....	VI, 39-41
" " Regulations, Scope of Beneficial....	VIII, 17, 22

	PAGE
Governments, Arbitrary Interference of—Its Effect..	IV, 138-140
“ Intervention of—in the Affairs of Railways,	V, 18
“ Obligations of.....	III, 86
“ Policy of.....	III, 45
“ Rules Prescribed by—for Heating Cars....	IV, 163
“ Status of—Toward Railways.....	VI, 39
“ Vouchers in Favor of.....	VII, 435
Governor— <i>Illustration, Plate I</i>	I, 58-59
“ Air Pressure— <i>Illustration, Plate II</i>	I, 116-117
“ Automatic.....	I, 485
“ Double.....	I, 356
“ Pin Valve.....	I, 365
“ Pump.....	I, 309, 315, 336, 538
“ “ — <i>Illustration</i>	I, 539
“ “ —Duplex— <i>Illustration</i>	I, 355
“ “ —Improved— <i>Illustration</i>	I, 354
“ “ —Instructions to Engine House Foremen and Inspectors.....	I, 328
“ “ —Operations of.....	I, 352-356
“ Speed.....	I, 455
“ The Best.....	II, 203
Governors, Double.....	I, 313
Grab Iron End— <i>Illustration, Plate III</i>	I, 170-171
“ “ Roof— <i>Illustration, Plate III</i>	I, 170-171
“ “ Side— <i>Illustration, Plate III</i>	I, 170-171
Grade Crossings, Accidents at.....	IV, 130, 131
“ “ Trains Approaching.....	IV, 355
“ of Trains—Meaning of Term.....	IV, 318
Grades, Bettering.....	II, 231
“ Descending.....	I, 327
“ Effect of—on Chilled Wheels.....	IV, 206
“ “ “ Cost of Operation.....	III, 392
“ Grading”.....	VII, 462, 463
Graduating Pin— <i>Illustration</i>	I, 344
“ Spring— <i>Illustrations</i>	I, 341, 344
“ Stem— <i>Illustrations</i>	I, 341, 344
“ Valve.....	I, 340-342
“ “ — <i>Illustrations</i>	I, 341, 344
“ “ Pin— <i>Illustration</i>	I, 341
Graham, J. M.....	VI, 20
Grain. Cars for Handling.....	I, 224
“ Door— <i>Illustration, Plate III</i>	I, 170-171
“ “ Battens— <i>Illustration, Plate III</i>	I, 170-171
“ “ Floor Block— <i>Illustration, Plate III</i>	I, 170-171
“ “ Guide Arm— <i>Illustration, Plate III</i>	I, 170-171
“ “ Guides— <i>Illustration, Plate III</i>	I, 170-171
“ “ Hold-up Hooks— <i>Illustration, Plate III</i>	I, 170-171
“ “ Leaf— <i>Illustration, Plate III</i>	I, 170-171
“ “ “ Battens— <i>Illustration, Plate III</i>	I, 170-171
“ “ “ Hinges— <i>Illustration, Plate III</i>	I, 170-171

	PAGE
"Grain Elevators".....	VII, 459, 460
Grain, Loading.....	VI, 99
" Strips, Beveled— <i>Illustration, Plate III</i>	I, 170-171
Grand Trunk Railway of Canada.....	III, 88
Granger Agitation.....	VIII, 198
Grant, General—Baggage of.....	V, 278
Grass, Cutting.....	III, 240
" Removing.....	III, 285
"Grasshopper" Locomotives, First Construction of.....	I, 32
Grate— <i>Illustration</i>	I, 67
" <i>Plate II</i>	I, 116-117
" and Damper, Section Showing— <i>Illustration</i>	I, 96
" Circulation of Water in.....	I, 96
" Inner Shell of.....	I, 96
" Locomotive.....	I, 95
" Outer Shell of.....	I, 96
" Rigging.....	I, 286
" Rocking—The First Engine with— <i>Illustration</i>	I, 43
" Shaker— <i>Illustration, Plate II</i>	I, 116-117
" Shaking Rig— <i>Illustration, Plate I</i>	I, 58-59
" Size of.....	I, 72
" Surface, Locomotive.....	I, 72, 73
Grates.....	I, 286
" for Anthracite Coal.....	I, 96
" Rocking— <i>Illustration, Plate I</i>	I, 58-59
Gratuities, Acceptance of.....	IV, 331
" —in Great Britain.....	IV, 445
" Entering—on Pay Rolls.....	VII, 392
Gravel Ballast.....	III, 221, 222
Gravity Bar, Back— <i>Illustration, Plate II</i>	I, 116-117
" " Front Face Plate— <i>Illustration, Plate II</i>	I, 116-117
" " Fulcrum Bolt— <i>Illustration, Plate II</i>	I, 116-117
" Battery, Cell of—Electro-Motive Force of.....	I, 401
" Effect of—on Brakes.....	I, 334
" Loading Cars by.....	I, 246
" Marshalling Trains by.....	IV, 94-96
Great Britain, Baggage in.....	V, 284
" " Builders of.....	I, 152
" " Delivery of Freight in.....	I, 173
" " Early History of Railways in.....	I, 168, 169
" " Flat Car in.....	I, 207
" " Freight Car Load in.....	I, 206
" " " or Goods Car of.....	I, 31
" " " " Trains in.....	I, 63
" " " Traffic of.....	VI, 8-11
" " Government Supervision in.....	III, 51
" " Heating Cars in.....	IV, 152; V, 236
" " Labor Unions in.....	II, 37
" " Laws of.....	II, 45
" " Manufactories in.....	I, 32

	PAGE
Great Britain, Manufacturers of Locomotives and Cars in.....	J, 138
“ “ Methods of Capitalization in.....	III, 487-490
“ “ Particulars of Train Service in.....	IV, 440-464
“ “ Proprietors of Collieries in.....	II, 45
“ “ Protection of Trains in.....	IV, 92-94
“ “ Railway Equipment of.....	III, 129
“ “ “ Managers in.....	III, 148
“ “ “ Taxation in.....	III, 434, 435
“ “ Railways of.....	IV, 440
“ “ Relief Departments in.....	X, 325-329
“ “ Speed of Freight Trains in.....	I, 31
“ “ Train Signals in.....	I, 171
“ “ Use of Tarpaulins in.....	I, 204
“ “ “ “ the Cowcatcher or Pilot in.....	I, 56
“ “ “ “ “ Telegraph in Moving Trains in.....	IV, 87, 88
“ Indian Peninsular Railway.....	III, 178
“ Northern Railway of England.....	III, 267; IV, 331-334, 343, 344, 349, 360, 363, 378, 402, 405, 407, 409, 411, 414, 418, 419, 432; V, 225, 445, 447, 448, 540
“ “ Railway of England—Practices of.....	IV, 447-456
“ “ “ Ireland.....	III, 178, 183
“ Western Railway.....	I, 35-37
“ “ “ of England.....	III, 179, 191, 192; IV, 841, 349, 350, 382, 407, 410, 425, 433; V, 227, 229
Grecians, The.....	XI, 25, 85-88, 90-92
Greece.....	XI, 44, 104
“ Heroic Period of.....	XI, 40
“ Semi-Barbarous—Primitive Carriage in.....	XI, 83
“ Xerxes' Invasion of.....	XI, 133
Greeks.....	XI, 75, 89, 91, 92, 94
“ Ancient Ships of.....	XI, 93
“ Vehicles of Gods of.....	XI, 154, 155
Green, Signification of.....	IV, 340
Gresham, Sir Thomas.....	III, 11
Griffin, T. A.....	IV, 206
Grinder.....	I, 258
Grinders.....	I, 265
Groove in Air Cock Plugs.....	I, 372
Grooves, Flange.....	I, 304
“ Leakage.....	I, 377
Gross Earnings—a Basis for Taxation.....	III, 441-446
“ Unit of.....	II, 27
Ground, Selection of—for Roundhouse.....	I, 240
Grounds.....	I, 250
“ for Care and Maintenance of Rolling Stock.....	I, 238
Growth, Evolutionary Period of.....	I, 119
“ of the Locomotive.....	I, 38, 39
“ Man's—How Shown.....	I, 296

	PAGE
Grundmann, Professor	VII, 168
Guaranties	III, 422
" Execution of	VI, 141
" for Freight Charges	VI, 95, 96
" Moneys Deposited as	IX, 323, 324
" of Railway Debts	III, 39
Guaranty Bonds	IX, 158-177
" Companies	IX, 32, 353, 355
" Funds, Employes'	IX, 170, 353-355
" Premiums	IX, 169-172, 353, 354, 356
Guard Bridge— <i>Illustration</i>	III, 343
" Cattle— <i>American—Illustration</i>	III, 342
" Rails, for Bridges	III, 223, 224
" Frog	III, 232, 233
" Rod, Vestibule Door— <i>Illustration, Plate II</i>	I, 116-117
" Wheel— <i>Illustration, Plate I</i>	I, 58-59
Guards. (See also "Conductor.")	
" Cattle	III, 225, 256
" —Cost of Maintenance of	III, 292
" English—Wages of	IV, 452
Guards' Way Bills, English	V, 248
Guiana, British	III, 15
Guide Arm, Grain Door— <i>Illustration, Plate III</i>	I, 170-171
" Bar	I, 87
" Block— <i>Illustration, Plate I</i>	I, 58-59
" Bottom Face Plate— <i>Illustration, Plate II</i>	I, 116-117
" Brake Lever— <i>Illustration, Plate III</i>	I, 170-171
" Cylinder Lever— <i>Illustration, Plate II</i>	I, 116-117
" Dead Brake Lever— <i>Illustration, Plate III</i>	I, 170-171
" Gang	I, 286
" Hook, Dead Brake Lever— <i>Illustration, Plate III</i>	I, 170-171
" Top Face Plate— <i>Illustration, Plate II</i>	I, 116-117
" Work	I, 286
" Yoke— <i>Illustration, Plate I</i>	I, 58-59
Guides	I, 285
" — <i>Illustration, Plate I</i>	I, 58-59
" Grain Door— <i>Illustration, Plate III</i>	I, 170-171
Gunpowder, Transportation of	VI, 105
Gyges	XI, 100
Habit	I, 185, 186
Habits, Mechanical	II, 68
Hackworth, Timothy	I, 27
" —Locomotive Built by, "Sampson," 1838— <i>Illustration</i>	I, 40
Hadley, Arthur T.	III, 135
Half Box Car, Belgian Railroad— <i>Illustration</i>	I, 158
" " Italian— <i>Illustration</i>	I, 160

	PAGE
Half Box Car, with Tubular Frame, Belgium— <i>Illustration</i> , I	156
“ “ Cars.....	I, 207
“ Fare Permits.....	V, 120-123
“ “ “ Rules Governing.....	V, 123
“ “ Tickets.....	V, 133
“ “ Auditing.....	X, 125, 126
Halicarnassus.....	XI, 100
Hammer, Drop.....	I, 263
Hammers, Steam.....	I, 255
Hammersmiths.....	I, 263
Hammock Hooks— <i>Illustration</i> , Plate II.....	I, 116-117
Hammond, C. A.....	IV, 275, 295
Hand and Lamp Signals— <i>Illustrations</i>	IV, 479, 480
“ Brake Chain— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Connecting Rod— <i>Illustration</i> , Plate II.....	I, 116-117
“ “ Holder— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Modern— <i>Illustration</i>	I, 300
“ “ on Freight Cars.....	I, 378
“ “ Pawl— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Platform— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Ratchet— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Rest— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Staff— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Wheel— <i>Illustration</i> , Plate III.....	I, 170-171
“ Brakes.....	I, 332
“ “ on Air-Braked Cars—Instructions to Trainmen.....	I, 374
“ “ Use of—Instructions to Trainmen.....	I, 323
“ Braking by—Instructions to Enginemen.....	I, 319, 320
“ Car— <i>Illustration</i>	I, 148
“ “ Velocipede— <i>Illustration</i>	I, 149
“ “ Wheels.....	IV, 213, 214
“ Chain Brake.....	I, 297
“ Hold— <i>Illustration</i> , Plate I.....	I, 58-59
“ Hole— <i>Illustration</i>	I, 60
“ Lamp Signals, Rules Governing.....	IV, 348, 349
“ or Grab Rail Body— <i>Illustration</i> , Plate II.....	I, 116-117
“ Rail— <i>Illustrations</i> , Plate I.....	I, 58-59, 60
“ “ Arch— <i>Illustration</i> , Plate I.....	I, 58-59
“ “ Brackets— <i>Illustration</i> , Plate I.....	I, 58-59
“ Wheel, Brace— <i>Illustration</i> , Plate II.....	I, 116-117
“ Work, Replacing—by Machinery.....	I, 263
Hands, Use of—for Signals.....	IV, 264
Handbills.....	V, 115, 116
Handle, Ash Pan Damper— <i>Illustration</i> , Plate I.....	I, 58-59
“ Berth Catch— <i>Illustration</i> , Plate II.....	I, 116-117
“ Brake Valve.....	I, 315
“ for Steam Blow-Off— <i>Illustration</i> , Plate II.....	I, 116-117
“ Four-Way Cock— <i>Illustration</i>	I, 341
“ Side Door— <i>Illustration</i> , Plate III.....	I, 170-171

	PAGE
Headlight.....	I, 112
“ — <i>Illustration</i>	I, 60
“ Bracket— <i>Illustration, Plate I</i>	I, 58-59
“ Burner— <i>Illustration, Plate I</i>	I, 58-59
“ Case— <i>Illustration, Plate I</i>	I, 58-59
“ Reflector— <i>Illustration, Plate I</i>	I, 58-59
“ Step— <i>Illustrations, Plate I</i>	I, 58-59, 60
“ —The First in America	I, 57
Headlights	I, 57, 58
“ Covering	IV, 351
“ Double	I, 58
“ Use of	IV, 344, 427, 482
“ “ —in America	I, 57
“ “ “ England	I, 57
Headquarters, Examination of Way Bills at	IX, 57, 58
“ Railway Force at	III, 418, 419
Heafford, George H.	V, 49, 80
Heat, Artificial—Man’s Knowledge of	IV, 146
“ Effect of—on Chilled Wheels	IV, 205
“ Energy, Production of Electricity by	I, 397
“ —Its Effect on Brake Shoes	I, 302
“ Loss of	I, 74, 398
“ Non-Conductor of	I, 74
“ Power Appearing as—in a Wire	I, 405
“ Production of	I, 398
“ Quantity of	I, 398
“ Reduction of—in Smokestack	I, 53
“ Sources of	I, 397
“ Steam	I, 261
Heated Air, Circulation of	I, 261
Heater, Baker— <i>Illustration, Plate II</i>	I, 116-117
“ Hot Water Pipe from— <i>Illustration, Plate II</i>	I, 116-117
“ Top of— <i>Illustration, Plate II</i>	I, 116-117
Heaters, Electric	I, 402
Heating Appliances of Shops	I, 261
“ Cars	IV, 146-165
“ “ by Steam	I, 269
“ “ in England	I, 173
“ “ France	IV, 162
“ Effect of Electric Current	I, 398, 399
“ Furnaces	I, 258, 263
“ Hot Air System	IV, 161
“ “ Water Circulating System	IV, 158
“ “ “ Multiple Circuit System	IV, 160, 161
“ Low Pressure System	IV, 159, 160
“ Method of—for Roundhouses	I, 241
“ Motor Cars	I, 486
“ Pipes, Foot Guard Over— <i>Illustration, Plate II</i>	I, 116-117
“ Steam—Direct System	IV, 157, 158

	PAGE
Heating, Storage System.....	IV, 162, 163
“ Surface, Locomotive.....	I, 44, 72, 73
“ Trains, Methods of—in Europe.....	V, 232-236
“ Vacuum System.....	IV, 159
Hedges.....	III, 352
Hedley & Blackett.....	I, 50
“ William.....	I, 23
Hedley's Locomotive, “Puffing Billy”—Details of.....	I, 42
Hellmann Electric Locomotive.....	I, 516-519
“ Locomotive, The— <i>Illustration</i>	I, 518
Helmholtz, Professor.....	IV, 228
Helpers.....	I, 247
Hemlock Ties.....	III, 350
Hercules.....	XI, 62, 91
“Hercules” Locomotive, 1837—Details of.....	I, 51, 52
“ 1837—The First Engine Having Equalizing Levers— <i>Illustration</i>	I, 51
Hero.....	I, 17, 61
“ Writings of—Concerning Steam.....	XI, 510
Herodotus.....	II, 28, 79, 81, 99, 100, 102, 107, 114
Hetton Rail, 1824— <i>Illustration</i>	III, 191
Hides, Charges Collected for.....	VII, 414, 421, 422; IX, 426
“ —Used as Clothing.....	XI, 64
Hieroglyphic Writing.....	XI, 119
High Pressure Cylinder.....	I, 93
“ Steam.....	I, 21
“High Speed” Brake.....	I, 310-312, 354, 356
High Speed Brake, Safety Valve for— <i>Illustration</i>	I, 362
“ Safety Valve.....	I, 362, 363
“ Tension Alternating Current Transmission.....	I, 451
“ “ Line.....	I, 451
“ “ System with High Tension Trolley Line.....	I, 452, 453
Highways, Commercial.....	I, 163
“ Military.....	I, 163
“ Origin of.....	XI, 49
“ Perfection of—by the Romans.....	I, 163
Hill, Sir Rowland.....	III, 154, 160
Hillis, Dr. N. D.....	I, 136
Hindoos, Vehicles of Gods of.....	XI, 97
Hinge— <i>Illustration, Plate II</i>	I, 116-117
“ Door— <i>Illustration, Plate II</i>	I, 116-117
“ Seat— <i>Illustration, Plate II</i>	I, 116-117
Hinges, Vestibule Door— <i>Illustration, Plate II</i>	I, 116-117
Hiram.....	XI, 184
“Hire of Equipment”.....	VII, 490, 521
History of the Brake.....	I, 291-314
Hittites, Writing of the.....	XI, 120
Hodge Carrier— <i>Illustration, Plate II</i>	I, 116-117
“ Lever Connecting Rod— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Hog Chain or Overhang Truss Rod— <i>Illustration, Plate II</i> ..	I, 116-117
Holst, Pneumatic—for Emptying Clinker or Ash Pits— <i>Illustration</i> ..	I, 278
Holsts, Air ..	I, 246
“ Pneumatic ..	I, 260, 275
Hold, Hand— <i>Illustration, Plate I</i> ..	I, 58-59
Holder, Door— <i>Illustration, Plate II</i> ..	I, 116-117
“ Flag and Lamp— <i>Illustration, Plate II</i> ..	I, 116-117
“ Gas— <i>Illustration, Plate II</i> ..	I, 116-117
“ Globe— <i>Illustration, Plate II</i> ..	I, 116-117
“ Hand Brake— <i>Illustration, Plate III</i> ..	I, 170-171
“ Towel— <i>Illustration, Plate II</i> ..	I, 116-117
“ Valve— <i>Illustration, Plate II</i> ..	I, 116-117
Holding a Train—Meaning of Term ..	IV, 318
“ Power of Brakes ..	I, 364
Hold-Up Hooks, Grain Door— <i>Illustration, Plate III</i> ..	I, 170-171
Holland, Heating Cars in ..	V, 234, 235
“ Status of Railways in ..	III, 50
“ Use of Metal Ties in ..	III, 377
Hollow Brake Beam— <i>Illustration, Plate II</i> ..	I, 116-117
“ Spoke Wheel— <i>Illustration</i> ..	IV, 207
Holmgren, Professor ..	IV, 231, 233
Holt & Gresham ..	I, 53
Home Coupon Tickets ..	V, 88
Homer ..	XI, 28, 88, 103, 122, 123
“ Writings of ..	XI, 100
Honesty ..	XI, 40
“ —a Habit ..	IX, 29
Hood, End Door— <i>Illustration, Plate III</i> ..	I, 170-171
“ Platform— <i>Illustration, Plate II</i> ..	I, 116-117
“ Vestibule— <i>Illustration, Plate II</i> ..	I, 116-117
Hook, Brake Hanger— <i>Illustration, Plate III</i> ..	I, 170-171
“ Check Chain— <i>Illustration, Plate II</i> ..	I, 116-117
“ Coat— <i>Illustration, Plate II</i> ..	I, 116-117
“ “v” ..	I, 49
Hooks, Hammock— <i>Illustration, Plate II</i> ..	I, 116-117
Hopper, Cover for Iron— <i>Illustration, Plate II</i> ..	I, 116-117
“ Iron— <i>Illustration, Plate II</i> ..	I, 116-117
Hordes, Formation of ..	XI, 25
Horizontal Boiler Seam— <i>Illustration, Plate I</i> ..	I, 58-59
“ Cylinders ..	I, 46
“ Rotary Valve ..	I, 308
Horse Car, American— <i>Illustration</i> ..	I, 196
“ “ Belgian State Railroad— <i>Illustration</i> ..	I, 194
“ “ Victorian Railway— <i>Illustration</i> ..	I, 195
“ Development of the ..	XI, 84
“ Relation of—to Carriage ..	XI, 84
“ Street Car ..	I, 394
“ Use of—by the Greeks ..	XI, 84

	PAGE
Horse, Value of.....	XI, 88
Horses, Use of—by Railways.....	III, 126; VII, 211
Horsepower.....	I, 403, 404
" Electric—Delivered by a Dynamo.....	I, 404
" Motor Rated in.....	I, 473
Hose.....	I, 315, 336
" Air Brake.....	I, 321
" " — <i>Illustration, Plate I</i>	I, 58-59
" " — <i>Armored—Illustration, Plate II</i>	I, 116-117
" " Signal—Extra.....	I, 328
" Band— <i>Illustration, Plate II</i>	I, 116-117
" Blow Out—Instructions to Trainmen.....	I, 369
" Burst—Instructions to Trainmen.....	I, 326
" Clamp— <i>Illustration, Plate II</i>	I, 116-117
" Cock.....	I, 363
" Coupling, Air Brake.....	I, 308
" " — <i>Illustrations, Plate II</i>	I, 116-117, 309
" " Keeping Pressure in.....	I, 373
" " Signal— <i>Illustration, Plate II</i>	I, 116-117
" " Standard— <i>Illustration</i>	I, 370
" " Steam (Gibbs)— <i>Illustration, Plate II</i>	I, 116-117
" " " (Sewalls)— <i>Illustration, Plate II</i>	I, 116-117
" " Train Pipe— <i>Illustration, Plate III</i>	I, 170-171
" Exchange of—by Inspectors.....	I, 328
" Extra—Instructions to Enginemen.....	I, 321
" " Trainmen.....	I, 328
" Feed Pipe— <i>Illustration, Plate I</i>	I, 58-59
" for Washing Boilers and Filling Tanks.....	I, 242
" Hangers— <i>Illustration, Plate I</i>	I, 58-59
" Hanging Up—Instructions to Car Inspectors.....	I, 333
" Leaky.....	I, 371
" of Brakes Not in Use.....	I, 326
" Pulling Apart.....	I, 376
" Signal— <i>Armored—Illustration, Plate II</i>	I, 116-117
" " —Extra.....	I, 321
" " Pipe— <i>Illustration, Plate I</i>	I, 58-59
" Steam— <i>Illustration, Plate II</i>	I, 116-117
" Testing.....	I, 370
" Train Pipe— <i>Illustration, Plate I</i>	I, 58-59
Hospital Funds.....	X, 312, 313
Hot Air System.....	IV, 161
" " Overhead.....	I, 257
" " Use of—for Heating Cars.....	IV, 155, 156
" and Cold Water Cock— <i>Illustration, Plate II</i>	I, 116-117
" Boxes, Cause of.....	IV, 219
" Water Bottle.....	I, 204
" " Circulating Pipe— <i>Illustration, Plate II</i>	I, 116-117
" " " System.....	IV, 158
" " Jacket— <i>Illustration, Plate II</i>	I, 116-117
" " Multiple Circuit System.....	IV, 160, 161

	PAGE
Hot Water Pipe from Heater— <i>Illustration, Plate II</i> ...	I, 116-117
“ “ “ to Bowl— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Car— <i>Illustration, Plate II</i>	I, 116-117
“ “ Use of—for Heating Cars.....	IV, 155 156
Hotel Supplies, Handling	VII, 86 87
“ Requisitions for	VII, 87
Hour, Working by.....	I, 285
House, Coal.....	I, 246
“ Oil.....	I, 245
“ Power.....	I, 259, 272
Houses Oil.....	VII, 123, 124
“ Old—Collections for Sale of.....	VII, 422; IX, 427
Household, Establishment of.....	XI, 210
How Current is Produced in the Dynamo.....	I, 405-410
“ Motion, Is Produced in the Motor	I, 410-412
“ to Use the Air Brake.....	I, 314-333
Howard, James E.....	III, 331
Howe Truss Bridge Span— <i>Illustration</i>	III, 373
“ William—Device of.....	I, 48
Howe's Link Motion, or Gearing Attached to Driving Wheels of the Locomotive, 1842— <i>Illustration</i>	I, 49
Hub, Wheel— <i>Illustration, Plate III</i>	I, 170-171
Hudson, J. F.....	II, 47, 48
Humboldt.....	I, 286
Hungary, Status of Railroads in.....	VIII, 338
“ Use of Metal Ties in.....	III, 378, 379
Hydrants	I, 242
Hydraulic Brake	I, 292, 298
“ Riveting Machine.....	I, 255, 256
“ Plant	I, 262
Hygiene.....	IV, 68-70; V, 32-36
Hygienic Department.....	IV, 68
Hypothecated Baggage	V, 450-452
Iberians	XI, 56
Ice, Clearing Track of	III, 301
“ Removing—from Couplings	I, 323
Idean Jove.....	XI, 92
Ideas, New—Their Acceptance at Meetings of Railway Offi- cials.....	I, 288
Identification, Letters of Advice and ..	VII, 410, 411; IX, 398-400
Ideographic Writing	XI, 120
Idleness, Effect of—on Machinery.....	III, 424
Ignorance No Excuse for Neglect of Duty	IV, 329
Ilibery, George Edward	V, 285
Ilbad.....	XI, 103
Illinois, Railway Taxation in.....	III, 440
Immigration, Pauper—Danger of.....	XI, 46

GENERAL INDEX.

179

	PAGE
Implements, Agricultural—Advances on.....	IX, 89
“ Calking and Shipping	I, 262
“ Care of	VII, 297
“ Discussion of Questions Regarding.....	I, 289
“ Giving Out	I, 265
“ of the Aryans	XI, 63
“ Old—Return of	VII, 259
“ Ordering	VII, 298
“ Safety—Carried on Trains	IV, 120
“ Wear and Tear of.....	III, 299
Improved Pump Governor— <i>Illustration</i>	I, 354
Improvements.....	III, 140, 141
“ Expenditures for.....	II, 159
“ Incentive to.....	II, 24
“ Local :.....	II, 221
“ Means for Developing	III, 23
“ “ “ Extending	III, 23
“ Railway	X, 11
Inactivity.....	II, 22
Incandescent Lamps, Current Required by	I, 401
“ Electro-Motive Force of	I, 401
“ Lighting	I, 399, 423, 424
Inclined Cylinders	I, 46
Income Account.....	X, 176-181
“ “ Credits to	X, 177-179
“ “ Debits to.....	X, 179-181
“ Bonds.....	III, 92
“ Items Chargeable Against.....	VII, 525-527
“ Miscellaneous—Definition of.....	X, 179
“ Net—Its Relation to Capital.....	III, 56
“ —What Constitutes It.....	X, 27
“ Surplus—Use of.....	IV, 140
“ Use of—to Strengthen Properties.....	III, 74
Incompetency, Danger of.....	II, 31
Increase of Current—Its Effect.....	I, 428, 429
“ “ Pressure.....	I, 414
Indemnity Bonds. (See also “Bonds, Indemnity”).....	VI, 116; IX, 158-177, 353-358
“ “ for Lost Checks.....	X, 98
“ “ on Loss of Time Tickets.....	VII, 409
India.....	I, 217
“ Baggage Allowed in.....	V, 290
“ Construction In... ..	III, 152
“ Gauge Adopted in.....	III, 193
“ —Its Primitive Associations and Means of Carriage... ..	XI, 157-187
“ Labor In... ..	III, 152
“ Portable Railroads in.....	I, 223
“ —Primitive Carriage in— <i>Illustrations</i>	XI, 157-187
“ Railways in.....	III, 153

	PAGE
India, Relief Departments in.....	X, 350-352
" Transportation of Freight in.....	III, 125
Indianapolis, Cincinnati & LaFayette Railroad.....	II, 128
Indicator.....	I, 88, 89
" Section of— <i>Illustration</i>	I, 88
Indicators, Switch—Automatic Electric Block System.....	IV, 285
Individuals, Vouchers in Favor of.....	VII, 435
Indorsements.....	VII, 407, 444-446
" Making.....	IX, 342-347
Induction, Magnetic.....	I, 400
" Motor.....	I, 412, 442-449
" " Alternating Current— <i>Illustration</i>	I, 444
" " Primary, or Stationary Element, Showing Coils for Receiving the Current from the Circuit— <i>Illustration</i>	I, 442
" " Secondary, or Revolving Element, Show- ing Copper Bars in Which Current is Induced by the Current in the Pri- mary— <i>Illustration</i>	I, 443
Industrial Exposition, Berlin.....	I, 520
" World, Conditions of.....	II, 35
Industry, Recognition of—in Corporate Life.....	II, 19
Inefficiency.....	IV, 329
" Effect of.....	II, 135
Influences Affecting Capitalization.....	III, 53-58
Information, Afforded by Experience.....	I, 283
" Furnishing—to Public Officials.....	VII, 432
" Given by Agents.....	VI, 316
" Regarding the Character of Employes.....	IX, 167
" Value of—in Regard to Trains.....	IV, 11
" " —Regarding the Machinery Depart- ment.....	I, 232, 233
Initials, Car.....	VI, 143
Injector.....	I, 76, 77, 286
" — <i>Illustrations, Plate I</i>	I, 58-59, 60
" Feed Pipe— <i>Illustration</i>	I, 60
" Names of Parts of.....	I, 78
" Operation of.....	I, 78
" Origin of.....	I, 54
" Overflow— <i>Illustration, Plate I</i>	I, 58-59
" Section of— <i>Illustration</i>	I, 78
" Side View of— <i>Illustration</i>	I, 77
" Supply of Water to.....	I, 106
" Throttle— <i>Illustration, Plate I</i>	I, 58-59
Injuries, Claims for.....	II, 232, 235
" Disbursements for.....	III, 398
"Injuries to Persons".....	VII, 491, 521, 522
Ink, Use of.....	VI, 314
Inner Drawbar, Carey Iron— <i>Illustration, Plate II</i>	I, 116-117
" Face Plate— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Instructors, Agents'.....	IX, 251, 252
Instruments, Musical—Carriage of.....	V, 519
" Switch—Automatic Electric Block System.....	IV, 284
Insubordination.....	II, 13, 19
Insulated Car for Dairy Products—Victorian Railway— <i>Illustration</i>	I, 188
" Splice Bars, Automatic Electric Block System.....	IV, 283, 284
Insulating Blocks.....	I, 464
" Materials.....	I, 397
Insulation.....	I, 473, 474
" Burning the.....	I, 429
" of Coils.....	I, 457
Insulators.....	I, 462
"Insurance".....	VII, 496, 524
Insurance.....	III, 475, 476
" Looking After.....	III, 425
" Parcel—in England.....	V, 249
Insurers, Railroads as.....	VIII, 95
Integrity of Railway Officers and Employees.....	II, 65
Intelligence, Evidence of.....	VII, 19, 20
" Necessity of—in Handling Requisitions.....	VII, 71
" Recognition of—in Corporate Life.....	II, 19
Interchange of Cars.....	VI, 63
" Views—Its Value.....	I, 289, 290
Inter-Cooler.....	I, 384
"Interest".....	VII, 463
Interest, Abnormal Rates of.....	III, 28
" Association of—Between Carrier and Patron.....	II, 49
" Concentration of.....	II, 112
" Expenditures of Railways for.....	VIII, 24
" of Employer in Employee.....	II, 31, 32, 61
" " Employee—How Increased.....	II, 28, 29
" on Bonds.....	III, 96, 97
"Interest on Bonds" Account.....	VII, 526
Interest on Bonds, Accounting for.....	X, 178, 180
"Interest on Floating Debt, Discount and Exchange" Ac- count.....	VII, 526
Interest on Floating Debt, Discount and Exchange—Account- ing for.....	X, 180
" Payment of.....	II, 137, 189, 191; III, 96, 97
" Rate of.....	III, 16
" Reciprocal—of Capital and Labor.....	II, 33
" Waiving—by Bondholders.....	III, 462
Interests, Legal.....	II, 229
" Legislative.....	II, 232
" Mutual—of Employer and Employee.....	II, 58
Interference, Arbitrary.....	II, 203
" Government. (See "Government Interfer- ence.")	

GENERAL INDEX.

183

	PAGE
Interference, Legislative.....	VIII, 62, 205
Interior Department, Transportation for.....	V, 144
Interline Baggage, Checking.....	V, 55, 438
" Balances, Settling.....	IX, 358-361
" Charges Prepaid.....	VI, 156; IX, 126
" " Rules Governing.....	VI, 161, 162
" Claims, Rules Governing.....	VI, 297
" " Settlement of.....	VI, 21
" Excess Baggage, Returns of.....	V, 482
" " Traffic.....	V, 465
" " " " in the United States.....	V, 487, 488
" Freight Traffic.....	VI, 7
" Loss and Damage Claims, Rules Governing.....	VI, 300-306
" Overcharge Claims, Rules Governing.....	VI, 298-300
" Ticket Chart.....	V, 136-138
" " Register.....	V, 159, 160, 162, 163
" " Return, Monthly.....	V, 167-169
" " Sales, Weekly Return of.....	V, 167
" Tickets.....	V, 78, 88, 91, 102-107, 110, 111
" " Accounting for.....	V, 85
" " Auditing.....	X, 131-133
" " "Complete".....	V, 105, 137
" " Foreign.....	X, 127
" " Local.....	X, 127
" " "Paster" and "Extension".....	V, 106, 137
" " Selling.....	V, 136-138
" Traffic.....	II, 237
" " Auditing.....	II, 258
" " Handling—Proportions for.....	II, 251
" —Use of the Word.....	V, 88
" Way Bills.....	VI, 137, 230, X, 116
Interlocking.....	IV, 499
" Bolts.....	III, 330
" —Meaning of Term.....	IV, 318
" Mechanical.....	IV, 277, 278
" Switches.....	IV, 110-113
"Interlocking Switches".....	VII, 463
Intermediate Body Transom Pillar— <i>Illustration, Plate II</i> ...	I, 116-117
" " <i>Post—Illustration, Plate III</i>	I, 170-171
" " " <i>Rods—Illustration, Plate III</i>	I, 170-171
International Association of Car Accountants.....	VI, 54
" Railroad Congress.....	X, 42
Interstate Commerce Commission.....	IV, 118;
	V, 43, 45, 48, 196; VI,
	9, 27, 29, 32, 34, 35, 43,
	45, 64, 70, 71, 75; VII,
	467, 472; VIII, 15, 89, 122
" " " Discretion of.....	VIII, 273

	PAGE
Interstate Commerce Commission—Fourth Annual Report.....	V, 45, 48
“ “ “ Powers of.....	VIII, 279, 280
“ “ “ —Third Annual Report.....	V, 43
“ “ Law.....	V, 292; VI, 43, 45
“ “ “ Description of.....	VIII, 265, 272
“ “ “ Effect of.....	VIII, 280-282
“ “ “ Imperfections of.....	VIII, 290
“ “ “ Passage of.....	VII, 209
“ “ “ Summary of.....	VIII, 276-278
“ Traffic.....	III, 46
Intoxicants, Use of—by Employes.....	IV, 330
Introduction of Air Brakes.....	I, 294
“ to “The Science of Railways”.....	I, 7-13
Invention, Effect of Uniformity on.....	X, 41
“ of the Air Brake.....	I, 306
“ The Author’s—for Accounting.....	VI, 89, 90
Inventions, for Hastening Application of the Brake.....	I, 310
Inventories.....	VII, 341-348
“ Brasses.....	VII, 346, 347
“ Dining Car Supplies.....	VII, 346
“ Fuel.....	VII, 347, 348
“ of Construction Material.....	VII, 198
“ Stationery.....	VII, 346
“ Stockyard.....	VII, 347
“ Tools.....	VII, 346, 347
“ Track.....	VII, 344-346
Inventors of Transportation.....	XI, 155
Inverted Arch Bar— <i>Illustration, Plate III</i>	I, 170-171
“ “ “ Center Bearing— <i>Illustration, Plate II</i>	I, 116-117
Investigation, Need of—in Investing.....	III, 79-84
Investments.....	III, 15, 16
“ Railway—Acquisition of Capital for.....	VII, 18-27
“ Safe.....	III, 57
Investors.....	II, 119
“ Care Exercised by.....	III, 60
“ Foreign.....	III, 82-84
“ Precautions for.....	III, 79-84
“ Representatives of.....	III, 82-84
Invoices, Comparison of—with Material.....	VII, 99, 100
“ “ “ Requisitions.....	VII, 193
“ Corrections on.....	VII, 279, 281
“ Entering—in General Distribution of Material Book.....	VII, 317
“ Material.....	VII, 89, 100, 101, 278-282
“ of Material Purchased.....	VII, 280
“ “ Transferred.....	VII, 280-282
“ Preserving.....	VII, 279
“ Receipting.....	VII, 279, 280

	PAGE
Invoices, Recording.....	VII, 280
“ Safeguards Surrounding.....	VII, 100
“ Scrap.....	VII, 282
“ Statements of.....	VII, 281
“ Ticket.....	II, 258; V, 127, 128; IX, 122
Ionian Boatmen.....	XI, 83
Iowa, Railway Taxation in.....	III, 439
Ireland, Baggage in.....	V, 285
“ Gauge Used in.....	III, 194
“ Great Northern Railway of.....	III, 178, 183
Iron.....	III, 8; XI, 73
“ —A Conductor for Magnetic Flux.....	I, 407
“ Car— <i>Illustration</i>	I, 159
“ “ Baume-Marpent’s— <i>Illustration</i>	I, 162
“ Chilled— <i>Illustration</i>	IV, 202
“ Core.....	I, 400
“ Drawbar Carry— <i>Illustration, Plate II</i>	I, 116-117
“ Filings.....	I, 399, 400
“ Hopper— <i>Illustration, Plate II</i>	I, 116-117
“ “ Cover for— <i>Illustration, Plate II</i>	I, 116-117
“ Inner Drawbar Carry— <i>Illustration, Plate II</i>	I, 116-117
“ Inspection of.....	I, 278
“ Magnetic Saturation of.....	I, 427, 428
“ Ore, Weighing—Rules Governing.....	VI, 149
“ Permeability of—in the Motor.....	I, 429
“ Plates, Laminated.....	I, 457
“ Railways, Kinds of.....	III, 111
“ Russia.....	I, 74
“ Safety Beam— <i>Illustration, Plate II</i>	I, 116-117
“ Scrap—Use of, for Wheels.....	IV, 208, 209
“ Shoe.....	I, 464
“ Side Sill Knee— <i>Illustration, Plate II</i>	I, 116-117
“ Step— <i>Illustration, Plate II</i>	I, 116-117
“ Substitution of—for Wood.....	I, 166, 168
“ Tests of.....	I, 277
“ Top, Ring for Russia— <i>Illustration, Plate II</i>	I, 116-117
“ Truss Rod Anchor— <i>Illustration, Plate II</i>	I, 116-117
“ Use of—by Railways.....	VII, 209, 210
“ “ —for Brake Shoes.....	I, 302, 303
“ “ —in Building Cars.....	I, 157, 158
“ Yoke.....	I, 400
Irus.....	XI, 91
Islands, Miscellaneous—Their Primitive Associations and Means of Carriage.....	XI, 366-378
“ “ —Primitive Carriage in— <i>Illustrations</i>	XI, 366-378
Isle of Cephallnia.....	XI, 83
Israelites, Trade with—by the Phenicians.....	XI, 134
Italian Cattle Car— <i>Illustration</i>	I, 180
“ Express Locomotive— <i>Illustration</i>	I, 129

	PAGE
Italian Half Box Car— <i>Illustration</i>	I, 160
“ Inside Connected Freight Locomotive— <i>Illustration</i> , I,	120
“ “ “ Passenger Locomotive— <i>Illustration</i>	I, 120
Italy, Baggage Allowed in.....	V, 288
“ in.....	V, 285
“ Builders of.....	I, 152
“ Effect of Government Management in.....	VIII, 235
“ Gauge Used in.....	III, 194
“ Handling Baggage in.....	V, 385, 386, 433
“ —Its Primitive Associations and Means of Carriage...	XI, 429-436
“ Relief Departments in.....	X, 347-350
“ Responsibility for Baggage in.....	V, 311, 312
“ Status of Railways in.....	III, 50; VIII, 342
“ Use of Metal Ties in.....	III, 379
Ithaca.....	XI, 83
Jack, Track— <i>Illustration</i>	III, 332
Jacks.....	I, 243
“ Air.....	I, 269
“ —Portable.....	I, 275
“ for Raising Locomotives.....	I, 243
Jacket Bands— <i>Illustration, Plate I</i>	I, 58-59
“ Boiler— <i>Illustration, Plate I</i>	I, 58-59
“ Hot Water— <i>Illustration, Plate II</i>	I, 116-117
“ Steam Inlet— <i>Illustration, Plate II</i>	I, 116-117
“ Outlet— <i>Illustration, Plate II</i>	I, 116-117
James, William T.....	I, 48
“James” Locomotive—The First Fitted with Link Motion, I,	48
Japan, Comparative Value of Gold and Silver in.....	III, 12
“ —Its Primitive Associations and Means of Carriage..	XI, 188-218
“ Primitive Carriage in— <i>Illustrations</i>	XI, 188-218
“ Status of Railways in.....	VIII, 347
Jeans, J. S.....	III, 35, 143; IV, 98; VI, 37, 38, 55; X, 167
Jeffries, B. Joy.....	IV, 225, 226, 233
Jerking with Air Brakes.....	I, 368
Jervis, John B.....	I, 50, 51; II, 146, 211, 214; V, 182; X, 169
Jessop, William—Rail Introduced by.....	III, 177
Jessop's Cast Iron Fish-Bellied Rail, A. D. 1789— <i>Illustration</i>	III, 177
Jewelry, Transportation of.....	V, 519
Jezebel.....	XI, 135
“John Stevens” Locomotive, Camden & Amboy Railway, 1849— <i>Illustration</i>	I, 44
Joint Agents.....	IX, 234-236
“ Block, Wooden—New Jersey Railroad, A. D. 1860	— <i>Illustration</i> III, 278

	PAGE
Joint Chair and Wedge, Old Portage Railroad—A. D. 1832	
— <i>Illustration</i>	III, 204
“ Claims, Auditing.....	VI, 20
“ Fixture Used on Western Railroads, A. D. 1869— <i>Illustration</i>	III, 285
“ Rail, A. D. 1838— <i>Illustration</i>	III, 307
“ Service Compartment and Passenger Car— <i>Illustration</i>	I, 221
Joints.....	III, 301
“ Broken.....	III, 220, 221
“ Even.....	III, 220, 221
“ Pipe.....	I, 330
“ Rail.....	III, 334-347
“ —Effect of Depressions in.....	III, 341
“ Supported.....	III, 215, 216
“ Suspended.....	III, 215, 216
Journal.....	II, 273; IV, 199
“ Axle— <i>Illustration, Plate III</i>	I, 170-171
“ Bearing Axle— <i>Illustration, Plate III</i>	I, 170-171
“ “ Key— <i>Illustration, Plate III</i>	I, 170-171
“ “ or Brass— <i>Illustration, Plate II</i>	I, 116-117
“ Bill, Special—Freight Auditor's Advice of.....	VI, 307, 308
“ Box.....	IV, 199
“ “ — <i>Illustrations</i> , {.....	I, 67
<i>Plate II</i>	I, 116-117
<i>Plate III</i>	I, 170-171
“ “ Bolt— <i>Illustration, Plate III</i>	I, 170-171
“ “ Cover— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Bolt— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Spring— <i>Illustration, Plate II</i>	I, 116-117
“ “ Dust Guard— <i>Illustration, Plate III</i>	I, 170-171
“ “ Lid— <i>Illustration, Plate III</i>	I, 170-171
“ “ Spring Hanger to— <i>Illustration</i>	I, 67
“ General.....	X, 60-62
“ Voucher, Special—Freight Auditor's Advice of.....	VI, 307
“ Vouchers.....	X, 81, 82
Journals, Account.....	X, 77-79
“ Examination of—on Locomotives.....	I, 244
“ General Account—Entries in.....	X, 78, 81
“ Heating of.....	IV, 210
“ of Motor Car Trucks.....	I, 468
“ Side—Account.....	X, 77-79
Jove.....	XI, 92
Junctions, Arrival of Trains at.....	IV, 379, 380
“ Departure of Trains from.....	IV, 379, 380
“ Material Used at—Apportionment of Cost of.....	VII, 510
“ Trains Approaching.....	IV, 355
“ Wages of Employes at—Apportionment of.....	VII, 510
Jupiter.....	XI, 96
Justice, Denial of—to Railways—Effect of.....	VIII, 19

	PAGE
Labor, Artificial Associations of.....	II, 35
“ Associations.....	II, 36, 59, 60
“ Basis of Remuneration of.....	VIII, 42
“ Betterment of.....	II, 37
“ Blotter.....	VII, 362, 379
“ by Piece.....	I, 125, 126
“ Centralization of.....	III, 459
“ Charges for.....	VII, 424
“ Charging.....	VII, 379, 380
“ Classification of.....	VII, 379-382
“ Coercion of Capital by.....	II, 33
“ Common—Wages for.....	II, 100, 101
“ Compensation for.....	II, 34
“ Concentration of.....	I, 240
“ Cost of—in Repairs and Renewals of Roadway and Track.....	III, 284
“ “ —Upon What Dependent.....	VII, 235
“ Day.....	I, 125
“ Disbursement of.....	VII, 357
“ Disbursements for.....	X, 67
“ Discussion of Questions Relating to.....	I, 289
“ Distribution of.....	VII, 382-385
“ Diversity of Practices Relating to.....	VII, 239, 240
“ Division of.....	I, 134, 285, 286
“ Divisions of—on Railroads.....	II, viii
“ Domination of.....	II, 36
“ Economy of—in the United States as Compared with Other Countries.....	II, 13
“ Effect of a Debased Currency on.....	III, 21
“ “ Currency on.....	III, 19
“ Efforts of—to Raise Wages.....	II, 34
“ Element, Combination of the.....	II, 36, 37
“ Employment of.....	I, 143; II, 104
“ “ —Economy of Railways in.....	II, 27
“ Evolution of.....	II, 32-56
“ Expenditures of Railways for.....	VIII, 24
“ Fiscal Affairs Connected with.....	VII, 232-248
“ General Distribution Book.....	VII, 537
“ Influence of—on Cost of Maintenance.....	III, 383
“ in India.....	III, 152
“ “ Repair Shops.....	I, 261
“ Liabilities for.....	X, 61
“ Organization of.....	I, 237; III, 459
“ “ —in Repair Shops.....	I, 264, 267, 276
“ Organized.....	II, 18
“ “ —Strength of.....	II, 40
“ Outlay for.....	III, 399
“ Performed, Accounts Against Persons for....	VII, 414-429
“ “ for Others.....	VII, 380
“ Practices Governing.....	VII, 349-413

	PAGE
Labor, Principles Governing.....	I, 280
“ Problem, Solution of.....	II, 44
“ Railway.....	II, 109
“ “ —Tendency of.....	II, 26
“ Recapitulations of Accounts.....	VII, 538-541
“ Relative Cost of.....	II, 106
“ Saving Devices.....	VI, 91
“ Shop—Arrangement of.....	I, 283
“ “ —Distribution of.....	I, 285
“ Skilled.....	I, 270
“ “ —Differences in.....	I, 121
“ Status of—Toward Capital.....	II, 50
“ Subdivision of.....	I, 286
“ Track—Comparison of Cost of.....	VII, 375
“ “ —Relation Various Items Bear to Each Other.....	III, 491
“ Unions.....	II, 52, 53
“ “ Breaking of Contracts by.....	II, 38
“ “ Disfavor of.....	II, 38
“ “ Government of.....	II, 38, 39
“ “ in England.....	II, 37
“ Unskilled.....	I, 270
“ Upheavals—Their Effect.....	II, 40
“ “ “ Remedy.....	II, 38, 39
“ Vouchers for.....	VII, 435; IX, 368
Laboratories, Use of.....	VII, 102-104
Laboratory.....	I, 277-279; II, 265
“ and Office— <i>Illustrations</i>	I, 274, 275
“ Grouping of Offices in.....	I, 273
Laborer, Advancement of—Upon What Dependent.....	II, 35
“ Condition of—How Improved.....	II, 35
Laborers.....	I, 270
“ General.....	I, 286
“ Rights Exercised by.....	II, 54
“ Shop—Specializing the Work of.....	I, 285
“ Skilled.....	III, 468
“ Unskilled.....	I, 264
“ Work in Charge of Various Gangs of.....	I, 285, 286
Laboring Man, Status of.....	I, 135
Lacedemon.....	XI, 100
Laces, Carriage of.....	V, 519
Ladder Post— <i>Illustration, Plate III</i>	I, 170-171
Lagging— <i>Illustration</i>	I, 65
“ Boiler.....	I, 74
“ “ — <i>Illustration, Plate I</i>	I, 58-59
Laminated Iron Plates.....	I, 457
Lamp Filament.....	I, 399
“ Four-Arm— <i>Illustration, Plate II</i>	I, 116-117
“ Gauge— <i>Illustration, Plate I</i>	I, 58-59
“ Oil—for Lighting Cars.....	I, 204
“ Side— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Lamp, Signal— <i>Illustration, Plate I</i>	I, 58-59
“ Signals, Hand—Rules Governing.....	IV, 348, 349
“ Tail— <i>Illustration, Plate II</i>	I, 116-117
“ Vestibule— <i>Illustration, Plate II</i>	I, 116-117
Lamps, Filling.....	VII, 295
“ for Motor Cars.....	I, 486
“ Heat in.....	I, 402
“ Incandescent—Current Required by.....	I, 401
“ “ —Electro-Motive Force of.....	I, 401
“ Oil—Use of, for Light.....	IV, 169
“ Use of—on Trains. IV, 170, 172, 182, 183, 340, 342, 344-346	
Lancashire & Yorkshire Railway.....	III, 183
Land, Acquisition of—by Allen Peoples.....	XI, 46
“ “ “ Railways.....	III, 160
“ Bureau.....	II, 138
“ Carriage—Its Origin.....	XI, 52
“ —Disturbance in Value, Effect of.....	VIII, 20
“ Sale of—Collections for.....	VII, 422; IX, 427
“ Temporary Possession of.....	XI, 38
“ Tickets.....	V, 92, 107
Language.....	XI, 56, 59, 60
“ Origin of.....	IV, 244
Lansing, G. L.....	X, 173
Lantern Signals, Early.....	IV, 250-252, 255
Lanterns, Filling.....	VII, 295
“ Use of—for Lighting Cars.....	IV, 170
Lap Position, of Engineer's Brake and Equalizing Discharge Valve.....	I, 350
Latch, Thumb—Shade— <i>Illustration, Plate II</i>	I, 116-117
Late Slip.....	I, 266
Lathes.....	I, 265
Latrobe's Compound Rail, Baltimore & Ohio Railroad—A. D. 1841— <i>Illustration</i>	III, 231
Latta, Dr. S. W.....	V, 39
Lavatories.....	I, 203
Law Department.....	II, 137, 138
“Law Expenses”.....	VII, 496, 524
Law, Governing Triple Valve.....	I, 346
“ Interstate Commerce.....	VI, 43, 45
“ Makers.....	II, 228
“ Mosaic.....	XI, 41
“ of Supply and Demand.....	II, 34
“ Ohm's.....	I, 402
“ Practice of.....	II, 227
“ Study of.....	II, 227
Laws, Character of—Affecting Railroads.....	VIII, 214
“ Economic.....	II, 33
“ “ —Influence of, on Railways.....	IV, 8
“ General—Effect of.....	VIII, 317
“ Governing Water Transportation.....	II, 47, 48

	PAGE
Laws, Natural—Effect of Interference with.....	VIII, 21
“ “ —Governing Commerce.....	VIII, 21
“ of Great Britain.....	II, 45
“ Regulating the Issuance of Stock.....	III, 73
“ Restrictive—Effect of.....	VIII, 39
“ Statutory—Influence of, on Railways.....	IV, 8
“ Transportation.....	VIII, 54
Lawyer, Characteristics of.....	II, 233, 234
Lawyers as Law Makers.....	II, 228
“ Employment of.....	III, 425
“ Specialists Among.....	II, 227
Lay-Bye—Meaning of Term.....	IV, 315
Lead.....	III, 8
Lead-Lining Machines.....	I, 258
Lead, Use of—by Railways.....	VII, 209
Leaders, of Labor Associations.....	II, 36
Leaf, Grain Door— <i>Illustration, Plate III</i>	I, 170 171
“ Hinges, Grain Door— <i>Illustration, Plate III</i>	I, 170-171
Leakage Grooves.....	I, 377
Leaks.....	I, 262, 330
“ Cause of.....	I, 369
“ “ —Instructions to Switchmen and Yardmen.....	I, 376
“ Discovering—Instructions to Trainmen.....	I, 370, 371
“ in Air Signal Pipe.....	I, 376
Leases.....	III, 80
“ Authentication of.....	II, 182
“ Details of.....	III, 92-100
“ Drawing.....	II, 137, 232
Leasing Railway Property.....	II, 41-43
Leather, for Repairing Brake Cylinders.....	I, 382
“ Use of—for Brake Shoes.....	I, 301, 302
Leathers, Piston.....	I, 331
Leaving Train at Terminals—Instructions to Trainmen....	I, 375
“Te Caan” Brake.....	I, 292
“ “ 1796— <i>Illustration</i>	I, 293
LeCann’s Tram Rail, Wales, A. D. 1801— <i>Illustration</i>	III, 180
Ledger.....	II, 273
“ Account, Various Persons.....	VII, 425, 426
“ General.....	X, 60-62, 70-76
“ Stock.....	III, 89
Ledgers, Auxillary.....	X, 70, 73-75
“ Side.....	X, 70, 74, 75
Leeds.....	I, 21
Legal Advice, Cost of.....	III, 156
“ Department.....	II, 224-234
“Legal Expenses”.....	VII, 463
Legal Services, Expenditures for.....	III, 398
Legislation, Character of—in Great Britain.....	VIII, 269
“ III Considered—Effect of, on Railways.....	VIII, 22
“ Natural Divisions of.....	VIII, 266

	PAGE
Legislation, Necessary	VIII, 212
“ Oppressive	VIII, 208
“ Railway	III, 136
“ Unwise—Effect of.....	VIII, 19
Legislature, Right of—to Control Rates.....	VIII, 68, 163
Leicester & Swannington Railway.....	I, 54
Leland, C. P.	V, 80
Lessee, Profit of.....	II, 43
Lessees, Obligations of.....	III, 98, 99
Lessors, Duties of.....	III, 99, 100
Letourneau, Ch.....	XI, 28
Letter Board or Frieze— <i>Illustration, Plate II</i>	I, 116-117
Letters, Circular.....	IX, 41, 42
“ of Advice and Identification .	VII, 410, 411; IX, 398-400
“ “ to Accompany Pay Checks.....	X, 245, 246
Leuctra, Battle of.....	XI, 87
Level, Track— <i>Illustration</i>	III, 329
Lever Brake	I, 291
“ 1825— <i>Illustration</i>	I, 295
“ “ 1832— <i>Illustration</i>	I, 297
“ “ Early—1830— <i>Illustration</i>	I, 291
“ “ Equalizing— <i>Illustration, Plate II</i>	I, 116-117
“ “ Truck— <i>Illustration, Plate II</i>	I, 116-117
“ Cylinder	I, 332
“ “ — <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ <i>Plate III</i>	I, 170-171
“ “ Cock— <i>Illustration, Plate I</i>	I, 58-59
“ Engineer’s—in Connection with Reversing Gear— — <i>Illustration</i>	I, 91
“ Equalizing Effect of.....	I, 52
“ Floating— <i>Illustration, Plate III</i>	I, 170-171
“ “ or Hodge— <i>Illustration, Plate II</i>	I, 116-117
“ Operating— <i>Illustration, Plate II</i>	I, 116-117
“ Reverse— <i>Illustration, Plate I</i>	I, 58-59
“ Reversing.....	I, 91
“ “ — <i>Illustration</i>	I, 60
“ Sand— <i>Illustration, Plate I</i>	I, 58-59
“ “ Box— <i>Illustration, Plate I</i>	I, 58-59
“ Stub, Shake— <i>Illustration, Plate I</i>	I, 58-59
“ Throttle— <i>Illustrations, Plate I</i>	I, 58-59, 64
“ Truck—Dead— <i>Illustration, Plate II</i>	I, 116-117
“ “ —Live— <i>Illustration, Plate II</i>	I, 116-117
“ Uncoupling— <i>Illustration, Plate II</i>	I, 116-117
“ Wooden.....	I, 296
Levers	I, 292, 381
“ Brake.....	I, 214, 334
“ Equalizing.....	I, 51, 110
“ Reverse.....	I, 286
“ Truck—Dead	I, 329, 332
“ “ —Live.....	I, 332

	PAGE
Leverage	I, 378
Liabilities, Accounting for.....	X, 61
" Definition of.....	X, 61
" Description of.....	X, 183, 184
Liberty, Civil—How Maintained.....	XI, 45
Libraries, Free.....	X, 323
Lid, Journal Box— <i>Illustration, Plate III</i>	I, 170-171
Lift, Door Sash— <i>Illustration, Plate II</i>	I, 116-117
" Window— <i>Illustration, Plate II</i>	I, 116-117
" Blind— <i>Illustration, Plate II</i>	I, 116-117
Lifting Shaft.....	I, 90
Light.....	I, 273, 274
" Pintsch Gas— <i>Illustration</i>	IV, 174
" Production of—by Electricity.....	IV, 176
" " —from Galvanic Battery.....	IV, 175
" Provision for—in Roundhouses.....	I, 240, 243
" Push Car— <i>Illustration</i>	I, 147
Lights, Electric—Development of.....	I, 520
" Pintsch.....	I, 204
Lighting, Arc.....	I, 414
" —Biddle System.....	IV, 179
" Cars.....	I, 204; IV, 166-185; V, 36, 37
" " Cost of.....	IV, 184, 185
" " Systems of.....	IV, 171
" —Direct Current System.....	IV, 176-180
" Highest Form of.....	IV, 176
" Incandescent.....	I, 399, 423, 424
" Modern.....	IV, 169, 170
" Motor Cars.....	I, 426
" —Pintsch Gas System.....	IV, 173, 174
" " System of.....	V, 37
Lilliputian Railroad, Manufacturer of.....	I, 218
Limbs, Artificial.....	II, 232
Lime, Hauling—Railroads for.....	I, 217
" Use of—by Railways.....	VII, 213
Limitations of a Company's Equipment.....	VI, 49, 51-53
" " Electrical Apparatus.....	I, 427-430
" " Power.....	I, 429
" " Speed.....	I, 429, 430
" " the Motor.....	I, 429
Limited Companies.....	II, 41, 42
" Train—Meaning of Term.....	IV, 322
Limits, Electrical.....	I, 429
Linch-Pin.....	IV, 189
Lincoln, President—Conveyance of Remains of.....	I, 184
"Line of Way".....	III, 190
Line, The.....	I, 430
" High Tension.....	I, 451
" Train.....	I, 334, 336
" " —Disabled.....	I, 374

	PAGE
Line, Transmission.....	I, 439
“ Trolley—Double.....	I, 445
“ “ —High Tension.....	I, 452, 453
Linen, Facilities for Repairing.....	I, 274
Lines, Fast Freight.....	VI, 49, 75, 76
“ New—Construction of.....	II, 211
“ of Magnetic Force.....	I, 406
Lining, Inside— <i>Illustrations</i> , { <i>Plate II</i>	I, 116-117
{ <i>Plate III</i>	I, 170-171
Link— <i>Illustrations</i> , <i>Plate I</i>	I, 58-59, 60
“ Block.....	I, 90, 94
“ “ — <i>Illustration</i> , <i>Plate I</i>	I, 58-59
“ “ Pin— <i>Illustration</i> , <i>Plate I</i>	I, 58-59
“ Crescent— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Curved.....	I, 48
“ Expansion— <i>Illustration</i> , <i>Plate I</i>	I, 58-59
“ Hanger— <i>Illustration</i> , <i>Plate I</i>	I, 58-59
“ “ Crescent— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Hangers.....	I, 90
“ Motion.....	I, 48, 49, 115
“ “ First Introduction of—in England.....	I, 48
“ “ Locomotive Fitted with.....	I, 48
“ “ Howe's, 1842— <i>Illustration</i>	I, 49
“ “ Shifting—First Locomotive Fitted with.....	I, 48
“ Purpose of.....	I, 90
Links.....	I, 286
“ Suspension.....	I, 297
Lintel, Deck Sash— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
“ Door— <i>Illustration</i> , <i>Plate II</i>	I, 116-117
Liquid Fuel—Its Advantages Over Other Forms.....	I, 102, 103
“ Stored Under Pressure.....	I, 298
“ Susceptibility of—to Cold.....	I, 298
Liquids, Austrian Car for— <i>Illustration</i>	I, 165
“ Brake Operated by.....	I, 292
List of Railway Officers and Employes.....	II, 308-320
“ “ Uncollected Freight Bills.....	IX, 66, 266, 406
Little, A. E.....	V, 80
Live Brake Lever— <i>Illustration</i> , <i>Plate III</i>	I, 170-171
“Live” Rails, Objections to.....	I, 465
Live Steam Channel— <i>Illustration</i>	I, 65
“ Stock, Accidents to.....	IV, 426
“ “ —Caring for En Route.....	VI, 101, 102
“ “ Contracts.....	V, 204
“ “ —Crippled En Route.....	VI, 102
“ “ —Feeding En Route.....	VI, 102
“ “ Persons in Charge of.....	IV, 413
“ “ Shipments of.....	VI, 99, 100
“ “ —Transferring En Route.....	VI, 102
“ “ Transportation of.....	VI, 101, 102
“ “ Watering—Charges for.....	IX, 61

	PAGE
Live Stock, Waybilling.....	VI, 136, 138, 145
" " "—from Feeding Station	VI, 140
" Truck Lever— <i>Illustration, Plate II</i>	I, 116-117
" Levers.....	I, 333
Liverpool & Manchester Railway.....	III, 125, 128; V, 19
" " " " First Equipment of	I, 171
" " " " Freight Traffic of	I, 31
" " " " Opening of.....	I, 28, 29
Lloyds.....	XI, 81
Load, Freight Car	I, 205, 206
"—Methods of Carrying by the Ancients	XI, 102
Panel	I, 461
Upon Booster	I, 437
Loaded Car Ticket, Rules Governing	VI, 176-178
" " Tickets	VI, 132, 138, 173, 174
" " " Use of.....	IX, 51
Loading Cars, by Gravity	I, 246
" Charges for	IX, 61
Loans, Negotiation of	II, 191; III, 83, 84
" to Employes	X, 317-321
Local Baggage, Checking	V, 54
" Coupon Tickets.....	V, 99
" Excess Baggage Traffic	V, 465, 466
" Finances.....	II, 285
" Freight Agent.....	II, 139
" " Traffic	VI, 7
" Master Mechanics	I, 277
" Passenger Agent.....	II, 139
" " Service, Use of Electricity for.....	I, 507-509
" Ticket Register	V, 159-162
" " Return, Monthly.....	V, 162, 164-167
" Tickets	V, 91, 92-102, 110
" Traffic.....	II, 237; V, 13
" Way Bills	VI, 137, 230
Location, Influence of—on Railway Disbursements	III, 388, 389
" of Air Pumps.....	I, 381
" " Power Station.....	I, 454
" " Repair Shops.....	I, 237, 249, 250
" " Roundhouses.....	I, 237, 240
" " Shops.....	I, 237, 283
Lock, Door Sash— <i>Illustration, Plate II</i>	I, 116-117
" Nut, Cluster Stem— <i>Illustration, Plate II</i>	I, 116-117
" Seat— <i>Illustration, Plate II</i>	I, 116-117
" Vestibule Door— <i>Illustration, Plate II</i>	I, 116-117
" Window— <i>Illustration, Plate II</i>	I, 116-117
Locker Door— <i>Illustration, Plate II</i>	I, 116-117
Locks, Storing.....	VII, 294
" Switch—Automatic Electric Block System....	IV, 287-290
" Time—Use of.....	X, 271

	PAGE
Locks, Use of.....	IX, 338, 339
Locomotive. (See also "Engine").....	
" Ability of—to Run Backward or Forward....	I, 89
" Adhesive Power of.....	IV, 100
" Advent of.....	I, 163, 164
" Air Brake Apparatus on.....	I, 315
" " Signaling Apparatus on.....	I, 362
" —A Living Thing.....	I, 153, 154
" "America," 1829.....	I, 28
" American.....	I, 150
" " Built—Reward Offered for the Best..	I, 32
" " " —Superior Qualities of..	I, 80, 44, 151, 152
" and Tender, Belgian Passenger— <i>Illustration</i> ..	I, 136
" " " Combined, Belgian— <i>Illustration</i> ..	I, 126
" " " " Berlin - Hamburg Rail-	
" " " " " road— <i>Illustration</i> ..	I, 130
" " " " for Switching Purposes—French—	
" " " " " <i>Illustration</i>	I, 123
" Apparently Perfect Parts of.....	I, 61
" Application of the Sweeney Brake to.....	I, 383
" —as an Engine.....	I, 82, 83
" "Atlas," 1834	I, 31
" Austrian— <i>Illustrations</i>	I, 117, 135, 137
" Average Mileage of.....	I, 166
" " Performance of.....	I, 71
" Baldwin—"Atlantic Type"— <i>Illustration</i>	I, 143
" Baltimore & Ohio Railroad—The First Passen-	
" " ger Mogul, 1876— <i>Illustration</i>	I, 46
" Beauty of.....	I, 150
" "Best Friend," 1830— <i>Illustration</i>	I, 33
" Blackett's.....	I, 23
" " Second	I, 23
" Blenkinsop's—Details of	I, 41
" "Blucher," 1814—Stephenson's.....	I, 25
" " Stephenson's—Details of	I, 42
" Boiler, Effect of Impure Water Upon.....	I, 248
" " Filled with Water, Longitudinal Section	
" " " of— <i>Illustration</i>	I, 98
" Books on	IV, 36
" Brooks' Consolidation Freight— <i>Illustration</i> ..	I, 138
" "Brother Jonathan," 1832— <i>Illustration</i>	I, 34
" "Camel," 1848—Built by Ross Winans— <i>Illus-</i>	
" " tration	I, 42
" "Campbell," 1837— <i>Illustration</i>	I, 52
" Cast-Iron Driving Wheel with Steel Tire— <i>Illus-</i>	
" " tration	IV, 200
" Cleaning Material Stripped from	I, 261
" "Comet".....	I, 33

	PAGE
Locomotive, Committee.....	II, 131
“ Compound	I, 46, 92
“ “ —Auxiliary Cylinders— <i>Illustration</i>	I, 146
“ “ —Claim of Advocates of	I, 93
“ “ —Four-Cylinder	I, 93
“ Connecting Rods of	I, 87
“ Consolidation Freight or Goods—New South Wales— <i>Illustration</i>	I, 128
“ Construction of	I, 59
“ “ —Things to be Considered by the Builder	I, 64
“ Cugnot's—1769— <i>Illustration</i>	I, 18
“ Cylinder Power of	I, 64
“ Cylindrical Dome on	I, 76
“ Description of—Its Value	I, 115
“ “ the	I, 59
“ Design.....	I, 380, 381
“ Details of Working.....	I, 112, 113
“ Development of.....	IV, 100
“ “ —to Whom Due.	I, 27
“ “De Witt Clinton”—The First Cab.....	I, 56
“ “ “ “ 1831—The First Cab— <i>Illus-</i> <i>tration</i>	I, 55
“ Discovery of.....	I, 16
“ Distribution of Weight of.....	I, 109, 110
“ “Dragon,” 1848—The First Engine Built for Burning Cumberland Coal, and the First to Have a Rocking Grate— <i>Illustration</i>	I, 43
“ Earnings of.....	I, 166
“ Egyptian— <i>Illustration</i>	I, 120
“ Eight-Wheel Passenger— <i>Illustration</i>	I, 114
“ Electric.....	I, 467-469
“ “ — <i>Illustration</i>	I, 521
“ “ Baltimore & Ohio Railroad Tunnel— — <i>Illustration</i>	I, 388
“ “ The Heilmann	I, 516-519
“ Employes.....	II, 200
“ End Sought in a.....	I, 63
“ Engineers, Brotherhood of.....	II, 53
“ Evolution of.....	I, 15, 45, 529; XI, 512, 513
“ “Experiment,” 1832— <i>Illustration</i>	I, 56
“ “ 1832—The First Four-Wheeled Bogie in America.....	I, 50
“ Express, of Chemins de Fer de l'Etat Belge— <i>Illustration</i>	I, 128
“ First Passenger Mogul, 1876, <i>Illustration</i>	I, 46
“ “ Standard American Eight-Wheel— <i>Illus-</i> <i>tration</i>	I, 52
“ Force of.....	IV, 100

GENERAL INDEX.

199

	PAGE
Locomotive Frame.....	I, 108, 109
" Development of.....	I, 53
" Freight—Brooks' Consolidation— <i>Illustration</i>I, 138
" " —Italian, Inside Connected— <i>Illustration</i>I, 120
" Front View of— <i>Illustration</i>	I, 63
" Fuel, Use of Oil as.....	I, 100, 101
" "George W. Johnson," 1830—The First with a	Double Fire Box..I, 49
" " " " 1830—The First with a	Double Fire Box—
" " " " — <i>Illustration</i>	I, 49
" "Goliath".....	I, 31
" "Grasshopper" Pattern of.....	I, 32
" Grate of.....	I, 95
" " Surface of.....	I, 72, 73
" Growth of.....	I, 38
" Hauling Power of.....	III, 195; IV, 99
" Heating Surface of.....	I, 71-73
" Hedley's—"Puffing Billy"—Details of.....	I, 42
" "Hercules," 1837—Details of.....	I, 51, 52
" " " —The First Having Equalizing	Levers— <i>Illustration</i>I, 51
" History of—Its Value.....	I, 15
" How Looked Upon.....	I, 154
" " Prevented from Becoming Logy.....	I, 94
" " Regarded by Man.....	I, 61
" " Started.....	I, 113
" " Supplied with Fuel.....	I, 108
" Idea of—Origin of.....	III, 125
" Illustrations Portraying the.....	I, 59, 61
" Inspectors, Employment of.....	IV, 38
" Introduction of—Gauge Adopted.....	III, 193
" Inventor of.....	I, 20
" Invention of—by Trevithick.....	XI, 511
" Italian Express— <i>Illustration</i>	I, 129
" —Its Successful Operation in England.....	I, 28
" "James"—the First Fitted with Link Motion, I,	48
" "John Stevens," Camden & Amboy Railway,	1849— <i>Illustration</i>I, 44
" —Length of Time Kept in Service.....	I, 247, 248
" "Locomotion," Stephenson's—1825.....	I, 26
" Machine for Removing and Replacing Wheels ofI, 261
" Machinery of.....	I, 59
" Manufactories, Number of.....	I, 138
" Matthew's, 1840— <i>Illustration</i>	I, 41
" Metallic Parts of.....	I, 92
" Methods of Firing.....	I, 97

	PAGE
Locomotive, Modern	I, 58
“ “ —Details of	I, 115
“ Newton’s Experimental, 1680— <i>Illustration</i> ..	I, 17
“ “Northumbrian”	I, 29, 46
“ Objections to	I, 394
“ Obstacles Overcome by	IV, 97
“ of Chemins de Fer de l’Etat Belge	I, 150
“ “Old Ironsides,” 1832	I, 49
“ “ “ —The First Built by Mat- thias W. Baldwin— <i>Illus- tration</i>	I, 50
“ on China Railway— <i>Illustration</i>	I, 121
“ Opportunity to Become Familiar with	I, 116
“ Parts of	I, 530-532
“ Passenger—Baldwin Single Driver— <i>Illus- tration</i>	I, 142
“ “ —German Rapid Transit—Warschau- Wien Railroad— <i>Illustration</i> ..	I, 131
“ “ —Italian, Inside Connected— <i>Illus- tration</i>	I, 120
“ Perfection of—by Stephenson	I, 25
“ “Phoenix”	I, 33
“ “Pioneer,” 1836— <i>Illustration</i>	I, 39
“ “Planet,” 1830	I, 30
“ “ “Cylinders of	I, 46
“ Pneumatic	III, 120
“ Power of—How Determined	I, 65
“ “ “in 1830	I, 27
“ “Problem,” 1859	I, 54
“ Problems in Connection with	I, 61
“ “Puffing Billy”	I, 23
“ “ “1813— <i>Illustration</i>	I, 22
“ Rack Rail, Blenkinsop’s, 1811— <i>Illustration</i> ..	I, 21
“ Railway—The First with Multitubular Boiler— Seguin’s, 1828	I, 26
“ “ —The First with Multitubular Boiler— Seguin’s, 1828— <i>Illustration</i>	I, 26
“ Read’s, 1791—First Multitubular Boiler— <i>Illus- tration</i>	I, 19
“ Rear View of— <i>Illustration</i>	I, 64
“ Regulation of Fire in	I, 70
“ Repair Shop, Equipment of	I, 262
“ “ “Shops	I, 247-268
“ “ “Plan for— <i>Illustration</i>	I, 239
“ Resistance to	IV, 97-99
“ Richmond— <i>Illustration</i>	I, 144
“ “Rocket”	I, 30
“ “ —Stephenson’s, 1830— <i>Illustration</i> ..	I, 29
“ Rogers’— <i>Illustration</i>	I, 141
“ Russian Freight— <i>Illustration</i>	I, 124

	PAGE
Locomotive, Saddle Tank—American Four-Wheeled— <i>Illustration</i>	I, 105
“ “Sampson”.....	I, 53
“ “Samson”.....	I, 31
“ “ 1838—Built by Timothy Hackworth— <i>Illustration</i>	I, 40
“ Sand Pipe of—Supplemented by Steam Blast— <i>Illustration</i>	I, 111
“ Schenectady— <i>Illustrations</i>	I, 139, 140, 142
“ Scientific Features of the First.....	I, 294
“ Scottish Double Header— <i>Illustration</i>	I, 135
“ Sectional Views of— <i>Illustrations</i>	I, 65, 67
“ Siberian Railway— <i>Illustration</i>	I, 129
“ Side View of— <i>Illustration</i>	I, 59
“ Simple.....	I, 92
“ Single Expansion.....	I, 92, 95
“ Six-Wheeled—Value of.....	I, 33
“ Spring.....	I, 109
“ Standard American— <i>Illustration, Plate 1</i>	I, 58-59
“ Starting the.....	I, 94
“ Steam—Classes of Service Performed by.....	I, 507
“ “ Reservoir on.....	I, 76
“ Stephenson's First—“Blucher,” 1814— <i>Illustration</i>	I, 25
“ Stephenson Type of.....	I, 30
“ “Stourbridge Lion,” 1829.....	I, 28
“ “ “ “— <i>Illustration</i>	I, 28
“ Suburban.....	I, 67
“ Supplies, Accounting for.....	VII, 154
“ Supply Station— <i>Illustration</i>	I, 276
“ Tender.....	I, 101
“ “ for Pushing Trains, Belgian— <i>Illustration</i>	I, 126
“ “ French— <i>Illustrations</i>	I, 127, 131
“ “ Vestibuled.....	I, 198
“ “ Wheel, Cast-Iron— <i>Illustration</i>	IV, 197
“ Ten-Wheeled—Breda, Milan— <i>Illustration</i>	I, 133
“ “Thatcher Perkins,” 1863—First Ten-Wheeled Passenger Engine— <i>Illustration</i>	I, 45
“ The First Fitted with Shifting Link Motion.....	I, 48
“ “ Put in Operation in the United States.....	I, 28
“ “ Genius of the Railway System.....	I, 15
“ “ Heilmann— <i>Illustration</i>	I, 518
“ “ Standard Type of.....	I, 30
“ “Tom Thumb,” 1829—The First to Draw a Car on the American Continent— <i>Illustration</i>	I, 27
“ “Traveler,” 1832. First Distinctive Freight Engine— <i>Illustration</i>	I, 38
“ Trevithick's, 1803.....	I, 20, 21

	PAGE
Locomotive, Trevithick's, 1803— <i>Illustration</i>	I, 20
“ “ —Details of.....	I, 41
“ Truck, American—Side View of— <i>Illustration</i> , I,	68
“ “ Electric— <i>Illustration</i>	I, 513
“ “ Wheel, Paper— <i>Illustrations</i>	IV, 199
“ Value of—Its Appreciation by the Public.....	I, 33
“ Wheels, Construction of.....	I, 110
“ Without Smokestack— <i>Illustration</i>	I, 134
“ Work of.....	IV, 97
“ “York,” 1831.....	I, 32
“ “ —The Winner of the Baltimore & Ohio Prize of Four Thousand Dollars— <i>Illustration</i>	I, 33
Locomotives, Adaptability of.....	I, 165
“ “ —To Gradients and Curves.....	III, 114
“ American.....	I, 111
“ Baldwin— <i>Illustration</i>	I, 145
“ Builders of.....	I, 124
“ Care and Maintenance of.....	I, 230, 235, 283, 284
“ “ of.....	I, 231, 238-247
“ Classes of.....	I, 65
“ Competitive Trial of—in 1829.....	I, 29
“ Compound—While there are numerous references to the Compound Locomotive in Vol. I, and also a number of illustrations, yet the reader is referred for a full account of the Compound Locomotive, fully and practically illustrated, to Vol. XII.	
“ Construction of—in England.....	I, 28
“ Cost of Keeping in Order.....	III, 430, 431
“ Cranes for Lifting.....	I, 254, 255
“ Demand for.....	I, 138
“ Designs for.....	I, 277
“ Details of.....	I, 39
“ Differences in.....	I, 119, 120
“ “ “ Merits of.....	I, 122
“ Duties of Engineers and Firemen in Connection with the Operation of Locomotives, comprising some 120 pages: See.....	
“	Book I, Vol. XII
“ Early English—Fuel of.....	I, 53
“ “ —Fuel of.....	III, 120
“ Earnings of.....	I, 165
“ Effectiveness of—Upon What Dependent.....	IV, 35
“ Efficient Service Performed by.....	I, 237
“ Electric—of the Baltimore & Ohio Railroad, I,	464
“ English and American—Comparison of.....	I, 44
“ Employee Working on.....	I, 229
“ Equipment of—with Automatic Air Sanding Appliances.....	I, 313
“ Fitness of.....	I, 233
“ Four and Six Wheeled—Relative Value of...I,	33

	PAGE
Lombardy, State Management of Railroads in.....	VIII, 239
London & Birmingham Railway.....	I, 37
" " Northwestern Railway.....	I, 35, 36, 54; II, 15, 209; IV, 94; V, 282, 429, 432
" " " " Pension Fund of....	X, 326-328
" " " " Relief Department of....	X, 296
Long and Short Haul.....	VIII, 125, 126, 272-275
Longitudinal Stays, Forward— <i>Illustration</i>	I, 98
" " Rear— <i>Illustration</i>	I, 98
" " Ties.....	III, 179, 201, 202
" " —Use of.....	III, 318-320
" " Truss Rod— <i>Illustration, Plate III</i>	I, 170-171
Loop, Check Chain— <i>Illustration, Plate II</i>	I, 116-117
" " Draw Bar— <i>Illustration, Plate III</i>	I, 170-171
Lorry—Meaning of Term.....	IV, 315
Losh & Stephenson's Edge Rail. Stockton & Darlington Rail- road—A. D. 1816— <i>Illustration</i>	III, 189
"Loss and Damage".....	VII, 490, 521
Loss, in Pressure— <i>Illustrations</i>	I, 416
" " of Energy.....	I, 398
" " Heat.....	I, 398
" " Power.....	I, 430
" " —Its Effect.....	I, 415-419
" " —Upon What Dependent.....	I, 415-419
" " Pressure.....	I, 430
Losses.....	II, 290
" " Apportionment of.....	VII, 511, 512
" " Baggage.....	V, 315-322
" " Claims for.....	II, 232, 235, 242; VI, 18
" " From Unstable Currency.....	III, 25
" " Hidden.....	IX, 32
" " in Circuits.....	I, 415-419
" " Incurred by Carriers.....	VI, 19
" " Settlement of Claims for.....	VI, 283
Lost Baggage.....	V, 342-346
" " Rules Governing.....	V, 439, 440
" " Its Rights—Meaning of Term.....	IV, 318
" " Time—Meaning of Term.....	IV, 318
Louis XIV.....	I, 217
Louisiana. Railway Taxation in.....	III, 452
Louisville & Nashville Railroad.....	V, 556
Luggage. (See "Baggage.")	
Low Pressure Cylinder.....	I, 93
" " Admission Ports of.....	I, 93
" " System of Heating.....	IV, 159-160
Lowell & Suburban Street Railway Company—Use of Elec- tricity by.....	I, 498, 499
Lower Balance Spring— <i>Illustration, Plate II</i>	I, 116-117
" " Berth— <i>Illustration, Plate II</i>	I, 116-117
" " —Stop Bar— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Lower Brake Connecting Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Deck Ceiling— <i>Illustration, Plate II</i>	I, 116-117
“ Door Panels— <i>Illustration, Plate II</i>	I, 116-117
“ “ Sash— <i>Illustration, Plate II</i>	I, 116-117
“ Intermediate Purline— <i>Illustration, Plate III</i>	I, 170-171
“ Rail of Frame— <i>Illustrations, Plate I</i>	I, 58-59
“ Ridge Pole— <i>Illustrations, Plate III</i>	I, 170-171
“ Swing Hanger Pivot— <i>Illustration, Plate II</i>	I, 116-117
“ Wainscot Rail— <i>Illustration, Plate II</i>	I, 116-117
Lowering Transformers.....	I, 427, 451, 452
Loyalty of Employee to Employer.....	II, 31, 32
“ “ Railway Officers and Employees.....	II, 65, 66
Lubricants, Cost of.....	IV, 210
“ Inferior—Effect of Use of.....	III, 402, 403
“ Use of.....	VII, 122, 123
Lubricating Device— <i>Illustration</i>	I, 281
Lubricator.....	I, 315
“ Air Pump— <i>Illustration, Plate I</i>	I, 58-59
“ Cylinder— <i>Illustration, Plate I</i>	I, 58-59
“ Pipe— <i>Illustration</i>	I, 60
Lubricators, Continuous, Slight Feed.....	I, 253
Luce, F. M.....	IV, 60, 65
Lugano, Switzerland, Electric Tramway—Description of....	I, 505, 506
Lugs, Coupling.....	I, 371
“ Dome— <i>Illustration</i>	I, 98
“ Shell— <i>Illustration</i>	I, 98
Lumber, Purchase of.....	VII, 288, 289
“ Receipt of.....	VII, 288, 289
“ Storing.....	VII, 294
“ Yard.....	I, 272
Luxuries of Passenger Service—Their Origin.....	I, 198
“ “ Travel.....	I, 148
Lycurgus.....	XI, 100
Lydia.....	XI, 100
Lye Tank.....	I, 261
Machine and Erecting Shop.....	I, 251, 254, 264, 265
“ for Removing and Replacing Locomotive Wheels.....	I, 261
“ Multi-Polar.....	I, 411
“ Riveting—Hydraulic.....	I, 255, 256
“ Series— <i>Illustration</i>	I, 412
“ Shops.....	I, 239, 261, 269, 272, 273, 275, 286
“ Shunt— <i>Illustration</i>	I, 412
“ Tools.....	I, 265
Machinery, Age of.....	I, 134
“ Apportionment of Wear and Tear of.....	VII, 507
“ Care of.....	I, 125
“ Constructing and Repairing.....	I, 121

	PAGE
Machinery, Cost of Keeping in Order.....	III, 424, 430, 431
“ Cutting Off.....	I, 262
“ Department.....	I, 230, 240, 277; II, 176; IV, 25
“ “ Duties and Responsibilities of Officials in.....	I, 231
“ “ “ of Those in Charge.....	I, 250
“ “ —How Saving Is Effected.....	I, 284
“ “ Importance of.....	I, 233
“ “ Intelligence and Skill Displayed in.....	I, 234
“ “ Rank of Men in Charge.....	I, 230, 231
“ “ Status of—in Early Days.....	I, 234
“ “ Value of Information Regarding.....	I, 232, 233
“ Designs for.....	I, 277
“ Discussion of Questions Relating to.....	I, 289
“ Durability of.....	I, 249
“ Effect of Idleness on.....	III, 424
“ for Care and Maintenance of Rolling Stock,.....	I, 238
“ “ Cleaning Boiler Tubes.....	I, 261
“ “ Making Repairs.....	I, 239
“ Location of—in Roundhouses and Shops.....	I, 237
“ of Railway Shops.....	I, 122
“ “ the Brake.....	I, 294
“ Railway—When the First Railroad Was Opened.....	I, 294
“ Renewals of.....	III, 399
“ Replacing Hand Work by.....	I, 263
“ Riveting—Portable.....	I, 262
“ Scarfing.....	I, 262
“ Selection of.....	I, 143
“ Shop.....	I, 263
“ Tube Testing.....	I, 262
“ Use of.....	I, 135
“ Wear and Tear of.....	III, 299
“ Welding.....	I, 262
Machines, Boring.....	I, 258
“ Electric.....	I, 405-412
“ Facing and Sandpapering.....	262
“ Lead-lining.....	I, 258
“ Milling.....	I, 265
Machinists.....	I, 129, 247, 285; II, 63
Madagascar—Its Primitive Associations and Means of Carriage.....	XI, 359-361
Madras Railway Engine— <i>Illustration</i>	I, 133
Magazines, Carriage of.....	V, 520
Magnet.....	I, 405
“ Double.....	I, 400
“ Electro— <i>Illustration</i>	I, 400
“ “ Double— <i>Illustration</i>	I, 400

GENERAL INDEX.

207

	PAGE
Magnets, Poles of	I, 410
" Magnetic Blow-out"	I, 485
Magnetic Effect of Electric Current	I, 399, 400, 401
" Field	I, 399, 405-407
" Force, Lines of	I, 406
" Induction	I, 400
Magnetism, Alternating	I, 422
" Effect of—on Watches	IV, 337
Mail and Express Service	V, 515-563
" Cars	I, 183
" Delivery of	III, 414
" Earnings, Definition of	X, 178
" Railway—Handling	V, 405, 406
" Rates	V, 553-557
" Service	V, 552-563
" Trains, Speed of	IV, 376
Mails, Carriage of	V, 552-563
" Distribution of—in Cars	V, 561, 562
Main Frame— <i>Illustration, Plate I.</i>	I, 58-59
" Gas Cock— <i>Illustration, Plate II.</i>	I, 116-117
" Line—Meaning of Term.	IV, 447
" Reservoir	I, 334-336, 380
" — <i>Illustration.</i>	I, 539
" Rod— <i>Illustration, Plate I.</i>	I, 58-59, 60
" Connection— <i>Illustration, Plate I.</i>	I, 58-59
" Front Strap— <i>Illustration, Plate I.</i>	I, 58-59
" Shut-Off Valve— <i>Illustration, Plate II.</i>	I, 116-117
" Switch	I, 460
" Track—Meaning of Term.	IV, 319
Maintaining Air Pressure	I, 320
" and Constructing	III, 107-483
Maintenance	III, 272-483
" Cost of	III, 58, 145, 423
" " —Effect of Traffic on	III, 475
" " —Relation to Rates	VIII, 43
" " —Upon What Dependent	III, 383-412, 482
" Effect of the Rigid Wheel Base on	III, 148
" Fixed Expenses of	III, 466
" Influences Affecting	III, 458-483
" —Meaning of the Term	III, 388
" of Bridges, Cost of	III, 292
" Cars	I, 237
" Cattle Guards, Cost of	III, 292
" Culverts, Cost of	III, 292
" Equipment	I, 288; VII, 479-485, 516-518
" Locomotives and Cars	I, 230, 232, 235
" Roadway	II, 211
" Rolling Stock	I, 238
" Ties	III, 280-284
" Track	III, 206, 238-300

GENERAL INDEX.

209

	PAGE
Manager, General—His Relation to Subordinates	II, 155, 156, 162
“ “ —Motives of.....	II, 154
“ “ —Scope of.....	II, 173, 174
“ “ —Titles of.....	II, 153; VII, 250
“ “ Traffic.....	II, 138
“ Goods—English.....	II, 208, 246
“ Meaning of Title.....	II, 142
“ Relation of—to Accounting Officer.....	II, 299-301
“ The Best.....	II, 23
“ Title of.....	VII, 250
“ Traffic—Duties of.....	II, 237-241
“ “ —Title of.....	VII, 250
Manager's Car.....	VII, 225, 226
Managers, Acts of.....	VIII, 38
“ Adviser of.....	II, 229
“ Beliefs Fostered in Regard to.....	VIII, 23
“ Capacity of.....	VII, 170
“ Differences in.....	VIII, 48
“ Discretion of.....	VIII, 134
“ Frequent Changes of—Their Effect.....	VII, 148
“ Functions of.....	III, 418
“ Good Judgment in.....	II, 93
“ Influence on Rates.....	VIII, 56
“ Interest of—in Employees.....	IV, 24
“ Meetings of.....	I, 229
“ Need of.....	III, 418
“ of Corporations.....	II, 73
“ “ Railways.....	I, 37, 230
“ Power of.....	VIII, 82, 112
“ Qualifications of.....	II, 20
“ Railway.....	III, 429
“ “ —Ambition of.....	II, 119
“ “ —American.....	III, 141
“ “ —Duties of.....	V, 356
“ “ —Effect of Public Criticism on.....	V, 358
“ “ —Fidelity of.....	II, 79
“ “ —in Great Britain.....	III, 148
“ “ —Their Interest in Safety Appliances.....	IV, 109, 110
“ Statistics Required by.....	X, 33
“ Study of Statistics by.....	X, 23, 30
“ The Most Effective.....	II, 201
“ —Their Incentive to Foster Business.....	III, 425, 426
“ Traffic.....	II, 63; V, 15; VI, 11, 18
“ Value of Returns to.....	II, 285
“ View of Affairs by.....	X, 30
“ Wages of.....	III, 418
“ Wisdom of.....	II, 77-79
Manchester, Competitive Trial of Locomotives at.....	I, 29
Manhole Opening— <i>Illustration</i>	I, 98

	PAGE
Mankind, Relation of Property to.....	XI, 9
Manifolding Pens, Use of.....	VI, 202
Manipulation of Trains.....	II, 200
Mansfield, Gauge Adopted by.....	III, 192
Manuals.....	II, 111
" Embodiment of Rules in.....	IV, 306
Manufactories, Car—Specialists Among.....	I, 214
" in Great Britain.....	I, 33
" Locomotive and Car.....	I, 130, 138
" Operation of—by Owners.....	II, 44
" Prosperity of.....	I, 123
" Railroad.....	I, 225
" Relative Merits of.....	I, 122
" The First Known to Mankind.....	I, 130, 131
Manufacturer, Earliest Reference to.....	I, 132
" Liliputian Railroad.....	I, 218
" The Successful.....	IX, 22
Manufacturers.....	I, 119
" American.....	I, 152
" Car.....	I, 116
" " —in the United States.....	I, 196
" Contracts with.....	VII, 89
" Intelligence Exercised by.....	I, 125
" Labor of—Its Distribution.....	I, 285
" Locomotive.....	I, 34, 116
" " and Car.....	I, 141
" " " —in Great Britain.....	I, 138
" Merits of.....	I, 145, 146
" Methods of Business Pursued by.....	I, 125
" of Electrical Apparatus—Americans as.....	I, 139
" " Germany.....	I, 128, 129
" " Portable Railroads.....	I, 223
" " Railway Equipment.....	I, 126
" " Motors.....	I, 472
" Practices of.....	I, 133, 134
" Private.....	I, 141-143, 145
" Railway Equipment—Strife Among.....	I, 140
" Railways as.....	VII, 125-133
" Relation of—to Those of Other Countries.....	I, 138
" Requirements of—in Order to Construct	
" Cheaply.....	I, 124
" Result of Rivalry Among.....	I, 146, 147
" Successful—of Equipment.....	I, 145
" Wheel—Rivalry Among.....	IV, 220
" Influence of Germans on.....	I, 128
Manufacturing by Railway Companies.....	VII, 125-133
" Cost of.....	VII, 128, 131, 132
" Destruction of Material in.....	VII, 131, 132
" Plants, Enlistment of Scientific Men in.....	I, 129
" " Origin and Development of.....	I, 127

	PAGE
Manufacturing Shops, Privilege of Inspecting	I, 127
Maps	II, 213; V, 115
Marathon, Battle of	XI, 86
Marco Polo	XI, 28
Marine Engines	I, 103
" Hospitals, Transportation for	V, 144
Markers, Use of	IV, 344
Market of the World	III, 24
" the First	XI, 72
Markets, Effect of—on Rates	VIII, 61
Marshall, H. C.	V, 80
Maryland, Railway Taxation in	III, 452
Masonry	I, 253
" Arched	III, 129
" Partitions of	I, 272
Massachusetts, Legislation in—as to Color Blindness, IV, 241, 242	
" Railway Commission	VII, 200
Master Car Builder	I, 284
" Builders' Association, American	I, 208
" Carpenters	I, 230
" Mechanic, General	I, 277
" Mechanics	I, 129, 230, 233, 247, 264, 271, 277, 284; II, 63, 82, 138, 277; IV, 37
" Mechanics' Association of America	I, 64
" Mechanics, Division	II, 200, 201
" " Local	I, 277
" " Requisitions of	VII, 72, 73
" Station—English	II, 208
Match Striker— <i>Illustration, Plate II</i>	I, 116-117
Material. (See also "Supplies.")	
" Access to	VII, 293
" Account, Classification of	VII, 274
" Accounts	VII, 42-44, 252-272
" " Methods of Keeping	VII, 240, 244
" " What They Represent	VII, 273
" Accounting for	VII, 238, 252-276, 311-316; X, 87, 88
" " " —Practices of English Railways	VII, 528-530
" Amount Kept in Store—Upon What Dependent	VII, 59
" " " on Hand	VII, 29
" Balances	VII, 273
" Book, Use of	VII, 100, 101
" Brake Shoe	I, 301, 302
" Bridge—Shipping	VII, 191
" " —Storage of	VII, 190
" Building—Shipping	VII, 191
" Buying	VII, 76, 252, 258
" Care of	VII, 76, 252-265, 291-307
" Cataloguing	VII, 293

	PAGE
Material, Changes in.....	VII, 81
“ Charges for.....	VII, 424
“ Charging.....	VII, 265-266, 273, 274, 306, 311-315
“ Classifying Expenditures of.....	VII, 311-315
“ Comparison of—Invoices with.....	VII, 99, 100
“ Comparisons of.....	VII, 101, 102
“ Construction—Depots for.....	VII, 189-196
“ “ —Inspection of.....	VII, 193
“ “ —Inventories of.....	VII, 196
“ “ —Orders for.....	VII, 192
“ “ —Shipping.....	VII, 193
“ Contracts for.....	VII, 99
“ Cost of.....	III, 385, 396, 397
“ “ Substituting Old for New.....	III, 396
“ Department, English.....	VII, 105
“ Destruction of—in Manufacturing.....	VII, 131, 132
“ Disbursement of.....	VII, 76
“ “ —Rules Governing.....	VII, 177-183
“ Disbursements for.....	X, 67
“ Disbursing.....	VII, 262, 269-272, 307-336
“ Distribution of.....	VII, 311-315
“ “ —to the Erecting Shops.....	I, 272
“ Diversity of Methods in Handling.....	VII, 238, 239
“ Economical Purchase, Care and Use of.....	VII, 11, 226
“ Errors in Waybilling.....	VII, 277
“ Examination of—by Chemists.....	VII, 89
“ Facilities for Handling.....	VII, 33-37
“ Fiscal Affairs Connected with.....	VII, 232-248
“ Forwarded to Isolated Points.....	VII, 294
“Material Forwarded to Storehouses”.....	VII, 318
Material, Handling.....	I, 279
“ “ —Defects in Arrangements for.....	VII, 291
“ Heavy—Tracks for Handling on Push Cars.....	I, 275
“ Influence of—on Cost of Maintenance.....	III, 383
“ Inspecting.....	VII, 76, 282-289
“ “ —Importance of.....	VII, 91
“ Inspection of.....	I, 278
“ Inspectors.....	VII, 91-94
“ Inventories of.....	VII, 81
“ Inventorying.....	VII, 341-348
“ Invoices.....	VII, 100, 101, 278-282
“ Invoicing.....	VII, 89
“ Liabilities for.....	X, 61
“ Loading.....	VII, 309
“ Loss of.....	VII, 31
“ Manufactured by a Company, Charging.....	VII, 321-324
“ Marking.....	VII, 284, 310
“ “ —for Identification.....	VII, 96
“ Old. (See also “Scrap.”).....	VII, 81, 263
“ “ —Care of.....	VII, 139-144

	PAGE
Material, Old—Collection of.....	VII, 139-144
“ “ —Collections for.....	VII, 420
“ “ —Final Disposition of.....	VII, 89
“ “ —Inspection of.....	VII, 139, 140
“ “ —Return of.....	VII, 184, 185
“ “ —Sale of.....	VII, 143, 144
“ “ —Utility of.....	VII, 139-144
“ “ —Use of.....	VII, 88
“ “ —Value of.....	VII, 141
“ Ordering.....	VII, 76, 77, 252, 267
“ Orders for.....	VII, 55, 56
“ “ Transfer of.....	VII, 80
“ Paying for.....	VII, 89
“ Permanent.....	VII, 216-226
“ Prevention of Duplication of.....	VII, 78
“ Purchase, Care and Inspection of.....	I, 279
“ “ of.....	I, 125, 143; II, 137; VII, 39-41, 82
“ Purchased, Invoices of.....	VII, 280
“ Quantity of—Required to Lay One of Track	III, 495
“ Railway—Charges for Transporting.....	VII, 199-206
“ Raw—Transfer of.....	I, 275, 276
“ Recapitulations of Accounts.....	VII, 538-541
“ Receipt of.....	VII, 76
“Material Received”.....	VII, 317
Material Received Book.....	VII, 289-291
“Material Received from Purchasing Agents”.....	VII, 317
“ “ “ Storehouses”.....	VII, 317, 318
Material, Receiving.....	VII, 282-285
“ Records.....	VII, 269, 270
“ Repair of.....	VII, 90
“ Requisitions for Purchase of.....	VII, 79
“ Road—Care and Use of.....	VII, 106-113
“ “ —Charges Collected for.....	VII, 414, 421, 422; IX, 426
“ Safety of.....	VII, 181
“ Sale of.....	VII, 425
“ “ —Profits from.....	VII, 431
“ Selling.....	VII, 76
“ Shipped to Points Where There Are No Storekeepers.....	VII, 275, 281
“ Shipping.....	VII, 180, 309, 310
“ Sold, Accounts Against Persons for.....	VII, 414-429
“ Staple—Purchase of.....	VII, 52
“ Storage of—Rules Governing.....	VII, 177-183
“ Storing.....	VII, 291, 293
“ Stripped from Locomotives.....	I, 261
“ Surplus.....	VII, 62, 112
“ Switch—Storage of.....	VII, 190
“ System of Accounting for—Recommended by Association of American Railway Accounting Officers.....	VII, 535, 536

	PAGE
Material, Telegraphic Requests for.....	VII, 83
“ Testing—Laboratories for.....	VII, 102-104
“ Track—Charging.....	VII, 324-326
“ “ —Inspection of.....	VII, 110, 111
“ “ —Keeping Down Supply of.....	VII, 78
“ “ —Preparing for Sunday Work.....	III, 241
“ “ —Shipping.....	VII, 191
“ Transferred, Invoices of.....	VII, 280-282
“ Transportation Charges on.....	VII, 276-278
“ Use of.....	IV, 333; VII, 37, 38
“ Used in Repairs and Renewals of Roadway and Track.....	III, 284, 285
“ Vouchers, Charging.....	VII, 273
“ “ for.....	VII, 435; IX, 368; X, 83, 92
“ Weighing.....	VII, 310
Materials, Insulating.....	I, 397
“ —Tests of.....	I, 277
Matthew's Locomotive, Utica & Schenectady Railroad, 1840— — <i>Illustration</i>	I, 41
Mattresses, Berth— <i>Illustration, Plate II</i>	I, 116-117
McNally, Andrew.....	V, 80
Mechanic, Master, General.....	I, 277
Mechanics, American.....	I, 139
“ Master.....	I, 129, 230, 233, 247, 264, 271, 277, 284; II, 63, 82, 138, 277; IV, 37
“ “ —Requisitions of.....	VII, 72, 73
Mechanical Connections For Carrying Current.....	I, 430
“ Department.....	I, 277
“ Devices, Effect of—on Train Service.....	IV, 15, 16
“ Energy—How Measured.....	I, 403
“ “ —Its Conversion into Electrical Energy	I, 402
“ “ Production of Electricity by.....	I, 397
“ “ “ “ Heat by.....	I, 397
“ “ Transformation of Chemical Energy into.....	I, 393
“ Engineer.....	I, 277
“ Engineer's Office.....	I, 278
“ Transmission.....	I, 425
Mechanism, Reversing Valve.....	I, 308
Medical Examiners, Relief Department.....	X, 301, 312
Medicines, Expenditures for.....	II, 232; III, 398
Medieval Primitive Associations and Means of Carriage....	XI, 489-509
“ “ Carriage— <i>Illustrations</i>	XI, 489-509
Medium, Circulating.....	III, 7, 8, 14
“ —Paper as.....	III, 16
Meeting Place—Meaning of Term.....	IV, 319
“ Point—Meaning of Term.....	IV, 319
Meetings, General.....	I, 228

GENERAL INDEX.

215

	PAGE
Meetings, Monthly.....	I, 227-229
" Notices of.....	II, 181
" of Directors.....	II, 129, 130
" " Managers and Superintendents.....	I, 229
" " Officials in Charge of Passenger Traffic.....	I, 287, 288
" " Stockholders.....	II, 128, 129
Megabazus.....	XI, 105
Megiddo.....	XI, 103
Memberships, Relief Department.....	X, 309
Memorandum Books, Agents'.....	V, 512-514
" Way Bills.....	VI, 132, 137; IX, 52
Men, Characteristics of.....	II, 17
" Cultivated.....	I, 161
" Educated—Advantage of.....	I, 130
" Effeminacy of.....	I, 162
" Evidence of Worth in.....	II, 76
" Handling of.....	I, 125
" High Priced.....	II, 26, 27
" —How Controlled.....	II, 17
" Keeping Time of.....	I, 265-267
" Laboring—Associations of.....	II, 32, 33
" Selection of.....	II, 24
" Self-Made.....	VII, 26
" Scientific—Enlistment of, in Manufacturing Plants.....	I, 129
" Skilled—Lack of.....	I, 234
" Talented—Needs of.....	I, 118
" Talents of.....	I, 136
" Unsystematic.....	II, 22
Mendicants.....	II, 195
Merchandise, Car for Carrying—in America.....	I, 207
" Carriage of—as Baggage.....	V, 301, 302
" Lost.....	V, 344
Merchant, The Successful.....	IX, 22
Mercury, Use of—by Railways.....	VII, 209
Mesopotamia, Means of Transportation in.....	XI, 107
" Primitive Carts of.....	I, 132
Mesopotamian Valley.....	XI, 54
Messenger Boy, Station.....	VI, 14
Messengers, Express.....	V, 518, 519, 539, 540
Metal, Babbit. (See also "Brasses.")	
" " —Care of.....	VII, 134-138
" " —Inspection of.....	VII, 134-138
" " —Loss of.....	VII, 137
" " —Use of.....	VII, 134-138
" " " by Railways.....	VII, 209
" Baggage Checks.....	V, 55, 57, 58
" Check.....	I, 266
" Deterioration of—from Oxidation.....	III, 273
" "Pot" Tie, Midland Railway of India, A. D. 1889— <i>Illustration</i>	III, 311

	PAGE
Metal "Pot" Ties.....	III, 203
" Ties.....	I, 218; III, 202-204, 348, 365-369
" Advantages of.....	III, 366
" Construction of.....	III, 367, 368
" Corrosion of—How Prevented.....	III, 368
" Cost of.....	III, 369
" Durability of.....	III, 378
" Fastenings for.....	III, 368
" Requirements of.....	III, 381-382
" Use of.....	III, 177, 365-369
" " —in Austria.....	III, 378, 379
" " " " Belgium.....	III, 377
" " " " England.....	III, 376
" " " " France.....	III, 376
" " " " Germany.....	III, 377, 378
" " " " Holland.....	III, 377
" " " " Hungary.....	III, 378, 379
" " " " Italy.....	III, 379
" " " " Portugal.....	III, 379
" " " " Spain.....	III, 379
" " " " Switzerland.....	III, 379
Track, A. D. 1889— <i>Illustrations</i>	III, 314-319
" Advantages of.....	III, 380
" Midland Railway, A. D. 1889— <i>Illustration</i>	III, 312
" Queensland, A. D. 1889— <i>Illustration</i>	III, 312
Vehicles.....	I, 224
Metals, Ancient Workers in.....	XI, 134
" Art of Working.....	XI, 73
" Benches for Working in.....	I, 269
" Furnishers of.....	I, 182
" Precious.....	II, 242
" The Basis of Exchange.....	XI, 73
" Use of—by Railways.....	III, 320-322
" " —for Railroads.....	I, 218
" Utilization of.....	XI, 72
Metallic Gaskets.....	I, 381
" Packing.....	I, 381
" Salts, Use of.....	III, 352
Metallographists.....	III, 14
Method of Capitalization.....	III, 28-40
" Construction.....	III, 137-151
Methods, Business—of Manufacturers.....	I, 125
" —Uniformity in.....	VII, 337
" Comparison of.....	II, 278
" Governing Freight Traffic.....	VI, 93-108
" the Fiscal Affairs of Railroads....	VI, 77-92
" of Departmental Officers.....	II, 139
" Transportation.....	I, 201
" Political and Business.....	X, 11-15
" Publicity of.....	IX, 23

	PAGE
Methods, Railway.....	VII, 11-17
" " —Divergence of.....	II, 80
" to Be Observed in Handling Railway Revenue, IX, 20-34	
Metropolitan Elevated Railway, Chicago—Use of Electricity on.....	I, 495, 496
Mexico, Conquest of.....	XI, 85
—Its Primitive Associations and Means of Carriage.	IX, 404-417
" Primitive Carriage in— <i>Illustrations</i>	XI, 404-417
" Railway Travel in.....	I, 202
" Use of Wood in.....	VII, 162
Michigan, Railway Taxation in.....	III, 436, 438
Middle Door Panels— <i>Illustration, Plate II</i>	I, 116-117
" " Rail— <i>Illustration, Plate II</i>	I, 116-117
" Rail Side Door— <i>Illustration, Plate III</i>	I, 170-171
" Safety Beam— <i>Illustration, Plate II</i>	I, 116-117
" Sidings, Rules Governing.....	IV, 375, 376
" Transom— <i>Illustration, Plate II</i>	I, 116-117
" " Plate— <i>Illustration, Plate II</i>	I, 116-117
Middleman, Relation to Rates.....	VIII, 50
Middleton.....	I, 21
" & Leeds Railway, 1812-13— <i>Illustration</i>	I, 24
Midland Railway, England.....	V, 292, 430, 432
Milan, Breda Engine of.....	I, 151
Mile Train.....	II, 27
Mileage, Allowance of—to Owners of Cars.....	II, 45
" Coupons.....	V, 209, 210
" Daily—of Freight Cars.....	VI, 53
" Exchange Checks.....	V, 211
" Railway—Growth of.....	III, 42
" Tickets.....	V, 78, 92, 93, 97-99
" " Coupon.....	V, 471, 474, 475, 495
" " Rules Governing.....	V, 207-210
Military Cars.....	I, 224
" Purposes, Railroads for.....	I, 217
Milk Accounting for.....	X, 119
" Car, Suburban—American Standard— <i>Illustration</i>	I, 209
" Carriage of.....	V, 519
" Shipment of.....	VI, 247-250, 313
" Shipments, Daily Return of.....	VI, 250
" Tickets.....	V, 520; VI, 247-250
" " Book.....	VI, 252
Mill, Planing.....	I, 271-274
" " —Car Department—Side Elevation— <i>Illustration</i>	I, 260
" " —Section and End Elevation— <i>Illustration</i>	I, 261
"Miller" Platform.....	IV, 120
" " with Automatic Coupler— <i>Illustration</i> , IV, 119	
Milling Freight in Transit.....	VI, 267
" Machines.....	I, 265

	PAGE
Mineral Department, English.....	VI, 326
“ Salts, Use of.....	III, 361
“ Sperm Oil, Use of—for Lighting Cars.....	IV, 180, 181
“ Tank Engine, Scotland— <i>Illustration</i>	I, 123
“ Traffic, Agents’ Return for—English.....	VI, 326, 327
“ “ of Great Britain.....	VI, 8
Minerals, Waybilling.....	VI, 136
Minerva.....	XI, 96
Minnesota, Railway Taxation in.....	III, 439
Minors, Employment of.....	IV, 330; IX, 30
Mint, British.....	III, 11
Miscellaneous Charges.....	VI, 158
“ “ Accounting for.....	IX, 62-64
“ “ Prepaid.....	VI, 156, 158
“ “ Unpaid.....	VI, 158
“ Collections.....	IX, 60-62, 232
“ “ Remitting.....	IX, 424-427
“ Earnings.....	X, 149
“ “ Definition of.....	X, 178
“ “ English.....	VI, 327-329
“Miscellaneous Expenses”.....	VII, 463
Miscellaneous Goods, Manufacture of.....	I, 138
“ Income, Definition of.....	X, 179
“ Receipts—Auditing.....	X, 118
“Miscellaneous Structures”.....	VII, 460
Miscellaneous Tickets.....	V, 111
“ “ Auditing.....	X, 125, 126
“Miscellaneous Track Material”.....	VII, 463
Miscellaneous Traffic, English.....	V, 247
“ Way Bills, English.....	V, 247, 248
Misrepresentations of Shippers.....	VI, 5, 22-25
Mississippi, Railway Taxation in.....	III, 451, 456
Missouri Pacific Railway.....	II, 51, 52
Mixture, Standard—for Brake Shoes.....	I, 302
Modern Devices of Business.....	VII, 229-231
“ Hand Brake— <i>Illustration</i>	I, 300
“ Locomotive.....	I, 58
“ “ —Details of.....	I, 115
“ Travel.....	I, 148
Mohammed.....	XI, 41
Mohawk & Hudson Railroad.....	I, 56
Molder’s Floor.....	I, 258
Molding Cove—Window— <i>Illustration, Plate II</i>	I, 116-117
“ Eaves— <i>Illustration, Plate II</i>	I, 116-117
“ “ Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Window—Outside— <i>Illustration, Plate II</i>	I, 116-117
Monarchies, Formation of.....	XI, 32
Money, (See also “Cash”).....	XI, 13, 128
“ Access to.....	IX, 340
“ as Property.....	III, 2

	PAGE
Money, Care of.....	VII, 31, 32; IX, 133-135, 143, 328-330
“ Carrying from Banks.....	X, 226
“ Collecting.....	IX, 298, 325, 326
“ Collection of.....	VII, 422
“ “Conscience”—Accounting for.....	VII, 423
“ Coupon Tickets, Excess Baggage.....	V, 471, 472, 476, 477, 495
“ Disbursement of.....	II, 195; IX, 293
“ “ —by Agents.....	IX, 289
“ Drawers.....	IX, 337, 338, 341
“ Faithful Handling of.....	IX, 35-64
“ “Fiat”.....	III, 17
“ Foreign—Acceptance of.....	IX, 327
“ Free Circulation of.....	III, 11
“ “ Coinage of.....	III, 11
“ Guarding.....	IX, 339, 340
“ Handling.....	IX, 133-135, 242-245, 299, 302
“ “ —at Stations.....	IX, 178-192
“ How Faithfulness and Skill are Acquired in Handling.....	IX, 27, 28
“ Influences Affecting.....	III, 8, 9
“ Materials Used for.....	III, 7, 8
“ of Savages.....	III, 9
“ Orders of Agents to Pay.....	V, 146-150
“ —Origin of the Word.....	III, 9, 10
“ Paid Out by Agents.....	IX, 326, 327
“ Paper.....	III, 11
“ Plentifulness of.....	III, 28, 43
“ Purchasing Power of.....	III, 9
“ Receipting for.....	IX, 291, 325, 326
“ Receipts for.....	IX, 81-85
“ “ —English.....	VI, 323
“ Receiving.....	II, 195; IX, 327, 328
“ “ —in Treasurer’s Office.....	X, 262
“ Reconveying—Into the Treasury.....	X, 263
“ Remitting.....	IX, 135, 138, 139, 327, 328, 430; X, 135-141
“ Requirements of.....	III, 8
“ Scarcity of.....	III, 28
“ “ —in America.....	I, 50
“ Sending by Express.....	X, 265
“ the Standard.....	III, 8
“ Transferring—Between Banks and Offices.....	X, 262
“ Transportation of—in Early Days.....	III, 119
“ Weighing.....	III, 10
“ —What Constitutes it.....	III, 7
“ “ is Meant by.....	III, 7
Monopolies, Characteristics of.....	VIII, 175
“ Creation of.....	VIII, 84
Monopoly, Possibility of.....	VIII, 61
Montague, S. S.....	III, 163

	PAGE
Montespan, Mme. de—Chateau of.....	I, 217
Monthly Interline Ticket Return.....	V, 167-169
" Local Ticket Return.....	V, 162, 164-167
" Meetings.....	I, 227-229
" Return of Excess Baggage, Rules Governing. V,	507-512
Monumental Writing.....	XI, 118
Moon, Ancients' Idea of Carriage of.....	XI, 155
Morocco—Its Primitive Associations and Means of Car-	
riage.....	XI, 334-341
" —Primitive Carriage in— <i>Illustrations</i>	XI, 334-341
Morrison, Andrew.....	III, 207
Mortgage Bonds.....	III, 42, 64, 86, 88, 92-100, 158
" Foreclosures.....	III, 95
" Trustees.....	III, 94
Mortgages.....	III, 92-100, 103
" Drawing.....	II, 232
" Recording.....	III, 96
Moses.....	XI, 112
Motion, Conception of—by the Ancients.....	XI, 154
" Fork.....	I, 48
" How It Is Produced in the Motor.....	I, 410-412
" Lateral—Its Advantages in Connection with Brake	
Shoes.....	I, 304
" Link.....	I, 48, 49, 115
" " —First Locomotive Fitted with.....	I, 48
" " —Howe's 1842— <i>Illustration</i>	I, 49
" " —Introduction of—in England.....	I, 48
" Transfer of—from Links to Valve Rod.....	I, 94
" Valve—Direct Acting.....	I, 94
" " —Indirect Acting.....	I, 94
" " —of Air Pump.....	I, 308
Motive Power, Electricity as a.....	I, 387-526
" " Superintendents of.....	I, 233, 277; II, 138
Motor— <i>Illustration</i>	I, 410, 441
" Alternating Current.....	I, 426, 441
" " —Its Evolution.....	I, 445
" Brake Tests Upon.....	I, 476
" Car, Electric.....	I, 467-469
" " Equipment.....	I, 488
" " Mt. Holly Road— <i>Illustration</i>	I, 491
" Cars, Air Brakes for.....	I, 485
" " Heating.....	I, 486
" " Lighting.....	I, 486
" " Tests on.....	I, 480-482
" "Consequent Pole".....	I, 472, 473
" Constant Speed.....	I, 445
" Curves.....	I, 476-480
" " Diagrams of.....	I, 476, 477, 481-483
" Direct Current.....	I, 411

	PAGE
Motor, Electric	I, 394, 396
" " —The Place It Shall Occupy	I, 394, 396
" Energy of Steam in	I, 403
" for Heavy Street Railway Service— <i>Illustration</i>	I, 509
" Four-Pole	I, 472
" How Motion Is Produced in the	I, 410-412
" " Rated	I, 473
" Induction	I, 412, 442-449
" " —Alternating Current— <i>Illustration</i>	I, 444
" " Primary, or Stationary Element, Showing Coils for Receiving the Current from the Circuit— <i>Illustration</i>	I, 442
" " Secondary, or Revolving Element, Showing Copper Bars in Which Current is In- duced by the Current in the Primary— <i>Illustration</i>	I, 443
" Limitations of the	I, 429
" Narrow Gauge— <i>Illustration</i>	I, 487
" Power Delivered to a—How Found	I, 404
" Railway— <i>Illustrations</i>	I, 471, 524
" " Eighty Horsepower— <i>Illustration</i>	I, 510
" " —Armature Coils for— <i>Illustration</i>	I, 411
" " " of— <i>Illustration</i>	I, 413
" " —Complete— <i>Illustration</i>	I, 415
" " " (One Hundred Horsepower)— <i>Il- lustration</i>	I, 525
" " —Cross Section of a— <i>Illustration</i>	I, 403
" " —Electrical Characteristics of	I, 473, 474
" " —Evolution of	I, 472
" " —Field Coil for	I, 472
" " —Spring Mounted— <i>Illustration</i>	I, 469
" " —Top Field Removed, Showing Armature in Position. (One Hundred Horsepower)— <i>Illustration</i>	I, 524
" " —With Gear Case and Car Axle, Thirty-Five Horsepower— <i>Illustration</i>	I, 470
" Ready for Mounting on Axle— <i>Illustration</i>	I, 415
" Reduction of Voltage on a	I, 478
" Series	I, 412, 474-476, 485
" Shaft, Mechanical Energy Delivered by	I, 403
" Single Phase	I, 445
" Six-Pole	I, 472
" Size of	I, 429, 469
" Street Railway— <i>Illustration</i>	I, 429
" Strength of	I, 469, 470
" Suspension of	I, 470, 471
" Synchronous	I, 412, 442
" The	I, 401, 469-485

	PAGE
Motor Vehicle or Horseless Wagon.....	XI, 521, 522
" Weight of.....	I, 469, 470
" With Pinlon, Mt. Holly Road, (One Hundred Horse- power)— <i>Illustration</i>	I, 492
" " Upper Field Raised—Showing Armature and Upper Field Poles with the Coils Surround- ing Them— <i>Illustration</i>	I, 475
Motors, Alternating Current.....	I, 412, 442
" Capacity of.....	I, 429
" Constant Potential.....	I, 415
" Construction of.....	I, 471, 472
" Electric.....	I, 260, 264
" " —Controller for; Open, Showing Drum and Fixed Contacts— <i>Illustration</i>	I, 486
" for Railway Work.....	I, 449
" Geared.....	I, 470, 471
" Gearing of.....	I, 474
" Gearless.....	I, 470, 471
" Maintaining Pressure at the.....	I, 431
" Mechanical Energy in.....	I, 402
" Polyphase.....	I, 488
" Protection of—from Weather.....	I, 471
" Shunt.....	I, 412
" Steel.....	I, 470
Movable Points.....	III, 236, 237
Movement of Trains by Telegraph—Meaning of Term...	IV, 319
Mud Ring.....	I, 96
" " — <i>Illustrations</i>	I, 67, 68
Mule, First Appearance of.....	XI, 74
Mullion, Window Blind— <i>Illustration, Plate II</i>	I, 116-117
Multiplex System of Accounts.....	VI, 90, 120, 136, 175, 181, 187, 226, 254, 293; IX, 86
Multiplicity of Patterns and Devices.....	I, 284
Multi-Polar Machine.....	I, 411
Multitubular Boiler—First Railway Locomotive with—Se- gulin's, 1828....	I, 26
" " " " Locomotive with—Se- gulin's, 1828 — <i>Il- lustration</i>	I, 26
Munitions of War.....	I, 224
Murray, Matthew.....	I, 21
Musical Instruments, Carriage of.....	V, 519
Mutilated Currency.....	IX, 328
Mycene.....	XI, 89
Mylitta.....	XI, 99
Mythological Primitive Associations and Means of Carriage	XI, 489-509
" " Carriage— <i>Illustrations</i>	XI, 489-509

	PAGE
Nailing Strip, Center— <i>Illustration, Plate III</i>	I, 170-171
“ “ Outside— <i>Illustration, Plate III</i>	I, 170-171
“ Strips, Inside Intermediate— <i>Illustration, Plate III</i>	I, 170-171
Names, Entering—on Pay Rolls.....	VII, 393
Nantasket Beach Branch of New York, New Haven & Hartford Railroad—Use of Electricity on.....	I, 492-495
Naphtha, Handling.....	VI, 99
Narrow Gauge Motor— <i>Illustration</i>	I, 487
“ “ Roads.....	III, 143
“ “ Track.....	I, 275
Nasamonians.....	XI, 100
Nashua & Lowell Railroad.....	II, 128
Nation, Effect of a Debased Currency on a.....	III, 21
Nausicaa, Chariot of.....	XI, 152
Navy, Engineering Department of.....	I, 234
“ Introduction of Steam in.....	I, 234
Nearsightedness.....	IV, 241
Nebuchadnezzar.....	XI, 124
“ —Carriage in Time of.....	XI, 163
Necessaries, Cheapening Cost of.....	VIII, 36
Needle, Compass.....	I, 400
Needs, Public—Conformity of Facilities to.....	I, 201
Negative Holes.....	I, 410
Neilson Machine, Builder of.....	I, 151
Neilson's Twin Goods Engine, Scotland— <i>Illustration</i>	I, 125
Neolithic Age.....	XI, 55, 61
Neptune's Car.....	XI, 98
Netting— <i>Illustration, Plate I</i>	I, 58-59
“ Basket Rack— <i>Illustration, Plate II</i>	I, 116-117
Newcastle-on-Tyne.....	III, 110, 194
“ Brake Used at.....	I, 291
News Agents.....	V, 419
Newsboy (See also “Trainboy”).....	V, 397
Newspaper Parcels, Way Bills—English.....	V, 247
Newspapers, Advertising in.....	V, 116
“ Carriage of.....	V, 520
“ Comments of.....	V, 117
“ Publication of Time Tables by.....	V, 116
“ Tickets Given to.....	V, 117
Newton, Invention of.....	I, 17
Newton's Experimental Engine, 1680— <i>Illustration</i>	I, 17
New York, Lake Erie & Western Railroad.....	II, 128
“ “ New Haven & Hartford Railroad—Use of Electricity on Nantasket Beach Branch.....	I, 492-495
New Zealand, Baggage Allowed in.....	V, 290
Niagara Falls.....	I, 440
“ “ Power Company.....	I, 440
“ “ “ “ Dynamos of.....	I, 455
“ “ “ “ Use of Electricity by.....	I, 500-504

	PAGE
Niagara Power, Diagram Showing Utilization of.....	I, 503
Nickel, Use of—by Railways.....	VII, 209
Night Signals.....	IV, 263
Trips, Avoidance of.....	I, 57
Nile, Influence of—on Transportation.....	XI, 111
Kinds of Transportation on.....	XI, 107
Nineveh, Transportation of Building Material to.....	XI, 80
Nitroglycerine, Use of—by Railways.....	VII, 214
Noblemaire, G.....	X, 332, 345
No Fire in Heater Steam Jacket— <i>Illustration, Plate II</i> , I, 116—117	
Nomads, Scythian.....	XI, 100
North American Indians—Their Method of Transporting Goods.....	XI, 51
Northeastern Railway.....	I, 56
“Northumbrian” Locomotive.....	I, 29
“ “ Cylinders of.....	I, 46
Norway, Heating Cars in.....	V, 231, 235
Notarial Expenses, Cost of.....	III, 156
Notations on Way Bills.....	IX, 98, 99
Notes, Bank—Transportation of.....	V, 519
Collection of.....	V, 519, 521, 537
Indorsements on.....	IX, 345
Indorsing.....	VII, 445
Renewal of.....	II, 191
Notice to Consignee of Arrival of Freight.....	VI, 196
Notices, of Errors and Omissions in Abstracts—Rules Governing.....	VI, 195
“ “ “ “ “ “ Accounts.....	IX, 39
“ “ “ “ “ “ Summaries—Rules Governing.....	VI, 195
“ “ “ “ “ “ Way Bills—Rules Governing.....	VI, 192—195
“ Posting.....	III, 425
Nova Scotia.....	I, 40
Nozzle, Exhaust— <i>Illustration</i>	I, 65
Stand— <i>Illustration, Plate I</i>	I, 58—59
Tip— <i>Illustration, Plate I</i>	I, 58—59
Number Plate— <i>Illustration</i>	I, 60
“ — <i>Illustration, Plate I</i>	I, 58—59
Numbers, Car.....	VI, 143
“ Way Bill.....	VI, 141
Nurses, Expenditures for.....	II, 232; III, 398
Nuts.....	III, 285
Oak Ties.....	III, 350
Oakum, Use of—in Car Wheels.....	IV, 198
Oannes.....	XI, 10
Obedience, Necessity of.....	II, 18

	PAGE
Obedience, Necessity of—in Railway Service.....	VI, 17
Objections to the Locomotive.....	I, 394
Observation Car, American— <i>Illustration</i>	I, 228
" End of Car— <i>Illustration, Plate II</i>	I, 116-117
Odyssey.....	XI, 83
Office and Laboratory— <i>Illustrations</i>	I, 274, 275
" Audit—Goods and Mineral—English.....	VI, 329-331
" Blue Printing.....	I, 278
" Booking—Meaning of Term.....	IV, 315
" Car Accountant's.....	VI, 67
" Draughting.....	I, 278
" Mechanical Engineer's.....	I, 278
" Station Ledger—English.....	VI, 331, 332
" Supplies, Ordering.....	VII, 186
" Tenure of—in Railway Service.....	II, 100
" The Treasurer's.....	X, 257-290
" Ticket Auditor's.....	X, 121
Offices, Association of—in One Building—Its Result... I, 278, 279	
" Concentration of.....	I, 279
" Destruction of—by Fire.....	IX, 342
" Filling.....	II, 23, 133, 134
" " Petty.....	III, 417
" Great—Intellectual Requirements of.....	II, 120
" Grouping of—in Laboratory.....	I, 278
" Ticket—List of Supplies Required at.....	V, 593
" Train Order—Signals at.....	IV, 391
Officer, Accounting—Assistants of.....	II, 283, 284
" " —Authority of.....	II, 291
" " —Discretion of.....	II, 289
" " —Duties of.....	II, 272-305
" " —His Relation to Other Officers... II, 291, 298	
" " —Meaning of Title.....	II, 141
" " —Office of.....	V, 69, 70
" " —Relation of, to Manager.....	II, 299-301
" " " " Treasurer.....	II, 192, 193
" " —Requirements of.....	V, 72-74
" " —Title of.....	VII, 249
" Audit—of Passenger Accounts.....	V, 81
" Chief.....	II, 133
" " Managing—Dignity of.....	II, 145
" The Railway—Characteristics of.....	II, 167
Officers, Ability of.....	II, 134
" Accounting.....	V, 507; VI, 18; X, 48, 49
" " —Association of American Railway....	
VI, 92; VII, 348, 458, 465, 467, 535; II, 278	
" " —English.....	II, 274
" " —Knowledge Possessed by.....	X, 64
" and Employes, Relations Between.....	II, 27, 28
" Associations of—with Employes.....	I, 225
" Classification of.....	II, 306

	PAGE
Officers, Departmental.....	II, 200
" —Methods of.....	II, 139
" Divisional.....	I, 277
" Duties of.....	II, 135
" —on Different Railways.....	II, 172, 173
" Election of.....	II, 131
" Executive.....	II, 131
" —Duties of.....	II, 74, 75, 132
" Fitness of.....	II, 134
" General.....	II, 65, 117
" Inexperienced.....	II, 88-90
" Intercourse of—with Employes.....	II, 17, 18
" Obligations of.....	II, 21
" Operating—Duties of.....	VII, 264
" Owners Look to.....	II, 92
" Power Exercised by.....	II, 16
" Qualifications of.....	II, 13
" Railroad—in Early Days.....	II, 20
" Railway.....	II, 184; IX, 11-19; X, 203, 204
" —Changes of.....	II, 139
" —Definition of Titles of.....	II, 141, 142
" —Dependence of.....	II, 135
" —Discretion Exercised by.....	V, 321
" —Duties of.....	II, 66, 75, 139, 140
" —Effect of Education on.....	III, 139
" —Integrity of.....	II, 65
" —List of.....	II, 308-320
" —Loyalty of.....	II, 65, 66
" —Standing of.....	II, 135
" —Talent of.....	II, 115, 116
" —Titles of.....	VII, 249-251
" Relation of—to Subordinates.....	II, 13, 16-18
" Salaries of.....	II, 102
" Substitutes for.....	II, 87, 88
" Value of Experienced.....	II, 20
Officials, Baggage Department.....	V, 525
" Changes in.....	II, 89, 90
" Duties and Responsibilities of—in the Machinery Department.....	I, 231
" Government.....	V, 361, 362; VI, 276, 277
" Machinery Department.....	I, 233
" Minor—Wages of.....	III, 418
" Passenger Traffic—Meetings of.....	I, 287, 288
" Public—Furnishing Information to.....	VII, 432
" Qualifications of.....	IX, 146
" Railway—Acceptance of New Ideas by.....	I, 288
" —Authority of.....	II, 113, 114
" —Number of.....	II, 116
" —Value of Discussion Among.....	I, 288
" Rank of—in the Machinery Department.....	I, 231

	PAGE
Officials, Responsibility of	II, 117
“ Signatures of	VII, 431; IX, 428-430
“ Skill of	III, 468
“ Supervisory—Qualifications Required in	III, 416, 417
“ Track	II, 277
Ohio, Maximum Working Hours of Trainmen in	IV, 19
“ Railway Taxation in	III, 449
Ohm, Definition of	I, 401, 402
Ohm's Law	I, 402
Oil Boxes	I, 213
“ Burner	I, 101
“ Can Shelf— <i>Illustration, Plate I</i>	I, 58-59, 64
“ Charging	VII, 320, 321
“ Coal—Handling	VI, 98, 99
“ Comparative Cost of	I, 103
“ Cost of Introduction of—on Locomotives	I, 104
“ Crude	I, 103
“ —Its Use for Locomotives	I, 54
“ Cup for Pump— <i>Illustrations</i>	I, 539
“ Cylinder	I, 366
“ Devices for Use of	I, 101, 102
“ Economy of Use of—for Fuel	I, 263
“ Furnace	I, 256
“ House	I, 245
“ Houses	VII, 123, 124
“ Lamp, Use of—for Lighting Cars	I, 204; IV, 182, 183
“ Mineral Sperm—Use of, for Lighting Cars	IV, 180, 181
“ Pipe— <i>Illustration, Plate I</i>	I, 58-59
“ Plug— <i>Illustration, Plate I</i>	I, 58-59
“ Record of	VII, 320, 321
“ Requisitions for	VII, 119
“ Reservoir	I, 101
“ —Section Showing Fire Box and Tank Arrangement for Its Use as Fuel— <i>Illustration</i>	I, 101
“ Severity of—on Fire Box	I, 104
“ Stock Room	I, 274
“ Oil, Tallow and Waste for Locomotives ”	VII, 486, 519
Oil, Use of—as Fuel for Locomotives	I, 100, 101, 104, 105
“ —for Cleaning Valves, etc.	I, 365, 366
“ —in Early Times	I, 103, 104
“ Wood Creosote	III, 358
Oils, Care of	VII, 114-124, 261
“ Cost of	VII, 116, 117
“ Disbursing	VII, 117, 310
“ Exhibits of	VII, 118
“ Facilities for Storing	I, 269
“ Handling	VII, 119, 120
“ Heating	VII, 123, 124
“ High Priced	VII, 117
“ Inspection of	VII, 114-124

	PAGE
Oils, Manufacture of.....	VII, 120-122
" Precautions Against Loss of.....	VII, 294
" Receiving.....	VII, 284
" Reservoirs for.....	I, 245
" Saving in Use of.....	VII, 116, 118
" Stock of.....	VII, 116, 117
" Storage of.....	VII, 115, 119, 123, 293, 295
" Supplying Stations with.....	VII, 119
" Testing.....	IV, 182
" Tests of.....	I, 277; VII, 120-122
" Unloading.....	VII, 295
" Use of.....	VII, 114-124
" " —by Railways.....	VII, 212, 214
" " —for Lighting Cars.....	IV, 171, 172
Oiling Brake Cylinders.....	I, 329, 331
"Old Ironsides" Locomotive, 1832.....	I, 49
" " 1832—The First Locomotive Built by Matthias W. Baldwin— <i>Illustration</i>	I, 50
Olympia, Games at.....	XI, 85
Olympiad.....	XI, 86
Olympian Court.....	XI, 91
Omissions, from Way Bills.....	VI, 183, 186
Omitting Brake Tests.....	I, 363
Omnibus Lines.....	V, 205
On Time—Meaning of Term.....	IV, 319
Open Clasp, End Door— <i>Illustration, Plate III</i>	I, 170-171
" Side Door— <i>Illustration, Plate III</i>	I, 170-171
" Conduit System.....	I, 468
" Stop, End Door— <i>Illustration, Plate III</i>	I, 170-171
" Side Door— <i>Illustration, Plate III</i>	I, 170-171
" Switch—Meaning of Term.....	IV, 319
Opener, Deck Sash— <i>Illustration, Plate II</i>	I, 116-117
Opening, Saddle— <i>Illustration</i>	I, 98
" Smokestack— <i>Illustration</i>	I, 98
" Gondola— <i>Illustration</i>	I, 98
Operating Accounts.....	III, 404
" " Charges Against.....	VII, 64
" Cost of.....	II, 111, 112; III, 35, 36, 44, 58, 404; VIII, 51, 188
" " —Affected by Facilities.....	III, 427-432
" " " —How Lessened.....	III, 152
" " " —in America.....	III, 146
" " " —England.....	III, 145, 146
" " " —Its Relation to Earnings.....	II, 109, 110
" " " —Relation to Rates.....	III, 43, 52
" Department.....	II, 136, 138; IV, 28; IX, 223
" " Duty of.....	V, 70
" " Organization of.....	II, 173-176
" " Relation of—to the Accounting Department.....	II, 290, 305
" Differences in Cost of—in Different Countries, III, 146	

	PAGE
Operating, Difficulties of.....	II, 118
" Expenses	II, 109
"Operating Expenses" Account.....	VII, 526
Operating Expenses, Apportionment of— as Between Pas- senger and Freight Busi- ness....	X, 154-175
" " " " "—to Divisions.....	VII, 500-524
" " Charges to.....	VII, 456
" " Definition of.....	X, 179
" " Fixed.....	III, 413-426
" " Official Classification of.....	VII, 472-499
" " Reduction of.....	II, 27
" " Relative Cost of—for Steam and for Electricity.....	I, 515
" " Value of Classification of.....	X, 142-147
" " —What They Include.....	X, 62
" Force, Government of.....	II, 71
" " Organization of.....	II, 71
" " Lever— <i>Illustration, Plate II</i>	I, 116-117
"Operating Marine Equipment".....	VII, 491, 492, 522
Operating Officers, Duties of.....	VII, 264
" Percentage of Total Cost of—Due to Maintenance of Organization and the Prevention of De- struction of Property from Natural Causes	III, 493
" Reductions in Cost of.....	X, 145, 146
" Rod, for Release Valve— <i>Illustration</i>	I, 541
" Separation of Ownership from	II, 46
" the Train Air Signal—Instructions to Trainmen	I, 376
Operation, Cost of—Effect on Rates.....	III, 466
" " "—Upon What Dependent.....	III, 388-412
" Influence of Facilities on.....	III, 427-332
" of Railroads by Owners.....	II, 40, 41, 44
" " Questions Regarding the.....	I, 34, 35
" " the Sweeney Brake.....	I, 383
Operations of Engineer's Brake and Equalizing Discharge Valve.....	I, 349-352
" " the Pump Governor.....	I, 352-356
" " " Train Air Signal.....	I, 362
" " " Triple Valve.....	I, 337-346
" " Railway—First Days of.....	I, 234
" " "—Inauguration of, in America.....	I, 28
" " "—Necessities of, in America.....	I, 152
Operatives, Impecunious.....	II, 195, 229
Operators, Telegraph—Examination of.....	IV, 329
" " "—Rules Governing.....	IV, 435-439
Opportunities of Those Who Work for Railways	IX, 11-19

	PAGE
Opposition, Effect of.....	I, 227
Order, Inauguration of.....	XI, 29
" Maintenance of.....	XI, 31
Orders. (See also "Requisitions.")	
" Coupon—English.....	V, 239
" Disobedience of.....	IV, 329
" Exchange.....	V, 205
" Execution of.....	VI, 108
" Filing.....	IV, 333
" for Switching.....	VI, 255-258
" " Wages.....	X, 205, 231
" General—Issuing.....	IX, 41
" Material—Details of.....	VII, 83
" " —Excessive.....	VII, 64
" " —Filling.....	VII, 177, 179
" " —for Brasses.....	VII, 137
" " " Tools.....	VII, 152
" " —Foremen's.....	VII, 83
" " —How They Differ from Requisitions..	VII, 77
" " —Necessity of Promptness in Filling..	VII, 53
" " —Notations on.....	VII, 84
" " —Numbering.....	VII, 87
" " —Passing Upon.....	VII, 66, 67
" " —Preservation of.....	VII, 84, 311
" " —Rules Governing.....	VII, 77-88
" " —Writing.....	VII, 177, 178
" on Paymasters.....	VII, 411-413; IX, 400, 401
" " for Guaranty Premiums.....	IX, 171, 172
" Payment of—by Agents.....	IX, 180
" Specific—Reiteration of.....	IX, 33
" Telegraphic.....	IV, 383-400
" Ticket—Agents'.....	V, 146-150
" Train.....	IV, 358, 359
" " —Details of.....	IV, 84-86
" " —Forms of.....	IV, 465-478
" " —Miscellaneous.....	IV, 376-383
" " —Precedence of.....	IV, 395
" " —Repeating.....	IV, 397
" Transmission of.....	IV, 385-388
" Written.....	IV, 395
Orderliness, Necessity of.....	II, 21, 22
Ore Car— <i>Illustration</i>	I, 162
" Weighing—Rules Governing.....	VI, 149
Ores, First Use of.....	I, 132
Organization, Changes in Personnel of.....	III, 416
" Cost of.....	III, 468
" " Maintaining.....	III, 464
" Department of Equipment.....	II, 305a-305r
" Details of Railway.....	II, 128-140

	PAGE
Organization, Diversity in—of Different Corporations . . . II,	125
“ Efficient—Good Gov't Dependent on . . . II,	122-127
“ Expenditures III,	414
“ Expenses of III,	425
“ Fixed Expenses of III,	469, 470
“ for the Care of Cars I,	270
“ General Outline of II,	70
“ Impersonal—of Railways II,	127
“ Labor—of Car Repair Shops I,	276
“ of Accounts IX, 46; X,	35-59
“ Methods of—Origin of II,	125, 126
“ of Labor I,	237
“ “ in Locomotive Repair Shops I,	267
“ “ “ Repair Shops I,	264
“ Corporate Property II,	58, 59
“ Railroads, About Shops I,	229
“ Railways II, 110, 120, 143, 153; V,	321
“ Roadway Department III,	258-260
“ Shops I, 237, 283, 284	
“ Supply Department VII,	70
“ the Freight Service VI, 11, 12,	22
“ Preservation of Nucleus of III,	464
“ Principles of II,	91-95
“ Railway II	
“ Systematic II,	125
Organizations, Builders of II,	126
“ Elasticity of III,	420, 421
“ Power of II,	39
“ Railway—Rivalry in II,	124
Organized Civilization I,	136
“ Labor II,	18
“ Strength of II,	40
Origin and Development of Great Manufacturing Plants . . I,	127
“ Evolution of Transportation XI	
“ of Railways III,	110
“ “ the Brake I,	291
Oscillation of Pipes I,	381
Osiris XI,	10
“Other Expenses” . . . VII, 479, 484, 485, 495, 497, 516, 518, 523, 524	
“Other Supplies for Locomotives” VII,	486, 519
Outlay, Comparisons of I,	287
“ Shop—How Reduced I,	287
“Outside Agencies” VII,	493, 522
Outside Body Transom Pillar— <i>Illustration, Plate II</i> . . I,	116-117
“ Brake Beam Fulcrum— <i>Illustration, Plate II</i> . . I,	116-117
“ Casing— <i>Illustration, Plate II</i> I,	116-117
“ Connecting Rod— <i>Illustration, Plate II</i> I,	116-117
“ Cylinders I,	46, 87
“ Hung Brake I,	379
“ Nailing Strip— <i>Illustration, Plate III</i> I,	170-172

	PAGE
Owners, Railway—Capacity of	VIII, 170
“ “ —Characteristics of	VIII, 303-305
“ “ —Methods of	VIII, 33
“ “ —Relation to Public	VIII, 196
“ “ —Right of, to Manage Their Properties	VIII, 161
“ “ —Their Interest in Safety Appliances	IV, 109, 110
“ Relation of—to Employes	III, 472-475
“ —Their Incentive to Foster Business	III, 425, 426
“ Value of Returns to	II, 265
Ownership, Changes of	II, 139
“ Government. (See also “Government Ownership”)	III, 45
“ “ —in France	III, 46, 47
“ “ —Objections to	VII, 11, 12
“ of the Soil	XI, 30
“ Private—Evolution of	XI, 38
“ “ —of Realty	XI, 30
“ Railway	II, 74
“ Separation of—from Operating	II, 46
Oxidation, Effect of	III, 272-279
“ Prevention of	III, 273, 274
Packages, Baggage—Fastening	V, 325
“ Carriage of—by Conductors	IV, 406
“ Express—Unclaimed	V, 346
Packing, Metallic	I, 85, 88
“ Piston— <i>Illustration, Plate I</i>	I, 58-59
“ Pump	I, 381
“ Piston— <i>Illustration, Plate I</i>	I, 58-59
Pad, Expansion— <i>Illustration, Plate I</i>	I, 58-59
Paint Room	I, 274
“ Shop, Freight Car	I, 271
“ “ Passenger Car	I, 271
“ “ “ —Cross Section— <i>Illustration</i> ..	I, 269
“ “ “ —End Elevation— <i>Illustration</i> ..	I, 269
“ “ “ —Side Elevation— <i>Illustration</i> ..	I, 267
“ Shops	I, 251, 252, 257, 272-274
“ Material at	VII, 309
“ Storing	VII, 293
Paints	III, 481, 482
“ Tests of	I, 277
“ Use of—by Railways	VII, 214
Painting Locomotives	I, 252
Palace Car, American—Apartments in— <i>Illustration</i>	I, 223
“ “ An Apartment in— <i>Illustration</i>	I, 222
“ “ Companies	I, 196-199

	PAGE
Palace Car, for Day and Night Use—American— <i>Illustration</i>	I, 224
“ “ Interests, Growth of.....	I, 199
“ “ Popularity of	I, 201
“ Cars.....	I, 148, 182
Palæolithic Age.....	XI, 47, 58
“ “ People of the	XI, 55
Pan, Ash.....	I, 246
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ Dump— <i>Illustration, Plate II</i>	I, 116-117
“ Warming	I, 204
Pans, Portable.....	I, 246
Panel, Bunk— <i>Illustration, Plate II</i>	I, 116-117
“ Front— <i>Illustration, Plate II</i>	I, 116-117
“ Feeder.....	I, 461
“ Generator.....	I, 460
“ Load	I, 461
“ Wainscot— <i>Illustration, Plate II</i>	I, 116-117
“ Window— <i>Illustration, Plate II</i>	I, 116-117
Panels, Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Lower Door— <i>Illustration, Plate II</i>	I, 116-117
“ Middle Door— <i>Illustration, Plate II</i>	I, 116-117
“ Rocker— <i>Illustration, Plate II</i>	I, 116-117
“ Smoking Room— <i>Illustration, Plate II</i>	I, 116-117
Panic, Monetary—Effect of.....	VIII, 20
Panniers, Carriage of Women in.....	XI, 153
Paper, as Circulating Medium.....	III, 16
“ Gaskets.....	I, 371
“ Money.....	III, 11
“ Promises, Issuance of.....	III, 17
“ Use of—for Baggage Way Bills.....	V, 491
“ “ “ Brake Shoes.....	I, 302
“ “ “ —in Car Wheels.....	IV, 198, 200
“ Waste—Disposition of.....	IX, 432
Papers, Attached to Vouchers. VII, 434, 435, 439; IX, 377; X, 94	
“ Filing	VII, 431
“ Old—Disposition of.....	VII, 305; IX, 291, 432
“ Preservation of.....	IX, 42, 43
“ Traffic—Preservation of.....	VII, 142
“ Treasurer’s—Care of.....	X, 271, 272
“ Valuable—Remitting	IX, 430
Parallel Rod or Side— <i>Illustration, Plate I</i>	I, 58-59
Parcel Cash Book, English.....	V, 250, 251
“ Rooms, Rules Governing.....	V, 429, 430
“ Summaries and Returns, English.....	V, 265, 266
“ Tickets, Use of.....	V, 471-477
“ Traffic.....	V, 454-461, 468, 517-536; VI, 9
“ “ English.....	V, 246
“ “ Expenses Attending.....	V, 529-528
“ “ —What It Embraces.....	V, 517

	PAGE
Parcel Warehouse Book, English.....	V, 249
Parcels Delivery Book, English.....	V, 248
" Insurance of—in England.....	V, 249
" Way Bills, English.....	V, 247
Paris, Lyons & Mediterranean Railway.....	III, 362, 364; X, 332
Parlor Car, American— <i>Illustration</i>	I, 219
" " Passengers.....	V, 206, 207
" " Tickets.....	V, 95
" Cars.....	I, 174, 194, 195; V, 212, 221
" " American.....	I, 200
" " Use of Electricity for Lighting.....	IV, 179
Particularizing Work.....	I, 285, 286
Particulars of Construction.....	III, 152-166
Parties, Theatrical—Baggage Tickets for.....	V, 471
Parting Strip— <i>Illustration, Plate III</i>	I, 170-171
Partition Berth— <i>Illustration, Plate II</i>	I, 116-117
Partitions, of Masonry.....	I, 272
Parts of the Locomotive.....	I, 530-532
" Repair—Instructions to Car Inspectors.....	I, 332
Passage Tickets. (See also "Tickets").....	I, 332
" " English.....	II, 255, 256; V, 88; IX, 108-123
" " Evolution of.....	V, 237-240
" " Importance of.....	V, 71-78
" " Origin of.....	V, 75
" " Preparation of.....	V, 66-70
" " Systemization of.....	II, 257
" " Systemization of.....	V, 79-87
Passenger Accommodations, in America.....	V, 31, 32
" Accounts.....	II, 248
" " Auditing.....	IX, 117
" " Auditor of.....	V, v, 81
" and Freight Car Repair Shop, Section and End Elevation— <i>Illustration</i>	I, 255
" " " " Repair Shop, Side Elevation— <i>Illustration</i>	I, 252
" " Sleeping Car, American Standard— <i>Illustration, Plate II</i>	I, 116-117
" Business, Procurement of.....	V, 112-115
" " Receipts from.....	V, 172
" Brakemen, Rules Governing.....	IV, 417, 418
" Car, American Standard— <i>Illustration</i>	I, 215
" " First Class—German— <i>Illustration</i>	I, 214
" " Paint Shop.....	I, 271
" " " Cross Section— <i>Illustration</i>	I, 269
" " " End Elevation— <i>Illustration</i>	I, 269
" " " Side Elevation— <i>Illustration</i>	I, 267
" " Shop.....	I, 274
" Cars.....	I, 156, 197, 269
" " Construction and Maintenance of—Important Details.....	I, 178

	PAGE
Passenger Cars, Decorations of—in America.....	I, 147
“ “ English.....	III, 147
“ “ Erecting Shop for.....	I, 271
“ “ First Design of.....	I, 174
“ “ High Class—in America.....	I, 181, 182
“ “ Joint Use of.....	V, 26
“ “ Requirements of.....	I, 181
“ “ Suburban.....	I, 177, 178
“ Coach, American Standard— <i>Illustration</i>	I, 216
“ Coaches.....	I, 203
“ Conductors.....	VI, 14
“ “ Rules Governing.....	IV, 406-409
“ Department, Attaches of.....	V, 17, 18
“ “ Authority of.....	II, 252
“ “ Machinery of.....	II, 253
“ Earnings, Daily Exhibits of.....	V, 156-158
“ “ Definition of.....	X, 177
“ Engine, Bogie— <i>Illustration</i>	I, 132
“ “ —Description of.....	I, 66
“ “ First Ten-Wheeled—“Thatcher Perkins.” 1863— <i>Illustration</i>	I, 45
“ “ Suburban.....	I, 303
“ “ Through.....	I, 303
“ Engines, Weight on Drivers of.....	I, 64
“ Equipment, Advance in.....	I, 165
“ Locomotive and Tender, Belgian— <i>Illustration</i>	I, 136
“ “ Baldwin Single Driver— <i>Illustration</i>	I, 142
“ “ Eight-Wheel— <i>Illustration</i>	I, 114
“ “ German Rapid Transit — Warschau- Wien Railroad— <i>Illustration</i>	I, 131
“ “ Italian—Inside Connected— <i>Illustra- tion</i>	I, 120
“ Rates.....	V, 120-123
“ “ in Europe.....	V, 25
“ “ the United States.....	V, 25
“ Receipts, Protection of.....	IX, 112, 113
“ Records.....	V, 172
“ Returns.....	V, 172, 173
“ “ Auditing.....	X, 121-134
“ Service.....	V, 11-273
“ “ Adaptability of.....	V, 14, 15
“ “ Changes Affecting.....	V, 21
“ “ Comparison of English and American...	V, 30, 31
“ “ “ “ European and American Practices.....	V, 22-26
“ “ Difference of—from Freight Service.....	IV, 17
“ “ Familiarity with Needs of.....	V, 22
“ “ in Austria.....	V, 223-229

	PAGE
Passengers—Number Per Head of Population, in European	
" " " " " " " Russia, V,	24
" " " " " " " France .. V,	24
" " " " " " " Germany, V,	24
" " " " " " " Great Brit-	24
" " " " " " " ain. ... V,	24
" " " " " " " United	24
" " " " " " " States, V,	24
" " " " " " " Mile of Road, in Belgium..... V,	24
" " " " " " " France..... V,	24
" " " " " " " Germany..... V.	24
" " " " " " " Holland..... V,	24
" " " " " " " United King-	24
" " " " " " " dom..... V,	24
" " " " " " " United States, V,	24
" on Freight Trains.....	V, 150-156
" Parlor Car.....	V, 206, 207
" Peculiarities of.....	V, 409-414
" Personal Safety of.....	V, 29
" Protection of.....	IV, 121
" Quantity of Baggage Carried by.....	V, 456
" Rebates Allowed.....	V, 86
" Safety of.....	I, 178
" Sleeping Car.....	V, 206, 207
" Suburban.....	V, 409, 410
" Third-Class.....	I, 169, 170
" Ticketing.....	V, 130-136
" " —Early Methods of.....	V, 76, 77
" " —Way Bills for.....	V, 76
" Passes.....	II, 92; V, 43-45
" " Abuse of.....	V, 43, 44
" " Granting—to Employees.....	VII, 138
" " Improper Use of.....	V, 174, 175
" Passing Place—Meaning of Term.....	IV, 319
" Pasteur.....	III, 356
" Patent Covering Improvements in the Air Brake.....	I, 307
" Path, The First—How Formed.....	XI, 49
" Patroclus.....	XI, 91
" Patrons, Cars Owned by.....	VI, 49, 69-74
" " Influence of Agents on.....	IX, 76
" " Suburban.....	V, 40, 41
" Patternmakers.....	I, 274
" Patterns, Changes in.....	VII, 81
" " Multiplicity of.....	I, 284
" " Storing.....	VII, 294
" Pawnbrokers, Railways Acting as.....	V, 139-144
" Pawl, Hand Brake— <i>Illustration, Plate III</i>	I, 170-171
" Pay Accounts.....	VII, 353, 354
" " Access to.....	VII, 369
" " Cars, Appliances of.....	X, 220

	PAGE
Pay Cars, Care of.....	X, 221, 252
" Protection of.....	X, 223-227, 231
" Deductions from—of Employes.....	VII, 385-387, 392
" Rolls.....	I, 267; II, 98
" Access to.....	X, 222
" Auditing.....	X, 69
" —by Whom Made.....	X, 86, 87
" Certification of.....	VII, 394-396
" —by Foremen.....	X, 205
" Deductions from.....	VII, 420
" Distribution of.....	I, 280
" Engineers' and Firemen's.....	VII, 393, 394
" Examination of.....	VII, 394, 395; X, 90
" —by Paymasters.....	X, 222, 223
" Fictitious Entries on.....	X, 200, 204, 205
" Making.....	VII, 356-359, 369-371, 389-394
" Payment of.....	II, 194; VII, 388-397; X, 223-225, 276
" Protection of.....	X, 222
" Remainder.....	X, 228, 251
" Verifying.....	VII, 396, 397
" Sheets, Time Ticket.....	IX, 387
Payee, Agreement of—on Time Tickets.....	VII, 399, 400
Paying Vouchers.....	VII, 437-441
Paymasters, Accounts of.....	X, 238
" Authority of.....	X, 227
" Duties of.....	X, 202, 206, 228
" Employment of.....	X, 215, 216
" Examination of Pay Rolls by.....	VII, 395
" Importance of.....	X, 219
" Multiplication of.....	X, 200
" Orders on.....	VII, 411-413; IX, 400, 401
" " —for Guaranty Premiums.....	IX, 171, 172
" Qualifications of.....	X, 207, 219
" Responsibility of.....	X, 253
" Sending Pay Rolls to.....	X, 90
" Supervisor of.....	X, 261
" Transference of Money by.....	X, 226, 227
Payment of Wages.....	I, 280; X, 185-253
Payments, Made by Agents.....	IX, 326, 327
" Making.....	IX, 434
" Money.....	IX, 297; X, 92-95
Pear-Headed Rail, A. D. 1853— <i>Illustration</i>	III, 242
" " Buffalo, Corning & New York Railroad, A. D. 1855— <i>Illustration</i>	III, 261
" " New York Central Railroad, A. D. 1855— <i>Illustration</i>	III, 248
" " New York & Erie Railroad, A. D. 1855— <i>Illustration</i>	III, 249
" " Saratoga & Schenectady Railroad, A. D. 1855— <i>Illustration</i>	III, 250

	PAGE
Pedestal— <i>Illustration, Plate II</i>	I, 116-117
“ <i>Brace—Illustration, Plate I</i>	I, 58-59
“ “ <i>—Illustration, Plate II</i>	I, 116-117
“ “ <i>Engine Truck—Illustration, Plate I</i>	I, 58-59
“ <i>Engine Truck—Illustration, Plate I</i>	I, 58-59
“ <i>Stay Rod—Illustration, Plate II</i>	I, 116-117
“ <i>Tie Bar—Illustration, Plate II</i>	I, 116-117
Pegasus.....	XI, 86
Peloponnesus Railroad Car, for Small Cattle— <i>Illustration</i> ..	I, 190
Pelts, Charges Collected for.	VII, 414, 421, 422; IX, 426
Pencil, Use of.....	VI, 314
Penelope.....	XI, 83
Pens, Manifolding—Use of.....	VI, 202
Pensions.....	II, 266, 267
Pennsylvania Railroad.....	III, 183; V, 17
“ “ Company.....	I, 100
“ “ Relief Department of..	X, 296, 299, 303-307
“ “ Savings Fund of.....	X, 317
“ “ Use of Electricity on.....	I, 490-492
Pension Funds.....	X, 321-323
“ “ French.....	X, 329-345
“ “ in Great Britain.....	X, 326-328
“ “ India.....	X, 350-352
“ “ Italian.....	X, 347-349
Pensons.....	X, 297
Per Diem Charge for Use Foreign Cars.....	VI, 76
Perfected Air Brake, The.....	I, 333-363
Performance, Daily—of Freight Cars.....	VI, 53
“ of Locomotives.....	X, 100-108
Pericles.....	XI, 90
Periodicals, Carriage of.....	V, 520, 521
Perishable Goods Car, New South Wales— <i>Illustration</i>	I, 188
“ Property, Disposition of.....	II, 242
“ “ Guaranteeing Freight Charges on..	VI, 95
“ “ Unclaimed.....	V, 346
“ “ Way Bills.....	VI, 138
Permanent Danger Signals.....	IV, 367
“ Expenditures.....	VII, 525
“ Signals.....	IV, 261
“ Way.....	III, 314-317
“ “ Committee.....	II, 131
“ “ English—Section of— <i>Illustration</i>	III, 313
“ “ —Meaning of the Term.....	III, 130
“ “ Primary Purpose of.....	III, 110
“ “ Strength of.....	III, 195
“ “ —What It Represents.....	III, 189, 190
Permissive Block System.....	IV, 293
Permits, Baggage.....	V, 466, 467, 495
“ Half Fare.....	V, 120-123
“ “ —Rules Governing.....	V, 123

	PAGE
Permits, Improper Use of.....	V, 174, 175
Persia—Its Primitive Associations and Means of Carriage . . .	XI, 342-346
" Primitive Carriage in— <i>Illustrations</i>	XI, 342-346
" Worship of Fire in	I, 104
Persians, Horses of	XI, 87
Persons Injured, Claims for.....	II, 232
" Killed, Claims for	II, 232
Personal Property, Care of.....	VII, 297, 299
Peru, Use of Petroleum in.....	I, 104
Petit-Bourg.....	I, 215, 216
Petroleum, Gas Made from.....	IV, 174
" Use of—for Fuel.....	I, 104
" " " Locomotives.....	I, 102, 103
Petticoat or Draft Pipe— <i>Illustration, Plate I</i>	I, 58-59
Petty Repairs, Articles for Making	I, 270
" Supplies, Charging.....	VII, 321
Pheron	XI, 100
Philadelphia.....	I, 190, 191
Philætus.....	XI, 83
Phillip of Macedon	XI, 87
Phillips, Isaac N.....	X, 173
Phœnicians	XI, 114, 117, 120-125
" Ships of	XI, 133
" Trade of.....	XI, 131, 134
" Transportation Forms Among.....	XI, 117
"Phœnix" Locomotive.....	I, 33
Phoroneus.....	XI, 10
Phraseology, Train.....	IV, 314-324
Physical Tests.....	I, 277
Pictorial Writing	XI, 118
Pictures, Costly—Transportation of.....	V, 519
Piece of Frame, Tail— <i>Illustration, Plate I</i>	I, 58-59
Piecework	I, 284
Pierson, S. F.....	II, 253
Pilaster— <i>Illustration, Plate II</i>	I, 116-117
" Base— <i>Illustration, Plate II</i>	I, 116-117
" Cap— <i>Illustration, Plate II</i>	I, 116-117
Pilasters.....	I, 253
Pile Drivers.....	I, 378
Piles, Purchase of.....	VII, 288, 289
" Receipt of.....	VII, 288, 289
Piling.....	III, 129
Pillar, Center Bearing—Body Transom— <i>Illustration, Plate II</i>	I, 116-117
" Side Bearing—Body— <i>Illustration, Plate II</i>	I, 116-117
" Transom—Intermediate Body— <i>Illustration, Plate II</i>	I, 116-117
" " Outside Body— <i>Illustration, Plate II</i>	I, 116-117
Pillow Box— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Pillows, Berth— <i>Illustration, Plate II</i>	I, 116-117
Pilot.....	I, 56, 57, 109
“ — <i>Illustration</i>	I, 60
“ — <i>Illustration, Plate I</i>	I, 58-59
“ Bracket— <i>Illustration, Plate I</i>	I, 58-59
Pin, Brake Hanger— <i>Illustration, Plate II</i>	I, 116-117
“ Center— <i>Illustration, Plate II</i>	I, 116-117
“ “ Stem— <i>Illustration, Plate II</i>	I, 116-117
“ Crosshead— <i>Illustration, Plate I</i>	I, 58-59
“ Graduating— <i>Illustration</i>	I, 344
“ “ Valve— <i>Illustration</i>	I, 341
“ Knuckle— <i>Illustration, Plate II</i>	I, 116-117
“ Lifter Bracket, Deadwood— <i>Illustration, Plate III</i> , I, 170-171	
“ “ “ End Sill— <i>Illustration, Plate III</i> ...I, 170-171	
“ “ Chain— <i>Illustration, Plate III</i>	I, 170-171
“ “ Clevis— <i>Illustration, Plate III</i>	I, 170-171
“ “ Rod— <i>Illustration, Plate III</i>	I, 170-171
“ Side Pocket— <i>Illustration, Plate II</i>	I, 116-117
“ Valve.....	I, 352, 353
Pins.....	I, 381
Pine Ties.....	III, 350
Pintsch Gas Light— <i>Illustration</i>	IV, 174
“ “ System.....	IV, 173, 174
“ Lights.....	I, 204
“ System of Lighting.....	V, 37
“Pioneer,” 1836—One of Baldwin’s Early Engines— <i>Illustration</i>	I, 39
“ Sleeping Car.....	I, 194, 197
Pipe, Air Delivery—from Pump to Main Reservoir— <i>Illustration</i>	I, 539
“ “ —from Main Reservoir to Engineer’s Valve— <i>Illustration</i>	I, 539
“ “ Pump Exhaust— <i>Illustration, Plate I</i>	I, 58-59
“ “ Signal—Leaks in.....	I, 376
“ Branch— <i>Illustrations, { Plate I</i>	I, 58-59
“ “ —to Triple Valve— <i>Illustration</i>	I, 541
“ “ —Triple Valve to Auxiliary Reservoir— <i>Illustration</i>	I, 540
“ Cold Water— <i>Illustration, Plate II</i>	I, 116-117
“ Connection, Train— <i>Illustration, Plate I</i>	I, 58-59
“ Continuous Line of.....	I, 299
“ Cross Over.....	I, 324
“ Culvert— <i>Illustration</i>	III, 368
“ Dry.....	I, 286
“ — <i>Illustration, Plate I</i>	I, 58-59
“ “ Steam.....	I, 76
“ Exhaust Steam— <i>Illustration</i>	I, 539
“ Feed— <i>Illustration, Plate I</i>	I, 58-59
“ Filling— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Pipe, Floor— <i>Illustration, Plate II</i>	I, 116-117
“ “ Hanger, Feed— <i>Illustration, Plate I</i>	I, 58-59
“ Hangers— <i>Illustration, Plate II</i>	I, 116-117
“ “ Dry— <i>Illustration, Plate I</i>	I, 58-59
“ Hose, Signal— <i>Illustration, Plate I</i>	I, 58-59
“ Hot Water Circulating— <i>Illustration, Plate II</i> . . .	I, 116-117
“ Joint, Dry— <i>Illustration, Plate I</i>	I, 58-59
“ Joints	I, 330
“ Lubricator— <i>Illustration</i>	I, 60
“ Oil— <i>Illustration, Plate I</i>	I, 58-59
“ Pressure Retaining Valve— <i>Illustration, Plate III</i> . . .	I, 170-171
“ Radiating— <i>Illustration</i>	IV, 158
“ Sand— <i>Illustration, Plate I</i>	I, 58-59
“ Signal	I, 374, 379
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ Smoke— <i>Illustration, Plate II</i>	I, 116-117
“ Stand— <i>Illustration, Plate I</i>	I, 58-59
“ Steam	I, 286, 309
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ Circulating— <i>Illustration, Plate II</i>	I, 116-117
“ “ —to Pump— <i>Illustration</i>	I, 539
“ Supply— <i>Illustration, Plate II</i>	I, 116-117
“ Throttle— <i>Illustration, Plate I</i>	I, 58-59
“ to Bowl, Cold Water— <i>Illustration, Plate II</i>	I, 116-117
“ “ Hot Water— <i>Illustration, Plate II</i>	I, 116-117
“ “ Lamps— <i>Illustration, Plate II</i>	I, 116-117
“ “ Pressure Retaining Valve— <i>Illustration</i>	I, 541
“ “ Triple Valve— <i>Illustration, Plate II</i>	I, 116-117
“ Train	I, 307-310, 315, 320, 329, 330, 379
“ “ — <i>Illustrations,</i> { <i>Plate I</i>	I, 58-59
“ “ { <i>Plate III</i>	I, 170-171
“ “ {	I, 539-541
“ “ Brake— <i>Illustration, Plate II</i>	I, 116-117
“ “ Cocks in	I, 321, 323, 324
“ “ Signal— <i>Illustration, Plate II</i>	I, 116-117
“ Vent— <i>Illustration, Plate II</i>	I, 116-117
“ Water	I, 106
“ “ — <i>Illustration, Plate I</i>	I, 58-59
Piped Cars	I, 373
Pipes	I, 286
“ Air—for Testing Purposes	I, 382
“ “ —in Engine House	I, 328
“ Arch Support—Plugs at— <i>Illustration</i>	I, 64
“ Branch	I, 336
“ Broken and Leaky—Cause of	I, 376
“ Carrying Dry Steam to Live Steam Channel— <i>Illustration</i>	I, 65
“ Exhausting Air from	I, 299
“ Leaky	I, 371

	PAGE
Pipes, Signal.....	I, 362
“ Steam.....	I, 285
Piping.....	I, 262, 379
“ Locomotive.....	I, 380, 381
“ Steam.....	I, 241, 242
Piston— <i>Illustration</i>	I, 65
“ Air.....	I, 352, 353
“ and Stem— <i>Illustrations</i>	I, 341, 344
“ Brake.....	I, 313, 334
“ “ Cylinder.....	I, 332
“ “ —Power Exerted by.....	I, 377
“ Emergency— <i>Illustration</i>	I, 344
“ Equalizing.....	I, 328
“ Head— <i>Illustration, Plate I</i>	I, 58-59
“ Leathers.....	I, 331
“ Movement of—in Cylinder.....	I, 85, 86
“ Packing— <i>Illustration, Plate I</i>	I, 58-59
“ “ Pump— <i>Illustration, Plate I</i>	I, 58-59
“ “ Ring— <i>Illustration</i>	I, 341
“ “ Rings— <i>Illustration, Plate I</i>	I, 58-59
“ Rod.....	I, 86, 329
“ — <i>Illustration, Plate I</i>	I, 58-59
“ (or Push) Rod Crosshead— <i>Illustration</i>	I, 540
“ Rod Crosshead— <i>Illustration, Plate II</i>	I, 116-117
“ Rods, Packing of.....	I, 381
“ Section of— <i>Illustration</i>	I, 83
“ Stroke of.....	I, 83
“ The Ramsbottom.....	I, 86
“ Travel.....	I, 329, 332, 336
“ “ — <i>Illustrations</i>	I, 358, 359
“ “ —Its Effect on Braking Power.....	I, 356-361
“ Triple Valve.....	I, 338-340
Pistons.....	I, 85, 86, 286, 305, 329, 331
“ Brake.....	I, 315
“ Metallic.....	I, 85
“ Steam Pressure on.....	I, 67
“ Velocity of.....	I, 67
Pit, Annealing.....	IV, 204
“ Ash— <i>Illustration, Plate II</i>	I, 116-117
“ Clinker.....	I, 246
Pits.....	I, 241, 242, 254, 255
“ Clinker or Ash—Pneumatic Hoist for Emptying— <i>Illustration</i>	I, 278
“ Depressed.....	I, 246
“ Drop.....	I, 244
“ “ —Pneumatic.....	I, 344
Pivot Bearing Spring Hanger— <i>Illustration, Plate II</i>	I, 116-117
“ Deck Sash— <i>Illustration, Plate II</i>	I, 116-117
“ Swing Hanger, Lower— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Upper— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Plain Automatic Brake.....	I, 325
“ “ Triple Valve.....	I, 340-344
“ “ “ —Illustrations.....	I, 325, 341
“ Brake Shoes.....	I, 303, 304
“ Straightway Cock—Illustrations.....	I, 322, 372
“ Triple Valve.....	I, 373
“ Vacuum Brake.....	I, 292
Plan for Car Repair Shops—Illustration.....	I, 242
“ “ Locomotive Repair Shops—Illustration.....	I, 239
“Planet” Locomotive, 1830.....	I, 30
“ “ “ Cylinders of.....	I, 46
Planing Mill.....	I, 271-274
“ “ Car Department, Side Elevation—Illustration, I,	260
“ “ Section and End Elevation—Illustration.....	I, 261
“ “ Tools for.....	I, 243
Plank Cap, Truss—Illustration, Plate II.....	I, 116-117
“ Spring—Illustration, Plate II.....	I, 116-117
Plant, Power.....	I, 252, 253, 263, 273
“ “ —Central.....	I, 243
“ “ —Riveting Hydraulic.....	I, 262
Plants, Station.....	I, 437
“ “ Testing—Yard.....	I, 382
Plate—Illustration, Plate II.....	I, 116-117
“ Balance—Illustration, Plate I.....	I, 58-59
“ Body End—Illustration, Plate II.....	I, 116-117
“ Boiler—Inspection of.....	I, 278
“ Buffers, Face—Illustration, Plate II.....	I, 116-117
“ Center—Body—Illustration, Plate II.....	I, 116-117
“ “ —Truck—Illustration, Plate II.....	I, 116-117
“ Chafing—Check Chain—Illustration, Plate II.....	I, 116-117
“ “ —Spring Beam—Illustration, Plate II.....	I, 116-117
“ “ —Transom—Illustration, Plate II.....	I, 116-117
“ “ —Truck Bolster—Illustration, Plate II.....	I, 116-117
“ Corner—End Sill—Illustration, Plate II.....	I, 116-117
“ “ —Iron—Illustration, Plate III.....	I, 170-171
“ “ —Transom—Illustration, Plate II.....	I, 116-117
“ Crown.....	I, 96
“ Deck—Illustration, Plate II.....	I, 116-117
“ Deflector—Illustration, Plate I.....	I, 58-59
“ Diaphragm Face—Illustration, Plate II.....	I, 116-117
“ End—Illustration, Plate III.....	I, 170-171
“ “ Piece—Illustration, Plate II.....	I, 116-117
“ Foot—Illustration, Plate II.....	I, 116-117
“ Frame.....	I, 53
“ Gravity Bar—Front Face—Illustration, Plate II, I,	116-117
“ Guide—Bottom Face—Illustration, Plate II.....	I, 116-117
“ “ —Top Face—Illustration, Plate II.....	I, 116-117
“ Handle, Safety—Illustration, Plate II.....	I, 116-117
“ Inner Face—Illustration, Plate II.....	I, 116-117
“ Layers.....	I, 22

	PAGE
Plate, Number— <i>Illustration, Plate I</i>	I, 58-59
“ Short Buffer— <i>Illustration, Plate II</i>	I, 116-117
“ Side— <i>Illustration, Plate III</i>	I, 170-171
“ Table Hook— <i>Illustration, Plate II</i>	I, 116-117
“ Threshold— <i>Illustration, Plate II</i>	I, 116-117
“ Transom—Middle— <i>Illustration, Plate II</i>	I, 116-117
“ “ —Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Truck Bolster— <i>Illustration, Plate III</i>	I, 170-171
“ Wheel—Outside— <i>Illustration, Plate II</i>	I, 116-117
Plates	III, 301
“ Barrel— <i>Illustration</i>	I, 98
“ Center	I, 214
“ “ Bearing Beam— <i>Illustration, Plate II</i>	I, 116-117
“ Diaphragm	I, 108
“ Iron—Laminated	I, 457
“ Tie	III, 213
“ “ —Use of	III, 332, 333, 352
“ Transverse	I, 108
Platform End Sill— <i>Illustration, Plate II</i>	I, 116-117
“ Floor— <i>Illustration, Plate II</i>	I, 116-117
“ Gate— <i>Illustration, Plate II</i>	I, 116-117
“ Hand Brake— <i>Illustration, Plate III</i>	I, 170-171
“ Hood— <i>Illustration, Plate II</i>	I, 116-117
“ Rail— <i>Illustration, Plate II</i>	I, 116-117
“ Railing Chain— <i>Illustration, Plate II</i>	I, 116-117
“ “ Post— <i>Illustration, Plate II</i>	I, 116-117
“ Roof— <i>Illustration, Plate II</i>	I, 116-117
“ “ Carline— <i>Illustration, Plate II</i>	I, 116-117
“ “ End Carline— <i>Illustration, Plate II</i>	I, 116-117
“ Short Sill— <i>Illustration, Plate II</i>	I, 116-117
“ Sill— <i>Illustration, Plate II</i>	I, 116-117
“ Step Riser— <i>Illustration, Plate II</i>	I, 116-117
“ The “Miller”	IV, 120
“ Tie Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Trap Door— <i>Illustration, Plate II</i>	I, 116-117
Platforms	I, 252, 274
“ Influence of—on Cost of Maintenance	III, 383
Platinum, Use of—by Railways	VII, 209
Pleasure Parties' Tickets, English	V, 239
Pledges, Acceptance of—Rules Governing	V, 142-144, 450-452
“ Property—for Sums Due Railways	V, 139-144
“ Receipts for	V, 143
Pliny	XI, 28
Plow, Introduction of	XI, 37
“ Steam Snow— <i>Illustration</i>	I, 147
“ Snow—Use of	III, 302-305
Plowing, by Steam	I, 215
Plug, Boiler Fuse—Section of— <i>Illustration</i>	I, 81
“ for Cluster— <i>Illustration, Plate II</i>	I, 116-117
“ Oil Pipe— <i>Illustration, Plate I</i>	I, 58-59

	PAGE
Plug, Rotary.....	I, 308
Plugs, Air Cock.....	I, 872
" at Arch Support Pipes— <i>Illustration</i>	I, 64
" Safety.....	I, 81
" Wash Out— <i>Illustration, Plate I</i>	I, 58-59
Pneumatic Drop Pits.....	I, 244
" Hoist for Emptying Clunker or Ash Pits— <i>Illustration</i>	I, 278
" Holsts.....	I, 260, 275
" Locomotive.....	III, 120
Pocket Pin, Side— <i>Illustration, Plate II</i>	I, 116-117
Pointer, Black.....	I, 319
Points, Movable.....	III, 236, 237
Pointsmen, English—Wages of.....	IV, 452
Pole, William.....	IV, 230
Poles, Field.....	I, 406, 408
" for Supporting Wires.....	I, 463, 464
" of Engine Type Railway Generator.....	I, 456
" " Magnets.....	I, 410
" Negative.....	I, 410
" Positive.....	I, 410
" Securing Different Numbers of.....	I, 448
" Telegraph.....	III, 354
" " —Painting.....	IV, 351
Police, Railway—English.....	IV, 453
Political Economy, Laws of—Applicable to Railroads.....	VIII, 184
" " Observance of Its Laws in Rate Making.....	VIII, 25
" Methods.....	X, 11-15
Polybius.....	XI, 28
Polynesia.....	XI, 53
Polyphase Currents.....	I, 425, 426
" Motors.....	I, 488
Polytechnic Schools.....	I, 234
Pony Truck, American—Side View <i>et—Illustration</i>	I, 66
Pooling.....	VI, 58
Pools.....	VIII, 10, 107
" Compared to Guilds.....	VIII, 154
" Effect of.....	VIII, 61, 115, 116, 151, 190
" Influence of.....	VIII, 34
" Necessity of.....	VIII, 141, 157
" Practices Attending.....	VIII, 155
" " —in England.....	VIII, 153
" " " Europe.....	VIII, 152, 233
" " of Governments.....	VIII, 148
" Preventive of Rate Cutting.....	VIII, 75
" Purpose of.....	VIII, 206
" Relation to Competition.....	VIII, 155
" Theory of.....	VIII, 147
" Use of—in England.....	VIII, 76

	PAGE
Pools, Use of—in United States	VIII, 77
“ Value of	VIII, 141
“ “ —to Railroads	VIII, 147
“ “ “ the Public	VIII, 147
Poor, Baggage of the	V, 413
Poppet Valve, Double	I, 308
Population, Effect of—On Cost of Operation	III, 394
“ Relation of Traffic to	V, 24
Porcelain Bowl— <i>Illustration, Plate II</i>	I, 116-117
Porcher, Samuel	IV, 215
Port, Cylinder— <i>Illustration</i>	I, 341
“ Exhaust— <i>Illustration</i>	I, 344
“ — <i>Illustration, Plate I</i>	I, 58-59
“ Slide Valve— <i>Illustration</i>	I, 341
Ports	I, 308
“ — <i>Illustration</i>	I, 344
“ Admission—Low Pressure Cylinder	I, 95
“ Feed— <i>Illustrations</i>	I, 341, 344
“ Steam— <i>Illustration, Plate I</i>	I, 58-59
Portable Pans	I, 246
“ Railroads	I, 215-225
“ “ Manufacturers of	I, 223
“ Riveting Machinery	I, 262
Porters, Railway—English	IV, 450-454
Portugal, Baggage Allowed in	V, 288
“ Comparative Value of Silver and Gold in	III, 13
“ —Its Primitive Associations and Means of Carriage	XI, 468-476
“ —Primitive Carriage in— <i>Illustrations</i>	XI, 468-476
“ Status of Railways in	VIII, 342
“ Use of Metal Ties in	III, 379
Position, Running—Instructions to Engineers	I, 365
Positions of Engineer's Brake and Equalizing Discharge Valve	I, 349, 350
Positive Poles	I, 410
Post and Brace Pocket— <i>Illustration, Plate III</i>	I, 170-171
“ Base Washer for Ralling— <i>Illustration, Plate II</i>	I, 116-117
“ Brace, Body Queen— <i>Illustration, Plate II</i>	I, 116-117
“ Body Queen— <i>Illustration, Plate II</i>	I, 116-117
“ Bumping— <i>Illustration</i>	III, 349
“ Corner— <i>Illustration, Plate III</i>	I, 170-171
“ Deck— <i>Illustration, Plate II</i>	I, 116-117
“ “ Screen— <i>Illustration, Plate II</i>	I, 116-117
“ Door— <i>Illustration, Plate III</i>	I, 170-171
“ End— <i>Illustration, Plate II</i>	I, 116-117
“ “ — <i>Illustration, Plate III</i>	I, 170-171
“ Intermediate— <i>Illustration, Plate III</i>	I, 170-171
“ J. W.	III, 327
“ King— <i>Illustration, Plate III</i>	I, 170-171
“ Ladder— <i>Illustration, Plate III</i>	I, 170-171

	PAGE
Post, Platform Railing— <i>Illustration, Plate II</i>	I, 116-117
“ Queen— <i>Illustration, Plate III</i>	I, 170-171
“ Routes, Establishment of.....	XI, 105
“ Transom— <i>Illustration, Plate III</i>	I, 170-171
“ Whistling—Meaning of Term.....	IV, 323
Posts, Clearance.....	III, 238
“ Requisitions for.....	VII, 83
“ Signal.....	IV, 252, 253
“ Window— <i>Illustration, Plate II</i>	I, 116-117
Postage Stamps, Accounting for.....	X, 287, 288
Postal Car, American—Interior of— <i>Illustration</i>	I, 206
“ “ “—Standard— <i>Illustration</i>	I, 205
“ “ Austrian— <i>Illustration</i>	I, 207
“ “ “—Interior View of— <i>Illustration</i>	I, 208
“ Cars.....	I, 198; V, 462
“ Cards, Accounting for.....	X, 287, 288
“ Service.....	V, 552-563
“ “ Beginning of.....	XI, 151
“ Telegraph, English.....	V, 245, 246
Posters.....	V, 115
Postoffice Cars.....	V, 557
“ Department.....	V, 554, 558, 559, 561
“ United States—Emblem of.....	XI, 105
Pot, Fire— <i>Illustration, Plate II</i>	I, 116-117
“Pot” Tie, Metal—Midland Railway of India—A. D. 1889— <i>Illustration</i>	III, 311
“ Ties, Metal.....	III, 203
Pottery, the Art of.....	XI, 65
Potts, Jos. D.....	X, 161, 163
Poultry Car— <i>Illustration</i>	I, 189
Powder, Use of—by Railways.....	VII, 214
Powders, Storing.....	VII, 283
Power, Animal—Use of.....	I, 394
“ Appearing as Heat in a Wire—How Found.....	I, 405
“ Arbitrary.....	II, 73, 125
“ “—Love of.....	II, 110
“ Brake—Cause of Loss in.....	I, 378
“ Braking.....	I, 311, 378-380
“ “—Effect of Piston Travel on.....	I, 356-361
“ “—Instructions to Car Inspectors.....	I, 332
“ Conveyance of—from a Stationary Engine to a Mov- ing Car.....	I, 393
“ Cost of—at Main Stations.....	I, 440
“ “—Its Effect Upon Transportation.....	I, 392, 393
“ Cranes.....	I, 260
“ Cylinder—Calculation of.....	I, 64
“ Delivered to a Motor—How Found.....	I, 404
“ Electric—Delivered by a Dynamo.....	I, 404
“ Electrical—How Measured.....	I, 403
“ Facilities.....	I, 262

	PAGE
Power, Generation of—in Booster System.....	I, 435
“ Hauling—of a Locomotive.....	III, 195
“ Holding—of Brakes.....	I, 364
“ House.....	I, 269, 272
“ Law-Making.....	II, 47
“ Lifts.....	I, 244
“ Limitations of.....	I, 429
“ Loss of.....	I, 430
“ “ —Its Effect.....	I, 415-419
“ “ —Upon What Dependent.....	I, 415-419
“ Lost in Conductors.....	I, 451
“ “ the Wire.....	I, 450
“ Motive—Superintendent of.....	I, 277
“ Niagara—Diagram Showing Utilization of.....	I, 503
“ of Locomotive in 1830.....	I, 27
“ Organizations.....	II, 39
“ Plant.....	I, 252, 253, 263, 273
“ “ Central.....	I, 243
“ Production and Application of.....	I, 392, 393
“ Source of—Its Effect Upon Transportation....	I, 392, 393
“ Sources of.....	I, 393
“ Station.....	I, 454, 455
“ “ for the Alternating Current System.....	I, 488
“ “ “ “ “ “ —Direct Current System.....	I, 487
“ System, Electrical.....	I, 402
“ Tractive—How Secured.....	I, 64
“ Transmission of.....	I, 387, 388
“ “ —by Direct Current.....	I, 425
Practical Experience.....	I, 117
Practices, Comparison of European and American.....	V, 22-26
“ Disciplinary.....	II, 16
“ Improper—in Treasurer's Office.....	X, 261
Pratt, E. W.....	I, 333
Precious Metals.....	II, 242
“ Stones.....	II, 242
“ “ Transportation of.....	V, 519
Preference Shares.....	III, 88
“ Undue.....	VIII, 63
Preferment, in Railway Service.....	II, 94
“ Roads to.....	II, 61, 62, 114
Preferred Stock.....	III, 65-69, 88
Preliminary Construction Work.....	III, 130
Premium, Paid for Risk.....	III, 75
“ System.....	III, 249
Premiums.....	III, 301; IV, 25
“ Awarding—to Employees.....	II, 29-31
“ Guaranty.....	IX, 169-172, 353, 354
“ Payment of.....	III, 324, 325
Prepaid Charges, Interline.....	IX, 126-129

	PAGE
Pressure, Water Stored Under.....	I, 298
Prevention, Necessity of.....	IV, 38
Priam, Palace of.....	XI, 89
Prices, Effect of Competition on.....	VIII, 147
Primary Battery System.....	IV, 176
" Current.....	I, 423
Primer— <i>Illustration, Plate I</i>	I, 58-59
Priming.....	I, 74
Primitive Application of Steam to Engines, Road Wagons and Locomotives.....	XI, 510-520
" Application of Steam to Engines, Road Wagons and Locomotives— <i>Illustrations</i>	XI, 510-520
" Brake, Forms of.....	I, 291
" Carriage in Semi-Barbarous Greece.....	XI, 83
" Cart.....	I, 293
" Man.....	I, 160
" Peoples, Wealth of.....	XI, 9
" Wheel— <i>Illustration</i>	IV, 198
Principles and Laws, Electrical.....	I, 396-405
" Governing Freight Traffic.....	VI, 93-108
" " Labor.....	I, 280
" " the Fiscal Affairs of Railroads... ..	VI, 77-92
" " Organization of the Forces of Cor- porations.....	II, 108-121
" of Government.....	II, 128-140
" Organization.....	II, 91-95
" to Be Observed in Handling Railway Revenue... ..	IX, 20-34
Printing.....	III, 158
" Charging.....	VII, 321
Private Carriers, Use of Railroads by.....	II, 47
" Cars.....	VI, 49, 69-74
" " Charges for Use of.....	VI, 159
" " Collections for Use of.....	IX, 427, 428
" " Owners of.....	II, 46
" " Use of—in England.....	II, 45
" Corporations, Efficient Service of.....	II, v
" " Growth of.....	II, 135
" Enmities.....	II, 16
" Ownership, Evolution of.....	XI, 38
" " Value of.....	VIII, 12, 13, 227
" Property, Recognition of.....	XI, 67
Prize, Baltimore & Ohio—Winner of— <i>Illustration</i>	I, 82
Prizes.....	IV, 24-27
Problem, Labor—Solution of.....	II, 44
" Railway—Solution of.....	II, 46, 47
" The Electric.....	I, 394, 395
"Problem" Locomotive, 1859.....	I, 54
Process, Exhaust—of Conveyance.....	I, 274
Procession, Liverpool & Manchester, 1830.....	I, 29

	PAGE
Producer, Effect of Rates on.....	VIII, 26
“ Relation of—to Rates.....	VIII, 50
Production and Application of Power.....	I, 392, 393
“ Effect of Rates on.....	VIII, 63, 80
“ of Electricity.....	I, 397
Products, Relation of Carriers to.....	VIII, 82
Profession, Engineering.....	II, 223
Profiles.....	II, 213
Profit and Loss Account.....	X, 176-181
“ “ “ “ Credits to.....	X, 177-179
Profits, Effect of—on Rates.....	VIII, 43
“ Limitation of.....	VIII, 244
“ of Carriers.....	VIII, 85
“ Relative.....	VIII, 74
“ —Margins of.....	VIII, 47
“ —Upon What Dependent.....	IV, 57
Progress, Electrical.....	I, 522-525
“ Railway—Advancement of.....	I, 288
Projects, Visionary—Advocates of.....	I, 34
Promises, Paper—Issuance of.....	III, 17
Promotion.....	II, 23; IV, 12
“ Avenues of—to the Presidency.....	II, 81
“ —English Railways.....	IV, 448
Promptness, Necessity of—in Agents.....	V, 113
Property. (See also “Freight.”)	
“ Acceptance of—to Cover Shortages.....	IX, 196, 197
“ Acquisition of.....	VII, 22; XI, 43
“ Advances on.....	IX, 87-89, 290, 318-320
“ Care of.....	I, 125; VII, 31-33
“ Carriage of—on Passenger Trains.....	V, 297, 298
“ Claims for Damage to.....	II, 232, 233
“ Corporate—Government of.....	II, v
“ —Organization of.....	II, 58, 59
“ Cost of—Influence on Rates.....	VIII, 50, 52
“ Damaged—Collections for.....	VII, 414
“ Damages to—Liability of State for.....	III, 463
“ Delivery of.....	IX, 75, 76, 94
“ Development of Love of.....	XI, 32
“ Disintegration of—from Natural Causes.....	III, 465
“ Effect of Climate on.....	III, 477, 478
“ Evolution of.....	XI, 9
“ First Cost of.....	VII, 453
“ Private.....	XI, 11
“ Growth of.....	XI, 40
“ History of.....	XI, 44
“ Improvement of.....	VIII, 24
“ Influence of—on Cost of Maintenance.....	III, 383
“ in Slaves.....	XI, 25
“ —Its History and Relation to Mankind.....	XI, 9
“ Kinds of.....	III, 109

	PAGE
Property, Losses and Damages to.....	III, 398
“ Maintenance of.....	VII, 22
“ Man's First Idea of.....	XI, 11
“ Means of Acquiring—by Savages.....	XI, 29
“ Money as.....	III, 8
“ Origin and Growth of.....	III, 109
“ Ownership of.....	III, 475
“ Perishable—Disposition of.....	II, 243
“ “ —Handling.....	IX, 106
“ Personal—Care of.....	VII, 297, 299
“ Persons in Charge of—on Freight Trains... V, 150-156	
“ Pledges, for Sums Due Railways.....	V, 139-144
“ Productiveness of.....	III, 28
“ Prosperity of—Upon What Dependent.....	II, 147, 148
“ Railway—Characteristics of.....	III, 109
“ “ —Deterioration of.....	III, 460
“ “ —Effect of Idleness on.....	III, 460
“ “ —Guarding.....	III, 462, 463
“ “ —How Strengthened.....	III, 71
“ “ —Its Similarity to Other Property.....	III, 462
“ “ —Improvement of.....	II, 188
“ “ —Leasing.....	II, 41-43
“ “ —Limitations of.....	III, 110
“ “ —Maintenance of.....	III, 301-347
“ “ —Natural Decay of.....	III, 467, 468
“ “ —Preservation of.....	II, 213, 214; III, 463
“ “ —Privileges of.....	III, 109
“ “ —Productiveness of.....	III, 41
“ “ —Resurveying.....	II, 171
“ “ —Rights of.....	III, 109
“ “ —Safety of.....	III, 463
“ “ —What It Represents.....	VII, 26, 27
“ Real and Personal—a Basis for Taxation... III, 446, 447	
“ Receipts for Delivery of.....	IX, 317, 318
“ Recognition of Private.....	XI, 67
“ Relation of—to Barbarism.....	XI, 9
“ “ “ Civilization.....	XI, 9
“ “ “ Savagery.....	XI, 9
“ Result of Accumulation of.....	XI, 44
“ “ Protection of.....	XI, 44
“ Status of—How Fixed.....	III, 169
“ Supervision of.....	II, 16
“ Unclaimed—Collections for.....	VII, 414
“ “ —Disposition of, by Carrier.....	V, 342-346
“ Warfare on.....	III, 73
“ —What It Represents.....	VII, 22
Properties, Consolidation of.....	II, 27
Proprietors, Grievances of.....	III, 472-475
“ Relation of—to Employes.....	III, 472-475
Proprietorship of Man.....	XI, 12

	PAGE
Prosperity	III, 10
" of Employes, Bases of	II, 57
Proxies, Giving	III, 81
Prudence, Necessity of—in Handling Requisitions	VII, 71
Public Auditors, English	II, 275
" Corporations	II, vi
" Criticism, Effect of—on Railway Managers	V, 358
" Interest of—in Baggage Department	V, 353
" Officials, Furnishing Information to	VII, 432
" Opinion, Effect of—on Railways	V, 354, 355
" " " Rates	VIII, 39, 228
" Relation of Railways to	IX, 13
"Puffing Billy," 1813	I, 22, 23, 42
" " —Illustration	I, 22
Pull, Deck Sash— <i>Illustration, Plate II</i>	I, 116-117
Pulley, Chain—Berth— <i>Illustration, Plate II</i>	I, 116-117
Pullman, George M.	I, 193, 198, 199
" Palace Car Company	I, 147, 196-199; VI, 73
" Service	I, 202
" Vestibule	I, 198
Pump, Air	I, 292, 306, 315, 320, 336, 485, also Vol. XII
" " — <i>Illustration</i>	I, 539, also Vol. XII
" " Cylinder Brake— <i>Illustration, Plate I</i>	I, 58-59
" " —Instructions to Enginehouse Foremen and In-	
spectors	I, 328
" " —Testing	I, 328
" " —Westinghouse	I, 538
" Connection— <i>Illustration, Plate I</i>	I, 58-59, also Vol. XII
" Exhaust Connection— <i>Illustration, I</i>	I, 58-59, also Vol. XII
" Failure—Cause of	I, 366
" for Compressing Air ..	I, 334
" Governor	I, 309, 315, 336, 538
" " — <i>Illustration</i>	I, 539
" " Duplex— <i>Illustration</i>	I, 355
" " Improved— <i>Illustration</i>	I, 354
" " —Instructions to Engine House Foremen	
and Inspectors	I, 328
" " Operations of	I, 352-356
" Inspectors	III, 259
" Lubricator, Air— <i>Illustration, Plate I</i>	I, 58-59
" Packing	I, 381
" Piston Packing— <i>Illustration, Plate I</i>	I, 58-59
" Steam	I, 244, 298
" " Connection— <i>Illustration, Plate I</i>	I, 58-59
" " Cylinder Brake— <i>Illustration, Plate I</i>	I, 58-59
" Stopped—Instructions to Engineers	I, 366
" Throttle, Air— <i>Illustration, Plate I</i>	I, 58-59
" Valve Case— <i>Illustration, Plate I</i>	I, 58-59
Pumps, Air	I, 384
" " —Location of	I, 381

	PAGE
Pumps, Air—Steam Unions of	I, 381
Punches, Baggage	V, 485
" Ticket	V, 198, 199, 202; IX, 118, 119
Purchasing Agent.....	II, 138
" " Character of	II, 261, 262, 268
" " Material Received from.....	VII, 317
" " Opportunities of.....	II, 263
" " Selection of	II, 266
" Agents, Relief Vouchers Made by.....	IX, 371
" " Requirements of.....	VII, 49
" and Sales Agent.....	II, 260-271
Purlins.....	I, 212
Pursers, Receipts Given by.....	VI, 220, 221
Purveyors.....	II, 42
Push Button, Electric— <i>Illustration, Plate II</i>	I, 116-117
" Car, Light— <i>Illustration</i>	I, 147
" Cars.....	I, 261, 262, 275
" Rod— <i>Illustration</i>	I, 541
Quadrant— <i>Illustration, Plate I</i>	I, 58-59
Quadrirème.....	XI, 108
Quantity, Influence of—on Rates	VIII, 53
Quarter Phase System.....	I, 425
Quartermaster-General's Office, Transportation for.....	V, 144
Quayle, Robert.....	I, 52, 235, 236, 333
Queen Post— <i>Illustration, Plate III</i>	I, 170-171
" " Overhang Truss Rod— <i>Illustration, Plate II</i>	I, 116-117
Question Box.....	I, 223
" " Use of.....	IV, 305, 306
Questions, Discussion of.....	I, 228, 229
Quick Action Brake.....	I, 310, 311, 324, 373
" " Cylinder.....	I, 312, 313
" " Triple Valve.....	I, 343-346
" " " — <i>Illustration</i>	I, 344
" " " Result of Defective.....	I, 365
Quinquerème.....	XI, 108
Race, The Turanian.....	XI, 57
Rack, Basket—Continuous— <i>Illustration, Plate II</i>	I, 116-117
" Rail Locomotive—Blenkinsop's, 1811— <i>Illustration</i>	I, 21
Racks	I, 259, 274
" for Storing Damaged Articles.....	I, 272
Radial Stay Bolts— <i>Illustration, Plate I</i>	I, 58-59
Radiating Pipe— <i>Illustration</i>	IV, 158
Radiation, Loss of Heat by	I, 74
Radiators, Seat— <i>Illustration, Plate II</i>	I, 116-117
Radicalism.....	VII, 19

	PAGE
Rafter— <i>Illustration, Plate II</i>	I, 116-117
“ Cornices— <i>Illustration, Plate II</i>	I, 116-117
Rafts, Use of—on Tigris	XI, 80
Raids, Occurrence of	XI, 36
Rail, Action of—on Tie— <i>Illustration</i>	III, 321
“ and Joint Tongue, Laid on Camden & Amboy Railroad, A. D. 1831— <i>Illustration</i>	III, 199
“ Ashbel Welsh—A. D. 1866— <i>Illustrations</i>	III, 279-281
“ Barlow’s “Saddle Back”—A. D. 1856— <i>Illustration</i>	III, 264
“ Belt— <i>Illustration, Plate II</i>	I, 116-117
“ Birkenshaw’s Wrought Iron—A. D. 1830— <i>Illustration</i>	III, 190
“ Body, Hand or Grab— <i>Illustration, Plate II</i>	I, 116-117
“ Boston & Worcester Railroad—A. D. 1850— <i>Illustration</i>	III, 238
“ Bottom Door— <i>Illustration, Plate II</i>	I, 116-117
“ “ —Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ Box—A. D. 1855— <i>Illustration</i>	III, 258
“ “ —A. D. 1858— <i>Illustration</i>	III, 274
“ Brackets, Hand— <i>Illustration, Plate I</i>	I, 58-59
“ Bridge	III, 200
“ Buffalo, Corning & New York Railroad—A. D. 1855— <i>Illustration</i>	III, 251
“ Bull-Headed—London & Northwestern Railway—A. D. 1889— <i>Illustration</i>	III, 309
“ Camden & Amboy Railroad—A. D. 1848— <i>Illustration</i>	III, 237
“ Cap Belt— <i>Illustration, Plate II</i>	I, 116-117
“ Carlisle’s Wrought Iron—A. D. 1811— <i>Illustration</i>	III, 188
“ Chair, Invention of	III, 177
“ “ the First—New-Castle-on-Tyne, A. D. 1797— <i>Illustration</i>	III, 177
“ Chairs	III, 332, 341
“ “ Use of	III, 374
“ “ Compound—New York Central Railroad, A. D. 1855— <i>Illustrations</i>	III, 252, 253, 255
“ “ —Troy Union Railroad, A. D. 1855— <i>Illustrations</i>	III, 254, 257
“ Designed by Robert L. Stevens—A. D. 1830— <i>Illustration</i>	III, 197
“ Double-Headed	III, 200
“ Early Methods of Strengthening the	III, 180-182
“ End—Seat— <i>Illustration, Plate II</i>	I, 116-117
“ English Fish-Belly—New Jersey Railroad, A. D. 1832— <i>Illustration</i>	III, 203
“ Erie—A. D. 1857— <i>Illustration</i>	III, 268
“ Evolution of the . . . I, 163, 164; II, 212; III, 126, 175-178, 204	
“ Fastenings	III, 197, 198
“ First Rolled in America—Baltimore & Ohio Railroad— <i>Illustration</i>	III, 233

	PAGE
Rail, Flat-bottomed	III, 200
“ Foot— <i>Illustration, Plate II</i>	I, 116-117
“ Frog, Wood’s—New Jersey—A. D. 1859— <i>Illustration</i>	III, 276
“ Girder	I, 462
“ Great Western Railway—A. D. 1857— <i>Illustration</i>	III, 265
“ Hand— <i>Illustration, Plate I</i>	I, 58-59
“ Hetton—1824— <i>Illustration</i>	III, 191
“ Importance of	III, 126, 127
“ Jessop’s Cast Iron Fish-Bellied—A. D. 1789— <i>Illustration</i>	III, 177
“ Joint, A. D. 1888— <i>Illustration</i>	III, 307
“ “ —Reinforced— <i>Illustration</i>	III, 338
“ “ Showing Action of the Wheel On— <i>Illustration</i>	III, 339
“ Joints	III, 334-347
“ “ Effect of Depressions in	III, 341
“ Latrobe’s Compound—Baltimore & Ohio Railroad—A. D. 1841— <i>Illustration</i>	III, 231
“ LeCann’s Tram—Wales, A. D. 1801— <i>Illustration</i>	III, 180
“ Lehigh Valley Railroad—A. D. 1890— <i>Illustration</i>	III, 326
“ Long Island Railroad—A. D. 1855— <i>Illustration</i>	III, 247
“ Losh & Stephenson’s—Stockton & Darlington Railroad—A. D. 1816— <i>Illustration</i>	III, 189
“ Lower Wainscot— <i>Illustration, Plate II</i>	I, 116-117
“ “Meat Yard” Pattern—A. D. 1884— <i>Illustration</i>	III, 302
“ Middle Door— <i>Illustration, Plate II</i>	I, 116-117
“ “ —Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ New York Central Railroad—A. D. 1855— <i>Illustration</i>	III, 248
“ “ “ & Erie Railroad—A. D. 1855— <i>Illustration</i>	III, 249
“ Notched or Rack	I, 22
“ of Frame—Lower— <i>Illustration, Plate I</i>	I, 58-59
“ Pear-Headed—A. D. 1833— <i>Illustration</i>	III, 242
“ Pennsylvania Railroad—A. D. 1867— <i>Illustration</i>	III, 266
“ Platform— <i>Illustration, Plate II</i>	I, 116-117
“ Proposed by D. Chanute—A. D. 1874— <i>Illustration</i>	III, 290
“ Rectangular—A. D. 1838— <i>Illustration</i>	III, 224
“ Saratoga & Schenectady Railroad—A. D. 1855— <i>Illustration</i>	III, 250
“ Sheathing— <i>Illustration, Plate II</i>	I, 116-117
“ Standard—A. D. 1868— <i>Illustrations</i>	III, 282, 284
“ “ —A. D. 1870— <i>Illustrations</i>	III, 286-289
“ “ —A. D. 1875— <i>Illustrations</i>	III, 291-293
“ “ —A. D. 1879— <i>Illustrations</i>	III, 294, 297
“ “ —A. D. 1880— <i>Illustrations</i>	III, 298, 299
“ “ —A. D. 1881— <i>Illustration</i>	III, 300
“ “ —A. D. 1885— <i>Illustration</i>	III, 303
“ “ —A. D. 1886— <i>Illustration</i>	III, 305

	PAGE
Rail, Standard—A. D. 1887— <i>Illustration</i>	III, 306
“ “ —of Belgium Government—A. D. 1889— <i>Illustration</i>	III, 310
“ “ —A. D. 1890— <i>Illustrations</i>	III, 323, 324, 325
“ “ —A. D. 1897— <i>Illustrations</i>	III, 345, 346
“ Stephenson's Fish-Belly—Manchester & Liverpool Railway—A. D. 1829— <i>Illustration</i>	III, 196
“ “Stevens”	III, 200
“ “ —A. D. 1854— <i>Illustration</i>	III, 244
“ “ —France, A. D. 1888— <i>Illustration</i>	III, 308
“ “ —Great Western Railway of England—A. D. 1858— <i>Illustration</i>	III, 275
“ “ —Supported by Cast-Iron Chair—A. D. 1837— <i>Illustration</i>	III, 220
“ “ —Vicksburg & Jackson Railroad—A. D. 1841— <i>Illustration</i>	III, 227
“ “ —Western Railway of France—A. D. 1855— <i>Illustration</i>	III, 259
“ Strap—Albany & Schenectady Railroad—A. D. 1837— <i>Illustration</i>	III, 223
“ “ —Baltimore & Ohio Railroad—A. D. 1833— <i>Illustration</i>	III, 208
“ Strength of	I, 64
“ The First Iron	III, 176
“ Third	I, 464, 465
“ “ Supported on Special Wood Blocks Dowelled into the Ties—Nantasket Road— <i>Illustration</i>	I, 464
“ Top Door— <i>Illustration, Plate II</i>	I, 116-117
“ “ Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ Tram—Surrey Railway, A. D. 1803— <i>Illustration</i>	III, 183
“ Upon Which Trevithick's First Locomotive Ran— <i>Illustration</i>	III, 186
“ Upper Wainscot— <i>Illustration, Plate II</i>	I, 116-117
“ Use of—by the Romans	I, 163
“ “Vignoles”	III, 200
“ Weight of	I, 165
“ “ Placed on	I, 64
“ Woodhouse's Patent Concave—for Wagons, A. D. 1803.— <i>Illustration</i>	III, 184
“ Wyatt's Hexagonal—North Wales, A. D. 1802— <i>Illustration</i>	III, 181
Rails	II, 269; III, 301; VII, 464
“ Accounting for	VII, 296
“ Action of Car Wheels on	IV, 211-213
“ Cast	III, 176
“ Changing	III, 241
“ Charging	VII, 296
“ Cost of Keeping in Order	III, 423
“ Creeping of	III, 333, 339
“ Curving	III, 214, 215

	PAGE
Rails, Cutting of Ties by.....	III, 333
“ Defective—Discovery of, by Enginemen.....	IV, 377
“ Deterioration of.....	III, 272-279, 467
“ Differences in.....	III, 127
“ Durability of.....	III, 334, 398
“ Duration of.....	III, 424
“ Early Methods of Laying.....	III, 199
“ Effect of Ballast on.....	III, 328
“ “ “ Climate on.....	III, 272-277, 467
“ “ “ Friction of Wheels on.....	III, 274
“ “ “ on Cost.....	X, 166
“ “ “ Passing Trains on.....	III, 329, 331
“ “ “ Rust on.....	III, 277, 278
“ “ “ Speed on.....	III, 276
“ “ “ Traffic on.....	III, 278
“ “ “ Wheels on.....	III, 201
“ Filing.....	III, 242, 243
“ Frog Guard.....	III, 232, 233
“ Gang for Changing—on Sunday.....	III, 243
“ Guard—for Bridges.....	III, 223, 224
“ Hardness of—Its Effect on Wear.....	III, 322, 323
“ Inferior—Use of.....	III, 398, 399
“ Influence of—On Cost of Maintenance.....	III, 383
“ Inspecting.....	III, 214
“ Inspection of.....	VII, 295
“ Inventorying.....	VII, 344
“ Jointing.....	III, 243
“ Laying.....	III, 196, 197, 332, 333
“ Life of.....	III, 278, 279
“ “Live”—Objections to.....	I, 465
“ Loose.....	III, 331
“ Maintenance of.....	III, 277, 278
“ Purchase of.....	VII, 52, 84, 295
“ Records of.....	VII, 295
“ Receiving.....	VII, 296
“ Requisitions for.....	VII, 83
“ Returns of.....	VII, 296
“ —Riveted to Ties.....	I, 219
“ Rolled.....	III, 176
“ Sanding.....	I, 110, 321, 369
“ Securing to Ties.....	III, 331, 332
“ Shipping.....	VII, 191
“ Spiking.....	III, 332
“ Standard—Adoption of.....	III, 127
“ Storage of.....	VII, 190
“ “Strap”.....	III, 176
“ Supports for.....	III, 179
“ The First.....	III, 110
“ Uniform Patterns of.....	III, 127

	PAGE
Rails, Unloading.....	III, 241, 242
" Unused—Life of.....	III, 275-277
" Use of Sand on.....	I, 318
" Used in Street Railway Construction.....	I, 462
" " —Life of.....	III, 275-277
" Weak Spots in.....	III, 341
" Weight of.....	III, 178
" Worn.....	III, 430
" Wooden.....	III, 175, 176
" Wrought-Iron.....	III, 178, 179
Railing Chair, Platform— <i>Illustration, Plate II</i>	I, 116-117
" Post, Base Washer for— <i>Illustration, Plate II</i>	I, 116-117
" " Platform— <i>Illustration, Plate II</i>	I, 116-117
Railroad. (See also "Railway" and "Railways.")	
" Appliances of a.....	I, 281
" Atchison, Topeka & Santa Fe.....	III, 361
" Baltimore & Ohio.....	I, 464; III, 148
" " " —Pension Fund of.....	X, 321-323
" " " —Relief Department of.....	X, 296, 298, 307-309
" " " —Reward Offered by.....	I, 32
" " " —Savings Fund of.....	X, 313
" Boston & Worcester—Headlight of.....	I, 58
" Burlington & Mt. Holly Branch of the Pennsylvania—Use of Electricity on..	I, 490-492
" Camden & Amboy.....	III, 176
" Central—of New Jersey.....	III, 363
" " Pacific.....	III, 163; V, 287, 432
" Charleston & Hamburg—Train on— <i>Illustration</i> , I,	33
" Chicago, Rock Island & Pacific.....	III, 360
" Companies, Manufacture of Rolling Stock by.....	I, 141-144
" Cumberland Valley—Introduction of Sleeping Car on.....	I, 189
" Decauville's.....	I, 215-225
" Equipment of a.....	I, 237, 238
" Indianapolis, Cincinnati & Lafayette.....	II, 128
" Lilliputian—Manufacturer of.....	I, 218
" Louisville & Nashville.....	V, 556
" Mohawk & Hudson.....	I, 56
" " " " 1832—First Truck Engine, "Brother Jonathan"— <i>Illustration</i>	I, 34
" New York, Lake Erie & Western.....	II, 128
" " " New Haven & Hartford—Use of Electricity on Nantasket Beach Branch.....	I, 462-495
" Nashua & Lowell.....	II, 128
" Operations, First Days of.....	I, 234
" Pennsylvania.....	III, 183; V, 17

	PAGE
Railroad, Pennsylvania—Relief Department of, X, 296, 299, 303-307	
—Savings Fund of	X, 317
Portable—Manufacturers of	I, 233
Relative Cost of Operating—By Steam Locomotives and by Electricity	I, 514-516
Shops	I, 124, 225, 233
Value of—On What Dependent	I, 233
Vehicles of	I, 156
Railroads. (See also "Railways.")	
American—Earning Capacity of	I, 166
" —Low Rates of	I, 207
Cars of	I, 156, 157
Comparison of Electrical Systems for Operating	I, 450-453
Co-Operation Among	I, 287
Cost of Operating	II, 50
Duplication of—How Lessened	II, 46
Early History of	I, 220
" " —Experimental Efforts During, I, 168	
" " Patrons of	I, 168
Effect of Introduction of	XI, 98
Equipment furnished by	VI, 54, 55
Evolution of	I, 230
Fiscal Affairs of—Principles and Methods Govern- ing	VI, 77-92
History of	II, 108
Improvement in	II, iv
Joint Use of Cars by	VI, 63-68
Machinery of—Responsibilities of Men in Charge	I, 231
Officers of—In Early Days	II, 20
Operation of—by Owners	II, 40, 41, 44
" " —Questions Regarding the	I, 34, 35
Organization of—About Shops	I, 229
Original Purpose of	VI, 5
Passenger Service of—Origin of Luxuries Con- nected Therewith	I, 198
Portable	I, 215-225
Temporary Closing of—Its Effect	II, 54-56
Use of—by Private Carriers	II, 47
Railway. (See also "Railroad" and "Railroads.")	
Accidents	IV, 106-109
" —In Early Days	III, 121
Accounting, Needs of	VI, 87-90
Accounts, Auditing	II, 258, 259
" Necessity of	VI, 77
A. D. 1800—Illustration	III, 179
Administration, Cure of Faults in	III, 33
" —How Like Civil Government	II, 64, 65

	PAGE
Railway, Electric—Elements of an	I, 453-485
“ “ —The First.....	I, 520
“ Employees	IX, 11-19
“ “ Charges for Transporting	VII, 190-206
“ “ Definition of Titles of.....	II, 141, 142
“ “ List of.....	II, 306-320
“ “ Number of	II, 306
“ “ Strike of—in 1886	II, 33
“ “ Titles of.....	VII, 249-251
“ Employment, Opportunities to Find.....	IX, 14
“ Engine, Madras— <i>Illustration</i>	I, 133
“ Equipment.....	I
“ “ —Construction of.....	I, 138
“ “ —of Great Britain.....	III, 129
“ “ Manufacturers of.....	I, 126
“ “ Strife of Manufacturers of.....	I, 140
“ Evolution	III, 109-122
“ Force, Changes in.....	II, 67
“ “ Characteristics of.....	II, 13
“ “ Division of.....	II, 19, 20
“ “ Equality of.....	II, 14
“ “ Favoritism in	II, 14
“ “ Incompetency in	II, 21
“ “ Mental Requirements of.....	II, 15
“ “ Moral Requirements of.....	II, 15
“ “ Natural Adaptation of Its Members.....	II, 15
“ “ Physical Requirements of.....	II, 15
“ “ Relation of Officers to Subordinates ..	II, 17, 18
“ “ Supervision of	II, 201
“ Force, Value of Practical Experience to.....	II, 20
“ Forces, Discipline of.....	II, 18
“ “ Necessity of Courage in.....	II, 19
“ “ “ <i>Esprit de Corps</i> in.....	II, 19
“ “ “ Intelligence in.....	II, 19
“ “ “ Interest in.....	II, 19
“ Generator (800 Kilowatt)— <i>Illustration</i>	I, 508
“ “ Armature, Winding a— <i>Illustration</i>	I, 404
“ “ Baltimore & Ohio Railroad (500 Kilowatt) — <i>Illustration</i>	I, 497
“ “ Field with Brush Holder (1500 Kilowatt) — <i>Illustration</i>	I, 390
“ “ Hestonville, Mantau & Fairmount Pas- senger Railroad (400 Kilowatt)— <i>Il- lustration</i>	I, 506
“ “ in Motion (800 Kilowatt)— <i>Illustration</i> , I,	459
“ Generators— <i>Illustration</i>	I, 522
“ “ Connected to Horizontal Engines, North and West Chicago Rail- way (800 Kilowatt)— <i>Illustration</i> . I,	428
“ Glasgow & Garnkirk—Opening of.....	I, 31
“ Grand Trunk—of Canada.....	III, 88

	PAGE
Railway, Great Indian Peninsular.....	III, 178
" Northern—of England.....	III, 267-270; IV, 331-334, 343, 344, 349, 360, 363, 378, 402, 405, 407-409, 411, 414, 418, 419, 432; V, 225, 445, 447, 448, 540
" Northern—of England—Practices of..	IV, 447-456
" " Ireland.....	III, 178, 183
" Western.....	I, 35-37
" " —of England.....	III, 179, 191, 192; IV, 341, 349, 350, 382, 407, 410, 425, 433; V, 227, 229
Interests—Protection of.....	II, 124, 125
Labor.....	II, 109
" Tendency of.....	II, 26
Lancashire & Yorkshire—Coal Cars Used on.....	I, 131; III, 183
Leases, Details of.....	III, 92-100
Legislation.....	III, 136
Leicester & Swannington.....	I, 54
Liverpool & Manchester.....	III, 125, 181; V, 19
" " " —Freight Traffic of.....	I, 31
" " " —Opening of.....	I, 28, 29
" " " —Passenger Accommoda- tions.....	I, 171
London & Birmingham.....	I, 37
" " Northwestern..	I, 35, 36, 54; II, 15, 209; IV, 94; V, 282, 429, 432
" " " —Relief Department of..	X, 296
Machinery, Where the First Railroad Was Opened..	I, 294
Mail, Handling.....	V, 405, 406
Maintenance, Things Involved in.....	III, 481, 482
Management, Responsibilities of.....	II, 67, 68
Managers.....	III, 429
" Ambition of.....	II, 119
" American.....	III, 141
" Duties of.....	V, 356
" Effect of Public Criticism on.....	V, 358
" Fidelity of.....	II, 79
" in Great Britain.....	III, 148
" Wisdom of.....	II, 77-79
Men—as Authors.....	II, vii; III, 32, 72
Methods, Divergence of.....	II, 80
Metropolitan Elevated, Chicago—Use of Electricity on.....	I, 495, 496
Middleton & Leeds, 1812-13— <i>Illustration</i>	I, 24
Midland—of England.....	V, 282, 430, 432
Mileage, Growth of.....	III, 42
Missouri Pacific.....	II, 51, 52
Motor— <i>Illustrations</i> —.....	I, 471, 524
" (80-Horsepower)— <i>Illustration</i>	I, 510

	PAGE
Railway Motor, Armature Coils for— <i>Illustration</i>	I, 411
“ “ “ of— <i>Illustration</i>	I, 413
“ “ Complete— <i>Illustration</i>	I, 415
“ “ “ (100-Horsepower)— <i>Illustration</i> , I, 525	I, 525
“ “ Cross Section of a— <i>Illustration</i>	I, 403
“ “ Electrical Characteristics of	I, 473, 474
“ “ Evolution of	I, 472
“ “ Field Coil for— <i>Illustration</i>	I, 472
“ “ Spring Mounted— <i>Illustration</i>	I, 469
“ “ Street— <i>Illustration</i>	I, 429
“ “ Top Field Removed, Showing Armature in Position (100-Horsepower) <i>Illustration</i> , I, 524	I, 524
“ “ With Gear Case and Car Axle (35-Horse- power)— <i>Illustration</i>	I, 470
“ Northeastern	I, 56
“ Officers	II, 184; IX, 11-19; X, 203, 204
“ “ Definition of Titles of	II, 141, 142
“ “ Dependence of	II, 135
“ “ Discretion Exercised by	V, 321
“ “ Duties of	II, 75
“ “ Effect of Education on	III, 139
“ “ List of	II, 308-320
“ “ Standing of	II, 135
“ “ Talent of	II, 115, 116
“ “ Titles of	VII, 249-251
“ Officials, Authority of	II, 113, 114
“ “ Number of	II, 116
“ Operations, Inauguration of—in America	I, 28
“ “ Necessities of—in America	I, 152
“ Organization	II, 11
“ Organizations, Rivalry in	II, 124
“ Owners	III, 429
“ Paris, Lyons & Mediterranean	III, 362, 364; X, 332
“ Practice, Evolution of—in America	II, 272
“ Practices, in Spain	I, 174
“ Presidents	II, 58
“ Problem, Solution of	II, 46, 47
“ Progress, Advancement of	I, 288
“ Property, Characteristics of	III, 109
“ “ Deterioration of	III, 460
“ “ Effect of Idleness on	III, 460
“ “ Extent of—Its Influence on Cost of Operating	II, 111, 112
“ “ Guarding	III, 462, 463
“ “ —How Strengthened	III, 71
“ “ Improvement of	II, 188
“ “ Leasing	II, 41-43
“ “ Limitations of	III, 110
“ “ Maintenance of	III, 301-347
“ “ Natural Decay of	III, 467, 468

	PAGE
Railway Property, Preservation of.....	II, 213, 214; III, 463
“ “ Privileges of.....	III, 109
“ “ Productiveness of.....	III, 41
“ “ Resurveying.....	II, 171
“ “ Rights of.....	III, 109
“ “ Safety of.....	III, 463
“ “ Similarity of—to Other Property.....	III, 462
“ “ —What It Represents.....	VII, 26, 27
“ Revenue, Collection of.....	IX, 7-292
“ “ Handling—Principles and Methods to Be Observed.....	IX, 20-34
“ “ Men Who Handle.....	IX, 26
“ Science, The.....	VII, 232
“ Service, Advancement in.....	II, 295
“ Securities.....	III, 53-55
“ “ in America.....	III, 72, 73
“ “ Fluctuations in.....	III, 42
“ “ Precautions to Investors in.....	III, 79-84
“ “ Purchase of.....	III, 64
“ Service Attaches of.....	II, 123
“ “ Changes in—Due to the Introduction of Electricity.....	I, 392
“ “ Charm of.....	II, 123
“ “ Characteristics of.....	II, 63, 64
“ “ Description of.....	II, 24
“ “ Electrical Systems for.....	I, 430-453
“ “ Glamour of.....	II, 72
“ “ Improvements in.....	V, 32
“ “ Limitations of.....	IX, 100
“ “ in United States.....	I, 249
“ “ Natural Fitness and Selection in.....	II, 20
“ “ Necessity of Obedience in.....	VI, 17
“ “ Organization of—Compared with Government Service.....	II, 122
“ “ Peculiarities of.....	IX, 100
“ “ Preferment in.....	II, 94
“ “ Specialists in.....	II, 62
“ “ Tenure of Office in.....	II, 100
“ Shops, Machinery of.....	I, 122
“ Shutt End.....	I, 28
“ Single Rail.....	III, 111, 112
“ Southern Pacific.....	III, 359
“ Speculation.....	I, 34
“ Station Switchboard, for Three Generators and Eight Feeders— <i>Illustration</i>	I, 460
“ Stockton & Darlington.....	I, 27, 45; IV, 247, 248
“ “ —Opening of.....	I, 26
“ Subjects, Influence of Stephenson on.....	I, 30
“ Suggestion of the Name.....	III, 178
“ Superintendents, American Association of.....	IV, 28

	PAGE
Railway Supplies.....	VII, 14, 15
“ Charges for Transporting.....	VII, 199-206
“ System, Economy of Operation of—in the United States.....	II, 25, 26
“ “ Father of.....	I, 20
“ “ Formal Inauguration of.....	I, 31
“ “ Genius of the.....	I, 15
“ “ History of.....	II, 70
“ “ Magnitude of.....	II, 70
“ “ Methods of.....	II, 70
“ “ Three Wire.....	I, 437
“ Taxation.....	III, 433-457
“ The First.....	III, 110, 111; V, 19
“ Track, Advent of.....	I, 294
“ “ Electric.....	I, 462, 463
“ “ First Use of.....	III, 126
“ Traffic—Cessation of... ..	II, 51, 52
“ Transportation, Details of.....	I, 201
“ Union Pacific... ..	III, 361
“ “ Passenger—Use of Electricity on.....	I, 520, 521
“ Universities, Establishment of.....	II, 222
“ Work, Motors for.....	I, 449
“ World, Vastness of.....	II, 57
Railways. (See also “Carriers” and “Railroads.”)	
“ Ability of—to Purchase Cheaply.....	VII, 51
“ Accounts of.....	V, 72; VIII, 296; X, 21-34
“ “ —Difficulty of Handling... ..	X, 35
“ Acquisition of Capital Invested in.....	VII, 18-27
“ “ Land by.....	III, 160
“ Acts of.....	VIII, 143
“ Adaptability and Skill of.....	III, 71
“ Additions to.....	III, 76, 77
“ Adjustability of.....	III, 128
“ Administration of.....	X, 65, 66
“ Adoption of Devices by.....	V, 89, 90
“ Agents of.....	III, 172, 173
“ Agitation Against.....	VIII, 113
“ Agreements Among to Maintain Uniform Rates... ..	VIII, 56
“ American—Track of.....	III, 185
“ “ —Train Service of.....	IV, 10
“ Antagonism to.....	VIII, 123, 207
“ Appliances of.....	III, 168; V, 72; X, 40
“ Articles Manufactured by.....	VII, 207
“ “ Used by.....	VII, 29
“ “ —Number of.....	VII, 207-215
“ as Consumers.....	VIII, 285
“ “ Fixtures.....	VIII, 102
“ “ Insurers.....	VIII, 95
“ “ Manufacturers.....	VII, 125-133

	PAGE
Railways as Monopolies	VIII, 69, 92, 175
“ Attacks on.....	VIII, 186
“ Austrian—Rules Governing Passenger Service of	V, 223-229
“ Authorizations of.....	III, 45
“ Bankrupt.....	III 31; VIII, 191
“ Belgian.....	III, 178, 183
“ Beneficiaries of	VIII, 289, 290
“ Benefits of—to Localities	III, 154, 155
“ Bills Against	VII, 420
“ Building of—How Affected.....	III, 7
“ “ —Without Reference to Needs.....	III, 61
“ Business of.....	VIII, 38
“ “ —Influences Governing.....	IV, 8
“ By Whom Built.....	III, 30
“ Capital of.....	III, 154
“ “ Invested in	III, 62; VIII, 288
“ Capitalization of.....	III, 28-106; VIII, 293
“ “ —in America	III, 69
“ “ “ England.....	III, 65-71
“ “ —Influences Affecting.....	III, 53-58
“ Cars of.....	I, 159
“ Changes in.....	III, 384
“ “ Methods of.....	X, 187
“ Cheap.....	III, 169, 170
“ Civil Service of.....	II, 143, 153, 204
“ Classes of Business of.....	V, 354
“ Closing.....	III, 458-462
“ Collusion with Shippers.....	VIII, 37
“ Combinations of.....	VIII, 57, 145
“ Competition of.....	V, 30
“ Competitive Practices of.....	VIII, 73
“ Complaints Regarding.....	VIII, 64
“ Completion of.....	VIII, 293
“ Concentration of.....	III, 62
“ Conditions Engendered by.....	VIII, 41
“ “ Necessary for Maximum Usefulness of	VIII, 21
“ Consolidation of.....	III, 62; VIII, 145
“ Construction of.....	III, 113, 114
“ “ —Authority for.....	VIII, 166
“ “ —in America.....	III, 143, 149, 151
“ “ “ Early Days.....	II, 168
“ “ “ Europe and America.....	II, 26
“ “ “ the United States.....	I, 30
“ “ —to What Due.....	VII, 12
“ “ Parallel.....	VIII, 199
“ “ Work of.....	II, 166-172
“ Contest of—with Water Courses.....	III, 134
“ Cost of.....	VIII, 293, 298

	PAGE
Railways, Cost of—Estimates of.....	III, 31
“ “ “ —in America.....	III, 45
“ “ “ “ England.....	III, 44
“ “ “ “ Europe.....	III, 45
“ “ “ —How Affected.....	III, 30
“ “ “ —Per Mile.....	III, 163
“ Creative Force of.....	IV, 12
“ Criticisms of.....	VIII, 63, 111, 114, 134, 141, 142, 162, 195, 202, 203, 246, 257
“ Decision of Supreme Court Affecting.....	VIII, 268
“ Demands Upon.....	VIII, 57
“ Departments of.....	II, 136, 137
“ Development of.....	II, 62
“ “ —in America.....	III, 383, 384
“ “ “ —to What Due.....	VII, 12
“ Devices of—for Handling Traffic.....	VIII, 309
“ Differences Between American and European.....	III, 184
“ “ “ English and American.....	III, 65, 66
“ “ “ Great and Little Men on.....	II, 295
“ Difficulties of Operating.....	II, 118
“ Disbursements of.....	VII; VIII, 285, 286
“ Discretion of.....	VIII, 115
“ Downfall of—Its Cause.....	II, 113
“ Duties of Officers on Different.....	II, 172, 173
“ Early—Construction of.....	III, 55
“ “ —Development of—to What Due.....	III, 134
“ “ History of.....	II, 71, 103, 111, 114, 115, 143, 153, 210, 248, 265, 287; III, 32, 136, 296; IV, 27, 28, 80, 170, 259, 374; V, 76, 318; VII, 29, 102, 114; IX, 27, 301; X, 196
“ “ “ —in Great Britain.....	I, 168, 169
“ “ “ —in America.....	III, 115-117, 188
“ “ “ —Operation of.....	III, 117-121
“ Economic Aspects of.....	IV, 7-11
“ Economy of—in the Employment of Labor... ..	II, 27
“ Edge.....	III, 111
“ Effect of.....	VIII, 163
“ “ Cost on Rates.....	VIII, 75
“ “ Fiscal Disturbances on.....	VIII, 19
“ “ Governmental Interference on.....	VI, 39-41
“ “ Inadequate Wages on.....	II, 105
“ “ Injuries to.....	VIII, 19
“ “ —on Development.....	IV, 10
“ “ Over-Production of.....	VIII, 185
“ “ Public Opinion on.....	V, 354, 355
“ “ “ Sentiment on.....	II, 231
“ “ Remunerative.....	III, 142
“ “ Unremunerative.....	III, 142
“ Efficiency of American.....	V, 357

	PAGE
Railways, Efficiency of—In the United States	VIII, 14, 168
“ Efforts to Defraud	V, 48, 49; IX, 115, 116, 118, 120
“ Electric—in Europe	I, 505, 506
“ Electricity as a Motive Power for	I, 387-526
“ English	I, 50
“ “ —Complaints Regarding	VIII, 64
“ “ —Cost of	III, 148
“ “ —Fiscal Affairs of	V, 237-273; VI, 318-333
“ “ —Passenger Accounts of	V, 237-273
“ “ —Practices of, in Employing Operatives	II, 15
“ “ —Safety Devices of	III, 36, 37
“ European	V, 22-26
“ “ —Cost of	III, 163, 164
“ Expenditures of	VIII, 285
“ Facilities of—for Handling Baggage	V, 323, 324
“ Federation of	VIII, 158
“ First Tickets Used by	V, 67
“ “ Use of	III, 178
“ Fiscal Affairs of	VII, 233; X, 35
“ Fixed Exhibits of	X, 62
“ Fixtures of	VIII, 173
“ Forces that will Secure their Equitable Management	VIII, 22
“ Free Construction of	VIII, 162
“ Function of Electricity in the Operation of	I, 396
“ Gauges of—That Have Been in Use in Different Countries	III, 494
“ German—Government of	IV, 133
“ “ Rules Governing Passenger Service of	V, 229-232
“ Government-Aided	VIII, 67
“ “ Control of—in the United States	III, 46
“ “ of	II, 136; IV, 8
“ “ Ownership of—Effect of	V, 355
“ “ Supervision of—Effect of	V, 355
“ Great—Management of	II, 112, 113
“ Growth of	V, 18, 19; III, 76, 77
“ “ —in the United States	VIII, 205
“ History of	IX, 433
“ Hospitality of	VII, 222-225
“ How Controlled	II, 124
“ Hygienic Department of	IV, 68
“ Impartiality of	VIII, 31
“ Impersonal Organization of	II, 127
“ Improvement in	III, 164, 165
“ Improvements in Operation of	X, 11
“ Improvident Management of—Effect of	VIII, 19
“ Inception of	V, 19
“ Income of	VIII, 164

	PAGE
Railways, Inconsistencies of	VIII, 162
“ Incorporation of.....	VIII, 266
“ in India.....	III, 153
“ Indiscriminate Construction of.....	VIII, 211
“ Influence of Law of Supply and Demand on.....	VIII, 7, 184
“ Injustice to—Cause of.....	VIII, 25
“ Instincts of.....	VIII, 149
“ Interest of Community in.....	VIII, 292
“ “ —in Employes.....	X, 294
“ Introduction of—Effect on Transportation, III, 112, 113	
“ “ “ upon Values.....	III, 154
“ Iron—Kinds of.....	III, 111
“ Laws Governing.....	VIII, 282
“ Leaders of.....	II, 71
“ Legal Requirements of.....	II, 226
“ Legislation for.....	VIII, 22, 82, 191
“ “ in Great Britain.....	VIII, 269, 270
“ Liability of	V, 14
“ “ —as Warehousemen.....	VI, 107
“ Like Governments	IX, 14
“ Limitation of Territory of.....	VIII, 168
“ Lines that Should Be Built.....	VIII, 165
“ Local Business of.....	VIII, 90, 206
“ Locating.....	III, 133, 157, 161
“ Location of.....	III, 131, 134, 136; VIII, 165
“ “ —by Governments.....	VIII, 174
“ “ —in United States	VIII, 167, 178
“ Loss Caused by Stoppage of	III, 469
“ Low Rates of American	VIII, 16, 65
“ Luxuries of	IV, 136
“ Magnitude of the Affairs of.....	II, 149; X, 37
“ Mail Service of	V, 552-563
“ Maintenance of.....	III, 44; VIII, 173
“ Managed by Public Servants.....	VIII, 196
“ Management of.....	II, 74-79;
“ “ “ III, 249, 250, 405; VII, 12, 13; X, 11	
“ “ “ —Characteristics of	VIII, 40
“ Managers of.....	I, 37, 230
“ Means of Crippling	VIII, 36
“ Methods of.....	IV, 125; VIII, 35, 205
“ “ Capitalizing.....	III, 59
“ “ Defrauding	V, 329, 330
“ “ Raising Money for Construction of..	
“	III, 30
“ Military Value of	III, 136
“ Multiplication of	VIII, 162
“ Mutuality of Interest in.....	VIII, 285
“ Narrow Gauge.....	III, 143
“ Necessities of.....	IV, 136

	PAGE
Railways, Objective Point of.....	IX, 21
“ Officers of.....	II, 139, 140
“ Opening for Business.....	VIII, 298, 299
“ Operating Force of.....	II, 71
“ Operation of—By the Government.....	II, 49
“ “ “—How Affected.....	III, 7
“ “ “—In Europe and America.....	II, 26
“ “ “ “ United States.....	II, 72
“ Operations of.....	VIII, 16, 209; IX, 99, 100
“ “—Principles Underlying.....	V, iii
“ Opportunities of Those Who Work for.....	IX, 11-19
“ Opposition to—in England.....	III, 117
“ Organization of....	II, 110, 120, 143, 153; V, 321; X, 36
“ “—in Connection with Handling Material.....	VII, 57
“ “ “ General Law.....	III, 157
“ “ “—under Charter.....	III, 156
“ Origin of.....	III, 110
“ Over-production of.....	VIII, 201
“ “—Concomitants of.....	VIII, 186
“ “—Effect of.....	VIII, 19
“ Ownership of.....	II, 74
“ “—in France.....	III, 46, 47
“ Owners of.....	II, 45; III, 60, 61, 63
“ “—Carriage of Traffic by.....	II, 48
“ Passenger Traffic of.....	V, 13-50
“ Permanency of.....	VIII, 173, 287
“ Permanent Character of.....	VII, 217, 218
“ “ Way of—Primary Purpose of.....	III, 110
“ Physical Life of....	IV, 8
“ Policy of American.....	II, 188
“ Political Importance of.....	III, 135
“ Poor.....	III, 169, 170
“ Poverty of American.....	II, 95
“ Power of.....	VIII, 162
“ Practices in Vogue on....	V, 304, 305
“ Presidents of.....	II, 152
“ Principles Governing.....	VIII, 19, 210
“ “ “ the Business of.....	VII, 221
“ “ “ “ Forces of.....	II, 97-107
“ Private <i>versus</i> Government Control of.....	VIII
“ Productiveness of.....	III, 42; VIII, 190
“ Profits of.....	VIII, 35, 51, 301
“ Progress of—to What Due.....	VII, 12
“ Proper Scope of Laws Regulating.....	VIII, 214
“ Property Pledges for Sums Due.....	V, 139-144
“ Prosperity of.....	VIII, 40
“ Prosperous.....	III, 169, 170
“ Protection of—from Snow.....	III, 302-305
“ Province of.....	J>

	PAGE
Railways, Purpose of	V, 18; VIII, 7, 159
“ Rank and File of—Distinctions in	IX, 12
“ Rate Making Power of	VIII, 50
“ Relation of Employes to	II, 57-69
“ “ “ —Owners to Public	VIII, 196
“ “ “ “ Passenger Traffic to	V, 68
“ “ “ “ —to Community	VIII, 90, 268
“ “ “ “ Employes	II, 91
“ “ “ “ Rates	VIII, 50
“ Relations of—to Patrons	VI, 107
“ “ “ “ the Public	IX, 13
“ “ “ “ Trade	VIII, 188, 213
“ Relief Department of	X, 291-353
“ —Requirements of Their Service	II, 70, 71
“ “ “ “ Those Who Work for	IX, 11-19
“ Responsibility of	V, 307-314
“ “ “ “ —for Baggage	V, 60, 61, 335, 336
“ Restriction of	VIII, 40
“ Result of Natural Laws	VIII, 201
“ Revenue of	IX, 22
“ Rights Accorded	III, 45, 46
“ Rivalry of	VIII, 81, 144
“ Safety Devices of	III, 36-38
“ “ “ “ of—in Europe and America	II, 26
“ Science of	IV, 401
“ Securities of	III, 86
“ Servants of	IX, 12
“ Serve Particular Districts	VIII, 27
“ Shortcomings of	VIII, 41
“ Short—Construction of	III, 170
“ Speculative—Construction of	III, 171, 172
“ Spirit that Animates	VIII, 161
“ State Aided	VIII, 67
“ Standard Articles Used by	III, 313
“ “ “ “ —in Different Countries	III, 178
“ “ “ “ Time of	IV, 335
“ State Laws Governing	VIII, 282
“ Statistics of	X, 21, 22, 36
“ Status of	VIII, 111
“ “ “ “ —in Australia	VIII, 331
“ “ “ “ Austria	III, 49, 50; VIII, 338
“ “ “ “ Belgium	VIII, 342
“ “ “ “ Canada	VIII, 325
“ “ “ “ Different Countries	VIII, 215
“ “ “ “ England	VIII, 318
“ “ “ “ France	VIII, 334
“ “ “ “ Germany	III, 48-50; VIII, 332
“ “ “ “ Holland	III, 50
“ “ “ “ Hungary	VIII, 338
“ “ “ “ Italy	III, 50; VIII, 342

	PAGE
Railways, Status of—in Japan.....	VIII, 347
“ “ “ Portugal.....	VIII, 342
“ “ “ Russia.....	III, 51; VIII, 346
“ “ “ Spain.....	VIII, 342
“ Strong.....	VIII, 191
“ “ versus Weak.....	VIII, 156
“ Tenure Under the Law.....	VIII, 265
“ the Effect of a Debased Currency Upon.....	III, 7, 26
“ —Their Effect on the Commercial World.....	III, 135
“ Through Business of.....	VIII, 206
“ Ticket System of—Its Cost.....	V, 80
“ Tickets Used by—in America.....	V, 88-111
“ Titles Used by.....	IX, 307
“ Track Accounts of.....	III, 284
“ Travel on.....	VIII, 164
“ Treatment of—in United States.....	VIII, 210
“ Universality of.....	VIII, 22
“ Unnecessary.....	VIII, 161
“ “ —Construction of.....	VIII, 182
“ “ —Effect of.....	III, 170-171; VIII, 165, 177
“ Unproductive.....	III, 31; VIII, 170, 198
“ “ —Construction of.....	III, 43
“ “ —Safety Appliances of.....	IV, 136
“ Unremunerative—Effect of.....	VIII, 29, 102
“ Use of Metals by.....	III, 320-322
“ “ Signals by.....	IV, 244
“ “ Wood by.....	III, 348-352
“ Value of Eminent Domain to.....	VIII, 58
“ “ Private Ownership.....	VIII, 217
“ Wages Paid by.....	II, 24
“ Wastage of Resources.....	VIII, 211
“ Weak.....	VIII, 191
“ Weakness of.....	VIII, 206
“ Wealth of.....	VIII, 162
Raising Transformer (375 Kilowatt)— <i>Illustration</i>	I, 422
“ “ <i>Case—Illustration</i>	I, 423
“ Transformers.....	I, 451, 452
Ramsbottom, Mr.....	I, 85
Ratchet Brake— <i>Illustration, Plate II</i>	I, 116-117
“ Hand Brake— <i>Illustration, Plate III</i>	I, 170-171
“ Wheel, Brake— <i>Illustration, Plate II</i>	I, 116-117
Ratchets.....	I, 243
Rate Cutting.....	VIII, 48, 149
“ Maker, Discretion of.....	VIII, 50
“ “ Qualifications of.....	VIII, 78
“ Making, Essentials Required in.....	VIII, 70
“ Sheets.....	VI, 105
“ Wars.....	VIII, 142
“ “ Cause of.....	VIII, 159
“ “ Effect of.....	VIII, 149

	PAGE
Rates.....	III, 135, 136
“ Ability to Heighten.....	VIII, 85
“ American Railway.....	VIII, 14, 64
“ Arbitrary Reduction of	VIII, 146
“ as Tolls.....	VIII, 60
“ Average Ton Mile.....	VI, 37
“ Baggage.....	V, 296
“ Based on Averages.....	VIII, 60
“ —Distance	VIII, 107
“ Bases of.....	VIII, 7, 25, 49, 95
“ Car Mileage	VI 63, 64
“ Carriers’ Right to Change at Will.....	VIII, 40
“ Committee	II, 131
“ Compared to Taxes	VIII, 99
“ Competitive.....	VIII, 11, 146
“ Complaints Regarding	VIII, 64
“ Cost as a Basis of.....	VIII, 31, 86, 95, 232
“ Cutting of	VIII, 75
“ Deviation From—by Competitors.....	V, 114
“ Differential.....	VIII, 156
“ Discriminatory	VIII, 79, 107, 109, 135, 139
“ Duty of Determining	VIII, 192
“ Economic Theory of.....	VIII
“ Effect of Arbitrary Changes in.....	VIII, 21
“ “ “ “ Cost of Carriage on	VIII, 103
“ “ “ “ Property on	VIII, 75, 97
“ “ “ “ Government Making.....	VIII, 210
“ “ “ “ Management on....	VIII, 231, 243
“ “ “ Low	VIII, 16, 38
“ “ “ Normal Conditions.....	VIII, 190
“ “ “ Cost of Operation on	III, 466
“ “ “ Economy of Operation on	VIII, 241
“ “ “ Management on.....	III, 57, 58
“ “ “ Pools on.....	VIII, 148
“ “ “ Strikes on.....	II, 50
“ “ “ Terminal Expenses on.....	III, 411
“ “ “ Public Opinion on ..	VIII, 39
“ “ “ Supply and Demand on.....	VIII, 97
“ “ “ Value of Product on.....	VIII, 52
“ Enforced Reduction of.....	VIII, 189
“ Enforcement of.....	VIII, 159
“ Equitable, Means of Securing.....	VIII, 244
“ Essentials of.....	VIII, 8, 77
“ Evolution of.....	VIII, 30
“ Exacted of Express Companies, in United States...V,	521
“ Excess Baggage.....	V, 458
“ Excessive.....	VIII, 13, 211
“ Express.....	V, 533-536
“ Fair—Importance of.....	VIII, 7, 146
“ Fluctuation of.....	VIII, 33, 75

	PAGE
Rates, Force Employed in Determining.....	VIII, 192
“ Freight.....	II, 241
“ “ —Errors in.....	X, 110
“ “ —in England.....	III, 407
“ “ —of Different Countries.....	VI, 37-41
Government Interference with.....	VIII, 193
How Formulated.....	VI, 26, 27
Influence of Barter on.....	VIII, 79
“ “ “ Competition on.....	VIII, 9, 45
“ “ “ —on Traffic.....	V, 29
“ “ “ —on Cost of Railroads.....	VIII, 29
“ “ “ “ Operating Expenses of Railroads....	VIII, 29
“ “ “ Quality on.....	VIII, 53
“ “ “ Risk on.....	VIII, 95
“ “ “ Water Routes on.....	VIII, 46
Influences Affecting.....	VIII, 25, 49, 95
Interstate—Posting.....	V, 116
Laws that Fix... ..	VIII, 26
Local.....	VIII, 90
Low.....	VIII, 116
“ —in America.....	I, 207; III, 36, 146; V, 26, 27
Lowering, Cause of.....	VIII, 39
Making.....	II, 239, 240
Mail.....	V, 553-557
Maintenance of.....	VIII, 157
Maximum.....	VIII, 36, 52, 135
Minimum.....	VIII, 170
Moderation of Wise Governments in Meddling with..	VIII, 315
“ Passenger.....	V, 120-123
“ “ —Compilation of.....	II, 250, 251
“ “ —in Europe.....	V, 25
“ “ “ the United States.....	V, 25
Prescribing.....	II, 239, 240
Principles Governing—Conditions Affecting.....	VIII, 95
“ “ Underlying.....	VIII, 7, 237
Prohibitive—in England.....	VI, 37
Raising—Cause of.....	VIII, 38
Reasonable.....	VIII, 7, 26, 30, 57, 211
Reduced—Savings from.....	III, 35
Reduction of.....	II, 110
“ “ —by Interstate Commerce Commission..	VIII, 150
“ “ “ —in the United States.....	VI, 26, 37-41
“ “ “ —Its Cause and Effect.....	I, 166
“ “ “ “ Effect on Traffic.....	VI, 38, 39
Reductions in.....	III, 42; V, 30, 40; VIII, 14, 38, 85
Relation of People to.....	VIII, 54
“ “ “ to Service.....	VIII, 28

	PAGE
Rates, Rules Governing Application of.....	VI, 151, 152
“ “ “ “ Cost of Property	VIII, 50
“ “ “ “ Maintenance	VIII, 43
“ “ “ “ Operating.....	VIII, 43
“ “ “ “ Markets	VIII, 44
“ “ “ “ Products	VIII, 47
“ “ “ “ Return on Investment.....	VIII, 43
“ Remunerative.....	VIII, 30
“ Requisites of	VIII, 73
“ Right of Legislature to Control	VIII, 68
“ “ “ “ Fix.....	VIII, 163
“ Schedules of—Regulations Governing	VI, 42-43
“ Special.....	V, 121, 122; VIII, 34, 37, 38, 79, 107, 129
“ “ —Authority for.....	V, 175
“ “ —Justice of.....	VIII, 132
“ “ —Necessity of.....	VIII, 66, 132
“ “ —Notice of.....	V, 122
“ “ —Objections to.....	VIII, 133
“ “ —Purpose of.....	VIII, 132
“ Stable—Value of.....	VIII, 16, 148
“ System for Formulating	VIII, 184
“ Tendency of—in United States.....	VIII, 151
“ Unauthorized.....	V, 174
“ Undue Reduction of—Effect of.....	VIII, 187
“ Uniform.....	VIII, 7, 44, 81, 114
“ “ —Maintenance of	VIII, 56
“ “ —Universality of Their Effect.....	VIII, 26
“ Unjust	VIII, 61
“ Unremunerative.....	VIII, 7, 127
“ —Upon What Dependent.....	III, 136, 142
“ Value of	VIII, 100
“ “ “ Service as a Basis for.....	VIII, 42, 85, 95
“ “ —What They Represent.....	VIII, 60, 77
Rating, of a Motor.....	I, 473
Ratio, Between Silver and Gold.....	III, 12, 13
“ of Auxillary Reservoir to Brake Cylinder— <i>Illustrations</i>	I, 357-359
“ “ Cost to Gross Earnings.....	III, 144, 145
Rattler.....	I, 258
Ravensworth, Lord.....	I, 25
Raw Material, Transfer of.....	I, 275, 276
Rawlinson, Sir Henry	II, 164
Reach Rod— <i>Illustration, Plate I</i>	I, 58-59
“ “ “ Cylinder Cock— <i>Illustration</i>	I, 60
Reactions Between Currents and Magnets—Where Utilized	I, 401
Read, Nathan—Experiments of.....	I, 18
Read's Steam Carriage, 1791—First Multitubular Boiler— <i>Illustration</i>	I, 19
“ Real Estate”.....	VII, 494

GENERAL INDEX.

279

	PAGE
Real Estate, Outlay for.....	III, 159
" " Procurement of.....	III, 159, 160
" " Purchase of.....	III, 172
Reamers.....	I, 262
Recapitulations.....	VII, 538-541
Receipt Book, Substitutes for.....	IX, 95
" for Cash Collected for Ferriage.....	VI, 220, 221
" Miscellaneous Freight Charges.....	VI, 217, 218
Receipts, Agents'—Signatures to.....	VII, 446
" Baggage—European.....	V, 386
" Blank.....	VI, 87, 88
" Cash—Remittance of.....	IX, 178-182
" Collection of.....	II, 291; X, 68, 69
" Conductors' Cash Fare.....	IX, 83, 84, 113, 114, 421
" Consignees'—for Freight Charges.....	VI, 197-210
" Current—Crediting.....	X, 29, 30
" Delivering—to Payees.....	IX, 84
" Division of.....	X, 31
" Duplicate—Use of.....	VI, 203
" Duty of Accounting Officer in Relation to.....	II, 265, 287
" " Collecting.....	II, 193
" English.....	VI, 323
" Express Traffic.....	V, 548-551
" for Baggage.....	V, 53, 56, 57
" " Freight, Rules Governing.....	VI, 123-126
" " Moneys Collected.....	X, 264
" " Paid by Agents.....	IX, 90, 91
" " Overcharges Refunded.....	VI, 265
" " Switching Charges.....	VI, 255-258
" Unrefunded Charges.....	VI, 263, 264
" Forms of.....	IX, 97
" Freight.....	VI, 94, 114, 115; IX, 84
" " —Signatures to.....	VII, 446
" Giving.....	VI, 200-210
" Issuing—for Cash Fares.....	V, 194-198
" Miscellaneous—Auditing.....	X, 118
" Money.....	IX, 81-85, 297, 324-326
" " —Care of.....	IX, 85-87
" Passenger—Protection of.....	IX, 112, 113
" Property.....	IX, 317, 318
" Purposes Served by.....	IX, 63, 64
" Signatures to.....	IX, 84
" Signing.....	IX, 342-347
" Special.....	IX, 95
" Stamping.....	IX, 84
" Taking.....	VII, 444-446; IX, 96
" Value of.....	V, 191, 192
" Writing.....	IX, 433
Receivers, Practices of.....	VIII, 256
" Ticket.....	V, 17

	PAGE
Receiving Agent	VI, 109
" Freight	VI, 93
Recharging Auxiliary Reservoirs	I, 327
Reclamation Vouchers	IX, 131
Reclining Chairs, American— <i>Illustration</i>	I, 218
Recognition of the Engineering Department	I, 234
Reconsigning Ticket—Rules Governing	VI, 178
Record Books, Access to	V, 173
" " Use of	V, 173
" Cash Fare	V, 195
" Conductors'—of Freight Loaded at Stations Where There Are No Agents	VI, 310-312
" of Amounts Charged, Collected and Refunded for Car Service	VI, 219, 220
" " Book Milk Ticket Sales	VI, 252
" " Cash Collected for Frriage	VI, 220, 221
" " Freight Loaded	VI, 310-312
" " " Manipulated in Transit	VI, 268
" " " Received	VI, 197
" " Interline Way Bills Passing Junctions	VI, 242, 243
" " Milk Ticket Sales	VI, 251
" " Miscellaneous Freight Charges Collected, VI, 217, 218 Monthly Abstracts of Interline Way Bills Re- ceived	VI, 230, 235
" " " " " Local Way Bills For- warded	VI, 230, 232
" " " " " Local Way Bills Received	VI, 230, 233
" " " Summary of Local Way Bills	VI, 238, 239
" " Overcharges	VI, 261-263
" " " Refunded	VI, 265
" " Switching	VI, 255-258
" " " Charges	VI, 255-258
" " " " Collectible	VI, 260, 261
" " " " Due Other Companies, VI, 258, 259	VI, 258, 259
" " Unrefunded Charges	VI, 263, 264
Records	II, 273
" Baggage	V, 337-341, 434, 435
" Car Seal	VI, 104
" Connected with Railway Accounts	VI, 77
" Excess Baggage	V, 506-514
" Express Traffic	V, 545-548
" Keeping	VII, 431, 432
" Material	VII, 269, 270
" of Movements of Cars	VI, 56, 57
" Old—Disposition of	VII, 305; IX, 431-433
" " —Preservation of	VII, 142
" Overcharge	IX, 365
" Passenger	V, 172
" Permanent	X, 88

	PAGE
Records, Preservation of.....	IX, 43
" Station.....	IX, 93-97
" —Care of.....	IX, 152, 153
" —Passenger—English.....	V, 242
" Ticket.....	X, 128
" —Station.....	V, 159, 160
" Treasurer's Office.....	X, 290
" Use of.....	VI, 316
" Value of.....	IX, 431
" Writing Up.....	IX, 433
Recorder of Deeds.....	III, 96
Rectangular Rail, Thick—A. D. 1838— <i>Illustration</i>	III, 224
Red, Signification of.....	IV, 340
Reduced Rate Tickets, English.....	V, 239
Reducing Elbow— <i>Illustration, Plate II</i>	I, 116-117
" Valve— <i>Illustrations</i>	I, 386
Reduction of Rates—Its Cause and Effect.....	I, 166
Redwood Ties.....	III, 350
Reece, Benjamin.....	III, 306
Reed, H. W.....	III, 207, 356
Reflector.....	I, 112
" — <i>Illustration, Plate II</i>	I, 116-117
" Headlight— <i>Illustration, Plate I</i>	I, 58-59
Reflectors, Silver-Plated Copper—Development of.....	I, 58
Refrigerator Car, Capacity of.....	I, 165
" New South Wales— <i>Illustration</i>	I, 187
" Cars.....	VI, 102
Refund Tickets, Mileage.....	V, 208, 210
Refunds, Auditing—by Traveling Auditors.....	IX, 285
" of Excess Fares.....	V, 196
" Overcharge.....	IX, 365, 366
Register Bills.....	X, 68, 85
" Interline Ticket.....	V, 159, 160, 162, 163
" Local Ticket.....	V, 159-162
" Ticket.....	IX, 122
" Various Persons Bills.....	VII, 427, 428
" Vouchers.....	VII, 436; X, 68, 83-85
Registered Bills, Collections for.....	IX, 427
" Bonds.....	III, 97
Regular Train—Meaning of Term.....	IV, 319
" Trains.....	IV, 352
Regulations. (See also "Rules.")	
" Governing Schedules of Fares and Freight Rates.....	VI, 42-48
Regulator— <i>Illustration, Plate II</i>	I, 116-117
" Automatic.....	IV, 164
Reinforce Brake.....	I, 312
" " Cylinder.....	I, 312
" Valve.....	I, 312
Reinforced Rail Joint— <i>Illustration</i>	III, 338

	PAGE
Relation Between Electricity and Magnetism	I, 405
" " Track and Traffic	III, 184-187
" of Electricity to Transportation	I, 392-396
" " Railway Employes to Railways	II, 57-69
Relations, Between Officers and Employes	II, 27, 28
Relative Cost of Operation by Steam Locomotives and by Electricity	I, 514-516
Relay, Controlling Operation of Automatic Electric Block Signal— <i>Illustration</i>	IV, 282
Relays, Automatic Electric Block System	IV, 281-283
Release, Form of—for Excess Baggage Traffic	V, 443
" Position, of Engineer's Brake and Equalizing Dis- charge Valve	I, 350
" Rods	I, 78
" Shipper's	VI, 112
" Spring— <i>Illustration, Plate II</i>	I, 116-117
" " Center Brake— <i>Illustration, Plate II</i> ..	I, 116-117
" Valve	I, 538
" " — <i>Illustration</i>	I, 541
" " Auxiliary Reservoir— <i>Illustration, Plate III</i>	I, 170-171
" " Rod— <i>Illustration, Plate III</i>	I, 170-171
Releases, for Freight	VI, 96
Releasing a Part Air Train When Moving	I, 367
" Brakes	I, 334-336, 348, 365
" " —Instructions to Trainmen	I, 374
" " on Freight Trains	I, 367
Reliability, Lack of	II, 110
Relief, Agents' Claims for	VI, 295, 296
" Cock, Cylinder— <i>Illustrations</i>	I, 113
" Department, in France	X, 329-345
" " Germany	X, 345-347
" " " Great Britain	X, 325-329
" " " India	X, 350-352
" " " Italy	X, 347-350
" " " the United States	X, 293-324
" " The	X, 291-353
" Funds—Sickness, Accident and Death	X, 298-309
" Valve— <i>Illustration, Plate I</i>	I, 58-59
" " Automatic	I, 310
" " " Graduated	I, 312, 313
" Valves, Water	I, 95
" Vouchers	IX, 371-374, 427
Religion	XI, 33, 75, 77
Remittances, Agents' ... V, 174; IX, 179, 265, 291, 412-419; X, 266	
" " —Receiving and Opening	IX, 186
" Cash	V, 222; IX, 135,
179, 181, 182, 327, 328; X, 135-139, 288, 289	
" " —Various Persons' Accounts	VII, 417-419
" Conductors' ... V, 174; IX, 181, 182, 265, 291, 419-424	

	PAGE
Remittances, Deficient	IX, 351
“ Fictitious	IX, 205, 206
“ Non-Bankable	IX, 418, 424-427
“ Opening—in Treasurer’s Office	X, 263
“ Over	IX, 351
“ Special	IX, 419
“ Station	IX, 352
“ Test	IX, 286
Remusat	XI, 28
Renewal of Locomotives and Cars	I, 232
Renewals, Cost of	III, 423
“ Renewals of Rails”	VII, 475, 514
“ Renewals of Ties”	VII, 514
“ Renewals of Ties—Operating”	VII, 475
“ Rentals” Account	VII, 526, 527
Rentals, Accounting for	X, 180
“ Payment of	III, 98
Rents, Collections for	VII, 422; IX, 427
“ Rents for Tracks, Yards and Terminals”	VII, 494, 523
“ Rents of Buildings and Other Property”	VII, 494, 523
Rents, Water—Payment of	IX, 403
Repair Shops	VII, 130, 131
“ of Locomotives and Cars	I, 232
“ Parts—Instructions to Car Inspectors	I, 332
“ Shed for Freight Cars, End Elevation— <i>Illustration</i> , I, 258	
“ “ “ “ Longitudinal Section— <i>Illustration</i>	I, 255
“ Sheds	I, 271
“ Shop, Locomotive—Equipment of	I, 262
“ “ Passenger and Freight Car—Section and End Elevation— <i>Illustration</i>	I, 255
“ “ “ “ Freight Car—Side Elevation— <i>Illustration</i>	I, 252
“ Shops	I, 122, 230, 250
“ “ Car	I, 271-279
“ “ —Plan for— <i>Illustration</i>	I, 242
“ “ for Cars and Locomotives	I, 271
“ “ General	I, 248, 250, 270
“ “ Labor in	I, 264
“ “ Location, Design and Equipment of	I, 237
“ “ “ of	I, 249, 250
“ “ Locomotive	I, 247-268
“ “ —Plan for— <i>Illustration</i>	I, 239
“ “ Number of	I, 283
“ “ Organization of Labor in	I, 264
“ Tracks	I, 268, 269, 275
“ Yards	I, 269
“ Repairs and Renewals of Bridges and Culverts”	VII, 475, 476, 514, 515

	PAGE
"Repairs and Renewals of Buildings and Fixtures".....	VII, 477, 478, 515
"Repairs and Renewals of Docks and Wharves"....	VII, 478, 515
"Repairs and Renewals of Fences, Road Crossings, Signs and Cattle Guards".....	VII, 476, 477, 515
"Repairs and Renewals of Freight Cars".....	VII, 482, 517
"Repairs and Renewals of Locomotives"....	VII, 479-481, 516, 517
"Repairs and Renewals of Marine Equipment".....	VII, 483, 484, 517
"Repairs and Renewals of Passenger Cars"....	VII, 481, 482, 517
"Repairs and Renewals of Shop Machinery and Tools".....	VII, 484, 517, 518
"Repairs and Renewals of Telegraph"....	VII, 478, 479, 515, 516
"Repairs and Renewals of Work Cars".....	VII, 482, 483, 517
Repairs, Buildings and Machinery for Making.....	I, 239
" Freshet	III, 285
" Made in Roundhouses.....	I, 239, 240
"Repairs of Dining Cars".....	VII, 301
Repairs of Cars.....	I, 271-279, 382
" Locomotives.....	I, 237, 247, 267, 382
"Repairs of Roadway".....	VII, 473-475, 514
Repairs of Roadway and Track.....	III, 284, 285
" Petty—Articles for Making	I, 270
" Spring	III, 239
" —Why Required	I, 231
" Winter.....	III, 247
Repairers, Car.....	I, 270, 271
Repairing Triple Valves.....	I, 382
Report—Use of the Word.....	V, 142
Reports, Locomotive	X, 100-108
" Ticket—Auditing.....	X, 128-133
" Traveling Auditors'....	VII, 433; IX, 277-283, 287, 288
Reporting Defects to Inspectors—Instructions to Trainmen.....	I, 327
Representatives of Investors.....	III, 82-84
Requests for Time Tickets	VII, 405, 406; IX, 390
" Government—for Transportation.....	V, 144-146
Requirements, Conformity of Cars to	I, 203
" of Those Who Work for Railways.....	IX, 11-19
Requisitions. (See also "Orders.").....	II, 292; VII, 70-90
" Alterations in	VII, 61, 80
" Approval of	VII, 73, 74
" Cancellation of	VII, 80
" Certification of.....	VII, 79
" Classes of.....	VII, 70
" Countersigning.....	VII, 62, 63, 78
" Delay in Filling.....	VII, 49, 50, 72-74
" Different Methods of Handling.....	VII, 72
" Discretion Exercised in Filling.....	VII, 60
" Filling.....	VII, 79
" for Postage Stamps	X, 287

	PAGE
Requisitions for Tickets	V, 123-127
" " " —English.....	V, 240, 241
" " Hotel Supplies	VII, 87
" " Manufacturing Material	VII, 323
" " Oil.....	VII, 119
" " Posts.....	VII, 83
" " Rails.....	VII, 83
" " Stationery.....	VII, 86
" " Ties.....	VII, 83
" " Timber.....	VII, 83
" " Time Tickets.....	VII, 400
" Fuel.....	VII, 85
" —How They Differ from Orders.....	VII, 77
" Information Afforded by.....	VII, 70
" Making.....	VII, 57
" Numbering.....	VII, 87
" —on Whom Made.....	VII, 70
" Passing Upon.....	VII, 66, 67
" Preservation of.....	VII, 84
" Prevention of Excessive.....	VII, 78
" Principles Governing.....	VII, 71-77
" Records of.....	VII, 83
" Rules Governing.....	VII, 77-88
" Signing.....	VII, 62, 63, 78
" Times for Making.....	VII, 78, 79
Reserve Fund.....	III, 461, 462
Reservoir, Air.....	I, 292
" Storage.....	I, 244, 262
" Auxiliary.....	I, 306-308, 324, 325, 335, 336, 356-361
" " —Illustrations, {	
Plate II.....	I, 540, 541
Plate III.....	I, 170-171
" " —Charging.....	I, 371
" " —for Driver Brakes— <i>Illustration</i>	I, 539
" " —Ratio of, to Brake Cylinder— <i>Illustrations</i>	I, 357-359
" Block— <i>Illustration, Plate III</i>	I, 170-171
" Brake Valve— <i>Illustration, Plate I</i>	I, 58-59
" Car, for Liquids—French— <i>Illustration</i>	I, 164
" Cock.....	I, 324
" Equalizing—for Engineer's Valve— <i>Illustration</i>	I, 539
" for Compressed Air.....	I, 305
" in a Gas Plant.....	I, 438
" Main.....	I, 309, 334-336, 380
" " — <i>Illustration</i>	I, 539
" Oil.....	I, 101
" Steam—on Locomotives.....	I, 76
Reservoirs.....	I, 315
" Auxiliary—Draining.....	I, 332
" " —Exhausting Pressure from.....	I, 377

	PAGE
Reservoirs, Auxiliary—Recharging.....	I, 327
“ Draining.....	I, 329, 330
“ for Oils.....	I, 245
Resistance.....	I, 484
“ Comparative—on Highways and Railways.....	III, 113
“ Measure of.....	I, 401
“ of Circuit.....	I, 415, 416, 432, 433, 475, 476
“ Tractive.....	I, 64
“ —Upon What Dependent.....	I, 398
Responsibilities, of Directors.....	II, 130
Responsibility, Concentration of.....	I, 284
“ Division of.....	II, 113
“ —Its Effect on Wages.....	II, 102
“ of Inspectors—Instructions to Car Inspectors.....	I, 333
“ “ Railway Management.....	II, 67, 68
Rest, Arm— <i>Illustration, Plate II</i>	I, 116–117
“ Hand Brake— <i>Illustration, Plate III</i>	I, 170–171
“ Seat End— <i>Illustration, Plate II</i>	I, 116–117
Retainer Stopped Up—Instructions to Trainmen.....	I, 375
Retaining Chain, Face Plate— <i>Illustration, Plate II</i>	I, 116–117
“ Valve.....	I, 375
Return Bend— <i>Illustration, Plate II</i>	I, 116–117
“ Local Ticket—Monthly.....	V, 162, 164–167
“ Monthly—Interline Ticket.....	V, 167–169
“ Use of the Word.....	V, 142
“ Weekly—of Interline Ticket Sales.....	V, 167
“ “ Ticket Sales.....	V, 163, 164
Returns. (See also “Reports.”)	
“ Agents’—English.....	VI, 324–326
“ Auditing.....	II, 285
“ Baggage.....	V, 337–341, 432
“ Baggage-men’s.....	V, 434, 435, 446, 447
“ Cash Fare—Rules Governing.....	V, 218–221
“ —Channels Through Which They Pass.....	X, 86–90
“ Coaching—English.....	V, 252–259
“ Conductors’—of Freight Loaded.....	VI, 310–312
“ “ “ Hauled.....	VI, 179, 180
“ Corporate.....	IX, 219
“ Daily—of Freight Earnings.....	VI, 243–247
“ “ Milk Shipments.....	VI, 250
“ Division of.....	X, 60–62
“ Errors in.....	V, 176
“ Examination of.....	II, 285
“ Excess Baggage.....	X, 134
“ Express Traffic.....	V, 545–548
“ —Ferry Collections.....	VI, 221, 222
“ for Mineral Traffic—English.....	VI, 326, 327
“ Freight.....	VI, 314
“ “ —Auditing.....	X, 109–120

	PAGE
Returns, Fuel.....	VII, 332-336
“ Functions of.....	II, 284
“ —How Often They Should Be Made.....	X, 45-59
“ Interline Excess Baggage.....	V, 482
“ “ Traffic—English.....	V, 261, 262
“ Junction—of Interline Way Bills.....	VI, 241, 242
“ Milk.....	VI, 247, 248
“ Miscellaneous Freight Collections Not Waybilled..	VI, 218, 219
“ Monthly—of Book Milk Ticket Sales.....	VI, 252
“ “ “ Comodities, for Freight Forwarded..	VI, 272-274
“ “ “ “ for Freight Waybilled Through from Sta- tions on Other Rail- roads...VI, 274-276	
“ “ “ Excess Baggage—Rules Governing..	V, 507-512
“ “ “ Milk Ticket Sales.....	VI, 251
“ “ “ Unrefunded Charges.....	VI, 265, 266
“ of Conductors.....	V, 216-222
“ “ Freight Forwarded After Having Been Manipu- lated in Transit.....	VI, 270
“ “ “ Received to Be Manipulated in Transit..	VI, 269
“ “ Interline Way Bills Passing Junctions..	VI, 242, 243
“ “ Milling, Cleaning and Shelling in Transit...VI,	267
“ “ Monthly Abstracts of Interline Way Bills Re- ceived.....	VI, 230, 235
“ “ “ “ Local Way Bills For- warded...VI,	230, 232
“ “ “ “ Local Way Bills Re- ceived.....	VI, 230, 233
“ “ “ Summary of Local Way Bills..	VI, 238, 239
“ “ Overcharges.....	VI, 261-263
“ “ Switching Charges Collectible.....	VI, 260, 261
“ “ “ Due Other Companies.....	VI, 258, 259
“ Passenger.....	V, 172, 173
“ “ —Auditing.....	X, 121-134
“ Purpose of Agents' and Conductors'.....	V, 156-158
“ Railway.....	III, 41
“ Rendering.....	III, 425
“ Required of Agents.....	VI, 83
“ “ Conductors.....	VI, 83
“ Routine of.....	X, 86-90
“ Station Agents'.....	X, 67
“ “ —Passenger—English.....	V, 242-245
“ Theory of.....	X, 63-69
“ Ticket.....	V, 83, 84

	PAGE
Returns, Ticket—Auditing.....	X, 128-133
“ “ —Conductors'	V, 221, 222
“ “ —Traveling Auditors'	IX, 160
“ Traffic—Daily System of.....	X, 53, 54
“ “ —Monthly System of	X, 52
“ “ —Time and Manner of Making.....	IX, 44
“ Train	IV, 62-67
“ Uniform—Governmental.....	X, 43, 44
“ Verification of	II, 288
Reunions, Notice of—to Officials.....	V, 113
Revenue Accounts	II, 290
“ Baggage	V, 63-65
“ Collection of, II, 186, 192, 274; IX, 20, 23-26, 178, 298, 314	
“ “ —Responsibility for	IX, 24
“ Disbursement of	II, 274
“ Excess Baggage	V, 455, 457, 460
“ “ —Accounting for	V, 506-514
“ “ —Collection of	V, 462-477
“ Handling	IX, 298
“ —How Derived.....	I, 165, 166
“ Influences Affecting.....	III, 454
“ of Fast Freight Lines.....	VI, 75
“ “ Transportation Companies.....	I, 159
“ Railway	IX, 22
“ “ —Collection of.....	VIII, 23; IX, 7-29
“ “ —Disbursement of.....	VIII, 23
“ “ —Men Who Handle.....	IX, 26
“ “ —Principles and Methods to Be Observed in Handling.....	IX, 20-34
“ “ —Uses to Which Put	VIII, 23
“ Surplus to Build Other Lines.....	VIII, 184
Revenues, Freight—Protection of	VI, 25
Reverse Lever— <i>Illustration, Plate I</i>	I, 58-59
“ Levers	I, 286
Reversible Seat	I, 188
“ “ American— <i>Illustrations</i>	I, 217
Reversing Gear	I, 49
“ “ End View of— <i>Illustration</i>	I, 90
“ “ Engineer's Lever in Connection with— <i>Illustration</i>	I, 91
“ “ Side View of— <i>Illustration</i>	I, 90
“ “ Spring Case— <i>Illustration</i>	I, 67
“ Lever	I, 91
“ “ — <i>Illustration</i>	I, 60
“ “ Reach Rod— <i>Illustration</i>	I, 60
“ Rod	I, 91
“ Valve Mechanism.....	I, 308
Revetments	III, 254
Revolving Shaft	I, 441
Reward, Baltimore & Ohio	I, 32

	PAGE
Rewards	II, 24, 29-31; III, 324, 325; IV, 24-27
Rheostat	I, 410, 460
Rhodes, G. W.	I, 236, 240, 241, 244, 252, 253, 257-259, 260, 262, 276, 279, 333
Rich, Baggage of the	V, 413
Richard Cœur de Leon, Baggage of	V, 280
Richmond Locomotive— <i>Illustration</i>	I, 144
Ridge Pole, Lower— <i>Illustration, Plate III</i>	I, 170-171
Riding Backward	I, 187, 188
Riebenack, M.	V, 17, 110
Rig, Grate Shaking— <i>Illustration, Plate I</i>	I, 58-59
" Whistle— <i>Illustration, Plate I</i>	I, 58-59
Rigging, Cylinder Cocks— <i>Illustration, Plate I</i>	I, 58-59
" Draft	I, 210
" Grate	I, 286
" Throttle	I, 286
"Right of Way"	VII, 464
Right of Way, Claims for	II, 233
" " Cost of	III, 45
" to the Road—Meaning of Term	IV, 319, 320
Rights of a Train—Meaning of Term	IV, 320
" " Railway Corporations	VII, 27
" " the Common Carrier	VI, 6, 7
Rim, Wheel— <i>Illustration, Plate III</i>	I, 170-171
Ring, Dry Pipe— <i>Illustration</i>	I, 98
" for Russia Iron Top— <i>Illustration, Plate II</i>	I, 116-117
" Joint and Wedge—West Jersey Railroad— <i>Illustration</i>	III, 245
" Mud— <i>Illustration</i>	I, 98
" Piston Packing— <i>Illustration</i>	I, 341
Rings, Curtain— <i>Illustration, Plate II</i>	I, 116-117
" Piston Packing— <i>Illustration, Plate I</i>	I, 58-59
"Riprap"	III, 254
Riser— <i>Illustration, Plate II</i>	I, 116-117
" Platform Step— <i>Illustration, Plate II</i>	I, 116-117
Risk, Influence of—on Rates	VIII, 95
" Premium Paid for	III, 75
Rivalry in Railway Organizations	II, 124
" Result of—Among Manufacturers	I, 146, 147
Rivers, Changes in Channels of	III, 163
Riveting Machine, Hydraulic	I, 255, 256
" Machinery, Portable	I, 262
" Plant, Hydraulic	I, 262
Rivets	I, 75
" Use of—In the Boiler	I, 74
Road Building, Art of	I, 163
" Cable	I, 393
" Crossings	III, 256, 257
"Road Crossings and Signs"	VII, 464, 465
Road Crossings, Duties of Conductors in Relation to	IV, 404

	PAGE
Road Crossings, Effect of—on Cost of Operation	III, 394
“ “ Maintenance of	III, 300
“ Equipment, Electrical	I, 462-469
“ Inspection of	III, 248, 249
“ Material, Care and Use of	VII, 106-113
“ “ Charges Collected for	VII, 421, 422; IX, 426
“ Wagons, Primitive Application of Steam to	XI, 510-520
“ “ “ “ “ —Illustrations	XI, 510-520
Roads, Creation of	XI, 49
“ Electric	I, 489-506
“ Necessity of Good	I, 162, 163
“ to Preferment	II, 61, 62
“ Tram	III, 111
Roadbed	III, 250, 251
“ Chicago & North-Western Railway	III, 353
“ “ “ “ “ —Illustration	III, 362
“ Cost of Keeping in Order	III, 422, 423
“ Drainage of	III, 251-255
“ Effect of—on Cost	X, 166
“ Electric Railway	I, 462
“ Preparation of	III, 208
Roadmaster	III, 259
Roadmaster's Division	III, 259
Roadmasters, Requisitions of	VII, 73
Roadway and Track, Care of	III, 206-271
“ “ “ Construction of	III, 206-271
“ “ “ Cost of Repairs and Renewals of	III, 234
“ “ “ Expenses of—Due to Climatic Causes	III, 291
“ “ “ “ “ “ “ Traffic	III, 291
“ “ “ Maintenance of	III, 206-271
“ “ “ Material Used in Repairs and Renewals of	III, 284, 285
“ Department, Organization of	III, 258-260
“ “ Rules Governing	III, 260-271
“ Maintenance of	II, 211
“ Superintendent of	III, 259
Robinson, Doctor	XI, 510
Rock Cuts	III, 326
Rocker—Illustration, Plate I	I, 58-59
“ Arm	I, 90, 94
“ Box—Illustration, Plate I	I, 58-49
“ Panels—Illustration, Plate II	I, 116-117
“ Shaft	I, 94
“ “ —Illustration	I, 60
Rockers	I, 286
“Rocket” Locomotive	I, 30

	PAGE
"Rocket" Locomotive—Stephenson's, 1830— <i>Illustration</i> . . .	I, 29
Rocking Grates— <i>Illustration, Plate I</i>	I, 58-59
Rod Balance Spring— <i>Illustration, Plate II</i>	I, 116-117
" " Center Brake— <i>Illustration, Plate II</i>	I, 116-117
" Basket Rack— <i>Illustration, Plate II</i>	I, 116-117
" Body Truss— <i>Illustration, Plate II</i>	I, 116-117
" Bush— <i>Illustration, Plate I</i>	I, 58-59
" Connecting—Cylinder Lever— <i>Illustration, Plate II</i>	I, 116-117
" " —Hand Brake— <i>Illustration, Plate II</i>	I, 116-117
" " Hodge Lever— <i>Illustration, Plate II</i>	I, 116-117
" " Lower Brake— <i>Illustration, Plate II</i>	I, 116-117
" " to Truck Gear— <i>Illustration, Plate II</i>	I, 116-117
" " Upper Brake— <i>Illustration, Plate II</i>	I, 116-117
" Connection, Main— <i>Illustration, Plate I</i>	I, 58-59
" Counterbrace— <i>Illustration, Plate II</i>	I, 116-117
" Curtain— <i>Illustration, Plate II</i>	I, 116-117
" End Sill Tie— <i>Illustration, Plate II</i>	I, 116-117
" Hog Chain or Overhang Truss— <i>Illustration, Plate II</i>	I, 116-117
" " Inside—Connecting— <i>Illustration, Plate II</i>	I, 116-117
" " Main— <i>Illustration, Plate I</i>	I, 58-59
" " Operating—for Release Valve— <i>Illustration</i>	I, 541
" " Outside—Connecting— <i>Illustration, Plate II</i>	I, 116-117
" " Pin Lifter— <i>Illustration, Plate III</i>	I, 170-171
" " Piston	I, 329
" " — <i>Illustration, Plate I</i>	I, 59-59
" " Platform Tie— <i>Illustration, Plate II</i>	I, 116-117
" " Push— <i>Illustration</i>	I, 541
" " Reach— <i>Illustration, Plate I</i>	I, 58-59
" " Release Valve— <i>Illustration, Plate III</i>	I, 170-171
" " Reversing	I, 91
" " Side or Parallel— <i>Illustration, Plate I</i>	I, 58-59
" " Sill and Tie— <i>Illustration, Plate II</i>	I, 116-117
" " " Tie— <i>Illustration, Plate II</i>	I, 116-117
" " Seat, Overhang Truss— <i>Illustration, Plate II</i>	I, 116-117
" " Sliding— <i>Illustration, Plate II</i>	I, 116-117
" " Stay—Pedestal— <i>Illustration, Plate II</i>	I, 116-117
" " Straining, Brace Rod— <i>Illustration, Plate II</i>	I, 116-117
" " Tension	I, 214
" " Tie—Safety Beam— <i>Illustration, Plate II</i>	I, 116-117
" " Truss—Transom— <i>Illustration, Plate II</i>	I, 116-117
" " Uncoupling— <i>Illustration, Plate II</i>	I, 116-117
" " Valve	I, 94
" " " Stem— <i>Illustration, Plate I</i>	I, 58-59
" " Vestibule Door Guard— <i>Illustration, Plate II</i>	I, 116-117
" " Washer Brace— <i>Illustration, Plate II</i>	I, 116-117
" " Window Curtain— <i>Illustration, Plate II</i>	I, 116-117
Rods	I, 272, 381

	PAGE
Rods, Connecting	I, 92, 334
“ Corner Post— <i>Illustration, Plate III</i>	I, 170-171
“ Counter Brace— <i>Illustration, Plate III</i>	I, 170-171
“ Door Post— <i>Illustration, Plate III</i>	I, 170-171
“ Eccentric	I, 89
“ “ —Stephenson's Locomotive	I, 48
“ Intermediate Post— <i>Illustration, Plate III</i>	I, 170-171
“ Piston—Packing of	I, 381
“ Release	I, 378
“ Stay	I, 75
“ Truss	I, 210
Rogers' Locomotive— <i>Illustration</i>	I, 141
Roll, Head— <i>Illustration, Plate II</i>	I, 116-117
Rolling Stock	I, 120, 462
“Rolling Stock”	VII, 465
Rolling Stock, Care and Maintenance of	I, 238
“ “ Collections for Repairs of	VII, 421
“ “ Comparison of English and American	III, 148
“ “ —Cost of Keeping in Repair	III, 430, 431, 478, 479
“ “ Inspectors of	II, 47
“ “ Manufacture of—by Railroad Companies, I, 141-144	
“ “ Supervision of	II, 201
Roman Cart Wheel, Ancient— <i>Illustration</i>	IV, 189
Romans, Ratio of Silver and Gold Among the	III, 12
“ Road Building by	I, 163
“ The	XI, 25, 146
Rome	XI, 44
“ Highways of	VII, 216-218
Roof Apron— <i>Illustration, Plate II</i>	I, 116-117
“ Boards— <i>Illustration, Plate II</i>	I, 116-117
“ Car	I, 211, 212, 214
“ “ Line, Platform— <i>Illustration, Plate II</i>	I, 116-117
“ Casting— <i>Illustration, Plate II</i>	I, 116-117
“ Covering— <i>Illustration, Plate III</i>	I, 170-171
“ Grab Iron— <i>Illustration, Plate III</i>	I, 170-171
“ of Car Repair Shops	I, 273
“ “ Roundhouses	I, 243
“ “ Shop Buildings	I, 253
“ Platform— <i>Illustration, Plate II</i>	I, 116-117
“ Trusses	I, 253, 256
Roofing, Corrugated Iron— <i>Illustration, Plate III</i>	I, 170-171
Room, Check	I, 266
“ Dynamo	I, 259
“ Engine	I, 259
“ Erecting	I, 261
“ Paint	I, 274
“ Smoking	I, 200
“ “ — <i>Illustration, Plate II</i>	I, 116-117
“ Stock Oil	I, 274
“ Upholstery	I, 274

	PAGE
Room, Yard.. .. .	I, 250, 275
Rooms, Core	I, 257
“ Parcel	V, 427-430
“ —Rules Governing	V, 429, 430
“ Toilet	I, 184, 185
Rope, Bell—Use of, as Signal	IV, 250, 251
“ Safety—Berth— <i>Illustration, Plate II.</i>	I, 116-117
“ Use of—by Railways	VII, 212
Rotary, Converter	I, 427
“ Disc Valve	I, 329
“ Plug	I, 309
“ Power, Production of—by Cugnot	I, 18
“ Transformer	I, 427
“ “ (400 Kilowatt)— <i>Illustration</i>	I, 424
“ “ Armature (400 Kilowatt)— <i>Illustration</i>	I, 425
“ “ at Buffalo— <i>Illustration</i>	I, 502
“ “ Niagara Power House (500 Horsepower) — <i>Illustration</i>	I, 501
“ Transformers	I, 440, 451, 452
“ Valve	I, 365
“ “ Horizontal	I, 308
“ “ Vertical	I, 308
Rotterdam and Antwerp Steamship Company	V, 289
Roumanian State Car— <i>Illustration</i>	I, 220
Round Trip Card Tickets	V, 94, 95
Roundhouse, Design of	I, 241
“ Employees	I, 229, 271
“ Floor of	I, 243
“ Force	I, 247
“ Foreman	I, 247, 316
“ Handling Cinders at	I, 260
“ Selection of Ground for	I, 240
Roundhouses	I, 238-247, 250, 269
“ Arrangement of	I, 230
“ Fuel Stored at	VII, 334
“ Location of	I, 237, 240
“ Method of Heating	I, 241
Route Agents, Express	V, 539
Routes, Surveys of	III, 157
Royal Commission	II, 45
“ “ of England	VI, 69-71
“ “ on Railways	III, 169
“ “ Report of	III, 154
Rubber Seat— <i>Illustration</i>	I, 344
“ Use of—by Railways	VII, 213
Rule, The First Freight	VI, 84
Ruler, Needs of—How Met	XI, 33
Rules and Regulations Governing the Use of the Brake, I, 314-333	
“ Differences in—on Different Railways	IV, 308-313

	PAGE
Rules, Early Train—in Great Britain.....	I, 171
“ Effect of.....	IX, 302
“ Formulation of—for Handling Accounts.....	VI, 84, 85
“ Governing Movement of Trains.....	IV, 325-439
“ “ the Treasurer's Office.....	X, 257-290
“ “ Use of Foreign Cars.....	VI, 65, 66
“ Miscellaneous—Governing the Handling of Freight	VI, 105-108
“ Necessity of Study of.....	IV, 330
“ Obedience to.....	IV, 329
“ Object of.....	IX, 308
“ Printed.....	IV, 228, 329
“ Railway—Early.....	IX, 301
“ Train—English.....	IV, 331-334, 340, 343-345, 348-350, 357, 360-364, 366, 367, 374, 377-382, 402, 403, 405-419, 421, 424, 425, 431-435, 441, 461
“ “ —Growth of.....	IV, 302-313
“ “ —Object of.....	IV, 328
“ “ —Standard.....	IV, 509
“ “ —Value of.....	VII, 302-313
“ Value of.....	IV, 246
Run Regardless—Meaning of Term.....	IV, 320
Running Against a Train—Meaning of Term.....	IV, 330
“ Board.....	I, 331
“ “ —Illustrations, { Plate I.....	I, 58-59
“ “ “ Plate III.....	I, 170-171
“ “ Saddle—Illustration, Plate III.....	I, 170-171
“ Position—Instructions to Engineers.....	I, 365
“ “ of Engineer's Brake and Equalizing Dis- charge Valve.....	I, 350
“ Tests of Brakes.....	I, 363, 364
Runways, Overhead.....	I, 256, 260, 275
Russia.....	I, 100; XI, 54
“ Baggage Allowed in.....	V, 288
“ Gauge Used in.....	III, 194
“ Heating Cars in.....	V, 234, 235
“ Iron.....	I, 74
“ —Its Primitive Associations and Means of Carriage	XI, 448-458
“ Primitive Carriage in—Illustrations.....	XI, 448-458
“ Status of Railways in.....	III, 51; VIII, 346
“ Use of Oil in.....	I, 54, 102
Russian Freight Locomotive—Illustration.....	I, 124
Russians, Use of Portable Railroads by.....	I, 222
Rust, Effect of.....	III, 272-279
“ Prevention of.....	III, 273, 274
Saddle, Casting—Illustration.....	I, 60
“ Cylinder—Illustration, Plate I.....	I, 58-59
“ Opening—Illustration.....	I, 98

	PAGE
Saddle, Running Board— <i>Illustration, Plate III</i>	I, 170-171
“ Tank Engine, American Four-Wheeled— <i>Illustration</i>	I, 105
Saddles	I, 93, 109, 286
Safeguards	VI, 78, 79, 81, 82
“ Enforcement of	II, 126
“ Fiscal—Enforcement of	IX, 297
“ Origin of	XI, 40
“ Value of	IX, 28
Safes, Changing Combinations of	IX, 134, 336
“ Locked—Opening	X, 272
“ Money	X, 270, 271
“ Use of	IX, 188, 189, 329, 334-337
Safety Appliances	IV, 106-145; VIII, 316
“ “ Adoption of	II, 26; IV, 134, 135, 137, 138
“ “ —How Looked Upon by Governments	III, 38
“ “ Power of State to Enforce	IV, 138
“ Beam— <i>Illustration, Plate II</i>	I, 116-117
“ “ Iron— <i>Illustration, Plate II</i>	I, 116-117
“ “ Middle— <i>Illustration, Plate II</i>	I, 116-117
“ “ Tie Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Bearing, Axle— <i>Illustration, Plate II</i>	I, 116-117
“ Coupling Chain— <i>Illustration, Plate II</i>	I, 116-117
“ Devices	III, 36-38
“ Hanger— <i>Illustration, Plate I</i>	I, 58-59
“ “ Center Brake— <i>Illustration, Plate II</i>	I, 116-117
“ Plate Handle— <i>Illustration, Plate II</i>	I, 116-117
“ Plugs	I, 81
“ Rope, Berth— <i>Illustration, Plate II</i>	I, 116-117
“ Strap, Axle— <i>Illustration, Plate II</i>	I, 116-117
“ “ Brake— <i>Illustration, Plate II</i>	I, 116-117
“ Valve	I, 81, 82
“ “ Connections— <i>Illustration</i>	I, 98
“ “ for High Speed Brake— <i>Illustration</i>	I, 362
“ “	I, 362, 363
“ “ Section of— <i>Illustration</i>	I, 82
“ Valves— <i>Illustration, Plate I</i>	I, 58-58
Salaries—English Railways	IV, 447, 448
“Salaries of Clerks and Attendants”	VII, 496, 523
“Salaries of General Officers”	VII, 495, 523
Sales Agent. (See “Purchasing and Sales Agent.”)	
Saloon Car, Austrian Imperial— <i>Illustration</i>	I, 220
Salts, Metallic—Use of	III, 352
“ Mineral—Use of	III, 361
Sample Cases, Checking	V, 497, 498
“Sampson” Locomotive	I, 53
“Samson” Locomotive	I, 31
“ “ 1838. Built by Timothy Hackworth — <i>Illustration</i>	I, 40
Sand, Application of—to Rails	I, 110, 321

	PAGE
Sand, Ballast.....	III, 373
“ Blast.....	I, 53
“ “ Introduction of.....	I, 53
“ Box.....	I, 110
“ “ — <i>Illustrations, Plate I</i>	I, 58-59, 60
“ “ Lever— <i>Illustration, Plate I</i>	I, 58-59
“ Cranes.....	I, 247
“ Ejector.....	I, 53
“ Funnel.....	I, 103
“ Lever— <i>Illustration, Plate I</i>	I, 58-59
“ Papering Machines.....	I, 262
“ Pipe— <i>Illustrations, { Plate I</i>	I, 58-59
“ “ Locomotive—Supplemented by Steam Blast— — <i>Illustration</i>	I, 60 I, 111
“ Supply of—for Locomotives.....	I, 246
“ Use of—on Rails.....	I, 313
“ Waste of—Its Prevention.....	I, 53
Sanding Appliances, Air—Automatic.....	I, 313
“ Rails.....	I, 369
Sanitation.....	V, 37-39
Sardis.....	XI, 129
Sargent, George M.....	I, 302
Sash, Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Lift Door— <i>Illustration, Plate II</i>	I, 116-117
“ Lintel, Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Lower Door— <i>Illustration, Plate II</i>	I, 116-117
“ Opener, Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Pivot, Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Pull, Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Upper Door— <i>Illustration, Plate II</i>	I, 116-117
“ Window— <i>Illustration, Plate II</i>	I, 116-117
“ “ Blind— <i>Illustration, Plate II</i>	I, 116-117
Savagery.....	XI, 43
“ Relation of Property to.....	XI, 9
Savages, Advancement of.....	XI, 53
“ Money of.....	III, 9
Saving, Habit of—What It Represents.....	VII, 22, 23
“ —How Effected in the Machinery Department.....	I, 284
Savings Funds.....	X, 313-320
Saw Track— <i>Illustration</i>	III, 333
Sawdust, Removal of.....	I, 274
Saxon State Railways of Germany, Freight Cars of.....	I, 121
Scaffolding.....	I, 274
Scalpers, Ticket.....	V, 45-49
“ “ —Operations of.....	V, 46, 47
Scarfig Machinery.....	I, 262
Schedule—Meaning of Term.....	IV, 320
“ of Standard Accounts and Statistics of Railroads.....	X, 357-361

	PAGE
Schedule, Train.....	IV, 75, 76
Schedules, Arbitrary.....	II, 35
" of Fares and Freight Rates—Regulations Govern- ing.....	VI, 42-48
Schenectady.....	I, 44
" Locomotive— <i>Illustrations</i>	I, 139, 140, 142
Schlemann, Doctor.....	XI, 89
Schools, Polytechnic.....	I, 234
Schweinfurth.....	XI, 28
Science, Electrical.....	I, 390
" Railway— <i>The</i>	VII, 232
Scientific Instruction.....	I, 234
Scoop Water.....	I, 106
Scotch Block—Meaning of Term.....	IV, 315
Scott, Charles F.....	I, 391
Scottish Double Header Locomotive— <i>Illustration</i>	I, 135
Scrap, Accounting for.....	VII, 305, 306
" Assorting.....	VII, 302
" Brass—Care of.....	VII, 303
" Care of.....	VII, 263, 302, 303
" Collection of.....	VII, 302, 303
" Collections for.....	VII, 420, 421
" Final Disposition of.....	VII, 89
" Furnaces.....	I, 255
" Inventorying.....	VII, 345
" Invoicing.....	VII, 282
" Iron, Use of—for Wheels.....	IV, 208, 209
" Orders for Transfer of.....	VII, 80
" Records of.....	VII, 303
" Returns for.....	VII, 303, 305
" Shipping.....	VII, 304, 305, 310, 311
" Storing.....	VII, 304
" Value of.....	VII, 263
" Weighing.....	VII, 305, 311
Screen Post, Deck— <i>Illustration, Plate II</i>	I, 116-117
Screens, Window—Deck— <i>Illustration, Plate II</i>	I, 116-117
Scriptures, The.....	XI, 28
Scythians, Horses of.....	XI, 87
Seal, Corporate—Care of.....	II, 182
" Cost of.....	III, 156
" Pin, End Door— <i>Illustration, Plate III</i>	I, 170-171
" " Side Door— <i>Illustration, Plate III</i>	I, 170-171
Seals, Car.....	VI, 49-51, 103, 104
Seam, Circumferential— <i>Illustration, Plate I</i>	I, 58-59
Seams, Boiler.....	I, 74
Seat, Car—Evolution of.....	I, 186, 187
" End— <i>Illustration, Plate II</i>	I, 116-117
" " Rail— <i>Illustration, Plate II</i>	I, 116-117
" " Rest— <i>Illustration, Plate II</i>	I, 116-117
" Hinge— <i>Illustration, Plate I</i>	I, 116-117

	PAGE
Seat, Introduction of—for Vehicles.....	I, 162
“ Lock— <i>Illustration, Plate II</i>	I, 116-117
“ Overhang Truss Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Radiators— <i>Illustration, Plate II</i>	I, 116-117
“ Reversible.....	I, 188
“ “ American— <i>Illustrations</i>	I, 217
“ Rubber— <i>Illustration</i>	I, 344
“ Spring— <i>Illustration, Plate III</i>	I, 170-171
“ “ —Bolster— <i>Illustration, Plate II</i>	I, 116-117
“ “ Equalizing Bar— <i>Illustration, Plate II</i>	I, 116-117
“ Truss Rod—Transom— <i>Illustration, Plate II</i>	I, 116-117
“ Valve— <i>Illustration, Plate I</i>	I, 58-59
Secondary Current.....	I, 423
Secretary.....	II, 131, 138
“ Duties of.....	II, 177-185
“ of the Treasury.....	II, 292, 293
“ Powers of—on English Railways.....	II, 179, 180
“ Qualifications of.....	II, 177
“ Records of.....	II, 177, 178
Section Gangs.....	III, 238
“ of a Dynamo, Showing Electro-Magnets or Fields and the Armature Within— <i>Illustration</i>	I, 406
Sections, Length of.....	III, 238
Sectional Brake.....	I, 298
Securities. (See also “Bonds, Indemnity.”)	
“ Character of Different Kinds of.....	III, 59-71
“ Custody of.....	II, 193
“ Discount on.....	III, 28
“ Fluctuations of.....	III, 56
“ in Stocks.....	III, 16
“ Interest on.....	III, 28
“ Issuing.....	III, 53, 54
“ Land.....	III, 16
“ Negotiations and Sale of.....	II, 137
“ of Prospective Railways.....	III, 31
“ Railway—Fluctuations in.....	III, 42
“ “ —Holders of.....	III, 54, 55
“ “ —in America.....	III, 72, 73
“ “ —Investments in Worthless.....	III, 33
“ “ —Precautions to Investors.....	III, 79-84
“ “ —Price of.....	III, 54
“ “ —Purchase of.....	III, 64
“ Sale of.....	II, 191; III, 158, 159
“ Value of—Upon What Dependent.....	III, 102
Security, Exacting—from Employes Who Handle Money....	
“.....	IX, 26, 27, 158-177
“ Forms of.....	IX, 168, 169
Segment of a Commutator, Showing Grooves at Top of Neck for Attaching Wires from Armature— <i>Illustration</i>	I, 407

	PAGE
Seguin's Locomotive—The First with Multitubular Boiler, 1828..	I, 26
“ “ “ “ “ Multitubular Boiler, 1828— <i>Illustration</i>	I, 26
Seine River..	I, 215
Selection, Law of..	II, 14
Self-Excited Dynamo..	I, 408, 409
Semaphore, First Use of..	IV, 262
“ —Meaning of Term..	IV, 320
“ Signals.. 248, 249, 255, 261, 262, 274, 278, 292	
“ “ Automatic Block— <i>Illustrations</i> , IV, 502, 503	
“ Signification of..	IV, 349, 350
Semaphores..	IV, 391
Semite..	I, 163
Senate, Carthaginian..	XI, 141
Separately Excited Dynamo..	I, 409
Serfs..	XI, 35
Series Machine— <i>Illustration</i>	I, 412
“ Motors..	I, 412, 474–476, 485
Servants, Government—Peculiarities of..	VI, 276–279
Service, Application of the Air Brake in—Instructions to Enginemen	I, 317, 318
“ “ Position, of Engineer's Brake and Equalizing Discharge Valve..	I, 350, 351
“ Baggage	V, 275–514
“ —Needs of..	V, 63–65
“ Car..	VI, 49, 53–57
“ “ —Superintendent of..	VI, 57
“ Corporate—Vicissitudes of	II, 60
“ Cost of—Effect on Rates..	VIII, 110
“ Definiteness of..	II, 99
“ Difference Between Freight and Passenger	IV, 17
“ Efficiency of—How Improved	II, 96
“ “ —How Secured..	II, 84, 85
“ Efficient..	VI, 5, 11–18
“ <i>Esprit de Corps</i> of—How Maintained..	II, 23
“ Express and Mail..	V, 515–563
“ Express—In United States..	V, 537–551
“ Freight—Organization of..	VI, 11, 12, 22
“ “ Use of Electricity for..	I, 513
“ Inefficient	II, 25
“ Passenger..	V, 11–273
“ “ —Adaptability of..	V, 14, 15
“ “ —Changes Affecting..	V, 21
“ “ —Comparison of English and American	V, 22–26, 30, 31
“ “ —Familiarity with Needs of..	V, 22
“ “ —Intricacies of	V, 15
“ “ —Requirements of..	V, 17, 18

	PAGE
Service, Promotion in.....	II, 23
“ Pullman.....	I, 202
“ Railway—Advancement in.....	II, 295
“ “ —Attaches of.....	II, 123
“ “ —Characteristics of.....	II, 63, 64
“ “ —Charm of.....	II, 123
“ “ —Description of.....	II, 24
“ “ —Electrical Systems for.....	I, 430-453
“ “ —Improvements in.....	V, 32
“ “ —in United States.....	I, 249
“ “ —Natural Fitness and Selection in.....	II, 20
“ “ —Necessity of Obedience in.....	VI, 17
“ “ —Tenure of Office in.....	II, 100
“ —Relation to Rates.....	VIII, 28
“ Requirements of the Community.....	VIII, 28
“ Station and Train.....	I, 233
“ “ —The Railway School.....	IV, 10
“ Suburban—Requirements of.....	I, 67; V, 41, 42
“ Time a Locomotive May Be Kept in.....	I, 247, 248
“ Train.....	IV
“ “ —Attractiveness of.....	IV, 14, 15
“ “ —Changes in.....	V, 20
“ “ —Conditions Governing.....	IV, 8
“ “ —Dangers of.....	IV, 15
“ “ —Effective.....	IV, 62-67
“ “ —in Great Britain.....	IV, 440-464
“ “ —Injuries Growing Out of.....	II, 234
“ “ —Methods of Improving.....	IV, 23, 24
“ “ —Morale of.....	IV, 12-32
“ “ —of American Railways.....	IV, 10
“ “ —Particulars of.....	IV, 97-105
“ “ —Practices Characterizing.....	IV, 20-23
“ “ —Requirements of.....	IV, 18
“ “ —The Author's Books on.....	IV, 9, 10
“ Uninterrupted—Value of.....	II, 91
“ Unit of.....	VIII, 76
“ Value of.....	VIII, 85
“ “ —as Basis for Rates.....	VIII, 42, 49
“ Wagner.....	I, 202
Services, Legal—Expenditures for.....	III, 398
Sesostris.....	XI, 113
Setting a Switch—Meaning of Term.....	IV, 330
“ Brakes.....	I, 348
“ Out Air-Braked Cars.....	I, 374
Settlements, Express.....	V, 550, 551
Sewerage.....	I, 242, 273
Shade, Bottom Bar of— <i>Illustration, Plate II</i>	I, 116-117
“ Fringe— <i>Illustration, Plate II</i>	I, 116-117
“ Stop— <i>Illustration, Plate II</i>	I, 116-117
“ Thumb Latch— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Shade, Window— <i>Illustration, Plate II</i>	I, 116-117
Shaft, Armature.....	I, 405
“ Arm, Tumbling— <i>Illustration, Plate I</i>	I, 58-59
“ Brake.....	I, 298
“ “ Chain— <i>Illustration, Plate II</i>	I, 116-117
“ Driving.....	I, 456
“ Dynamo.....	I, 456
“ Lever, Tumbling— <i>Illustration, Plate I</i>	I, 58-59
“ Lifting.....	I, 90
“ Motor—Mechanical Energy Delivered by.....	I, 403
“ Revolving.....	I, 441
“ Rock.....	I, 94
“ Tumbling— <i>Illustration, Plate I</i>	I, 58-59
“ Uncoupling— <i>Illustration, Plate II</i>	I, 116-117
Shafting.....	I, 274
Shafts.....	I, 83, 92
“ Tumbling.....	I, 286
Shake Lever Stub— <i>Illustration, Plate I</i>	I, 58-59
Shaker Grate— <i>Illustration, Plate II</i>	I, 116-117
Shakespeare, Use of the Word “Baggage” by.....	V, 277
Shank— <i>Illustration, Plate II</i>	I, 116-117
Shareholders. (See also “Stockholders”).....	III, 81, 85
“ Practice of—in America.....	III, 81
“ “ “ England.....	III, 81
“ Redemption by.....	III, 87
Shares, Classes of.....	III, 87, 88
“ Different Kinds of.....	III, 85
“ Issue of.....	III, 65
“ Issuing.....	III, 30
“ Par Value of.....	III, 87
“ Preference.....	III, 88
“ Sale of.....	III, 85
Sharp, Roberts & Company.....	I, 32
Sharrukin.....	XI, 102, 106
Shavings, Removal of.....	I, 274
Sheathing Furring— <i>Illustration, Plate II</i>	I, 116-117
“ Outside— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ “ { <i>Plate III</i>	I, 170-171
“ Rail— <i>Illustration, Plate II</i>	I, 116-117
“ Side Door— <i>Illustration, Plate III</i>	I, 170-171
Sheave Bracket, Chain— <i>Illustration, Plate II</i>	I, 116-117
“ Chain— <i>Illustration Plate II</i>	I, 116-117
Sheds, Repair.....	I, 271
“ Snow—Use of.....	III, 302-305
Shelling Freight in Transit.....	VI, 267
Sheep Car, Victorian— <i>Illustration</i>	I, 193
Sheet, Crown.....	I, 75, 81, 96, 97
“ “ — <i>Illustration</i>	I, 98
“ Flue.....	I, 97
“ Tube— <i>Illustration, Plate I</i>	I, 58-59

	PAGE
Sheets, Boiler	I, 248
" Flue— <i>Illustration</i>	I, 98
Shelf, Oil Can— <i>Illustrations, Plate I</i>	I, 58-59, 64
Shell, Boiler— <i>Illustration</i>	I, 98
" Dome— <i>Illustration</i>	I, 98
" Lugs— <i>Illustration</i>	I, 96
Shimming	III, 247, 248, 332
Shinn, William P	X, 167
Shippers, Freight Charges Advanced by	IX, 320-323
" Misrepresentations of	VI, 5, 22-25
" Ownership of Cars by	VI, 69
" Receipts Given to	IX, 63, 114
Shipping Bill	VI, 94, 109, 115, 139
" Rules Governing the Use of	VI, 110-114
" Bills, Changes in—After Freight Is Forwarded, VI, 114	
" " Numbering	VI, 113
" Directions	VI, 94
" Implements	I, 262
" Tickets, Use of	IX, 48-50
Shocks, Preventing—to Trains	I, 318, 369
" Prevention of—to Motors	I, 470
Shoe and Third Rail. Brooklyn Bridge Terminal— <i>Illustration</i>	I, 466
" Brake— <i>Illustrations</i> , { <i>Plate II</i>	I, 116-117
" " and Its Application to the Driver— <i>Illustration</i>	I, 170-171
" " —Clogging	I, 304
" " —Pressure of, Against the Wheel	I, 311
" Center Brake— <i>Illustration, Plate II</i>	I, 116-117
" Driving Box— <i>Illustration, Plate I</i>	I, 58-59
" for Third Rail Between Main Rails—Nantasket Beach <i>Railway—Illustration</i>	I, 465
" Iron	I, 464
Shoes	I, 286
" Brake	I, 291, 292, 301-305, 314, 334
" " —Slack of	I, 332
Shop, Blacksmith	I, 132, 251, 256, 262, 263, 271, 272, 275
" " —Car Department—End Elevation— <i>Illustration</i>	I, 264
" " " " —Side Elevation— <i>Illustration</i>	I, 263
" " —Cross Section— <i>Illustration</i>	I, 265
" Boller	I, 251, 255, 262
" Boilers	I, 255
" Buildings, Design for	I, 253
" Car—Passenger	I, 274
" " Repair—Section and End Elevation— <i>Illustration</i>	I, 255
" " " —Side Elevation— <i>Illustration</i>	I, 252

	PAGE
Shop, Erecting.....	I, 251, 273, 274
“ “ and Machine	I, 254
“ “ —for Freight Cars.....	I, 271
“ “ “ Passenger Cars.....	I, 271
“ “ —Locomotive Department—Cross Section— <i>Illustration</i>	I, 248
“ “ “ “ —End Elevation— <i>Illustration</i>	I, 246
“ “ “ “ —Side Elevation— <i>Illustration</i>	I, 245
“ “ —Tracks in	I, 261, 262
“ Foremen.....	I, 264, 265
“ Forge.....	I, 251, 256, 271, 272
“ Labor, Arrangement of.....	I, 283
“ “ Distribution of.....	I, 285
“ Locomotive Repair—Equipment of.....	I, 262
“ Machine.....	I, 261, 272, 273, 275, 286
“ “ and Erecting.....	I, 251, 264, 265
“Shop Machinery and Tools”.....	VII, 465
Shop, Outlay—How Reduced.....	I, 287
“ Paint	I, 251, 252, 257, 273, 274
“ “ —Freight Car.....	I, 271
“ “ —Passenger Car.....	I, 271
“ “ “ —Cross Section— <i>Illustration</i>	I, 269
“ “ “ —End Elevation— <i>Illustration</i>	I, 269
“ “ “ —Side Elevation— <i>Illustration</i>	I, 267
“ Purposes, Compressed Air for.....	I, 384
“ Supplies, Inventorying.....	VII, 344
“ Tank	I, 251
“ Telephone System	I, 279
“ Tin and Copper— <i>Illustration</i>	I, 251
“ Work, Arrangement and Systemization of.....	I, 288
“ “ Discussion of Matters Relating to.....	I, 289, 290
Shops, Arrangement and Systemization of.....	I, 283, 288
“ Blacksmith.....	I, 130, 131
“ Boiler, Tin, Flue, Wood and Blacksmith—Locomotive Department— <i>Illustrations</i>	I, 249
“ Car Repair.....	I, 271–279
“ “ —Plan for— <i>Illustration</i>	I, 242
“ Collections at.....	VII, 415
“ Comparisons of Work at Different.....	I, 287
“ Construction—Location of.....	I, 122, 123
“ Discussion of Questions Relating to the Machinery of.....	I, 289, 290
“ Employes of.....	I, 229
“ “ —Meetings of.....	I, 227–229
“ “ —Value of Discussion Among.....	I, 289, 290
“ Equipment of.....	I, 259
“ Erecting.....	I, 272
“ “ —Distribution of Material to	I, 272

	PAGE
Shops, Erection of	I, 143
Examinations at—by Traveling Auditors	VII, 433
Facilities of	I, 235
Fuel Stored at	VII, 334
General Repair	I, 248, 250
Government of	I, 283
Heating Appliances of	I, 261
Keeping Accounts at	VII, 244
Location of	I, 237, 283
Locomotive Repair—Plan for— <i>Illustration</i>	I, 239
Machine	I, 239, 269
Machinery of	I, 283
Making Pay Rolls at	VII, 369, 370
Manufacturing—Privilege of Inspecting	I, 127
Organization of	I, 232, 237, 283, 284
Paint	I, 272
—Material at	VII, 309
Railway	I, 124, 225
—Arrangement of	I, 230
—Machinery of	I, 122
Repair	I, 122, 239, 250; VII, 130, 131
—Car	I, 271-279
—General	I, 270
—For Cars and Locomotives	I, 271
—Labor in	I, 264
—Location of	I, 249, 250
—Locomotive	I, 247-268
—Number of	I, 283
—Organization of Labor in	I, 264
—Their Location, Design and Equipment	I, 237
Restriction of Number of	VII, 130
"Shops, Roundhouses and Turntables"	VII, 458, 459
Shops, Time Tickets Issued at	VII, 401
Upholstery—Material at	VII, 309
Workings of	I, 283
Shortages. (See also "Defalcations.")	
Adjustment of	IX, 196-212
Cause of	IX, 23
Devices for Covering Up	IX, 136, 137, 139, 140
Information Regarding	IX, 167
Short Buffer Plate— <i>Illustration, Plate II</i>	I, 116-117
Sill, Platform— <i>Illustration, Plate II</i>	I, 116-117
Shumir	XI, 120
Shumiro-Accades, Religion of	XI, 75, 76
Shunt Machine, A— <i>Illustration</i>	I, 412
Motors	I, 412
Winding	I, 409, 410
Shunters, English—Wages of	IV, 453
"Shunter's Stick"	I, 172, 173
Shunting—Meaning of Term	IV, 320

	PAGE
Shut-off Valve, Main— <i>Illustration, Plate II</i>	I, 116-117
Shutt End Railway.....	I, 28
Siam, Its Primitive Associations and Means of Carriage....	XI, 237-253
" —Primitive Carriage in— <i>Illustrations</i>	XI, 237-253
Siberia—Its Primitive Associations and Means of Carriage..	XI, 448-458
" —Primitive Carriage in— <i>Illustrations</i>	XI, 448-458
Siberian Railway Locomotive— <i>Illustration</i>	I, 119
Sicily.....	XI, 91
Sickness, Amelioration of the Condition of Railway Men and Their Families in Cases of	X, 291-353
Side Bearing, Body— <i>Illustration, Plate III</i>	I, 170-171
" " Bridge— <i>Illustration, Plate II</i>	I, 116-117
" " " Body— <i>Illustration, Plate II</i>	I, 116-117
" " Pillar Body— <i>Illustration, Plate II</i>	I, 116-117
" " Truck— <i>Illustration, Plate II</i>	I, 116-117
" " " Bolster— <i>Illustration, Plate III</i>	I, 170-171
Bearings.....	I, 214
Door Bottom Rail— <i>Illustration, Plate III</i>	I, 170-171
" " Braces— <i>Illustration, Plate III</i>	I, 170-171
" " Bracket— <i>Illustration, Plate III</i>	I, 170-171
" " " Wedge— <i>Illustration, Plate III</i>	I, 170-171
" " Chafing Strip— <i>Illustration, Plate III</i>	I, 170-171
" " Closed Clasp— <i>Illustration, Plate III</i>	I, 170-171
" " " Stop— <i>Illustration, Plate III</i>	I, 170-171
" " Furring— <i>Illustration, Plate III</i>	I, 170-171
" " Handle— <i>Illustration, Plate III</i>	I, 170-171
" " Hanger— <i>Illustration, Plate III</i>	I, 170-171
" " Hasp— <i>Illustration, Plate III</i>	I, 170-171
" " Middle Rail— <i>Illustration, Plate III</i>	I, 170-171
" " Open Clasp— <i>Illustration, Plate III</i>	I, 170-171
" " " Stop— <i>Illustration, Plate III</i>	I, 170-171
" " Seal Pin— <i>Illustration, Plate III</i>	I, 170-171
" " Sheathing— <i>Illustration, Plate III</i>	I, 170-171
" " Staple— <i>Illustration, Plate III</i>	I, 170-171
" " Stille— <i>Illustration, Plate III</i>	I, 170-171
" " Threshold Plate— <i>Illustration, Plate III</i>	I, 170-171
" " Top Rail— <i>Illustration, Plate III</i>	I, 170-171
" " Track— <i>Illustration, Plate III</i>	I, 170-171
" " Wedge— <i>Illustration, Plate III</i>	I, 170-171
Side Fascia— <i>Illustration, Plate III</i>	I, 170-171
" Girts— <i>Illustration, Plate III</i>	I, 170-171
" Grab Iron— <i>Illustration, Plate III</i>	I, 170-171
" Lamp— <i>Illustration, Plate II</i>	I, 116-117
" " Bracket— <i>Illustration, Plate II</i>	I, 116-117
" " Chimney— <i>Illustration, Plate II</i>	I, 116-117
" " " or Parallel Rod— <i>Illustration, Plate I</i>	I, 58-59
" Plate— <i>Illustration—Plate III</i>	I, 170-171

	PAGE
Side Pocket Pin— <i>Illustration, Plate II</i>	I, 116-117
“ Sill— <i>Illustration, Plate II</i>	I, 116-117
“ “ Knee Iron— <i>Illustration, Plate II</i>	I, 116-117
“ Stem Spring— <i>Illustration, Plate II</i>	I, 116-117
“ Thimble— <i>Illustration, Plate II</i>	I, 116-117
“ Stems— <i>Illustration, Plate II</i>	I, 116-117
“ Track—Meaning of Term	IV, 320, 321
“ Tracks, New	II, 321
“ “ Use of—Charges for	III, 407
“Sidings”	VII, 465
Sidings, Construction of	II, 211
“ Middle—Rules Governing	IV, 375, 376
Sidon	XI, 123
Siemens & Halske	I, 520
Signal, Air	I, 321
“ “ —Care of	I, 362
“ “ —Instructions to Engineers	I, 366
“ “ —Train	I, 317, 322, 330
“ “All Right”— <i>Illustration</i>	IV, 245
“ Apparatus	I, 376
“ “Back Up”— <i>Illustration</i>	IV, 480
“ Branch Pipe Cut-Out Cock— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ to Car Discharge Valve— <i>Illustration, Plate II</i>	I, 116-117
“ “Caution”— <i>Illustration</i>	IV, 245
“ Cord	I, 362
“ “ — <i>Illustration, Plate II</i>	116-117
“ Coupling, Air	I, 375
“ Disc—“Caution, Run Slow”— <i>Illustration</i>	IV, 504
“ “ —“Clear, Proceed”— <i>Illustrations</i>	IV, 504
“ “ —“Danger, Stop”— <i>Illustration</i>	IV, 504
“ Dwarf —“Clear, Proceed”— <i>Illustration</i>	IV, 501
“ “ —“Danger, Stop”— <i>Illustration</i>	IV, 501
“ Distant—“Caution, Run Slow”— <i>Illustration</i>	IV, 500
“ “ —“Clear, Proceed”— <i>Illustration</i>	IV, 500
“ Fire Basket as a	I, 57
“ “Go Ahead”— <i>Illustration</i>	IV, 479
“ Home—“Clear, Proceed”— <i>Illustration</i>	IV, 500
“ “ —“Danger, Stop”— <i>Illustration</i>	IV, 500
“ Hose, Air— <i>Illustration, Plate I</i>	I, 58-59
“ “ Armored— <i>Illustration, Plate II</i>	I, 116-117
“ “ Coupling— <i>Illustration, Plate II</i>	I, 116-117
“ “ Extra	I, 321
“ Lamp— <i>Illustration, Plate I</i>	I, 58-59
“ Operating the Train Air—Instructions to Trainmen	I, 376
“ Pipe	I, 374, 379
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ Air—Leaks in	I, 376

	PAGE
Signal Pipe Hose— <i>Illustration, Plate I</i>	I, 58-59
“ “ Strainer— <i>Illustration</i>	I, 386
“ “ Train— <i>Illustration, Plate II</i>	I, 116-117
“ Pipes.....	I, 362
“ Posts.....	IV, 262, 263
“ Semaphore—“Caution, Run Slow”— <i>Illustration</i>	IV, 502
“ “ —“Clear, Proceed”— <i>Illustration</i>	IV, 503
“ “ —“Danger, Stop”— <i>Illustration</i>	IV, 502
“ Station—Meaning of Term.....	IV, 341
“ “Stop”— <i>Illustrations</i>	IV, 245, 479
“ Train Air—Operations of.....	I, 362
“ “Train Parted”— <i>Illustration</i>	IV, 480
“ Two-Arm Home—“Main Route Clear, Proceed”— <i>Illustration</i>	IV, 501
“ “ “ —“Diverging Route Clear, Proceed”— <i>Illustration</i>	IV, 501
“ Valve— <i>Illustration</i>	I, 386
“ “ Car— <i>Illustration, Plate II</i>	I, 116-117
“ Whistle— <i>Illustration</i>	I, 386
“ “ — <i>Illustration, Plate I</i>	I, 58-59
Signals.....	III, 262; IV, 244-301
“ Absence of.....	IV, 366
“ Air.....	IV, 250
“ at Telegraph Stations.....	IV, 398
“ Audible.....	IV, 272, 273
“ Automatic.....	IV, 15
“ “ Block—Disc Form— <i>Illustrations</i>	IV, 504
“ “ “ —Semaphore Form— <i>Illustrations</i>	IV, 502, 503
“ “ —Electric Block System.....	IV, 280, 281
“ Ball.....	IV, 252, 254
“ Bell Cord—Rules Governing.....	IV, 347, 348
“ Block.....	IV, 276-301
“ “ —Automatic Electric— <i>Illustrations</i>	IV, 280, 282-285
“ “ System.....	I, 311
“ “ —Systems of.....	IV, 276, 277
“ Care of.....	IV, 433
“ Classification of.....	IV, 269, 270, 295-298
“ Crossing—Early.....	IV, 254, 255
“ Danger—Permanent.....	IV, 367
“ Defective.....	IV, 270
“ Detonating.....	IV, 271-273
“ Disc—Early.....	IV, 248, 249
“ Diversity of.....	IV, 256-258, 267
“ Duties of Brakemen in Relation to.....	IV, 417
“ Early— <i>Illustrations</i>	IV, 245, 247-249, 251-255
“ “ —at Telegraph Stations.....	IV, 249, 250
“ “ —Forms of.....	IV, 244-256
“ “ —in England.....	IV, 247-249

	PAGE
Signals, Early—Use of, in Great Britain.....	I, 171
“ Expenditures for.....	IV, 245, 246
“ Failure of.....	IV, 366
“ Fixed—at Train Order Offices.....	IV, 391
“ “ —First Forms of.....	IV, 246
“ “ —Rules Governing.....	IV, 349, 350
“ Flag—Early.....	IV, 248, 253, 255
“ Freight Train Pushed by a Locomotive by Night— <i>Illustration</i>	IV, 494
“ Gate.....	IV, 254
“ Hand and Lamp— <i>Illustrations</i>	IV, 479, 490
“ “ Lamp—Rules Governing.....	IV, 348, 349
“ —How They Are Displayed on Trains and Locomo- tives Under the American Standard— <i>Illustra- tions</i>	IV, 481-494
“ Importance of—In the Movement of Trains.....	IV, 256
“ Lantern—Early.....	IV, 250-252, 255
“ Locomotive Running Backward by Day Alone or Pushing Cars — <i>Illustrations</i>	IV, 487
“ “ “ “ “ Night— <i>Illus- tration</i>	IV, 491
“ “ “ “ “ Night Alone or Pushing Cars— <i>Illus- trations</i>	IV, 491
“ “ “ “ Forward Alone by Day— <i>Illus- tration</i>	IV, 491
“ “ “ “ “ by Night— <i>Il- lustration</i> , IV,	493
“ —Meaning of Term.....	IV, 321
“ New—Use of.....	IV, 352
“ Passenger Train Pushed by a Locomotive by Night — <i>Illustration</i>	IV, 493
“ Permanent.....	IV, 261
“ Rear of Train by Day— <i>Illustration</i>	IV, 483
“ “ “ “ Night While Running— <i>Illustration</i>	IV, 484
“ “ “ “ on Side Track by Night— <i>Illustration</i>	IV, 485
“ Removing.....	IV, 396
“ Rules Governing.....	IV, 340-343
“ “ Use of.....	IV, 350-352
“ Semaphore.....	IV, 248, 249, 255, 261, 262, 274, 278, 292
“ Track.....	IV, 495-504
“ “ — <i>Illustrations</i>	IV, 500-504
“ Train.....	IV, 246
“ “ —Rules Governing.....	IV, 344-346

	PAGE
Signals, Train Running Forward by Day— <i>Illustrations</i>	IV, 486, 488
“ “ “ “ “ Night— <i>Illustrations</i>	IV, 486, 489
“ Uniformity of	IV, 258-261, 264-267
“ Use of—by Railways	IV, 244
“ Value of	IV, 268, 269
“ Whistle—Rules Governing	IV, 346, 347
Signaling Apparatus, Air—Train— <i>Illustrations</i>	I, 385, 386
“ Fog—in England	IV, 271, 272
“ Functions of	IV, 276
Signalmen, English—Wages of	IV, 453
Signatures	VII, 446
“ Authorization of	IX, 428-430
“ Officials’	VII, 431
“ on Indemnity Bonds	IX, 172, 173
“ Stamp	VI, 126; IX, 84, 346, 347
“ “ —Use of	VI, 314
“ Witnessing	VII, 444; IX, 344, 393
Signs, Maintenance of	III, 300
“ Meaning of—on Time Table	IV, 340
“ Uniformity in	IV, 303
“ Use of—in Telegraphic Orders	IV, 392
Silks, Carriage of	V, 519
Sill and Tie Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Corner Iron— <i>Illustration, Plate III</i>	I, 170-171
“ Deck— <i>Illustration, Plate II</i>	I, 116-117
“ “ End— <i>Illustration, Plate II</i>	I, 116-117
“ End— <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ “ <i>{ Plate III</i>	I, 170-171
“ Facing Deck— <i>Illustration, Plate II</i>	I, 116-117
“ Platform— <i>Illustration, Plate II</i>	I, 116-117
“ “ End— <i>Illustration, Plate II</i>	I, 116-117
“ Side— <i>Illustration, Plate II</i>	I, 116-117
“ Step— <i>Illustration, Plate III</i>	I, 170-171
“ Tie Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Timbers	I, 209
“ Window—Inside— <i>Illustration, Plate II</i>	I, 116-117
“ “ —Outside— <i>Illustration, Plate II</i>	I, 116-117
Sills, Car	I, 179
“ Center— <i>Illustration, Plate III</i>	I, 170-171
“ Inside Intermediate— <i>Illustration, Plate III</i>	I, 170-171
“ Outside— <i>Illustration, Plate III</i>	I, 170-171
“ “ Intermediate— <i>Illustration, Plate III</i>	I, 170-171
“ Switch	III, 228
Silver	III, 8; XI, 73
“ Bullion	III, 18
“ Causes of Decline in Value of	III, 13
“ Demontization of	III, 13
“ Early Use of—for Money	XI, 128

	PAGE
Silver, Fluctuations of.....	III, 16
" Ratio of—to Gold.....	III, 12, 13
" Status of—in the United States.....	III, 14
" Transportation of.....	V, 519
" Use of—by Railways.....	VII, 209
Simple Trolley System and Rail Return— <i>Illustration</i>	I, 433
Sinclair, A.....	III, 160; IV, 36, 38, 44
Single Expansion Locomotive.....	I, 92, 95
" Order System of Telegraphic Dispatching.....	IV, 83, 84
" Phase Motor.....	I, 445
" " System.....	I, 425
" Plate Wheel— <i>Illustration</i>	IV, 207
Sinking Funds.....	II, 137, 191
" " Accounting for.....	VII, 434, 449-452
" " Particulars of.....	III, 101-105
Six-Pole Motor.....	I, 472
Size of Motor.....	I, 469
" " Unit, in a Power Station.....	I, 454
Skill—Its Effect on Wages.....	II, 102
Skilled Labor.....	I, 270
" Workmen.....	I, 247, 264
Skylights.....	I, 243, 257
Slab— <i>Illustration, Plate II</i>	I, 116-117
" Adjusters, Automatic.....	I, 361, 362
" of Brake Shoes.....	I, 332
Slag Ballast.....	III, 221, 222
Slate.....	I, 253
Slats, Window Blind— <i>Illustration, Plate II</i>	I, 116-117
Slaves.....	XI, 25
Sledge, Origin of.....	XI, 51
Sleepers, Longitudinal.....	III, 201, 202
Sleeping and High Class Passenger Car, American Standard	
— <i>Illustration</i>	I, 223
" Car, American.....	I, 200
" " Compartment—Austrian— <i>Illustration</i>	I, 226
" " Early.....	I, 165
" " Interests, Development of.....	I, 198, 199
" " Passengers.....	V, 206, 207
" " "Pioneer".....	I, 194, 197
" " Tickets.....	V, 95, 206
" Cars.....	I, 188-194; V, 221
" " in England.....	I, 201
" " Rules Governing Use of.....	V, 212
" " Use of Electricity for Lighting.....	IV, 179
Slide, Cinder Chute— <i>Illustration, Plate I</i>	I, 58-59
" Valve.....	I, 308
" " — <i>Illustrations</i>	I, 65, 341, 344
" " Port— <i>Illustration</i>	I, 341
" Valves, Action of—Method of Governing.....	I, 91
" " Defective.....	I, 382

	PAGE
Sliding Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Wheels	I, 313, 363, 379; IV, 321
“ “ Avoidance of.....	I, 369
“ “ —Instructions to Enginemen	I, 321
Sling Stay— <i>Illustration, Plate I</i>	I, 58-59
“ Stays.....	I, 97
“ “ — <i>Illustration</i>	I, 98
“ “ Dome— <i>Illustration</i>	I, 98
Slip, Late.....	I, 266
“ Switches.....	III, 235, 236
Slopes.....	III, 225
“ Drainage of.....	III, 226
“ Protection of.....	III, 254
“ Springs on.....	III, 226
Slothfulness.....	II, 22
Smith, L. L.....	I, 285
Smoke Annoyance.....	I, 70
“ Arch Door— <i>Illustration, Plate I</i>	I, 58-59
“ “ Front— <i>Illustration, Plate I</i>	I, 58-59
“ Bell— <i>Illustration, Plate II</i>	I, 116-117
“ Box.....	I, 93, 97
“ “ Destruction of—How Overcome.....	I, 53
“ Burners.....	I, 70
“ Flue— <i>Illustration, Plate II</i>	I, 116-117
“ “ Base— <i>Illustration, Plate II</i>	I, 116-117
“ Pipe— <i>Illustration, Plate II</i>	I, 116-117
Smokestack.....	I, 97
“ — <i>Illustrations</i> , { <i>Plate I</i>	I, 58-59
“ “ Coal Burner— <i>Evolution of—Illustration</i>	I, 60
“ “ Exhausting Steam Into.....	I, 69
“ “ Height of.....	I, 68
“ “ Locomotive Without— <i>Illustration</i>	I, 134
“ “ Opening— <i>Illustration</i>	I, 98
“ “ Reduction of Heat in.....	I, 53
Smokestacks, Destruction of.....	I, 38
Smoking Car, American Buffet— <i>Interior of—Illustration</i> ..	I, 212
“ “ Buffet	I, 182, 196
“ “ Compartment in an American Car— <i>Illustration</i> ..	I, 213
“ “ Room	I, 200
“ “ — <i>Illustration, Plate II</i>	I, 116-117
“ “ Panels— <i>Illustration, Plate II</i>	I, 116-117
Snow, Clearing Track of.....	III, 285, 289, 301-305
“ Fences, Use of.....	III, 302-305
Snowplow.....	I, 56, 57, 109
“ Cylindrical.....	I, 56
“ Rotary.....	I, 56, 57
“ Steam— <i>Illustration</i>	I, 147
Snowplows, Use of.....	III, 302-305

	PAGE
Snow Shed in the Sierra Nevadas— <i>Illustration</i>	III, 351
“ Sheds, Use of	III, 302-306
Societe Nouvelle des Etablissements	I, 315
Sofa— <i>Illustration, Plate II</i>	I, 116-117
Soft Coal, Use of	I, 69
Soil, Ownership of	XI, 30
Solid Spoke Wheel— <i>Illustration</i>	IV, 207
Solomon	XI, 134
Solon	XI, 100
Soot Bags	I, 170
“ Device for Keeping Flues Free from	I, 103
Soper, Arthur W.	IV, 115, 118
Source of Electric Currents	I, 397, 398
Sources of Heat	I, 397
South Africa, Government Management in	VIII, 241
“ America—Its Primitive Associations and Means of Carriage	XI, 418-428
“ “ —Primitive Carriage in— <i>Illustrations</i>	XI, 418-428
“ “ —Use of Petroleum in	I, 104
Southern Pacific Railway	III, 359
“ Railway & Steamship Association	VI, 61
“ “ “ “ “ Demurrage Rules of	VI, 337, 338
Southwark & Deptford Tramway Company	III, 454
Southwell, H. E.	VII, 288
Spain, Baggage Allowed in	V, 288
“ “ in	V, 286
“ “ Storage Charges in	V, 425
“ Comparative Value of Silver and Gold in	III, 13
“ Gauge Used in	III, 194
“ Its Primitive Associations and Means of Carriage	XI, 468-476
“ Primitive Carriage in— <i>Illustrations</i>	XI, 468-476
“ Railway Practices in	I, 174
“ Responsibility for Baggage in	V, 313, 314
“ Status of Railways in	VIII, 342
“ Use of Metal Ties in	III, 379
Span, Howe Truss Bridge— <i>Illustration</i>	III, 373
Spark Arrester	I, 100
“ “ Extension End for— <i>Illustration</i>	I, 60
“ “ Section Showing— <i>Illustration</i>	I, 100
Sparking, Cause of	I, 429
“ Evil Effects of	I, 473
Spartans, The	XI, 64
Special Accounts	VII, 414-429
“ Collections, Accounting for	VII, 414-429
“ Committee	II, 121
“ Conditions, Use of Electricity Under	I, 614

	PAGE
Special Rates. (See also "Rates, Special").....	V, 121, 122
" " Authority for.....	V, 175
" " Notice of.....	V, 122
" Receipts.....	IX, 95
" Remittances.....	IX, 419
" Train—Meaning of Term.....	IV, 321
Specialists.....	I, 286
" Among Car Manufactories.....	I, 214
" in Railway Service.....	II, 62
Specialization of Work.....	I, 283
Specializing Work.....	I, 285, 286
Specifications for Ties.....	III, 212, 213
" of Cost, for Construction.....	III, 131
Speculation, in Railway Construction and Operation.....	III, 134
" Railway.....	I, 34
Speculators, Railways Built by.....	III, 171, 172
Speed.....	I, 63, 415, 428, 429, 475, 476
" Checking—of Trains.....	I, 317, 318
" Comparison of—in England and America.....	IV, 103
" Control of—by Brakes.....	I, 294
" " —in a Locomotive.....	I, 113, 115
" Danger in Increasing.....	IV, 102
" Effect of—on Cost.....	X, 161-164, 167-170
" " " Suburban Service.....	IV, 103
" " " Track.....	X, 167
" Governor.....	I, 455
" —How Acquired.....	I, 67
" Limitations of.....	I, 429, 430; IV, 99
" Necessity of Increased.....	IV, 104
" of Dynamo.....	I, 407
" " Freight Trains.....	VI, 10, 11
" " Trains.....	I, 249
" " Tendency to Increase.....	I, 310
" Relation of—to Accidents.....	IV, 125
" " " Earnings.....	IV, 104
" " " Track, Etc.....	IV, 101, 102
" Synchronous.....	I, 442, 445, 446
Speeds, of Engine Type Railway Generators.....	I, 459
" Variable.....	I, 445
Spencer.....	XI, 28
Sperry, H. W.....	IV, 112
Spike, Action of—on Tie— <i>Illustration</i>	III, 321
" Track— <i>Illustration</i>	III, 320
Spikes.....	III, 197, 285, 301, 330, 331
" Effect of Passing Trains on.....	III, 329, 330
" Rectangular.....	III, 198
" Wedge.....	III, 198
Spiking.....	III, 211
" Damage to Ties by.....	III, 213, 214
Spiral Spring, Berth— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Splice Bar, Angle—A. D. 1875— <i>Illustration</i>	III, 293
“ “ “ “ “ 1879— <i>Illustration</i>	III, 296
“ “ “ “ “ 1880— <i>Illustration</i>	III, 298
“ “ “ “ “ 1885— <i>Illustration</i>	III, 303
“ “ Double—A. D. 1856— <i>Illustration</i>	III, 262
“ “ “ “ “ 1857— <i>Illustration</i>	III, 269
“ “ Plain—A. D. 1870— <i>Illustration</i>	III, 289
“ “ Single—A. D. 1855— <i>Illustration</i>	III, 261
“ Bars	III, 285, 301, 341, 342
“ “ Insulated—Automatic Electric Block System,	IV, 283, 284
“ “ Use of	III, 335-340
“ Frame— <i>Illustration, Plate I.</i>	I, 58-59
Splices	III, 215
Split Switch— <i>Illustration</i>	III, 340
“ Switches	IV, 113, 114
“ “ Three-Way	III, 233, 234
“Sprag” Brake— <i>Illustration</i>	I, 294
Sprag—Meaning of Term	IV, 315
Spreading System of Locomotive Firing	I, 97, 99
Spring and Rig, Counter Balance— <i>Illustration, Plate I.</i>	I, 58-59
“ Balance—Center Brake— <i>Illustration, Plate II.</i>	I, 116-117
“ “ —Lower— <i>Illustration, Plate II.</i>	I, 116-117
“ Band— <i>Illustration, Plate II.</i>	I, 116-117
“ “ Engine Truck— <i>Illustration, Plate I.</i>	I, 58-59
“ Beam— <i>Illustration, Plate II.</i>	I, 116-117
“ “ Chafing Plate— <i>Illustration, Plate II.</i>	I, 116-117
“ Bearings	I, 213
“ Block— <i>Illustration, Plate II.</i>	I, 116-117
“ Bolster— <i>Illustration, Plate II.</i>	I, 116-117
“ Cap Bolster— <i>Illustration, Plate II.</i>	I, 116-117
“ “ Equalizing Bar— <i>Illustration, Plate II.</i>	I, 116-117
“ Catch— <i>Illustration, Plate II.</i>	I, 116-117
“ Center Stem— <i>Illustration, Plate II.</i>	I, 116-117
“ Chain Berth— <i>Illustration, Plate II.</i>	I, 116-117
“ Check Valve— <i>Illustration</i>	I, 344
“ Draft— <i>Illustration, Plate II.</i>	I, 116-117
“ Driver— <i>Illustration, Plate I.</i>	I, 58-59
“ Engine Truck— <i>Illustration, Plate I.</i>	I, 58-59
“ Equalizing Bar— <i>Illustration, Plate II.</i>	I, 116-117
“ Followers Draft— <i>Illustration, Plate II.</i>	I, 116-117
“ Frame, Berth— <i>Illustration, Plate II.</i>	I, 116-117
“ Graduating— <i>Illustrations</i>	I, 341, 344,
“ Hanger— <i>Illustration</i>	I, 60
“ “ to Journal Box— <i>Illustration</i>	I, 67
“ “ Engine Truck— <i>Illustration, Plate I.</i>	I, 58-59
“ Hangers	I, 109
“ “ Driver— <i>Illustration, Plate I.</i>	I, 58-59
“ Journal Box Cover— <i>Illustration, Plate II.</i>	I, 116-117

	PAGE
Spring, Plank— <i>Illustration, Plate II</i>	I, 116-117
“ “ Bearing— <i>Illustration, Plate II</i>	I, 116-117
“ Plate, Truck Bolster— <i>Illustration, Plate III</i>	I, 170-171
“ Release— <i>Illustration, Plate II</i>	I, 116-117
“ “ —Center Brake— <i>Illustration, Plate II</i> , 1,	116-117
“ Repairs.....	III, 239
“ Seat— <i>Illustration, Plate III</i>	I, 170-171
“ “ —Bolster— <i>Illustration Plate II</i>	I, 116-117
“ “ Equalizing Bar— <i>Illustration, Plate II</i>	I, 116-117
“ Side Stem— <i>Illustration, Plate II</i>	I, 116-117
“ Spiral—Berth— <i>Illustration, Plate II</i>	I, 116-117
“ Strap, Draft— <i>Illustration, Plate II</i>	I, 116-117
Springs.....	I, 210, 211
“ — <i>Illustration</i>	I, 60
“ Cost of.....	III, 403
“ Draw Bar— <i>Illustration, Plate III</i>	I, 170-171
“ for Suspending Motor.....	I, 470
“ Locomotive.....	I, 109
“ on Slopes.....	III, 226
“ Tests of.....	I, 277
“ Truck— <i>Illustration, Plate III</i>	I, 170-171
Sprinkler, Track—A. D. 1851— <i>Illustration</i>	III, 240
Spur Track—Meaning of Term.....	IV, 321
Stack Base— <i>Illustration, Plate I</i>	I, 58-59
“ Smoke— <i>Illustration, Plate I</i>	I, 58-59
Staff, Hand Brake— <i>Illustration, Plate III</i>	I, 170-171
“ System of Protecting Trains.....	IV, 92-94
“ Train—Meaning of Term.....	IV, 315
Stages, Days of.....	I, 148
Stained Glass, Carriage of.....	V, 519
Stakes, Engineers'—Care of.....	III, 244
Stamp, Government.....	III, 10
“ Signatures.....	VI, 126; IX, 84, 346, 347
“ “ Use of.....	VI, 314
Stamps, Adhesive.....	V, 427, 428
“ Baggage.....	V, 486
“ Postage—Accounting for.....	X, 287, 288
“ Ticket.....	IX, 122, 123
“ “ —Rules Governing Use of.....	V, 130
Stand Bell— <i>Illustration, Plate I</i>	I, 58-59
“ Nozzle— <i>Illustration, Plate I</i>	I, 58-59
“ Pipe— <i>Illustration, Plate I</i>	I, 58-59
Standard American Flat Cars— <i>Illustration</i>	I, 153
“ “ Gondola Car— <i>Illustration</i>	I, 160
“ “ Locomotive— <i>Illustration, Plate I</i>	I, 58-59
“ “ Passenger and Sleeping Car— <i>Illustration, Plate II</i>	I, 116-117
“ Baggage and Buffet Smoking Car, American— <i>Illustration</i>	I, 211
“ “ Car, American— <i>Illustration</i>	I, 209

	PAGE
Standard Track of Camden & Amboy Railroad, A. D. 1837— <i>Illustration</i>	III, 216
“ Train Line Air Pressure	I, 312
“ Rules.....	IV, 509
Staple Casting, Swing Hanger— <i>Illustration, Plate II</i> ... I, 116-117	
“ End Door— <i>Illustration, Plate III</i>	I, 170-171
“ Iron Used as a Makeshift for a Frog, Camden & Am- boy Railroad—A. D. 1831— <i>Illustration</i>	III, 201
“ Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ Swing Hanger— <i>Illustration, Plate II</i>	I, 116-117
Starting Valve.....	I, 94
“ “ and Relief Cock, Compound Cylinder— Application of— <i>Illustra-</i> <i>tion</i>	I, 95
“ “ “ “ “ Section of— <i>Illustration</i>	I, 94
State Laws.....	VIII, 282
“ Needs of—How Met.....	XI, 33
Statements.....	I, 267
“ Fixed—of Railways.....	X, 62
“ Passenger.....	V, 172
Station Accounts, Auditing.....	IX, 77-97
“ Affairs.....	IX, 124-157
“ Agent.....	II, 58; VI, 13, 14, 16, 17
“ Responsibility of.....	VI, 107
“ Appliances.....	V, 37-39
“ Baggage-men.....	V, 388-391
“Station Buildings and Fixtures”.....	VII, 458
Station, Division of—Into Units.....	I, 435
“ Employes.....	VI, 18
“ Facilities.....	III, 410, 411
“ Cost of.....	III, 45
“ Force, Characteristics of.....	IV, 12
“ Rules and Regulations Governing.....	II, 14
“ Function of the Storage Battery in the.....	I, 439
“ Generators.....	I, 431
“ Inspectors, English—Wages of.....	IV, 452
“ Ledger Office, English.....	VI, 331, 332
“ Location of.....	I, 419
“ Locomotive Supply— <i>Illustration</i>	I, 276
“ Master, English.....	II, 208
“ —Meaning of Term.....	IV, 321
“ Messenger Boy.....	VI, 14
“ Plants.....	I, 437
“ Power.....	I, 454, 455
“ —for the Alternating Current—Direct Cur- rent System.....	I, 487
“ —for the Alternating Current System.....	I, 488
“ Records.....	IX, 93-97
“ Care of.....	IX, 152, 153
“ Passenger—English.....	V, 242
“ Returns, Passenger—English.....	V, 242-245

	PAGE
"Station Service".....	VII, 488, 489, 520, 521
Station Service.....	I, 233
" Signal—Meaning of Term.....	IV, 341
"Station Supplies".....	VII, 489, 490, 521
Station Supplies, Care of	VII, 184-188
" " Charging.....	VII, 321
" " Disbursement of.....	VII, 308, 309
" " Orders for.....	VII, 186
" " Storage of.....	VII, 184-188
" Ticket Records.....	V, 159, 160
Stations, Accounting at	IX, 330
" Announcing Names of.....	IV, 418
" at Which There Are No Agents, Delivering Baggage	
at	V, 448, 449
" " " " " " " Receiving Baggage	
at.....	V, 448, 449
" Burglarizing	IX, 123, 183
" Changes in Names of.....	V, 169
" Clerical Forces at	IX, 303
" Collections at	IX, 65-74
" Credits at	IX, 65-74
" Disposition of Articles Used at	VII, 298
" Employes at—Appointment of.....	IX, 25
" Examination of Accounts at.....	IX, 136-138, 140, 141
" " " —by Traveling Auditors.....	
...IX, 226-231, 236-240, 248, 284-286	
" for Making Light Repairs.....	I, 270
" Freight Trains Running Past.....	IV, 414
" Handling Freight at	IX, 98-107
" " Money at.....	IX, 178-192
" Inspecting.....	I, 270
" Irregular Practices at	IX, 37
" Junction—Rebilling Freight at	VI, 317
" Large—Fiscal Methods at.....	IX, 229-234
" Leaving Cars at	IV, 413
" Lights at.....	VII, 321
" Making Pay Rolls at.....	VII, 370
" Payment of Vouchers at	IX, 374
" Prepaid.....	VI, 153
" Prevention of Accidents at	IV, 121
" Railway—in Spain	I, 174
" Remittances of	IX, 353
" Responsibility at	IX, 347-349
" Safeguards at	IX, 191
" Supervision of Accounts at.....	IX, 220
" Trains Approaching.....	IV, 365-367
" " Leaving	IV, 354, 355, 376
Stationary Engineer	I, 253
" Engines	I, 68, 103, 108
" " for Moving Trains.....	III, 120

	PAGE
Stationer, Duties of	VII, 85, 86, 400
"Stationery and Printing"....	VII, 479, 484, 494, 495, 516, 518, 523
"Stationery and Printing (General Offices)".....	VII, 496, 524
"Stationery Bonds, Shares and Other Forms".....	VII, 465, 466
Stationery, Charging	VII, 321
" Handling	VII, 85
" Inventorying.....	VII, 346
" Ordering.....	VII, 186
" Orders for.....	VII, 85
" Requisitions for.....	VII, 86
" Supply Store.....	VII, 85
" Use of.....	VI, 314
" " "—by Employes.....	VII, 137, 138
" " " " Railways.....	VII, 211
Stationmaster. (See "Yardmaster.")	
Statistician, The.....	X, 16-20
Statistics.....	I, 267
" Accident.....	IV, 123
" Different Methods in Keeping.....	X, 50, 51
" Functions of.....	X, 32, 33
" Locomotive.....	X, 100-108
" Necessity of—to Owners.....	X, 31
" Object of.....	X, 21-34
" —on What Based.....	X, 50
" Railway.....	X, 21, 22, 36
" —Classified Schedule of.....	X, 357-361
" Train.....	IV, 62-67
" Unnecessary.....	X, 89
" Value of.....	X, 34
Statuary, Transportation of.....	V, 519
Statutory Laws, Influence of—on Railways.....	IV, 8
Stay Bolts.....	I, 75, 97
" " —Illustrations, Plate I.....	I, 58-59, 98
" " Drilling Out and Replacing.....	I, 243
" " Radial—Illustration, Plate I.....	I, 58-59
" Rod Pedestal—Illustration, Plate II.....	I, 116-117
" Rods.....	I, 75
" Sling—Illustration, Plate I.....	I, 58-59
Stays, Cross—Illustration.....	I, 98
" Forward Longitudinal—Illustration.....	I, 98
" Rear Longitudinal—Illustration.....	I, 98
" Sling.....	I, 97
" " —Illustration.....	I, 98
Steam.....	I, 223
" Action of—in Compound Cylinder.....	I, 93
" " " " " —Illustration.....	I, 92
" " " " Cylinder.....	I, 84, 85
" " " " " —Illustration.....	I, 83
" Admission of—to Cylinders.....	I, 91
" Ballast Unloaders.....	III, 263

	PAGE
Steam, Bell Ringer— <i>Illustration, Plate I</i>	I, 58-59
“ Blast.....	I, 30, 110
“ “ Effect of.....	I, 72
“ Blow-Off for— <i>Illustration, Plate II</i>	I, 116-117
“ “ Handle for— <i>Illustration, Plate II</i>	I, 116-117
“ Brake.....	I, 292, 305, 380
“ “ for Driving Wheels, Stephenson's, 1833— <i>Illustration</i>	I, 292
“ “ “ Tender, 1832— <i>Illustration</i>	I, 298
“ “ Robert Stephenson's.....	I, 297
“ Car Brake Operated by—1839— <i>Illustration</i>	I, 299
“ Chest— <i>Illustrations, Plate I</i>	I, 58-59, 60
“ “ Casing Cover— <i>Illustration, Plate I</i>	I, 58-59
“ “ Cover— <i>Illustration, Plate I</i>	I, 58-59
“ “ Cylindrical.....	I, 93
“ “ —How Kept Free from Cinders.....	I, 95
“ Chests.....	I, 83, 286
“ Circulating Pipe— <i>Illustration, Plate II</i>	I, 116-117
“ Connection Pump— <i>Illustration, Plate I</i>	I, 58-59
“ Cylinder Brake Pump— <i>Illustration, Plate I</i>	I, 58-59
“ Derrick.....	III, 258
“ Distribution of.....	I, 259
“ Ditchers.....	III, 258
“ Dome— <i>Illustration</i>	I, 60
“ Dry Versus Wet.....	I, 76
“ Energy of.....	I, 402, 403
“ Engine.....	I, 453, 454
“ Expansion of—in Cylinder.....	I, 91
“ First Utilization of—for Land Locomotion.....	I, 18
“ “ “ “ Propelling Carriages in America.....	I, 18
“ for Heating Cars.....	I, 269
“ “ “ Purposes.....	I, 252
“ Gauge.....	I, 82
“ “ — <i>Illustration, Plate I</i>	I, 58-59
“ “ Exterior of— <i>Illustration</i>	I, 83
“ “ Interior of— <i>Illustration</i>	I, 82
“ Gearing of Brake Operated by—France, 1840— <i>Illustration</i>	I, 300
“ Generation of.....	I, 68, 72
“ Hammers.....	I, 255
“ Heat.....	I, 261
“ Heating—Direct System.....	IV, 157, 158
“ High Pressure.....	I, 21
“ Hose— <i>Illustration, Plate II</i>	I, 116-117
“ “ Coupling (Gibbs)— <i>Illustration, Plate II</i>	I, 116-117
“ “ (Sewell)— <i>Illustration, Plate II</i> , I, 116-117	I, 116-117
“ Influence of.....	IV, 7
“ Inlet, Jacket— <i>Illustration, Plate II</i>	I, 116-117
“ Introduction of—in the Navy.....	I, 234

	PAGE
Steam, Introduction of—Its Effect Upon Carriage.....	I, 18
" Jacket, No Fire in Heater— <i>Illustration, Plate II</i> , I, 116—117	I, 116—117
" Locomotive, Classes of Service Performed by.....	I, 507
" Objections to Use of.....	I, 298, 299
" Outlet, Jacket— <i>Illustration, Plate II</i>	I, 116—117
" Pipe— <i>Illustration, Plate I</i>	I, 58—59
" " Exhaust— <i>Illustration</i>	I, 539
" " Gang.....	I, 286
" " to Pump— <i>Illustration</i>	I, 539
" Piping.....	I, 241, 242
" Pipes.....	I, 285, 286, 309
" Plowing by.....	I, 215
" Ports— <i>Illustration, Plate I</i>	I, 58—59
" Pressure.....	I, 67
" " American Locomotive.....	I, 44
" " in Cylinder—How Ascertained.....	I, 88, 89
" Primitive Application of—to Engines, Road Wagons, and Locomotives.....	XI, 510—520
" Primitive Application of—to Engines, Road Wagons, and Locomotives— <i>Illustrations</i>	XI, 510—520
" Pump.....	I, 244, 298
" —Quantity Generated by One Pound of Coal.....	I, 71
" Shovel Car— <i>Illustration</i>	I, 200
" " Frame Work of— <i>Illustration</i>	I, 199
" Snow Plow— <i>Illustration</i>	I, 147
" Successful Creation of.....	I, 20, 21
" Superheated.....	I, 104
" Supply.....	I, 328
" " Required from Boiler.....	I, 70, 71
" Susceptibility of—to Cold.....	I, 298
" Trevithick's Device for Making.....	I, 23
" Turret— <i>Illustration, Plate I</i>	I, 58—59
" Use of—for Heating Cars.....	IV, 157
" " " " in Europe.....	V, 234, 235
" Utility of—Its Demonstration.....	I, 16
" Utilization of—for Heating Purposes.....	I, 204
" Value of—as a Motive Power.....	XI, 510
" " —Its Discovery.....	I, 17
" Valve.....	I, 352, 353
" " — <i>Illustrations, Plate I</i>	I, 58—59, 539
" Varied Use of.....	XI, 513
" Whistle.....	I, 111
" " — <i>Illustrations</i>	I, 111
" " Origin of.....	I, 54—55
" Wrecking Car— <i>Illustration</i>	I, 201
Steamboats, Effect of Introduction of.....	XI, 98
Steel Beams, Trough of.....	I, 464
" Bogie Truck— <i>Illustration</i>	I, 229
" Flat Car, American— <i>Illustration</i>	I, 153

	PAGE
Stephenson's First Locomotive, "Blucher," 1814— <i>Illustration</i> I,	25
" Fish-Belly Rail, Manchester & Liverpool Rail- way—A. D. 1829— <i>Illustration</i> III,	196
" Fork Valve Motion or Gearing Attached to Driving Axles of the Locomotive, 1835— — <i>Illustration</i> I,	48
" "Locomotion," 1825 I,	26
" Locomotive Steam Brake for Driving Wheels, 1833— <i>Illustration</i> I,	299
" "Rocket," 1830 I,	29
" " — <i>Illustration</i> I,	29
"Stevens" Rail III,	200
" " A. D. 1854— <i>Illustration</i> III,	244
" " France—A. D. 1838— <i>Illustration</i> III,	308
" " Great Western Railway of England—A. D. 1858— <i>Illustration</i> III,	275
" " Supported by Cast-Iron Chair—A. D. 1837— — <i>Illustration</i> III,	220
" " Vicksburg & Jackson Railroad—A. D. 1841— <i>Illustration</i> III,	227
" " Western Railway of France—A. D. 1855— <i>Il- lustration</i> III,	259
Stevens, Robert L. III,	176
Stick, Shunter's, I,	172, 173
Stiff Brake Rigging I,	378
Stile, Side Door— <i>Illustration, Plate III</i> I,	170-171
" Window— <i>Illustration, Plate II</i> I,	116-117
Stilling, Dr. IV,	225
Stock Book, Use of VII,	81
" Books, Closing III,	89-91
" Capital III,	42, 80, 85-91, 158
" " —a Basis for Taxation III,	446
" " —Form of Certificate of III,	87
" " —Meaning of the Term III,	86
" " —Voting II,	129
" Car, American Standard— <i>Illustration</i> I,	192
" Classes of III,	88, 89
" Common III,	65-69, 88
" Debenture III,	42, 95
" Dividends on—Accounting for X,	179, 180
" Duplication of III,	75
" Form of Transfer of III,	90
" Issue of III,	53-58, 76
" " —in England III,	73
" " " the United States III,	73
" Laws Regulating the Issuance of III,	78
" Ledger III,	89
" Preferred III,	65-69, 88
" " —Rights of Holders III,	89

	PAGE
Stock, Purchase of—of Other Companies.....	III, 75
“ Rolling.....	I, 120, 463
“ “ —Cost of Keeping in Repair.....	III, 430, 431, 478, 479
“ “ Manufacture of by Railroad Companies.....	I, 141-144
“ Room, Oil.....	I, 274
“ Transfers of.....	III, 89, 90
“ “Watered”.....	III, 34, 72-78; VIII, 75
“ “ —Its Effect on Rates.....	III, 77
“ “ —What It Represents.....	III, 75
Stocks, Negotiation and Sale of.....	II, 137
“ Spurious.....	II, 194
Stockholders. (See also “Shareholders”).....	III, 81
“ Meetings of.....	II, 128, 129; III, 90
Stockton & Darlington Railway.....	I, 27, 45; IV, 247, 248
“ “ Opening of.....	I, 26
“Stockyards”.....	VII, 466
“Stockyards and Elevators”.....	VII, 493, 494, 522, 523
Stockyards, Business at.....	VII, 336-341
“ Collections at.....	VII, 340, 341
“ Incidental Expenses at.....	VII, 338, 339
“ Inventories.....	VII, 347
“ Supplies for.....	VII, 337-340
Stolen Tickets.....	IX, 123
Stone Arch Culvert— <i>Illustration</i>	III, 369
“ Ballast.....	III, 231
“ Block, Rail and Joint Tongue Laid on Camden & Amboy Railroad, A. D. 1831— <i>Illustration</i>	III, 199
“ Cars for Handling.....	I, 224
“ Handling—Railroads for.....	I, 217
“ Stringer and Strap Rail. Baltimore & Ohio Railroad, A. D. 1833— <i>Illustration</i>	III, 208
“ Use of—by Railways.....	VII, 213
“ “ —In Construction.....	III, 129
Stones, Precious.....	II, 242
“ “ —Transportation of.....	V, 519
Stool, Center Bearing— <i>Illustration, Plate II</i>	I, 116-117
Stop Bar, Lower Berth— <i>Illustration, Plate II</i>	I, 116-117
“ Brake Lever— <i>Illustration, Plate II</i>	I, 116-117
“ Cock, Train Signal— <i>Illustration, Plate II</i>	I, 116-117
“ Cocks.....	I, 102
“ Shade— <i>Illustration, Plate II</i>	I, 116-117
“ Window— <i>Illustration, Plate II</i>	I, 116-117
Stop-Over Tickets.....	V, 213-216
“ “ “ Conductors’.....	X, 127, 128
Stopping Triple Valve Blow.....	I, 374, 375
Stops, Making.....	I, 369
Storage Batteries.....	I, 438-440
“ Use of.....	IV, 176, 180
“ Battery System.....	IV, 176

	PAGE
Storage Charges, Baggage.....	V, 424-427, 509, 510
“ “ “ Collection of.....	V, 504, 505
“ “ for.....	VI, 107
“ “ —in Europe.....	IX, 81
“ Rates for.....	II, 242
“ Reservoir—Air.....	I, 244, 262
“ System of Heating.....	IV, 162, 163
“ Tickets.....	V, 505
“Storage Warehouses”.....	VII, 460
Storehouse.....	I, 245, 258, 270, 273, 275
“ Car Department—Cross Section— <i>Illustration</i> ..	I, 273
“ “ “ —End Elevation— <i>Illustration</i> ..	I, 273
“ “ “ —Side Elevation— <i>Illustration</i> ..	I, 270
“ Central.....	VII, 142
“ General.....	I, 252; VII, 182
“ the First.....	XI, 32
Storehouses. (See also “Supply Depots”).....	I, 268
“ Approaches to.....	VII, 293
“ Arrangement of.....	VII, 293
“ Care of Supplies at.....	VII, 256
“ Closing.....	VII, 347
“ Examinations at—by Traveling Auditors.....	VII, 433
“ for Care and Maintenance of Rolling Stock.....	I, 238
“ Inspection of—by Traveling Auditors.....	IX, 283
“ Kinds of.....	VII, 257
“ Local—Supplies at.....	VII, 78
“ Material forwarded to.....	VII, 318
“ “ Received from.....	VII, 317, 318
“ Number of.....	VII, 107, 181
“ —Shop—Requisitions for Material for.....	VII, 78
Storekeeper, General.....	VII, 76
“ “ —Duties of.....	VII, 88
“ “ —Inspections by.....	VII, 82
“ “ —Requisitions on.....	VII, 79
“ Meaning of Title.....	II, 141, 142
“ Title of.....	VII, 63, 70, 71, 249, 253
Storekeepers, Construction.....	VII, 194-197
“ Difference Between Good and Poor.....	VII, 55
“ Duties of.....	VII, 87, 170, 180, 192, 254-264, 270, 271, 284, 292, 303, 304, 307, 308, 327, 336, 341, 345, 354, 355, 418, 419, 430-433
“ “ “ Subordinates of.....	VII, 81
“ Inspection of Material by.....	VII, 95, 97
“ Orders on.....	VII, 311
“ Reports of.....	X, 67
“ Requirements of.....	VII, 45, 46
“ Returns of.....	VII, 325
“ Supervision of.....	VII, 291, 292
“ Vouchers Chargeable to.....	VII, 318, 319
Store, Stationery Supply.....	VII, 85

	PAGE
Superintendent, Division—Authority of	II, 196
“ “ —Characteristics of	II, 199, 202
“ “ —Discretion of	II, 198, 200
“ “ —Duties of	II, 198-209
“ “ —His Relation to the General Manager	II, 199
“ “ —Scope of	II, 175
“ “ —Title of	VII, 250
“ Engine	I, 27
“ General	II, 138
“ “ —Scope of	II, 174, 175
“ Motive Power	I, 277
“ of Car Service	VI, 57
“ “ Cars	I, 270, 271, 277
“ “ Dining Cars	II, 138
“ “ Early Times	II, 114
“ “ Motive Power and Machinery	II, 138
“ “ Roadway	III, 259
“ “ Telegraph	II, 138
“ Power Exercised by	II, 144
“ Relief Department	X, 311
“ Transportation	VI, 57
Superintendents, Division—Relief Vouchers Made by	IX, 372
“ Meetings of	I, 229
“ of Cars	I, 230, 233
“ “ Motive Power	I, 233
“ Railway—American Association of	IV, 28
“ Requisitions of	VII, 72, 73
Supervision, Costly	I, 284
“ Effective	VII, 75
“ Government—Objections to	VII, 11, 12
“ Necessity of—Over Young Employees	IX, 29, 30
“ of Property	II, 16
Supervisors, Necessity of—to See That Rules Are Obeyed	IV, 306
“ Track	II, 138; III, 259
Supervisory Force, for the Care of Cars	I, 271
Supplies. (See also “Material.”)	
“ Amounts Charged to	VII, 15
“ Arrangement of	VII, 256, 294
“ Baggage Car—Accounting for	VII, 187, 188
“ Business Car—Accounting for	VII, 187, 188
“ Caboose Car—Accounting for	VII, 187, 188
“ Care of	VII, 45-53
“ Carpenters’—Accounting for	VII, 187, 188
“ Classifying	VII, 91-105
“ Construction—Depots for	VII, 189-198
“ Cost of	III, 395, 396; VII, 14, 38
“ “ Handling	VII, 274
“ “ —Upon What Dependent	VII, 235

GENERAL INDEX.

329

	PAGE
Supplies, Dining Car.....	VII, 299-301
" " —Accounting for.....	VII, 187
" " —Inventorying.....	VII, 346
Disbursement of.....	VII, 184
" " —at Night.....	VII, 182, 183, 308
Disposition of—in Accounts.....	VII, 28, 29
Drawing Room Car—Accounting for.....	VII, 187, 188
Efficient Handling of.....	V, 123, 124
Expenditures of Railways for.....	VIII, 24
Facilities for Storing.....	VII, 34-37
Fuel.....	I, 273
Grouping.....	I, 246
Handling of.....	II, 291; VII, 28-44
" " —English Practices.....	VII, 104, 105
Hotel.....	VII, 86, 87
Inferior—Purchase of.....	III, 398
Inspecting.....	VII, 91-105
Inventorying.....	VII, 341-348
Liabilities for.....	X, 61
List of—Required at Ticket Offices.....	V, 593
" " by Conductors.....	V, 593
Locomotive—Accounting for.....	VII, 154, 187, 188
Machinists'—Accounting for.....	VII, 187, 188
Maintenance of—by Agents.....	V, 115
Manufacture of—by Railways.....	VII, 275
Money Invested in.....	VII, 26
Ordering.....	VII, 54-69
Orders for—Used on Trains.....	VII, 65
Passenger Car—Accounting for.....	VII, 187, 188
Petty—Accounting for.....	VII, 269
" " —Charging.....	VII, 276, 321
Purchase and Care of—Customs of United States Army.....	II, 270
Purchase of.....	II, 260; III, 397, 398; VII, 39-41, 45-53; X, 91
Purchasing.....	V, 124
Railway.....	VII, 14, 15
" " —Charges for Transporting.....	VII, 199-206
Receiving.....	VII, 91-105
Reserve.....	VII, 76
Sale of.....	II, 192, 260; VII, 425
Shipping.....	VII, 180
Shop—Inventorying.....	VII, 344
Sleeping Car—Accounting for.....	VII, 187, 188
Station—Accounting for.....	VII, 181, 185, 187, 188
" " —Care of.....	VII, 184-188
" " —Charging.....	VII, 321
" " —Disbursement of.....	VII, 303, 309
" " —Orders for.....	VII, 186
" " —Storage of.....	VII, 184-188

	PAGE
Supplies, Stockyard.....	VII, 337-340
" Track—Accounting for	VII, 269
" —Ordering.....	VII, 106, 107
" Trackmen's—Accounting for.....	VII, 187, 188
" Train—Accounting for.....	VII, 185
" —Care of.....	VII, 184-188
" —Disbursement of.....	VII, 308, 309
" —Storage of.....	VII, 184-188
" Value of—on Hand.....	VII, 29
" —What They Represent.....	VII, 30, 264
" Wrecking Car—Accounting for.....	VII, 187, 188
Supply and Demand, Effect of—on Rates.....	VIII, 11, 56, 98
" " Law of—How Far Applicable to Rail-roads.....	VIII, 184
" Department, Organization of.....	VII, 70
" Depots. (See also "Storehouses.")	
" Inspectors of.....	VII, 77
" Pipe— <i>Illustration, Plate II</i>	I, 116-117
" Station, Locomotive— <i>Illustration</i>	I, 276
" Steam.....	I, 328
Supports, Gas-Holder— <i>Illustration, Plate II</i>	I, 116-117
" Rail.....	III, 179
Sureties, Guaranty.....	IX, 172, 173
Surety Companies.....	IX, 158-165
Surface Conductors, for Collecting Current.....	I, 464, 465
Surfacing.....	III, 285
Surgeon.....	II, 224, 234, 236
" Duties of.....	II, 236
" Relation of—to the Company.....	II, 236
Surgeons, Fees of.....	III, 398
Surgical Appliances.....	II, 232
Surveys of Routes.....	III, 157
Susa.....	XI, 105
Suspension Lamp, Center— <i>Illustration, Plate II</i>	I, 116-117
" Links.....	I, 297
" of Motor.....	I, 470, 471
" Stud— <i>Illustration, Plate I</i>	I, 58-59
Swann, John.....	III, 85
Sweden, Heating Cars in.....	V, 235
Sweeney Air Compressor, The— <i>Illustration</i>	I, 383
" Brake.....	I, 383
Swing Hanger Pivot Bearing— <i>Illustration, Plate II</i>	I, 116-117
" " Lower— <i>Illustration, Plate II</i>	I, 116-117
" " Upper— <i>Illustration, Plate II</i>	I, 116-117
" " Staple— <i>Illustration, Plate II</i>	I, 116-117
" " Casting— <i>Illustration, Plate II</i>	I, 116-117
" Hangers— <i>Illustration, Plate II</i>	I, 116-117
Swinging Cranes.....	I, 260
" or Dumping Car— <i>Illustration</i>	I, 149
Switch Engines, Weight on Drivers of.....	I, 64

	PAGE
Switch, Flying—Meaning of Term	IV, 318
“ Indicators, Automatic Electric Block System	IV, 285
“ Instruments Automatic Electric Block Signals— <i>Illustrations</i>	IV, 284
“ “ “ “ “ System	IV, 284
“ Main	I, 460
“ Material, Storage of	VII, 190
“ —Meaning of Term	IV, 321
“ Old-Fashioned—with “Ball” Counterweight— <i>Illustration</i>	III, 328
“ Sills	III, 228
“ Split— <i>Illustration</i>	III, 340
“ Stand, Automatic Safety— <i>Illustration</i>	III, 336
“ The Interlocking	IV, 110-113
“ The Split	IV, 113, 114
Switches	III, 227, 228; I, 223
“ Automatic	IV, 15
“ Care of	IV, 433
“ Closed—Meaning of Term	IV, 317
“ Conductors Responsible for	IV, 359
“ Derailing	III, 237, 238
“ Duties of Conductors in Relation to	IV, 404
“ Flying—Making	IV, 380
“ for Changing Motor Connections	I, 484
“ “ Resistance	I, 484
“ in Colliery Railroads, England, A. D. 1825— <i>Illustration</i>	III, 194
“ Interlocking—Use of, in England	VIII, 323
“ on Outside of Curves	III, 237
“ Open—Meaning of Term	IV, 319
“ Opening	IV, 359
“ Shipping	VII, 191
“ Slip	III, 235, 236
“ Three-Way Split	III, 233, 234
“ Trains Approaching	IV, 365-367
Switchboard, Connections Between Dynamo and Feeders in — <i>Illustration</i>	I, 461
“ Metropolitan Elevated Railway, Chicago— <i>Illustration</i>	I, 516
“ Railway Station—for Three Generators and Eight Feeders— <i>Illustration</i>	I, 460
“ The	I, 460, 461
Switching	IV, 362-364
“ Switching Charges Balance”	VII, 490, 521
Switching, Charges for	VI, 252-255; IX, 61
“ Duties of Conductors in Relation to	IV, 414, 415
“ Engines, Description of	I, 65
“ —Meaning of Term	IV, 322
“ Order for	VI, 255-258
“ Receipt for Charges for	VI, 255-258

	PAGE
Switching, Record of.....	VI, 255-258
" " " Charges for.....	VI, 255-261
" Tracks.....	I, 250
" Yard.....	I, 268
"Switchmen, Flagmen, and Watchmen".....	VII, 488, 520
Switchmen, Instructions to.....	I, 376, 377
" Tools of.....	IV, 433
" Use of Signals by.....	IV, 342
Switchtenders, Use of Signals by.....	IV, 342
Switzerland, Heating Cars in.....	IV, 163, 164; V, 234, 235
" Maximum Working Hours of Trainmen in.....	IV, 19
Syctalæ of the Time of Alexander the Great, 332 B. C.— <i>Illustration</i>	IV, 187
Symmington, William.....	XI, 511
Synchronous Motor.....	I, 412, 442
" Speed.....	I, 442, 445, 446
Syria.....	XI, 102
System, Alternating Current.....	I, 431, 441-449, 452, 453, 488, 489
" " " —Direct Current.....	I, 430, 440, 451, 487, 488
" " " —Supplying Polyphase Current by Two Trolleys and Rail Return to Alternating Current Motors on the Cars— <i>Illustration</i>	I, 441
" " " —Supplying Rotary Transformers Which Deliver Direct Current to the Trolley System— <i>Illustration</i>	I, 426
" Block.....	III, 38
" " —Signals of.....	I, 311
" Booster.....	I, 434-437, 450, 451
" Closed Conduit.....	I, 466
" Direct Current.....	I, 454
" " " —Direct Fed.....	I, 451
" Electric—the First Practically Operated.....	I, 520
" Electrical—Elements of.....	I, 396
" " —Storage Battery in an.....	I, 438, 439
" High Tension—with High Tension Trolley Line.....	I, 452, 453
" Open Conduit.....	I, 466
" Overhead Hot Air.....	I, 257
" Piecework.....	I, 265
" Premium.....	III, 249
" Railway—Formal Inauguration of.....	I, 31
" Simple Trolley, and Rail Return— <i>Illustration</i>	I, 433
" Three-Wire.....	I, 437, 438
" Trolley.....	I, 463, 464
Systems, Direct Current.....	I, 430-440
" " " Feeder— <i>Illustrations</i>	I, 433

	PAGE
Systems, Electrical—Comparison of	I, 450-453
“ “ for Railway Service	I, 430-453
“ “ —Variety of	I, 413
“ of Checking Baggage	V, 53-58
“ Underground—for Collecting Current	I, 466
Systematic Co-Operation	I, 284
Systemization, Necessity of	II, 21, 22
“ of Shops and Shop Work	I, 288
Table, Drop	I, 261
“ Hook Plate— <i>Illustration, Plate II.</i>	I, 116-117
“ Time	IV, 71-75
“ “ —Meaning of Term	IV, 322
“ “ —Rules Governing	IV, 338-340
Tables, Transfer	I, 264, 273
Tablets, Clay—of Babylon	XI, 129
Tact, Value of	II, 17
Tag, Defect	I, 325
Tail Boat— <i>Illustration, Plate II.</i>	I, 116-117
“ Lamp— <i>Illustration, Plate II.</i>	I, 116-117
“ Piece of Frame— <i>Illustration, Plate I.</i>	I, 58-59
Talent, Administrative—of Builders	I, 126
“ Diversity of	II, 63
“ Needed for Corporate Service	II, 156
“ Versatility of	II, 134
Talents, Men's	I, 136
Tallow, Charges Collected for	VII, 421, 422; IX, 426
“ Charging	VII, 320, 321
“ Record of	VII, 320, 321
Tally Book	VI, 127
“ “ —Rules Governing	VI, 128
Tamarack Ties	III, 350
Tamping	III, 216, 217, 254
Tank, Air— <i>Illustration, Plate II.</i>	I, 116-117
“ Approach to— <i>Illustration.</i>	I, 106
“ Engine	I, 106
“ “ —Means of Filling with Water	I, 106
“ “ —Mineral—Scotland— <i>Illustration</i>	I, 123
“ Filler, Water— <i>Illustration, Plate II.</i>	I, 116-117
“ Lye	I, 261
“ Shop	I, 251
“ Tender—Construction of	I, 107
“ Track	I, 106
“ Water	I, 246
“ “ — <i>Illustrations, Plate II.</i>	I, 116-117, 280
“ “ —Approach to Tank— <i>Illustrations</i>	I, 106
Tanks, Oil	I, 101, 245
“ Water—Repair of Locomotive	I, 251
Taps	I, 263

	PAGE
Tariff, Construction of First.....	VIII, 20
" —Meaning of the Term.....	VI, 42
" Passenger—Turkish Railroad, Java to Jerusalem... V,	595
" Zone.....	VIII, 339
Tariffs, Changes in.....	IX, 42
" List of—Required at Ticket Offices.....	V, 593
" of Rates—Compilation of.....	II, 251
" Passenger.....	V, 121
" Posting.....	V, 122
" Printing.....	VIII, 129
" Promulgation of.....	III, 425
" Rules Governing Use of.....	VI, 151, 152
" Regulating—in the United States.....	VI, 43-48
" Study of—by Agents.....	IX, 57, 89
Tarpaulin.....	I, 172
Tarpaulins, Use of—in Great Britain.....	I, 204
Tax Bureau.....	II, 138
Taxes.....	III, 46, 47, 476, 477
" Taxes " Account.....	VII, 526
Taxes, Accounting for.....	X, 179
" Disbursements for.....	III, 422
" Expenditures of Railways for.....	VIII, 24
" Payment of—by Lessees.....	III, 99
" Rates Likened to.....	VIII, 55, 99
Taxation, Committee of Railroad Commissioners on, III, 441, 445	
" Differences in Systems of.....	III, 440, 441
" Railway—Basis of.....	III, 433-457
" —Discrimination in.....	III, 436, 444
" —in Alabama.....	III, 451
" " Belgium.....	III, 433, 434
" " Dakota.....	III, 452
" " Georgia.....	III, 450, 451
" " Great Britian.....	III, 434, 435
" " Illinois.....	III, 440
" " Iowa.....	III, 439
" " Kentucky.....	III, 449, 450
" " Louisiana.....	III, 452
" " Maryland.....	III, 452
" " Michigan.....	III, 436, 438
" " Minnesota.....	III, 439
" " Mississippi.....	III, 451, 456
" " Ohio.....	III, 449
" " Tennessee.....	III, 449, 450
" " the United States.....	III, 435-453
" " Vermont.....	III, 452
" " Wisconsin.....	III, 436, 437, 444
" True Method of.....	III, 447-449
Tayleur & Company.....	I, 32
Taylor, E. L.....	IV, 211
Teak Wood, Use of—for Car Wheels.....	IV, 215

	PAGE
Teamsters, Delivery of Freight to.....	VI, 107; IX, 317
Technical Force	III, 470
Tee Fitting— <i>Illustration, Plate II</i>	I, 116-117
Telegrams.....	VI, 314
"Telegraph".....	VII, 466
Telegraph—Block System.....	IV, 276
" Dispatching Trains by—Forms Used.....	IV, 465-478
" Duplicate Order System.....	IV, 83, 84
"Telegraph Expenses".....	VII, 488, 520
Telegraph Expenses, Apportionment of.....	VII, 509, 510
" Movement of Trains by.....	IV, 291, 292, 383-400
" " " "—Meaning of Term.....	IV, 319
" Operators, Examination of.....	IV, 329
" " Rules Governing.....	IV, 435-439
" Poles.....	III, 354
" Painting.....	IV, 351
" Postal—English.....	V, 245, 246
" —Single Order System.....	IV, 83, 84
" Stations, Early Signals at.....	IV, 249, 250
" Superintendent of.....	II, 138
" —Triplicate Order System.....	IV, 83, 84
" Use of—in Great Britain.....	IV, 87, 88
" " " Moving Trains.....	IV, 78, 83-92
Telegraphic Apparatus.....	I, 401
Telephone System, Shop.....	I, 279
Telephones, Introduction of.....	I, 279
Telescoping, Devices Preventing.....	I, 198
" of Cars.....	I, 179
Temporary Expenditures.....	VII, 525
Temporizing.....	II, 18
Tenacity of Brake Shoe.....	I, 301
Tender, Air Brake Apparatus on.....	I, 315
" Brake.....	I, 381
" Adjustment of.....	I, 329
" Construction of Tank on.....	I, 107
" Device for Filling When Train Is in Motion.....	I, 106, 107
" Front View of, with Scoop in Track Tank— <i>Illustration</i>	I, 108
" Locomotive.....	I, 101, 106, 198
" Quantity of Water and Fuel Carried in.....	I, 106
" Rear View of— <i>Illustration</i>	I, 108
" Section of—Showing Water Scoop in Track Tank— <i>Illustration</i>	I, 106
" Side View of (with Water Scoop Dropped)— <i>Illustration</i>	I, 106
" Steam Brake for—1832— <i>Illustration</i>	I, 298
Tennessee, Railway Taxation in.....	III, 449
Tension Rod.....	I, 214
Ten-Wheeled Locomotive, Breda, Milan— <i>Illustration</i>	I, 183
Terminal Charges.....	III, 408, 409

	PAGE
Terminal Expenses	III, 409-411
" Facilities, Cost of.....	III, 409
Terminals, in Dynamo and Battery	I, 397
" Leaving Train at—Instructions to Trainmen	I, 375
Test Brakes After any Change—Instructions to Trainmen	I, 375, 376
" of Brakes—Instructions to Engineers	I, 363, 364
Tests, Brake—Upon Motor	I, 476
" Chemical	I, 377
" Engineer of.....	I, 277, 278
" Laboratory for Making	I, 277-279
" on Motor Cars.....	I, 480-482
" Physical	I, 277
" Running—of Brakes.....	I, 363, 364
" Value of.....	II, 264, 265
Testing Air Pump.....	I, 328
" Brakes.....	I, 269, 375
" " —Instructions to Car Inspectors.....	I, 330, 331
" " " Enginemen.....	I, 317
" " " Trainmen.....	I, 321-323
" Engine for Leaks.....	I, 370
" Hose.....	I, 370
" Laboratories.....	VII, 102
" Plants, Yard.....	I, 382
*Thatcher Perkin's" Locomotive, 1863—First Ten-Wheeled Passenger Engine— <i>Illustration</i>	I, 45
The Act of Paying Railway Employes Their Wages... X,	185-290
Theatrical Parties, Baggage Tickets for.....	V, 471
The Heilmann Locomotive— <i>Illustration</i>	I, 518
The Western Classification.....	VI, 444
Theorists.....	I, 288
Theory of Railway Carriage.....	I, 392
" " the Application of the Automatic Brake and Brake Shoe to the Driving Wheels— <i>Illustration</i>	I, 542
Thermal Batteries.....	I, 397
Thimble— <i>Illustration, Plate II</i>	I, 116-117
" Side Stem— <i>Illustration, Plate II</i>	I, 116-117
Third Rail.....	I, 464, 465
" " and Shoe, Brooklyn Bridge Terminal— <i>Illustration</i>	I, 466
" " Shoe for—Between Main Rails—Nantasket Beach Railway— <i>Illustration</i>	I, 465
" " Supported on Special Wood Blocks Doweled into the Ties—Nantasket Road— <i>Illustration</i>	I, 464
" Track—Meaning of Term.....	IV, 322
" " Rules Governing.....	IV, 376, 376
Thrall Ticket.....	V, 207
" W. A.....	V, 80
Three-Phase System.....	I, 425

	PAGE
Three-Way Cock.....	I, 347
“ “ —Illustrations, Plate II.....	I, 116-117, 348
“ “ Stem of—Illustration, Plate II.....	I, 116-117
“ Split Switches.....	III, 233, 234
Three-Wire System.....	I, 437, 438
“ “ —Illustration.....	I, 433
Threshold Plate—Illustration, Plate II.....	I, 116-117
“ “ End Door—Illustration, Plate III.....	I, 170-171
“ “ Side Door—Illustration, Plate III.....	I, 170-171
Throttle.....	I, 83
“ —Illustration.....	I, 62
“ Air Pump—Illustration, Plate I.....	I, 58-59
“ Bell Crank—Illustration, Plate I.....	I, 58-59
“ Injection—Illustration, Plate I.....	I, 58-59
“ Lever—Illustrations, Plate I.....	I, 58-59, 64
“ Pipe—Illustration, Plate I.....	I, 58-59
“ Rigging.....	I, 286
“ Stem—Illustration, Plate I.....	I, 58-59
“ Valve—Illustration, Plate I.....	I, 58-59
Through Passenger Service, Use of Electricity for....	I, 509-513
“ Plate Girder Bridge—Illustration.....	III, 376
“ Traffic.....	V, 13
“ Train—Meaning of Term.....	IV, 322
Thucydides.....	XI, 28
Thumb Latch Shade—Illustration, Plate II.....	I, 116-117
Ticket Accountants.....	II, 248
“ Accounts.....	V, 75; IX, 108, 109
“ “ Bureau of.....	V, 17
“ “ Communications Referring to.....	V, 175
“ “ Handling—in America.....	V, 81
“ Auditor.....	II, 139; V, v, 81; X, 67
“ “ Duties of.....	II, 268
“ Auditor's Office.....	X, 121
“ Auditors, Relief Vouchers Made by.....	IX, 372
“ Cases.....	IX, 190, 191
“ “ English.....	V, 240
“ “ Rules Governing Use of.....	V, 128, 129
“ Chart, Interline.....	V, 136-138
“ Collections, Conductors'.....	X, 123, 124
“ Collectors.....	V, 16, 17, 83
“ Commissions.....	V, 49, 50
“ Coupons.....	V, 175
“ Inspectors.....	V, 83
“ Invoices.....	IX, 122
“ Offices, Examination of—by Traveling Auditors, IX,	116
“ “ List of Supplies Required at.....	V, 593
“ Punches.....	V, 198, 199, 202
“ Receivers.....	V, 17
“ Record Books.....	X, 128
“ Records, Station.....	V, 159, 160

	PAGES
Ticket, Register, Interline.....	V, 159, 160, 162, 163
" Local.....	V, 159-162
" Reports, Auditing.....	X, 128-133
" Returns, Conductors'.....	V, 221, 222
" " Traveling Auditors'.....	IX, 150
" Sales, Weekly Return of.....	V, 163, 164
" Scalpers.....	V, 45-49
" Operations of.....	V, 46, 47
" Scalping, Practice of.....	V, 47, 48
" Suppression of.....	V, 48
" Sellers, Appointment of.....	II, 261
" Transfer of.....	IX, 260
" Stamps, Rules Governing Use of.....	V, 130
" System, Cost of—to Railways.....	V, 80
" Thrall.....	V, 207
" Windows, Obstruction to.....	V, 119
Tickets, Alterations in.....	V, 130, 134
" Apportioning—Forms Used for.....	V, 85
" Assorting and Examining.....	X, 122
" Arrangement of.....	V, 128, 129
" Auditing.....	X, 122
" —by Traveling Auditors.....	IX, 285
" Book.....	V, 95-97
" Canceled.....	V, 81
" Canceling.....	IX, 122
" Cancellation of.....	V, 189, 198-202
" Card.....	V, 93-95
" —English.....	V, 238
" —Excursion.....	V, 95
" —Origin of.....	V, 92
" —Round-Trip.....	V, 94-95
" Care of—Rules Governing.....	V, 128, 129
" Cases for Storing.....	V, 77, 78
" Changes in Forms of.....	V, 20, 21
" Charging Agents with.....	V, 82
" Checking—with Returns.....	X, 122
" Closing Number of.....	V, 169, 170
" Collected by Conductors.....	X, 67
" Collection of.....	V, 198-216
" " —in England.....	V, 83
" " —Rules Governing.....	V, 221, 222
" Commencing Number of.....	V, 169, 170
" Commutation.....	V, 93, 99-101
" Comparison of.....	V, 83, 84
" —Comparisons of Sales with Collections.....	IX, 116, 117, 137; X, 56
" Contracts on—Execution of.....	V, 175
" Convention.....	V, 92, 107
" Counterfeit.....	IX, 117
" Counting—by Agents.....	IX, 122

	PAGE
Tickets, On upon.....	V, 88, 102
" —Local.....	V, 99
" Custodian of.....	V, 81
" Dealing in—by Employes.....	IX, 291
" Destruction of—by Fire.....	IX, 342
" Devices for Improving.....	V, 101, 102
" Duplicate—Preventing Use of.....	IX, 117
" Examination of—in the Accounting Office.....	IX, 108, 109
" Excess Baggage.....	V, 509
" —Use of.....	V, 471-477
" Exchanged for Those of Other Lines.....	V, 170
" Excursion.....	V, 92, 99, 107-111
" —English.....	V, 239
" Fair.....	V, 92, 107
" Foreign.....	V, 83, 102
" " Coupon.....	V, 88
" Fuel.....	VII, 334, 335
" Good for More Than One Trip—Auditing.....	X, 126
" Half Fare.....	V, 133
" " Excursion and Miscellaneous—Auditing.....	X, 125, 126
" Harvest.....	V, 92, 107
" Home.....	X, 127
" " Coupon.....	V, 88
" Honoring.....	V, 203-210
" Improper Use of.....	V, 174, 175
" Improvements in.....	V, 79
" Interline.....	V, 78, 88, 91, 102-107, 110, 111
" " —Accounting for.....	V, 85
" " —Auditing.....	X, 131-133
" " —"Complete".....	V, 105, 137
" " —Foreign.....	X, 127
" " —Local.....	X, 127
" " —"Paster" and "Extension".....	V, 106, 137
" " —Selling.....	V, 136-138
" Inventorying.....	IX, 291
" Invoices of.....	II, 258
" Invoicing.....	V, 82, 127, 128, 169
" Kinds of—Used in America.....	V, 88-111
" Land.....	V, 92, 107
" Limitation of.....	V, 90, 91; IX, 117, 118
" Limited.....	V, 90, 133, 134, 204
" Limiting Life of.....	X, 57
" Loaded Car—Rules Governing.....	VI, 132, 138, 173, 174, 176-178
" " —Use of.....	IX, 51
" Local.....	V, 91, 92-102, 110
" " Card—Auditing.....	X, 124, 125
" Lost or Stolen.....	V, 129, 162
" Manufacture of.....	V, 74, 75

	PAGE
Tickets, Mileage	V, 78, 92, 93, 97-99
" " Coupon	V, 471, 474, 475, 495
" —Rules Governing	V, 207-210
" Milk	V, 520; VI, 247, 248
" —Auditing	X, 119
" —Record of Sales of	VI, 249, 251
" Miscellaneous	V, 111
" Missing	IX, 121
" Money Coupon—Excess Baggage	V, 471, 472, 476, 477, 495
" Numbering	V, 82, 83
" Obtaining—Before Entering Cars	V, 83
" Omnibus	V, 205
" Orders of Agents to Deliver	V, 146-150
" Packing	V, 127
" Parcel—Use of	V, 471-477
" Parlor Car	V, 95
" Passage	II, 255, 256; V, 88; IX, 108-123
" —English	V, 237-240
" —Evolution of	V, 71-78
" —Importance of	V, 75
" —Origin of	V, 66-70
" —Preparation of	II, 257
" —Systemization of	V, 79-87
" Permits for Half Fare—Rules Governing	V, 123
" Pleasure Parties'—English	V, 239
" Printing	V, 76, 77
" Procuring—Before Entering the Cars	V, 117-119
" Punching	IX, 118, 119; X, 123
" Receipting for	V, 169
" Reconsigning—Rules Governing	VI, 178
" Reduced Rate—English	V, 239
" Reducing Class of	V, 134
" Refund—Mileage	V, 208, 210
" Registering—Forms Used for	V, 85
" Reporting	V, 83, 84, 169
" Requisitions for	V, 123-127
" —English	V, 240, 241
" Re-sale of	IX, 115, 116
" Returned by Conductors	V, 84
" Returns of	V, 83, 84
" Selling	V, 130-136
" Shipping	V, 127, 128
" Signatures on	V, 204, 208, 209
" Sleeping Car	V, 95, 206
" Sold at Unauthorized Rates	V, 174
" Spilled	V, 162, 168, 170, 171
" Stamping	V, 130; IX, 122, 123, 291
" Station Records of	IX, 121, 123
" Stolen	IX, 123

	PAGE
Tickets, Stolen—Notice of.....	IX, 335
“ Stop-Over.....	V, 213-216
“ “ —Conductors’.....	X, 127, 128
“ Storage.....	V, 505
“ Stubs of.....	V, 171
“ Suburban.....	V, 40
“ Supply to Be Kept.....	V, 119
“ —The First Used by Railways.....	V, 67
“ Time.....	IX, 380-390
“ “ —Agreement on.....	VII, 399; IX, 383, 384
“ “ —Alterations on.....	IX, 386
“ “ —Cancellation of.....	VII, 413; IX, 397, 398
“ “ —Indorsements on.....	VII, 407, 444-446
“ “ —Indorsing.....	IX, 346, 393, 394, 396
“ “ —Issuing.....	VII, 398-405
“ “ —Lost.....	VII, 409; IX, 396
“ “ —Numbering.....	IX, 385
“ “ —Payment by.....	VII, 397, 398
“ “ “ of.....	VII, 406-410; IX, 390-397
“ “ “ by Agents.....	IX, 180
“ “ —Remitting.....	IX, 425
“ “ —Requests for.....	VII, 405, 406; IX, 390
“ “ —Requisitions for.....	VII, 400
“ “ —Signing.....	IX, 885
“ “ —Traffic in.....	IX, 392
“ Tourist.....	V, 92, 107
“ “ —English.....	V, 239
“ Trafficking in—by Employes.....	V, 176
“ Unlimited.....	V, 90
“ Unsold.....	V, 135, 136
“ Unused—Redemption of.....	V, 171
“ Use of.....	V, 89
“ “ —Beyond Their Destination.....	V, 213
“ Void.....	X, 133
“ Writing on.....	V, 133, 134
Tie, Action of Rail on— <i>Illustration</i>	III, 321
“ “ Spike on— <i>Illustration</i>	III, 321
“ Bar— <i>Illustration, Plate III</i>	I, 170-171
“ Cross—Split Half Log— <i>Illustration</i>	III, 213
“ “ “ Quarter Log— <i>Illustration</i>	III, 212
“ “ —Whole Log, Hewn Both Sides— <i>Illustration</i>	III, 214
“ Frame— <i>Illustrations</i>	I, 64, 98
“ Metal—Midland Railway of India, A. D. 1889— <i>Illustration</i>	III, 311
“ Plates.....	III, 213
“ “ Use of.....	III, 332, 333, 352, 372-374
“ Rod, Carline— <i>Illustration, Plate III</i>	I, 170-171
“ “ End Plate— <i>Illustration, Plate III</i>	I, 170-171
“ “ “ Sill— <i>Illustration, Plate II</i>	I, 116-117
“ “ Platform— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Tie Rods, Safety Beam— <i>Illustration, Plate II</i>	I, 116-117
“ “ Sill— <i>Illustration, Plate II</i>	I, 116-117
“ Steel—London & Northwestern Railway, A. D. 1885— <i>Illustration</i>	III, 304
“ Timber, Cross— <i>Illustration, Plate II</i>	I, 116-117
Ties.....	II, 269; III, 255, 256; VII, 466
“ Accounting for.....	VII, 287
“ Bids for.....	VII, 97, 98
“ Burnettized.....	III, 359, 360
“ Cause of Wear of.....	III, 333
“ Cedar.....	III, 350
“ Chestnut.....	III, 350
“ Cost of.....	III, 280, 283
“ “ Keeping in Order.....	III, 422, 423
“ “ Preserving.....	III, 361-363
“ Cross.....	III, 179, 203
“ Cutting of—by Rails.....	III, 332
“ Cypress.....	III, 350
“ Damage to—by Spiking.....	III, 213, 214
“ Deterioration of.....	III, 280-283
“ Duration of.....	III, 281-283, 334, 350, 365
“ Effect of Ballast on.....	III, 280-282
“ “ Passing Trains on	III, 329
“ “ Traffic on.....	III, 282
“ Hemlock.....	III, 350
“ Inferior—Use of.....	III, 400
“ Inspecting.....	VII, 285-289
“ Inventorying.....	VII, 344
“ Kinds of Wood Used for.....	III, 350
“ Laying.....	III, 211
“ Life of.....	III, 283
“ “ —How Prolonged	III, 350, 351
“ Longitudinal.	III, 179, 201, 202
“ “ —Use of.....	III, 318-320
“ Maintenance of	III, 280-284
“ Marking.....	VII, 287
“ Metal.....	I, 218; III, 202-204, 348, 365-369
“ “ —Advantages of.....	III, 366
“ “ —Construction of.....	III, 367, 368
“ “ —Corrosion of	III, 368
“ “ —Cost of.....	III, 369
“ “ —Durability of.....	III, 378
“ “ —Fastenings for.....	III, 368
“ “ —Requirements of.....	III, 381, 382
“ “ —Use of.....	III, 177, 365-369
“ “ “ “ in Austria	III, 378, 379
“ “ “ “ “ Belgium.....	III, 377
“ “ “ “ “ England.....	III, 376
“ “ “ “ “ France.....	III, 376
“ “ “ “ “ Germany.....	III, 377, 378

	PAGE
Ties, Metal—Use of in Holland	III, 377
“ “ “ “ Hungary	III, 378, 379
“ “ “ “ Italy	III, 379
“ “ “ “ Portugal	III, 379
“ “ “ “ Spain	III, 379
“ “ “ “ Switzerland	III, 379
“ Number of—Per Mile of Track	III, 350
“ Oak	III, 350
“ Old—Charges Collected for	VII, 422; IX, 426
“ Payment for.....	VII, 287
“ Piling.....	III, 371
“ Pine.....	III, 350
“ Purchase of.....	VII, 52, 84, 286, 288, 289
“ Rails Riveted to.....	I, 219
“ Receiving.....	VII, 286-289
“ Redwood.....	III, 350
“ Relative Deterioration of.....	III, 282
“ Renewing.....	III, 239, 240
“ Requisitions for.....	VII, 83
“ Return of Inspection of.....	VII, 287
“ Seasoning.....	III, 371, 372
“ Shipping.....	VII, 191
“ Soft Wood.....	III, 333
“ “ —Cost of.....	III, 401
“ Specifications for	III, 212, 213
“ Steel—Use of, in Tropical Countries.....	III, 365, 366
“ Storage of.....	VII, 190
“ Tamarack.....	III, 350
“ Treatment of—in France	III, 355, 356
“ White Oak.....	III, 281
“ Wooden.....	III, 180, 202
“ “ —Increasing Cost of.....	III, 138
“ Worn-Out.....	III, 400, 401
Tiglath Pileser.....	XI, 103
Timber.....	II, 269
“ Brace, Floor— <i>Illustration, Plate II</i>	I, 116-117
“ Causes of Decay of.....	III, 356
“ Cross-Tie— <i>Illustration, Plate II</i>	I, 116-117
“ Draft	I, 209
“ Drawbar— <i>Illustration, Plate II</i>	I, 116-117
“ Inspectors of.....	III, 259; VII, 94
“ Requisitions for.....	VII, 83
“ Sill.....	I, 209
“ Storing.....	VII, 294
“ Transportation of—in England.....	I, 172
“ Truck.....	I, 332
“ “ —Tracks for Handling on Push Cars	I, 275
Time Book, Engineers' and Firemen's.....	VII, 366, 376-379
“ “ General.....	VII, 372, 373
“ Books.....	VII, 357, 364, 365, 368-372

	PAGE
Time Books, Certification of.....	VII, 371
“ Cards	V, 115
“ Chart	IV, 71-75
“ Checks	VII, 361-363
“ Clerks.....	X, 67
“ Distribution of	VII, 359
“ Keeping—of Men.....	I, 265-267; II, 291
“ Locks, Use of	X, 271
“ Lost—Meaning of Term.....	IV, 318
“ Making—Meaning of Term	IV, 319
“ “ Up—by Trains.....	IV, 82, 376
“ —Meaning of Term.....	IV, 322
“ Standard—Rules Governing.....	IV, 335-338
“ Table.....	IV, 71-75
“ “ Chart—Form of.....	IV, 505
“ “ Form of.....	IV, 506
“ “ —Meaning of Term.....	IV, 323
“ “ —Rules Governing.....	IV, 338-340
“ Tables—English.....	IV, 78, 79
“ Taking—of Employes	VII, 360-363
“ Ticket Pay Sheets.....	IX, 387
“ Tickets.....	IX, 380-390
“ “ Agreement on.....	VII, 399; IX, 383, 384
“ “ Alterations on.....	IX, 386
“ “ Cancellation of.....	VII, 413; IX, 397, 398
“ “ Indorsements on.....	VII, 407, 444-446
“ “ Indorsing.....	IX, 346, 393, 394, 396
“ “ Issuing	VII, 398-405
“ “ Lost.....	VII, 400; IX, 396
“ “ Numbering.....	IX, 385
“ “ Payment by	VII, 397, 398
“ “ “ of	VII, 406-410; IX, 390-397
“ “ “ —by Agents	IX, 180
“ “ Remitting.....	IX, 425
“ “ Requests for	VII, 405, 406; IX, 390
“ “ Requisitions for	VII, 400
“ “ Signing	IX, 385
“ “ Traffic in.....	IX, 392
“ Value of—in Suburban Traffic.....	I, 176
Timekeeper	I, 266
Timekeeping	VII, 350-379
“ “ “Check” System of.....	I, 265, 266; VII, 361-363
“ “ “Clock” System of	I, 266
“ “ —Practices of English Railways.....	VII, 531, 532
Timepieces, Use of—by Railways.....	VII, 209
Tin.....	III, 8
“ and Copper Shop— <i>Illustration</i>	I, 261
“ Shop, Locomotive Department— <i>Illustrations</i>	I, 249
“ Use of—by Railways.....	VII, 209
“ Nozzle— <i>Illustration, Plate I</i>	I, 58-59

	PAGE
Tips, Burner— <i>Illustration, Plate II</i>	I, 116-117
Effect of.....	V, 391-395
Tire, Driving Wheel— <i>Illustrations, Plate I</i>	I, 58-59, 67
" Engine Truck— <i>Illustration, Plate I</i>	I, 58-59
Tires, Inspection of.....	I, 278
Tiryns.....	XI, 89
Titles.....	II, vii
" Definition of.....	II, 141, 142; VII, 249-251
" Railway.....	IX, 307
" Significance of.....	VII, 249-251
" Use of.....	II, 307
" Used in America.....	II, 307
" " England.....	II, 307
Toggle Joint.....	I, 297
Toilet Rooms.....	I, 184, 185
Tolls.....	II, 43; VI, 5
" Rates Compared to.....	VIII, 60
"Tom Thumb" Locomotive, 1829, Built by Peter Cooper— The First Engine to Draw a Car on the American Continent— <i>Illustration</i>	I, 27
Tonnage Rating, Experiments with.....	I, 165
Tool Cars.....	I, 379
Tools.....	I, 136, 243, 259, 260, 265, 275
" Accounting for.....	VII, 149, 150
" Acquisition of.....	VII, 145-161
" Care of.....	VII, 259, 261, 297, 298
" Construction.....	VII, 107
" Custody of.....	VII, 145-161
" Disbursement of.....	VII, 150, 155, 156, 298
" Discussion of Questions Regarding.....	I, 289, 290
" English Rules Governing.....	VII, 148, 158-161
" Guarding.....	VII, 150
" Inventorying.....	VII, 152, 346, 347
" Loss of.....	VII, 145-147
" Marking.....	VII, 151
" of Trackmen.....	III, 285
" Old—Return of.....	VII, 262
" Ordering.....	VII, 83, 298
" Orders for.....	VII, 152, 311
" Preservation of.....	VII, 145-161
" Purchase of.....	I, 125
" Records of.....	VII, 150, 151
" Renewals for.....	III, 399
" Repairing.....	VII, 157
" Return of Old.....	VII, 152
" Shipping.....	VII, 157, 158
" Storage of.....	I, 268; VII, 150
" Track.....	III, 257, 258; VII, 109
" Use of.....	VII, 145-161
" Used on Locomotives.....	VII, 153

	PAGE
Tools Used on Trains.....	VII, 155
" Value of—in Hands of Employes.....	VII, 187
Top Door Rail— <i>Illustration, Plate II</i>	I, 116-117
" Face Plate Guide— <i>Illustration, Plate II</i>	I, 116-117
" of Heater— <i>Illustration, Plate II</i>	I, 116-117
" Plate Body Bolster— <i>Illustration, Plate III</i>	I, 170-171
" Rail, Side Door— <i>Illustration, Plate III</i>	I, 170-171
Torch, Use of—for Light.....	IV, 168
Torches, Filling.....	VII, 295
T, or Nigger Head— <i>Illustration, Plate I</i>	I, 58-59
Torpedoes, Use of.....	IV, 272, 273, 341-343, 352, 360, 404
Torque.....	I, 412, 446-448, 473-476
Tourist Tickets.....	V, 92, 107
" —English.....	V, 239
Towel Holder— <i>Illustration, Plate II</i>	I, 116-117
" Bracket— <i>Illustration, Plate II</i>	I, 116-117
Tower Lift.....	I, 256
Town Bonds.....	III, 16
Townships, Vouchers in Favor of.....	VII, 435
Track.....	I, 223
" Accounts.....	III, 206, 284; VII, 111
" Action of Frost on.....	VII, 220
" Alignment of.....	III, 334
" Appliances.....	II, 212
" " Evolution of.....	III, 174, 199, 200
" Articles Found on.....	III, 270
" Ballasting.....	II, 221
" Bolt— <i>Illustration</i>	III, 323
" Camden & Amboy Railroad, A. D. 1837— <i>Illustration</i>	III, 216
" " " " Railroad—Rails Laid on Piling, Through Marshes, A. D. 1837 — <i>Illustration</i>	III, 219
" Care of.....	III, 206-271
" Center Bound.....	III, 217
" Chicago & North-Western Railway—Gravel Ballast— — <i>Illustration</i>	III, 353
" Clearing—of Snow.....	III, 285, 289
" Construction of.....	III, 206-238
" " —Principles Governing.....	III, 195, 196
" Curved—Counteraction of Centrifugal Force on.....	III, 187, 188
" Curvature of—Its Effect on Cost of Operation... ..	III, 393
" Defects in—Reporting.....	IV, 381
" Depressed.....	I, 246
" Details.....	III, 301-347
" Development of the.....	III, 190
" Double—Movement of Trains on.....	IV, 80, 81
" Drill— <i>Illustration</i>	III, 330
" (Dust) Sprinkler, A. D. 1851— <i>Illustration</i>	III, 240

	PAGE
Track, Effect of—on Cost of Maintenance	III, 399, 400
“ “ “ Movement of Trains	IV, 364
“ “ “ Speed on	X, 167
“ Elasticity of	III, 179
“ “ —How Increased	III, 369
“ Employes, Rules Governing	III, 260-271
“ Expenses, Chargeable to Traffic	III, 285-292
“ “ Classification of	III, 287, 288
“ “ Items of—Their Relation to Total Track Expenses	III, 491
“ Fastenings	III, 328-334, 341
“ Fixtures, Shipping	VII, 191
“ Force, Rules and Regulations Governing	II, 14
“ Foremen	III, 310, 311
“ “ Returns of	VII, 324, 325
“ “ Use of Signals by	IV, 342
“ Gauge	IV, 211
“ “ — <i>Illustration</i>	III, 331
“ Illumination of—at Night	I, 112
“ Improvements in	III, 323, 324
“ Improving—Points to Be Considered	III, 186, 187
“ Inspection Car— <i>Illustration</i>	I, 148
“ “ of	III, 248, 249
“ Invention of	III, 175
“ Inventory	VII, 344-346
“ —Its Construction and Evolution	III, 174-205
“ Jack— <i>Illustration</i>	III, 332
“ Joints	III, 334-347
“ Labor, Cost of—Comparison of	VII, 375
“ “ Items of—Their Relation to Each Other	III, 491
“ Laying	III, 207, 209-211
“ “ Gangs	III, 209
“ Level— <i>Illustration</i>	III, 329
“ Lining	III, 217, 218
“ Main—Meaning of Term	IV, 319
“ Maintenance of	III, 206, 238-300
“ “ —in England	III, 307-309
“ “ “ France	III, 309, 310
“ “ “ Supplies Required for	VII, 106
“ Material, Care of	VII, 106-113
“ “ Charging	VII, 324-326
“ “ Inspection of	VII, 110, 111
“ “ Inspectors of	VII, 94
“ “ Keeping Down Supply of	VII, 78
“ “ —Preparing for Sunday Work	III, 241
“ “ Shipping	VII, 191
“ “ Use of	VII, 106-113
“ Metal—A. D. 1889— <i>Illustrations</i>	III, 314-319
“ “ —Advantages of	III, 380
“ “ —Midland Railway, A. D. 1889— <i>Illustration</i>	III, 312

	PAGE
Track, Metal—Queensland, A. D. 1889— <i>Illustration</i>	III, 313
“ Moorings of.....	III, 328
“ Moving—During the Week.....	III, 246, 247
“ “ —on Sunday.....	III, 245, 246
“ Narrow Gauge.....	I, 375
“ Number of Ties Per Mile of.....	III, 350
“ Obstructions to—by Accidents.....	IV, 377, 378
“ “ —Reporting.....	IV, 361
“ of American Railways.....	III, 185
“ Officials.....	II, 277
“ Old—Moving.....	III, 244
“ Pennsylvania Railroad— <i>Illustrations</i>	III, 356-358, 361
“ Preparing—for Sunday Work....	III, 244, 245
“ Prevention of Access to.....	IV, 121
“ Protecting—When Under Repair.....	IV, 381
“ Protection of—from Snow.....	III, 302-305
“ Quadruple—Movement of Trains on.....	IV, 80
“ Quantity of Material Required to Lay One Mile of...	III, 495
“ Railway—Advent of.....	I, 294
“ “ —Electric.....	I, 462, 463
“ “ —First Use of.....	III, 126
“ Raising.....	III, 216
“ Relation of—to Traffic.....	III, 184-187
“ Renewing.....	III, 239, 240
“ Repair of—Supplies Required for.....	VII, 106
“ Right of.....	IV, 353
“ Saw— <i>Illustration</i>	III, 333
“ Section of—New South Wales— <i>Illustration</i>	III, 354
“ Side Door— <i>Illustration, Plate III</i>	I, 170-171
“ “ —Meaning of Term.....	IV, 320, 321
“ Signals.....	IV, 495-504
“ “ — <i>Illustrations</i>	IV, 500-504
“ Single—Movement of Trains on.....	IV, 80
“ Spike— <i>Illustration</i>	III, 320
“ Spur—Meaning of Term.....	IV, 321
“ Stability of.....	I, 233
“ Standard—of Different Railways.....	III, 178
“ Status of—in 1846-47.....	I, 36
“ Straight—Necessity of.....	I, 30
“ Supervision of.....	II, 136, 211, 212
“ Supervisor of.....	II, 138
“ Supplies, Accounting for.....	VII, 269
“ “ Ordering.....	VII, 106, 107
“ Tamping.....	III, 216, 217
“ Tank.....	I, 106
“ Third—Meaning of Term.....	IV, 322
“ “ —Rules Governing.....	IV, 375, 376
“ Time (and Distribution) Book.....	VII, 373-375
“ Tools.....	III, 257, 258

	PAGE
Track, Treble—Movement of Trains on.....	IV, 80
“ Variations of.....	II, 27
“ Watchmen.....	III, 248, 285
“ “ Cost of.....	III, 289
“ Wire System.....	IV, 178
“ Y.....	IV, 324
Tracks, Arrangement of—at Supply Depots.....	VII, 190
“ Erecting.....	I, 255, 265
“ in Boiler Shop.....	I, 255
“ “ Erecting Shop.....	I, 261, 262
“ “ Machine and Erecting Shop.....	I, 254
“ Joint Use of—by Two or More Companies.....	II, 46
“ Repair.....	I, 268, 269, 275
“ Requisitions for Material for.....	VII, 78
“ Side—Charges for Use of.....	III, 407
“ Switching.....	I, 250
“Tracklaying and Surfacing”.....	VII, 466
Trackmen, Disposition of Articles Used by.....	VII, 298
“ Money Collected by—Account Various Persons... ..	VII, 421, 422
“ Tools of.....	III, 285
Trackwalkers.....	III, 248
Traction, Electric and Steam—Comparison of Advantages of	I, 515, 516
“ “ —for General Railway Purposes.....	I, 507-514
“ “ —History of.....	I, 519-522
“ “ —Possibilities and Limitations of.....	I, 395
“ Purposes, Motor Used for.....	I, 474
Tractive Power, Locomotive—How Secured.....	I, 64
Trade, Competition of.....	I, 127
“ Ethics of.....	VIII, 19
“ Interference with—Result of.....	VIII, 20
“ Relation of Railroads to.....	VIII, 7, 213
“ Value of Education to.....	I, 129
Tradesmen.....	I, 264
Traffic Accounts.....	IX, 341
“ “ Auditing.....	II, 248, 249
“ “ Posting.....	X, 68
“ Adaptation of Equipment to.....	III, 168, 169
“ Baggage.....	V, 51-65
“ “ —Classification of.....	V, 462
“ “ —Comparison of, with Freight Traffic.....	V, 480, 481
“ “ —Handling.....	V, 79
“ Balances.....	IX, 367
“ “ Drafts for.....	X, 267
“ by Water—How Carried on.....	II, 41, 42
“ Carriage of—by Owners of Railways.....	II, 48
“ Cheap.....	VIII, 55
“ Classes of.....	V, 354

	PAGE
Traffic, Classification of.....	II, 240; VIII, 307
“ “Coaching”—in England.....	V, 237
“ “Committee.....	II, 131
“ “Competitive.....	VIII, 146
“ “Conditions Attending.....	III, 145
“ “Cost of Conducting.....	III, 383
“ “Department.....	II, 137-139, 237, 239
“ “ “Duty of.....	V, 70
“ “Devices for Handling.....	VIII, 309
“ “Division of.....	VIII, 307
“ “Effect of—on Bridges.....	III, 292-295
“ “ “Ralls.....	III, 278
“ “ “Ties.....	III, 282
“ “Encouragement of First and Second Class.....	I, 169
“ “Equities of.....	VIII, 209
“ “Excess Baggage.....	V, 454-461
“ “ “—Form of Release for.....	V, 443
“ “ “—Interline.....	V, 465
“ “ “—Local.....	V, 465, 466
“ “ “—Organization of.....	V, 469
“ “Excursion.....	V, 108, 110
“ “Expenses of.....	VIII, 103
“ “Express.....	V, 468, 517-536; VI, 9
“ “ “—Expenses Attending.....	V, 526-528
“ “Fluctuations of.....	I, 268
“ “Foreign Parcel—English.....	V, 267
“ “Freight.....	VIII, 311
“ “ “—Kinds of.....	VI, 7
“ “ “—Meaning of the Term.....	VI, 7
“ “ “—Necessities of, in 1831.....	I, 31
“ “ “—of Different Countries.....	VI, 8-11
“ “ “—Returns of.....	X, 67
“ “Handling—Cost of.....	III, 409, 410
“ “ “—Principles Governing.....	IX, 35
“ “ “—Rules Governing.....	II, 239
“ “ “—Separation of, from Maintenance.....	II, 32
“ “High Class.....	VIII, 55
“ “How to Be Considered.....	VIII, 80
“ “Indivisibility of.....	VIII, 308
“ “Influence of—on Cost of Maintenance.....	III, 383
“ “ “ “ “Operation.....	III, 405
“ “ “ “ “Expenses.....	III, 419-421
“ “ “ “Rates on.....	V, 29
“ “Interline.....	II, 237
“ “ “—Auditing.....	II, 258
“ “ “—Proportions for Handling.....	II, 251
“ “Interstate.....	III, 46; VIII, 307
“ “Items Chargeable to.....	III, 299, 300
“ “Local.....	II, 237; III, 410; VIII, 307
“ “Manager.....	II, 63; V, 15; VI, 11, 18

	PAGE
Traffic Manager, Duties of.....	II, 237-241
“ “ General.....	II, 138
“ “ —Meaning of Title.....	II, 142
“ “ Title of.....	VII, 250
“ Maximum.....	VIII, 170
“ Milk.....	V, 519, 520
“ Miscellaneous—English.....	V, 247
“ Needs of—Knowledge of.....	V, 16
“ Papers, Preservation of.....	VII, 142
“ Parcel.....	V, 454-461, 463, 517-536; VI, 9
“ “ —English.....	V, 246
“ “ —Expenses Attending.....	V, 526-528
“ “ —What It Embraces.....	V, 517
“ Passenger.....	III, 113; V, 13-50; VIII, 312
“ “ —Classes of.....	V, 13
“ “ —Classification of—English.....	V, 244
“ “ —Development of.....	V, 29, 30
“ “ —English.....	V, 237-245
“ “ —Handling.....	V, 79
“ “ —Its Relation to Railways.....	V, 68
“ “ —Local.....	V, 13
“ “ —Meetings of Officials in Charge of, I, 287,	288
“ “ —Rates for.....	II, 250
“ “ —Returns of.....	X, 67
“ “ —Suburban.....	V, 13
“ “ —Through.....	V, 13
“ Profitable.....	IV, 57
“ Railway—Cessation of.....	II, 51, 52
“ Relation of Construction to.....	III, 169
“ “ —to Expenditures.....	III, 413-426
“ “ “ Population.....	V, 24
“ Returns.....	IX, 45
“ “ Daily System of.....	X, 53, 54
“ “ Monthly System of.....	X, 52
“ “ Time and Manner of Making.....	IX, 44
“ Securing.....	VI, 108
“ “ —by Agents.....	V, 115
“ Separation of Local from Through.....	VIII, 307
“ “ “ State from Interstate.....	VIII, 307
“ Suburban.....	V, 40-43
“ “ —Dangers of.....	V, 41
“ “ —Suitable Car for.....	I, 177, 178
“ State.....	VIII, 307
“ Third Class—Discouragement of, by Railway Owners.....	I, 169
“ Through.....	III, 410; VIII, 307
“ “ —Settlements for.....	III, 407
“ Track—Expenses Chargeable to.....	III, 285-292
“ —Upon What Dependent.....	II, 27
“ Variations of.....	II, 27

	PAGE
Traffic, Various Classes of Railroad.....	I, 168, 169
“ —What It Will Bear.....	VIII, 68
T Rail, Boston & Worcester Railroad, A. D. 1850— <i>Illustration</i>	III, 238
“ “ Long Island Railroad, A. D. 1855— <i>Illustration</i>	III, 247
“ “ Origin of.....	III, 178
“ Rails for Electric Railways.....	I, 462
Train Accidents. (See also “Accidents”).....	I, 333; IV, 81
“ Agents.....	V, 17
“ Air Signal.....	I, 317, 322, 330
“ “ Operations of.....	I, 362
“ “ Operating the—Instructions to Trainmen, I, 376	
“ “ Signaling Apparatus— <i>Illustrations</i>	I, 385, 386
“ and Station Service—the Railway School.....	IV, 16
“ Applying Brakes from the.....	I, 326
“ Austrian Imperial—Engine Tender of— <i>Illustration</i>	I, 118
“ Average Number of Cars per.....	I, 165
“ Baggage-men.....	V, 404-406
“ “Bleeding” a—Instructions to Switchmen and Yardmen.....	I, 376, 377
“ Brake Pipe— <i>Illustration, Plate II</i>	I, 116-117
“ Brakes.....	I, 380
“ Breaking into Two or More Parts—Instructions to Trainmen.....	I, 324
“ Construction.....	III, 209
“ Dispatcher.....	II, 199
“ “ Duties of.....	IV, 88-92
“ “ —Meaning of Term.....	IV, 322
“ Dispatching.....	IV, 87, 88
“ Expenses.....	III, 414, 415
“ Force.....	II, 200; III, 470
“ “ Characteristics of.....	IV, 12, 18
“ “ English.....	IV, 442
“ “ Hours of Work of.....	IV, 19
“ “ Qualifications of.....	IV, 13, 14
“ “ Selection of.....	IV, 27, 28
“ “ The.....	IV, 33-56
“ Leaving at Terminals—Instructions to Trainmen... I, 375	
“ Line.....	I, 334, 336
“ “ Air Pressure—Standard.....	I, 312
“ “ Couplings.....	I, 375
“ “ Disabled.....	I, 374
“ Mile.....	II, 27
“ Orders.....	IV, 358, 359
“ “ Details of.....	IV, 84-86
“ “ Forms of.....	IV, 465-478
“ “ Miscellaneous.....	IV, 376-383
“ “ Precedence of.....	IV, 396
“ “ Repeating.....	IV, 397
“ “ Telegraphic.....	IV, 393-400

	PAGE
Train, Origin of the	III, 176
“ Part Air—Releasing When Moving	I, 367
“ Parted—Instructions to Engineers	I, 368
“ Phraseology	IV, 314-324
“ Pipe	I, 307-310, 315, 320, 329, 330, 379
“ “ —Illustrations, { Plate I.....	I, 58-59
“ “ { Plate III.....	I, 170-171
“ “	I, 539-541
“ “ Angle Cock—Illustration, Plate III.....	I, 170-171
“ “ Branch Pipe to—Illustration, Plate II.....	I, 116-117
“ “ Cocks in	I, 321, 323, 324, 326
“ “ Connection—Illustration, Plate I.....	I, 58-59
“ “ Coupling—Illustration, Plate III.....	I, 170-171
“ “ Hose—Illustration, Plate III.....	I, 170-171
“ “ Hose—Illustration, Plate I.....	I, 58-59
“ “ Pressure in	I, 307, 308
“ Returns.....	IV, 62-67
“ Reuniting a Broken	I, 324
“ Rules, Early—in Great Britain	I, 172
“ “ English.....	IV, 331-334, 340, 343-345, 348-350, 357, 360-364, 366, 367, 374, 377-382, 402, 408, 405-419, 421, 424, 425, 431-435, 441, 461
“ “ Growth of.....	IV, 302-313
“ “ —Object of.....	IV, 328
“ “ —Standard.....	IV, 509
“ “ —Value of.....	IV, 302-313
“ Safety of.....	I, 179
“ Separation of.....	I, 295
“Train Service”.....	VII, 487, 520
Train Service.....	I, 233; IV
“ “ Attractiveness of.....	IV, 14, 15
“ “ Changes in.....	V, 20
“ “ Conditions Governing.....	IV, 8
“ “ Dangers of.....	IV, 15
“ “ Effective.....	IV, 62-67
“ “ in Great Britain.....	IV, 440-464
“ “ Injuries Growing Out of.....	II, 234
“ “ Methods of Improving.....	IV, 23, 24
“ “ Morale of.....	IV, 12-32
“ “ of American Railways.....	IV, 10
“ “ Particulars of.....	IV, 97-105
“ “ Practices Characterizing.....	IV, 20-23
“ “ Requirements of.....	IV, 18
“ “ The Author’s Books on.....	IV, 9, 10
“ Signal Pipe—Illustration, Plate II.....	I, 116-117
“ Stop Cock—Illustration, Plate II.....	I, 116-117
“ Signals.....	IV, 246
“ “ Rules Governing.....	IV, 344-346
“ Sliding, The.....	I, 312
“ Staff—Meaning of Term.....	IV, 315
“ Starting a.....	I, 113

	PAGE
Train, Statistics.....	IV, 62-67
" Stopping—in Emergency.....	I, 326
"Train Supplies and Expenses".....	VII, 487-520
Train Supplies, Care of.....	VII, 184-188
" Disbursement of.....	VII, 308, 309
" Storage of.....	VII, 184-188
" Two or More Engines Coupled to a.....	I, 372, 373
" Uncoupling Engine from.....	I, 375
" —Use of the Word.....	IV, 352, 447
" Vestibule.....	I, 182, 197, 198
Trains, Abandoned.....	IV, 392
" Announcement of.....	V, 114
" Atmospheric Resistance to—How Diminished.....	I, 198
" Authority of Conductors Over.....	IV, 402, 403
" Average Speed of.....	X, 165
" Baggage of.....	V, 409-412
" Ballast.....	IV, 374
" Carriage of Signals by.....	IV, 369, 370
" Cash Collections on.....	IX, 112, 113
" Changing Time of.....	V, 20
" Checking Speed of.....	I, 317, 318
" Circus—Waybillings.....	VI, 133
" Classes of.....	IV, 317
" Classification of.....	IV, 352, 353
" Collision of.....	IV, 123, 124
" Company's Property Carried by.....	IV, 406
" Consolidation of.....	IV, 368
" Construction—Meaning of Term.....	IV, 317
" —Rules Governing.....	IV, 372-375
" Control of—by Brakes.....	I, 294
" Cost of Movement of.....	III, 414
" Delayed.....	IV, 358, 368, 376, 403, 404, 415
" Detention of—Reporting.....	IV, 381
" Differences in Weight of.....	X, 165
" Disabled.....	IV, 358
" Dispatching—by Telegraph—Forms Used.....	IV, 465-478
" Disposition of Articles Used on.....	VII, 298
" Early Devices for Moving.....	III, 120, 121
" Extra.....	IV, 352, 353
" —Meaning of Term.....	IV, 317
" Freight—Charges for Baggage Carried on.....	V, 511
" —Charging.....	I, 371
" —Collection of Fares on.....	V, 151-156
" —in Great Britain.....	I, 63
" —Operation of.....	IX, 100
" —Passenger Fares Collected on.....	VI, 317
" —Passengers on.....	V, 150-156
" —Releasing Brakes on.....	I, 367
" —Speed of.....	I, 31; VI, 10, 11
" —Testing Brakes on.....	I, 363

	PAGE
Trains, Goods—in Great Britain.....	I, 63
“ “ —Meaning of Term.....	IV, 447
“ Grade of—Meaning of Term.....	IV, 318
“ Grades of.....	IV, 76
“ Handling—Instructions to Engineers.....	I, 366, 367
“ Heavy—Use of Vacuum Brake on.....	I, 300
“ Held Between Stations.....	IV, 371
“ How Signals Are Displayed on—Under the American Standard— <i>Illustrations</i>	IV, 481-494
“ Identification of—at Meeting Points.....	IV, 365
“ in Europe—How Made Up.....	I, 202, 203
“ Inspection of—by Conductors.....	IV, 409-411
“ Jar of—Effect on Bridges and Culverts.....	III, 293
“ Limited—Meaning of Term.....	IV, 322
“ Local—Quality of Baggage Carried on.....	V, 411, 412
“ Making Up.....	I, 324; IV, 432, 434
“ “ “ —Instructions to Car Inspectors.....	I, 330, 331
“ “ “ “ “ Enginemen.....	I, 317
“ “ “ “ “ Trainmen.....	I, 321-323
“ Mail—Speed of.....	IV, 376
“ Manipulation of.....	II, 200
“ Marshalling.....	IV, 94-96
“ Methods of Heating—in Europe.....	V, 232-236
“ “ That Govern.....	IV, 312
“ Movement of.....	IV, 353-371
“ “ “ —by Telegraph.....	IV, 78, 83-92, 291, 292, 383-400
“ “ “ “ —Meaning of Term.....	IV, 319
“ “ “ —How Expedited.....	IV, 80-96
“ “ “ —Importance of Signals in.....	IV, 256
“ “ “ —Rules Governing.....	IV, 325-339
“ Nomenclature of.....	IV, 314
“ Numbers of.....	III, 414; IV, 76
“ Officer Having Control of.....	V, 15, 16
“ Operations of—Vicissitudes Attending.....	IV, 18
“ Orders for Supplies Used on.....	VII, 65
“ “ “ Tools Used Upon.....	VII, 155
“ Parting.....	IV, 356, 357
“ Passenger.....	I, 66
“ “ —Carriage of Property on.....	V, 297, 298
“ “ —Express and Freight Cars in.....	IV, 379
“ “ —Instructions to Engineers.....	I, 368, 369
“ “ —Rates for.....	II, 250
“ Protection of.....	IV, 355, 356, 359-365
“ “ “ —by Signals, in Great Britain.....	I, 171
“ “ “ —from Collisions.....	IV, 293-301
“ “ “ Fire.....	IV, 363
“ “ “ —The Staff System.....	IV, 92-94
“ Punctuality of—in Starting.....	IV, 81, 82

	PAGE
Trains, Pushing	IV, 379
“ Record of Movements of.....	IV, 395
“ Regular	IV, 76, 352
—Meaning of Term.....	IV, 319
“ Regularity of Movements of.....	IV, 82
“ Regulation of.....	IV, 71-79
“ Relative Importance of.....	IV, 77
“ Rights of.....	IV, 77, 78
“ Rough Handling of.....	I, 379
“ Running.....	IV, 378
“ Rules and Regulations Governing.....	II, 14
“ Safety Implements Carried on.....	IV, 120
“ of.....	IV, 405
“ Signal Appliances on.....	IV, 403, 404
“ Special.....	IV, 78
“ —Meaning of Term.....	IV, 321
“ Speed of.....	I, 249, 295; III, 135; IV, 103
“ “ —Effect on Rails.....	III, 276
“ “ —in England.....	I, 170
“ “ “ Spain.....	I, 174
“ “ —Its Relation to Earnings.....	IV, 104
“ “ —Tendency to Increase.....	I, 310
“ “ Suburban—Requirements of.....	I, 67
“ Staple.....	IV, 73, 74
“ Starting.....	IV, 379, 409, 423
“ Stopping.....	IV, 378, 409, 422
“ Suburban.....	V, 41, 42
“ —Baggage of.....	V, 409
“ Switching.....	IV, 94-96
“ Table of.....	IV, 71-75
“ Time Interval Between.....	IV, 353, 354
“ Through—Meaning of Term.....	IV, 322
“ Value of Information in Regard to.....	IV, 11
“ Vestibuled.....	I, 203, 204
“ Wants of.....	V, 419
“ Way—Meaning of Term.....	IV, 323
“ Weight of.....	I, 295
“ “ —Effect on Bridges and Culverts.....	III, 293
“ “ “ “ Movement.....	IV, 364
“ Wild.....	IV, 78
“ —Meaning of Term.....	IV, 324
“ Wiring—for Electricity.....	IV, 177
“ Work.....	IV, 359
Trainboy, The. (See also “Newsboy”).....	V, 418-423
Training, Early.....	II, 81
Trainmaster.....	II, 138
Trainmen, Apportionment of Wages of.....	VII, 510
“ Authority Over.....	IV, 380
“ Changes Among.....	IV, 257
“ Construction.....	III, 209

	PAGE
Trainmen, Duties of.....	IV, 14, 400, 401; IX, 120
“ “ —in America	IV, 17
“ Examinations of.....	IV, 304, 305, 329
“ Freight—Duties of.....	IV, 409-415
“ General Instructions to.....	I, 321-328
“ Instructions to	I, 369-376
“ Keeping Time of	VII, 367
“ Phrases Used by	IV, 314
“ Requirements of.....	IV, 14
“ Responsibilities of.....	IV, 16
“ Use of Uniforms by.....	IV, 20, 409
“ Watchfulness of.....	IV, 307, 308
Tram Rail, Surrey Railway, A. D. 1803— <i>Illustration</i>	III, 183
“ “ with Stone Supports, Upon Which Trevithick’s First Locomotive Ran— <i>Illustration</i>	III, 186
“ Roads	III, 111
Tramway, Electric—Lugano, Switzerland.....	I, 505, 506
Tramways	III, 178
Transfer Cable.....	I, 254
“ Lines.....	V, 205
“ of Raw Material	I, 275, 276
“ “ Stock, Form of.....	III, 90
“ Statement of	IX, 257
“ Table	I, 264, 272
Transferring Cars.....	VI, 222, 223
Transformer.....	I, 422
“ Alternating Current	I, 423, 424
“ “ —Windings of	I, 422, 423
“ Raising (375 Kilowatt)— <i>Illustration</i>	I, 422
“ Rotary (400 Kilowatt)— <i>Illustration</i>	I, 424
“ “ at Buffalo— <i>Illustration</i>	I, 502
“ “ (500-Horsepower)—Niagara Power House— <i>Illustration</i>	I, 501
Transformers.....	I, 487, 488
“ Lowering.....	I, 427, 451, 452
“ Raising.....	I, 451, 452
“ Rotary.....	I, 427, 440, 451, 452
Transmission.....	I, 412-427
“ Alternating Current—High Tension.....	I, 451
“ Circuits.....	I, 396, 449
“ Cost of.....	I, 430
“ Line.....	I, 439
“ Mechanical.....	I, 425
“ of Power.....	I, 387, 388
“ Superiority of the Alternating Current Sys- tem for.....	I, 441
“ Variations in.....	I, 431
Transom Bars, Truck Bolster— <i>Illustration, Plate III</i>	I, 170-171
“ Center Bearing Pillar, Body— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Transom Center Brake— <i>Illustration, Plate II</i>	I, 116-117
“ Chafing Plate— <i>Illustration, Plate II</i>	I, 116-117
“ Corner Plate— <i>Illustration, Plate II</i>	I, 116-117
“ Middle— <i>Illustration, Plate II</i>	I, 116-117
“ Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Pillar, Body—Intermediate— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ —Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Plate, Middle— <i>Illustration, Plate II</i>	I, 116-117
“ “ Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Post— <i>Illustration, Plate III</i>	I, 170-171
“ Truss Rod— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Seat— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ Washer— <i>Illustration, Plate II</i>	I, 116-117
Transoms, Cross.....	I, 213
Transportation. (See also “Carriage.”)	
“ —A Commodity.....	VIII, 71
“ —A Matter of Emulation.....	VI, 73
“ Beginning and Growth of.....	XI, iii, iv
“ Companies, Revenue of.....	I, 159
“ Cost of.....	VIII, 31, 95, 103, 104
“ Conducting.....	VII, 485-495, 518-528
“ Continuation of Primitive Methods of... ..	XI, 149
“ Cost of—Upon What Dependent.....	I, 392
“ Evolution of.....	I, 159; III, 109
“ Forms Among the Phœnicians.....	XI, 117
“ Fundamental Problem in.....	I, 392
“ Government Requests for.....	V, 144-146
“ Inventors of.....	XI, 155
“ Methods of.....	I, 201
“Transportation of Men”.....	VII, 467
“Transportation of Material”.....	VII, 466
Transportation, Origin and Evolution of.....	XI
“ Principles of.....	VIII, 73
“ Necessities of—in the United States.....	I, 44
“ Railway—Details of.....	I, 201
“ Relation of Community.....	VIII, 173
“ “ “ Electricity to.....	I, 392-396
“ Superintendent of.....	VI, 57
“ Varied Character of.....	VIII, 49
“ Water—How Carried on.....	II, 41, 42
“ “ —Laws Governing.....	II, 47, 48
Trans-shipment, Charges for.....	IX, 61
Transverse Plates.....	I, 108
Trap Door Platform— <i>Illustration, Plate II</i>	I, 116-117
Traps, Avoidance of—in Piping.....	I, 390, 381
Travel, Appliances of.....	V, 33
“ Classes of.....	I, 202, 203
“ Comforts of.....	I, 147, 148
“ Modern.....	I, 148

	PAGE
Travel, Peculiarities of—in Different Countries.....	I, 202
“ Piston.....	I, 332, 388
“ “ — <i>Illustrations</i>	I, 358, 359
“ “ —Its Effect on Braking Power.....	I, 356-361
“ Luxuries of.....	I, 148; V, 31
“Traveler,” 1832—First Distinctive Freight Engine— <i>Illustration</i>	I, 38
Traveler, Overhead.....	I, 246
Travelers, Commercial—Baggage Tickets for.....	V, 471
“ Rivalry Among—in America.....	I, 202
Traveling Auditors.....	IX, 271-292
“ “ Authority of.....	VI, 316
“ “ Communications of.....	IX, 222, 223
“ “ Co-Operation of.....	IX, 240, 241, 247
“ “ Duties of, VII, 433; IX, 37, 42, 43, 54, 56, 57, 61, 62, 68, 77, 86, 90, 93, 99, 116, 120-123, 125, 127, 133, 136, 143, 144, 146, 147, 152, 153, 166, 168, 173, 186, 190, 191, 195, 197, 200-204, 211, 224, 225, 236-240, 246, 251, 253-261, 271-292, 432	
“ “ Duty of—in Regard to Old Papers..	VII, 142
“ “ Examinations of.....	IX, 284-286
“ “ General—Duties of.....	IX, 276, 277
“ “ Influence of.....	IX, 223, 224
“ “ Qualifications of.....	IX, 147, 148
“ “ Reports of.....	IX, 277-283, 287, 288
“ Cranes.....	I, 253, 255, 257, 260, 261, 264
“ Freight Agent.....	II, 139
“ Inspectors, English.....	II, 207
“ Night.....	I, 190, 191
“ Passenger Agent.....	II, 139
Tray, Drip— <i>Illustration, Plate II</i>	I, 116-117
Tread Board— <i>Illustration, Plate II</i>	I, 116-117
“ Wheel.....	I, 304, 305
“ “ — <i>Illustration, Plate III</i>	I, 170-171
Treasurer.....	II, 63, 131, 138, 287
“ Conservatism of.....	II, 194
“ Drafts Drawn on.....	X, 272-275
“ Duties of.....	II, 186-197; X, 257-290
“ —Meaning of Title.....	II, 141
“ Power of.....	II, 192
“ Routine Work of.....	II, 189
“ Staff of.....	X, 259
“ Title of.....	VII, 249; X, 258, 259
Treasury, Auditor of the.....	II, 292
“ Department, Conduct of.....	II, 193
“ Reconveying Money into the.....	X, 283
“ Secretary of the.....	II, 292, 293
Treenalls.....	III, 197
Trees, Protection of Track by.....	III, 303

	PAGE
Trolley Wire, Nantasket Road— <i>Illustration</i>	I, 493
“ Wires.....	I, 488
“ Pressure Between.....	I, 437
Trolleys.....	I, 260, 275
Trough, of Steel Beams.....	I, 464
Troy, Siege of.....	XI, 88
Truck, American Bogle—Side View of— <i>Illustration</i>	I, 66
“ “ Locomotive—Side View of— <i>Illustration</i> , I, 68	
“ “ Standard Freight Car— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ “ “ “ —Plan of— <i>Illustration</i>	I, 180
“ “ “ “ “ —Section Showing Body and Truck Bolsters— <i>Illustration</i>	I, 179
“ Axle Collar— <i>Illustration</i>	I, 65
“ Baltimore & Ohio Railroad— <i>Illustration</i>	I, 512
“ Bogle.....	III, 145, 149
“ “ —Advantages of.....	III, 114
“ Bolster— <i>Illustrations</i> , { Plate II.....	I, 116-117
“ “ { Plate III.....	I, 170-171
“ “ Chafing Plate— <i>Illustration</i> , Plate II.....	I, 116-117
“ “ Center Plate— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Plate— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Side Bearing— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Spring Plate— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Strut— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Transom Bars— <i>Illustration</i> , Plate III.....	I, 170-171
“ Bolsters.....	I, 213
“ Brake— <i>Illustration</i> , Plate I.....	I, 58-59
“ “ Lever— <i>Illustration</i> , Plate II.....	I, 116-117
“ Center Casting— <i>Illustration</i> , Plate I.....	I, 58-59
“ “ Pin— <i>Illustration</i>	I, 65
“ “ Plate— <i>Illustration</i> , Plate II.....	I, 116-117
“ Column— <i>Illustration</i> , Plate III.....	I, 170-171
“ “ Guide— <i>Illustration</i> , Plate III.....	I, 170-171
“ Engine— <i>Illustration</i> , Plate I.....	I, 58-59
“ for Electric Locomotive— <i>Illustration</i>	I, 513
“ “ Motor Cars of Suburban Railroads— <i>Illustration</i> , I, 468	
“ Frame— <i>Illustration</i>	I, 60
“ “ End Piece of— <i>Illustration</i> , Plate II.....	I, 116-117
“ Gear, Connecting Rod to— <i>Illustration</i> , Plate II, I, 116-117	
“ Lever, Dead— <i>Illustration</i> , Plate II.....	I, 116-117
“ “ Fulcrum— <i>Illustration</i> , Plate II.....	I, 116-117
“ “ Live— <i>Illustration</i> , Plate II.....	I, 116-117
“ Levers, Dead.....	I, 329, 332
“ “ Live.....	I, 332
“ Logging—American— <i>Illustration</i>	I, 154
“ of Electric Motor Cars.....	I, 468

	PAGE
Truck, Passenger—Austrian Railway— <i>Illustration</i>	I, 229
“ Side Bearing— <i>Illustration, Plate II</i>	I, 116-117
“ Slewing of	I, 379
“ Spring Engine— <i>Illustration, Plate I</i>	I, 58-59
“ Steel Bogie— <i>Illustration</i>	I, 229
“ Swiveling or Bogie	I, 51
“ Transom of—Stress on	I, 468
“ Timber	I, 332
“ Timbers, Tracks for Handling—on Push Cars	I, 275
“ Wheels— <i>Illustration</i>	I, 60
“ with Motors and Controller, Brooklyn Bridge Motor Cars— <i>Illustration</i>	I, 467
“ “ “ Geared to Axles— <i>Illustration</i>	I, 487
Trucks	I, 429
“ Car—Axles of	I, 468
“ Cattle—Use of, for Passengers	I, 169
“ —Device for Changing from Narrow Gauge to Wide Gauge, and Vice Versa— <i>Illustration</i>	I, 203
“ Engine	I, 286
“ Handling	I, 275
“ Number of Brakes Used on	I, 313, 314
“ Removing	I, 244
Trumpet	I, 55
Trunks and Their Owners	V, 399-403
Truss Plank— <i>Illustration, Plate II</i>	I, 116-117
“ “ Cap— <i>Illustration, Plate II</i>	I, 116-117
“ “ Rod Anchor Iron— <i>Illustration, Plate II</i>	I, 116-117
“ “ Body— <i>Illustration, Plate II</i>	I, 116-117
“ “ Brake Beam— <i>Illustration, Plate III</i>	I, 170-171
“ “ Hog Chain or Overhang— <i>Illustration, Plate II</i> ..	I, 116-117
“ “ Longitudinal— <i>Illustration, Plate III</i>	I, 170-171
“ “ Seat, Transom— <i>Illustration, Plate II</i>	I, 116-117
“ “ Transom— <i>Illustration, Plate II</i>	I, 116-117
“ “ Washer, Transom— <i>Illustration, Plate II</i> ..	I, 116-117
“ “ Rods	I, 210
Trusses, Roof	I, 253, 256
Trustees, Mortgage	III, 94
“ Remuneration of	III, 425
“ Sinking Fund	III, 102; VII, 449-452
Tube Sheet— <i>Illustration, Plate I</i>	I, 58-59
“ Testing Machinery	I, 262
Tubes, Boiler	I, 71
“ “ —Machinery for Cleaning	I, 261
“ “ —Number of	I, 73
“ “ —Size of	I, 73
“ Wrought-Iron	I, 96
Tumbling Shaft— <i>Illustration, Plate I</i>	I, 58-59
“ “ Arm— <i>Illustration, Plate I</i>	I, 58-59
“ “ Lever— <i>Illustration, Plate I</i>	I, 58-59

	PAGE
Underground Systems, for Collecting Current.....	I, 466
Undertakers, Fees of.....	II, 232
" Railways Acting as.....	V, 139-144
Uniform Braking.....	I, 361
" Classification, Impracticability of.....	VI, 25-37
" " —Its Effect on Commercial Interests.....	VI, 34
" Pressure.....	I, 432, 433
" " Device for Maintaining.....	I, 309
Uniformity in Accounts.....	X, 38-44
" " Car Construction.....	VI, 50
" " Classification.....	VI, 26, 30-37
" " of Wages.....	II, 28
" " The Stickler for.....	VI, 41
" " of Work and Compensation.....	II, 35
Uniforms, Rules Governing—in England.....	IV, 454-456
" " Use of—by Trainmen.....	IV, 20
" " Wearing.....	IV, 409
" " —in Great Britain.....	IV, 444
Union Pacific Railway.....	III, 361
" " Passenger Railway—Use of Electricity on.....	I, 520, 521
Unions, Growth of—Among Railway Employees.....	II, 59
" " Labor.....	II, 52, 53
" " —Breaking of Contracts by.....	II, 38
" " —Disfavor of.....	II, 38
" " —Government of.....	II, 38, 39
" " —in Great Britain.....	II, 37
" " Railway.....	II, 95
Unit of Service.....	VIII, 70
" " Value.....	III, 8
" " Size of—in a Power Station.....	I, 454
Units, Division of Station into.....	I, 435
" " Electrical.....	I, 401, 402
United Kingdom, Baggage Allowed in.....	V, 289
" " " Storage Charges in.....	V, 425
" " " Method of Handling Baggage in.....	V, 354
" " " Responsibility for Baggage in.....	V, 306
United States.....	XI, 45
" " " Army.....	II, 120, 121
" " " Baggage Allowed in.....	V, 288, 290-292
" " " Storage Charges in.....	V, 425
" " " Caboose Car in.....	I, 199
" " " Car Manufacturers in.....	I, 196
" " " Carrying Capacity of Cars in.....	VI, 51, 52
" " " Checking Baggage in.....	V, 53-56
" " " Construction of Railway Equipment in.....	I, 141
" " " Classifications for Different Sections of... VI, 34	
" " " Economy of Operating Railways in.....	II, 25, 26
" " " Engines Used in.....	I, 164
" " " Experience of—in Regard to Money.....	III, 19

	PAGE
United States, Express Service in.....	V, 537-561
“ “ First Locomotive Put in Operation in the...I,	28
“ “ Freight Cars in	I, 121
“ “ Traffic of.....	VI, 8-11
“ “ Gauge Used in	III, 194
“ “ Government Control of Railways in.....	III, 46
“ “ of—On What Based	II, 44
“ “ Interline Excess Baggage Traffic in... V,	487, 488
“ “ —Its Primitive Associations and Means of Carriage.....	XI, 379-403
“ “ National Museum.....	III, 175
“ “ Necessities of Transportation in... ..	I, 44
“ “ Ownership of Property in.....	XI, 45
“ “ Passenger Rates in.....	V, 26
“ “ Primitive Carriage in— <i>Illustrations</i> ...XI,	379-403
“ “ Railway Construction in.....	I, 30; III, 129
“ “ “ Improvements in.....	X, 11
“ “ “ Management in.....	III, 57
“ “ “ Operations in	II, 72
“ “ “ Service in.....	I, 249
“ “ “ Taxation in	III, 435 453
“ “ Rates Exacted of Express Companies in... V,	521
“ “ Reduction of Railway Rates in—Its Cause... ..	VI, 26, 37-41
“ “ Relief Departments in	X, 293-325
“ “ Responsibility for Baggage in.....	V, 308, 309
“ “ Rules Regulating Tariffs in	VI, 43-48
“ “ Superannuation Funds in.....	II, 60
“ “ Threatened Dangers to	XI, 46
“ “ Transferring Baggage in	V, 332
“ “ Use of the Cowcatcher, or Pilot, in.....	I, 56
Unity, Necessity of.....	II, 117
Universities, Railway—Establishment of.....	II, 222
Unloading, Charges for.....	IX, 61
Unpaid Freight Charges.....	VI, 152
Unselfishness of Officers and Employees—Its Value.....	II, 63
Unskilled Labor	I, 270
“ Laborers	I, 264
Upheavals, Labor—Their Effect	II, 40
“ “ Remedy	II, 38, 39
Upholstering, Facilities for.....	I, 274
Upholstery, Cleaning.....	I, 269
“ Room.....	I, 274
“ Shops, Material at	VII, 309
Upper Balance Spring— <i>Illustration, Plate II</i>	I, 116-117
“ Berth, Down— <i>Illustration, Plate II</i>	I, 116-117
“ “ Up— <i>Illustration, Plate II</i>	I, 116-117
“ Brake Connecting Rod— <i>Illustration, Plate II</i> ..	I, 116-117
“ Deck Carline— <i>Illustration, Plate II</i>	I, 116-117
“ Door Sash— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Upper Swing Hanger Pivot— <i>Illustration, Plate II</i>	I, 116-117
Wainscot Rail— <i>Illustration, Plate II</i>	I, 116-117
Utah Power Company, Use of Electricity by.....	I, 499, 500
Use of Hand Brakes—Instructions to Trainmen.....	I, 323
Utensils, Care of.....	VII, 259, 297
" Ordering.....	VII, 298
Vacancies, Filling.....	II, 75, 76, 92
Vacuum Brake.....	I, 299-301
" " — <i>Illustration</i>	I, 306
" " Automatic.....	I, 292
" " Coupling— <i>Illustration</i>	I, 308
" " Plain.....	I, 292
" Cylinder.....	I, 292
" System of Heating.....	IV, 159
Value, The Unit of.....	XI, 72
Values—Their Effect on the Classification of Rates.....	VI, 27
Valve, Angle— <i>Illustration, Plate II</i>	I, 116-117
" Drip— <i>Illustration, Plate II</i>	I, 116-117
" Balanced— <i>Illustration, Plate I</i>	I, 58-59
" Basin— <i>Illustration, Plate II</i>	I, 116-117
" Brake—Emergency Position of.....	I, 319
" " — <i>Engineer's</i>	I, 309, 315, 317, 319, 320, 338
" " — <i>Illustration</i>	I, 349
" " —Instructions to Enginehouse Foremen and Inspectors.....	I, 328
" Car Discharge—Signal Branch Pipe to— <i>Illustration, Plate II</i>	I, 116-117
" Case, Check— <i>Illustration, Plate I</i>	I, 58-59
" " Pump— <i>Illustration, Plate I</i>	I, 58-59
" Chamber.....	I, 93
" Check.....	I, 79
" " — <i>Illustrations, Plate I</i>	I, 58-59, 79, 344
" Conductor's— <i>Illustration, Plate II</i>	I, 116-117
" " —Brake.....	I, 319
" " —Branch Pipe to— <i>Illustration, Plate II</i>	I, 116-117
" " —for Applying Brakes— <i>Illustration</i>	I, 540
" " —Instructions to Trainmen.....	I, 326
" Cover— <i>Illustration</i>	I, 65
" " Filling— <i>Illustration, Plate II</i>	I, 116-117
" Cut-Off and Relief.....	I, 310
" Cut-Out— <i>Illustration, Plate I</i>	I, 58-59
" Discharge—Car— <i>Illustration</i>	I, 386
" Emergency— <i>Illustration</i>	I, 344
" Engineer's.....	I, 305, 306, 313, 334, 347-349
" " Brake— <i>Illustration, Plate I</i>	I, 58-59
" " " and Equalizing Discharge—Oper- ations of.....	I, 349-352

	PAGE
Valve, Engineer's Brake—and Equalizing Discharge—with Feed Valve Attachment— <i>Illustration</i>	I, 351
“ Equalizing Brake—Engineer's— <i>Illustration</i>	I, 539
“ Feed.....	I, 365
“ Gang, Work in Charge of.....	I, 285, 286
“ Gear, Stephenson's Locomotive.....	I, 48
“ Governor Pin.....	I, 365
“ Graduating.....	I, 340-342
“ “ — <i>Illustrations</i>	I, 341, 344
“ Holder— <i>Illustration, Plate II</i>	I, 116-117
“ in Air Pipe, Check— <i>Illustration, Plate II</i>	I, 116-117
“ Main Shut-Off— <i>Illustration, Plate II</i>	I, 116-117
“ Motion, Air Pump.....	I, 308
“ “ Direct Acting.....	I, 94
“ “ Indirect Acting.....	I, 94
“ “ Work.....	I, 286
“ Pin.....	I, 352, 353
“ Poppet—Double.....	I, 308
“ Pressure Retaining.....	I, 336, 346, 347, 538
“ “ “ — <i>Illustrations, Plate III</i>	I, 170-171, 327, 347, 541
“ “ “ — <i>Instructions to Trainmen</i>	I, 327
“ Reducing— <i>Illustrations</i>	I, 386
“ “Reinforce”.....	I, 312
“ Release.....	I, 538
“ “ — <i>Illustration</i>	I, 541
“ “ — <i>Auxiliary Reservoir — Illustration, Plate III</i>	I, 170-171
“ Relief— <i>Illustration, Plate I</i>	I, 58-59
“ “ — <i>Automatic</i>	I, 310
“ “ “ Graduated.....	I, 312, 313
“ Retaining.....	I, 375
“ Rod.....	I, 94
“ Rotary.....	I, 365
“ “ Disc.....	I, 329
“ “ Horizontal.....	I, 308
“ “ Vertical.....	I, 308
“ Safety.....	I, 81, 82
“ “ —for High Speed Brake— <i>Illustration</i>	I, 362
“ “ High Speed.....	I, 362, 363
“ “ Section of— <i>Illustration</i>	I, 82
“ Seat— <i>Illustration, Plate I</i>	I, 58-59
“ Seats, Facing.....	I, 243
“ Signal— <i>Illustration</i>	I, 386
“ “ — <i>Car—Illustration, Plate II</i>	I, 116-117
“ Slide.....	I, 308
“ “ — <i>Illustrations</i>	I, 65, 341, 344
“ “ — <i>Defective</i>	I, 382
“ “ Method of Governing the Action of.....	I, 91
“ “ Starting.....	I, 94

	PAGE
Valve, Steam.....	I, 352, 353
" " — <i>Illustrations, Plate I</i>	I, 58-59, 539
" Stem — <i>Illustrations, Plate I</i>	I, 58-59, 60
" " Packing— <i>Illustration, Plate I</i>	I, 58-59
" " Rod— <i>Illustration, Plate I</i>	I, 58-59
Stems.....	I, 90
Throttle— <i>Illustration, Plate I</i>	I, 58-59
Triple.....	I, 307, 308, 320, 324, 335, 336, 538
" " — <i>Illustrations, { Plate I.....</i>	I, 116-117
" " " <i>{ Plate III.....</i>	I, 170-171
" " — <i>Defective</i>	I, 371
" " — <i>Draining the</i>	I, 329, 330
" " — <i>for Driver Brakes—Illustration</i>	I, 539
" " — <i>Law Governing</i>	I, 346
" " — <i>Operations of</i>	I, 337-346
" " — <i>Pipe to—Illustration, Plate II</i>	I, 116-117
" " — <i>Plain</i>	I, 373
" " " — <i>Illustrations</i>	I, 325, 341
" " " Automatic.....	I, 340-344
" " — <i>Quick Action</i>	I, 343-346
" " " — <i>Illustration</i>	I, 344
Water— <i>Illustration, Plate I</i>	I, 58-59
Whistle Signal— <i>Illustration, Plate I</i>	I, 58-59
Yoke— <i>Illustration, Plate I</i>	I, 58-59
Valves.....	I, 285
" Adjustment of.....	I, 85
" Air.....	I, 95
" Brake— <i>Conductor's</i>	I, 330
" Clean— <i>Instructions to Engineers</i>	I, 365
" Engineer's.....	I, 353, 354
" Feed.....	I, 313
" Relief.....	I, 95
" Safety— <i>Illustration, Plate I</i>	I, 58-59
" Setting.....	I, 286
" Triple— <i>Cleaning—Instructions to Car Inspectors</i>	I, 331, 332
" " — <i>Draining</i>	I, 332
" " — <i>Effect of Quick Action on</i>	I, 369
" " — <i>Repairing</i>	I, 382
Vanderbilts.....	XI, 81
Van Etten, E.....	VI, 55
Variable Speeds.....	I, 445
Variation of Current.....	I, 414
Variations in Transmission.....	I, 431
" of Trank and Traffic.....	II, 27
"Various Persons Accounts".....	VII, 319
Various Persons Accounts.....	VII, 417-429
" " Bills, Cancellation of.....	VII, 428, 429
Varnishes.....	III, 481, 482
" Storing.....	VII, 293

	PAGE
Varnishes, Use of—by Railways.....	VII, 214
Varrentrapp, Professor	VII, 169
Varsovie-Vienna Railroad Car— <i>Illustration</i>	I, 157
Vault, Cash—Care of.....	X, 270
Vaults, Money.....	X, 270, 271
Vegetables, Carriage of.....	V, 519
Vegetable Oils, Use of—for Lighting Cars.....	IV, 172
Vehicles, Beginnings of	I, 132
“ Chinese—Wheels of.....	IV, 191
“ —Comparison of Past with Present.....	I, 164
“ Decoration of.....	I, 197
“ Devices for Checking and Moderating.....	I, 297
“ Early Methods of Heating	IV, 163
“ Evolution of.....	I, 156
“ for Military Uses.....	I, 224
“ “ Purposes of War.....	I, 162
“ Interchange of—by Railroads.....	II, 46
“ Invention of.....	XI, 51
“ Means of Controlling the Movement of.....	I, 294
“ Metal	I, 224
“ Number of Brakes Used on.....	I, 313, 314
“ of Railroads.....	I, 156
“ Primitive—Gauge of.....	III, 190
“ Use of—by the Aryans	I, 159, 160
Velocipede Hand Car— <i>Illustration</i>	I, 149
Venezuela	III, 15
Vent from Water Tank, Air— <i>Illustration, Plate II</i>	I, 116-117
“ Pipe— <i>Illustration, Plate II</i>	I, 116-117
Ventilating Chimney— <i>Illustration, Plate II</i>	I, 116-117
Ventilation.....	I, 259, 273, 274; IV, 68, 69
“ of Cars.....	V, 33-36
“ “ Tunnels.....	III, 188, 199
Ventilators.....	I, 256, 257
“ — <i>Illustrations</i> , { <i>Plate I</i>	I, 58-59
“ { <i>Plate II</i>	I, 116-117
Vermont, Railway Taxation in.....	III, 452
Vestibuled Car.....	IV, 119, 120
Vertical Rotary Valve	I, 308
Vessels, Art of Constructing—Evolution of	XI, 99
“ Sea-Going—Perfection of.....	XI, 107
Vestibule Car, American— <i>Illustration</i>	I, 221
“ “ in Austria	I, 204
“ “ “ Germany	I, 204
“ Dome— <i>Illustration, Plate II</i>	I, 116-117
“ Door— <i>Illustration, Plate II</i>	I, 116-117
“ “ Drop Handle— <i>Illustration, Plate II</i>	I, 116-117
“ “ Hinges— <i>Illustration, Plate II</i>	I, 116-117
“ “ Guard Rod— <i>Illustration, Plate II</i>	I, 116-117
“ “ Lock— <i>Illustration, Plate II</i>	I, 116-117
“ End Carline— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Vestibule, Glass in Door— <i>Illustration Plate II</i>	I, 116-117
“ Hood— <i>Illustration, Plate II</i>	I, 116-117
“ Lamp— <i>Illustration, Plate II</i>	I, 116-117
“ Pullman.....	I, 198
“ Train.....	I, 182, 197, 198
Vestibuled Locomotive Tender.....	I, 198
“ Trains.....	I, 203, 204
“V” Hook.....	I, 49
Viaducts, Effect of—on Cost of Operation.....	III, 394
Vice-President.....	II, 131, 285
Vicissitudes, of Corporate Service.....	II, 60
Victoria.....	XI, 115
Victorian Baggage and Compartment Passenger Car— <i>Illustration</i>	I, 210
“ Box Car— <i>Illustration</i>	I, 183
“ Railway Gondola Car— <i>Illustration</i>	I, 156
“ “ Horse Car— <i>Illustration</i>	I, 195
“ Sheep Car— <i>Illustration</i>	I, 193
Views, Interchange of—Its Value.....	I, 289, 290
“Vignoles” Rail.....	III, 200
Villages, Vouchers in Favor of.....	VII, 435
Virgil.....	XI, 93
Void Tickets.....	X, 133
Volt, Definition of.....	I, 401
Voltage, Reduction of—on a Motor.....	I, 478
Voltmeter.....	I, 461
Voucher, Special Journal—Freight Auditor’s Advice of..	VI, 307
Vouchers.....	II, 292; VII, 434-437; IX, 366-369
“ Agents’ Relief.....	X, 277, 280
“ Approval of.....	VII, 437
“ Ascertaining Amount of Unpaid.....	X, 84, 85
“ Cancellation of.....	VII, 442-444; IX, 379, 380
“ Care of.....	X, 271, 272, 282
“ Certifying.....	X, 92, 94
“Vouchers Chargeable to Storekeepers”.....	VII, 318, 319
Vouchers, Charging.....	IX, 368; X, 83, 84
“ Duplicates of.....	X, 95-97
“ Errors in.....	VII, 435, 440; IX, 368, 377
“ Filing.....	X, 96, 97
“ Fraudulently Claimed as Paid by Agents..	IX, 217, 218
“ Indorsing.....	X, 283
“ Journal.....	X, 81, 82
“ Lost.....	VII, 440; IX, 377
“ Making.....	X, 92, 94
“ Material—Charging.....	VII, 273
“ Notations on.....	VII, 435, 437
“ Papers Attached to..	VII, 434, 435, 439; IX, 377; X, 94
“ Paying.....	VII, 435, 437-441, 444; X, 94-98, 275-284
“ “ —Before Approval.....	X, 274
“ “ —to Third Persons.....	X, 281, 282

GENERAL INDEX.

371

	PAGE
Vouchers, Payment of.....	IX, 218, 368
" " —by Agents.....	IX, 180, 374-378
" Petty—Paying.....	X, 98
" Receipting.....	VII, 439; IX, 376; X, 94, 97, 98
" Reclamation.....	IX, 131
" Register of.....	X, 68, 83-85
" Relief.....	IX, 371-374, 427
" Remitting.....	IX, 425
" Stamping.....	VII, 440; IX, 377
" Unpaid.....	VII, 438
" Used as Drafts.....	X, 279
Voyage, Sea—The First.....	XI, 111
Vulcanizing.....	III, 374
Wages.. I, 281; II, 13, 24, 25, 28, 50, 51, 60, 69; III, 145, 415, 418-420	
" Certificates of. (See also "Time Tickets").....	IX, 380-390; X, 271
" " —Payment of.....	IX, 390-397; X, 286
" Charging.....	VII, 274
" Computation of.....	II, 24, 25
" Deceased Employes'	X, 284
" Dissimilarity in.....	II, 104
" Distribution of.....	VII, 359
" Effect of Danger on.....	II, 101
" " the Circulating Medium on.....	III, 19, 21-23
" Efforts of Labor to Raise.....	II, 34
" English.....	IV, 448-454
" Fictitious—Checks for.....	X, 198
" Fluctuation of.....	II, 106, 107
" for Common Labor.....	II, 100, 101
" Garnished.....	X, 284
" Garnishment of.....	IX, 401-403
" Inadequate—Their Effect on Railways.....	II, 105
" in England.....	X, 233, 234
" Influences Affecting.....	II, 98, 102, 104
" Keeping Account of.....	VII, 240
" Method of Computing.....	VII, 367, 368
" of Deceased Employes.....	VII, 403, 407; IX, 394
" Orders for.....	IX, 400, 401; X, 205, 231
" Payment of.....	I, 280; VII, 393, 406-410; IX, 380, 390-397; X, 185-253, 285, 286
" Pay Rolls for.....	VII, 388-397
" Principles Governing the Fixing of.....	II, 97-107
" The Act of Paying Railway Employes Their.....	X, 185-230
" Time of Paying.....	X, 216, 217
" Traffic in.....	VII, 398; IX, 434
" Uncalled for.....	X, 197, 251
" Withheld.....	X, 286
" Withholding.....	IX, 177, 388, 389

	PAGE
Wagner Palace Car Company.....	I, 147, 196-199; VI, 73
Service.....	I, 202
Wagon, Evolution of.....	XI, 52
First Introduction of.....	I, 160; XI, 54
" Horseless.....	XI, 521, 522
" Introduction of.....	XI, 52
" Peddler's—The Railway Car a Substitute for.....	I, 168
Wagons, of Primitive Ages.....	I, 293
" Use of—by Railways.....	VII, 211
" " —for Houses.....	XI, 66
Waincot Panel— <i>Illustration, Plate II.</i>	I, 116-117
" Rail, Lower— <i>Illustration, Plate II.</i>	I, 116-117
" " Upper— <i>Illustration, Plate II.</i>	I, 116-117
Wake.....	XI, 28
Walls, of Car Repair Shops.....	I, 273
" " Shop Buildings.....	I, 253
War Chariots, Wheels of.....	IV, 190
" Department, Transportation for.....	V, 144
" First Vehicles for.....	I, 162
" Munitions of.....	I, 224
" on Private Interests, Effect of.....	VIII, 161
Warehousemen, Carriers' Responsibility as.....	IX, 75
Warehouses, Examinations of.....	IX, 106
" Preventing Blocking of.....	IX, 75
" Use of—Charges for.....	III, 406; VI, 55
Waste Paper, Disposition of.....	IX, 432
Water Rents, Payment of.....	IX, 403
Watering Live Stock, Charges for.....	IX, 61
Wars, Rate.....	VIII, 142
Watchmen, Use of Signals by.....	IV, 342, 351
Water, Blow-Off for— <i>Illustration, Plate II.</i>	I, 116-117
" Circulation of—in Grate.....	I, 96
" Cock, Hot and Cold— <i>Illustration, Plate II.</i>	I, 116-117
" Cocks— <i>Illustration</i>	I, 64
" Conveyance of—from Tender to Engine.....	I, 106
" Cooler— <i>Illustration, Plate II.</i>	I, 116-117
" " Faucet— <i>Illustration, Plate II.</i>	I, 116-117
" Cranes.....	I, 247
" Drinking—on Cars.....	I, 181
" Drip— <i>Illustration, Plate II.</i>	I, 116-117
" Falling.....	I, 393
" for Cleaning Cars.....	I, 269
" Gauge.....	I, 80
" " — <i>Illustration</i>	I, 64
Warming Pan.....	I, 204
Wash Bowl— <i>Illustration, Plate II.</i>	I, 116-117
Washout Plugs— <i>Illustration, Plate I.</i>	I, 58-59
Washer, Brace Rod— <i>Illustration, Plate II.</i>	I, 116-117
" Truss Rod— <i>Illustration, Plate II.</i>	I, 116-117
Waste, Cause of.....	I, 124

	PAGE
Waste, Charging	VII, 320, 321
Wastefulness	II, 118
Waste Pipe Basin— <i>Illustration, Plate II</i>	I, 116-117
“ Record of.....	VII, 320, 321
“ Use of—by Railways.....	VII, 212
Watch Certificate, Form of.....	IV, 336
Watches, Rules Governing.....	IV, 335-338
Watchmen, Track.....	III, 248, 285
“ “ —Cost of.....	III, 289
Water Glass or Tumbler — <i>Illustration, Plate II</i>	I, 116-117
“ Height of—in Boiler—How Ascertained	I, 80, 81
“ Hot—Use of, for Heating Cars.....	IV, 155, 156
“ “ “ —in Europe, for Heating Cars.....	V, 235
“ —How Supplied to the Boiler.....	I, 76, 77, 79, 105, 106
“ Impure—Its Effect on a Locomotive Boiler.....	I, 248
“ Jacket, Hot— <i>Illustration, Plate II</i>	I, 116-117
“ Pipe	I, 106
“ — <i>Illustration, Plate I</i>	I, 58-59
“ “ Arch Support— <i>Illustration</i>	I, 98
“ “ Cold— <i>Illustration, Plate II</i>	I, 116-117
“ “ “ —to Bowl— <i>Illustration, Plate II</i>	I, 116-117
“ —Quantity Carried in Tender.....	I, 106
“ “ Converted into Steam by One Pound of Coal.....	I, 71
“ “ of—in Locomotive Boiler.....	I, 78
“ Relief Valves	I, 95
“ Scoop	I, 106
“ Space.....	I, 96
“Water Stations”.....	VII, 459
Water Stored Under Pressure.....	I, 298
“ Strainer— <i>Illustration, Plate II</i>	I, 116-117
“Water Supply for Locomotives”.....	VII, 486, 519
Water, Taking—for Locomotives.....	IV, 428
“ Tank	I, 246
“ “ — <i>Illustrations, Plate II</i>	I, 116-117, 280
“ “ Air Vent from— <i>Illustration, Plate II</i>	I, 116-117
“ “ Approach to— <i>Illustrations</i>	I, 106
“ “ Filler— <i>Illustration, Plate II</i>	I, 116-117
“ Tanks, Locomotive—Repair of	I, 251
“ Transportation.....	VIII, 69
“ “ —How Carried on.....	II, 41, 43
“ “ Laws Governing.....	II, 47, 48
“ Tests of.....	I, 277
“ Use of Impure.....	I, 263, 264
“ Valve— <i>Illustration, Plate I</i>	I, 58-59
“Watered” Stock.....	III, 34, 72-78; VIII, 75
“ “ —Its Effect on Rates.....	III, 77
“ “ —What It Represents.....	III, 75
Waterways	III, 254
Watt, Alexander.....	VII, 162

	PAGE
Watt, James.....	XI, 511
Wattmeter	I, 461
Watts.....	I, 403, 404
Way Bills.....	I, 171; VI, 80, 94, 129-141
“ “ Abstracts of.....	IX, 44, 45
“ “ “ “ Interline—Forwarded.....	VI, 227, 228, 230, 234
“ “ “ “ “ —Received.....	VI, 228-230, 235
“ “ “ “ Local—Forwarded... VI, 223-226, 230, 232	
“ “ “ “ —Received.....	VI, 227, 230, 233
“ “ Auditing.....	IX, 208
“ “ Baggage. (See also “Checks”).....	V, 56, 57, 369, 370, 372-376
“ “ “ C. O. D.....	V, 484
“ “ “ —Colored Paper for.....	V, 491
“ “ Canceling.....	VI, 195
“ “ —Changing En Route.....	VI, 164
“ “ Charges Not Specified on.....	VI, 215-217
“ “ Collecting Fares on	V, 153-156
“ “ Collection.....	IX, 92, 93, 310, 311
“ “ “ —Rules Governing	VI, 211-213
“ “ Columns for Miscellaneous Charges on... IX, 62, 63	
“ “ —Comparing with Freight.....	IX, 98, 102, 290
“ “ Comparison of—with Traveling Auditors’ Abstracts.....	IX, 149
“ “ —Copies Required.....	VI, 83
“ “ Correcting	IX, 363
“ “ Dating.....	VI, 143
“ “ Duplicate—Examination of	VI, 186
“ “ Duplicates of.....	VI, 135, 180, 181
“ “ —Entering in Freight Received Book, VI, 201, 209, 210	
“ “ Errors in.....	VI, 183, 186; IX, 59
“ “ “ —Notice of	X, 111
“ “ Estray Freight.....	VI, 165-168
“ “ Examination of.. VI, 133, 190; IX, 56-60, 99; X, 109-111	
“ “ Excess Baggage.....	V, 449, 450, 486, 487, 489, 495, 496, 501, 502, 504
“ “ “ —Austrian.....	V, 493
“ “ Express.....	V, 543, 544
“ “ for Charges Advanced by Shippers	IX, 322, 323
“ “ “ Special Charges.....	VI, 131
“ “ “ Circus Trains	VI, 138
“ “ “ Ticketing Passengers.....	V, 76
“ “ Forms of	VI, 136
“ “ Forwarding Apart from Freight	IX, 53
“ “ Functions of	IX, 47-49
“ “ Government Freight.....	VI, 281, 283
“ “ Guard’s—English.....	V, 248
“ “ Inserting Prepaid Charges on.....	IX, 126, 127
“ “ Insertion of Charges on—Rules Governing... VI, 134	

	PAGE
Way Bills, Insertion of Weights on—Rules Governing...	VI, 134
" " Interline.....	VI, 137, 230; X, 116
" " —Junction Returns of.....	VI, 241, 242
" " —Monthly Summary of.....	VI, 239-241
" " Live Stock.....	VI, 102, 138
" " Local.....	VI, 137, 230
" " " Charges on.....	VI, 129, 130
" " " Monthly Summary of.....	VI, 236
" " Making—for Freight Received at Prepaid Stations.....	VI, 163, 157
" " " Freight Bills from.....	VI, 204, 205
" " Marking.....	VI, 145
" " Memorandum.....	VI, 132, 137; IX, 52
" " Miscellaneous—English.....	V, 247, 248
" " Names of Consignees on.....	VI, 144
" " " Stations on.....	VI, 144
" " Newspaper Parcels—English.....	V, 247
" " Notations on.....	IX, 98, 99
" " Notices of Errors and Omissions in—Rules Governing.....	VI, 192-195
" " Numbering.....	VI, 134, 141
" " " —Errors in.....	VI, 142
" " Omissions from.....	VI, 183, 186
" " Original—Examination of.....	VI, 183
" " " —Revision of.....	VI, 183-186
" " Overcharges Accruing on.....	IX, 365
" " Parcels—English.....	V, 247
" " Perishable Property.....	VI, 138
" " Recording.....	IX, 52
" " Records of.....	IX, 96
" " " —by Traveling Auditors.....	IX, 54, 55
" " Revision of.....	VI, 177; X, 110, 111
" " Routing.....	VI, 142, 143
" " Rules Governing the Use of.....	VI, 131, 137
" " Safeguards Attending Use of.....	IX, 46, 48
" " —Sending Duplicates to Headquarters.....	IX, 57
" " Station Records of.....	IX, 94-96
" " Substitutes for.....	VI, 132, 178
" " Suppressing.....	IX, 48, 54, 56, 149, 206-211; X, 58
" " Switching.....	VI, 257, 258
" " —Their Place in Freight Accounts.....	VI, 130
" " Tissue Copies of.....	VI, 182
" " Traveling Auditors' Returns of.....	IX, 211, 212
" " Uniformity of.....	VI, 131
" " Use of.....	V, 436
" " Weights Shown on.....	VI, 138, 139
Waybilling Baggage, European Methods.....	V, 492, 493
" Directions.....	VI, 310-312
" Errors in.....	V, 344
" Free.....	VI, 139

	PAGE
Way Freight	IV, 413
" Loading	VI, 98, 99
" Train—Meaning of Term	IV, 323
Wealth, Acquisition of	VII, 19-27
" First Step Toward	VII, 24
Weapon, The First	XI, 62
Wear and Tear	I, 63
" " of Locomotives and Cars	I, 231
Weather, Effect of—on Movement of Trains	IV, 364
" Protection of Motors from	I, 471
Webb, F. W.	I, 46
Wedge Bolt— <i>Illustration, Plate I</i>	I, 58-59
" Driving Box— <i>Illustration, Plate I</i>	I, 58-59
" Filling, Body Bolster— <i>Illustration, Plate III</i>	I, 170-171
" Side Door— <i>Illustration, Plate III</i>	I, 170-171
" Spikes	III, 198
Wedges	I, 213, 286, 292
Weeds, Cutting	III, 240
" Removing	III, 285
Weekly Return of Interline Ticket Sales	V, 167
" " Ticket Sales	V, 163, 164
Weighers, of Freight	VI, 24
Weighing Bulk Freight at Destination—Rules Governing	VI, 150
" Cars	VI, 222, 223
" Freight en Route—Rules Governing	VI, 148
" Ore—Rules Governing	VI, 149
Weight, Counter Balance— <i>Illustration, Plate I</i>	I, 58-59
" Distribution of—on Cars	I, 218-219
" Division of—Effect of the Bogle	I, 24
" Effect of—on Cost	X, 161-164
" Locomotive—Distribution of	I, 66, 109, 110
" of Armature	I, 469
" " Motor	I, 469, 470
" " Railway Equipment	I, 165
" Shortages in	IX, 105
Weights, Actual	VI, 147
" Estimated	VI, 147
" Incorrect	VI, 22, 23
" —How Fixed	VI, 146
" Table of	VI, 146
Welding Machinery	I, 262
Wells, Gas	I, 104
Western Classification, The	VI, 444
Westinghouse Air Pump	I, 538
Wheel— <i>Illustration, Plate II</i>	I, 116-117
" Action of—on Rail Joint— <i>Illustration</i>	III, 339
" Ancient— <i>Illustration</i>	IV, 191
" " Egyptian— <i>Illustration</i>	IV, 191
" " Chariot— <i>Illustration</i>	IV, 190
" " —from Cyprus— <i>Illustration</i>	IV, 194

	PAGE
Wheel, Ancient Roman Cart— <i>Illustration</i>	IV, 189
“ and Axle, The First Form of— <i>Illustration</i>	IV, 188
“ Assyrian Chariot—600 B. C.— <i>Illustration</i>	IV, 190
“ Barlow—Invention of	I, 519
“ Base, Rigid—in England	I, 24
“ “ —Its Effect on Maintenance	III, 148
“ “ Short	I, 65
“ Brackets— <i>Illustration, Plate III</i>	I, 170-171
“ Bulgarian— <i>Illustration</i>	IV, 195
“ Car, English— <i>Illustration</i>	IV, 215
“ “ —Number of Men Required to Manufacture	I, 133
“ Cast-Iron Driving—with Steel Tire— <i>Illustration</i>	IV, 200
“ “ —with Steel Tire— <i>Illustration</i>	IV, 209
“ Chilled Iron—for Passenger Cars— <i>Illustration</i>	IV, 201
“ Cog	I, 22
“ —Difficulty to Make It Revolve	I, 293
“ Double Plate— <i>Illustration</i>	IV, 207
“ “ —Master Car Builders' Washburn Pattern — <i>Illustration, Plate III</i>	I, 170-171
“ Driving—Its Ability to Carry a Load	I, 64
“ Engine Truck— <i>Illustration, Plate I</i>	I, 58-59
“ Evolution of the	IV, 187-195
“ Flange	I, 304
“ “ — <i>Illustrations, { Plate II</i>	I, 116-117
“ “ “ — <i>Plate III</i>	I, 170-171
“ Flanges, Importance of	IV, 210, 211
“ Freight Car—Cast-Iron— <i>Illustration</i>	IV, 196
“ Gang	I, 286
“ Gauge	IV, 211
“ Guard— <i>Illustration, Plate I</i>	I, 58-59
“ Hand—Brace— <i>Illustration, Plate II</i>	I, 116-117
“ “ Brake— <i>Illustration, Plate III</i>	I, 170-171
“ Hollow Spoke— <i>Illustration</i>	IV, 207
“ Hub— <i>Illustration, Plate III</i>	I, 170-171
“ Locomotive Tender—Cast-Iron— <i>Illustration</i>	IV, 197
“ “ Truck—Paper— <i>Illustrations</i>	IV, 199
“ Piece— <i>Illustration, Plate II</i>	I, 116-117
“ “ Plate, Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Plate, Outside— <i>Illustration, Plate II</i>	I, 116-117
“ Pressure of Brake Shoe Against	I, 311
“ Primitive— <i>Illustration</i>	IV, 188
“ “ —from Germany— <i>Illustration</i>	IV, 192
“ Ratchet—Brace— <i>Illustration, Plate II</i>	I, 116-117
“ Rim— <i>Illustration, Plate III</i>	I, 170-171
“ Single Plate— <i>Illustration</i>	IV, 207
“ Solid Spoke— <i>Illustration</i>	IV, 207
“ Steel Tired Cast Iron— <i>Illustration</i>	IV, 208
“ Tread— <i>Illustration, Plate III</i>	I, 170-171
“ Weight Placed on	I, 64
“ Wrought Iron—French Design	IV, 209, 210

	PAGE
Wheels.....	I, 49, 120, 121, 218, 285, 293, 334
“ Action of—on Rails	IV, 211-213
“ Ancient Bronze— <i>Illustration</i>	IV, 193
“ Bearings of	IV, 199
“ Breakage of Different Forms of.....	IV, 221
“ Breaking of.....	IV, 405
“ Car.....	I, 178; IV, 186-223
“ “ —How They Differ from Other Wheels.....	IV, 196
“ “ —Inspection of.....	I, 278
“ “ —Kinds of.....	IV, 198
“ “ —Storing.....	I, 272
“ Cast Iron	IV, 206, 215, 216, 220
“ “ Steel.....	IV, 198
“ Chilled	I, 302; IV, 198
“ “ —Manufacture of.....	IV, 200-207
“ “ —Patterns of.....	IV, 207
“ Coach—Steel Tired.....	I, 302, 303
“ Cost of.....	III, 403
“ Defective	III, 430
“ Diameter of.....	IV, 216-220
“ Driving	I, 87, 286
“ “ — <i>Illustration</i>	I, 60
“ “ —Application of Flanged Brake Shoe to ..	I, 304
“ “ —Brake Used on.....	I, 297
“ “ —Load on.....	III, 195
“ “ —Number Required	I, 66
“ “ —Removing	I, 244
“ “ —Statement of Number of	I, 39
“ “ —Steel Tired	I, 302
“ “ —Theory of the Application of the Auto- matic Brake and Brake Shoe to the— <i>Il- lustration</i>	I, 542
“ “ —The Largest Ever Known	I, 35
“ “ —Use of Brakes on.....	I, 314
“ “ —Weight on.....	I, 64
“ Durability of—Effect of Rest on	IV, 210
“ Effect of—on Rails.....	III, 201
“ Emery—Use of, by Railways.....	VII, 212
“ Facilities for Storing.....	I, 269
“ Flanged—Introduction of	III, 177
“ Flange of—Application of Brake Shoe to.....	I, 304
“ Friction on	I, 302
“ Hand Car.....	IV, 213, 214
“ Handling	I, 275
“ Locking the	I, 312
“ Locomotive—Construction of	I, 110
“ “ —Machine for Removing and Replacing	I, 261
“ Manufacturers of—Rivalry Among	IV, 220
“ of Motor Car Trucks.....	I, 468, 469

	PAGE
Wheels of War Chariots.....	IV, 190-193
“ Paper.....	IV, 200
“ Passenger Car—English.....	IV, 215
“ Shrinkage of.....	IV, 213
“ Sliding.....	I, 311-313, 363, 379; IV, 321
“ “ —Avoidance of.....	I, 369
“ “ —Instructions to Enginemen.....	I, 321
“ Steel Tired.....	IV, 207-209
“ “ —Manufacture of.....	IV, 208
“ Tread of.....	IV, 199
“ Truck— <i>Illustration</i>	I, 60
“ Use of Brakes on.....	I, 313, 314
“ “ Scrap Iron for.....	IV, 208, 209
“ Weight of.....	IV, 213
When a Train Has Lost Its Rights—Meaning of Phrase.....	IV, 323
Whirllicotes.....	XI, 105
Whistle.....	I, 362
“ — <i>Illustration</i>	I, 60
“ Air.....	IV, 115
“ Rig— <i>Illustration, Plate I</i>	I, 58-59
“ Signal— <i>Illustrations, Plate I</i>	I, 58-59, 386
“ “ Valve— <i>Illustration, Plate I</i>	I, 58-59
“ Signals, Rules Governing.....	IV, 346, 347
“ Steam.....	I, 111
“ “ — <i>Illustrations</i>	I, 111
“ “ —Origin of.....	I, 54, 55
“ Use of.....	IV, 264, 268, 350, 351
Whistles, Automatic.....	I, 112
“ Chime— <i>Illustration, Plate I</i>	I, 58-59
Whistling Post—Meaning of Term.....	IV, 323
White, Richard Grant.....	IV, 315
“ Signification of.....	IV, 340
Wild Train—Meaning of Term.....	IV, 324
Wilmer, A. B.....	VI, 54
Winans, Ross—Locomotive Built by— <i>Illustration</i>	I, 42
Winding a Railway Generator Armature— <i>Illustration</i>	I, 404
“ Field—in Booster System.....	I, 435
“ Shunt.....	I, 409, 410
Windings of an Alternating Current Transformer.....	I, 422, 423
“ the Induction Motor.....	I, 443, 444
Window Blind Lift— <i>Illustration, Plate II</i>	I, 116-117
“ “ Mullion— <i>Illustration, Plate II</i>	I, 116-117
“ “ Sash— <i>Illustration, Plate II</i>	I, 116-117
“ “ Slats— <i>Illustration, Plate II</i>	I, 116-117
“ Casing— <i>Illustration, Plate II</i>	I, 116-117
“ Cove Molding— <i>Illustration, Plate II</i>	I, 116-117
“ Curtain Rod— <i>Illustration, Plate II</i>	I, 116-117
“ Drapery— <i>Illustration, Plate II</i>	I, 116-117
“ Glass— <i>Illustration, Plate II</i>	I, 116-117
“ Lift— <i>Illustration, Plate II</i>	I, 116-117

	PAGE
Window Lock— <i>Illustration, Plate II.</i>	I, 116-117
“ Molding—Outside— <i>Illustration, Plate II.</i>	I, 116-117
“ Panel— <i>Illustration, Plate II.</i>	I, 116-117
“ Posts— <i>Illustration, Plate II.</i>	I, 116-117
“ Sash— <i>Illustration, Plate II.</i>	I, 116-117
“ “ Outside—Deck— <i>Illustration, Plate II.</i>	I, 116-117
“ Screens, Deck— <i>Illustration, Plate II.</i>	I, 116-117
“ Shade— <i>Illustration, Plate II.</i>	I, 116-117
“ Sill, Inside— <i>Illustration, Plate II.</i>	I, 116-117
“ “ Cornice Board— <i>Illustration, Plate II.</i>	I, 116-117
“ “ Outside— <i>Illustration, Plate II.</i>	I, 116-117
“ Stile— <i>Illustration, Plate II.</i>	I, 116-117
“ Stop— <i>Illustration, Plate II.</i>	I, 116-117
Winter Repairs.	III, 247
Wire, Automatic Electric Block System.	IV, 284
“ Copper.	I, 397
“ Heat Produced in Various Sizes of.	I, 398
“ Power Appearing as Heat in a—How Found.	I, 405
“ “ Lost in the.	I, 450
“ Trolley—Nantasket Road— <i>Illustration.</i>	I, 493
Wires and Plugs—Automatic Electric Block System.	IV, 283
“ Armature.	I, 410
“ Energy of Steam Wasted in Heating.	I, 403
“ Heat in.	I, 402
“ Overhead.	I, 463
“ Trolley.	I, 488
“ —Pressure Between.	I, 437
Wisconsin Railway, Taxation in.	III, 436, 437, 444
Witnesses, Fees of.	II, 232
Woman, the First Carrier.	XI, 13, 47, 101
Women, Carriage of—in Panniers.	XI, 153
Wood, Benches for Working in.	I, 269
“ Bids for.	VII, 98, 99
“ Car for Creosoting or Impregnating—Austrian— <i>Illustration.</i>	I, 197
“ Cars for Handling.	I, 224
“ Cost of.	VII, 163, 176
“ Deterioration of.	VII, 162, 327
“ Early Use of—for Locomotives.	I, 54
“ Economy in the Use of.	III, 349
“ Heating Capacity of Different Kinds of.	VII, 162
“ Kinds of—Used for Ties.	III, 350
“ Marking.	VII, 330
“ Piling.	VII, 330, 331
“ Preservation of.	III, 349-375
“ “ —in Europe.	III, 351
“ “ “ India.	III, 352
“ Preservatives.	III, 370-375
“ Purchase of.	VII, 288, 289, 330
“ Receipt of.	VII, 288, 289

	PAGE
Wood, Sawing	VII, 331, 332
Screws	III, 197
Shop, Locomotive Department— <i>Illustrations</i>	I, 249
Substitutes for	III, 365, 369, 370
Substitution of Iron and Steel for	I, 166, 168
Supply of—Kept on Hand	VII, 164
Train—Meaning of Term	IV, 324
Use of—by Railways	III, 348-382
" " —for Brake Shoes	I, 302
" " " Fuel	VII, 163
" " —in Car Wheels	IV, 198
" " " Constructing Cars	I, 158
" " " Construction	III, 129
Work, Cleaning	I, 269
Woods, Furnishers of	I, 182
—Kinds Used by Railways	VII, 211, 212
Wooden Joint Block, New Jersey Railroad, A. D. 1860— <i>Illustration</i>	III, 278
Stringer and Strap Rail, Albany & Schenectady Railroad, A. D. 1837— <i>Illustration</i>	III, 223
Ties	III, 202
Woodhouse's Patent Concave Rail for Wagons, A. D. 1803— <i>Illustration</i>	III, 184
Work Benches	I, 243
Comparisons of—at Different Shops	I, 287
Cost of Different Kinds of	I, 287
Distribution of	I, 267, 286
Gradation of	II, 63
Guide	I, 286
Hand—Replacing by Machinery	I, 263
Inspection of	I, 267
Particularizing	I, 285, 286
Shop—Arrangement and Systemization of	I, 288
Specializing	I, 283, 285, 286
Tendency to Subdivide	I, 287
Trains	IV, 359
Valve Motion	I, 286
Works, Petit-Bourg	I, 216
Working Fund	II, 189
Funds, Agents'	IX, 180, 265, 329, 332-334
" " Conductors'	IX, 182
Workmen for Care and Maintenance of Rolling Stock	I, 238
Keeping Time of	I, 279, 280
Skilled	I, 247, 264
World, Advancement of—to What Due	II, 35, 36
Ancient—Governing Forces of	XI, 129
Civilization of—to What Due	II, 34
Industrial—Conditions of	II, 35
Locomotives and Cars of the	I, 116
Railway—Vastness of	II, 57

	PAGE
World's Railway Commerce Congress.....	V, 49
Worsdell, T. W.....	I, 56
Worsted, Use of—for Tests for Color Blindness.....	IV, 233-239
Worth, Evidence of—in Men.....	II, 76
" M.....	XI, 47
Worthlessness, Indications of.....	II, 22
Wrecking Car— <i>Illustration</i>	I, 206
" Steam— <i>Illustration</i>	I, 201
" Cars.....	I, 378
Wrecks.....	IV, 382
" Due to Defective Equipment.....	IV, 60
Wrenches.....	I, 243
Writers on Railway Subjects.....	III, 32, 72
Writing, Cuneliform.....	XI, 118
" —Invention of.....	XI, 130
" Hieroglyphic.....	XI, 119
" Ideographic.....	XI, 120
" Monumental.....	XI, 118
" Phonetic.....	XI, 131
" Pictorial.....	XI, 118
Writings, of Railway Men.....	II, 72
Wrought Iron Rails.....	III, 178, 179
" Wheel, French Design.....	IV, 209, 210
Wurtemberg Car— <i>Illustration</i>	I, 152
" Railroad Car— <i>Illustration</i>	I, 158
Wyatt's Hexagonal Rail, North Wales, A. D. 1802— <i>Illustration</i>	III, 181
Wylam Colliery.....	I, 23
Xenophon.....	XI, 28, 86
Xerxes.....	XI, 87, 104
" Baggage of.....	V, 278
Yard Facilities, Cost of.....	III, 45
" Lumber.....	I, 272
" Room.....	I, 250, 275
" Switching.....	I, 268
" Testing Plants.....	I, 382
Yards, Construction.....	VII, 189-198
" Repair.....	I, 269
Yardmaster, Rules Governing.....	IV, 431-435
Yardmasters, Traffic Returns of.....	IX, 53
Yardmen, Instructions to.....	I, 376, 377
" Traffic Returns of.....	IX, 56
Year, Division of into Periods.....	XI, 70
Yoke Guide— <i>Illustration, Plate I</i>	I, 58-59
" Iron.....	I, 400
" Valve— <i>Illustration, Plate I</i>	I, 58-59

GENERAL INDEX.

383

	PAGE
"York" Locomotive, 1831.....	I, 32
" " " The Winner of the Baltimore & Ohio Prize of Four Thousand Dollars— <i>Illustration</i>	I, 32
Young, Thomas.....	IV, 228
Y Track.....	IV, 324
Zeal, Effect of Too Much	II, 145, 146
" How Heightened.....	III, 325
Zinc-Tannin Process	III, 361
Zinc, Use of—by Railways	VII, 209
Zone Tariff	VIII, 339

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