HIGH STEAM-PRESSURES IN LOCOMOTIVE SERVICE.

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INTRODUCTION.

A SUMMARY OF CONCLUSIONS.

The results of the study concerning the value of high steam-pressures in locomotive service, the details of which are presented by succeeding pages, may be summarized as follows:

1. The results apply only to practice involving single-expansion locomotives using saturated steam. Pressures specified are to be accepted as running pressures. They are not necessarily those at which safety valves open.

2. Tests have been made to determine the performance of a typical locomotive when operating under a variety of conditions with reference to speed, power, and steam-pressure. The results of one hundred such tests have been made of record.

3. The steam consumption under normal conditions of running has been established as follows:

Boiler pressure 120 pounds, steam per indicated horsepower hour 29.1 pounds.
Boiler pressure 140 pounds, steam per indicated horsepower hour 27.7 pounds.
Boiler pressure 160 pounds, steam per indicated horsepower hour 26.6 pounds.
Boiler pressure 180 pounds, steam per indicated horsepower hour 26.0 pounds.
Boiler pressure 200 pounds, steam per indicated horsepower hour 25.5 pounds.
Boiler pressure 220 pounds, steam per indicated horsepower hour 25.1 pounds.
Boiler pressure 240 pounds, steam per indicated horsepower hour 24.7 pounds.

4. The results show that the higher the pressure, the smaller the possible gain resulting from a given increment of pressure. An increase of pressure from 160 to 200 pounds results in a saving of 1.1 pounds of steam per horsepower hour, while a similar change from 200 pounds to 240 pounds improves the performance only to the extent of 0.8 pound per horsepower hour.

5. The coal consumption under normal conditions of running has been established as follows:

Boiler pressure 120 pounds, coal per indicated horsepower hour 4.00 pounds.
Boiler pressure 140 pounds, coal per indicated horsepower hour 3.77 pounds.
Boiler pressure 160 pounds, coal per indicated horsepower hour 3.59 pounds.
Boiler pressure 180 pounds, coal per indicated horsepower hour 3.50 pounds.
Boiler pressure 200 pounds, coal per indicated horsepower hour 3.43 pounds.
Boiler pressure 220 pounds, coal per indicated horsepower hour 3.37 pounds
Boiler pressure 240 pounds, coal per indicated horsepower hour 3.31 pounds.

6. An increase of pressure from 160 to 200 pounds results in a saving of 0.16 pound of coal per horsepower hour, while a similar change from 200 to 240 results in a saving of but 0.12 pound.

7. Under service conditions, the improvement in performance with increase of pressure will depend upon the degree of perfection attending the maintenance of the locomotive. The values quoted in the preceding paragraphs assume a high order of maintenance. If this is lacking, it may easily happen that the saving which is anticipated through the adoption of higher pressures will entirely disappear.

8. The difficulties to be met in the maintenance both of boiler and cylinders increase with increase of pressure.

9. The results supply an accurate measure by which to determine the advantage of increasing the capacity of a boiler. For the development of a given power, any increase in boiler capacity brings its return in improved performance without adding to the cost of maintenance or opening any new avenues for incidental losses. As a means to improvement, it is more certain than that which is offered by increase of pressure.

10. As the scale of pressure is ascended, an opportunity to further increase the weight of a locomotive should in many cases find expression in the design of a boiler of increased capacity rather than in one for higher pressures.

11. Assuming 180 pounds pressure to have been accepted as standard, and assuming the maintenance to be of the highest order, it will be found good practice to utilize any allowable increase in weight by providing a larger boiler rather than by providing a stronger boiler to permit higher pressures.

12. Wherever the maintenance is not of the highest order, the standard running pressure should be below 180 pounds.

13. Wherever the water which must be used in boilers contains foaming or scale-making admixtures, best results are likely to be secured by fixing the running pressure below the limit of 180 pounds.

14. A simple locomotive using saturated steam will render good and efficient service when the running pressure is as low as 160 pounds; under most favorable conditions, no argument is to be found in the economic performance of the engine which can justify the use of pressures greater than 200 pounds.

HIGH STEAM-PRESSURES IN LOCOMOTIVE SERVICE.

I. THE RESEARCH AND THE MEANS EMPLOYED IN ITS ADVANCEMENT.

1. Steam-Pressures in Locomotive Service.—For many years past there has been a gradual but nevertheless a steady increase in the pressure of steam employed in American locomotive service. Between 1860 and 1870 a pressure of 100 pounds per square inch was common. Before 1890 practice had carried the limit beyond 150 pounds. At the present time 200 pounds is most common, but an occasional resort to pressures above this limit suggests a disposition to exceed it.

High steam-pressure does not necessarily imply high power. It is but one of the factors upon which power depends. The forces which are set up by the action of the engine are as much dependent upon cylinder volume as upon boiler-pressure, and when the pressure is once determined the cylinders may be designed for any power. The limit in any case is to be found when the boiler can no longer generate sufficient steam to supply them. The relation between pressure and power is therefore only an indirect one. But anything which makes the boiler of a locomotive more efficient in the generation of steam, or the engines more economical in their use of steam, will permit an extension in the limit of power. If, for example, it can be shown that higher steam-pressure promotes economy in the use of steam, higher steam-pressure at once becomes an indirect means for increasing power. The fact to be emphasized is that an argument in favor of higher steam-pressures must concern itself with the effects produced upon the economic performance of the boiler or engine.

2. Preparations for an Experimental Study.—In view of the facts stated, and with the hope of ascertaining a logical basis from which to determine what the pressure should be for a simple locomotive, using saturated steam, it was long ago determined to undertake an experimental study of the problem upon the testing plant of Purdue University. A few experiments involving the use of different steam-pressures in locomotive service were made at Purdue as early as 1895, but as the boiler of the locomotive then upon the testing-plant was not capable of withstanding pressures greater

than 150 pounds, these early tests were limited in their scope.* The matter was, however, regarded as of such importance that in designing a new locomotive for use upon the plant, a pressure of 250 pounds was specified—a limit which then was and still is considerably in advance of practice. Thus equipped, an elaborate investigation was outlined, involving a series of tests under six different pressures, representing a sufficient number of different speeds and cut-offs to define the performance of the locomotive under a great range of conditions. But the expense of operating the locomotive under very high steam-pressures proved to be so great that the limited funds which could be devoted to the operations of the laboratory, in combination with the demands of students which could be most easily satisfied by work under lower pressures, made it impracticable for a time to proceed with the work. A grant from the Carnegie Institution of Washington was announced late in the fall of 1903. The first test in the Carnegie series was run February 15, 1904, and the last August 7, 1905. A registering counter attached to the locomotive shows that between these dates the locomotive drivers made 3,113,333 revolutions, which is equivalent to 14,072 miles.

3. THE TESTS.—The tests outlined included a series of runs for which the average pressure was to be, respectively, 240, 220, 200, 180, 160, and 120 pounds, a range which extends far below and well above pressures which are common in present practice. It was planned to have the tests of each series sufficiently numerous to define completely the performance of the engine when operated under a number of different speeds and when using steam in the cylinders under several degrees of expansion. So far as practicable, each test was to be of sufficient duration to permit the efficiency of engine and boiler to be accurately determined, but where this could not be done cards were to be taken. A precise statement of the conditions under which, in the development of this plan, the tests were actually run is set forth diagrammatically in figs. 1 to 6 accompanying, in which vertical distances represent speed and horizontal distances the point of cut-off as determined by the notch occupied by the latch of the reverse lever, counting from the center forward. Each complete circle in these diagrams represents an efficiency test, and each dotted circle, a shorter test under conditions involving the development of power in excess of that which could be constantly sustained. The numerals within the circles refer to the line numbers of the tabulated data (Appendix II).

4. The locomotive upon which the tests were made is that regularly employed in the laboratory of Purdue University, where it is known as *Schenectady No. 2*. It is described and illustrated in Appendix I, where there are also

*Results of these tests will be found published in Locomotive Performance, John Wiley & Sons.

shown several views of the testing-plant upon which the locomotive was operated.

5. THE DATA.—While it is one important purpose of these pages to discuss and summarize the results of experiments, a most interesting and promising field for study is supplied by the unembellished numerical data. These deal with conditions and results which best serve to disclose the effect

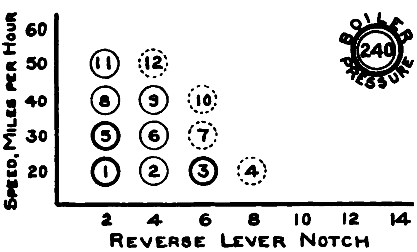


FIG. 1.—Reverse lever notch.

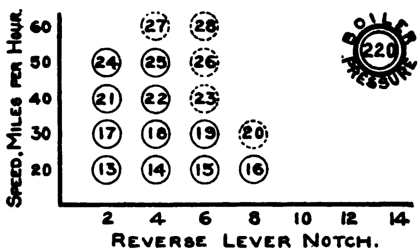


FIG. 2.—Reverse lever notch.

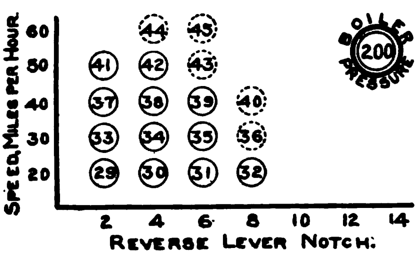


FIG. 3.—Reverse lever notch.

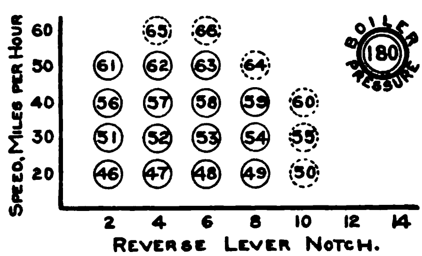


FIG. 4.—Reverse lever notch.

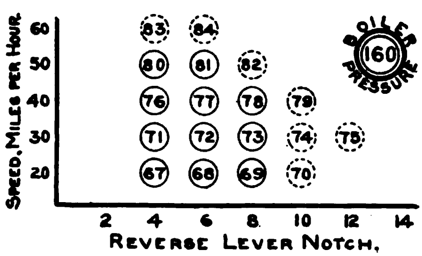


FIG. 5.—Reverse lever notch.

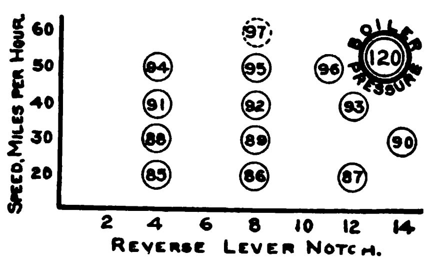


FIG. 6.—Reverse lever notch.

of different steam-pressures upon locomotive performance. There may be drawn from them, also, other series of facts, each telling its own story of cause and effect. The complete exhibit of data from tests, together with a description of the manner in which derived results have been calculated, is presented as Appendix II. The exhibit includes three duplicate tests, the designating numbers of which are followed by the subscript *a*. The results of those tests to which the subscript applies are regarded as less reliable than others only in reference to certain details, the record of which has been omitted from the tables. All values which are given in Appendix II may be accepted as equally reliable.

All tests at 180 pounds boiler-pressure were run by the use of fuel of a quality not standard to the tests, consequently all data which in any way depend upon the coal consumption for these particular tests are omitted from the record, not that the results are unreliable, but because they are not comparable with others given.

Except in those cases where incompleteness of record has necessitated some omissions, derived data are presented covering all of those relationships which have commonly been included in reports previously issued from the Purdue laboratory. Some of the facts given are not directly employed in the analysis showing the value of high-pressures, but their presence in the record makes the complete exhibit available as a means to a more general study of the conditions affecting locomotive performance.

6. An Alternative for Higher Steam-Pressures.—Previous publications from the Purdue laboratory have shown the possibility under certain conditions of finding a substitute for very high boiler-pressures in the adoption of a boiler of larger capacity, the pressure remaining unchanged. If, for example, in designing a new locomotive, it is found possible to allow an increase of weight in the boiler, as compared with that of some older type of machine, it becomes a question as to whether this possible increase in weight should be utilized by providing for a high-pressure or for an increase in the extent of heating surface. The results of tests (Appendix II), supplemented by facts concerning the weight of boilers designed for different pressures and for different capacities (Appendix III), supply the data necessary for an analysis of this question. Such an analysis is presented elsewhere.

7. Acknowledgments.—The research as a whole is the outgrowth of several different influences. Purdue University has contributed for a period of nearly two years the use of its testing-plant and its experimental locomotive. The university has furnished all supplies of oil and waste used during term time, has contributed the full time of one attendant who is the regular staff-fireman of the plant, and has also granted large liberties to those members of its instructional staff who are especially interested in the problems of the locomotive laboratory. As the work progressed and it became evident that some reconstruction of the locomotive boiler was needed, the university did not hesitate to meet the expense amounting to nearly $1,000, of putting the engine through heavy repairs. In this work they received generous assistance in the matter of transportation from the Lake Erie and Western Railroad Company and in the matter of shop facilities from the Pennsylvania Railroad Company.

Acknowledgment is especially due to Edward E. Reynolds, who, when assistant professor in experimental engineering, gave his time unstintingly to the advancement of the work; also, to Mr. Louis E. Endsley, who, as instructor in the locomotive laboratory, has had charge of the running of the tests. Many students of the university have given their assistance as observers during the tests, and some have found a more extensive part in the preparation of theses involving certain groups of the tests.

All coal needed was donated. That which was used during the spring of 1904, amounting to 130 tons, was given by the Cleveland, Cincinnati, Chicago and St. Louis Railroad Company. The remainder, 528 tons, a fuel of the highest quality, was supplied by the agent of C. Jutte & Co., of Pittsburg, at the cost of freight from North Bend, Indiana.

The American Locomotive Company has conducted a careful and somewhat laborious examination of its records that there might be made available for the research information concerning the weights of locomotive boilers designed for various pressures and for various capacities.

Under the grant of the Carnegie Institution of Washington, the staff of attendants available for work at the Purdue laboratory has been increased, and assistants who could serve as observers and computers have been employed in such numbers as would permit the continuous operation of the plant. The time of these and the cost of supplies or fixtures in excess of those normally furnished by the university, when not otherwise available, have been charged against the grant.

Finally, after the full account of the experiments had been put in type, several distinguished engineers, in response to the author's request, read and criticized the proof sheets. The attention thus bestowed by men whose routine responsibilities allow them little time for such a service, constitutes a valuable contribution to the completed work. Those who have given this assistance are Mr. George M. Basford, Mr. A. W. Gibbs, Mr. T. A. Lawes, Mr. C. J. Mellin, Mr. E. D. Nelson, Professor Edward C. Schmidt, Mr. C. A. Seley, and Mr. H. H. Vaughan.

II. DIFFICULTIES IN OPERATING UNDER HIGH-PRESSURES.

8. THE WORK WITH THE EXPERIMENTAL LOCOMOTIVE has shown that those difficulties which in locomotive operation are usually ascribed to bad water increase rapidly as the pressure is increased. The water-supply of the Purdue laboratory contains a considerable amount of magnesia and carbonate of lime. When used in boilers carrying low pressure there is no great difficulty in washing out practically all sediment. The boiler of the first experimental locomotive, *Schenectady No. 1*, which carried but 140 pounds and was run at a pressure of 130 pounds, after serving in the work of the laboratory for a period of six years, left the testing-plant with a boiler which was practically clean. Throughout its period of service this boiler rarely required the attention of a boiler-maker to keep it tight. Water from the same source was ordinarily used in the boiler of *Schenectady No. 2*, which carried a pressure of 200 pounds or more. It was early found that this boiler operating under the higher pressure frequently required the attention of a boiler-maker. After having been operated for no more than 30,000 miles, cracks developed in the side-sheets, making it impossible to keep the boiler tight, and new side-sheets were applied. In operating under pressures as high as 240 pounds, the temperature of the water delivered by the injector was so high that scale was deposited in the check-valve, in the delivery-pipe, and in the delivery-tube of the injector. Under this pressure, with the water normal to the laboratory, the injectors often failed after they had been in action for a period of two hours. The interruptions of tests through failure of the injector, and through the starting of leaks at stay-bolts, as the tests proceeded, became so annoying that, as a last resort, a new source of water-supply was found in the return tank of the university heating-plant. This gave practically distilled water, and its use greatly assisted in running the tests at 240 pounds pressure.

Probably some of the difficulties experienced in operating under very high steam-pressures were due to the experimental character of the plant, and would not appear after practice had, by a gradual process of approach, become committed to the use of such pressures, but the results are clear in their indication that the problem of boiler maintenance, especially in bad-water districts, will become more complicated as pressures are further increased. Since, taking the country over, there are few localities where locomotives can be furnished with pure water, the conclusion stated should be accepted as rather far-reaching in its effect.

The tests developed no serious difficulties in the lubrication of valves and pistons under pressures as high as 240 pounds, though this could not be done with a grade of oil previously employed.

With increase of pressure any incidental leakage, either of the boiler or from cylinders, becomes more serious in its effect upon performance. In advancing the work of the laboratory, every effort was made to prevent loss from such causes, and tests were frequently thrown out and repeated because of the development of leaks of steam around piston and valve rods, or of water from the boiler. Notwithstanding the care taken, it was impossible under the higher pressures to prevent all leakage, and the best that can be said for the data under these conditions is that they represent results which are as free as practicable from irregularities arising from the causes referred to; that is, so far as leakage may affect performance, the results of the laboratory tests may safely be accepted as a record of maximum performance.

In concluding this brief review of the difficulties encountered in the operation of locomotives under very high steam-pressures, the reader is reminded that an increase of pressure is an embellishment to which each detail in the design of the whole machine must give a proper response. A locomotive which is to operate under such pressure will need to be more carefully designed and more perfectly maintained than a similar locomotive designed for lower pressure, and much of that which is crude and imperfect, but nevertheless serviceable in the operation of locomotives using a lower pressure, must give way to a more perfect practice in the presence of the higher pressure.

III. BOILER PERFORMANCE.

9. THE PERFORMANCE OF THE BOILER, as disclosed by the tests, is given in detail in columns 15 to 55 (Appendix II), and certain facts which are of importance in the present study are presented herewith in the form of diagrams (figs. 7 to 33). All of the results entered upon data sheets and represented in the diagrams were obtained by the use of a single grade of coal (Youghiogheny), which in all cases was fired by the same man. A number of tests were run with other coals, but in such cases the boiler performance has been omitted from the final record.

10. EVAPORATIVE EFFICIENCY AS AFFECTED BY THE RATE OF EVAPORATION.—The pounds of water evaporated per pound of coal, plotted in terms of the rate of evaporation, is shown for each of the several pressures by figs. 7 to 11. Through the plotted points of each diagram a mean line has been drawn, the equation of which is given upon the diagram. For example, upon fig. 7, the equation is

$$E = 11.04 - 0.221\ H$$

where E is the number of pounds of water evaporated from and at 212° per pound of coal, and H is the number of pounds of water evaporated from and at 212°, per foot of heating surface per hour. The area of heating surface employed is based upon the interior surface of the fire box and the exterior surface of the tubes. The diagrams will show that the points are not always sufficient in themselves to determine the location of a mean line, hence certain conventions have been adopted to define the slope and position of such lines. These and the reasons underlying them may be described as follows:

The only difference in the running conditions applying to the tests of each series is that of pressure, and as the terms employed in plotting the several diagrams are the same, it is evident that the differences in performance represented by the several diagrams (7 to 11) are only such as may result from the difference in pressure. Since the quantities are in terms of equivalent evaporation, the differences can not be great. Accepting this view, it was first sought to determine the slope of the lines for the several groups. This was done by plotting upon a single sheet all of the points, eight in number, available for the series at 240 pounds, together with eight points selected as fairly representative from each of the other series, making forty points in all. The result is shown in fig. 12. Points thus plotted were divided into two groups, one representing the lower rates of combustion, and the other representing the higher rates, the points being so chosen that each group contained four points from each of the several series. The ordinates and abscissæ for points of each group were then determined, and the several values thus obtained averaged. The final results were then plotted, giving the points shown by the circles inclosing a cross (fig. 12).

The equation from the line drawn through these points is

$$E = 11.305 - 0.221\ H$$

The line thus found (fig. 12) may fairly be assumed to represent the slope of the mean line of any number of points which for purposes of comparison may be selected from the larger group. Points thus chosen are plotted in figs. 7 to 11, which represent results at boiler pressures of 240, 220, 200, 160, and 120 pounds, respectively.

In determining, therefore, the location of the mean line, figs. 7 to 11, inclusive, the abscissæ and ordinates of all the points of each diagram were averaged and the results plotted. This mean point appears upon each diagram as a circle inclosing a cross. Through this derived point a line is drawn having the slope already found; that is, the mean line of fig. 12.

An examination of the diagrams (figs. 7 to 11) will show that with one exception the mean lines located in the manner described well represent the experimental points, but certain individual points, especially some of those obtained under the higher steam-pressures, are remote from the line. With reference to such points it should be said that the experimental data upon which they are based is believed to be as reliable as that which underlies other points which may fall upon the line. Inconsistencies are not due to faults in testing, but to variations in the condition of the fire. Under the high rates of combustion common in locomotive service it is practically impossible to duplicate the conditions at the grate from day to day; *e. g.*, in fig. 7, test 5 was run as a check on 5*a*; also, tests 1 and 1*a* were run under identical conditions, a repetition being necessary through a defect in the engine, which, however, did not interfere with the accuracy of the boiler work. The results for tests 5 and 5*a* are somewhat diverging; those for 1 and 1*a* are practically coincident.

The results obtained under a pressure of 220 pounds (fig. 8) are not well represented by a line of the same slope with the others, though such a line is drawn and its equation is given on the diagram. This is assumed to represent the general law, notwithstanding the fact that the individual points suggest a slope similar to that of the dotted line shown.

11. EFFECT OF CHANGES IN STEAM-PRESSURE UPON THE EVAPORATIVE EFFICIENCY OF THE BOILER.—The generation of steam at a pressure of 120 pounds involves a temperature of the water which is 50° less than that which must be dealt with in generating steam at a pressure of 240 pounds, and in general it has been assumed that any increase in boiler-pressure necessarily results in some loss of evaporative efficiency. It has been known that for the small ranges of pressure common in stationary practice this difference is not great, but the facts have not been established with reference to locomotive performance or for ranges as great as those covered by the experiments under consideration in any service.

The performance of the boiler experimented upon under a range of pressure varying from 240 to 120 pounds may be seen by comparing the mean curves already developed (figs. 7 to 12). Such a comparison is presented by fig. 13. This diagram shows that the lowest efficiency is obtained with the highest pressure and that with one exception the lines representing performance under different pressures fall in order, inversely with the pressure. The exception is to be found in the line representing performance at 120 pounds pressure. This line falls low, a condition which may be explained by the fact that the spark and cinder losses for these tests are known to have been excessive. The mean line located from 40 points representing all pressures (fig. 12) will represent any of the lines of fig. 13 with an error not greater than 0.2 pound.

The results clearly define four general facts, which may be stated as follows:

1. The evaporative efficiency of a locomotive boiler is but slightly affected by changes in pressure.

2. Changes in steam-pressure between the limits of 120 pounds and 240 pounds will produce an effect upon the efficiency of the boiler which will be less than 0.5 pound of water per pound of coal.

3. The equation $E = 11.305 - 0.221\ H$ represents the evaporative efficiency of the boiler of locomotive *Schenectady No. 2* when fired with Youghiogheny coal for all pressures between the limits of 120 pounds and 240 pounds with an average error for any pressure which does not exceed 2.1 per cent.

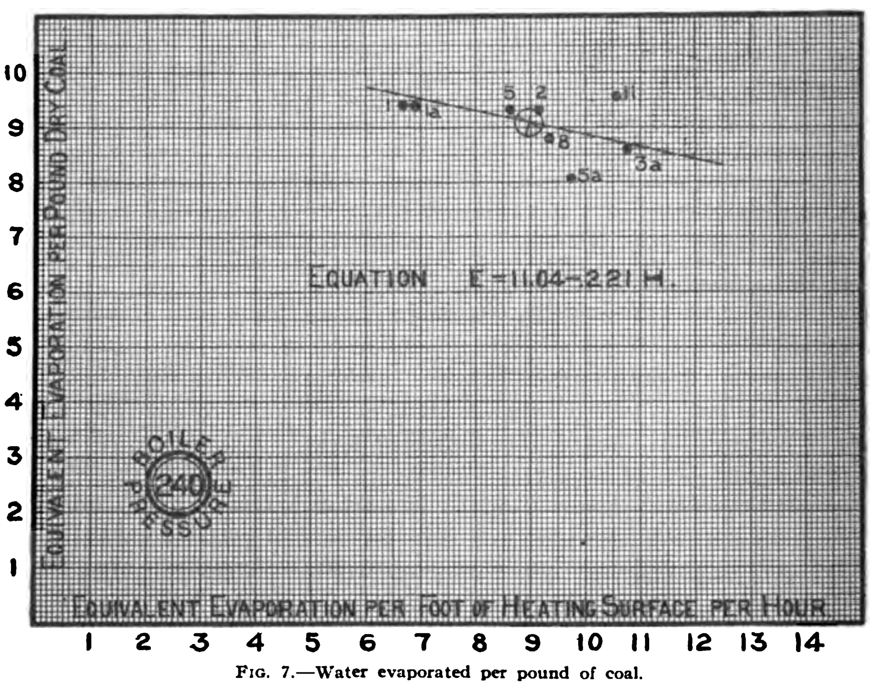


FIG. 7.—Water evaporated per pound of coal.

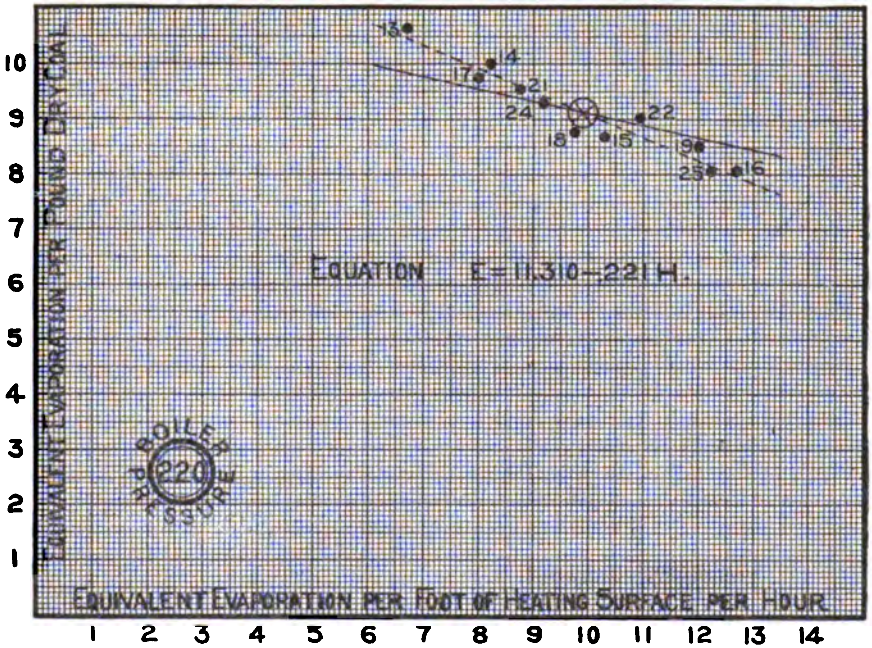


FIG. 8.—Water evaporated per pound of coal.

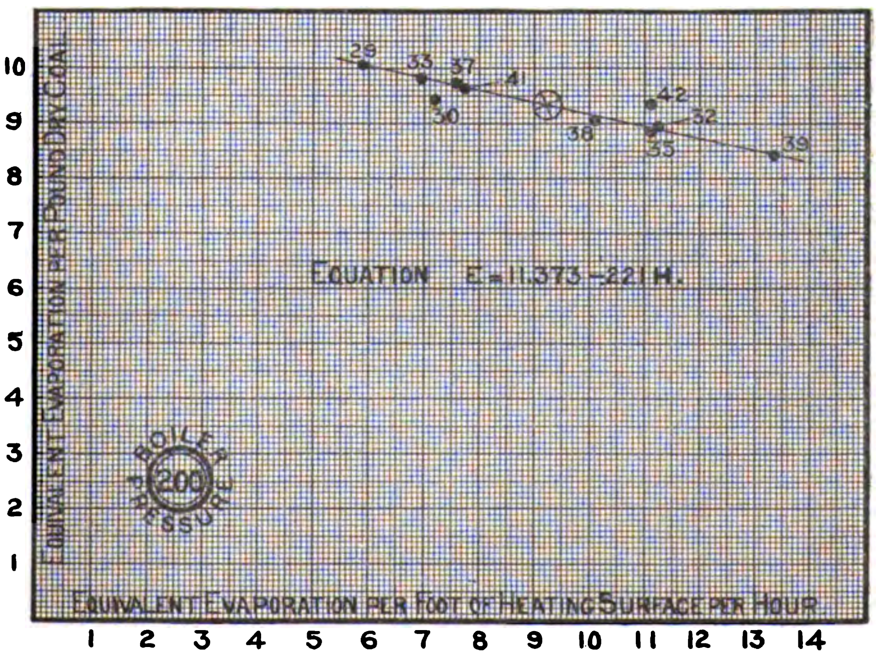


FIG. 9.—Water evaporated per pound of coal.

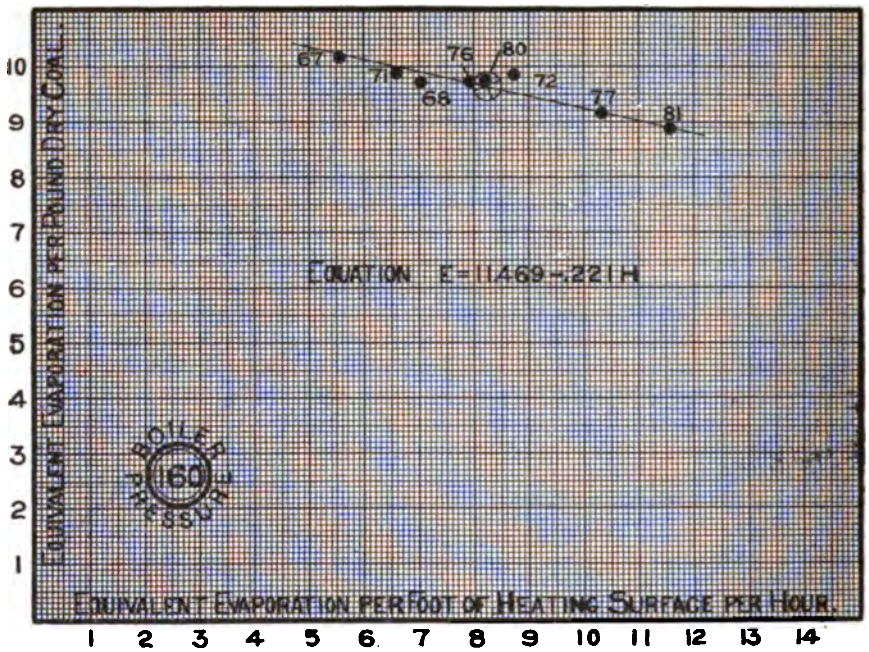


Fig. 10.—Water evaporated per pound of coal.

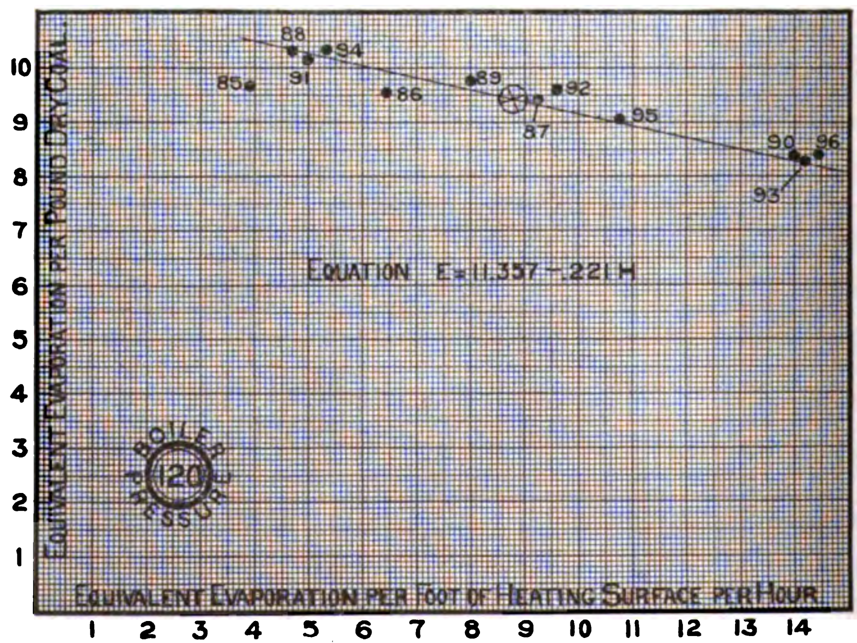


Fig. 11.—Water evaported per pound of coal.

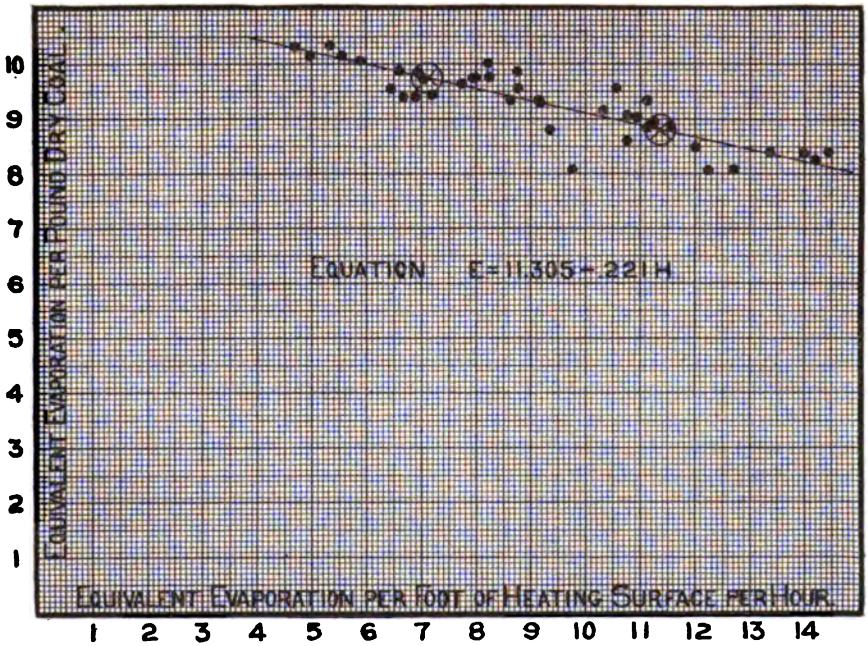


FIG. 12.—Evaporation per pound of coal under all conditions of pressure.

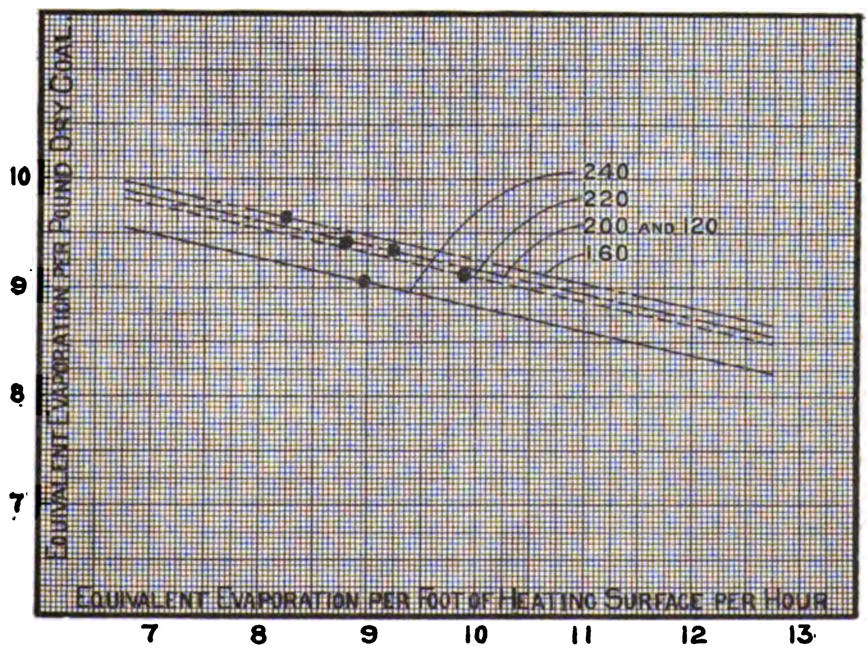


FIG. 13.—Evaporation per pound of coal under different conditions of pressure.

12. SMOKE-BOX TEMPERATURES.—The temperatures of the smoke-box gases were read from a high-grade mercurial thermometer. Numerical values will be found in column 36 (Appendix II) of the data. In all cases the temperature of the smoke-box increases as the rate of evaporation is increased, this relation being well shown by figs. 14 to 18, inclusive. In locating the lines which are drawn upon these figures, the average of all points was first obtained and entered as a cross within a circle. Through this derived point a straight line was then drawn, its slope being determined from an inspection of the points. An inspection of the diagrams will show them to be very similar for all pressures. All have the same slope, and, if superimposed, they would fall very closely together. Thus, they show that when the rate of evaporation is 9 pounds per foot of heating surface per hour, the smoke-box temperature for all pressures is between the limits of 700° and 730° F. There are but four results for a pressure of 240 pounds, in comparison with eight or more for other pressures. If the results from the tests at 240 pounds pressure be omitted it will be found that those remaining, which represent a range of pressure from 220 pounds to 120 pounds, are nearly identical. This is best shown by the equations of the curves in question, which are given in table 1.

TABLE 1.—*Smoke-box temperatures under different pressures.*

Boiler-pressure.	Equations.
220 pounds......	$T = 496.3 + 25.66\ H$
200 pounds......	$T = 491.0 + 25.66\ H$
160 pounds......	$T = 487.7 + 25.66\ H$
120 pounds......	$T = 478.9 + 25.66\ H$
Average......	$T = 488.5 + 25.66\ H$

The average of the several equations represents the average of any of the several groups of results obtained under different pressures, with an error which in no case exceeds 10° F., or 2 per cent.

Again, the equations show that the effect of increasing the pressure from 120 pounds to 220 pounds is to increase the smoke-box temperature 17°; that is, an increase of pressure of nearly 100 per cent results in an increase of smoke-box temperature of approximately 3.5 per cent.

In the preceding statements is to be found an explanation of the constancy in the evaporative efficiency of the boiler under different steam-pressures. The fact seems to be that the water in the boiler is about as effective in absorbing the heat of the gases when its temperature is 400° (240 pounds prèssure) as when its temperature is but 350° (120 pounds pressure).

The data sustain the following conclusions:

1. The smoke-box temperature falls between the limits of 590° F. and 850° F., the lower limit agreeing with a rate of evaporation of 4 pounds per foot of heating-surface per hour and the latter with a rate of evaporation of 14 pounds per foot of heating-surface per hour.

2. The smoke-box temperature is so slightly affected by changes in steam-pressure as to make negligible the influence of such changes in pressure for all ordinary ranges.

3. The equation $T = 488.5 + 25.66\ H$, where T is the temperature of the smoke-box expressed in degrees F. and H is pounds of water evaporated from and at 212° per foot of heating-surface per hour, possesses a high degree of accuracy.

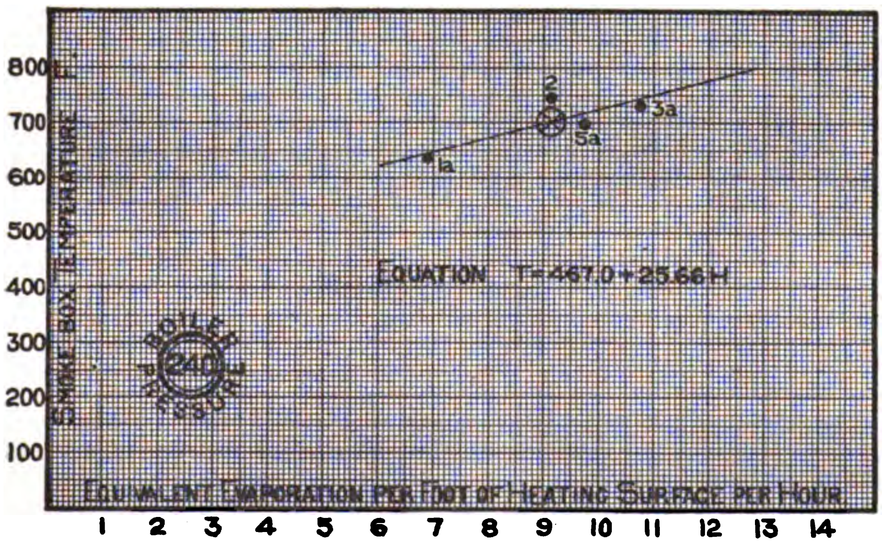
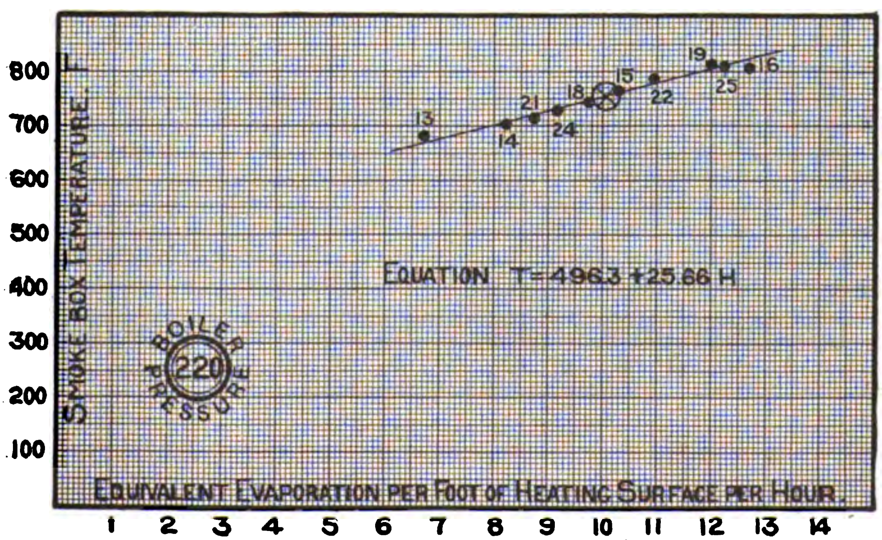


Fig. 14.—Smoke-box temperature.



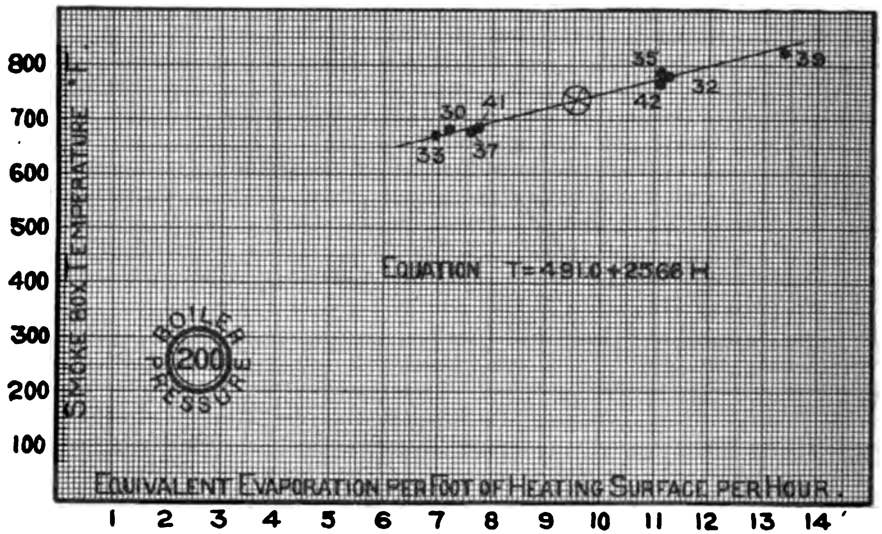


FIG. 16.—Smoke-box temperature.

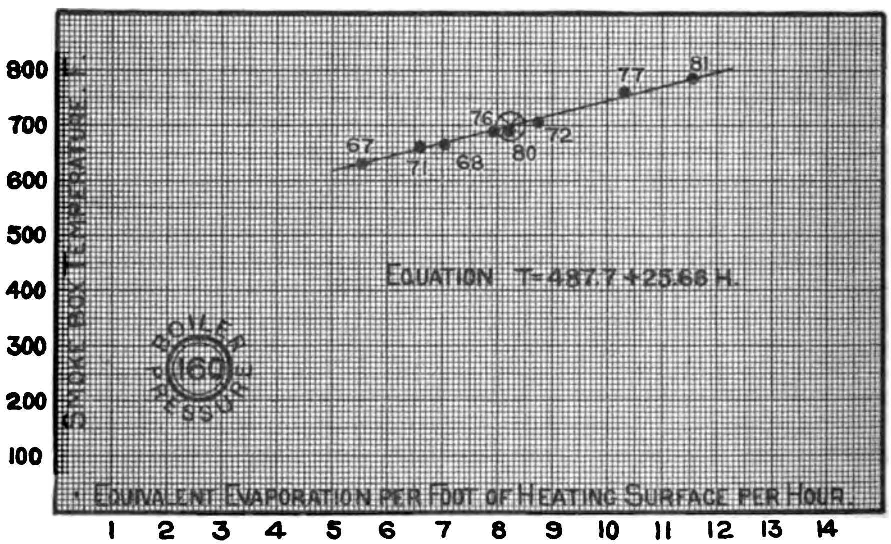


FIG. 17.—Smoke-box temperature.

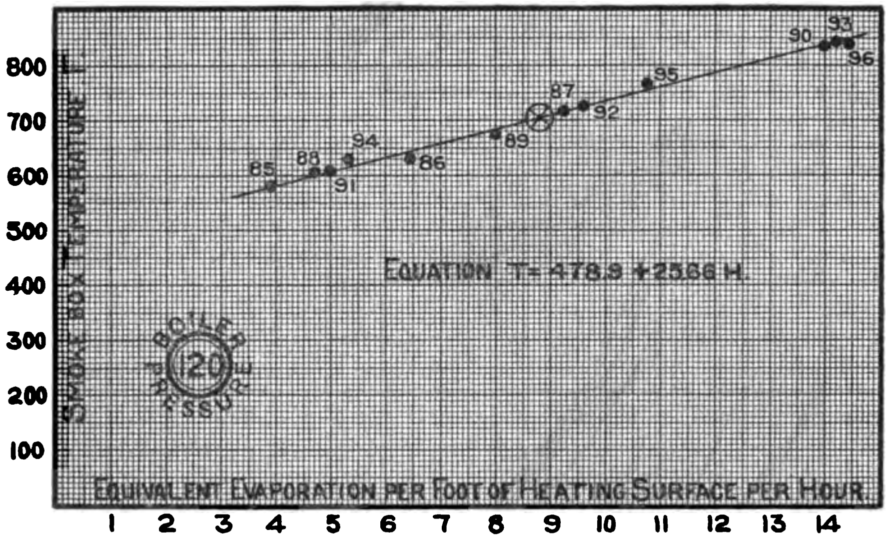


FIG. 18.—Smoke-box temperature.

13. DRAFT (Appendix II, columns 33 to 36).—The term "draft," as herein employed, represents a reduction of pressure as compared with that of the atmosphere expressed in inches of water. The draft was observed at three different points between the ash-pan and the stack. These were the smoke-box in front of the diaphragm, the smoke-box back of the diaphragm, and the fire-box. At each of these points connection was made with a U-tube containing water. The results for each different steam-pressure are given in figs. 19 to 23. In these figures the solid points represent the draft in the smoke-box in front of the diaphragm, the crosses the draft behind the diaphragm, and the circles the draft in the fire-box. Expressing the results in other terms, it appears that vertical distances between the highest curve and the intermediate represent the resistance of the diaphragm; vertical distances between the intermediate and the lowest curve the resistance of the tubes, and vertical distances between the lowest curve and the axis the resistance of the ash-pan, the grate, and the fire upon it. Values under this curve are a close approach to the effective draft. In general, draft values vary greatly with the conditions at the grate. A thin, clean fire results in comparatively low draft values throughout the system, while a thick fire, or one which is choked by clinkers, leads to the reverse results. It is for this reason that individual points representing draft sometimes vary widely from the mean of all results. By comparing the several curves (figs. 19 to 23) it will be seen that the draft is not much affected by changes in pressure. For

example, when the rate of evaporation is 10 pounds per foot of heating-surface per hour, the draft in front of the diaphragm is approximately 4 inches for all pressures. There is, in fact, no reason why the draft should vary materially with changes in pressure.

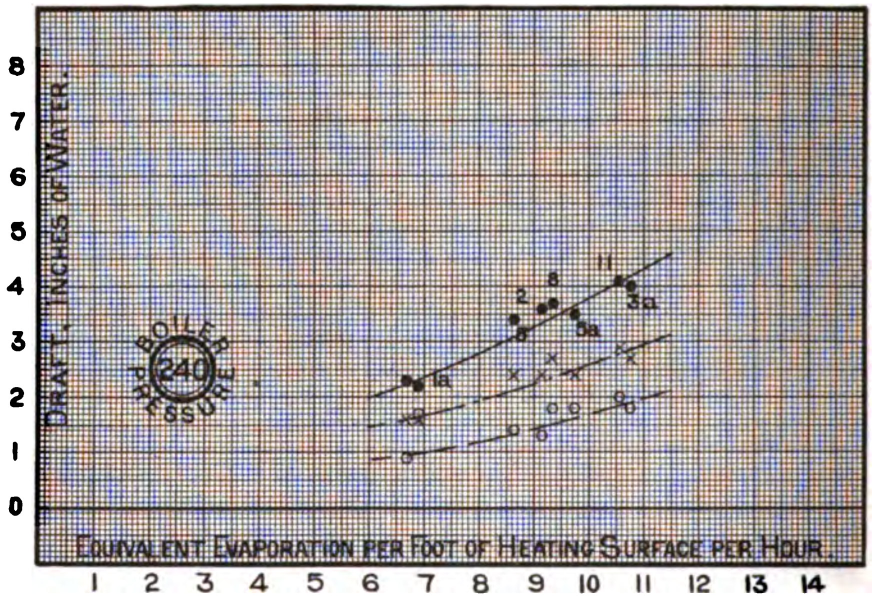


FIG. 19.—Draft.

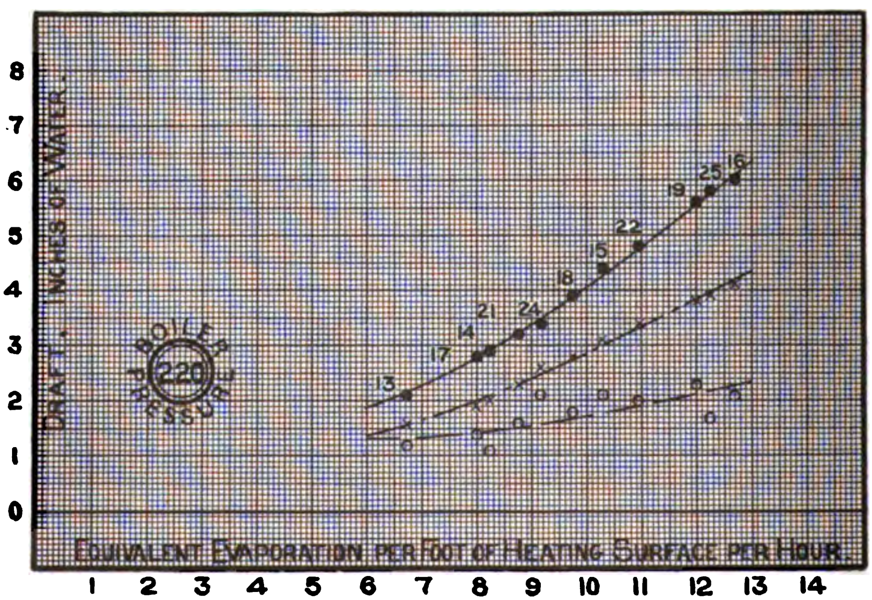


FIG. 20.—Draft.

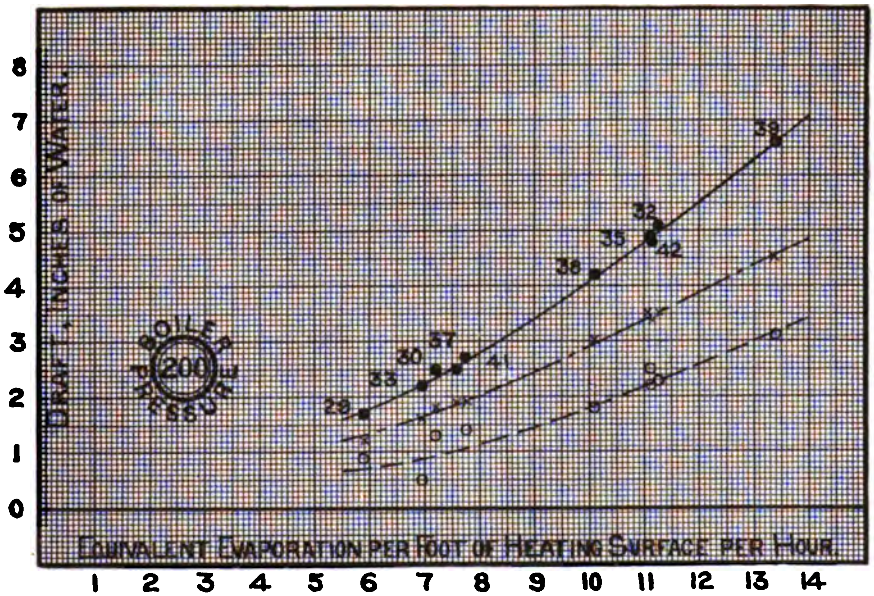


FIG. 21.—Draft.

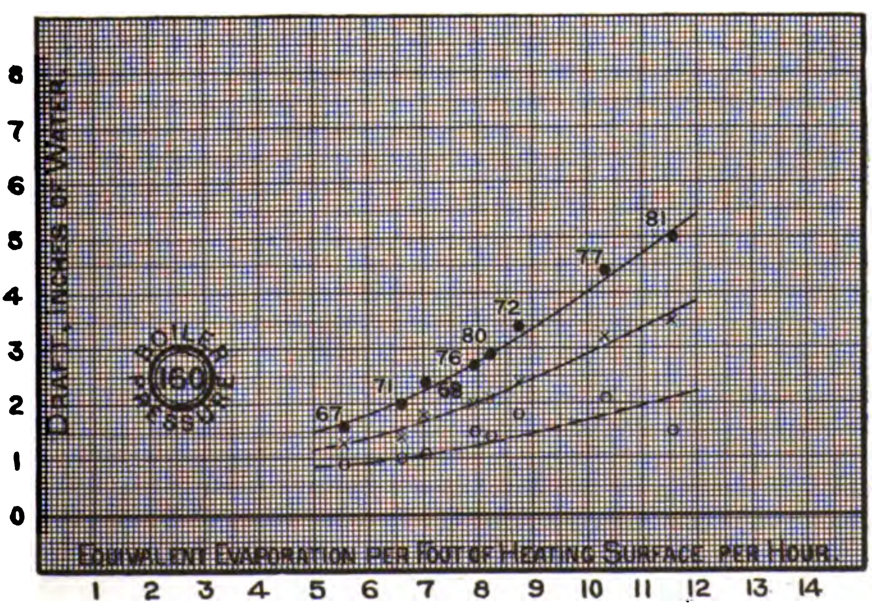


FIG. 22.—Draft.

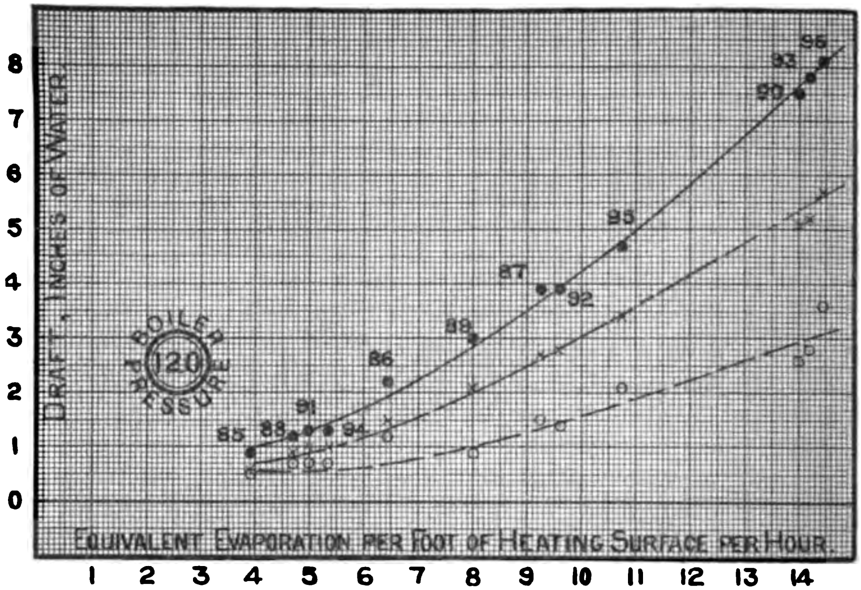


FIG. 23.—Draft.

14. COMPOSITION OF SMOKE-BOX GASES (Appendix II, columns 49 to 52).—As previous experiments had shown irregularities in the evaporative efficiency of boilers of locomotives, it was early decided to proceed with care in determining the composition of the smoke-box gases. It seemed probable that if the composition of these were known for each test, variations in the evaporative efficiency of the boiler might be explained. To this end, therefore, each step in the process was carefully considered, and the work of sampling and analyzing the gases was assigned to a chemist of experience who had no other duties to perform.

The gases were drawn from the smoke-box over mercury, a period of from a half hour to an hour and a half being employed in securing the sample. The sampling-tube was of copper and of small diameter. Its length was sufficient to extend to the center of the smoke-box, and gas was admitted to it by small perforations at the extreme end only. This tube could be drawn in and out through a stuffing-box to permit the sample to be taken either from the center of the smoke-box or from any location between that point and the shell. In securing the sample it was the practice to move the tube systematically at regular intervals of time. By these means it was assumed that abnormal results due to fluctuations in the condition of the fire would be entirely avoided.

The results, notwithstanding all precautions, have not proven entirely satisfactory. That is, where the evaporative performance is abnormal, they do not permit the assignment of a definite cause. The defects are doubtless due to faulty sampling, though it is not clear in what manner the sampling may be improved in connection with locomotive work. They do, however, entirely justify certain general conclusions. They show that the amount of excess air (figs. 24 to 28) admitted to the furnace is never great, and in most cases it is very small—far below the limits which are thought desirable in stationary practice. They show, also, that the excess air diminishes as the rate of combustion increases. It is apparent, therefore, that the loss in efficiency arising from excess air is under normal conditions smaller than in most other classes of service. Moreover, while the supply of air appears limited, it is significant that the losses from imperfect combustion, as shown by the presence of CO, are also small (figs. 29 to 33), the actual amount varying irregularly between limits which are very narrow.

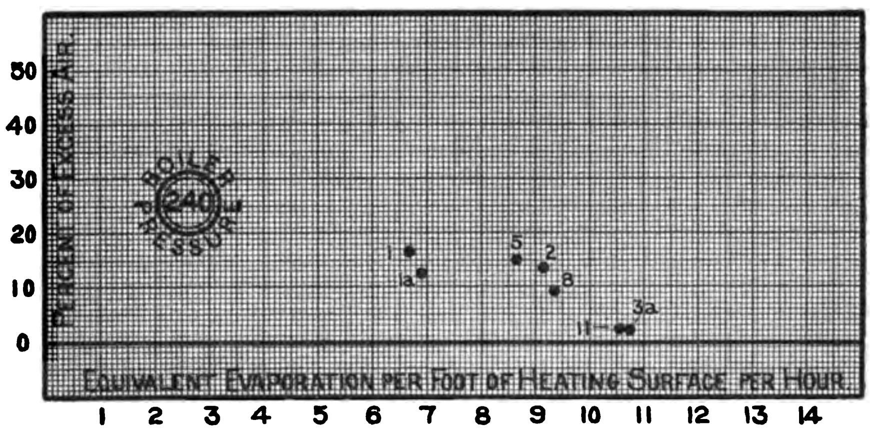


FIG. 24.—Excess air.

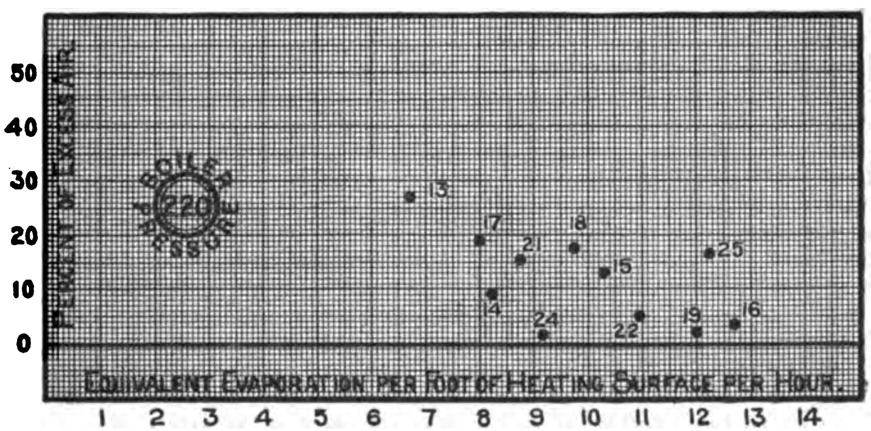


FIG. 25.—Excess air.

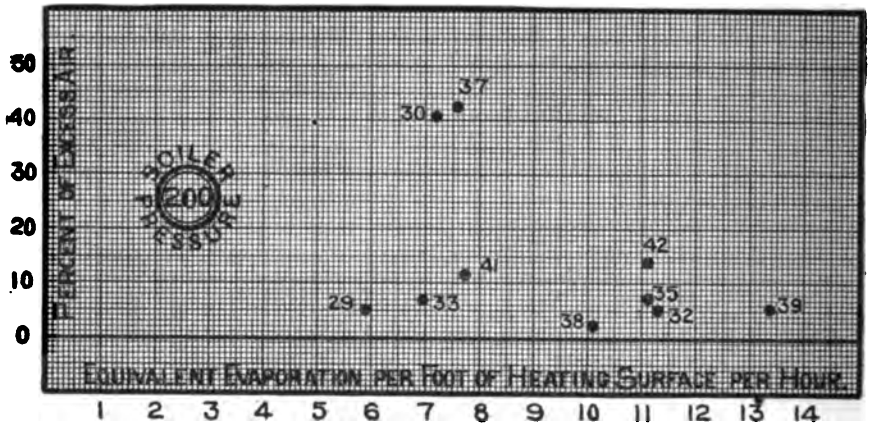


Fig. 26.—Excess air.

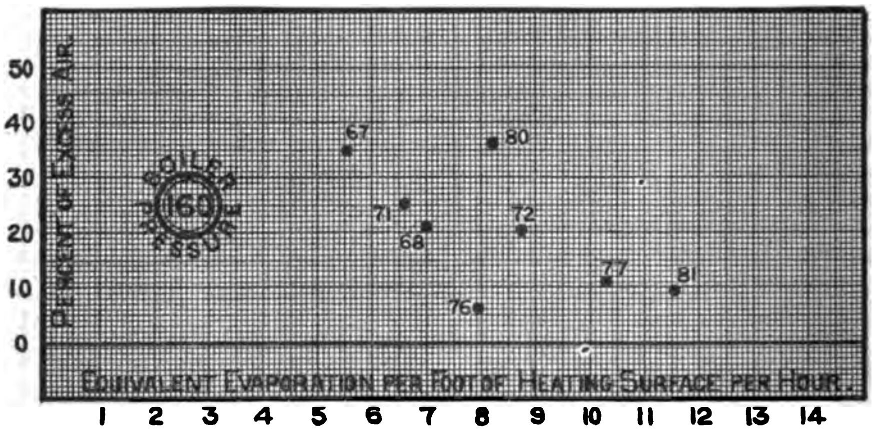


Fig. 27.—Excess air.

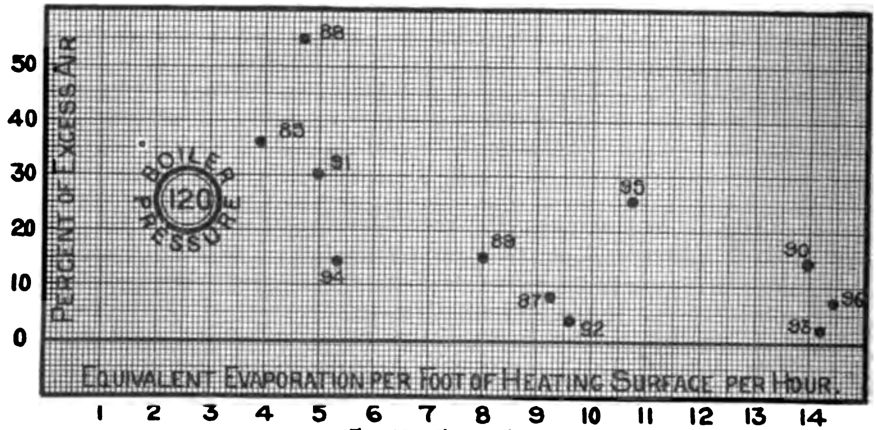


Fig. 28.—Excess air.

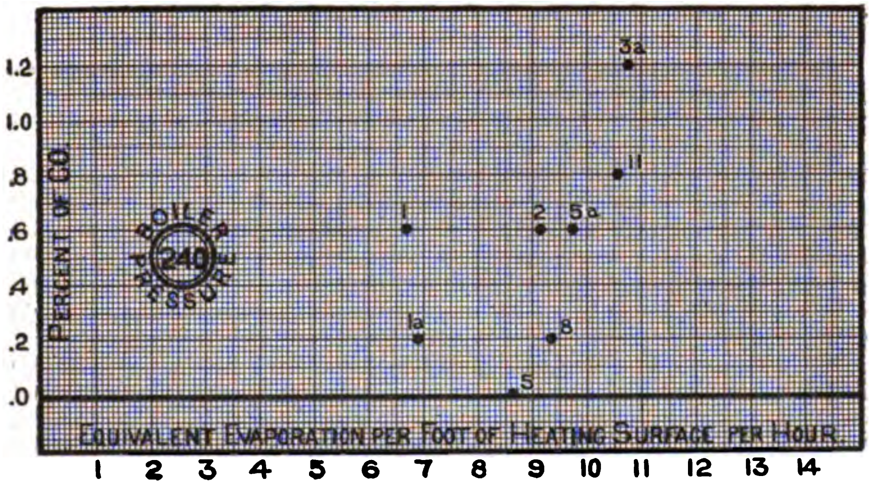


FIG. 29 —Per cent of carbon monoxide in the smoke-box.

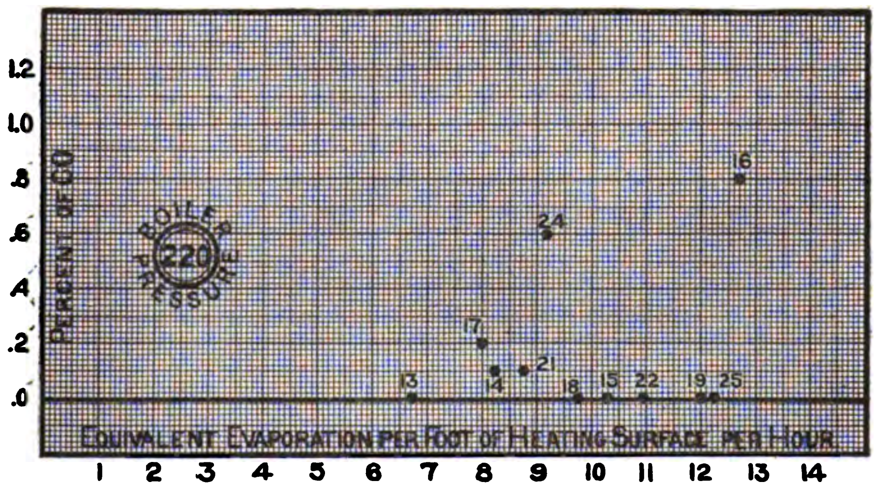
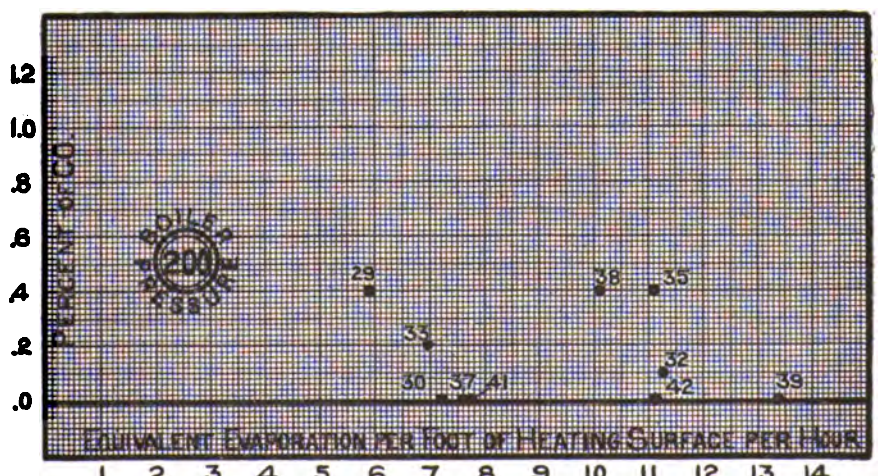


FIG. 30.—Per cent of carbon monoxide in the smoke-box.



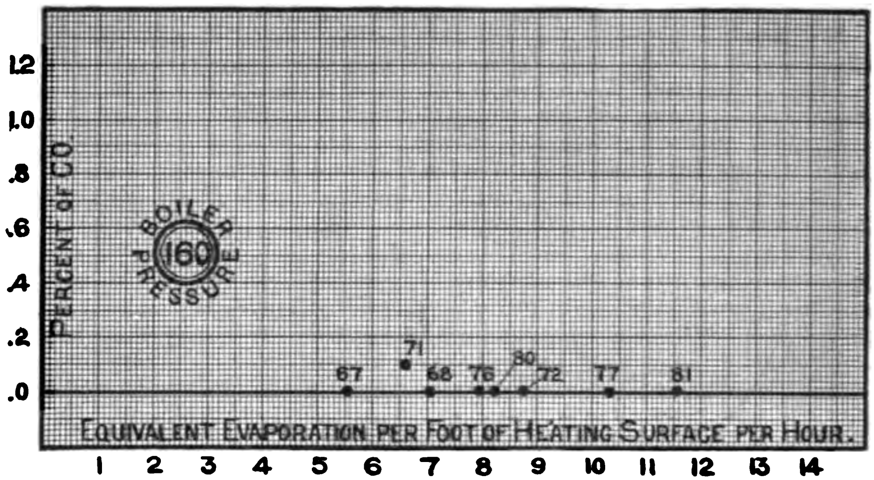


FIG. 32.—Per cent of carbon monoxide in the smoke-box.

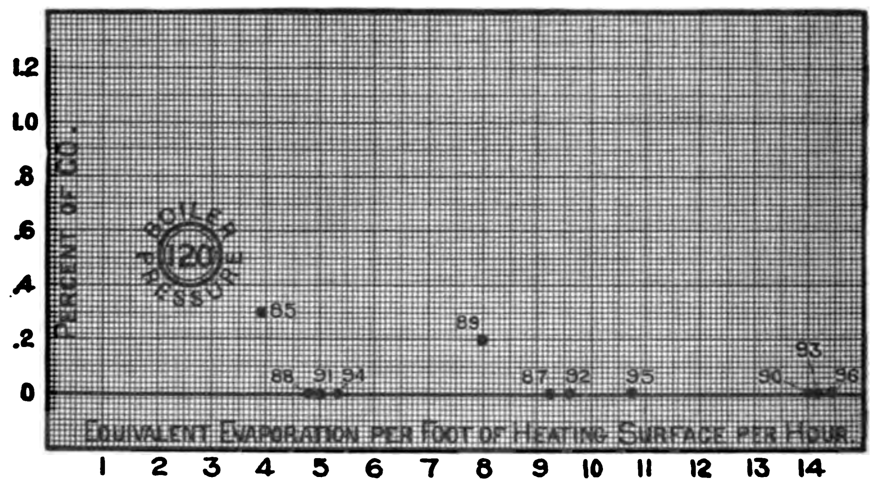


FIG. 33.—Per cent of carbon monoxide in the smoke-box.

15. THE QUALITY OF STEAM (Appendix II, column 21) was uniformly high under all conditions of pressure, the average for all tests being 99.08. The quality declined slightly with increase of pressure, but in no case does the moisture exceed 1.35 per cent.

IV. ENGINE PERFORMANCE.

16. Indicator-Cards.—The form of the cards as taken is shown by figs. 34 to 39. In comparing these figures it will be well to remember that the springs used in the indicators were changed from time to time as the pressure under which the locomotive operated was changed. One result of this practice is that the apparent height of the cards does not change materially with changes in pressure. To aid in estimating the significance of the cards upon each diagram, a scale of the spring employed is presented therewith.

Each pair of indicator-cards shown by full lines represent conditions under which an efficiency test was run. Those shown have been selected as representative of the average conditions of the test and in all cases are for the right side of the engine. The data of the test represented by any pair of cards will be found in Appendix II.

The indicator-cards shown by dotted outline upon the diagrams represent conditions for which it was found impracticable to continuously operate the engine, the capacity of the boiler being insufficient to supply steam to meet the demands of the cylinders. Short runs, however, were possible, and it was during such runs that the cards in question were obtained. By their use it is possible to extend comparisons involving the effect upon the form of the cards of changes in speed and cut-off.

As the small scale at which the cards (figs. 34 to 39) are reproduced makes them insufficient for some purposes of analysis, certain of them, representing typical conditions, reproduced at full size are presented as Appendix IV.

17. The Mean Effective Pressure for the several tests as arranged from all cards taken is shown by figs. 40 to 45 (Appendix II, columns 101 to 105). The values within the full-lined rectangles represent efficiency tests; those within the dotted-lined rectangles, conditions involving the consumption of steam in excess of that which the boiler could continuously supply. Each figure discloses the entire range of action under which it is found practicable continuously to operate the locomotive at the pressure given. A review of the several figures will show the extent to which the possible range of cut-off under a full open throttle is reduced with each increment of pressure. For example, under 120 pounds pressure it is possible to operate at 30 miles with the reverse lever in the fourteenth notch from the center, while at 240 pounds the longest cut-off under similar conditions of speed is represented by the fourth notch of the reverse lever. It is of interest to note, also, that within the range of the experiments each change in the position of the reverse lever results in a change in power which is nearly proportional to the extent of the movement of the reverse lever. The effect upon the mean effective pressure of changes in speed is well shown by each of the several diagrams.

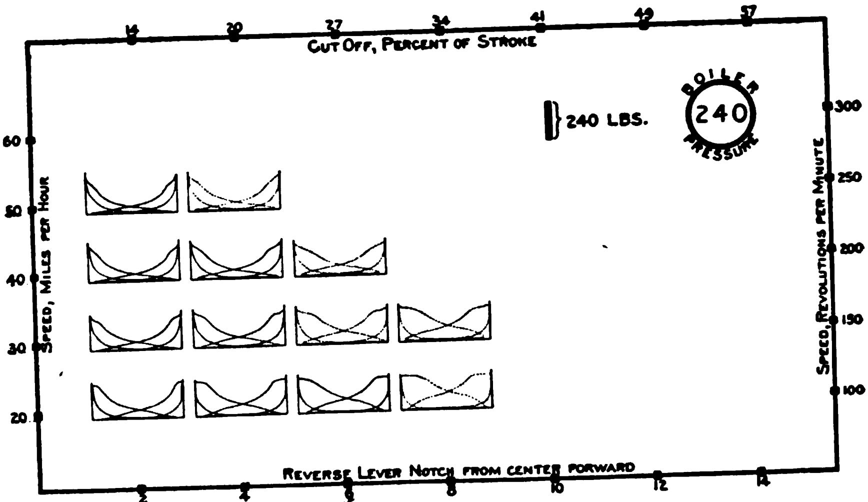


Fig. 34.

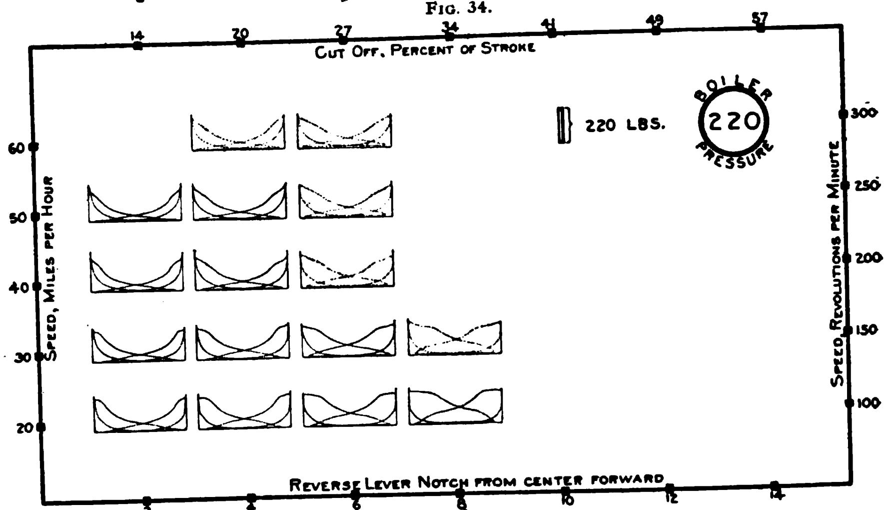


Fig. 35.

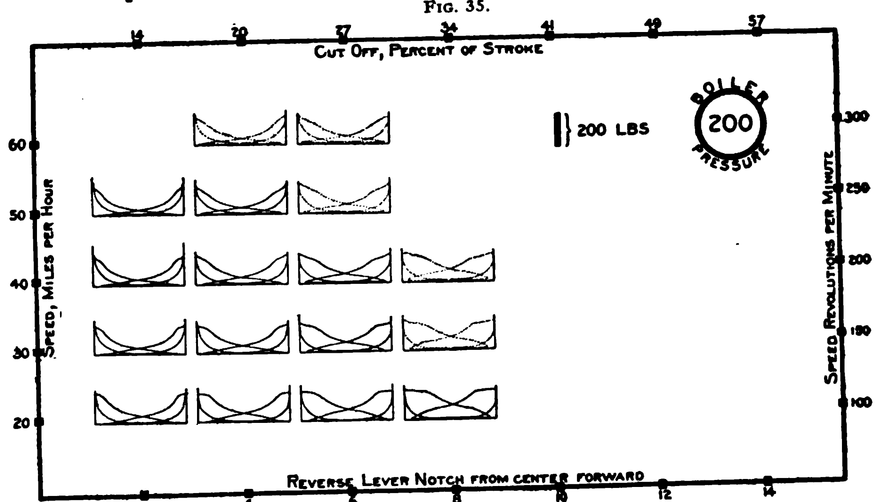


Fig. 36.

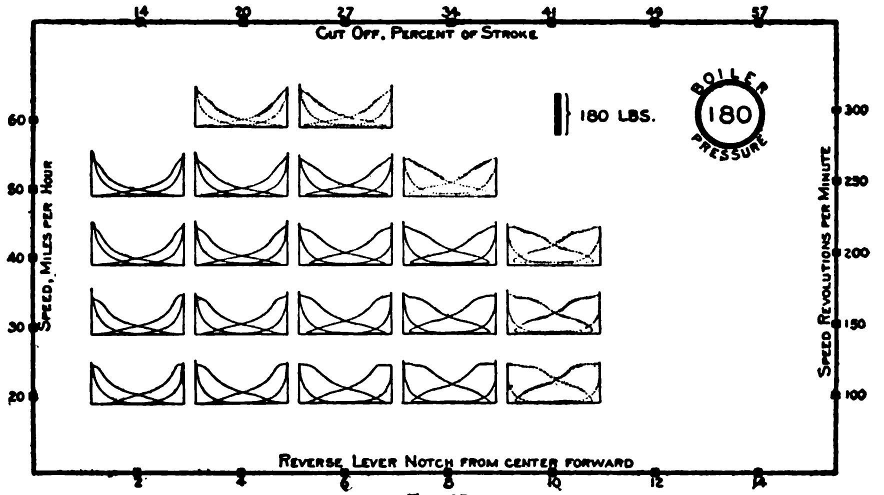


Fig. 37.

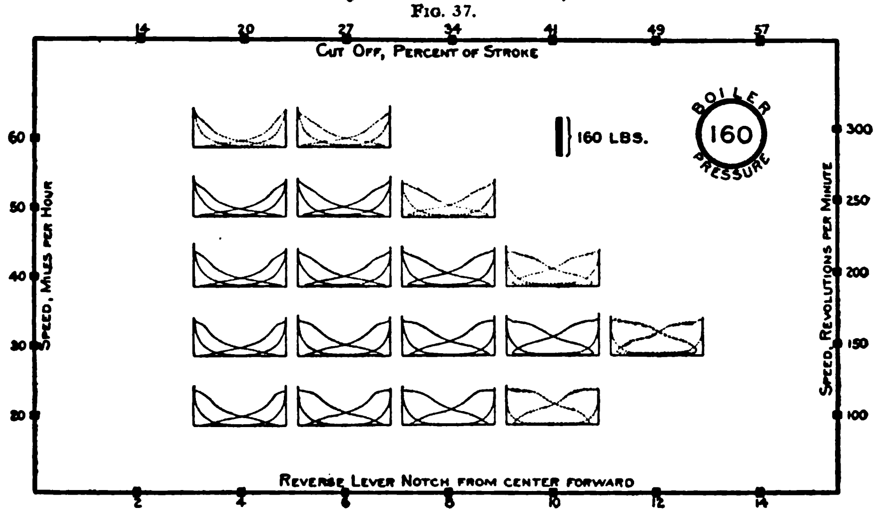


Fig. 38.

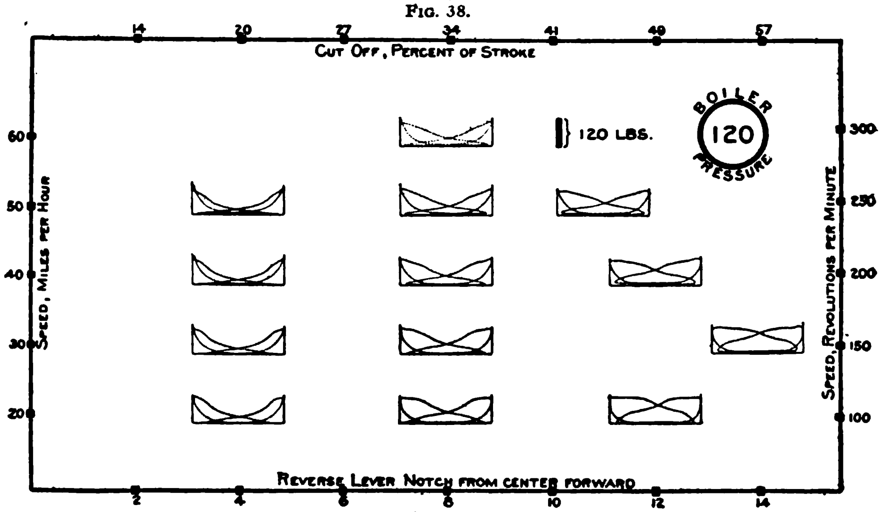


Fig. 39.

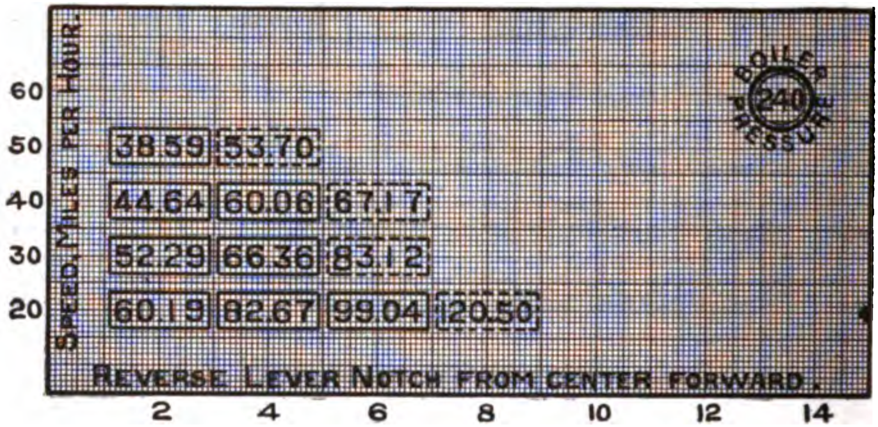


FIG. 40.—Mean effective pressure.

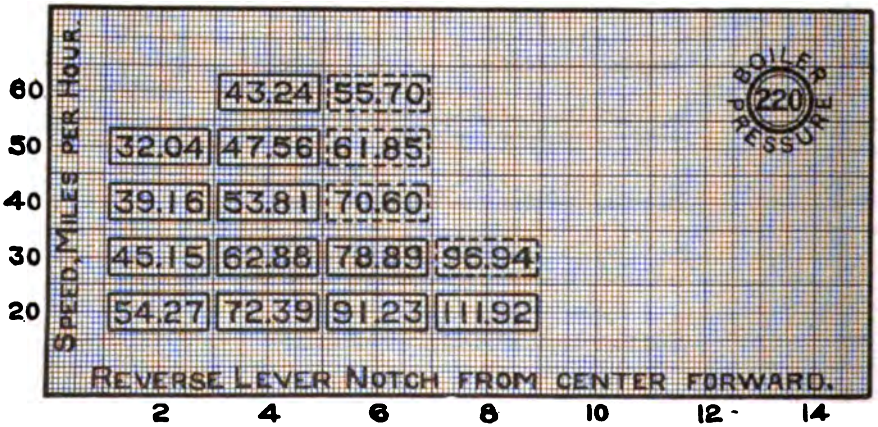


FIG. 41.—Mean effective pressure.

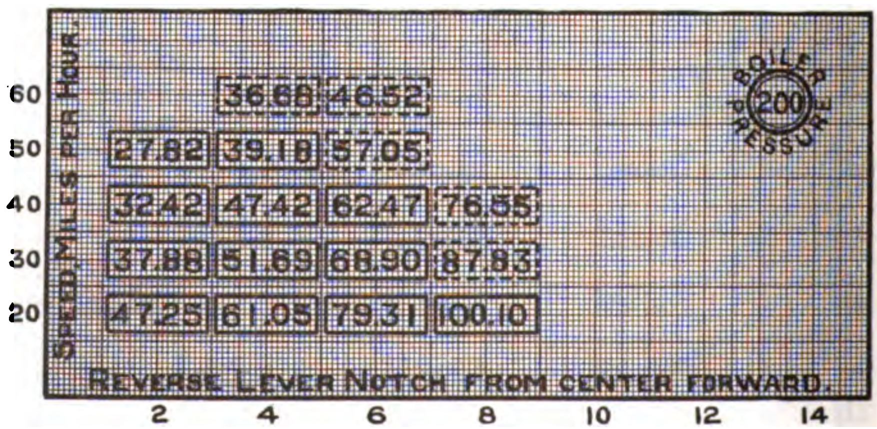


FIG. 42.—Mean effective pressure.

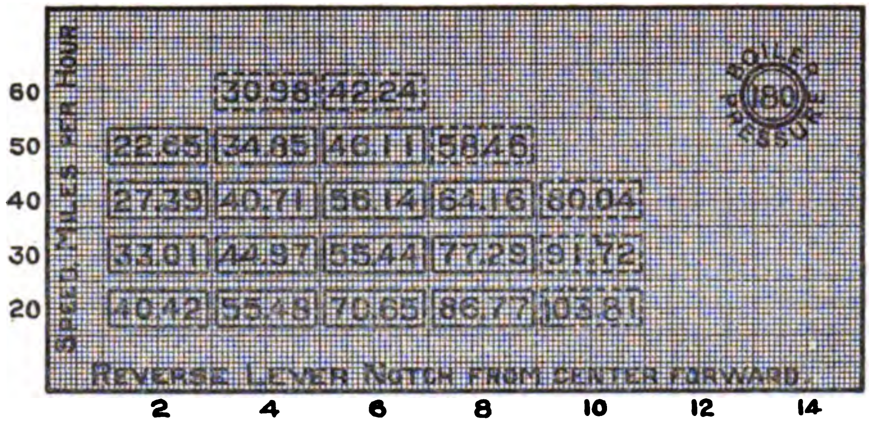


Fig. 43.—Mean effective pressure.

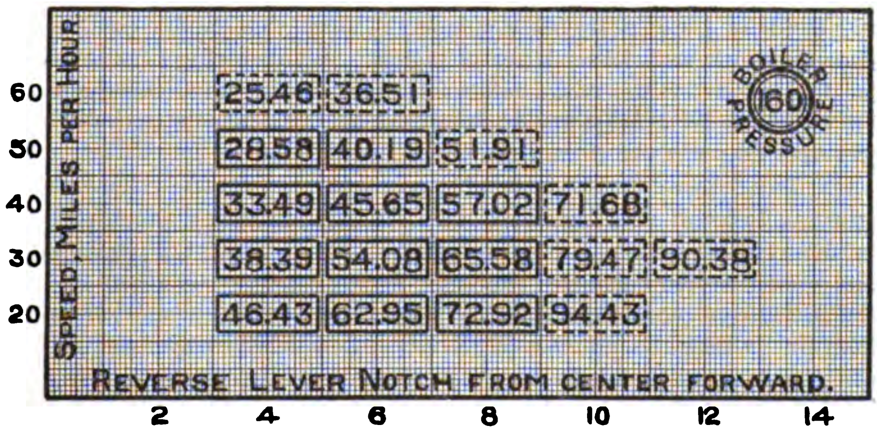


Fig. 44.—Mean effective pressure.

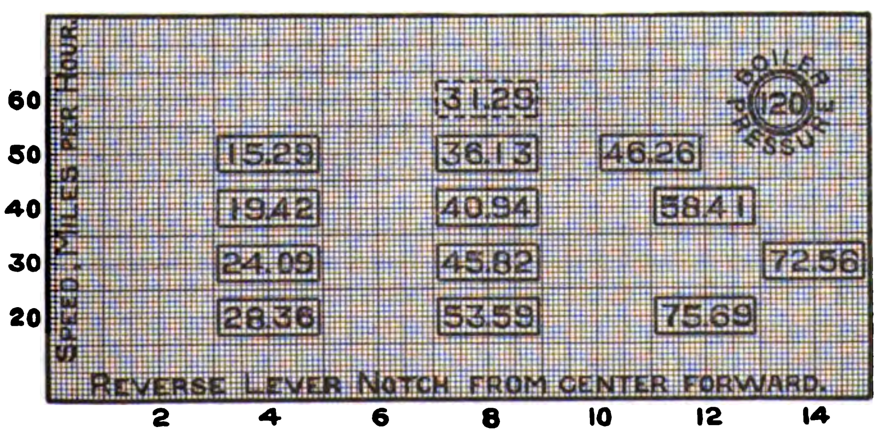


Fig. 45.—Mean effective pressure.

18. THE INDICATED HORSEPOWER for the several tests is shown by figs. 46 to 51 (columns 106 to 110, Appendix II). It will be seen that the range for all pressures falls between the limits of 134 and 610 horsepower. It appears from the results that with the coal used during the tests the normal power of the locomotive tested, when run at speed, is between 450 and 500 horsepower. The development of more than 500 horsepower was always attended by unusual efforts on the part of the fireman. By reference to fig. 46 it will be seen that the power of the engine, under a pressure of 240 pounds, was readily developed with the reverse lever in the second and fourth notches, while under 120 pounds pressure (fig. 51) either a high speed or a much longer cut-off must be employed before this condition is reached. All this, of course, grows out of the fact that in experiments involving a wide range of pressure the cylinder volume remained constant. It is significant that the only two tests giving a horsepower in excess of 600 were run at 180 and 200 pounds, respectively. It will hereafter be shown that the operation of the engine under these pressures was more efficient than under conditions of pressure which were either lower or higher. Remembering that the figures (46 to 51) disclose the entire range for which it was practicable to operate the engine under a full throttle, it will be seen at a glance that the higher pressures do not serve to increase the output of power.

19. THE STEAM PER INDICATED HORSEPOWER PER HOUR is shown by figs. 52 to 57 (column 111, Appendix II). The high efficiency which is implied by these results, and the narrow range which they represent, taken in connection with the comprehensive character of the running conditions involved, are matters of more than ordinary importance. For example, it appears from fig. 52 that at a pressure of 240 pounds the engine experimented upon, when working under a fully open throttle, gave a horsepower hour in return for the consumption of less than 24 pounds of steam, and under any condition of speed or cut-off for which it was found possible to operate the engine under a wide open throttle the consumption never exceeded 26.3 pounds. At lower pressures, involving the possibility of a wider choice in the condition of operating, the range is somewhat increased. Thus, at 120 pounds pressure (fig. 57) the minimum value is 27.5 and the maximum 33.8, a range which, while greater than that just referred to, is nevertheless extremely narrow as compared with the range incident to the operation of other classes of engines.

The most efficient point of cut-off for the lowest pressure is evidently that secured when the reverse lever is in the eighth notch, which is equal to 35 per cent of the stroke. At 200 pounds pressure the most efficient cut-off is that represented by the sixth notch, or 27 per cent of the stroke, and the data do not disclose that a shorter cut-off than this under a full-open throttle is profitable for the engine experimented upon, even though the pressures be raised to 240 pounds.

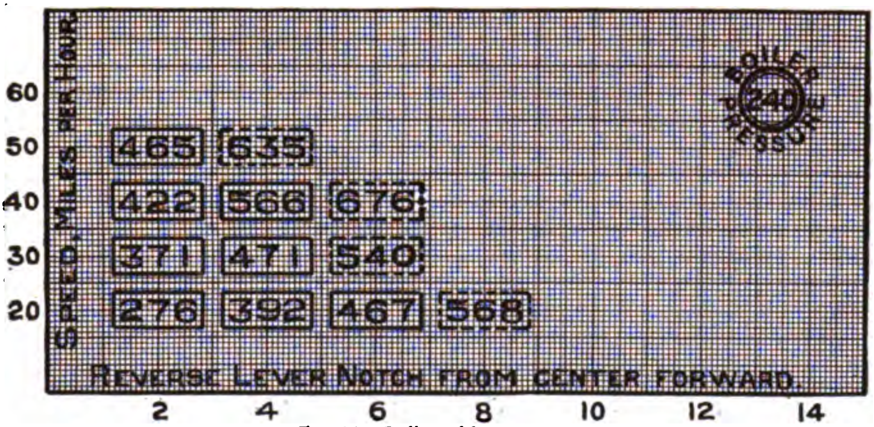


FIG. 46.—Indicated horsepower.

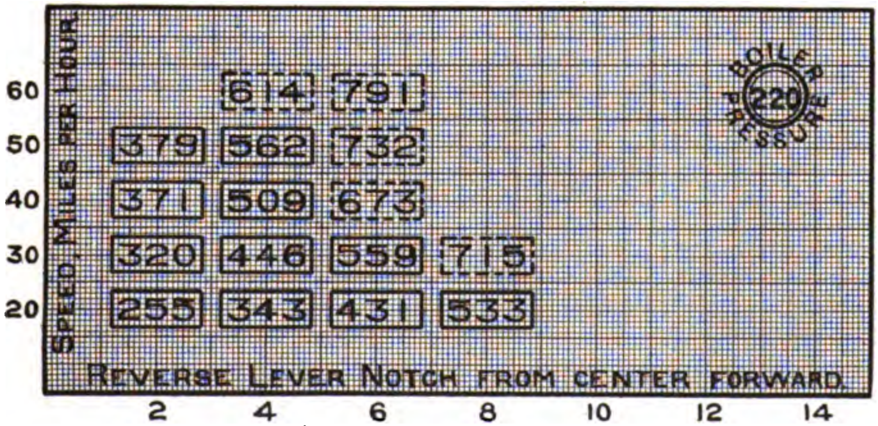
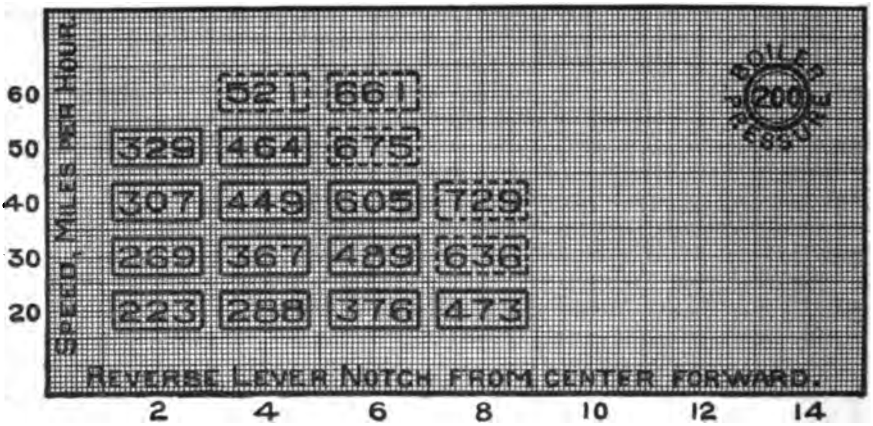


FIG. 47.—Indicated horsepower.

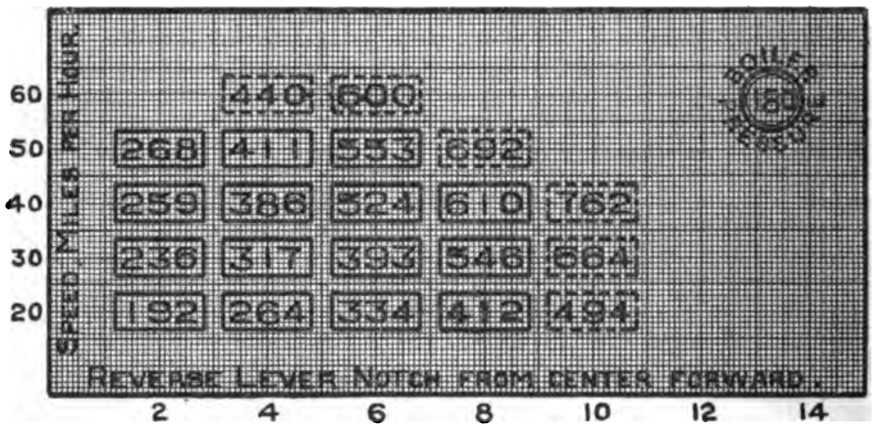
The effect of speed on steam consumption is readily seen by comparing values in vertical columns upon the several diagrams. In all cases the best results are obtained at a speed either of 20 or 40 miles an hour; for all pressures above 160 pounds, the most efficient speed is 40 miles. The law of the change of efficiency with changes in speed has been discussed and the reasons underlying pointed out elsewhere.*

The least steam consumption for each speed under the several different pressures employed is set forth in fig. 58. The values of the figure are of interest. They do not, however, constitute a satisfactory base upon which to form comparisons.

* Locomotive Performance, published by Messrs. John Wiley & Sons.



F.G. 48.—Indicated horsepower.



F.G. 49.—Indicated horsepower.

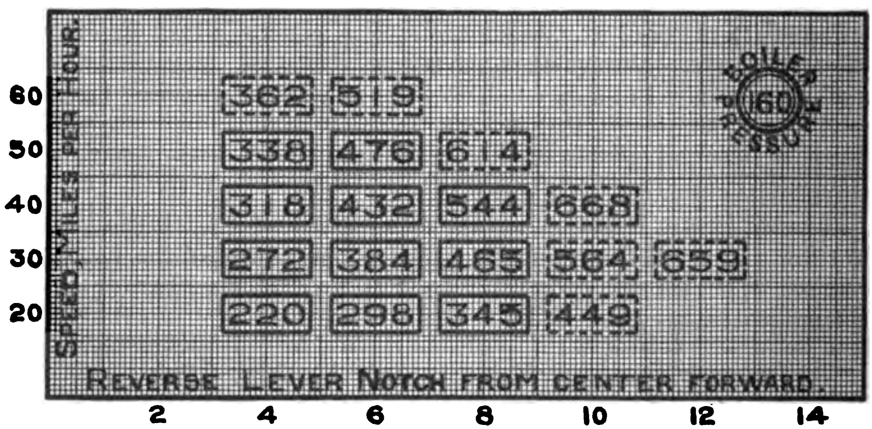


FIG. 50.—Indicated horsepower.

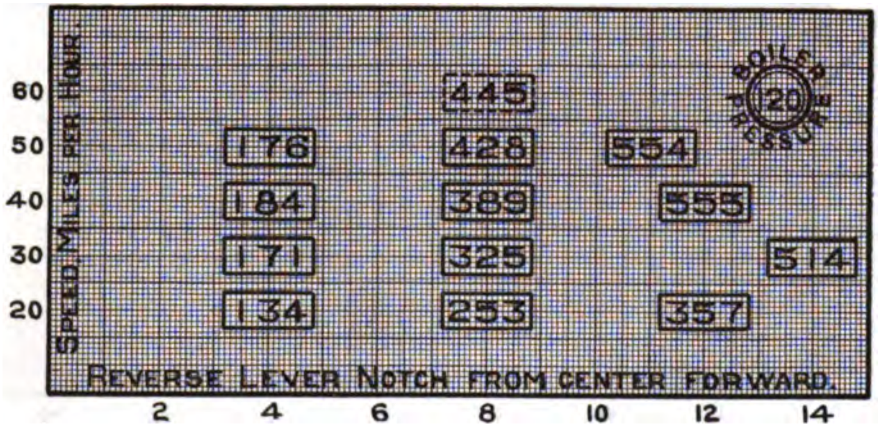


FIG. 51.—Indicated horsepower.

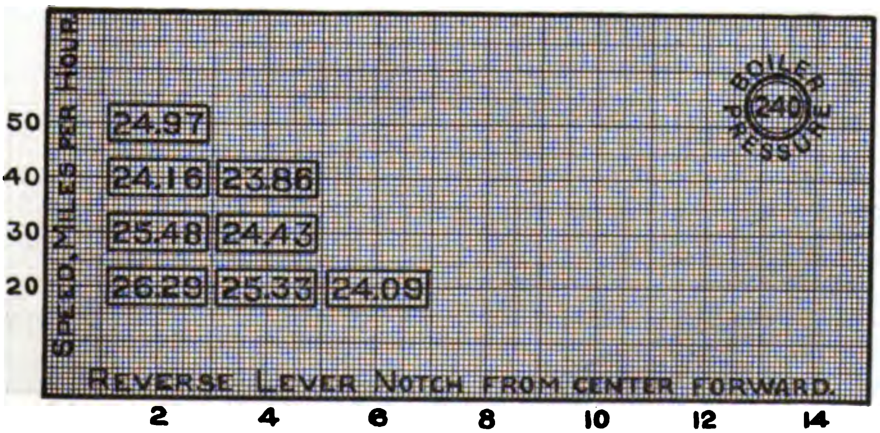


FIG. 52.—Steam per indicated horsepower hour.

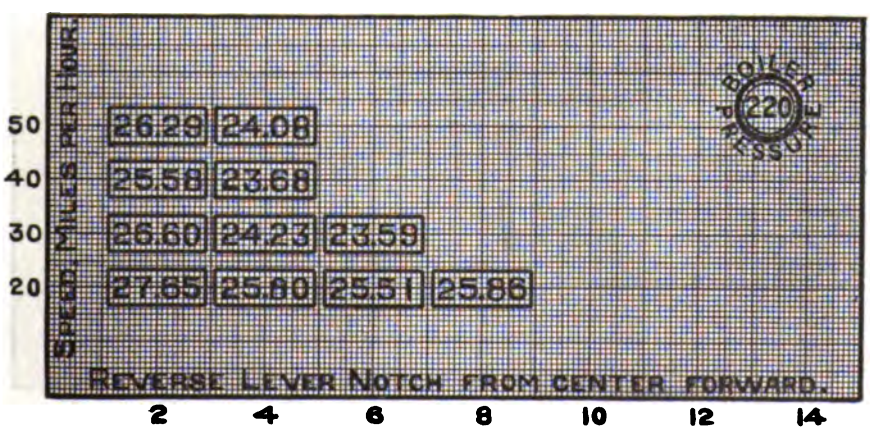


FIG. 53.—Steam per indicated horsepower hour.

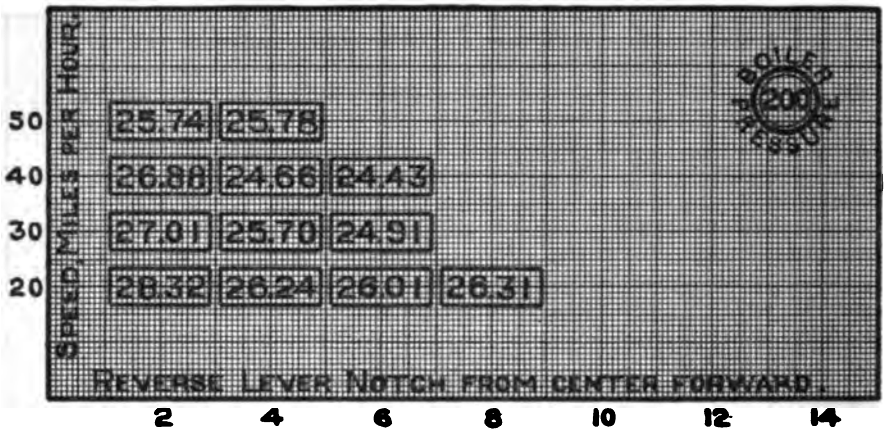


FIG. 54.—Steam per indicated horsepower hour.

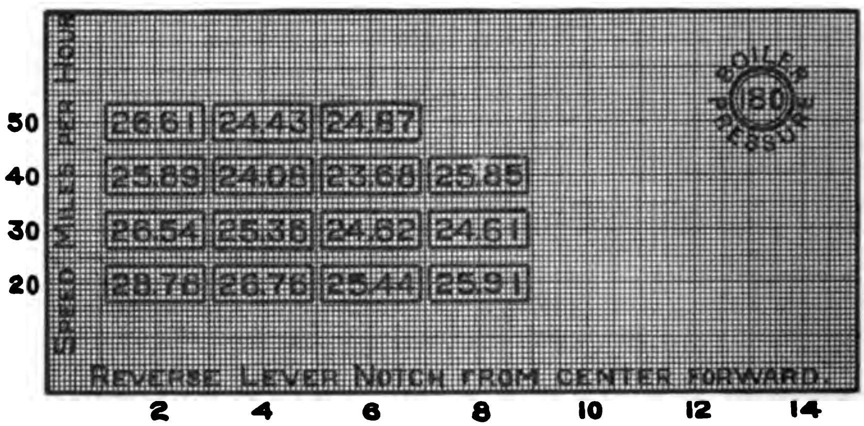


FIG. 55.—Steam per indicated horsepower hour.

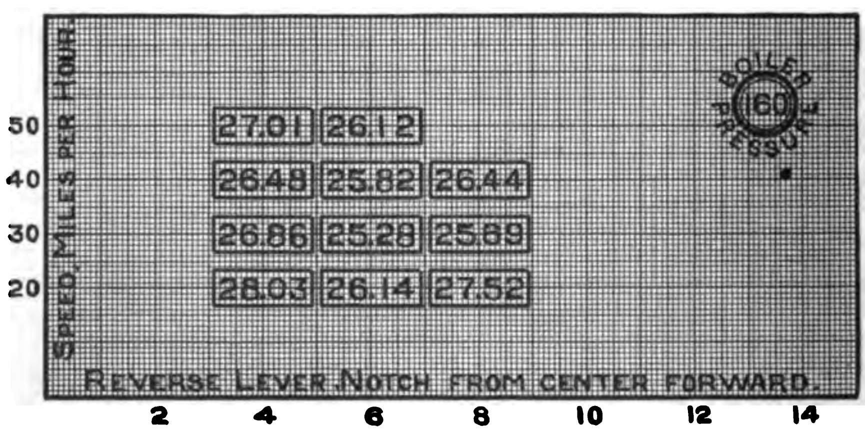


FIG. 56 —Steam per indicated horsepower hour.

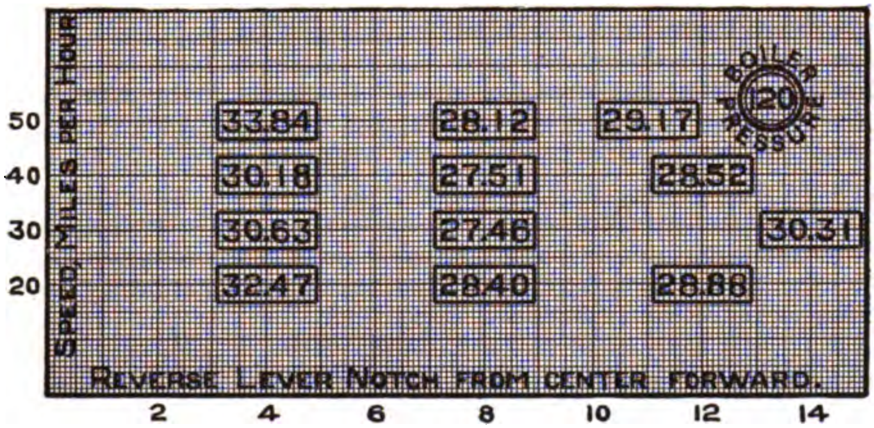


FIG. 57.—Steam per indicated horsepower hour.

Speed, Miles per Hour.	120	160	180	200	220	240
50	28.12	26.12	24.43	25.74	24.08	24.97
40	27.51	25.82	23.68	24.43	23.68	23.86
30	27.46	25.28	24.81	24.91	23.59	24.43
20	28.40	26.14	25.44	26.01	25.51	24.09
AVERAGE.	27.87	25.64	24.54	25.27	24.21	24.34

Boiler Pressure.

FIG. 58.—Least steam for each of the several speeds at different pressures.

20. STEAM CONSUMPTION UNDER DIFFERENT PRESSURES.—The shaded zone upon fig. 59 represents the range of performance as it appears from all tests run under the several pressures employed. For purposes of comparison it is desirable to define the effect of pressure on performance by a line, and to this end an attempt has been made to reduce the zone of performance to a representative line. In preparing to draw such a line, the average performance of all tests at each of the different pressures was obtained and plotted, the results being shown by the circles on fig. 59. Points thus obtained can be regarded as fairly representing the performance of the engine under the several pressures only so far as the tests run for each different pressure may be assumed to fairly represent the range of speed and cut-off under which the engine would ordinarily operate. The best result for each different pressure, as obtained by averaging the best results for each speed at constant pressure, is given upon the diagram in the form of a light cross. These points may be regarded as furnishing a satisfactory basis of comparison in so far as it may

be assumed that when the speed has been determined an engine in service will always operate under conditions of highest efficiency. Again, the left-hand edge of the shaded zone represents a comparison based on maximum performance at whatever speed or cut-off. In addition to the points already described, there is located upon the diagram (fig. 59) a curve showing the performance of a perfect engine,* with which the plotted points derived from the data of tests may be compared. Guided by this curve, representing the performance of a perfect engine, a line *A B* has been drawn proportional thereto, and so placed as to fairly represent the circular points derived from the experiments. It is proposed to accept this line as representing the steam consumption of the experimental engine under the several pressures employed. It is to be noted that it is not the minimum performance nor the maximum, but it is a close approach to that performance which is suggested by an average of all results derived from all tests which were run. Since its form is based upon a curve of perfect performance it has a logical basis, and since it does no violence to the experimental data its use seems justifiable.

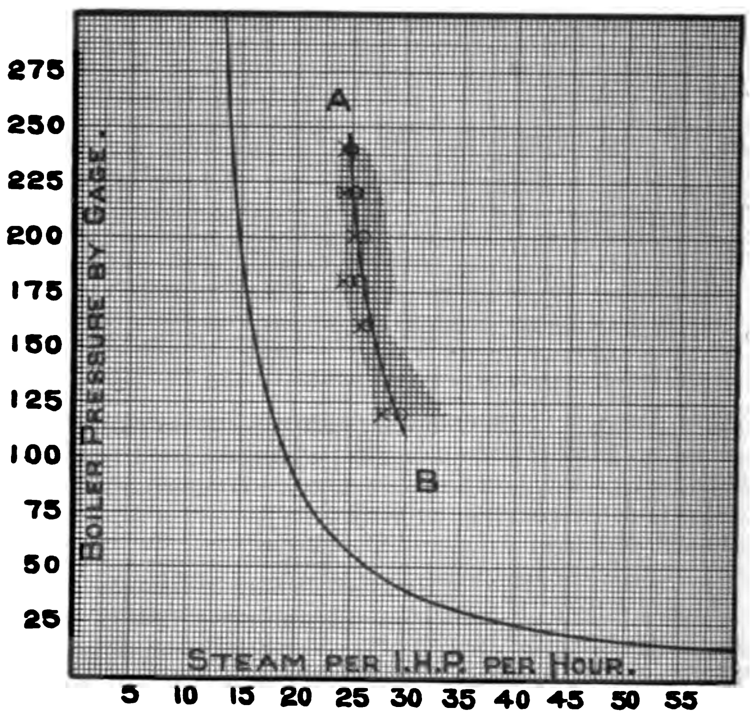


FIG. 59.—Steam consumption under different pressures

*This curve represents the performance of an engine working on Carnot's cycle, the initial temperature being that of steam at the several pressures stated, and the final temperature being that of steam at 1.3 pounds above atmospheric pressure. This latter value is the assumed pressure of exhaust in locomotive service.

21. Coal Consumption.—The results of certain of the tests which were run before the adoption of a standard coal have not been carried out for purposes of comparison, which fact accounts for the blanks appearing in column 113 of the data. An exhibit of all data which is comparable is set forth by figs. 60 to 64. These values, especially if confined to the tests run with the reverse lever in the second, fourth, and sixth notches, show but slight variation in the coal consumed per horsepower hour either with changes of speed or with changes in pressure. The fact, also, that the record shows but 3 out of 46 tests representing a great variety of running conditions, for which the consumption exceeds 4 pounds, argues well for the efficiency of the locomotive in ordinary service.

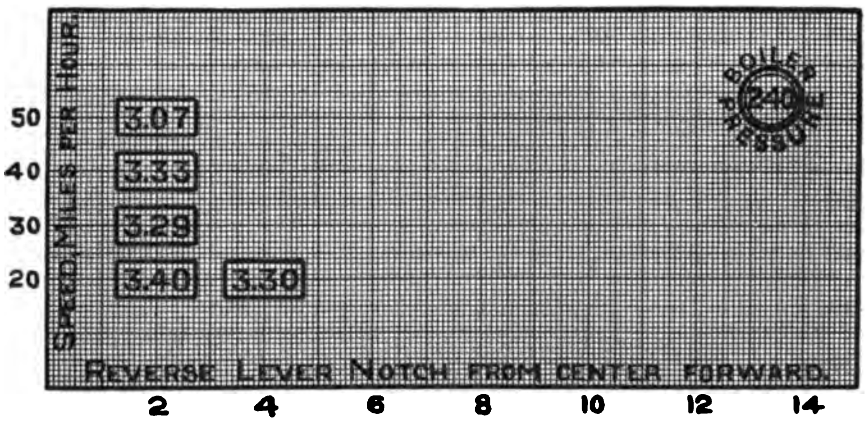


Fig. 60.—Coal per indicated horsepower hour.

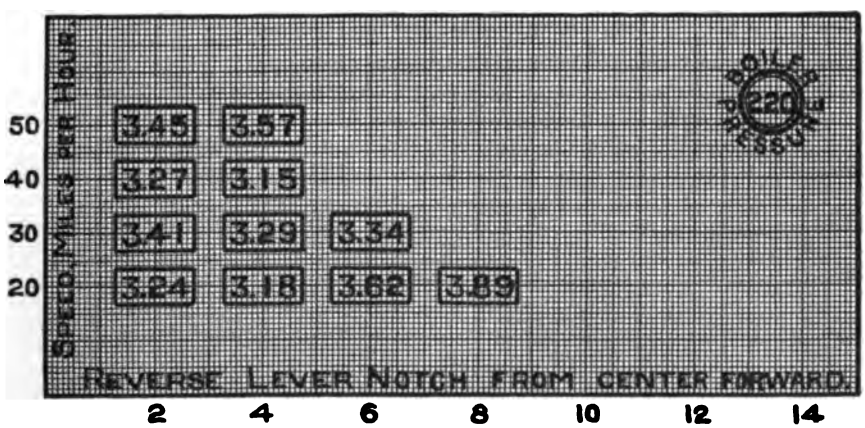


Fig. 61.—Coal per indicated horsepower hour.

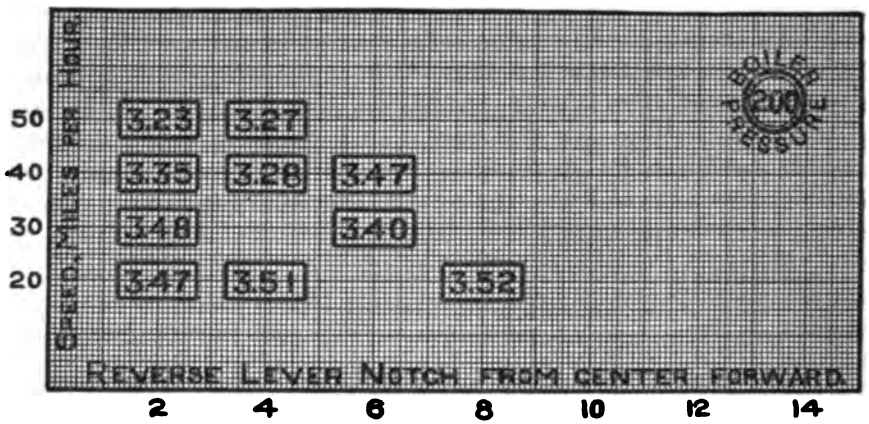


Fig. 62.—Coal per indicated horsepower hour.

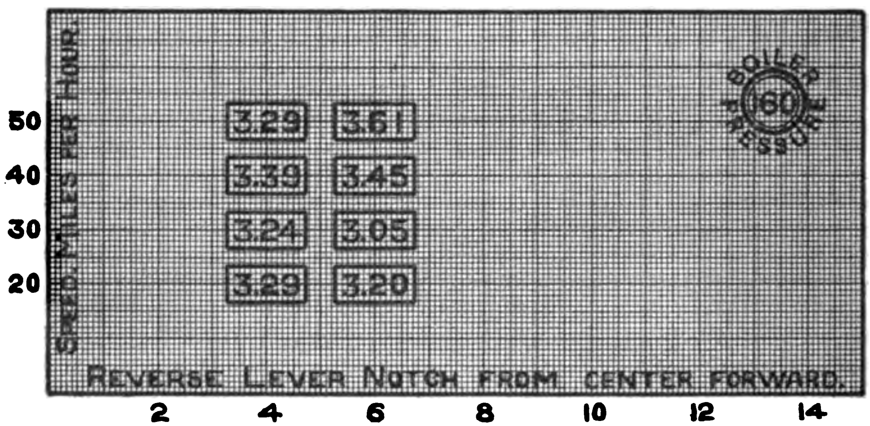


Fig. 63.—Coal per indicated horsepower hour.

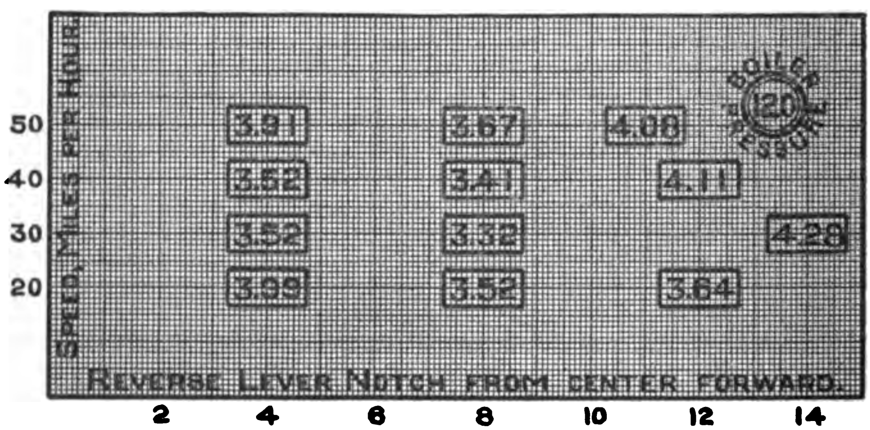


Fig. 64.—Coal per indicated horsepower hour.

22. PERFORMANCE UNDER DIFFERENT PRESSURES, A LOGICAL BASIS FOR COMPARISON.—The record of coal consumption, as set forth in the preceding paragraph, is that actually obtained from the several tests run. It has already been shown that this performance is affected by variations in the evaporative efficiency of the boiler, due doubtless to irregularities in firing, but which are in fact unaccounted for. One of the purposes of the discussion which occupies the preceding chapter has been to reduce the values actually resulting from the tests to a summarized statement which may be accepted as a general definition of performance, assuming all irregularities to have been eliminated. Such a summarized statement is that which is shown by fig. 12. It is also expressed by the equation

$$E = 11.305 - 0.221\ H$$

It is now proposed to determine the coal consumption per indicated horsepower, assuming the boiler efficiency to have been in all cases that which is expressed by this equation.

It appears, also, from the data that the steam consumed by the cylinders varies for each different pressure with changes in speed and cut-off, and it has been sought in the preceding paragraphs to summarize the facts derived from the experiments into a single expression. This appears in the form of the curve *A B*, fig. 59, which is to be accepted as representing the performance of the cylinders under different pressures without reference to speed or cut-off. Combining this general statement expressing cylinder performance with that already obtained covering boiler performance, it should be possible to secure an accurate measure of the coal consumption per indicated horsepower hour, for each different pressure which will represent the results of all tests at that pressure.

The steps in this process are set forth by table 2, in which—

Column 1 gives the several pressures embraced by the experiments.

Column 2 gives the steam consumption per indicated horsepower hour for each of these several pressures as taken from the curve *A B*, fig. 59.

Column 3 gives the number of thermal units in each pound of steam at the several pressures, assuming the feed-water in all cases to have had a temperature of 60° F. The values of this column show at a glance the rate of change in the amount of heat required to supply steam at the different pressures embraced by the experiments.

Column 4 gives the pounds of water from and at 212° F. per indicated horsepower hour. It equals column 2 × column 3 ÷ 965.8.

Column 5 gives the pounds of water evaporated from and at 212° F. per pound of coal and is calculated as follows: Assuming that a fair average load for the locomotive tests is 440 horsepower, and that this unit of power is delivered under all pressures, the corresponding rate of evaporation may be found by multiplying this value by those of column 4 and dividing by the area of heating surface; that is, the rate of evaporation = 440 × column 4 ÷ 1322. The equivalent pounds of water per pound of coal is found by substituting the rates of evaporation found for H in the equation, $E = 11.305 - 0.221\ H$.

Column 6 gives the pounds of coal per indicated horsepower per hour and equals column 4 ÷ column 5.

Column 7 gives the pounds of coal saved per horsepower hour for each 20-pound increment in steam-pressure.

Column 8 gives the percentage saving in coal for each 20-pound increment in steam-pressure.

TABLE 2.—*Engine performance under different pressures.*

Boiler pressure.	Steam per indicated horse-power per hour. Values from curve.	B. t. u. given to 1 pound steam feed-water. (Temp. = 60°.)	Equivalent pounds of water per indicated horse-power hour.	Equivalent pounds of water per pound of dry coal.	Pounds of coal per indicated horse-power hour.	Coal saving for each increment.	
						Lbs.	Per cent.
1	2	3	4	5	6	7	8
240	24.7	1176.6	30.09	9.10	3.31	.06	1.8
220	25.1	1174.4	30.52	9.06	3.37	.06	1.8
200	25.5	1172.0	30.94	9.03	3.43	.07	2 0
180	26.0	1169.5	31.48	8.99	3.50	.09	2.5
160	26.6	1166.8	32.14	8.94	3.59	.18	4.8
140	27.7	1163.8	33.38	8.85	3.77	.23	5.8
120	29.1	1160.5	34.97	8.73	4.00	...	...

The values of table 2, especially those of columns 2 and 6, are of more than ordinary significance. They represent logical conclusions based upon the results of all tests. Comparisons between them will show the extent to which the performance of a locomotive will be modified by changes in the steam-pressure under which it is operated. They show in the matter of steam consumption (column 2) that—

Increasing pressure from 160 to 180 pounds reduces the steam consumption 0.6 pound, or 2.3 per cent.
Increasing pressure from 180 to 200 pounds reduces the steam consumption 0.5 pound, or 1.9 per cent.
Increasing pressure from 200 to 220 pounds reduces the steam consumption 0.4 pound, or 1.6 per cent.
Increasing pressure from 220 to 240 pounds reduces the steam consumption 0.4 pound, or 1.6 per cent.

In the matter of coal consumption (column 6) they show that—

Increasing pressure from 160 to 180 pounds reduces the coal consumption 0.9 pound, or 2.5 per cent.
Increasing pressure from 180 to 200 pounds reduces the coal consumption 0.7 pound, or 2.0 per cent.
Increasing pressure from 200 to 220 pounds reduces the coal consumption 0.6 pound, or 1.8 per cent.
Increasing pressure from 220 to 240 pounds reduces the coal consumption 0.6 pound, or 1.8 per cent.

These values are from actual tests. Those who are inclined to insist upon basing their conclusions upon observed data will perhaps find in them a satisfactory conclusion of the whole investigation. The results show how slight is the gain to be derived from any increment of pressure when the basis of the increments is above 160 pounds. But they do not in fact tell the whole story. In order to secure such results from a single locomotive it was necessary to employ a machine designed for the highest pressure experimented upon. Obviously, for the tests at lower pressure, the locomotive was needlessly heavy for its dimensions. If for the tests under each of the lower pressures the excess weight could have been utilized in providing a boiler of greater heating-surface, the difference in performance with each increment of pressure would have been less than that to which attention has already been called. It is for this reason that the results already quoted, while significant and concise in their meaning, are nevertheless to be accepted as insufficient when regarded as a relative measure of the value of different steam-pressures. An extension of the discussion leading to a more general view of the matter will be found set forth in Chapters VI to VIII.

V. MACHINE FRICTION AND PERFORMANCE AT DRAW-BAR.

23. THE CYLINDERS VS. THE DRAW-BAR AS A BASE FROM WHICH TO ESTIMATE PERFORMANCE.—In the later paragraphs of the preceding chapter results are given disclosing the performance of boiler and engine as based upon cylinder performance. This is a correct basis from which to proceed in discussing the relative advantage of different steam-pressures, for the process of the cylinders represents the last of the thermodynamic changes by which the heat of the fuel is transformed into work. The cylinders are in fact one step nearer the problem in question than the draw-bar, which for many purposes is properly regarded a better basis from which to determine the performance of a locomotive. This being the case, the purpose of the present chapter will be entirely served if attention is called to a few of the more significant facts which center in the output of power at the draw-bar, leaving the general discussion as to the relative value of different steam-pressures to be continued in the chapters which follow.

24. MACHINE FRICTION.—This is the difference between work done in the engine cylinders and that which appears at the draw-bar. The facts for all tests will be found presented in the data (columns 141 to 143). The machine friction expressed in terms of mean effective pressure is best presented by figs. 65 to 70. With reference to these values it should be noted that machine friction when expressed in terms of mean effective pressure will be greater for a locomotive designed for high boiler-pressures than for another of equal power designed for lower pressure, since with the higher steam-pressure the cylinders are relatively smaller.

25. A GENERAL STATEMENT CONCERNING FRICTIONAL LOSSES.—It is difficult to summarize the facts concerning engine friction. This is not due to defects in the experimental process underlying the data, but to the fact that the frictional resistance of the machinery of the locomotive varies greatly from day to day.* Evidence of this is accessible even to the casual observer. During any given test it is likely that an axle-box or a crank-pin may run warm, while during another test under identical conditions of power the same part will remain perfectly cool. In reviewing the data (figs. 65 to 70) it should be remembered that the tests were not run in any predetermined order. Upon the diagram two adjacent results may represent tests between the running of which an interval of many months may have elapsed. This fact, together with the statement already made concerning variations in the frictional resistance of the machinery, is sufficient to account for the apparent irregularities presented.

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*A general discussion of this question with data will be found in Locomotive Performance.

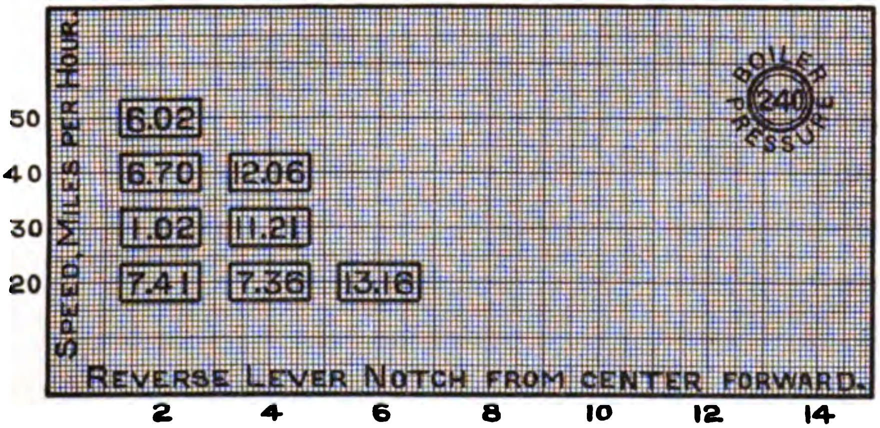


FIG. 65.—Friction mean effective pressure.

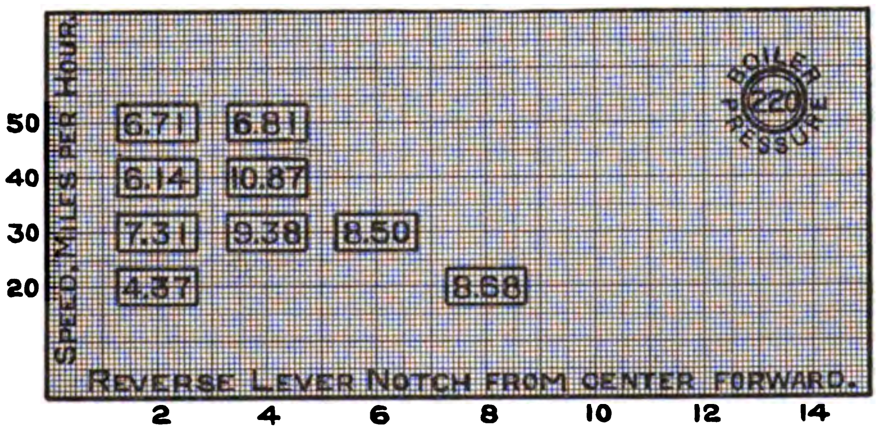


FIG. 66.—Friction mean effective pressure.

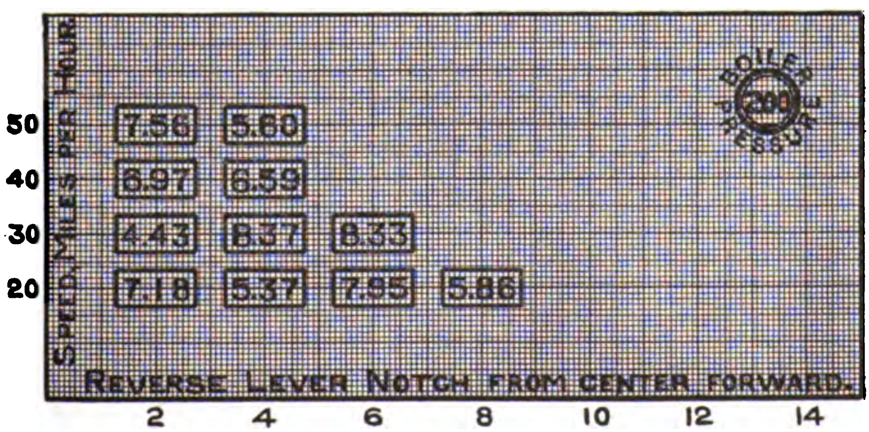


FIG. 67.—Friction mean effective pressure.

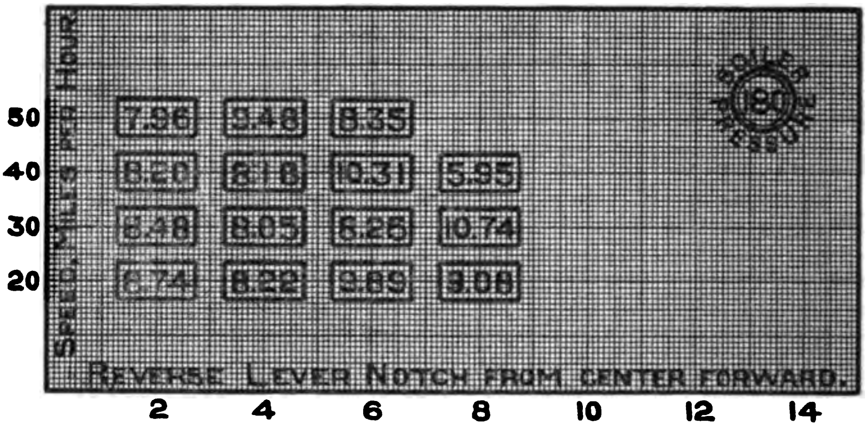


FIG. 68.—Friction mean effective pressure.

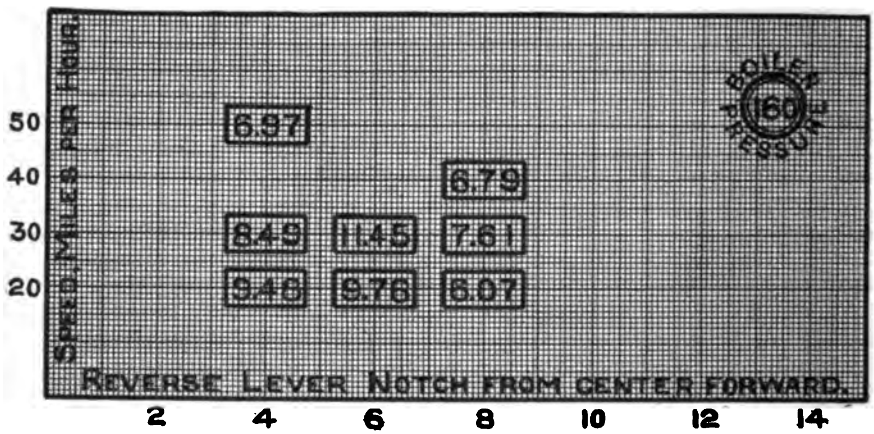


FIG. 69.—Friction mean effective pressure.

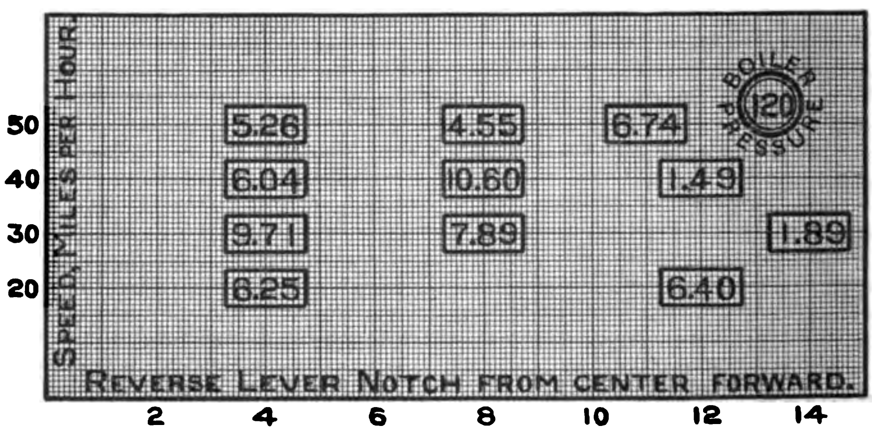


FIG. 70.—Friction mean effective pressure.

These statements make evident the difficulties to be encountered in attempting to derive an expression in simple form for engine friction. That the friction varies but slightly with increase in steam-pressure, the cylinder diameters remaining unchanged, is to be seen by fig. 71, giving all of the results obtained at different speeds and steam-pressures with the reverse lever in the fourth notch. Comparisons involving different positions of the reverse lever suggest

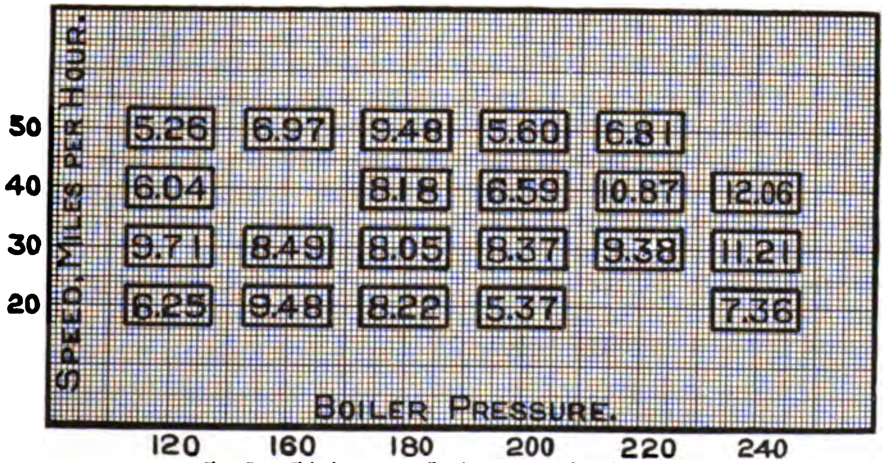


FIG. 71.—Friction mean effective pressure fourth notch.

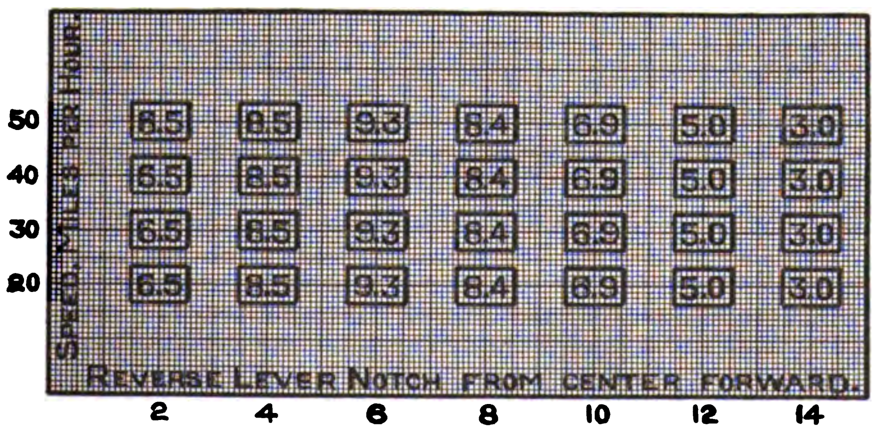


FIG. 72.—Corrected friction, mean effective pressure applicable to all pressures.

that changes in cut-off are most effective in modifying engine friction. Acting upon this suggestion, all results have been plotted in terms of cut-off. The results do not, of course, fall in line, but they take such positions as readily to suggest the form of a curve which in an approximate way may be employed to represent them. From such a curve the values set forth in fig. 72 have been derived. It is proposed to accept these values as an approximate measure of the frictional loss for locomotive *Schenectady No. 2* under all pressures. They are probably a little low for pressures above 200 pounds, and are perhaps somewhat high for pressures below this limit. It can not be assumed that they apply to any other locomotive than that which was involved by the experiments. The machine friction as expressed in pounds pull at the draw-bar may be found for any test by multiplying the mean effective pressure for that test by the constant 88.75.

26. STEAM PER DYNAMOMETER HORSEPOWER PER HOUR.—Values covering this factor are set forth in column 144 of the data. They express the combined efficiency of the cylinders and machinery of the locomotive. They disclose the fact that there are few conditions of running for which the locomotive requires more than 30 pounds of steam per dynamometer horsepower hour, and the consumption may fall below 27 pounds. While differences in performance for all pressures above 200 pounds are not great, the steam consumption is much greater when the pressure is as low as 120 pounds. The data show, also, that for best results the cut-off must be lengthened as the pressure is decreased. The facts as disclosed by the data are as follows:

For 240 pounds pressure the best cut-off is approximately the second notch, 14 per cent.
For 220 pounds pressure the best cut-off is approximately the fourth notch, 19 per cent.
For 180 pounds pressure the best cut-off is approximately the eighth notch, 33 per cent.
For 120 pounds pressure the best cut-off is approximately the twelfth or fourteenth notch, 47 per cent or 56 per cent.

It should be noted, however, that this summarized statement but imperfectly represents the full exhibit of data which, in this as in similar cases, will generally prove the most satisfactory source of information.

27. COAL PER DYNAMOMETER HORSEPOWER PER HOUR.—This factor (column 145) represents the combined performance of the boiler, the cylinders, and the machinery of a locomotive. It connects the energy developed in the boiler by the combustion of fuel with that which is developed at the draw-bar. In all cases where data are given the fuel consumed was of the same quality; hence all results are comparable. The data sheets are blank for all tests at 180 pounds pressure, since for these tests a different quality of fuel was used. The results may be easily reviewed by reference to figs. 73 to 77. Under a pressure of 240 pounds the range is between 3.35 and 5.01, while at a pressure of 160 pounds the range is between 3.79 and 4.78, results which are of interest from at least two points of view. First, because of the small difference in performances resulting from a relatively large change in pressure, and, second, because of the significance of the values quoted when accepted as a measure of locomotive performance. It is doubtful if any other type of steam-engine exhausting into the atmosphere can be

depended upon to deliver power from the periphery of its wheel in return for the expenditure of so small an amount of fuel.

28. CORRECTED RESULTS.—The values representing coal and steam consumption, which have thus far been referred to as performance at the drawbar, are those actually observed. A close comparison of these will sometimes fail to give consistent results because of irregularities in boiler performance or in the frictional resistance of the machinery growing out of causes already discussed.

In table 22 values are presented from which all such discrepancies have been eliminated. They are those which would have been obtained if the evaporative efficiency for all tests had been that indicated by the equation,

$$E = 11.305 - 0.221\ H$$

and the machine friction for all cases had been that shown by figure 72. Column 156 giving the corrected coal per dynamometer horsepower, and column 157 the corrected steam per dynamometer horsepower, may be accepted as representing the best information derived from the entire research.

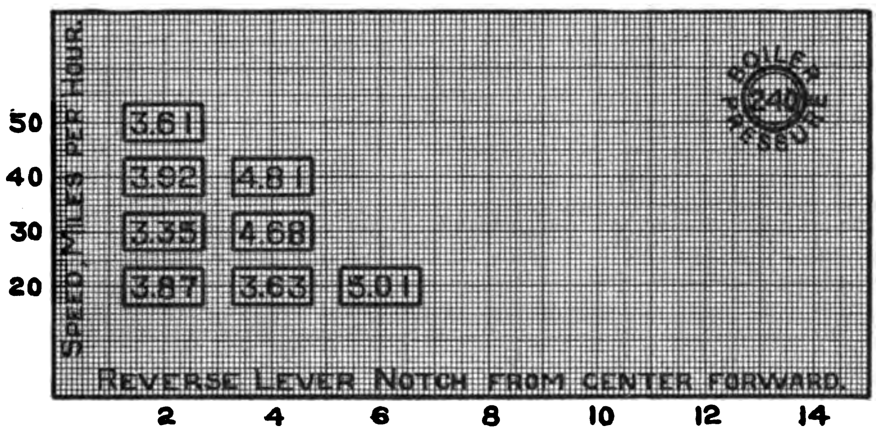


FIG. 73.—Coal per dynamometer horsepower hour.

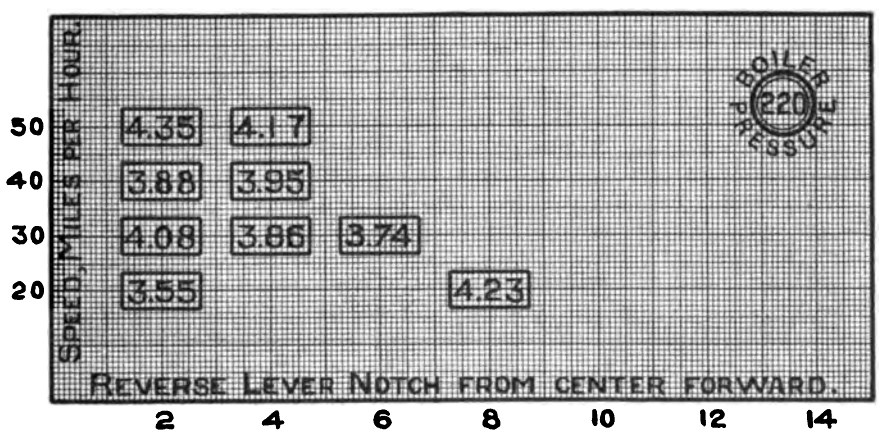


FIG. 74.—Coal per dynamometer horsepower hour

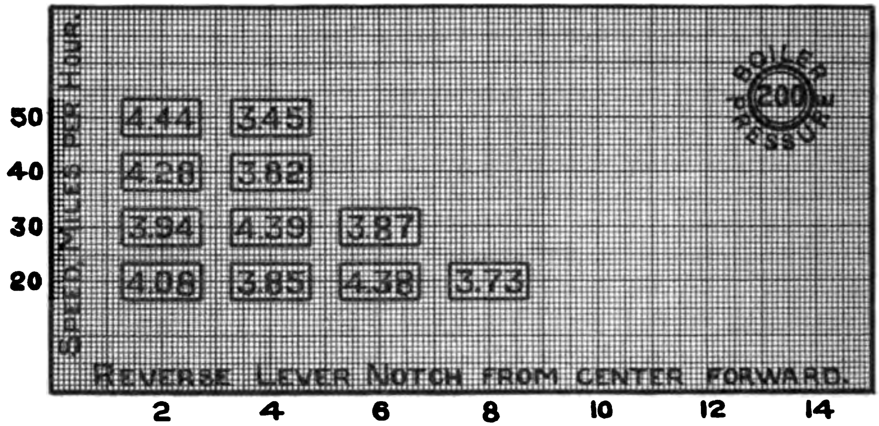


FIG. 75.—Coal per dynamometer horsepower hour.

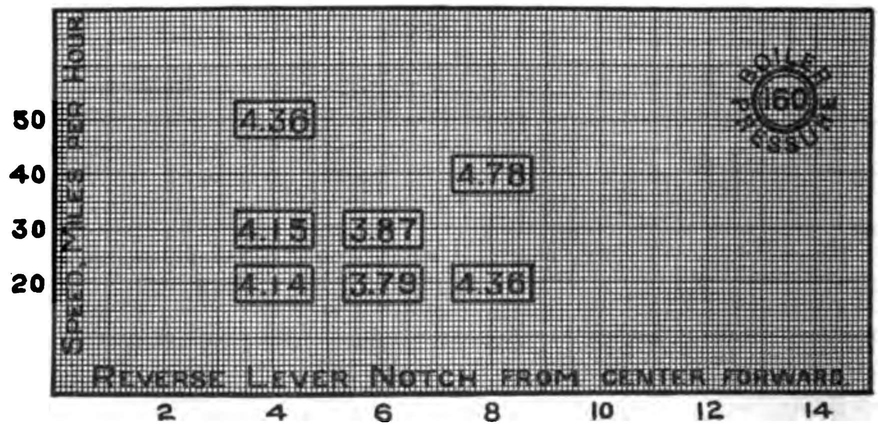


FIG. 76.—Coal per dynamometer horsepower hour.

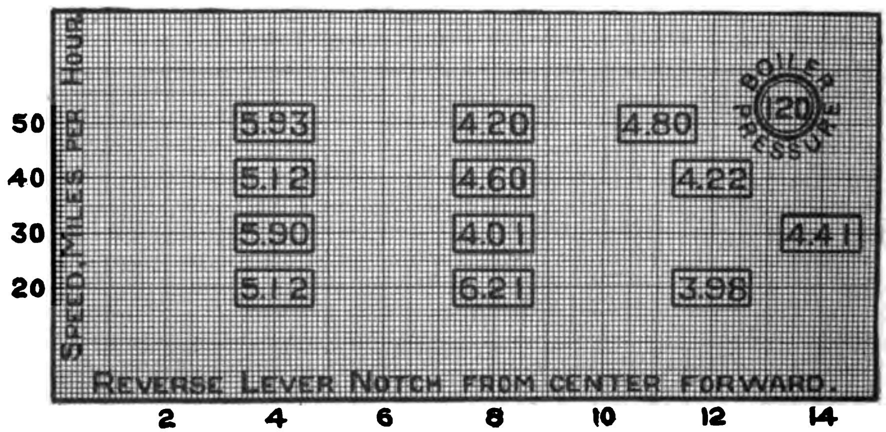


FIG. 77.—Coal per dynamometer horsepower hour.

VI. BOILER-PRESSURE AS A FACTOR IN ECONOMICAL OPERATION.

29. The amount of steam consumed by the locomotive per unit power developed, when operated under various pressures between the limits of 120 pounds and 240 pounds, has already been defined (fig. 59). Basing conclusions on results thus disclosed, it is now proposed to determine the increase in efficiency which may be secured through the adoption of higher pressure for any given increase in the weight of the boiler and its related parts. That this may be done, it is essential to determine the relation between boilers of a given size when designed for different pressures.

30. WEIGHT OF LOCOMOTIVE AS AFFECTED BY STEAM-PRESSURE.—The parts of a locomotive which are affected by changes in steam-pressure, assuming the power to remain constant, are the boiler and certain portions of the engine. The boiler to be adapted to a higher steam-pressure requires thicker plates, heavier riveting, and stronger staying, all tending to augment its weight. The effect of the change upon the engine, however, is to make it lighter, for since with increased pressure, cylinders, pistons, and valves become smaller, their weight will generally diminish. As a basis for exact values, defining their relationship, lines were laid down for a boiler of the following dimensions:*

Diameter of first ring, inches	63
Number of 2-inch tubes	258
Length of tubes, feet	14
Total heating-surface, square feet	2024
Length of grate, inches	90
Width of grate, inches	60
Area of grate, feet	37.5
Boiler-pressure, pounds	190

Four designs were made, adapted to four different pressures, respectively, from which designs weights were calculated, with results shown by table 3.

TABLE 3.—*Weight of those parts of a locomotive which are affected by changes in boiler-pressure.*

Boiler pressure.	Weight of boiler.	Weight of cylinders, valves, and pistons.	Weight of water.	Weight of all parts affected by changes in pressure.
1	2	3	4	5
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
160	30679	12580	16349	59608
190	32913	12240	16536	61689
220	36076	11990	16661	64727
250	38953	11620	16848	67421

*These and other determinations involve weights of boilers which were supplied by the courtesy of the American Locomotive Company. (See Appendix III.)

The weight of the cylinders, valves, and pistons which would be used with a boiler having 2024 feet of heating-surface in making up a representative locomotive carrying the different pressures designated is set forth in column 3. The weight of water when the boiler is filled to the second gage appears as column 4. The weight of steam is negligible. The total weight of all parts of the locomotive directly affected by the changes in pressure are given as column 5, and the values of this column have, for the purpose of interpolation, been plotted in terms of steam-pressure, with results set forth by fig. 78.

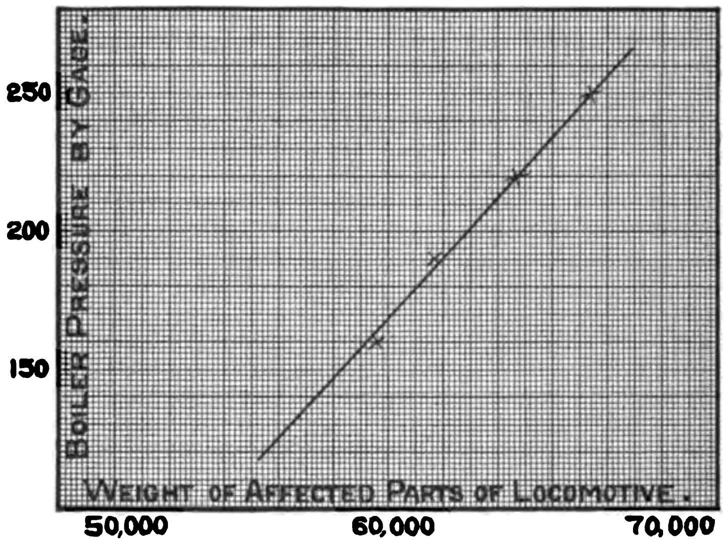


FIG. 78.—Weight of boiler as affected by changes in pressure.

With these data it is proposed to show the extent to which the performance of a typical locomotive using saturated steam may be improved by increasing the pressure carried within its boiler. For convenience, six different pressures having values between 120 pounds and 220 pounds will be utilized as bases from which to assume an increase of pressure. The increase of pressure from each base will be such as may be possible upon the allowance of definite increments in the weight of those portions of the locomotive affected by pressure, and in like manner the improvement in performance will be expressed as a per cent of that which is normal to the base. The results of the process outlined are presented in table 4. An explanation of the columns of this table, which are not self-evident, is as follows:

Column 3. *Weight of those parts of a typical locomotive affected by changes in steam-pressure, including water in boiler.*—The values of this column, for each of the several pressures stated in column 2, are taken directly from the diagram of fig. 78, the basis of which has already been explained.

Column 5. New boiler-pressure obtainable by utilizing the increase of weight in making a stronger boiler.—The values in this column for each of the several weights stated in column 4 were taken from the diagram of fig. 78.

Column 6. Steam per indicated horsepower per hour at the pressures given in column 2.—Values for this column are taken directly from the curve of fig. 59.

Column 7. Steam per indicated horsepower per hour at the new pressures given in column 5.—These values, also, were taken directly from the diagram (fig. 59).

TABLE 4.—*Total saving when a possible increase of weight is utilized as a means of increasing boiler-pressure.*

Increase of weight.	Boiler-pressures selected as bases.	Weight of those parts of a locomotive which are affected by changes in boiler-pressure.	Weight of affected parts increased by per cent given in column 1.	New boiler-pressure obtainable by utilizing the increase of weight in making a stronger boiler.	Steam per indicated horse-power per hour at the pressures given in column 2.	Steam per indicated horse-power per hour at the new pressures given in column 5.	Direct saving in steam consumption resulting from an increased weight equal to per cent shown in column 1.	Indirect saving due to reduced rate of evaporation.	Total saving.
1	2	3	4	5	6	7	8	9	10
Per ct.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*
5	120	55560	58340	150	29.1	27.1	6.87	1.67	8.54
	140	57390	60260	171	27.7	26.3	5.05	1.23	6.28
	160	59220	62180	192	26.6	25.7	3.39	.82	4.21
	180	61050	64100	213	26.0	25.2	3.08	.75	3.83
	200	62880	66020	234	25.5	24.8	2.75	.67	3.42
	220	64710	67940	255	25.1	24.5	2.39	.58	2.97
10	120	55560	61120	181	29.1	26.0	10.65	2.59	13.24
	140	57390	63130	203	27.7	25.4	8.31	2.02	10.33
	160	59220	65140	225	26.6	25.0	6.02	1.46	7.48
	180	61050	67150	247	26.0	24.6	5.38	1.31	6.69
15	120	55560	63890	211	29.1	25.3	13.06	3.17	16.23
	140	57390	66000	234	27.7	24.8	10.46	2.51	13.00
	160	59220	68100	257	26.6	24.5	7.90	1.92	9.82
20	120	55560	66670	241	29.1	24.7	15.12	3.67	18.79

Column 8. Direct saving in steam consumption, resulting from an increased weight equal to the per cent shown in column 1.—Values of this column are equal to 100 times those of column 6 minus those of column 7 divided by those of column 6.

Column 9. Indirect saving due to reduced rates of evaporation, per cent.—Assuming the locomotive to work at the same power at whatever pressure it may carry, the saving in steam resulting from the increased pressure set forth in column 8 diminishes the demand upon the boiler, and, as the efficiency of the boiler increases as the rate of evaporation is reduced, there results an indirect saving with each increase of pressure. The relation between the evaporative efficiency of the boiler and the rate of evaporation has already been defined (fig. 12). Assuming the normal rate of evaporation for the boiler under initial conditions to be 10, then a reduction of 1 per cent in the rate of evaporation will effect an increase in the evaporative efficiency of 0.243 per cent. The values in column 9, therefore, are those of column 8 multiplied by the constant 0.243.

Column 10. *Total saving.*—The total saving is the sum of columns 8 and 9.

The significance of this table may best be appreciated by the following examples:

By line 1 of the table it appears that the base is 120 pounds (column 2). The parts of the typical locomotive designed for this pressure, which are affected by changes in steam-pressure, weigh 55,560 pounds (column 3). If, now, in designing a new lot of locomotives, it becomes possible to increase this weight by 5 per cent (column 1), the weight of these parts for the new locomotive may be 58,340 pounds (column 4). This weight, if put into a boiler of the same capacity, will allow the pressure to be increased from 120 pounds (column 2) to 150 pounds (column 5), and as a result its steam consumption per horsepower hour will fall from 29.1 pounds (column 6) to 27.1 pounds (column 7), or 6.87 per cent (column 8). But the saving of 6.87 per cent in steam consumption diminishes the demand which is made upon the boiler for steam, and at the lower rate of evaporation the boiler becomes 1.67 per cent (column 9) more efficient, giving a total gain as a result of the change in pressure of 8.58 per cent (column 10). In a similar manner each line of the table presents a measure of the improvement to be expected from some definite increase of pressure.

A study of the analysis which has preceded will show that the values of column 10 may be accepted as fairly representing the increase in efficiency which may be secured in return for a given increase in steam-pressure, or, as is more clearly shown by table 4, in return for a given increase in the weight of those parts of the locomotive affected by increase of pressure.

While the comparison is based on improved efficiency, it will, of course, be understood that, at the limit, the saving shown may be converted into a corresponding increase of power. It would have been possible by assuming constant efficiency to have shown the improvement in terms of increase of power.

VII. BOILER CAPACITY AS A FACTOR IN ECONOMICAL OPERATIONS.

31. In the preceding chapter there is considered the advantage to be derived through the utilization of any possible increase in the weight of a locomotive, as a means by which to secure an increase of pressure. It is the purpose of this chapter to consider the benefit which may be derived by utilizing similar increments in weight to secure an increase in boiler capacity, the pressure remaining constant. The weights of boilers and related parts involved by such a comparison have been ascertained from considerations similar to those which controlled in the preceding case. A boiler of the dimensions already given (paragraph 30), designed for 190 pounds, was made the starting-point from which values were ascertained for boilers of different capacities designed to carry 160 pounds pressure. The characteristics of the several boilers thus designed are set forth in table 5.

TABLE 5.—*Characteristics of four boilers designed for 160 pounds pressure and different capacities.*

Diameter of boiler.	Number of 2-inch tubes.	Length of tubes.	Length of grate.	Width of grate.	Area of grate.	Area of heating surface.	Weight of boiler.	Weight of water in boiler.	Weight of parts of locomotive which are affected by changes in heating-surface.
1	2	3	4	5	6	7	8	9	10
In.		*Ft.*	*In.*	*In.*	*Sq. ft.*	*Sq. ft.*	*Lbs.*	*Lbs.*	*Lbs.*
63	258	14	90	60	37.4	2024	30,679	16,349	47,028
69	326	14	102	65	46.1	2538	36,321	19,344	55,665
67	338	16	102	65	46.1	3013	41,013	20,092	61,105
70	396	16	96	75	50.0	3498	42,894	21,965	64,859

The steam-pressure being constant, the dimensions and consequently the weight of the cylinders and related parts for the development of a given power remain unchanged. It is obvious, also, that since the only change in the locomotive is in the size of its boiler, the cylinder performance will be the same for locomotives having boilers of different size. The saving which will result from the employment of boilers of greater capacity will be only that which results from the diminished rate of evaporation per unit area of heating-surface. The relation of evaporative efficiency and rate of evaporation has already been defined (fig. 12), so that both factors in the problem now are known, namely, the increase in weight necessary for a given increase in capacity and the effect of any increase in capacity in improving the evaporative efficiency. By means of relations thus established values have been determined which are presented as table 6. An explanation of those columns of this table which are not self-evident, is as follows:

TABLE 6.—*Saving when a possible increase of weight is utilized as a means of increasing heating-surface.*

Increase of weight.	Boiler-pressures selected as bases.	Weight of parts of a typical locomotive (boiler, cylinders, valves, pistons, and water).	Allowable increase of weight.	Heating-surface of typical locomotives whose weights are given in column 3.	Increase of heating-surface obtainable by utilizing increase of weight in making a larger boiler.	Increase of heating-surface.	Saving in evaporative performance due to reduced rate.
1	2	3	4	5	6	7	8
Per ct.	*Lbs.*	*Lbs.*	*Lbs.*	*Sq. ft.*	*Sq. ft.*	*Per cent.*	*Per cent.*
5	120	55560	2778	2000	234.7	11.73	2.85
	140	57390	2869	2000	242.5	12.12	2.95
	160	59220	2961	2000	250.1	12.50	3.04
	180	61050	3052	2000	257.7	12.88	3.13
	200	62880	3144	2000	265.3	13.26	3.22
	220	64710	3235	2000	272.9	13.64	3.31
10	120	55560	5556	2000	469.4	23.47	5.70
	140	57390	5739	2000	484.9	24.24	5.89
	160	59220	5922	2000	500.4	25.02	6.08
	180	61050	6105	2000	515.9	25.79	6.27
15	120	55560	8334	2000	704.2	35.21	8.55
	140	57390	8608	2000	727.3	36.36	8.84
	160	59220	8883	2000	750.6	37.53	9.12
20	120	55560	11112	2000	939.0	46.95	11.41

Column 3 is the weight of boiler, the contained water, and the cylinders, pistons, and valves. While the cylinders, pistons, and valves do not change for any given pressure, their weights are included to make the values comparable with those employed in the analysis of the preceding chapter. They are in fact identical with the values of column 3, table 4.

Column 4. *Allowable increase in weight.*—The values of this column are the percentages indicated by column 1 of the values of column 3.

Column 6. *Increase of heating-surface.*—Values for this column have been obtained by plotting weight of affected parts in terms of heating-surface (columns 10 and 7, table 5). The results appear as fig. 79. From a representative line drawn through points thus obtained showing the relation between the weight of the boiler and water, and the number of square feet of heating-surface, it can be shown that an increase of 10,000 pounds in the weight of boiler and affected parts permits an increase of 845 square feet in heating-surface. Therefore, in table 6, column 6 equals column 4 multiplied by 0.0845. This relation was obtained from data of a boiler designed for 160 pounds pressure and is assumed to be approximately true for boilers of other pressures.

Column 7. Increase of heating-surface, per cent, is column 6 multiplied by 100 divided by column 5. It also shows the per cent reduction in the rate of evaporation.

Column 8. Saving in evaporative performance due to reduced rate, per cent.—Values in this column have been obtained from those of the preceding column by means of a relationship already established controlling evaporative efficiency of boiler and rate of combustion (fig. 12). This relation is such that a reduction of 1 per cent in the rate of combustion increases the evaporative efficiency 0.243 per cent. Values of column 8 are, therefore, those of column 7 multiplied by this factor.

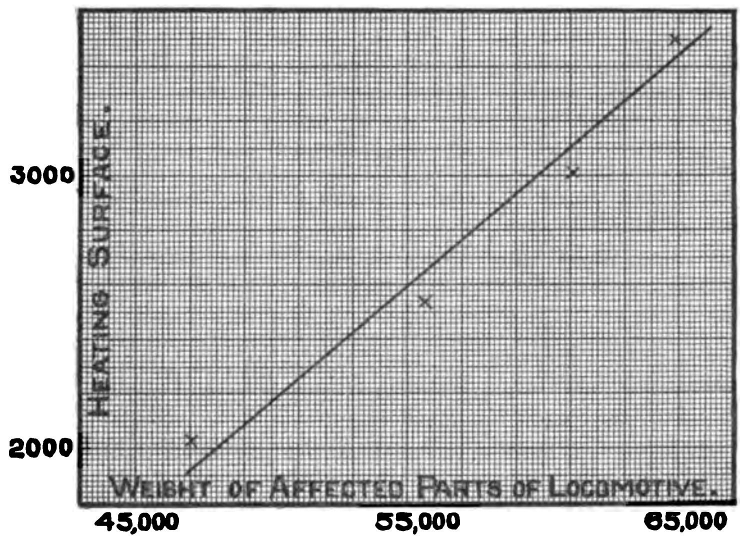


FIG. 79.—Weight of boiler as affected by changes in heating-surface.

The significance of table 6 will be understood from the following illustration, based upon the first line of the table. Assuming an existing locomotive operating under a pressure of 120 pounds (column 2) to have a boiler containing 2000 feet of heating surface (column 5) weighing with the contained water 55,560 pounds (column 3), an increase of 5 per cent (column 1) or 2778 pounds (column 4), will permit an extension in heating surface of 234.7 square feet (column 6) which, compared with its original surface is an increase of 11.73 per cent (column 7). This increase in the extent of heating-surface, assuming the power developed to remain unchanged, will result in an improvement in the performance of the boiler of 2.86 per cent (column 8). The facts underlying the analysis are primarily the results of tests.

VIII. CONCLUSIONS CONCERNING BOILER-PRESSURE VERSUS BOILER CAPACITY AS A MEANS OF INCREASING THE EFFICIENCY OF A SINGLE-EXPANSION LOCOMOTIVE.

32. In the preceding chapters an analysis has been given showing the saving which may result in locomotive service, first, by increasing the pressure, the boiler capacity remaining unchanged, and, second, by increasing the heating-surface, the pressure remaining unchanged. A summary of the conclusions of these chapters is presented as figs. 80 to 85, in which the full line represents the gain through increase of boiler-pressure and the dotted line the corresponding gain through increase of boiler capacity. The values for these diagrams are taken directly from tables 4 and 6. It will be seen that starting with pressures which are comparatively low, the most pronounced results are those to be derived from increments of pressure. With each rise in pressure, however, the chance for gain through further increase diminishes. With a starting-point as high as 180 pounds, the saving through increased pressure is but slightly greater than that which may result through increased boiler capacity.

The fact should be emphasized that the conclusions above described are based upon data which lead back to the question of coal consumption. The gains which are referred to are measured in terms of coal which may be saved in the development of a given amount of power. It will be remembered that conditions which permit a saving in coal will, by the sacrifice of such saving, open the way for the development of greater power, but the question as defined is one concerning economy in the use of fuel. It is this question only with which the diagrams (figs. 80 to 85) deal.

There are other measures which may be applied to the performance of a locomotive which, if employed in the present case, would show some difference in real values of the two curves (figs. 80 to 85). The indefinite character of these measures prevents them being directly applied as corrections to the results already deduced, but their effect may be pointed out. Thus, the extent to which an increase of pressure will improve performance has been defined, but the definition assumes freedom from leakage. If, therefore, leakage is allowed to exist, the result defined is not secured. Moreover, an increase of pressure increases the chance of loss through leakage, so that, to secure the advantage which has been defined, there must be some increase in the amount of attention bestowed, and this, in whatever form it may appear, means expense, the effect of which is to reduce the net gain which it is possible to derive through increase of pressure. Again, in parts of the country where the water-supply is bad, any increase of pressure will involve increased expense in the more careful and more extensive treatment of feed-water, or in the increased cost of boiler repairs, or in detentions arising from failure of injector, or from all of these sources combined. The effect of such expense is to reduce the net gain which it is possible to derive through increase of pressure. These statements call attention to the fact that the gains which have been defined as resulting from increase of pressure (figs. 80 to 85) are to be regarded as the maximum gross; as maximum because they are based upon results derived from a locomotive which was at all times maintained in the highest possible condition, and as gross because on the road conditions are likely to be introduced which will necessitate deductions therefrom.

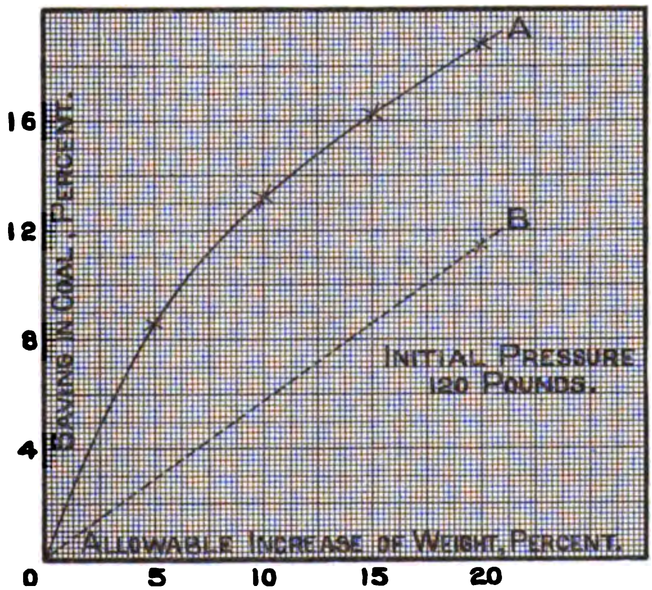


FIG. 80.

The line A represents the saving in fuel when an allowable increase in weight is utilized in making a stronger boiler to permit a higher pressure.
The line B represents the saving in fuel when an allowable increase in weight is utilized in making a larger boiler to give increased capacity.

The relation which has been established showing the gain to be derived through increased boiler capacity is subject to but few qualifying conditions. It rests upon the fact that for the development of a given power a large boiler will work at a lower rate of evaporation per unit area of heating-surface than a smaller one. The saving which results from diminishing the rate of evaporation is sure; whether the boiler is clean or foul, tight or leaky, or whether the feed-water is good or bad, the reduced rate of evaporation will bring its sure return in the form of increased efficiency. An increase in the size of a boiler will involve some increase in the cost of maintenance, but such increase is slight and of a sort which has not been regarded in the discussion involving boilers designed for higher pressures.

Keeping in mind the fact that as applied to conditions of service the line *A* is likely to be less stable in its position than *B*, the facts set forth by figs. 80 to 85 may be briefly reviewed.

Basing comparisons upon an initial pressure of 120 pounds (fig. 80), a 5 per cent increase in weight, when utilized in securing a stronger boiler, will improve the efficiency 8.5 per cent, while if utilized in securing a larger boiler the improvement will be a trifle less than 3 per cent. Arguing from this base, the advantage to be derived from an increase of pressure is great. If, however, the increase in weight exceeds 10 per cent, the curve *A* ceases to diverge from

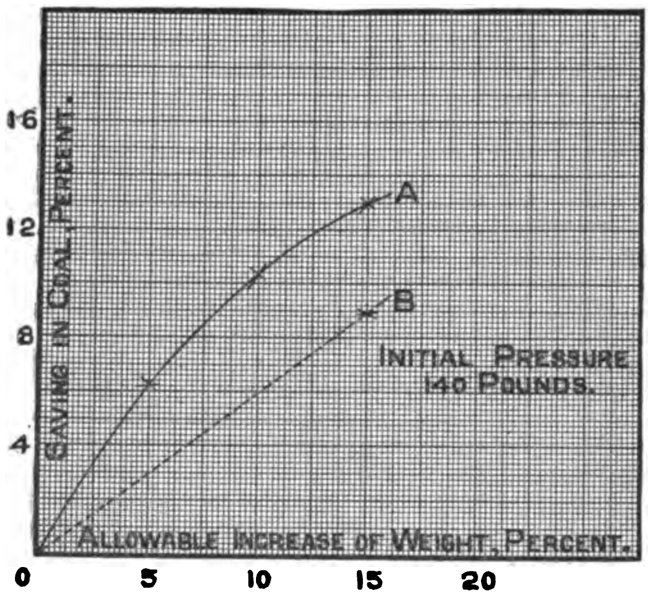


FIG. 81.

The line A represents the saving in fuel when an allowable increase in weight is utilized in making a stronger boiler to permit a higher pressure.
The line B represents the saving in fuel when an allowable increase in weight is utilized in making a larger boiler to give increased capacity.

B and if both curves are sufficiently extended, they will meet, all of which is proof of the fact that the rate of gain is greatest for relatively small increments of weight.

Basing comparisons upon an initial pressure of 140 pounds (fig. 81), the relative advantage of increasing the pressure diminishes, though on the basis of a 5 per cent increase in weight it is still double that to be obtained by increasing the capacity.

Basing comparisons upon an initial pressure of 160 pounds (fig. 82), the advantage to be gained by increasing the pressure over that which may be had by increasing the capacity is very small, so small in fact that a slight droop in the curve of increased pressure (*A*) would cause it to disappear. As the curve *B* may be regarded as fixed, while *A*, through imperfect maintenance of boiler or engine, may fall, the argument is not strong in favor of increasing pressure beyond the limit of 160 pounds.

Basing comparisons upon an initial pressure of 180 pounds (fig. 83), the advantage under ideal conditions of increasing the pressure, as compared with that resulting from increasing the capacity, has a maximum value of approximately one-half of 1 per cent. In view of the incidental losses upon the road the practical value of the advantage is nil. The curves *A* and *B*, fig. 83, constitute therefore no argument in favor of increasing pressure beyond the limit of 180 pounds.

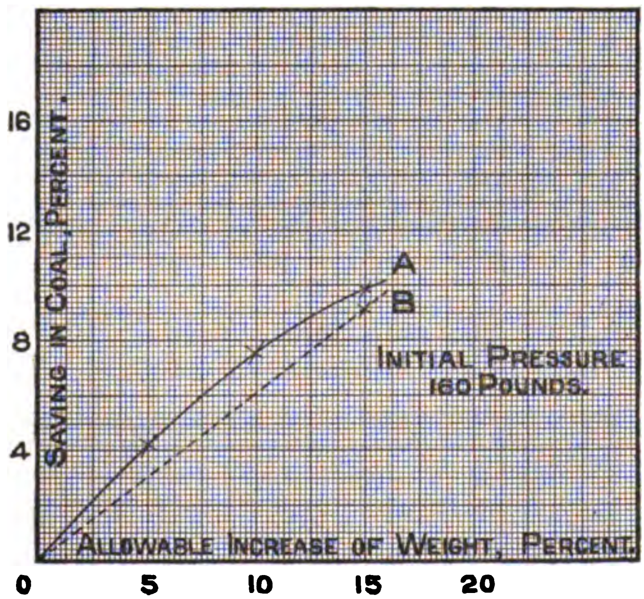


FIG. 82.

The line A represents the saving in fuel when an allowable increase in weight is utilized in making a stronger boiler to permit a higher pressure.
The line B represents the saving in fuel when an allowable increase in weight is utilized in making a larger boiler to give increased capacity.

Basing comparisons upon an initial pressure of 200 pounds (fig. 84), it appears that under ideal conditions either the pressure or the capacity may be increased with equal advantage which in effect is a strong argument in favor of increased capacity rather than of higher pressure.

Basing comparisons upon a pressure of 220 pounds (fig. 85), it appears that even under ideal conditions of maintenance the gain in efficiency resulting from an increase of pressure is less than that resulting from an increase of capacity. In view of this fact, no possible excuse can be found for increasing pressure above the limit of 220 pounds.

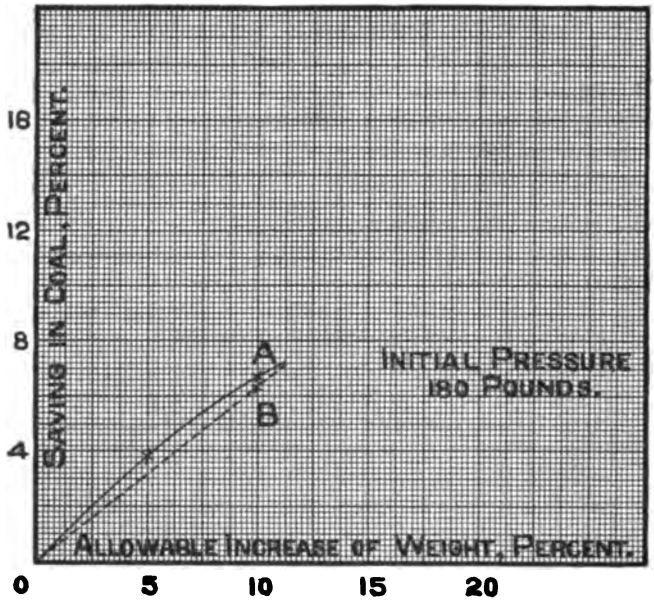


Fig. 83.

The line A represents the saving in fuel when an allowable increase in weight is utilized in making a stronger boiler to permit a higher pressure.
The line B represents the saving in fuel when an allowable increase in weight is utilized in making a larger boiler to give increased capacity.

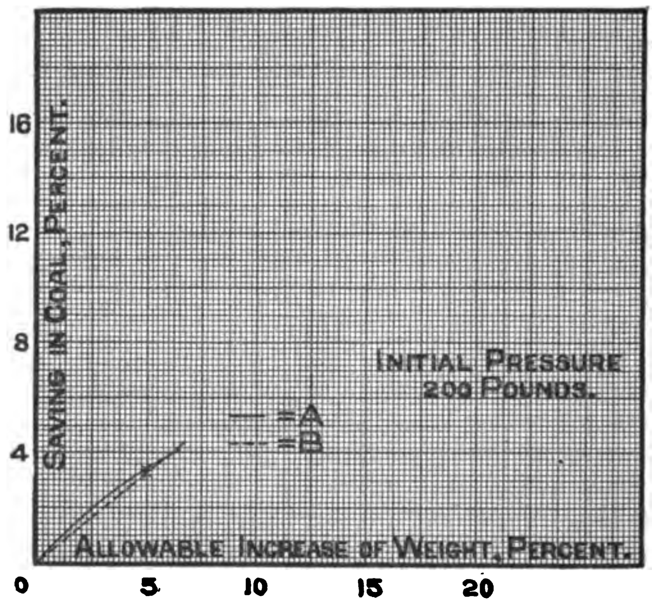


Fig. 84.

The line A represents the saving in fuel when an allowable increase in weight is utilized in making a stronger boiler to permit a higher pressure.
The line A represents the saving in fuel when an allowable increase in weight is utilized in making a larger boiler to give increased capacity.

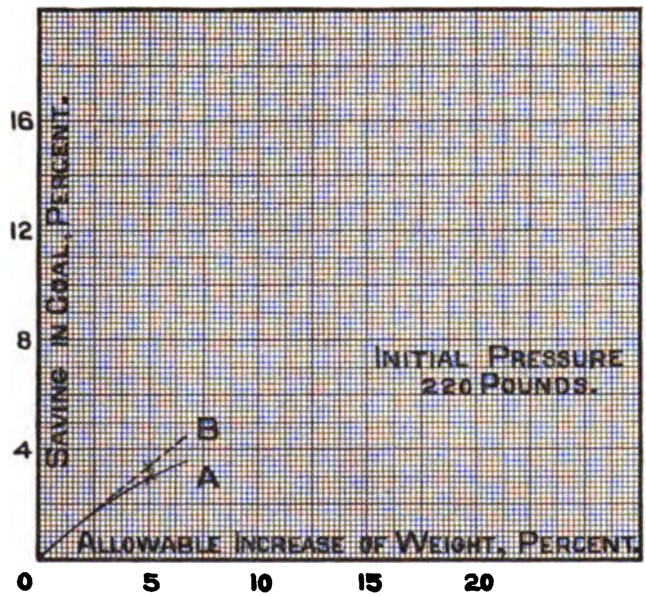


FIG. 85.

The line A represents the saving in fuel when an allowable increase in weight is utilized in making a stronger boiler to permit a higher pressure.
The line B represents the saving in fuel when an allowable increase in weight is utilized in making a larger boiler to give increased capacity.

APPENDIX I.

THE LOCOMOTIVE EXPERIMENTED UPON.

33. LOCOMOTIVE SCHENECTADY NO. 2 was ordered of the Schenectady Locomotive Works in 1897. In selecting a second locomotive which should serve the purposes of the Purdue testing-plant, it was decided to have the boiler of substantially the same capacity as that of the locomotive previously employed in the laboratory and which in later years has been known as *Schenectady No. 1*. In some other respects the new locomotive differed from its predecessor. Its boiler was designed to operate under pressures as high as 250 pounds, a limit which was then 25 per cent higher than the maximum employed in practice. Horizontal seams are butt-jointed with welt strips inside and out, and are sextuple-riveted. The design of its cylinders and saddle is such as readily to permit the conversion of the simple engine into a two-cylinder compound. The driving-wheels of the new locomotive are of larger diameter than those of *Schenectady No. 1*.

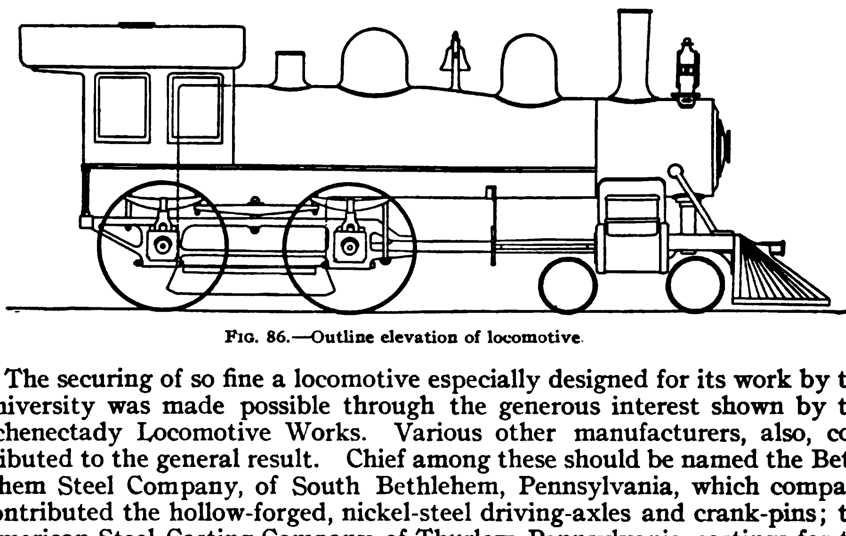


FIG. 86.—Outline elevation of locomotive.

The securing of so fine a locomotive especially designed for its work by the university was made possible through the generous interest shown by the Schenectady Locomotive Works. Various other manufacturers, also, contributed to the general result. Chief among these should be named the Bethlehem Steel Company, of South Bethlehem, Pennsylvania, which company contributed the hollow-forged, nickel-steel driving-axles and crank-pins; the American Steel Casting Company, of Thurlow, Pennsylvania, castings for the main frame, driving-wheel centers, crossheads, pistons, rock-shaft, driving-box saddles, and various smaller castings; the Ashton Valve Manufacturing Company, of Boston, safety valves; the Detroit Lubricator Company, of Detroit, cylinder lubricator; the Williams Sellers Company, of Philadelphia, injectors; and the Keasby & Mattison Company, of Ambler, Pennsylvania, magnesia boiler-covering.

The principal characteristics of the locomotive are as follows:

Type	4-4-0
Total weight, pounds	109,000
Weight on four drivers, pounds	61,000
Valves: Type, Richardson balanced.	
Maximum travel, inches	6
Outside lap, inches	$1\frac{1}{8}$
Inside lap, inches	0
Ports:	
Length, inches	12.0
Width of steam port, inches	1.5
Width of exhaust port, inches	3.0
Total wheel base, feet	23
Rigid wheel base, feet	8.5
Cylinders:	
Diameter, inches	16
Stroke, inches	24
Drivers, diameter front tire, inches	69.25
Boilers (style, extended wagon-top):	
Diameter of front end, inches	52
Number of tubes	200
Gage of tube	12
Diameter of tube, inches	2
Length of tube, feet	11.5
Length of fire-box, inches	72.06
Width of fire-box, inches	34.25
Depth of fire-box, inches	79.00
Heating-surface in fire-box, square feet	126.0
Heating surface in tubes, water side, square feet	1196.00
Heating surface in tubes, fire side, square feet	1086.00
Total heating surface including water side of tubes, square feet	1322.00
Total heating surface including fire side of tubes, square feet	1212.00
Total heating surface, value accepted for use in all calculations	1322.00
Ratio of total heating surface based on water side of tubes to that based on fire side of tubes	1.091
Grate area, square feet	17.00
Thickness of crown-sheet, inches	$\frac{7}{16}$
Thickness of tube sheet, inches	$\frac{9}{16}$
Thickness of side and back-sheets, inches	$\frac{3}{8}$
Diameter of stay-bolts, inches	1
Diameter of radial stays, inches	$1\frac{1}{8}$
Driving-axle journals:	
Diameter, inches	$7\frac{1}{2}$
Length, inches	$8\frac{1}{2}$

34. WORK WITH SCHENECTADY NO. 2.—The locomotive as delivered in November, 1897, was equipped with 20-inch cylinders which were bushed to 16-inch, and as soon as practicable thereafter was regularly operated in the routine work of the laboratory. As data accumulated it was discovered that the performance of the new engine was less satisfactory than that of the old. In seeking a cause for this result, it was found that the inside of the bushings was pitted by the tear of the tool which bored them and that the cylinder-covers were roughly turned. It was thought that these causes might have operated to increase cylinder condensation. The inside of the bushings and the surfaces of the cylinder heads were, therefore, carefully polished, but as the results were not all that had been anticipated, the 20-inch bushed cylinders, with their comparatively large clearance, were finally removed and new 16-inch cylinders applied in their place. Meantime, also, there were occa-

sional difficulties in the leakage of steam from the live steam ports to the exhaust ports in the joint between the cylinders and saddles. Since after each change it was necessary to allow considerable time for the natural processes of the laboratory to yield data from which to judge of its effect, progress in advancing the more substantial investigations was necessarily slow. Meantime, however, several incidental investigations of some importance were undertaken, such as an elaborate test of fuels,* a test of a new form of valve gear for locomotives, tests to determine the proportion of straight and tapered stacks,† and tests of a locomotive stoker.

With problems of the sort already described requiring attention, and with only sufficient money available to permit the operation of the testing-plant for purposes of instruction, a study of the effect of high-pressures made little progress. It was not until 1904 that the grant was received from the Carnegie Institution of Washington which made it possible for the work to be undertaken in a manner insuring its speedy conclusion. Thus aided, an organization was effected, assuring the continuous operation of the laboratory, and work was undertaken in earnest. During the following summer it became necessary to send the locomotive to the shops of the Pennsylvania Railroad Company at Indianapolis, where new side-sheets were applied to the fire-box of the boiler, it having been found difficult to keep the old ones absolutely tight in the presence of small cracks which had developed. At the beginning of the succeeding school year the work under the auspices of the Carnegie Institution of Washington was renewed, and continued throughout the school year. As in June, some tests still remained to be run, the work was continued into the summer; the last test having been run August 7, 1905.

35. PHOTOGRAPHS AND DRAWINGS.—Locomotive *Schenectady No. 2*, as it appeared when delivered to the University, is shown by fig. 86, a series of illustrations from photographs showing the engine as mounted in the laboratory by figs. 87 to 93, and line drawings of its most essential details by figs. 94 to 117.

*Tests of Coal for Locomotives, Proceedings of the Western Railway Club, Dec., 1898.

†Tests of Locomotive Stacks, American Engineer for the year 1902.

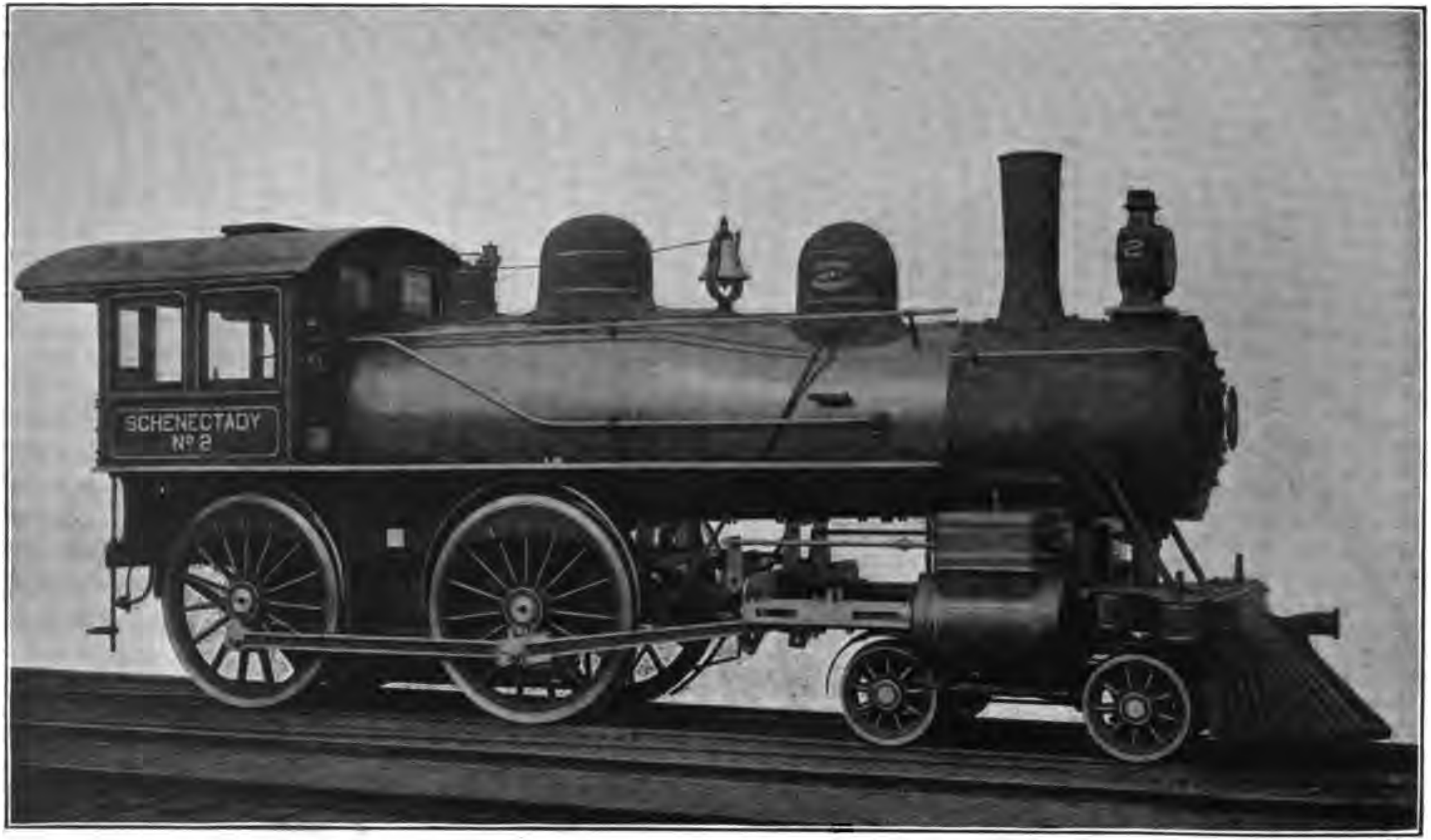


Fig. 87.—The experimental locomotive, *Schenectady No. 2.*

FIG. 88.—A center of control. Valves controlling water circulation in friction brakes, the traction dynamometer and scale case.

FIG. 89.—The locomotive from the rear

Fig. 90.—The cylinder and the indicator motion.

Fig. 91.—Locomotive driving wheels and their supporting wheels.

FIG. 92.—Supporting wheels and locomotive drivers.

FIG. 93.—A view beneath the locomotive showing supporting wheels.

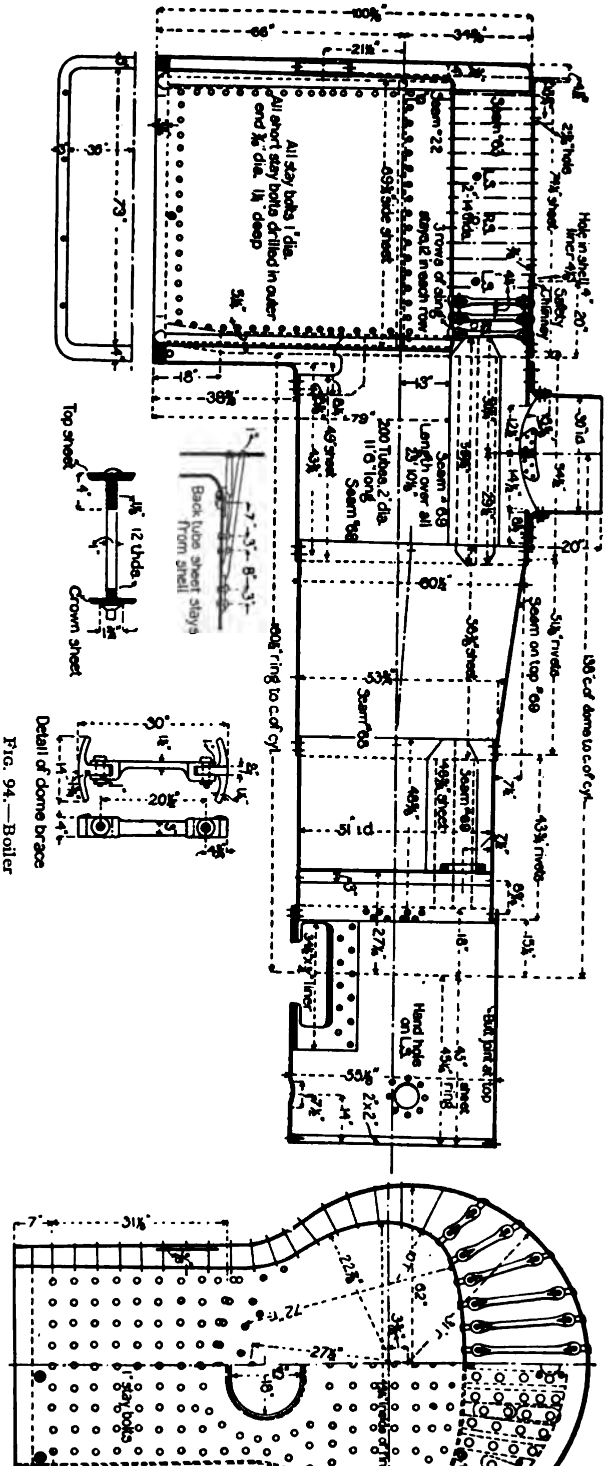


FIG. 94.—Boiler

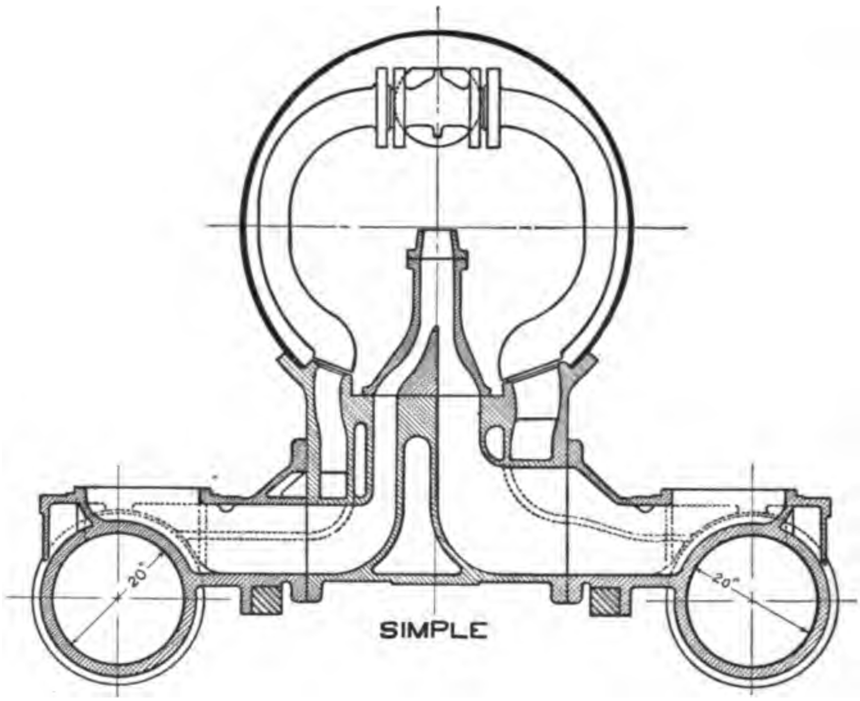
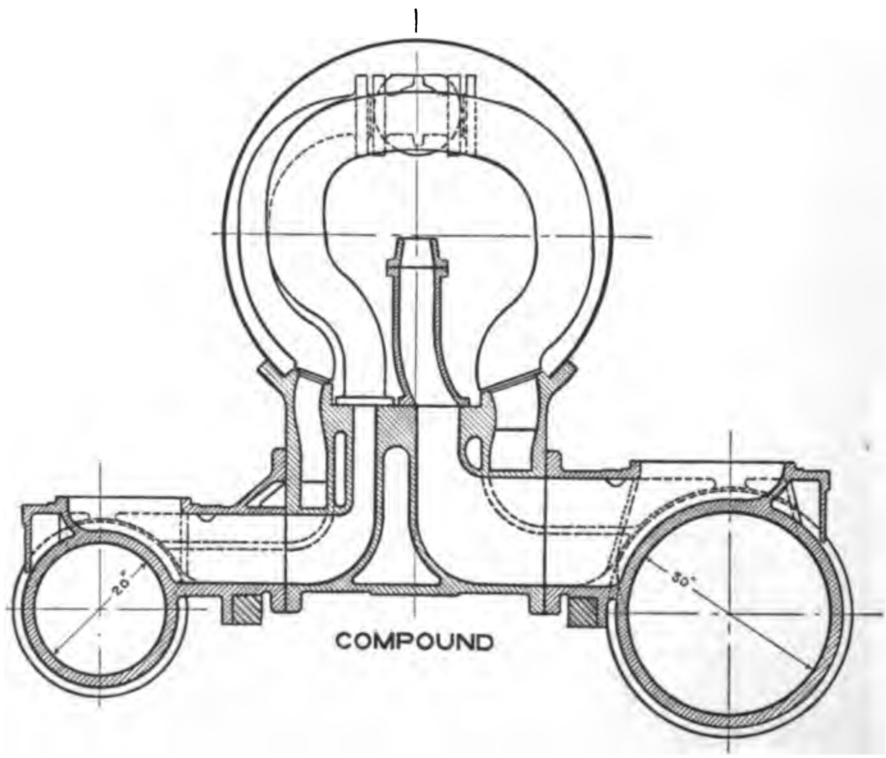


Fig. 95.—Cylinders, simple.



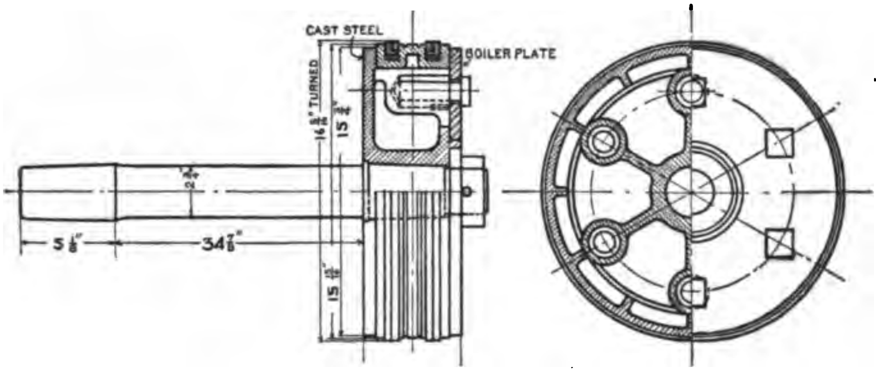


FIG. 97.—Piston and rod.

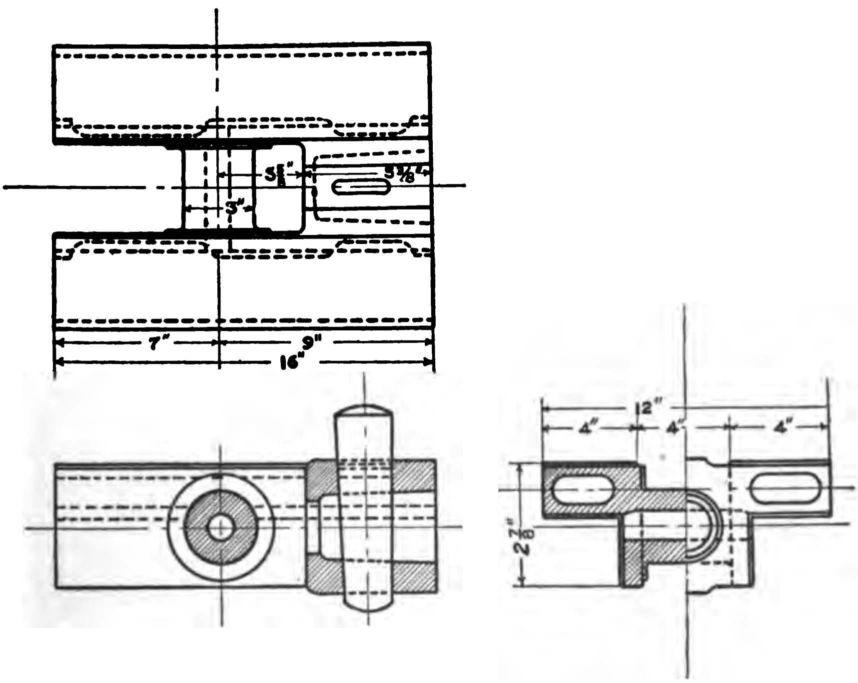


FIG. 98.—Crosshead.

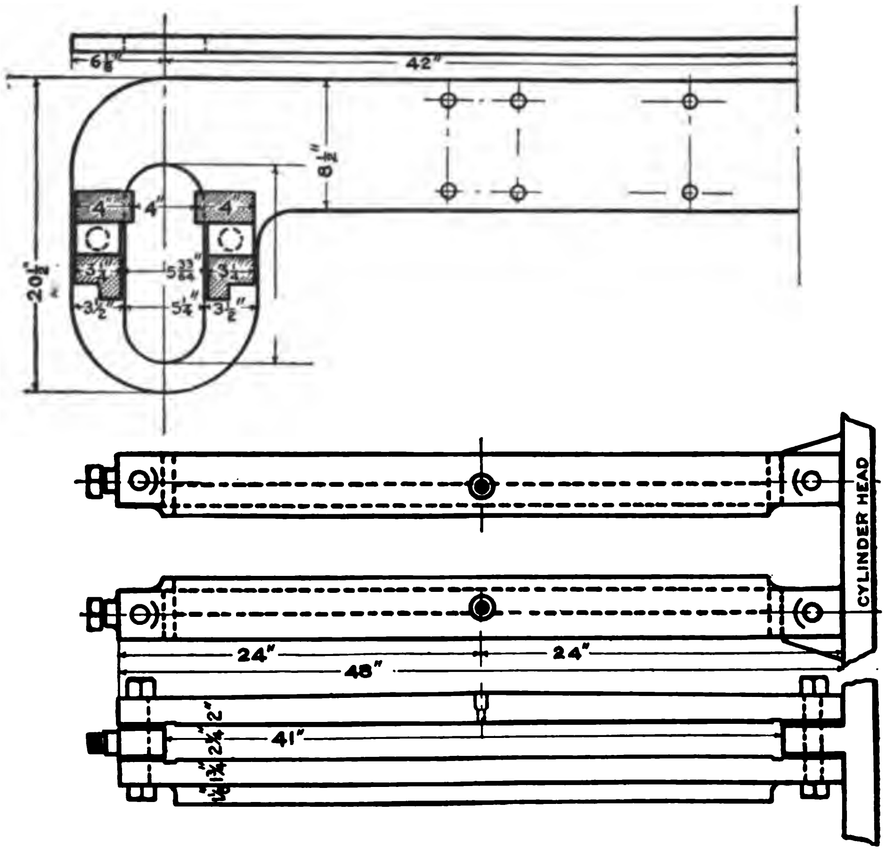


Fig. 99.—Yoke and guides.

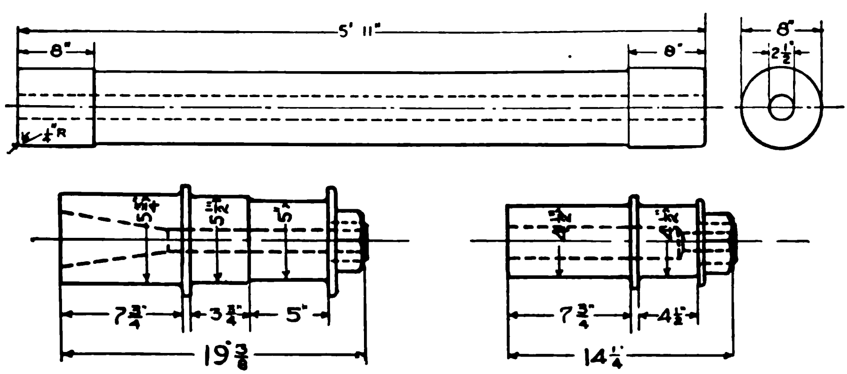


Fig. 100.—Axle and crank pins.

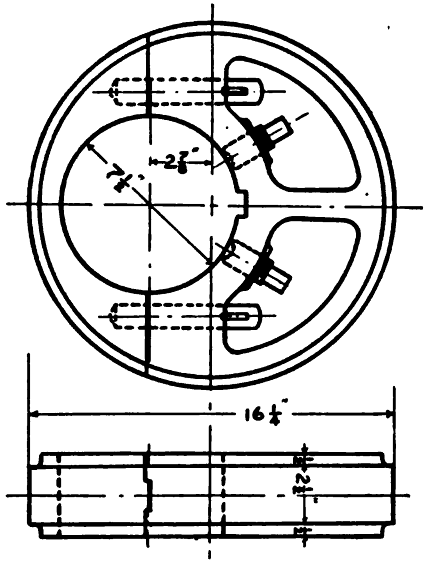


FIG. 101.—Eccentric

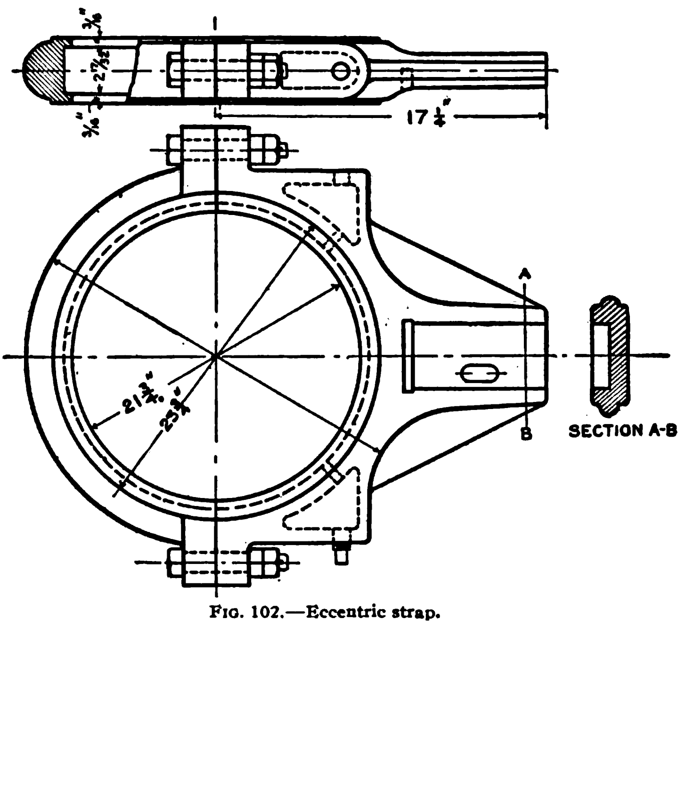


FIG. 102.—Eccentric strap.

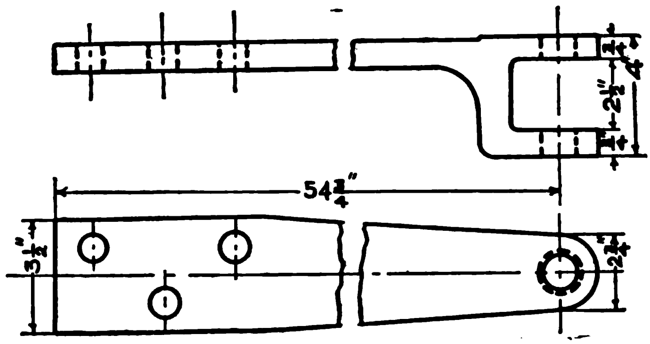


FIG. 103.—Eccentric blade.

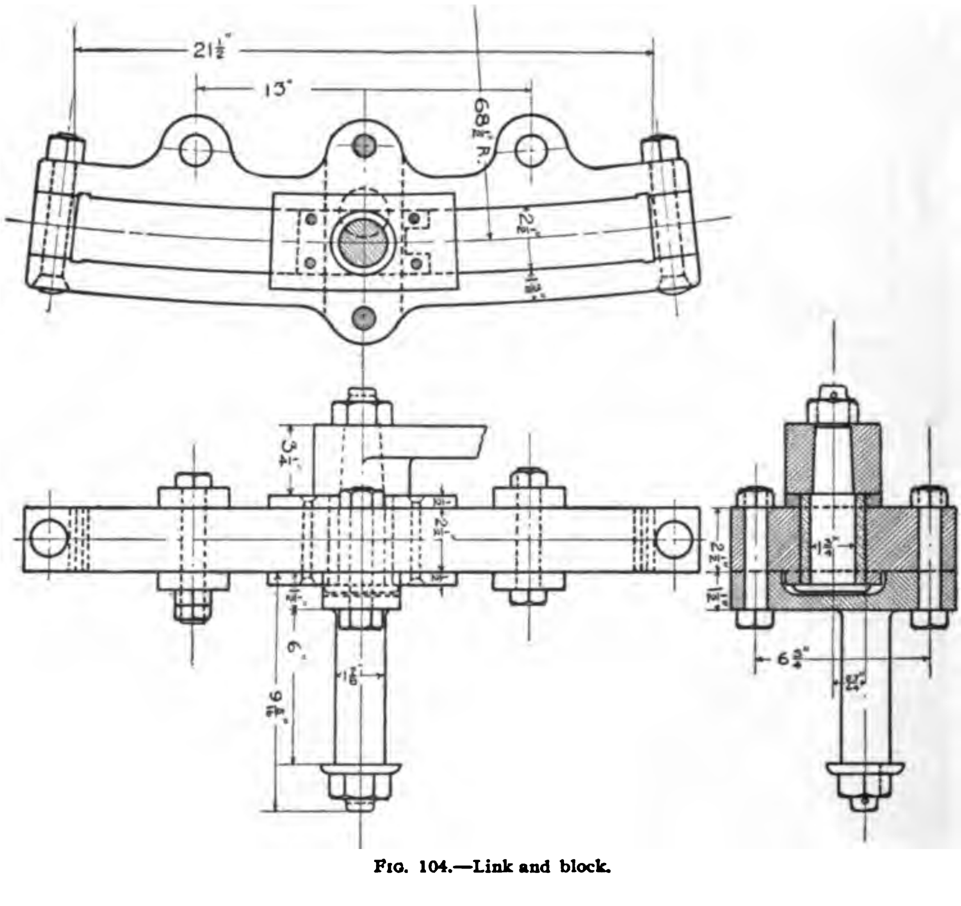


FIG. 104.—Link and block.

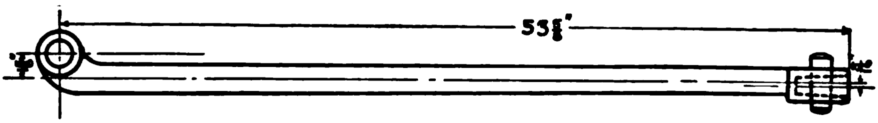


FIG. 105.—Valve rod.

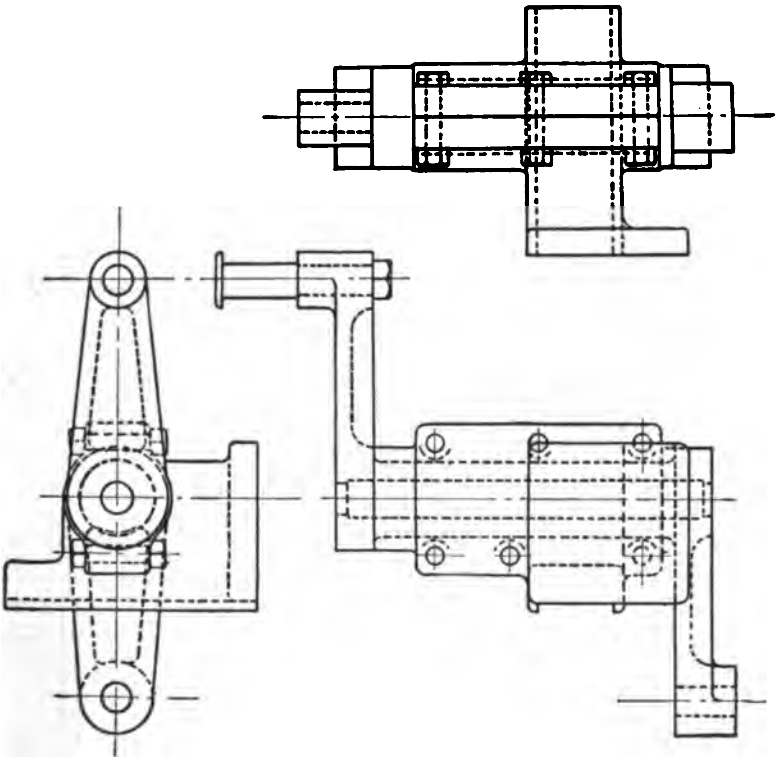


FIG. 106.—Rocker and rocker box.

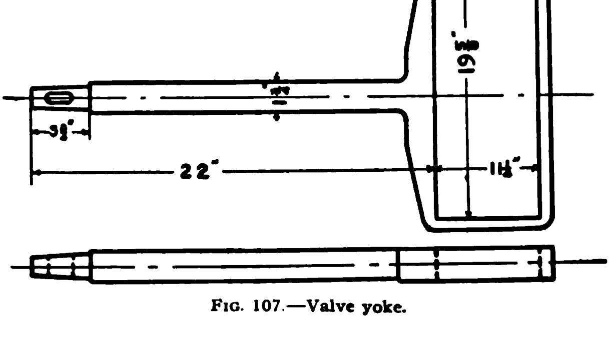


FIG. 107.—Valve yoke.

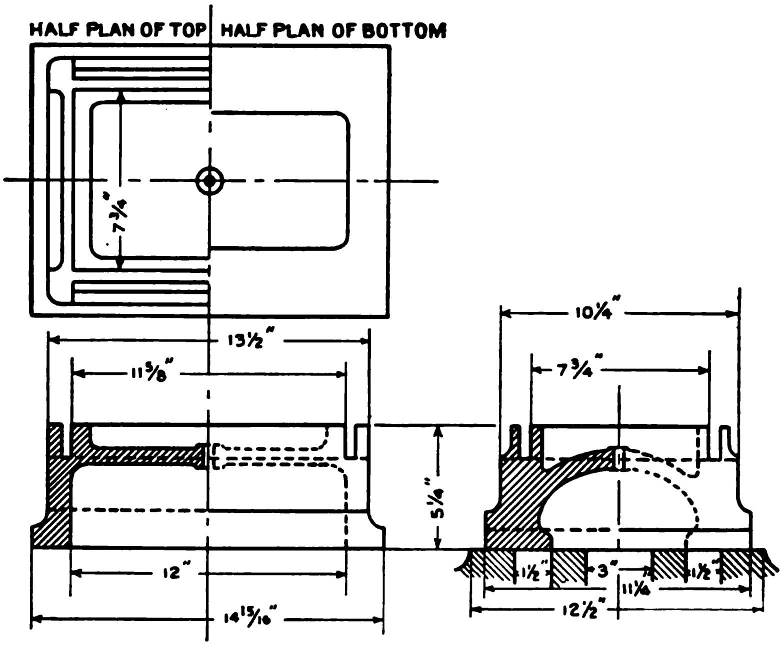


Fig. 108.—Slide valve.

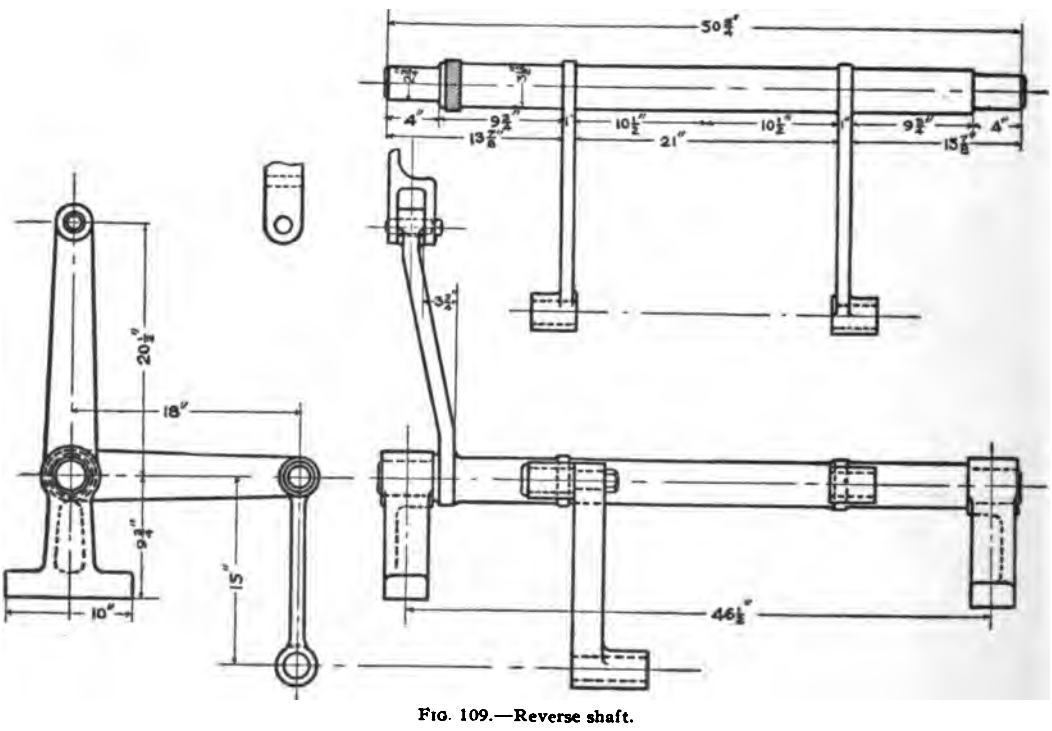
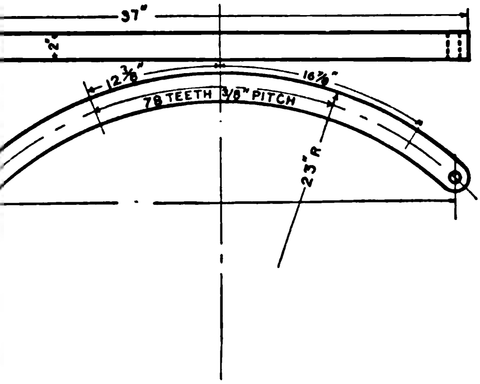


Fig. 109.—Reverse shaft.



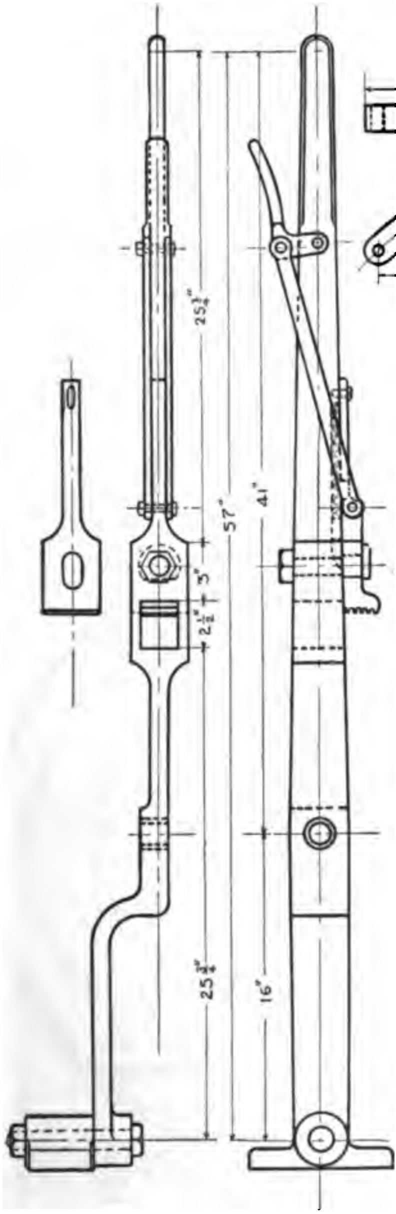


Fig. 110.—Reverse lever.

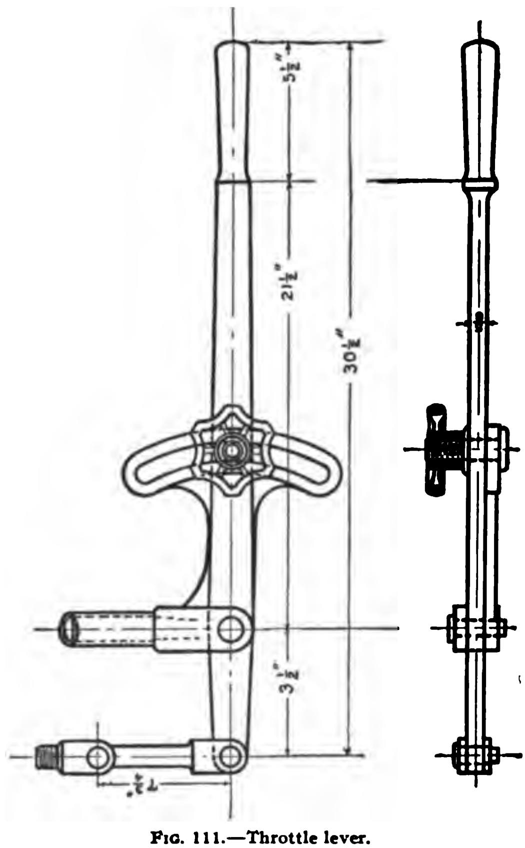


Fig. 111.—Throttle lever.

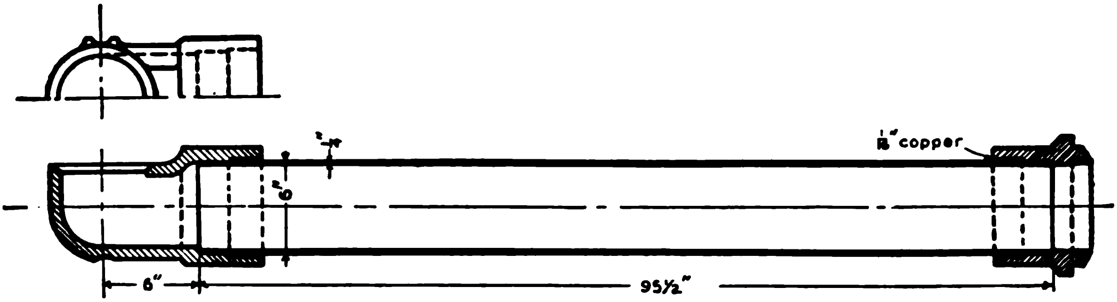


FIG. 112.—Dry pipe.

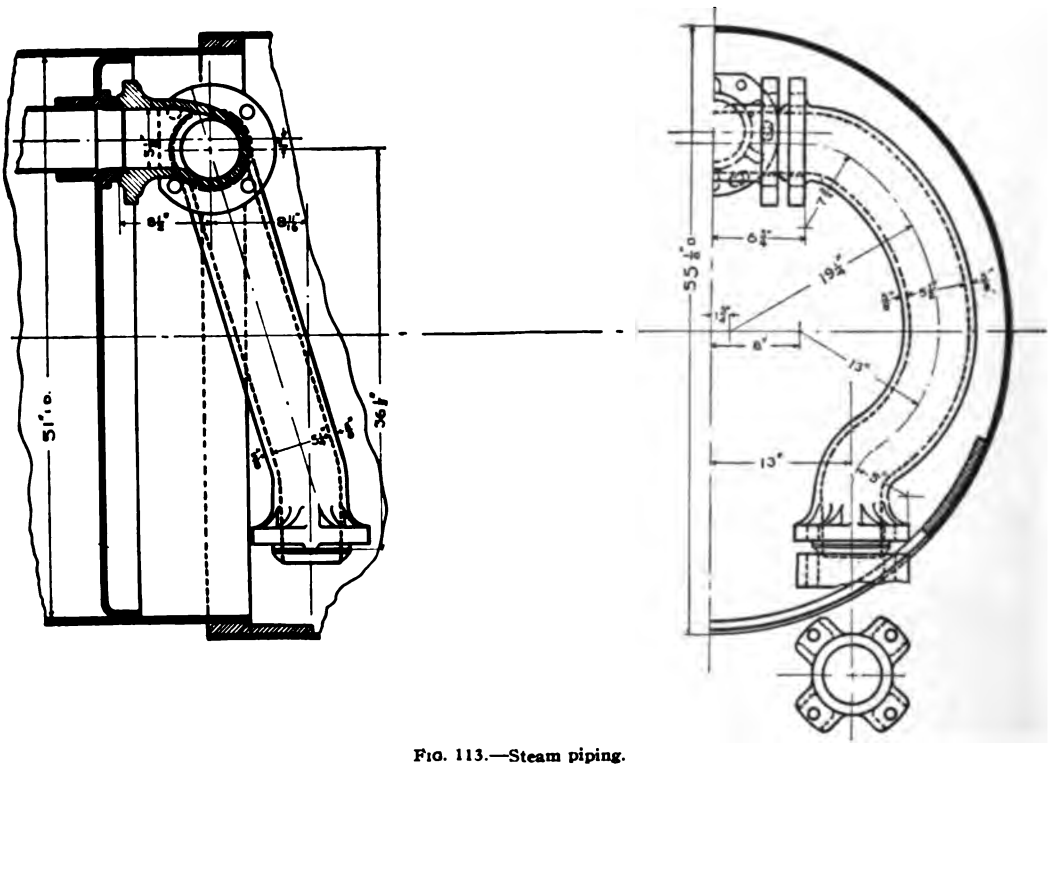


FIG. 113.—Steam piping.

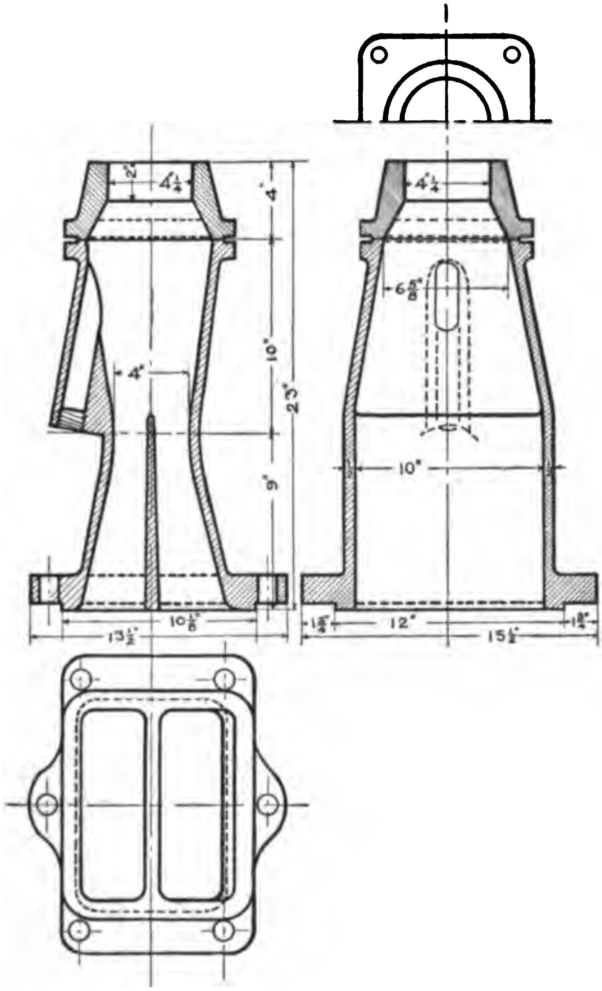


FIG. 114.—Exhaust pipe and tip.

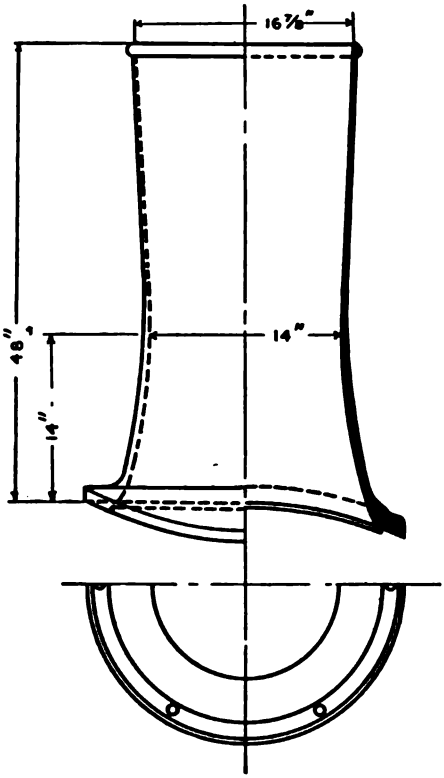


FIG 115.—Stack.

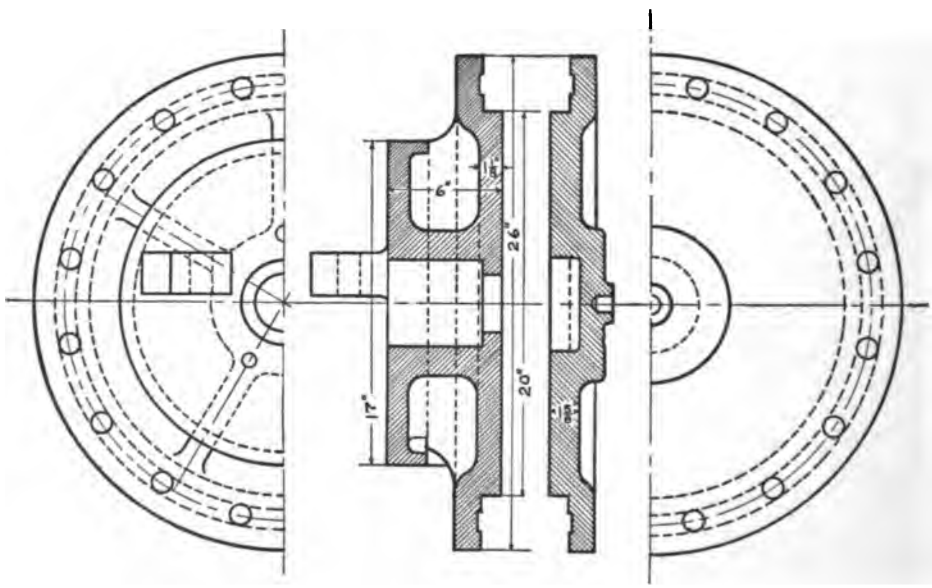


FIG. 116.—Cylinder heads.

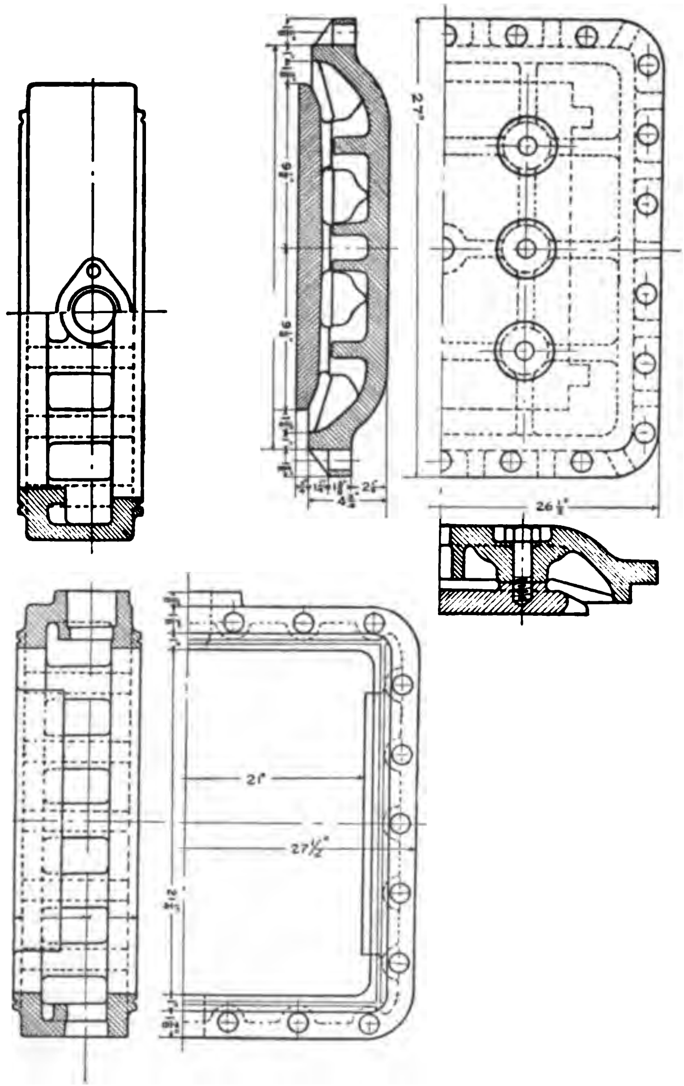


Fig. 117.—Steam chest and cover.

APPENDIX II.

METHODS, AND DATA DERIVED FROM TESTS.

36. **The Tests.**—All tests, the results of which are herewith presented, have been run under a full open throttle. Six different pressures have been employed, namely, 120, 160, 180, 200, 220, and 240 pounds by gage. At each of these pressures tests have been run at a speed of 20, 30, 40, and 50 miles, and under all conditions of pressure, save that of 240 pounds, tests have been run at 60 miles an hour. For each speed and pressure, where practicable, tests have been run at two or more different cut-offs. The plan of the tests has, therefore, involved three variables, namely, pressure, speed, and cut-off. The purpose of the plan has been to define the performance of the engine when running under a wide-open throttle, and within limits which were found practicable with reference to each of the three variables named.

Much has already been made of record concerning the methods of testing upon the Purdue locomotive testing-plant, making an elaborate description unnecessary in this connection.* Great pains were always taken to avoid all occasions for correcting observed data. Leaks, either of water or steam, were not permitted. In anticipation of a test, the engine was always warmed by a considerable period of preliminary running. As a check upon the work as it proceeded, observations were plotted as taken. Observers were employed as follows:

To keep running log and time and to read the smoke-box draft gages.................	1
To take indicator-cards, to read the dry-pipe pressure, the back-pressure, the draft in the fire-box, and to check time on the Bristol recording-gages....................	2
To control the speed by regulating the brake load...............................	1
To weigh feed-water..	2
To weigh coal and to observe boiler-pressure and smoke-box temperature..........	1
To read the dynamometer and the counter registering the continuous revolutions of driving-axles..	1
To read the throttling calorimeter, the barometer, and the thermometer showing laboratory temperature..	1
To weigh the injector overflow and to make a graphical running-log...............	1
To operate the cinder-trap..	2
To sample smoke-box gases..	1

37. **Observed and Calculated Data** are presented in detail by tables 7 to 22. In these tables each horizontal line represents a test and the several tests are grouped with respect to steam-pressure. The duplicate tests, 1*a*, 3*a*, and 5*a*, the results of which appear in the tables, have been included with the others chiefly for the purpose of securing as large a number of points as practicable from which to define the boiler performance under a pressure of 240 pounds. For convenience in presentation, the entire exhibit is separated into different tables, an explanation of which follows.

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*Locomotive Performance, John Wiley & Sons. Also, Tests of the Experimental Locomotive of Purdue University, Proceedings of the American Society of Mechanical Engineers.

TABLE 7.—GENERAL CONDITIONS.

Column 1. *Test number.*

Column 2. *Laboratory symbol.*—The first term of this symbol represents the speed in miles per hour, the second the position of the reverse lever upon its quadrant, expressed in notches forward of the center, and the third the steam-pressure. Thus, the symbol for test No. 1 is 20–2–240, which indicates that the test was run under a speed of 20 miles an hour, that the reverse lever was in the second notch forward of the center, and that the boiler-pressure was 240 pounds.

Column 3. *Date.*—This column will be of service to those who wish to trace the sequence of tests.

Column 4. *Duration of test in minutes.*—In general it was sought to have all tests of such length as would permit the burning of not less than 250 pounds of coal per foot of grate-surface, but it often happened, especially where the conditions of a test were such as to tax the capacity of the boiler, that the test was terminated because of some unexpected defect, such, for example, as a hot axle-box or crank-pin, or the failure of an injector.

Column 5. *Reverse lever, notch from center forward.*

Column 6. *Position of throttle.*—This, for all tests under consideration, is shown to have been wide open.

Column 7. *Barometer-pressure, pounds per square inch.*

Column 8. *Boiler-pressure,* determined by reference to a special gage so attached that it could readily be calibrated. The value given is the average of observations made at 5-minute intervals. The boiler-pressure was also registered by a special Bristol recording-gage, the chart of which was timed to make a complete revolution in 6 hours.

Column 9. *Dry-pipe pressure* was read from a gage attached to one of the branch-pipes. The value given is the average of observations made at five-minute intervals. Comparing the values obtained from it with those obtained from the boiler-gage should disclose the drop in pressure between the boiler and cylinder-saddle.

Column 10. *Temperature of the laboratory* is the average of observations taken at 10-minute intervals.

TABLE 8.—SPEED, WATER, AND STEAM.

Column 11. *Total revolutions* is the difference between the initial and final reading of the engine register. Readings from this register were taken at 10-minute intervals. The speed was also indicated and registered by a Boyer speed-recorder, the reading of which gives a ready means of noting fluctuations of speed during any given test.

Column 12. *Revolutions per minute* = column 11 ÷ column 4.

Column 13. *Miles equivalent to total revolutions* = column 11 × circumference of drivers in feet ÷ 5280 = column 11 ÷ 292.31.

Column 14. *Miles per hour* = column 13 × 60 ÷ column 4.

Column 15. *Temperature of feed-water,* the average of readings in degrees Fahrenheit at 10-minute intervals. The comparatively high temperature represented by some of the values given in this column are due to the use of distilled water obtained from the heating-plant.

Column 16. *Water delivered to boiler* is the total amount of water weighed to injectors, less that lost by injector overflow. The apparatus by means of which the feed-water was supplied and weighed consists of a circular tank 6 feet in diameter and 8 feet high, from which the injectors draw their supply. This tank is fitted with a single water-glass by which the level of the water within may be noted. Above this tank, a large weighing tank was mounted on a pair of scales, arranged with a quick-opening valve and an overflow. When in use, this tank was filled to overflowing and weighed, after which it was emptied as needed, and when empty weighed again, thus giving the exact weight of water used. A low-pressure Bristol recording gage connected with a small pipe opening downward into the weighing tank, by registering the difference in pressure as the tank was alternately filled and emptied, served as a check upon the count of the observers. This gage was screened and locked from those engaged in the weighing.

The locomotive having been brought to conditions of running prescribed for a test, in anticipation of the start the injectors were shut off, and the discharge valves of the weighing-barrels closed. Upon signal, the height of the water in the water-glass upon the boiler was noted by means of a graduated scale and the level in the large tank was defined by means of a light thread tied about the glass. As the test proceeded, the water level in the main tank was allowed to stand below the thread. At the end of a test it was sought to have the level of the water in the boiler the same as at the beginning. This was usually accomplished within a small fraction of an inch, variations in height being accounted for by allowing 36 pounds for each tenth of an inch difference in level. The injectors were shut off either before or at the end of a test, after which the main tank from which their supply is taken was filled to the thread on the glass. The water which passed the weighing tank from the time the test was started until the supply tank was filled to its original level represents water delivered to the injectors.

Water lost at the overflow of the injectors was received by a small calibrated tank upon the subfloor of the laboratory, readings of which were taken at the beginning and end of the test. Water thus accounted for, when deducted from the total weight delivered to the injectors, gives the water delivered to the boiler, as set forth in column 16.

Column 17. *Water lost from boiler* includes that discharged by the calorimeter and, in some few cases, that which was estimated to have been lost by incidental leaks which sometimes started during the progress of a test. The calorimeter loss per hour was:

54 pounds when boiler-pressure was 240 pounds.
49 pounds when boiler-pressure was 220 pounds.
43 pounds when boiler-pressure was 200 pounds.
37 pounds when boiler-pressure was 180 pounds.
34 pounds when boiler-pressure was 160 pounds.
20 pounds when boiler-pressure was 120 pounds.

Column 18. *Steam supplied to engine* = column 16 – column 17.

Column 19. *Water evaporated by boiler per hour* = column 16 × 60 ÷ column 4.

Column 20. *Steam supplied engine per hour* = column 18 × 60 ÷ column 4.

Column 21. *Quality of steam in dome of boiler.*—This was determined by a throttling calorimeter, the orifice of which was 0.072 inch in diameter. The calorimeter was attached close to the dome and was carefully wrapped as a precaution against radiation.

TABLE 9.—COAL.

Column 22. Kind of coal.—During some of the work involved by the tests under consideration, different samples of coal supplied by the Cleveland, Cincinnati, Chicago and St. Louis (Big Four) Railroad Company were used. The origin of this coal was not known to the laboratory authorities. The fact, however, that the coal was donated and that the principal interest in the investigation concerned cylinder performance, seemed to justify its use. Later, however, arrangements were made with the C. Jutte Company, under which Youghiogheny coal was donated f. o. b. Cincinnati, and this coal was exclusively used for all work which had not been done prior to September, 1904. The coal thus secured is a bituminous coal of recognized quality. It is one of the grades recommended by the committee of the American Society of Mechanical Engineers as a standard for boiler tests. While the records of the laboratory are complete for all tests, that of the boiler is omitted for tests not run with the Youghiogheny coal. All facts presented by the record are, therefore, entirely comparable. An analysis of the coal used is shown in table 6*a*.

TABLE 6*a*.—*Coal analysis.*

1 No. of test.	2 Combined moisture.	3 Ash.	4 Volatile combustible.	5 Fixed carbon.	6 Sulphur.
1	0.618	8.423	33.044	57.914	0.863
1*a*	0.385	9.567	33.054	56.993	0.765
2	0.752	6.425	33.707	59.115	0.901
3*a*	0.798	10.089	33.184	55.930	1.170
5	0.562	7.454	33.628	58.357	0.925
5*a*	0.926	8.711	32.936	57.426	0.862
8	0.612	7.140	33.266	58.981	0.876
11	0.727	7.440	33.854	57.979	0.796
13	1.060	7.028	33.989	57.922	0.900
14	0.980	6.161	33.989	58.869	1.022
15	0.853	7.779	33.580	57.787	0.946
16	1.040	7.092	33.665	58.203	0.779
17	0.976	6.320	34.698	58.005	0.890
21	0.933	6.385	34.296	58.385	0.794
22	1.050	7.950	34.385	56.615	0.909
24	1.057	6.986	33.745	58.211	0.859
29	0.992	6.845	34.160	58.002	0.879
30	1.718	7.170	34.503	57.609	0.879
32	0.773	6.224	34.485	58.518	0.766
33	0.457	6.907	34.248	58.387	0.883
35	1.442	6.899	33.616	58.042	0.856
37	1.313	7.203	33.420	58.064	1.021
38	0.656	7.291	32.675	59.377	0.823
39	1.019	6.274	34.194	58.512	0.884
41	1.015	6.705	35,475	56.785	1.185
42	0.852	6.968	34.120	58.060	0.891
67	0.985	7.890	35.640	55.485	1.040
68	0.855	6.950	35.320	56.875	0.900
76	0.811	6.326	34.026	58.836	0.851
77	0.540	8.327	34.212	56.921	0.811
81	0.709	6.711	34.431	58.139	0.853
87	0.850	8.010	35.520	55.615	1.610
89	0.212	8.840	34.418	56.495	1.150
92	1.015	9.370	34.450	55.165	1.095
94	1.100	7.410	35.500	55.945	1.227

Column 23. *Dry coal fired.*—By "dry coal" is meant the coal after incidental or surface moisture has been removed. A shovelful of coal was taken from each loaded barrow as it was delivered to the fireman, and placed in a galvanized-iron pan. At the conclusion of the test, all lumps in the coal thus obtained were broken to a fairly uniform size, after which the pile was thoroughly mixed and one-half rejected. This process of reducing in size, mixing, and discarding was continued until a sample of about 10 pounds weight was obtained, which was placed in a galvanized pan of suitable size, weighed, and deposited in a rack over the steam-pipes, where it was allowed to remain for not less than 8 hours. After this, it was again weighed. The loss in weight thus obtained is assumed to be the amount of moisture present in the coal, and was entered upon the log of the tests as a percentage record. The actual weighings of coal for the test were corrected for the moisture thus accounted for. The results appear in column 23.

Column 24. *Dry ash.*—In locomotive service, not all of the non-combustible content of the fuel appears as ash in the ash-pan. A proportion of the whole amount of ash, varying with the strength of the draft and consequently with the conditions under which the locomotive is operated, passes off by the stack. In the practice of the laboratory, the fire was vigorously shaken immediately before the beginning of a test and the ash-pan thoroughly cleaned. As the test proceeded, refuse accumulated in the ash-pan and at the conclusion of the test the fire was reduced by shaking to its original condition, after which the refuse in the ash-pan was sprinkled and drawn off into large galvanized-iron pans. Generally the whole amount was dried, and when dry was weighed. In some cases, however, the refuse was sampled in the same manner as the coal and weighed. The result in either case is set forth by column 24.

Column 25. *Dry coal minus dry ash.*—Judged by the manner in which the data are obtained, the values of this column would in stationary practice constitute the pounds of combustible fired. The fact that in locomotive service it is impracticable to account for all the ash deprives the values of this column of such significance. The values of column 25 are, therefore, not designated as pounds of combustible, but are presented merely as a difference based upon actual observations.

Column 26. *Combustible by analysis.*—The values of this column are obtained by multiplying column 23 by the sum of the volatile combustible and fixed carbon given in columns 4 and 5, respectively, in the table "Coal analysis" of this appendix, in the explanation of column 22.

Column 27. *Dry coal per hour* = column 23 $\times$ 60 $\div$ column 4.

Column 28. *Dry coal per square foot of grate-surface per hour*=col. 27 $\div$ 17.

Column 29. *Dry coal per sq. ft. of heating-surface per hour*=col. 27 $\div$ 1322.

Column 30. *Coal per mile run* = column 23 $\div$ column 13.

Column 31. *Cinders caught in front end.*—At the conclusion of each test the front door was opened and all cinders found therein shoveled into large galvanized-iron pans and weighed. The record will not be found entirely consistent, since the quantity of cinders collected is a function not only of the draft but also of the duration of the test. As the front end becomes filled, a smaller proportion of all solid matter going through the tubes remains therein. The observed results are given as obtained.

Column 32. *Sparks from the stack.*—A measure of the volume of solid matter discharged from the stack was obtained by the use of a sampling-tube above the stack, in a manner which has been elsewhere described.* By means of a suitably curved tube it is possible systematically to explore the issuing stream of steam and gases and to entrap all solid matter which comes within the area of the exploring-tube. From data thus obtained, an estimate has been made of the spark losses per hour, with the results set forth in column 32.

TABLE 10.—DRAFT AND BOILER PERFORMANCE.

Column 33. *Draft in front of diaphragm* is expressed in inches of water and is the average value of observations taken at 5-minute intervals.

Column 34. *Draft back of the diaphragm* is expressed in inches of water and is the average value of observations taken at 5-minute intervals. The difference between the values of column 33 and column 34 represents the resistance of the diaphragm.

Column 35. *Draft in fire-box* is expressed in inches of water and is the average of observations taken at 5-minute intervals. The connection with the fire-box was by means of a hollow stay-bolt. The difference between the values of column 34 and those of 35 should represent the resistance of the tubes.

Column 36. *Smoke-box temperature.*—The values of this column are the average of observations taken by means of a high-grade thermometer at 10-minute intervals.

Column 37. *Water evaporated per square foot of heating-surface per hour.*—This is column 19 ÷ 1322.

Column 38. *Water evaporated per pound of dry coal* = column 19 ÷ column 27. This column gives the actual evaporation.

Column 39. *Equivalent evaporation per hour* = column 19 × column 43 ÷ 965.8.

Column 40. *Equivalent evaporation per square foot of heating-surface per hour* = column 39 ÷ 1322.

Column 41. *Equivalent evaporation per square foot of grate surface per hour* = column 39 ÷ 17.

Column 42. *Equivalent evaporation per pound of dry coal* = column 39 ÷ column 27.

TABLE 11.—BOILER PERFORMANCE (CONTINUED).

Column 43. *B. t. u. taken up by each pound of water evaporated* $= xr + q - q_0$.

Column 44. *B. t. u. taken up by the boiler per minute = column* 19 × column 43 ÷ 60.

Column 45. *B. t. u. taken up by boiler per pound of dry coal* = column 38 × column 43.

Column 46. *B. t. u. taken up by boiler per pound of combustible* = column 45 × 100 ÷ per cent of combustible as shown by analysis in table 6*a*, "Coal Analysis," of this Appendix in the explanation of column 22.

Column 47. *B. t. u. taken up by boiler for* 100 *B. t. u. in coal* = column 45 × 100 ÷ column 55.

Column 48. *Boiler horsepower* = column 39 ÷ 34.5.

* Locomotive Sparks, published by John Wiley & Sons; also, The Effect of High Rates of Combustion upon the Efficiency of Locomotive Boilers, Proceedings of the New York Railroad Club, September, 1896.

TABLE 12.—CHEMICAL RESULTS.

Columns 49 *to* 52. *Composition of flue gases.*—The sampling of flue gases was accomplished by the use of a long copper tube passing through a suitable fixture attached to the shell of the smoke-box. The sampling-tube entered the smoke-box radially and was of sufficient length to extend to its center. Gas entered the sampling-tube by small perforations near its inside end. The arrangement was such that the penetration of the tube into the smoke-box could be varied from nothing to 28 inches. In taking a sample, the tube was systematically moved over a distance of 3 or 4 inches at a time and allowed to remain in each position for a period of several minutes. In this manner each sample was drawn from all points in the path of the tube. The samples were in all cases drawn from the smoke-box over mercury and were analyzed by means of an Orsat-Muncke apparatus. Every effort was made to secure accuracy in this work. A skillful chemist gave his entire time to securing samples of gas and coal and in analyzing the same. Notwithstanding the precautions taken, the results do not serve any large purpose in explaining the performance of the boiler. For example, among the results of the tests are some showing abnormally high boiler performance, and others for which the performance is low. It had been hoped that in some of these cases at least the composition of the smoke-box gases would disclose the reason for abnormal performance. It has been concluded, however, after an elaborate study of the whole matter that no safe relation can be traced between the actual evaporative performance of the boiler and the composition of the smoke-box gases. Computations have been made, also, for a considerable number of the tests, in the development of a heat balance, into the calculation of which the composition of the smoke-box gases enters. Such computations, however, developed a factor unaccounted for too large to justify the work. The defect in the process of determining the composition of the gases lies probably in the methods by which the sample is secured. The fact seems to be that no system has yet been devised by which a sufficiently representative sample of gas can be secured from the smoke-box of a locomotive into which gases of many different values are doubtless discharged, the movement of which is too rapid and the course by which they proceed too direct to insure any considerable amount of mixing in the smoke-box. The problem is one which merits further study.

Column 53. *Air used per pound of carbon* is calculated from an analysis of the flue gases.

Column 54. *Excess air.*

Column 55. *B. t. u. per pound of coal.*—Values in this column are calculated from the analysis of coal. From each sample of coal which had been submitted to the drying test a sample sufficient to fill a quart fruit jar was taken for chemical purposes. This sample was employed in determining the volatile combustible matter, fixed carbon and sulphur from which the result was determined. (See explanation of column 22.)

TABLE 13.—EVENTS OF THE STROKE FROM INDICATOR-CARDS.

The indicator work received careful attention. In all cases two instruments were used upon each cylinder. A short nipple and elbow constituted the only piping between the indicator and the cylinder. The drum motion was positive and provided a reciprocating-bar which moved just behind the drum of the indicators, permitting action from the shortest possible length of cord. The drum motion was designed to give a card of 3.75 inches in length. The design of the reducing-gear is shown by fig. 118. Cards were taken at 10-minute intervals throughout the test. The results recorded are the average for all cards.

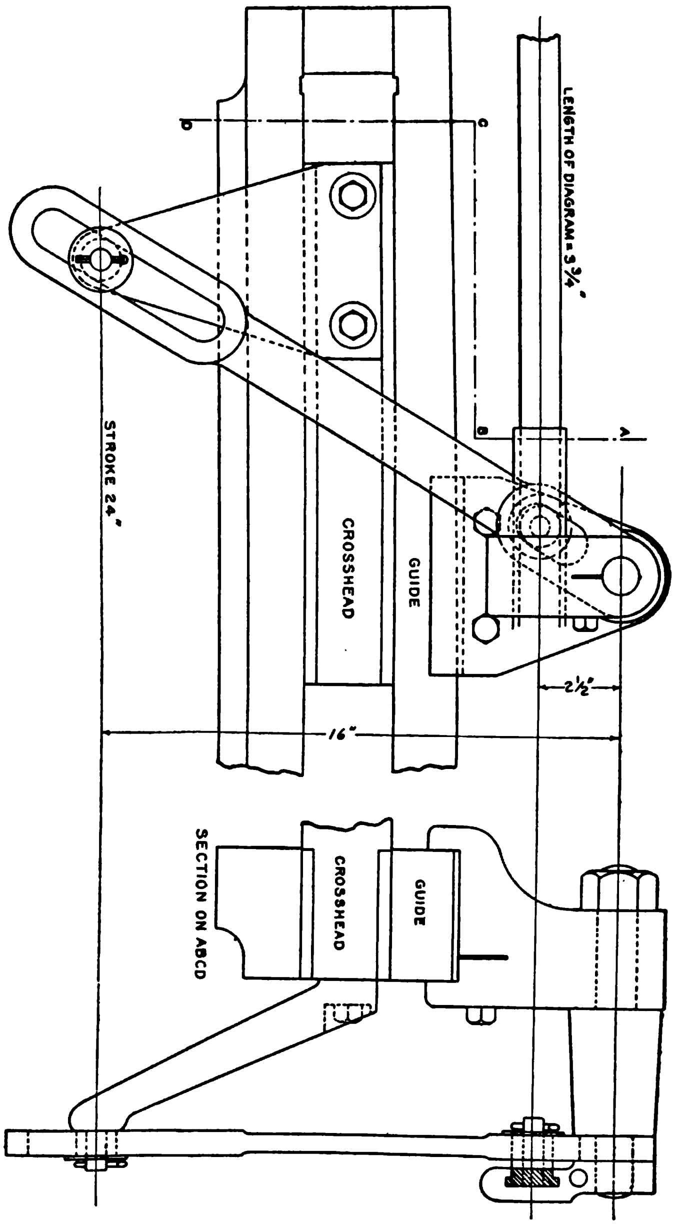


Fig. 118.—Reducing motion for indicator.

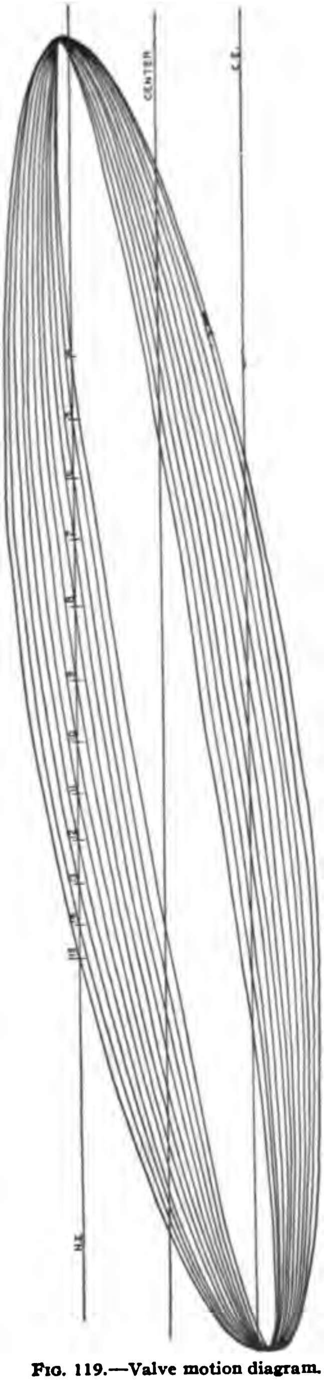


FIG. 119.—Valve motion diagram.

The valve setting for the test is best shown by the valve-motion diagram, fig. 119.

In reviewing the tabulated data, it will be found that the position of the reverse lever does not always define the events of the stroke. For example, the cards may show considerable variation in cut-off for two tests which were run with the same position of the reverse lever. This results from the inertia effects acting upon the valve and its gear and from differences in the condition of lubrication, in combination with lost motion in joints and strain in parts.

Columns 56 *to* 60. *Admission.*
Columns 61 *to* 65. *Cut-off.*

TABLE 14.—EVENTS OF THE STROKE (CONTINUED).

Columns 66 *to* 70. *Release.*
Columns 71 *to* 75. *Compression.*

TABLE 15.—PRESSURES FROM INDICATOR-CARDS.

Columns 76 *to* 80. *Initial.*
Columns 81 *to* 85. *At cut-off.*

TABLE 16.—PRESSURES FROM INDICATOR-CARDS (CONTINUED).

Columns 86 *to* 90. *At release.*
Columns 91 *to* 95. *At compression.*

TABLE 17.—PRESSURES FROM INDICATOR-CARDS (CONTINUED).

Columns 96 *to* 100. *Least back pressure.*
Columns 101 *to* 105. *Mean effective pressure.*

TABLE 18.—ENGINE PERFORMANCE.

Columns 106 *to* 110. *Indicated horsepower.*—The power was calculated by the use of a constant based upon the accurately determined dimensions of the engine and representing the horsepower, assuming the engine to make one revolution per minute in response to one pound mean effective pressure. These horsepower constants are as follows:

Horsepower constants:

Right side:	
Head end	0.01222
Crank end	.01186
Left side:	
Head end	0.01243
Crank end	.01207

The power for each cylinder end was determined by multiplying the horsepower constant by the average mean effective pressure for a test, columns 101 to 104, by the revolutions per minute, column 12.

Column 111. *Steam per indicated horsepower per hour by tank.*—This is column 20 ÷ column 110.

Column 112. *Steam per indicated horsepower per hour by indicator* = (column 127 − column 132) × 60 × column 12 ÷ column 110.

Column 113. *Coal per indicated horsepower per horsepower hour* = column 27 ÷ column 110.

Column 114. *B. t. u. supplied engine per minute* = column 20 × column 43 ÷ 60.

Column 115. *B. t. u. supplied engine per minute, assuming temperature of feed to have been equal to temperature of exhaust* = column 20 × (column 43 + T − 32 − q) ÷ 60 where T is the temperature of feed-water and q the heat in 1 pound of water at a temperature corresponding to the least back-pressure.

Column 116. *B. t. u. per indicated horsepower per minute* = column 114 ÷ column 110.

Column 117. *B. t. u. per indicated horsepower per minute, on the assumption that the temperature of the feed was equal to the temperature of exhaust* = column 115 ÷ 110.

TABLE 19.—STEAM SHOWN BY INDICATOR.

In determining the weight of steam present in the engine cylinder at any point in the stroke, three factors must be known, namely, the volume occupied by the steam in question, its pressure and its weight per unit volume. The constants for volumes employed in determining the weight of steam shown by indicator, as determined from accurate measurements, are as follows:

Piston displacement in cubic feet.

Right side:		Left side:	
Head end	2.8020	Head end	2.8486
Crank end	2.7196	Crank end	2.7660

Cylinder clearance, per cent of piston displacement:

Right side:		Left side:	
Head end	7.44	Head end	7.34
Crank end	7.98	Crank end	7.63

The volumes for any point in the stroke was found by adding the per cent of that portion of the whole stroke which the piston had passed over to reach the point in question (columns 56 to 75) to the per cent of clearance, and multiplying by the piston displacement.

The pressure above atmosphere at the several points in the stroke to be investigated appears in columns 76 to 95. The weight per unit volume corresponding to this pressure was found from Peabody's steam table.

Columns 118 *to* 122. *Pounds of steam shown by indicator at cut-off.*—The values given are the average of those obtained from indicator-cards taken at 10-minute intervals.

Columns 123 *to* 127. *Pounds of steam shown by indicator at release.*—The values given are the average of those obtained from indicator-cards taken at 10-minute intervals.

TABLE 20.—CYLINDER PERFORMANCE.

Columns 128 *to* 132. *Pounds of steam shown by the indicator at the beginning of compression.*—The values shown are the average of those obtained from indicator-cards taken at 10-minute intervals.

Column 133. *Weight of steam per revolution by tank* = col. 18 ÷ col. 11.

Column 134. *Weight of mixture in cylinder per revolution* = column 133 + column 132.

Column 135. *Per cent of mixture present as steam at cut-off* = 100 × column 122 ÷ column 134.

Column 136. *Per cent of mixture present as steam at release* = (100 × column 127) ÷ column 134.

Column 137. *Reevaporation per revolution* = column 127 − column 122.

Column 138. *Reevaporation per indicated horsepower per hour* = column 137 × 60 × column 12 ÷ column 110.

TABLE 21.—PERFORMANCE OF THE LOCOMOTIVE AS A WHOLE.

Column 139. *Draw-bar pull.*—The values given are the average of observations made from a traction dynamometer at 5-minute intervals.

Column 140. *Dynamometer horsepower.*—To aid in calculating dynamometer horsepower, a constant was employed representing the horsepower which would be developed if the drivers were to revolve one revolution a minute and the locomotive were to exert 1-pound pull at the draw-bar. One factor in such a determination is the circumference of the drivers, which by accurate measurement was found to be 18.063 feet. Upon this basis, the dynamometer horsepower constant is, $K = 0.000547$. The values in this column are, therefore, column 139 × column 12 × K.

Column 141. *Machine friction in terms of mean effective pressure* = column 105 − the M. E. P. equivalent to the pounds pull at the draw-bar, column 139

Column 142. *Machine friction, per cent of indicated horsepower* = (100 × column 141) ÷ column 105.

Column 143. *Machine friction horsepower* = column 142 × column 110.

Column 144. *Steam per dynamometer horsepower hour* = column 20 ÷ column 140.

Column 145. *Coal per dynamometer horsepower per hour* = column 27 ÷ column 140.

TABLE 22.—COMPARATIVE PERFORMANCE OF THE LOCOMOTIVE ASSUMING INCIDENTAL IRREGULARITIES IN THE RESULTS OF INDIVIDUAL TESTS TO HAVE BEEN ELIMINATED.

Column 146. *Equivalent steam to engine per hour, feed-water at a temperature of* 60° F. = column 20 × (column 43 + column 15 − 60) ÷ 965.8.

Column 147. *Equivalent evaporation per pound of dry coal, assuming the evaporative efficiency of the boiler to have been represented by the equation* $E = 11.305 - 0.221\,H$, where E is the equivalent evaporation per pound of coal and H is the rate of evaporation per foot of surface per hour. For values in question, H = item 146 ÷ 1322.

Column 148. *Dry coal fired per hour,* assuming the evaporative efficiency to be that shown by the equation, equals 146 ÷ column 147.

Column 149. *Dry coal per indicated horsepower hour* = column 148 ÷ column 110.

Column 150. *Equivalent steam per indicated horsepower hour* = column 146 ÷ column 110.

Column 151. *Machine friction in terms of mean effective pressure.*—The purpose of this column is to eliminate irregularities in action due to variations in lubrication, etc. The values given are those obtained by drawing a smooth curve through plotted points in the manner described in detail in paragraph 25, Chapter IV.

Column 152. *Machine friction horsepower* is the power-equivalent, assuming the friction M. E. P. to have been that shown by column 151.

Column 153. *Machine friction, per cent of indicated horsepower* = 100 × column 152 ÷ column 110.

Column 154. *Dynamometer horsepower* = column 110 − column 152.

Column 155. *Draw-bar pull* = 33,000 × col. 154 + (18.063 × col. 12).

Column 156. *Coal per dynamometer horsepower hour* = col. 148 ÷ col. 154.

Column 157. *Steam per dynamometer horsepower per hour* = column 146 ÷ column 154.

TABLE 7.—*General conditions.*

Designation of tests. Number.	Designation of tests. Laboratory symbol.	Designation of tests. Date.	Duration of test.	Reverse lever notch from center forward.	Position of throttle.	Barometer pressure.	Boiler pressure, by gage.	Dry-pipe pressure, by gage.	Temperature of laboratory.
1	2	3	4	5	6	7	8	9	10
			Min.			*Lbs.*	*Lbs.*	*Lbs.*	°*F.*
1	20–2–240	Mar. 1, '05	180	2	Wide open	14.47	241.5	240.9	72.0
1*a*	20–2–240	Jan. 27, '05	155	2	...do...	14.47	235.8	232.9	75.0
2	20–4–240	Feb. 18, '05	120	4	...do...	14.40	242.2	.....	69.0
3	20–6–240	May 13, '04	125	6	...do...	14.41	238.3	237.2	81.7
3*a*	20–6–240	Feb. 3, '05	150	6	...do...	14.70	236.4	233.9	80.0
4	20–8–240	Feb. 1, '05	...	8	...do...	14.60	240.0	.....	....
5	30–2–240	Feb. 20, '05	120	2	...do...	14.56	240.0	.....	78.0
5*a*	30–2–240	Jan. 9, '05	165	2	...do...	14.60	239.2	235.0	79.0
6	30–4–240	May 2, '04	140	4	...do...	14.48	240.2	235.1	....
7	30–6–240	Jan. 20, '05	35	6	...do...	14.45	237.5	232.0	73.4
8	40–2–240	Mar. 3, '05	165	2	...do...	14.34	242.0	240.5	77.0
9	40–4–240	Apr. 29, '04	115	4	...do...	14.39	241.1	239.2	89.0
10	40–6–240	Jan. 11, '05	...	6	...do...	14.34	240.0	228.0	81.0
11	50–2–240	Feb. 24, '05	60	2	...do...	14.45	242.0	.....	69.0
12	50–4–240	Feb. 6, '05	...	4	...do...	14.40	240.0	.....	....
13	20–2–220	May 8, '05	180	2	...do...	14.40	221.6	218.4	84.0
14	20–4–220	Apr. 24, '05	185	4	...do...	14.50	219.8	216.6	81.0
15	20–6–220	Apr. 26, '05	165	6	...do...	14.20	220.1	215.2	77.0
16	20–8–220	Mar. 24, '05	125	8	...do...	14.44	220.6	218.4	84.0
17	30–2–220	May 12, '05	210	2	...do...	14.47	220.5	219.7	83.0
18	30–4–220	Aug. 3, '05	120	4	...do...	14.40	220.0	219.1	82.1
19	30–6–220	July 10, '05	100	6	...do...	14.40	218.8	215.1	76.6
20	30–8–220	Aug. 1, '05	...	8	...do...	14.44	218.0	.....	....
21	40–2–220	May 17, '05	200	2	...do...	14.30	220.7	217.7	80.0
22	40–4–220	Aug. 7, '05	60	4	...do...	14.40	218.6	212.8	85.0
23	40–6–220	Aug. 1, '05	...	6	...do...	14.44	219.5	.....	....
24	50–2–220	May 19, '05	120	2	...do...	14.47	220.8	218.0	88.0
25	50–4–220	Aug. 4, '05	30	4	...do...	14.41	220.0	.....	83.0
26	50–6–220	....do....	...	6	...do...	14.41	220.0	.....	....
27	60–4–220	....do....	...	4	...do...	14.41	221.0	.....	....
28	60–6–220	....do....	...	6	...do...	14.41	220.0	.....	....
29	20–2–200	May 10, '05	210	2	...do...	14.40	200.2	196.9	90.0
30	20–4–200	Apr. 7, '05	210	4	...do...	14.37	199.6	196.9	75.0
31	20–6–200	Apr. 1, '04	175	6	...do...	14.46	199.7	.....	78.4
32	20–8–200	Mar. 27, '05	150	8	...do...	14.40	200.3	195.6	83.0
33	30–2–200	Apr. 10, '05	210	2	...do...	14.20	199.4	200.2	84.0
34	30–4–200	Apr. 6, '04	190	4	...do...	14.40	200.0	199.3	75.0
35	30–6–200	June 1, '05	150	6	...do...	14.40	199.4	196.7	84.0
36	30–8–200	Aug. 1, '05	...	8	...do...	14.44	200.0	.....	....
37	40–2–200	May 23, '05	180	2	...do...	14.50	200.4	195.9	87.0
38	40–4–200	Feb. 22, '05	165	4	...do...	14.50	201.6	.....	78.0
39	40–6–200	Apr. 28, '05	115	6	...do...	14.20	199.4	194.4	86.0
40	40–8–200	Aug. 1, '05	...	8	...do...	14.44	199.5	.....	....
41	50–2–200	July 8, '05	100	2	...do...	14.40	200.5	197.8	84.0
42	50–4–200	Apr. 5, '05	120	4	...do...	14.30	200.6	196.2	79.0
43	50–6–200	Aug. 4, '05	...	6	...do...	14.41	202.0	.....	....
44	60–4–200	....do....	...	4	...do...	14.41	200.0	.....	....
45	60–6–200	....do....	...	6	...do...	14.41	201.0	.....	....
46	20–2–180	Feb. 17, '04	240	2	...do...	14.60	183.0	181.2	74.0
47	20–4–180	Feb. 15, '04	240	4	...do...	14.54	181.6	179.0	73.0

TABLE 7.—*General conditions*—Continued.

Designation of tests.			Duration of test.	Reverse lever notch from center forward.	Position of throttle.	Barometer pressure.	Boiler pressure, by gage.	Dry-pipe pressure, by gage.	Temperature of laboratory.
Number.	Laboratory symbol.	Date.							
1	2	3	4	5	6	7	8	9	10
			Min.			*Lbs.*	*Lbs.*	*Lbs.*	*°F.*
48	20-6-180	Mar. 16, '04	210	6	Wide open	14.54	180.0	176.5	....
49	20-8-180	Mar. 18, '04	155	8	...do...	14.45	180.3	177.7	....
50	20-10-180	Aug. 1, '05	...	10	...do...	14.44	181.0	.....	....
51	30-2-180	Feb. 19, '04	240	2	...do...	14.18	181.6	178.6	79.0
52	30-4-180	Mar. 28, '04	220	4	...do...	14.47	178.6	178.9	74.0
53	30-6-180	Mar. 23, '04	150	6	...do...	14.58	170.0	170.0	81.0
54	30-8-180	Jan. 20, '04	100	8	...do...	14.43	179.4	175.5	78.0
55	30-10-180	Aug. 1, '05	...	10	...do...	14.44	180.3	.....	....
56	40-2-180	Feb. 26, '04	220	2	...do...	14.50	182.3	178.9	74.0
57	40-4-180	Feb. 24, '04	220	4	...do...	14.51	181.1	178.8	74.0
58	40-6-180	Dec. 6, '04	105	6	...do...	14.45	179.8	176.2	80.0
59	40-8-180	Apr. 11, '04	85	8	...do...	14.22	177.7	177.4	75.0
60	40-10-180	Aug. 1, '05	...	10	...do...	14.44	180.0	.....	....
61	50-2-180	Feb. 29, '04	120	2	...do...	14.29	182.3	181.6	75.0
62	50-4-180	Feb. 22, '04	115	4	...do...	14.48	181.3	176.7	....
63	50-6-180	Mar. 2, '04	60	6	...do...	14.31	180.7	175.5	77.0
64	50-8-180	Aug. 4, '05	...	8	...do...	14.41	179.0	.....	....
65	60-4-180	Aug. 4, '05	...	4	...do...	14.41	180.0	.....	....
66	60-6-180	Aug. 4, '05	...	6	...do ..	14.41	180.0	.....	....
67	20-4-160	July 19, '05	210	4	...do...	14.44	160.2	159.1	91.5
68	20-6-160	July 27, '05	210	6	...do...	14.40	160.2	158.5	86.0
69	20-8-160	Mar. 30, '04	185	8	...do...	14.29	159.3	157.3	74.0
70	20-10-160	Aug. 1, '05	...	10	...do...	14.44	161.0	.....	....
71	30-4-160	July 6, '05	210	4	...do...	14.35	160.7	160.3	87.0
72	30-6-160	July 18, '05	210	6	...do...	14.45	159.7	158.6	97.0
73	30-8-160	Apr. 18, '04	145	8	...do...	14.40	162.2	159.9	80.0
74	30-10-160	Dec. 16, '04	...	10	...do...	14.40	157.7	.....	....
75	30-12-160	Aug. 1, '05	...	12	...do...	14.44	160.0	.....	....
76	40-4-160	Apr. 12, '05	210	4	...do...	14.30	161.0	156.9	77.0
77	40-6-160	Apr. 19, '05	170	6	...do...	14.40	160.6	154.7	80.0
78	40-8-160	Apr. 13, '04	110	8	...do...	14.45	161.1	158.0	69.0
79	40-10-160	Aug. 1, '05	...	10	...do...	14.44	159.5	.....	....
80	50-4-160	July 28, '05	75	4	...do...	14.37	159.8	158.4	83.0
81	50-6-160	Apr. 17, '05	120	6	...do...	14.40	160.0	155.6	77.0
82	50-8-160	Aug. 4, '05	...	8	...do...	14.41	159.0	.....	....
83	60-4-160	Aug. 4, '05	...	4	...do...	14.41	160.0	.....	....
84	60-6-160	Aug. 4, '05	...	6	...do...	14.41	159.5	.....	....
85	20-4-120	July 7, '05	210	4	...do...	14.33	120.4	117.9	80.0
86	20-8-120	July 3, '05	210	8	...do...	14.20	121.3	118.0	90.0
87	20-12-120	July 11, '05	200	12	...do...	14.30	120.0	115.6	83.0
88	30-4-120	July 20, '05	210	4	...do...	14.43	120.5	119.1	90.5
89	30-8-120	July 5, '05	210	8	...do...	14.30	120.4	117.4	86.0
90	30-14-120	July 12, '05	120	14	...do...	14.40	120.1	114.3	86.0
91	40-4-120	July 21, '05	210	4	...do...	14.40	120.3	117.4	83.0
92	40-8-120	July 14, '05	190	8	...do...	14.50	120.5	117.1	87.0
93	40-12-120	July 13, '05	120	12	...do...	14.44	119.9	119.1	85.0
94	50-4-120	July 22, '05	120	4	...do...	14.40	119.9	118.6	84.0
95	50-8-120	July 25, '05	120	8	...do...	14.50	120.3	117.8	80.0
96	50-11-120	Aug. 7, '05	40	11	...do...	14.40	120.1	110.0	88.0
97	60-8-120	Aug. 4, '05	...	8	...do...	14.41	120.0	.....	....

TABLE 8.—*Speed, water and steam.*

Designation of tests.		Speed.				Water and steam.						
Number.	Laboratory symbol.	Total revolutions.	Revolutions per minute.	Miles equivalent to total revolutions.	Miles per hour.	Temperature of feed water.	Water delivered to boiler.	Water lost from boiler.	Steam supplied to engine.	Water evaporated by boiler per hour.	Steam supplied to engine per hour.	Quality of steam in dome, dry.
1	2	11	12	13	14	15	16	17	18	19	20	21
						°F.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	P. ct.
1	20–2–240	17,009	94.49	58.19	19.40	83.0	22,330	525	21,805	7,443	7,268	98.90
1a	20–2–240	15,007	97.27	51.57	19.96	82.0	20,012	....	....	7,746	....	98.92
2	20–4–240	11,727	97.72	40.20	20.10	69.6	20,172	308	19,864	10,086	9,932	98.90
3	20–6–240	12,137	97.09	41.52	19.92	60.5	23,500	68	23,432	11,280	11,247	99.16
3a	20–6–240	14,499	96.66	49.60	19.84	85.3	30,083	....	....	12,033	....	98.93
4	20–8–240	....	97.00	....	19.90	....	....	....	....	....	....	....
5	30–2–240	17,538	146.15	59.99	29.99	86.0	19,331	406	18,925	9,665	9,462	98.91
5a	30–2–240	24,018	145.56	84.74	30.81	94.0	30,211	....	....	10,986	....	98.65
6	30–4–240	20,441	146.00	69.93	30.00	61.5	26,912	77	26,835	11,534	11,500	98.76
7	30–6–240	....	133.80	....	27.46	....	....	....	....	....	....	....
8	40–2–240	32,086	194.46	109.76	39.91	80.6	28,616	586	28,030	10,405	10,192	98.97
9	40–4–240	22,383	194.63	76.57	39.95	61.1	25,959	63	25,896	13,544	13,511	98.74
10	40–6–240	....	207.00	....	42.47	....	....	....	....	....	....	....
11	50–2–240	14,903	248.38	50.96	50.96	82.3	11,777	150	11,627	11,777	11,627	98.93
12	50–4–240	....	243.60	....	50.00	....	....	....	....	....	....	....
13	20–2–220	17,434	96.83	59.64	19.88	75.2	22,376	1176	21,200	7,458	7,066	98.99
14	20–4–220	18,051	97.57	61.75	20.03	76.8	28,197	771	27,276	9,145	8,846	98.99
15	20–6–220	16,069	97.39	54.97	19.99	81.5	31,578	1305	30,273	11,483	11,008	99.18
16	20–8–220	12,225	97.80	41.82	20.07	83.4	29,555	830	28,725	14,186	13,788	99.01
17	30–2–220	30,665	146.05	104.95	29.97	66.0	30,842	1015	29,827	8,812	8,522	98.95
18	30–4–220	17,538	146.15	59.99	29.99	73.2	21,539	98	21,441	10,769	10,720	99.11
19	30–6–220	14,626	146.26	50.03	30.02	71.5	22,158	171	21,987	13,294	13,192	98.89
20	30–8–220	....	152.00	....	31.20	....	....	....	....	....	....	....
21	40–2–220	39,059	195.29	133.62	40.08	63.4	32,146	466	31,680	9,644	9,505	98.90
22	40–4–220	11,683	194.71	39.97	39.97	75.3	12,107	49	12,058	12,107	12,058	98.95
23	40–6–220	....	196.00	....	40.22	....	....	....	....	....	....	....
24	50–2–220	29,210	243.41	99.92	49.96	65.0	20,218	298	19,920	10,109	9,960	98.87
25	50–4–220	7,303	243.43	24.98	49.96	73.8	6,793	23	6,770	13,586	13,540	98.96
26	50–6–220	....	243.60	....	50.00	....	....	....	....	....	....	....
27	60–4–220	....	292.30	....	60.00	....	....	....	....	....	....	....
28	60–6–220	....	292.30	....	60.00	....	....	....	....	....	....	....
29	20–2–200	20,389	97.09	69.75	19.91	80.8	23,038	885	22,153	6,582	6,329	99.13
30	20–4–200	20,364	96.97	69.66	19.90	80.5	28,164	1740	26,424	8,046	7,549	99.07
31	20–6–200	17,067	97.52	58.38	20.02	62.0	28,601	81	28,520	9,806	9,778	98.92
32	20–8–200	14,587	97.25	49.80	19.92	82.8	31,500	392	31,108	12,600	12,443	99.15
33	30–2–200	30,683	146.11	104.96	29.97	77.4	27,069	1637	25,432	7,734	7,266	99.20
34	30–4–200	27,776	146.19	95.02	30.01	67.6	29,965	87	29,878	9,462	9,434	98.97
35	30–6–200	21,922	146.14	74.99	29.99	67.0	30,699	234	30,465	12,279	12,186	99.02
36	30–8–200	....	149.00	....	30.58	....	....	....	....	....	....	....
37	40–2–200	35,062	194.78	119.94	39.98	64.2	25,098	368	24,730	8,366	8,243	99.02
38	40–4–200	32,152	194.85	109.90	39.90	80.0	30,969	516	30,453	11,261	11,073	99.17
39	40–6–200	22,388	194.67	76.59	39.96	83.8	28,681	341	28,340	14,964	14,786	99.08
40	40–8–200	....	196.00	....	40.22	....	....	....	....	....	....	....
41	50–2–200	24,338	243.38	83.26	49.95	71.9	14,288	170	14,118	8,572	8,471	99.02
42	50–4–200	29,262	243.85	100.10	50.05	81.5	24,881	936	23,945	12,440	11,972	99.08
43	50–6–200	....	243.60	....	50.00	....	....	....	....	....	....	....
44	60–4–200	....	292.30	....	60.00	....	....	....	....	....	....	....
45	60–6–200	....	292.30	....	60.00	....	....	....	....	....	....	....
46	20–2–180	23,458	97.74	80.25	20.06	54.0	22,202	102	22,100	5,550	5,525	98.87
47	20–4–180	23,482	97.84	80.86	20.08	53.2	28,318	100	28,218	7,079	7,054	99.90

TABLE 8.—*Speed, water, and steam*—Continued.

Designation of tests.		Speed.				Water and steam.						
Number.	Laboratory symbol.	Total revolutions.	Revolutions per minute.	Miles equivalent to total revolutions.	Miles per hour.	Temperature of feed water.	Water delivered to boiler.	Water lost from boiler.	Steam supplied to engine.	Water evaporated by boiler per hour.	Steam supplied to engine per hour.	Quality of steam in dome, dry.
1	2	11	12	13	14	15	16	17	18	19	20	21
						°F	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*P. ct.*
48	20-6-180	20, 515	97.69	70.18	20.05	60.1	29, 834	87	29, 747	8, 524	8, 499	99.19
49	20-8-180	15, 137	97.66	51.78	20.02	60.7	27, 666	65	27, 601	10, 709	10, 668	99.11
50	20-10-180	....	98.00	....	20.11	....	....	....	....	....	....	....
51	30-2-180	35, 223	146.76	120.50	30.12	51.3	25, 131	101	25, 030	6, 282	6, 257	99.00
52	30-4-180	31, 982	145.37	109.35	29.82	63.9	29, 754	91	29, 663	8, 115	8, 090	98.94
53	30-6-180	21, 900	146.00	74.94	29.97	60.7	24, 273	59	24, 214	9, 709	9, 685	99.03
54	30-8-180	14, 676	146.76	50.20	30.12	59.1	22, 762	350	22, 412	13, 657	13, 447	99.06
55	30-10-180	....	149.00	....	30.58	....	....	....	....	....	....	....
56	40-2-180	42, 884	194.92	146.71	40.02	54.4	24, 696	93	24, 603	6, 736	6, 711	99.02
57	40-4-180	42, 927	195.12	146.85	40.58	53.0	34, 192	93	34, 098	9, 326	9, 301	98.95
58	40-6-180	20, 333	193.64	69.56	39.75	55.0	21, 996	294	21, 702	12, 563	12, 401	98.96
59	40-8-180	16, 722	196.72	57.20	40.39	60.0	22, 357	27	22, 330	15, 788	15, 771	99.10
60	40-10-180	....	196.00	....	40.22	....	....	....	....	....	....	....
61	50-2-180	29, 224	243.55	99.97	49.99	54.0	14, 316	50	14, 266	7, 158	7, 133	99.17
62	50-4-180	27, 919	242.77	95.51	49.85	50.6	19, 270	50	19, 220	10, 057	10, 032	99.05
63	50-6-180	14, 824	247.06	50.71	50.71	59.3	13, 791	25	13, 766	13, 791	13, 766	99.04
64	50-8-180	....	243.60	....	50.00	....	....	....	....	....	....	....
65	60-4-180	....	292.30	....	60.00	....	....	....	....	....	....	....
66	60-6-180	....	292.30	....	60.00	....	....	....	....	....	....	....
67	20-4-160	20, 442	97.34	69.93	19.98	73.3	21, 643	105	21, 538	6, 183	6, 153	99.32
68	20-6-160	20, 474	97.49	70.04	20.01	72.6	27, 416	108	27, 308	7, 833	7, 802	99.33
69	20-8-160	18, 018	97.39	61.64	19.99	62.3	29, 312	69	29, 243	9, 517	9, 494	99.07
70	20-10-160	....	98.00	....	20.11	....	....	....	....	....	....	....
71	30-4-160	30, 651	145.96	104.85	29.95	71.3	25, 693	103	25, 590	7, 340	7, 311	99.23
72	30-6-160	30, 683	146.11	104.96	29.99	72.7	34, 077	107	33, 970	9, 736	9, 705	99.29
73	30-8-160	21, 231	146.42	72.60	30.02	56.7	28, 922	59	28, 863	11, 968	11, 947	99.13
74	30-10-160	....	146.20	....	30.00	....	....	....	....	....	....	....
75	30-12-160	....	150.00	....	30.78	....	....	....	....	....	....	....
76	40-4-160	41, 006	195.27	140.28	40.08	75.9	30, 692	1533	29, 429	8, 846	8, 408	99.30
77	40-6-160	33, 096	194.68	113.22	39.96	76.8	32, 615	1037	31, 578	11, 511	11, 145	99.40
78	40-8-160	21, 544	195.85	73.70	40.20	60.0	26, 405	41	26, 364	14, 403	14, 380	99.00
79	40-10-160	....	192.00	....	39.40	....	....	....	....	....	....	....
80	50-4-160	18, 271	243.61	62.50	50.00	73.5	11, 460	38	11, 421	9, 168	9, 137	99.31
81	50-6-160	29, 263	243.86	100.11	50.05	69.0	25, 665	800	24, 865	12, 832	12, 432	99.27
82	50-8-160	....	242.60	....	50.00	....	....	....	....	....	....	....
83	60-4-160	....	292.30	....	60.00	....	....	....	....	....	....	....
84	60-6-160	....	292.30	....	60.00	....	....	....	....	....	....	....
85	20-4-120	20, 439	97.33	69.92	19.98	72.7	15, 299	70	15, 229	4, 371	4, 351	99.34
86	20-8-120	20, 387	97.08	69.74	19.92	71.4	25, 200	70	25, 130	7, 200	7, 180	99.43
87	20-12-120	19, 408	97.04	66.39	19.91	70.9	34, 439	66	34, 373	10, 331	10, 312	99.32
88	30-4-120	30, 692	146.15	104.99	29.99	74.3	18, 405	70	18, 335	5, 258	5, 238	99.44
89	30-8-120	30, 755	146.45	105.85	30.05	72.0	31, 354	70	31, 284	8, 959	8, 939	99.28
90	30-14-120	17, 497	145.81	59.86	29.93	70.6	31, 208	40	31, 168	15, 604	15, 584	99.37
91	40-4-120	40, 957	195.03	140.10	40.03	74.3	19, 516	70	19, 446	5, 576	5, 556	99.45
92	40-8-120	37, 052	195.01	126.75	40.02	71.5	33, 955	70	33, 885	10, 722	10, 702	99.28
93	40-12-120	23, 446	195.38	80.20	40.10	70.5	31, 700	40	31, 660	15, 850	15, 830	99.43
94	50-4-120	29, 246	243.71	100.05	50.02	74.5	11, 955	40	11, 915	5, 977	5, 957	99.47
95	50-8-120	29, 214	243.45	99.94	49.97	73.2	24, 088	40	24, 048	12, 044	12, 024	99.27
96	50-11-120	9, 844	246.10	33.67	50.51	73.4	10, 779	13	10, 766	16, 168	16, 149	99.39
97	60-8-120	....	292.30	....	60.00	....	....	....	....	....	....	....

TABLE 9.—*Coal.*

Designation of tests.		Coal.										
Number.	Laboratory symbol.	Kind of coal.	Dry coal fired.	Dry ash.	Dry coal minus dry ash.	Combustible by analysis.	Dry coal fired per hour.	Dry coal per sq. ft. of grate surface per hour.	Dry coal per sq. ft heating-surface per hour.	Coal per mile run.	Cinders caught in front end.	Sparks from stack per hour.
1	2	22	23	24	25	26	27	28	29	30	31	32
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	20-2-240	Youghiogheny.....	2818	260	2558	2562	939	55.2	0.71	48.4	70	35.0
1*a*	20-2-240	.....do...........	2524	247	2277	2271	977	57.4	0.74	64.6	85	40.9
2	20-4-240	.....do...........	2597	173	2424	2410	1298	76.2	0.98	64.4	87	50.9
3	20-6-240	Big Four "I".....	....	...	....	....	....	....	....	....	...	....
3*a*	20-6-240	Youghiogheny.....	4134	337	3797	3684	1654	97.3	1.25	83.3	167	78.0
4	20-8-240	....	....	...	....	....	....	....	....	....	...	....
5	30-2-240	Youghiogheny.....	2448	202	2246	2252	1224	72.0	0.92	40.8	202	23.8
5*a*	30-2-240	.....do...........	4391	380	4010	3969	1596	93.9	1.20	50.6	208	54.6
6	30-4-240	Big Four "H"....	....	...	....	....	....	....	....	....	...	....
7	30-6-240	....	....	...	....	....	....	....	....	....	...	....
8	40-2-240	Youghiogheny.....	3866	435	3431	3566	1405	82.6	1.06	35.2	107	37.2
9	40-4-240	Big Four "H"....	....	...	....	....	....	....	....	....	...	....
10	40-6-240	....	....	...	....	....	....	....	....	....	...	....
11	50-2-240	Youghiogheny.....	1459	67	1392	1339	1459	85.8	1.10	28.6	81	41.1
12	50-4-240	....	....	...	....	....	....	....	....	....	...	....
13	20-2-220	Youghiogheny.....	2502	203	2299	2300	834	49.0	0.63	41.9	56	18.7
14	20-4-220	.....do...........	3357	351	3006	3110	1088	64.0	0.82	54.6	85	....
15	20-6-220	.....do...........	4306	349	3957	3934	1565	92.0	1.18	78.3	121	54.4
16	20-8-220	.....do...........	4274	244	4030	3926	2077	122.2	1.57	103.5	198	117.1
17	30-2-220	.....do...........	3832	281	3551	3552	1094	64.3	0.83	35.8	92	24.5
18	30-4-220	.....do...........	2940	177	2763	2690	1470	86.5	1.11	49.0	100	52.3
19	30-6-220	.....do...........	3116	195	2921	2851	1869	109.9	1.43	62.2	116	126.7
20	30-8-220	....	....	...	....	....	....	....	....	....	...	....
21	40-2-220	Youghiogheny.....	4052	304	3748	3755	1215	71.5	0.92	30.3	135	43.5
22	40-4-220	.......do..........	1604	95	1509	1459	1604	94.3	1.21	40.1	63	56.0
23	40-6-220	....	....	...	....	....	....	....	....	....	...	....
24	50-2-220	Youghiogheny.....	2614	213	2401	2403	1307	76.9	0.98	26.1	98	80.8
25	50-4-220	....do............	1005	43	962	919	2010	118.2	1.52	40.2	57	121.1
26	50-6-220	....	....	...	....	....	....	....	....	....	...	....
27	60-4-220	....	....	...	....	....	....	....	....	....	...	....
28	60-6-220	....	....	...	....	....	....	....	....	....	...	....
29	20-2-200	Youghiogheny	2712	177	2535	2499	774	45.5	0.58	38.8	53	11.2
30	20-4-200	....do............	3534	345	3189	3255	1010	59.4	0.76	50.7	81	31.4
31	20-6-200	Big Four "I".....	....	...	....	....	....	....	....	....	...	....
32	20-8-200	Youghiogheny.....	4157	268	3889	3866	1663	97.8	1.25	83.4	158	60.8
33	30-2-200	.....do...........	3274	275	2999	3032	935	55.0	0.70	31.2	65	14.3
34	30-4-200	Big Four "I".....	....	...	....	....	....	....	....	....	...	....
35	30-6-200	Youghiogheny.....	4164	311	3853	3816	1665	98.0	1.25	55.5	150	63.7
36	30-8-200	....	....	...	....	....	....	....	....	....	...	....
37	40-2-200	Youghiogheny.....	3091	225	2866	2827	1030	60.6	0.79	25.7	85	24.5
38	40-4-200	.....do...........	4055	213	3842	3733	1474	86.7	1.11	36.8	105	72.6
39	40-6-200	.....do...........	4029	278	3751	3735	2102	123.6	1.59	52.6	135	123.1
40	40-8-200	....	....	...	....	....	....	....	....	....	...	....
41	50-2-200	Youghiogheny.....	1772	164	1608	1635	1063	62.5	0.80	21.0	68	28.2
42	50-4-200	....do............	3153	239	2914	2906	1576	92.7	1.11	31.5	121	72.7
43	50-6-200	....	....	...	....	....	....	....	....	....	...	....
44	60-4-200	....	....	...	....	....	....	....	....	....	...	....
45	60-6-200	....	....	...	....	....	....	....	....	....	...	....
46	20-2-180	Big Four "F".....	....	...	....	....	....	....	....	....	...	....
47	20-4-180	.....do...........	....	...	....	....	....	....	....	....	...	....

TABLE 9.—*Coal*—Continued.

Designation of tests.		Coal.										
Number.	Laboratory symbol.	Kind of coal.	Dry coal fired.	Dry ash.	Dry coal minus dry ash.	Combustible by analysis.	Dry coal fired per hour.	Dry coal per sq. ft. of grate surface per hour.	Dry coal per sq. ft. heating surface per hour.	Coal per mile run.	Cinders caught in front end.	Sparks from stack per hour.
1	2	22	23	24	25	26	27	28	29	30	31	32
			Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
48	20–6–180	Big Four "H"	....	....	....	....	....	....	....	....	....	....
49	20–8–180	....do	....	....	....	....	....	....	....	....	....	....
50	20–10–180	....	....	....	....	....	....	....	....	....	....	....
51	30–2–180	Big Four "G"	....	....	....	....	....	....	....	....	....	....
52	30–4–180	Big Four "I"	....	....	....	....	....	....	....	....	....	....
53	30–6–180	....do	....	....	....	....	....	....	....	....	....	....
54	30–8–180	Linton run of mine	....	....	....	....	....	....	....	....	....	....
55	30–10–180	....	....	....	....	....	....	....	....	....	....	....
56	40–2–180	Big Four "G"	....	....	....	....	....	....	....	....	....	....
57	40–4–180	....do	....	....	....	....	....	....	....	....	....	....
58	40–6–180	Linton run of mine	....	....	....	....	....	....	....	....	....	....
59	40–8–180	Big Four "H"	....	....	....	....	....	....	....	....	....	....
60	40–10–180	....	....	....	....	....	....	....	....	....	....	....
61	50–2–180	Big Four "G"	....	....	....	....	....	....	....	....	....	....
62	50–4–180	....do	....	....	....	....	....	....	....	....	....	....
63	50–6–180	....do	....	....	....	....	....	....	....	....	....	....
64	50–8–180	....	....	....	....	....	....	....	....	....	....	....
65	60–4–180	....	....	....	....	....	....	....	....	....	....	....
66	60–6–180	....	....	....	....	....	....	....	....	....	....	....
67	20–4–160	Youghiogheny	2531	191	2340	2306	723	42.5	0.54	36.19	58	12.51
68	20–6–160	....do	3352	238	3114	3090	957	56.3	0.72	47.8	77	13.21
69	20–8–160	Big Four "I"	....	....	....	....	....	....	....	....	....	....
70	20–10–160	....	....	....	....	....	....	....	....	....	....	....
71	30–4–160	Youghiogheny	3089	276	2814	2815	882	51.9	0 66	29.13	74	13.05
72	30–6–160	....do	4100	332	3768	3719	1171	68.9	0.88	39.0	107	29.13
73	30–8–160	Big Four "H"	....	....	....	....	....	....	....	....	....	....
74	30–10–160	....	....	....	....	....	....	....	....	....	....	....
75	30–12–160	....	....	....	....	....	....	....	....	....	....	....
76	40–4–160	Youghiogheny	3775	288	3487	3505	1078	63.4	0.81	26.8	80	24.7
77	40–6–160	....do	4223	295	3928	3848	1490	87.6	1.12	37.3	117	44.4
78	40–8–160	Big Four "H"	....	....	....	....	....	....	....	....	....	....
79	40–10–160	....	....	....	....	....	....	....	....	....	....	....
80	50–4–160	Youghiogheny	1393	75	1318	1281	1114	65.5	0.84	22.3	48	23.22
81	50–6–160	....do	3444	237	3207	3187	1722	101.3	1.30	34.4	105	77.9
82	50–8–160	....	....	....	....	....	....	....	....	....	....	....
83	60–4–160	....	....	....	....	....	....	....	....	....	....	....
84	60–6–160	....	....	....	....	....	....	....	....	....	....	....
85	20–4–120	Youghiogheny	1873	164	1709	1707	535	31.4	0.40	31.4	32	13.07
86	20–8–120	....do	3119	300	2819	2838	891	52.4	0.67	44.7	88	12.0
87	20–12–120	....do	4327	289	4038	3942	1299	76.4	0.98	65.3	139	34.2
88	30–4–120	....do	2107	150	1957	1943	602	35.4	0.45	20.1	31	9.1
89	30–8–120	....do	3785	333	3452	3441	1081	63.6	0.82	36.0	88	54.1
90	30–14–120	....do	4412	258	4154	4051	2206	130.7	1.68	74.3	170	194.5
91	40–4–120	....do	2271	179	2092	2071	648	38.2	0.49	16.2	41	45.5
92	40–8–120	....do	4190	275	3915	3753	1323	77.8	1.00	33.3	117	32.9
93	40–12–120	....do	4563	275	4288	4122	2281	134.2	1.72	56.9	153	219.7
94	50–4–120	....do	1366	90	1276	1249	683	40.5	0.52	13.7	33	15.5
95	50–8–120	....do	3137	241	2896	2886	1568	92.3	1.18	31.4	94	63.6
96	50–11–120	....do	1512	68	1444	1391	2268	133.4	1.71	44.9	86	173.0
97	60–8–120	....	....	....	....	....	....	....	....	....	....	....

TABLE 10.—*Draft and boiler performance.*

Designation of tests.		Draft.				Boiler performance.					
Number.	Laboratory symbol.	Front of diaphragm, inches of water.	Back of diaphragm, inches of water.	In fire-box, inches of water.	Smoke box, temperature of.	Water evaporated per sq. ft. heating-surface per hour.	Water evaporated per pound of dry coal.	Equivalent evaporation per hour.	Equivalent evaporation per sq. ft. heating-surface per hour.	Equivalent evaporation per sq. ft. grate surface per hour.	Equivalent evaporated per pound of dry coal.
1	2	33	34	35	36	37	38	39	40	41	42
						Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	20-2-240	2.3	1.6	0.9	...	5.63	7.90	8,838	6.68	519.9	9.40
1a	20-2-240	2.2	1.6	1.7	635	5.86	7.90	9,189	6.90	540.5	9.40
2	20-4-240	3.6	2.4	1.3	743	7.63	7.78	12,095	9.15	712.0	9.32
3	20-6-240	4.5	2.6	1.7	745	8.53	....	13,648	10.31	802.3	....
3a	20-6-240	4.0	2.7	1.8	730	9.10	7.27	14,230	10.76	837.0	8.60
4	20-8-240	...	...	...	...	....	....	....	....	....	....
5	30-2-240	3.4	2.4	1.4	...	9.31	7.89	11,427	8.64	672.2	9.33
5a	30-2-240	3.5	2.4	1.8	698	8.31	6.88	12,893	9.75	758.0	8.08
6	30-4-240	4.4	2.7	1.5	759	8.72	....	13,913	10 52	818.4	....
7	30-6-240	...	...	...	...	....	....	....	....	....	....
8	40-2-240	3.7	2.7	1.8	...	9.87	7.42	12,369	9.35	727.6	8.79
9	40-4-240	5.6	3.1	2.3	809	10.25	....	16,385	12.39	963.8	....
10	40-6-240	...	...	...	...	....	....	....	....	....	....
11	50-2-240	4.1	2.9	2.0	...	8.91	8.07	13,977	10.57	822.0	9.57
12	50-4-240	...	...	...	...	....	....	....	....	....	....
13	20-2-220	2.1	1.6	1.2	682	5.64	8.47	8,888	6.72	522.8	10.65
14	20-4-220	2.9	2.0	1.1	703	6.92	8.40	10,882	8.23	640.0	10.00
15	20-6-220	4.3	3.1	2.1	764	8.69	7.33	13,612	10.29	800.0	8.69
16	20-8-220	6.0	4.1	2.2	806	10.73	6.82	16,790	12.70	987.7	8.08
17	30-2-220	2.7	1.9	1.4	...	6.67	8.05	10,583	8.00	622.0	9.75
18	30-4-220	3.9	2.8	1.8	743	8.15	7.32	12,901	9.75	758.8	8.77
19	30-6-220	5.6	3.8	2.3	813	10.06	7.11	15,880	12.01	934.0	8.49
20	30-8-220	...	...	...	...	....	....	....	....	....	....
21	40-2-220	3.2	2.3	1.6	716	7.30	7.93	11,602	8.77	682.0	9.54
22	40-4-220	4.8	3.4	2.0	786	9.16	7.54	14,487	10.95	852.0	9.03
23	40-6-220	...	...	...	...	....	....	....	....	....	....
24	50-2-220	3.4	2.6	2.1	728	7.64	7.73	12,144	9.18	714.0	9.29
25	50-4-220	5.8	3.9	1.7	810	10.29	6.75	16,205	12.25	953.0	8.06
26	50-6-220	...	...	...	...	....	....	....	....	....	....
27	60-4-220	...	...	...	...	....	....	....	....	....	....
28	60-6-220	...	...	...	...	....	....	....	....	....	....
29	20-2-200	1.7	1.2	0.9	...	4.98	8.50	7,796	5.89	458.0	10.07
30	20-4-200	2.5	1.8	1.3	682	6.09	7.96	9,528	7.20	560.0	9.43
31	20-6-200	3.4	2.1	1.6	685	7.42	....	11,801	8.92	694.0	....
32	20-8-200	5.1	3.5	2.3	780	9.53	7.58	14,903	11.27	876.6	8.96
33	30-2-200	2.2	1.6	0.5	673	5.85	8.26	9,192	6.96	540.0	9.82
34	30-4-200	3.0	1.9	1.4	682	7.16	....	11,313	8.56	665.0	....
35	30-6-200	4.9	3.5	2.5	788	9.29	7.37	14,708	11.12	865.0	8.83
36	30-8-200	...	...	...	...	....	....	....	....	....	....
37	40-2-200	2.5	1.9	...	676	6.33	8.11	10,046	7.59	591.0	9.75
38	40-4-200	4.2	3.0	1.8	...	8.52	7.63	13,362	10.10	786.0	9.06
39	40-6-200	6.6	4.5	3.0	833	11.31	7.12	17,690	13.38	1040.0	8.41
40	40-8-200	...	...	...	...	....	....	....	....	....	....
41	50-2-200	2.6	1.9	1.4	687	6.48	8.08	10,255	7.75	603.2	9.64
42	50-4-200	4.8	3.4	2.2	768	9.41	7.89	14,725	11.13	866.7	9.34
43	50-6-200	...	...	...	...	....	....	....	....	....	....
44	60-4-200	...	...	...	...	....	....	....	....	....	....
45	60-6-200	...	...	...	...	....	....	....	....	....	....
46	20-2-180	1.4	1.0	0.7	595	4.20	....	6,705	5.07	393.0	....
47	20-4-180	2.0	1.3	1.7	628	5.35	....	8,556	6.47	502.5	....

TABLE 10.—*Draft and boiler performance*—Continued.

Designation of tests.		Draft.				Boiler performance.					
Number.	Laboratory symbol.	Front of diaphragm, inches of water.	Back of diaphragm, inches of water.	In firebox, inches of water.	Smokebox temperature of.	Water evaporated per sq. ft. heating-surface per hour.	Water evaporated per pound of coal.	Equivalent evaporation per hour.	Equivalent evaporation per sq. ft. heating-surface per hour.	Equivalent evaporation per sq. ft. grate surface per hour.	Equivalent evaporated per pound of dry coal.
1	2	33	34	35	36	37	38	39	40	41	42
						Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
48	20–6–180	2.8	1.7	1.3	673	6.45	....	10256	7.75	603.3	....
49	20–8–180	3.9	2.3	1.7	718	8.10	....	12878	9.74	758.0	....
50	20–10–180	...	...	...	...	....	....	....	....	....	....
51	30–2–180	1.7	1.1	0.7	654	4.75	....	7611	5.76	447.7	....
52	30–4–180	2.5	1.6	1.2	639	6.14	....	9720	7.35	571.7	....
53	30–6–180	3.6	2.3	2.0	688	7.34	....	11651	8.81	686.3	....
54	30–8–180	5.8	3.3	2.1	762	10.33	....	16424	12.42	966.4	....
55	30–10–180	...	...	...	...	....	....	....	....	....	....
56	40–2–180	1.8	1.2	0.8	636	5.10	....	8107	6.13	476.0	....
57	40–4–180	3.0	1.9	1.6	687	7.05	....	11272	8.53	663.4	....
58	40–6–180	5.2	3.2	2.0	750	9.51	....	15171	11.47	892.0	....
59	40–8–180	7.6	4.7	2.9	831	11.94	....	18962	14.34	1115.0	....
60	40–10–180	...	...	...	...	....	....	....	....	....	....
61	50–2–180	1.8	1.2	0.9	639	5.41	....	8651	6.53	508.0	....
62	50–4–180	3.5	2.3	1.6	707	7.61	....	12186	9.22	716.8	....
63	50–6–180	5.5	3.1	2.2	778	10.43	....	16596	12.55	976.2	....
64	50–8–180	...	...	...	...	....	....	....	....	....	....
65	60–4–180	...	...	...	...	....	....	....	....	....	....
66	60–6–180	...	...	...	...	....	....	....	....	....	....
67	20–4–160	1.6	1.3	0.9	631	4.68	8.55	7348	5.55	432.0	10.16
68	20–6–160	2.4	1.8	1.1	667	5.93	8.18	9314	7.04	548.0	9.72
69	20–8–160	3.4	2.1	1.2	678	7.20	....	....	8.61	670.0	....
70	20–10–160	...	...	...	...	....	....	....	....	....	....
71	30–4–160	2.0	1.4	1.0	662	5.55	8.31	8735	6.60	513.0	9.89
72	30–6–160	3.4	2.4	1.8	707	7.36	8.31	11573	8.75	681.0	9.87
73	30–8–160	4.9	2.9	1.8	763	9.05	....	....	10.91	848.0	....
74	30–10–160	...	...	...	...	....	....	....	....	....	....
75	30–12–160	...	...	...	...	....	....	....	....	....	....
76	40–4–160	2.7	2.0	1.5	690	6.69	8.20	10493	7.94	617.0	9.73
77	40–6–160	4.4	3.2	2.1	761	8.71	7.72	13647	10.32	803.0	9.16
78	40–8–160	6.2	3.8	2.3	790	10.90	....	....	13.06	1016.0	....
79	40–10–160	...	...	...	...	....	....	....	....	....	....
80	50–4–160	2.9	2.1	1.4	691	6.94	8.22	10892	8.23	641.0	9.76
81	50–6–160	5.0	3.5	1.5	786	9.71	7.45	15302	11.57	900.0	8.88
82	50–8–160	...	...	...	...	....	....	....	....	....	....
83	60–4–160	...	...	...	...	....	....	....	....	....	....
84	60–6–160	...	...	...	...	....	....	....	....	....	....
85	20–4–120	0.9	0.6	0.5	581	3.31	8.17	5171	3.91	304.0	9.67
86	20–8–120	2.2	1.5	1.2	630	5.45	8.07	8531	6.45	501.0	9.56
87	20–12–120	3.9	2.7	1.5	718	7.81	7.96	12235	9.25	719.0	9.41
88	30–4–120	1.2	0.9	0.7	608	3.98	8.73	6214	4.70	364.0	10.32
89	30–8–120	3.0	2.1	0.9	676	6.78	8.28	10571	7.99	621.0	9.77
90	30–14–120	7.5	5.1	2.6	835	11.80	7.07	18507	13.99	1088.0	8.38
91	40–4–120	1.3	1.0	0.7	606	4.22	8.58	6591	4.98	387.0	10.15
92	40–8–120	3.9	2.8	1.4	727	8.11	8.10	12693	9.60	746.0	9.59
93	40–12–120	7.8	5.2	2.8	842	11.99	6.94	18794	14.20	1105.0	8.27
94	50–4–120	1.3	1.0	0.7	630	4.52	8.75	7063	5.34	415.0	10.34
95	50–8–120	4.7	3.4	2.1	765	9.11	7.68	14230	10.76	837.0	9.07
96	50–11–120	8.1	5.7	3.6	838	12.23	7.12	19116	14.45	1124.0	8.41
97	60–8–120	...	...	...	...	....	....	....	....	....	....

TABLE 11.—*Boiler performance.*

Designation of tests.		Boiler performance (continued).					
		B. t. u. taken up by—					Boiler horse-power, A.S.M.E. standard
Number.	Laboratory symbol.	Each pound of water evaporated.	Boiler per minute.	Boiler per pound of dry coal.	Boiler per pound of combustible.	Boiler per 100 B. t. u. in coal.	
1	2	43	44	45	46	47	48
1	20-2-240	1146.8	142,260	9087	9991	63.77	256
1a	20-2-240	1145.7	147,909	9085	10093	63.75	266
2	20-4-240	1158.2	194,693	9013	9712	63.25	350
3	20-6-240	1168.6	219,696	....	....	....	396
3a	20-6-240	1142.2	229,068	8304	9319	58.25	412
4	20-8-240	....	....	....	....	....	....
5	30-2-240	1141.9	183,948	9017	9801	63.28	331
5a	30-2-240	1133.5	207,543	7801	8629	54.73	373
6	30-4-240	1164.9	223,932	....	....	....	403
7	30-6-240	....	....	....	....	....	....
8	40-2-240	1147.1	198,941	8490	....	59.58	358
9	40-4-240	1165.5	263,753	....	....	....	475
10	40-6-240	....	....	....	....	....	....
11	50-2-240	1146.1	224,960	9241	10066	46.85	405
12	50-4-240	....	....	....	....	....	....
13	20-2-220	1151.1	143,081	10290	11197	72.21	257
14	20-4-220	1149.3	175,172	9654	10425	67.75	315
15	20-6-220	1144.8	219,107	8391	9184	58.88	395
16	20-8-220	1143.1	270,277	7804	8495	54.76	486
17	30-2-220	1159.9	170,350	9343	10079	65.56	307
18	30-4-220	1153.9	207,113	8453	9238	59.32	374
19	30-6-220	1153.7	255,613	8235	9000	57.79	461
20	30-8-220	....	....	....	....	....	....
21	40-2-220	1162.3	186,828	9226	9955	64.74	336
22	40-4-220	1150.2	233,093	8720	9582	61.19	426
23	40-6-220	....	....	....	....	....	....
24	50-2-220	1160.3	195,491	8975	9766	62.98	352
25	50-4-220	1152.0	260,851	7788	8530	54.66	470
26	50-6-220	....	....	....	....	....	....
27	60-4-220	....	....	....	....	....	....
28	60-6-220	....	....	....	....	....	....
29	20-2-200	1144.0	125,496	9728	10555	68.27	226
30	20-4-200	1143.8	153,383	9117	9896	63.98	276
31	20-6-200	1161.1	189,978	....	....	....	342
32	20-8-200	1142.3	239,887	8658	9310	60.76	432
33	30-2-200	1148.0	147,977	9482	10236	66.54	266
34	30-4-200	1154.9	192,126	....	....	....	328
35	30-6-200	1156.9	236,755	8547	9324	59.98	426
36	30-8-200	....	....	....	....	....	....
37	40-2-200	1159.8	161,714	9413	10290	66.06	291
38	40-4-200	1145.5	214,987	8709	9671	61.12	387
39	40-6-200	1140.6	284,465	8119	8758	56.97	512
40	40-8-200	....	....	....	....	....	....
41	50-2-200	1152.1	164,596	9309	10086	65.33	297
42	50-4-200	1143.5	237,085	9024	9790	63.33	426
43	50-6-200	....	....	....	....	....	....
44	60-4-200	....	....	....	....	....	....
45	60-6-200	....	....	....	....	....	....
46	20-2-180	1166.5	107,924	....	....	....	194
47	20-4-180	1167.3	137,731	....	....	....	248

TABLE 11.—*Boiler performance*—Continued.

Designation of tests.		Boiler performance (continued).					
		B. t. u. taken up by—					Boiler horse-power, A.S.M.E. standard.
Number.	Laboratory symbol.	Each pound of water evaporated.	Boiler per minute.*	Boiler per pound of dry coal.	Boiler per pound of combustible.	Boiler per 100 B. t. u. in coal.	
1	2	43	44	45	46	47	48
48	20-6-180	1162.3	165,101	....	....	....	297
49	20-8-180	1161.3	207,298	....	....	....	373
50	20-10-180	....	....	....	....	....	....
51	30-2-180	1170.0	122,512	....	....	....	220
52	30-4-180	1156.9	156,470	....	....	....	282
53	30-6-180	1159.0	187,549	....	....	....	338
54	30-8-180	1161.4	264,357	....	....	....	476
55	30-10-180	....	....	....	....	....	....
56	40-2-180	1167.0	130,550	....	....	....	235
57	40-4-180	1167.3	181,540	....	....	....	326
58	40-6-180	1165.7	244,209	....	....	....	439
59	40-8-180	1160.6	305,254	....	....	....	549
60	40-10-180	....	....	....	....	....	....
61	50-2-180	1167.2	139,254	....	....	....	250
62	50-4-180	1170.7	196,164	....	....	....	353
63	50-6-180	1162.3	267,148	....	....	....	481
64	50-8-180	....	....	....	....	....	....
65	60-4-180	....	....	....	....	....	....
66	60-6-180	....	....	....	....	....	....
67	20-4-160	1147.7	118,281	9817	10773	68.89	212
68	20-6-160	1148.5	149,879	9426	10223	66.14	269
69	20-8-160	1156.6	183,251	....	....	....	330
70	20-10-160	....	....	....	....	....	....
71	30-4-160	1149.3	140,605	9550	10477	67.01	253
72	30-6-160	1148.1	186,302	9544	9839	66.97	335
73	30-8-160	1163.2	232,019	....	....	....	417
74	30-10-160	....	....	....	....	....	....
75	30-12-160	....	....	....	....	....	....
76	40-4-160	1145.1	168,914	9401	10125	65.97	303
77	40-6-160	1145.1	219,687	8845	9706	62.07	396
78	40-8-160	1158.3	278,044	....	....	....	500
79	40-10-160	....	....	....	....	....	....
80	50-4-160	1147.4	175,328	9431	10251	66.18	315
81	50-6-160	1151.7	246,310	8582	9271	60.22	443
82	50-8-160	....	....	....	....	....	....
83	60-4-160	....	....	....	....	....	....
84	60-6-160	....	....	....	....	....	....
85	20-4-120	1142.7	83,245	9335	10241	65.50	150
86	20-8-120	1144.4	137,331	9235	10148	64.81	247
87	20-12-120	1143.8	196,950	9105	9994	63.89	354
88	30-4-120	1141.6	100,049	9985	10830	70.07	180
89	30-8-120	1142.3	170,543	9468	10414	66.44	306
90	30-14-120	1145.5	297,898	8092	8882	56.79	536
91	40-4-120	1141.6	106,096	9810	10756	68.84	190
92	40-8-120	1143.3	204,319	9264	10695	65.01	368
93	40-12-120	1145.2	302,523	7956	8840	55.83	544
94	50-4-120	1141.3	113,692	9987	10922	70.08	204
95	50-8-120	1141.1	229,056	8763	9525	61.49	412
96	50-11-120	1141.9	307,707	8140	8848	57.12	554
97	60-8-120	....	....	....	....	....	....

TABLE 12.—*Chemical results.*

Designation of tests.		Chemical results.						
Number.	Laboratory symbol.	Composition of flue gases.				Air used per pound of carbon.	Excess air.	B. t. u. per pound of coal.
		CO_2	O_2	CO	N_2			
1	2	49	50	51	52	53	54	55
						Lbs.	*Per cent.*	
1	20–2–240	13.9	2.7	0.6	82.8	13.44	16.46	14158
1a	20–2–240	14.0	2.0	0.2	83.8	13.00	12.65	14030
2	20–4–240	14.6	2.4	0.6	82.4	13.12	13.69	14446
3	20–6–240	....	....	....	....	...	....	......
3a	20–6–240	14.8	1.0	1.2	83.0	11.78	2.08	13828
4	20–8–240	....	....	....	....	....	....	......
5	30–2–240	14.4	2.2	0.0	83.4	13.28	15.08	14310
5a	30–2–240	14.5	1.1	0.6	83.8	....	....	......
6	30–4–240	....	....	....	....	....	....	......
7	30–6–240	....	....	....	....	....	....	......
8	40–2–240	15.0	1.6	0.2	83.2	12.61	9.27	14357
9	40–4–240	....	....	....	....	....	....	......
10	40–6–240	....	....	....	....	....	....	......
11	50–2–240	15.6	0.8	0.8	82.8	11.80	2.25	14302
12	50–4–240	....	....	....	....	....	....	......
13	20–2–220	13.2	3.7	0.0	83.1	14.77	27.99	14296
14	20–4–220	15.5	1.4	0.1	83.0	12.60	9.18	14437
15	20–6–220	15.4	2.0	0.0	82.6	13.04	13.00	14212
16	20–8–220	16.4	1.0	0.8	81.8	11.94	3.46	14310
17	30–2–220	14.0	2.8	0.2	83.0	13.72	18.89	14428
18	30–4–220	14.6	2.6	0.0	82.8	13.59	17.76	14310
19	30–6–220	17.2	0.4	0.0	82 4	11.78	2.08	14180
20	30–8–220	....	....	....	....	....	....	......
21	40–2–220	15.6	2.4	0.1	81.9	13.23	15.51	14435
22	40–4–220	16.7	0.9	0.0	82.4	12.13	5.11	14159
23	40–6–220	....	....	....	....	....	....	......
24	50–2–220	15.8	0.6	0.6	83.0	11.74	1.73	14314
25	50–4–220	15.1	2.5	0.0	82.4	13.45	16.55	14300
26	50–6–220	....	....	....	....	....	....	......
27	60–4–220	....	....	....	....	....	....	......
28	60–6–220	....	....	....	....	....	....	......
29	20–2–200	14.8	1.0	0.4	83.8	12.12	5.03	14344
30	20–4–200	12.2	5.0	0.0	82.8	16.24	40.73	14336
31	20–6–200	....	....	....	....	....	....	......
32	20–8–200	15.8	0.9	0.1	83.2	12.14	5.20	14489
33	30–2–200	15.4	1.2	0.2	83.2	12.35	7.02	14418
34	30–4–200	....	....	....	....	....	....	......
35	30–6–200	15.6	1.4	0.4	82.6	12.38	7.28	14268
36	30–8–200	....	....	....	....	....	....	......
37	40–2–200	12.1	5.2	0.0	82.7	16.47	42.72	14221
38	40–4–200	15.6	0.6	0.4	83.4	11.81	2.34	14322
39	40–6–200	17.0	1.1	0.0	81.9	12.28	6.41	14429
40	40–8–200	....	....	....	...	....	....	......
41	50–2–200	15.4	1.8	0.0	82.8	12.89	11.61	14327
42	50–4–200	15.6	2.2	0.0	82.2	13.15	13.95	14345
43	50–6–200	....	....	....	....	....	....	......
44	60–4–200	....	....	....	....	....	....	......
45	60–6–200	....	....	....	....	....	....	......
46	20–2–180	....	....	....	....	....	....	......
47	20–4–180	....	....	....	....	....	....	......

TABLE 12.—*Chemical results*—Continued.

Designation of tests.		Chemical results.						
		Composition of flue gases, volumetric per cent.				Air used per pound of carbon.	Excess air.	B. t. u. per pound of coal.
Number.	Laboratory symbol.	CO_2	O_2	CO	N_2			
1	2	49	50	51	52	53	54	55
						Lbs.	*Per cent.*	
48	20–6–180	....	....	....	....	....	....	......
49	20–8–180	....	....	....	....	....	....	......
50	20–10–180	....	....	....	....	....	....	......
51	30–2–180	....	....	....	....	....	....	......
52	30–4–180	....	....	....	....	....	....	......
53	30–6–180	....	....	....	....	....	....	......
54	30–8–180	....	....	....	....	....	....	......
55	30–10–180	....	....	....	....	....	....	......
56	40–2–180	....	....	....	....	....	....	......
57	40–4–180	....	....	....	....	....	....	......
58	40–6–180	....	....	....	....	....	....	......
59	40–8–180	....	....	....	....	....	....	......
60	40–10–180	....	....	....	....	....	....	......
61	50–2–180	....	....	....	....	....	....	......
62	50–4–180	....	....	....	....	....	....	......
63	50–6–180	....	....	....	....	....	....	......
64	50–8–180	....	....	....	....	....	....	......
65	60–4–180	....	....	....	....	....	....	......
66	60–6–180	....	....	....	....	....	....	......
67	20–4–160	12.0	4.2	0.0	83.8	15.57	34.92	14163
68	20–6–160	13.4	2.8	0.0	83.8	13.96	20.97	14346
69	20–8–160	....	....	....	....	....	....	......
70	20–10–160	....	....	....	....	....	....	......
71	30–4–160	11.1	2.9	0.1	85.9	14.46	25.30	14246
72	30–6–160	13.2	2.7	0.0	84.1	13.88	20.28	14400
73	30–8–160	....	....	....	....	....	....	......
74	30–10–160	....	....	....	....	....	....	......
75	30–12–160	....	....	....	....	....	....	......
76	40–4–160	15.8	1.0	0.0	83.2	12.26	6.24	14458
77	40–6–160	14.6	1.6	0.0	83.8	12.82	11.09	14191
78	40–8–160	....	....	....	....	....	....	......
79	40–10–160	....	....	....	....	....	....	......
80	50–4–160	13.8	5.0	0.0	81.2	15.72	36.22	14350
81	50–6–160	15.0	1.4	0.0	83.6	12.61	9.27	14412
82	50–8–160	....	....	....	....	....	....	......
83	60–4–160	....	....	....	....	....	....	......
84	60–6–160	....	....	....	....	....	....	......
85	20–4–120	11.1	4.3	0.3	84.3	15.71	36.13	14300
86	20–8–120	....	....	....	....	....	....	......
87	20–12–120	15.9	1.3	0.0	82.8	12.48	8.14	14095
88	30–4–120	11.2	6.2	0.0	82.6	17.89	55.02	14400
89	30–8–120	14.1	2.3	0.2	83.4	13.31	15.34	14116
90	30–14–120	15.2	2.2	0.0	82.6	13.20	14.38	14050
91	40–4–120	13.2	4.0	0.0	82.8	15.03	30.24	14300
92	40–8–120	15.8	0.6	0.0	83.6	11.98	3.81	13914
93	40–12–120	17.0	0.4	0.0	82.6	11.79	2.17	14000
94	50–4–120	15.0	2.2	0.0	82.8	13.21	14.47	14199
95	50–8–120	13.2	3.4	0.0	83.4	14.51	25.74	14280
96	50–11–120	16.4	1.2	0.0	82.4	12.38	7.28	14300
97	60–8–120	....	....	....	....	....	....	......

TABLE 13.—*Events of the stroke from indicator-cards.*

Designation of tests.		Indicator results—Events of stroke—per cent.									
		Admission.					Cut-off.				
		Right side.		Left side.			Right side.		Left side.		
Number.	Laboratory symbol.	H. E.	C. E.	H. E.	C. E.	Average	H. E.	C. E.	H. E.	C. E.	Average
1	2	56	57	58	59	60	61	62	63	64	65
1	20–2–240	4.40	3.02	2.65	1.70	2.94	16.70	11.90	16.39	11.75	14.18
1a	20–2–240	....	....	....	....	....	....	....	....	....	....
2	20–4–240	2.00	1.80	.30	1.10	1.55	19.60	17.30	21.30	17.90	19.02
3	20–6–240	1.87	1.20	1.88	1.75	1.45	28.88	22.90	26.10	26.30	26.05
3a	20–6–240	....	....	....	....	....	....	....	....	....	....
4	20–8–240	1.30	1.00	1.00	1.50	1.20	35.00	29.00	35.00	32.50	32.88
5	30–2–240	4.45	3.65	3.70	2.49	3.57	17.03	14.77	18.99	13.36	16.04
5a	30–2–240	....	....	....	....	....	....	....	....	....	....
6	30–4–240	3.40	2.50	2.30	2.60	2.70	20.00	18.80	21.00	19.00	19.70
7	30–6–240	2.50	1.63	.96	.93	1.50	26.23	23.03	25.53	25.83	25.15
8	40–2–240	5.10	4.35	3.45	1.23	3.28	16.24	14.17	16.47	14.11	15.24
9	40–4–240	3.40	2.60	2.50	2.30	2.70	19.80	20.40	21.80	21.00	20.75
10	40–6–240	2.50	2.30	1.40	1.50	1.92	27.60	26.50	28.20	29.00	27.82
11	50–2–240	4.60	3.38	3.01	1.95	3.23	17.18	14.61	16.45	13.85	15.52
12	50–4–240	.80	2.00	.50	1.10	1.10	16.10	21.60	23.60	23.20	21.12
13	20–2–220	3.65	3.57	2.26	1.57	2.76	16.12	12.68	16.08	12.88	14.44
14	20–4–220	1.71	1.77	0.66	1.12	1.31	19.98	17.56	20.53	20.03	19.52
15	20–6–220	1.60	1.13	0.38	0.87	0.99	28.76	23.34	27.10	28.73	26.98
16	20–8–220	0.76	0.68	0.65	0.64	0.68	36.73	30.12	37.35	36.95	35.28
17	30–2–220	3.71	3.66	1.93	2.68	2.97	13.22	12.38	14.74	13.43	13.45
18	30–4–220	2.00	1.87	1.79	1.66	1.83	23.87	18.66	21.60	20.45	21.14
19	30–6–220	1.52	1.39	1.10	0.58	1.14	27.13	23.28	27.37	27.87	26.41
20	30–8–220	1.00	1.10	.80	1.00	.97	37.00	32.70	36.00	37.80	35.87
21	40–2–220	4.34	3.00	2.49	1.86	2.92	14.99	14.04	15.59	12.95	14.38
22	40–4–220	2.40	3.10	1.60	1.10	2.05	20.60	19.60	20.00	21.60	20.45
23	40–6–220	1.00	1.20	.70	0.20	.77	29.70	30.70	33.40	25.50	29.82
24	50–2–220	4.91	3.52	2.77	1.05	3.06	16.17	13.68	15.46	12.73	14.51
25	50–4–220	2.40	2.40	1.87	1.17	1.96	21.70	18.60	22.70	21.60	21.15
26	50–6–220	1.50	2.10	1.10	1.00	1.42	33.00	26.60	35.20	35.50	32.57
27	60–4–220	2.90	2.50	1.80	1.20	2.10	28.10	21.20	32.20	26.20	26.92
28	60–6–220	1.70	.70	.80	.70	.97	39.00	31.40	34.60	33.10	34.52
29	20–2–200	3.55	3.77	2.20	1.90	2.84	14.75	12.10	14.13	12.43	13.35
30	20–4–200	1.92	2.23	1.28	1.19	1.66	19.47	17.76	22.30	19.52	19.76
31	20–6–200	2.80	1.80	1.60	1.50	1.92	28.50	23.70	28.70	26.90	26.95
32	20–8–200	1.60	1.20	0.60	0.40	.95	38.30	30.30	37.70	37.50	35.95
33	30–2–200	4.13	4.06	2.48	2.22	3.22	14.52	12.54	16.64	13.07	14.19
34	30–4–200	4.30	3.00	2.20	2.50	3.00	20.50	17.40	20.20	17.40	18.87
35	30–6–200	1.41	1.31	1.10	0.65	1.12	27.64	24.08	27.74	27.53	26.75
36	30–8–200	.00	.80	.50	.80	.52	37.50	30.80	35.60	35.10	34.75
37	40–2–200	4.92	3.52	2.62	1.57	3.16	13.90	13.54	12.97	12.70	13.28
38	40–4–200	3.20	2.60	2.60	1.10	2.38	20.20	19.00	20.30	19.40	19.72
39	40–6–200	1.77	1.77	0.80	0.81	1.04	28.47	26.61	26.95	29.53	27.89
40	40–8–200	1.00	1.90	.50	.70	1.02	37.00	31.00	34.30	37.00	34.82
41	50–2–200	4.01	3.46	2.61	1.71	2.94	14.88	12.09	14.79	11.81	13.39
42	50–4–200	3.40	1.80	1.40	1.10	1.90	21.50	19.30	22.90	19.30	20.75
43	50–6–200	1.40	1.50	1.00	1.50	1.35	36.10	30.20	35.80	31.70	33.45
44	60–4–200	.80	1.70	1.50	1.20	1.30	27.20	24.20	30.20	28.20	27.45
45	60–6–200	3.00	1.00	1.50	1.50	1.75	34.30	26.50	30.50	30.70	30.50
46	20–2–180	5.40	3.70	3.90	3.00	4.01	17.02	13.46	15.06	12.10	11.91
47	20–4–180	2.75	1.90	1.95	1.66	2.06	21.14	17.18	19.88	17.70	18.97

TABLE 13.—*Events of the stroke from indicator-cards*—Continued.

Designation of tests.		Indicator results—Events of stroke—per cent.									
		Admission.					Cut-off.				
Number.	Laboratory symbol.	Right side.		Left side.		Average	Right side.		Left side.		Average
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	56	57	58	59	60	61	62	63	64	65
48	20-6-180	2.24	1.40	1.50	1.67	1.69	29.17	24.26	28.59	25.87	26.94
49	20-8-180	1.80	.80	1.10	1.00	1.17	36.00	31.00	35.00	34.70	34.17
50	20-10-180	.50	.80	0.00	.50	.45	45.50	35.50	40.40	45.00	41.60
51	30-2-180	5.41	3.50	3.83	3.53	4.06	15.69	12.56	14.90	12.34	13.87
52	30-4-180	4.36	2.81	3.02	2.40	3.14	20.50	17.31	21.27	17.86	19.23
53	30-6-180	2.86	1.73	1.60	1.80	1.99	27.20	24.06	27.90	26.53	26.42
54	30-8-180	1.78	1.65	1.67	.76	1.46	35.50	32.20	34.50	34.70	34.20
55	30-10-180	.70	.90	.60	.70	.72	45.00	37.00	40.50	45.00	41.87
56	40-2-180	6.20	3.98	4.42	3.16	4.44	15.47	14.12	17.09	12.70	14.84
57	40-4-180	4.33	2.71	2.63	1.96	2.91	21.51	19.50	22.74	19.54	20.82
58	40-6-180	2.52	1.33	2.14	0.98	1.74	27.20	23.00	27.79	26.58	26.14
59	40-8-180	2.61	1.33	1.75	1.03	1.68	35.98	32.48	35.51	35.33	34.80
60	40-10-180	.40	1.70	.50	.90	.87	42.00	41.90	41.80	44.70	42.60
61	50-2-180	5.81	3.92	4.04	3.48	4.30	16.94	13.25	17.00	13.53	15.17
62	50-4-180	4.12	2.58	2.98	2.19	2.94	22.25	18.89	23.70	19.70	21.13
63	50-6-180	3.33	1.91	2.16	1.58	2.24	29.75	27.50	30.33	28.91	29.12
64	50-8-180	1.00	1.00	.90	.70	.90	37.00	31.00	36.10	36.70	35.20
65	60-4-180	.70	1.50	1.60	1.50	1.32	27.80	30.00	30.00	25.00	28.20
66	60-6-180	1.00	1.60	1.20	.50	1.07	35.00	30.90	39.20	32.20	34.35
67	20-4-160	2.59	2.69	1.92	1.85	2.26	20.90	16.04	20.21	18.42	18.89
68	20-6-160	1.53	1.60	1.28	.84	1.33	28.10	21.60	26.60	26.30	25.65
69	20-8-160	2.27	1.41	1.61	1.13	1.58	35.16	31.05	34.38	33.55	33.50
70	20-10-160	.00	1.40	.50	.80	.67	42.50	35.10	38.20	43.90	39.92
71	30-4-160	3.04	2.92	2.28	1.85	2.52	17.80	15.92	19.11	18.54	17.84
72	30-6-160	1.86	1.79	1.50	1.20	1.59	26.78	22.52	26.55	26.84	25.67
73	30-8-160	2.21	1.40	1.55	1.20	1.59	34.29	30.96	33.34	33.66	33.06
74	30-10-160	1.00	1.00	1.10	1.00	1.02	43.90	41.50	41.60	46.20	43.30
75	30-12-160	.60	.80	.80	1.00	.80	47.30	40.30	46.20	53.40	46.80
76	40-4-160	3.80	2.63	1.60	1.51	2.43	20.59	18.97	19.82	19.05	19.62
77	40-6-160	2.24	1.58	1.21	0.73	1.43	26.37	23.54	26.90	27.62	26.11
78	40-8-160	2.30	1.90	1.60	1.00	1.70	35.20	33.40	34.60	36.00	34.80
79	40-10-160	1.00	1.10	0.60	.80	.87	41.70	35.30	38.50	43.40	39.72
80	50-4-160	3.20	2.68	1.78	1.57	2.30	19.94	15.68	22.14	19.85	19.40
81	50-6-160	2.01	1.37	0.86	0.61	1.21	29.97	25.54	29.07	27.67	28.06
82	50-8-160	.90	.80	.90	.60	.80	35.40	34.00	36.40	35.20	35.25
83	60-4-160	.90	2.50	1.10	2.00	1.62	27.00	24.50	28.30	25.00	26.20
84	60-6-160	1.00	1.00	1.00	.90	.97	30.60	28.40	31.50	31.50	30.50
85	20-4-120	3.40	3.20	3.20	1.90	2.92	19.70	15.90	19.30	16.90	17.95
86	20-8-120	1.47	1.32	.98	.65	1.10	36.24	28.80	33.65	34.80	33.37
87	20-12-120	.85	.90	.87	.62	.81	51.65	43.52	48.90	50.70	48.69
88	30-4-120	3.88	3.14	3.28	2.42	3.18	18.26	16.07	18.85	17.33	17.62
89	30-8-120	1.69	1.61	1.57	1.09	1.49	35.19	29.21	33.07	33.69	32.79
90	30-14-120	.70	.20	.40	.00	.10	58.20	51.40	56.00	59.40	56.25
91	40-4-120	4.00	2.94	2.51	2.11	2.89	18.96	16.51	19.37	16.11	17.74
92	40-8-120	1.50	1.80	1.20	1.00	1.40	35.60	31.40	34.70	35.30	34.25
93	40-12-120	.78	.65	.69	.21	.56	51.50	45.20	51.20	52.00	49.97
94	50-4-120	3.83	2.80	0.95	1.87	2.36	21.10	17.80	18.80	18.70	19.10
95	50-8-120	2.70	1.60	.70	.90	1.47	37.20	32.10	36.40	36.70	35.60
96	50-11-120	.50	.50	.50	.50	.50	49.00	40.87	46.62	50.25	46.68
97	60-8-120	1.00	1.10	1.10	1.00	1.05	30.00	28.50	33.30	30.00	30.45

TABLE 14.—*Events of the stroke.*

Designation of tests.		Indicator results—Events of stroke—per cent.									
		Release.					Compression.				
Number.	Laboratory symbol.	Right side.		Left side.		Average	Right side.		Left side.		Average
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	66	67	68	69	70	71	72	73	74	75
1	20–2–240	60.13	53.25	60.39	49.77	55.88	27.45	24.83	26.88	23.68	25.71
1*a*	20–2–240	....	....	....	....	....	....	....	....	....	....
2	20–4–240	69.50	65.80	68.10	67.50	67.70	21.70	20.00	22.90	21.90	21.62
3	20–6–240	71.00	67.00	69.40	69.20	70.10	31.40	28.10	27.70	29.20	29.10
3*a*	20–6–240	....	....	....	....	....	....	....	....	....	....
4	20–8–240	76.00	71.00	74.50	73.00	73.62	29.00	24.00	25.00	26.50	26.12
5	30–2–240	59.66	55.21	61.73	56.72	58.33	32.87	29.48	30.23	29.44	30.50
5*a*	30–2–240	....	....	....	....	....	....	....	....	....	....
6	30–4–240	62.70	62.50	64.60	63.00	63.20	36.50	34.70	35.00	34.00	35.05
7	30–6–240	63.90	65.03	68.67	69.00	66.65	31.87	32.90	33.30	31.43	32.37
8	40–2–240	58.53	54.01	59.89	56.34	57.19	26.88	24.51	28.64	23.98	26.00
9	40–4–240	63.60	64.80	62.70	63.20	63.60	38.00	36.40	40.00	38.00	38.10
10	40–6–240	66.00	70.50	72.00	68.70	69.30	39.50	37.30	40.50	33.50	37.70
11	50–2–240	63.38	55.36	61.21	55.70	58.91	31.01	28.06	31.65	31.85	30.84
12	50–4–240	69.50	65.80	69.40	57.80	65.62	35.00	29.50	34.40	32.10	32.75
13	20–2–240	61.67	55.73	61.58	58.02	59.25	19.50	16.94	18.09	15.30	17.45
14	20–4–220	68.63	63.02	66.84	66.04	66.13	14.21	12.90	15.50	12.55	13.79
15	20–6–220	73.24	66.49	71.05	69.47	70.06	16.08	10.95	13.69	10.47	12.79
16	20–8–220	76.58	71.31	76.35	71.95	74.04	17.40	12.51	15.26	12.80	14.49
17	30–2–220	61.05	54.24	61.44	57.14	58.47	19.87	17.50	19.52	16.91	18.45
18	30–4–220	66.62	59.50	65.50	62.41	63.50	20.79	16.66	21.12	18.91	19.37
19.	30–6–220	72.09	65.37	71.24	66.90	68.90	18.59	15.79	18.19	16.13	17.17
20	30–8–220	78.70	76.00	74.60	78.60	76.97	29.60	22.20	27.50	28.00	26.82
21	40–2–220	61.79	58.10	61.70	56.17	59.47	21.37	18.55	20.75	18.08	19.70
22	40–4–220	65.60	62.30	67.60	62.60	64.52	20.20	18.30	19.50	21.80	19.95
23	40–6–220	70.20	69.70	71.00	71.20	70.52	35.50	30.70	33.50	34.00	33.42
24	50–2–220	61–60	57.63	61.60	56.48	61.83	23.11	20.48	22.20	19.23	21.25
25	50–4–220	65.80	59.70	66.00	61.20	63.17	22.50	17.70	25.40	19.60	21.30
26	50–6–220	71.00	72.10	75.00	72.10	72.55	34.10	33.40	38.80	31.50	34.45
27	60–4–220	70.70	69.50	68.40	68.80	69.35	44.20	42.50	42.00	38.40	41.77
28	60–6–220	74.50	73.50	72.20	74.50	73.67	36.50	35.70	35.30	34.70	35.55
29	20–2–200	61.40	56.58	60.48	56.15	58.65	20.27	18.93	17.83	18.30	18.83
30	20–4–200	65.37	57.93	64.44	58.35	61.52	16.24	13.76	16.76	14.48	15.31
31	20–6–200	69.10	56.30	70.40	69.50	68.82	31.25	27.80	27.80	27.30	28.54
32	20–8–200	77.10	59.40	75.10	71.40	73.25	16.50	14.30	14.70	12.50	14.50
33	30–2–200	60.21	52.50	60.15	54.97	56.96	21.60	17.82	21.78	18.22	19.85
34	30–4–200	62.40	62.10	63.50	64.00	63.00	37.50	33.90	34.20	32.90	34.62
35	30–6–200	70.59	64.00	69.83	64.09	67.13	15 81	13.18	14.69	14.01	14.42
36	30–8–200	76.20	72.80	75.50	76.00	75.12	30.50	28.00	27.50	26.00	28.00
37	40–2–200	60.95	56.44	60.16	57.01	58.64	22.01	20.07	20.68	18.93	20.42
38	40–4–200	66.95	60.50	64.90	62.70	63.76	30.70	25.90	29.90	26.70	28.30
39	40–6–200	72.47	65.48	71.44	67.35	69.23	17.37	13.29	14.91	12.25	14.45
40	40–8–200	71.40	74.90	71.30	73.60	72.80	29.50	27.00	29.40	31.80	29.42
41	50–2–200	60.93	53.51	63.16	56.23	58.45	25.43	21.77	22.55	22.17	22.98
42	50–4–200	64.90	58.80	64.40	58.90	61.75	21.70	19.50	20.90	17.40	19.88
43	50–6–200	72 00	67.40	72.30	66.00	66.67	40.00	33.30	39.00	35.10	36.85
44	60–4–200	68.50	63.30	69.20	66.90	66.97	45.00	42.00	45.70	38.00	42.67
45	60–6–200	73.00	71.10	73.00	72.70	72.45	46.50	34.00	43.70	35.50	39.22
46	20–2–180	58.92	54.64	57.10	56.45	56.78	43.53	37.64	39.61	36.74	39.33
47	20–4–180	60.47	57.53	61.53	59.83	59.84	33.65	31.48	33.23	33.80	33.04

TABLE 14.—*Events of the stroke*—Continued.

Designation of tests.		Indicator results—Events of stroke—per cent.									
		Release.					Compression.				
Number.	Laboratory symbol.	Right side. H. E.	Right side. C. E.	Left side. H. E.	Left side. C. E.	Average	Right side. H. E.	Right side. C. E.	Left side. H. E.	Left side. C. E.	Average
1	2	66	67	68	69	70	71	72	73	74	75
48	20–6–180	69.00	66.71	69.60	68.76	68.52	32.07	27.85	30.31	29.91	30.02
49	20–8–180	73.80	72.40	73.00	73.10	73.07	28.60	25.00	26.00	26.00	26.40
50	20–10–180	80.00	74.00	78.70	81.50	78.55	23.60	21.40	24.50	21.50	22.75
51	30–2–180	58.46	55.42	57.97	56.70	57.14	44.85	40.18	42.26	41.87	42.29
52	30–4–180	63.00	61.40	63.77	62.60	62.69	37.27	33.31	37.45	34.18	35.55
53	30–6–180	67.06	66.00	67.70	66.83	66.89	38.06	30.70	33.00	32.13	33.47
54	30–8–180	72.20	70.70	72.20	71.50	71.60	30.15	29.75	28.40	27.05	28.83
55	30–10–180	79.00	75.90	77.10	80.60	78.15	26.50	24.00	25.00	25.50	25.25
56	40–2–180	57.55	57.40	58.60	57.30	57.71	46.47	37.72	43.02	40.18	41.85
57	40–4–180	63.50	63.00	64.48	63.80	63.69	42.07	37.46	41.37	36.91	39.45
58	40–6–180	65.64	64.25	67.50	67.86	66.31	36.84	31.41	33.00	31.78	33.25
59	40–8–180	72.23	70.25	72.84	72.33	71.91	30.11	26.74	28.08	29.26	28.54
60	40–10–180	76.10	76.50	78.00	80.20	77.70	28.30	25.00	28.00	26.70	27.00
61	50–2–180	58.00	57.46	57.50	57.26	57.55	45.20	41.54	45.37	43.31	43.83
62	50–4–180	62.62	63.30	63.58	64.29	63.45	41.88	38.25	41.03	37.00	39.54
63	50–6–180	67.58	67.50	65.33	68.16	67.14	42.66	38.33	38.50	38.25	39.43
64	50–8–180	76.00	67.60	75.00	73.00	72.90	38.60	27.80	37.50	29.10	33.25
65	60–4–180	69.10	66.60	71.60	70.00	69.32	57.80	50.70	47.40	42.40	49.57
66	60–6–180	73.00	72.90	72.00	73.00	72.72	47.00	41.80	46.60	34.60	42.50
67	20–4–160	65.61	60.21	65.00	61.66	62.97	19.95	16.59	19.40	16.83	17.94
68	20–6–160	71.60	64.97	71.10	68.10	68.94	15.50	13.50	15.40	13.17	14.39
69	20–8–160	74.08	71.30	73.61	73.86	73.17	29.77	24.93	27.38	26.08	27.07
70	20–10–160	82.20	77.30	81.40	82.00	80.72	25.80	22.00	25.20	22.90	23.97
71	30–4–160	66.11	58.88	65.26	62.71	63.24	18.50	17.07	19.90	16.88	18.09
72	30–6–160	71.73	65.85	70.75	65.85	68.49	17.66	16.16	17.28	12.76	15.96
73	30–8–160	71.42	70.12	72.44	71.94	71.48	29.31	27.71	28.29	27.42	28.18
74	30–10–160	76.30	74.60	78.00	75.10	76.00	33.30	23.90	25.30	26.70	27.30
75	30–12–160	86.10	81.80	83.00	82.60	83.37	24.00	20.60	24.40	20.80	22.45
76	40–4–160	62.96	56.74	63.56	58.63	60.76	22.65	19.26	19.17	16.10	19.44
77	40–6–160	71.33	61.44	71.12	64.90	67.20	16.64	13.16	15.03	13.25	14.50
78	40–8–160	71.30	70.50	71.10	71.80	71.17	30.40	29.60	28.00	29.70	29.42
79	40–10–160	81.90	76.70	80.30	79.50	79.60	23.00	28.50	26.80	24.50	25.70
80	50–4–160	65.12	59.43	68.35	62.35	63.38	18.81	16.31	21.78	18.14	18.76
81	50–6–160	71.25	59.77	69.11	62.34	65.62	17.63	15.17	16.90	13.53	15.81
82	50–8–160	78.90	67.00	70.50	73.10	72.37	39.10	28.10	30.80	28.80	31.70
83	60–4–160	64.00	67.50	67.00	69.00	66.87	42.00	38.00	41.90	34.60	39.12
84	60–6–160	69.00	70.30	74.30	74.60	72.05	45.60	38.00	42.60	34.50	40.17
85	20–4–120	64.80	55.80	65.10	58.90	61.15	19.70	16.30	19.10	16.10	17.80
86	20–8–120	75.76	68.60	75.21	71.70	72.81	17.50	14.12	16.03	11.65	14.82
87	20–12–120	84.22	77.15	82.32	79.90	80.89	15.35	10.57	11.90	10.90	12.18
88	30–4–120	65.38	58.85	63.64	57.40	61.31	20.59	17.90	19.59	15.83	18.47
89	30–8–120	76.54	67.61	75.09	70.54	72.44	18.40	13.35	17.90	14.59	16.03
90	30–14–120	87.10	81.10	86.00	83.40	84.40	10.70	9.50	9.62	9.08	9.72
91	40–4–120	64.68	56.27	64.12	57.21	60.57	21.21	25.24	20.63	15.43	18.13
92	40–8–120	75.10	69.10	75.10	69.20	72.12	15.80	14.60	15.90	14.80	15.27
93	40–12–120	84.20	73.40	82.80	79.30	79.92	13.60	11.10	12.10	10.30	11.77
94	50–4–120	66.80	58.20	66.20	58.50	62.25	20.90	18.20	19.20	18.37	19.16
95	50–8–120	76.50	68.50	75.70	69.00	72.42	18.50	17.90	15.90	16.30	17.15
96	50–11–120	82.87	77.62	83.62	81.12	81.30	14.00	12.62	10.75	13.12	12.62
97	60–8–120	77.80	76.50	76.50	76.50	76.82	32.80	31.00	25.00	28.30	29.27

TABLE 15.—*Pressures from indicator-cards.*

Designation of tests.		Indicator results—Pressure above atmosphere.									
		Initial.					At cut-off.				
Number.	Laboratory symbol.	Right side.		Left side.		Average	Right side.		Left side.		Average
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	76	77	78	79	80	81	82	83	84	85
1	20–2–240	225.5	218.8	228.1	214.2	221.6	156.3	185.8	165.2	163.3	167.6
1a	20–2–240	....	....	....	....	....	....	....	....	....	....
2	20–4–240	228.2	227.1	218.7	223.8	224.4	183.4	192.4	170.4	179.6	181.5
3	20–6–240	226.5	225.6	213.9	218.7	221.2	167.0	183.4	165.0	175.6	172.7
3a	20–6–240	....	....	....	....	....	....	....	....	....	....
4	20–8–240	223.5	220.0	220.5	228.0	223.0	180.0	186.0	169.5	186.0	180.4
5	30–2–240	229.5	235.3	224.6	234.0	230.8	150.8	161.5	136.8	162.3	152.8
5a	30–2–240	....	....	....	....	....	....	....	....	....	....
6	30–4–240	233.0	228.0	224.0	213.0	224.0	155.0	157.0	151.0	151.6	153.6
7	30–6–240	224.7	218.0	215.0	217.0	218.7	151.7	162.3	152.7	151.0	154.4
8	40–2–240	234.9	234.8	222.4	205.4	224.3	135.7	151.9	135.4	136.0	139.7
9	40–4–240	239.0	236.0	227.0	221.0	230.7	147.0	147.3	137.5	135.0	141.7
10	40–6–240	215.0	212.0	207.0	200.0	208.5	134.0	129.0	124.0	123.0	127.5
11	50–2–240	242.3	245.1	239.6	227.8	238.7	123.3	144.1	126.1	127.0	130.1
12	50–4–240	235.0	231.0	225.0	212.0	225.7	165.0	120.0	130.0	112.0	131.7
13	20–2–220	209.7	207.2	201.9	202.7	205.3	151.3	163.3	145.6	160.5	155.1
14	20–4–220	205.5	212.5	190.7	204.2	203.2	156.1	168.6	145.0	166.5	159.0
15	20–6–220	208.3	206.2	181.5	202.0	197.0	156.3	169.1	146.8	165.5	159.4
16	20–8–220	215.2	209.2	189.2	185.5	199.8	166.0	166.0	152.5	170.3	163.7
17	30–2–220	209.5	207.4	205.5	196.1	204.6	151.1	153.9	142.1	147.2	148.6
18	30–4–220	210.1	204.0	199.0	189.6	200.7	140.7	151.0	139.1	144.9	143.9
19	30–6–220	211.3	203.1	191.7	190.1	199.0	144.0	155.9	135.8	147.9	145.9
20	30–8–220	213.0	200.0	196.0	200.0	202.2	151.0	152.0	142.0	152.0	149.2
21	40–2–220	219.2	218.8	214.6	204.3	214.3	130.5	142.2	128.7	132.1	133.3
22	40–4–220	218.3	201.6	205.8	200.0	206.4	135.8	136.6	131.3	125.8	132.4
23	40–6–220	210.0	195.0	200.0	195.0	200.0	132.0	115.5	112.5	144.5	126.0
24	50–2–220	221.7	219.8	218.3	205.1	216.2	115.1	129.8	117.2	126.1	122.0
25	50–4–220	217.6	216.6	211.0	200.0	211.3	118.3	136.0	113.0	119.0	121.6
26	50–6–220	213.0	205.0	200.0	198.0	204.0	112.0	110.0	97.0	112.0	107.7
27	60–4–220	215.0	207.0	205.0	195.0	205.5	92.0	107.0	80.0	95.0	93.5
28	60–6–220	210.0	200.0	200.0	193.0	200.7	92.0	100.0	100.0	108.0	100.0
29	20–2–200	192.9	190.8	180.7	183.8	187.0	141.1	154.1	143.9	147.7	146.7
30	20–4–200	183.9	186.8	177.5	177.7	182.7	132.6	145.3	127.4	140.6	136.5
31	20–6–200	194.1	185.4	184.0	184.8	187.0	139.1	149.3	135.5	141.9	141.4
32	20–8–200	195.5	189.1	165.5	152.5	173.4	142.8	156.5	132.2	152.0	155.8
33	30–2–200	188.3	187.0	180.5	176.5	183.1	123.8	140.5	117.9	128.1	127.6
34	30–4–200	194.0	186.6	187.0	181.0	187.1	126.0	134.6	125.2	128.6	128.6
35	30–6–200	190.6	180.5	177.6	179.1	181.9	127.5	131.8	119.0	131.0	127.3
36	30–8–200	200.0	188.0	185.0	190.0	190.7	133.0	145.0	130.0	150.0	139.5
37	40–2–200	202.1	193.4	191.3	191.0	194.4	126.3	126.6	124.8	120.9	124.6
38	40–4–200	198.7	191.5	189.0	188.6	191.9	121.3	124.6	115.8	116.9	119.6
39	40–6–200	185.4	184.6	172.2	178.1	180.1	114.9	125.9	111.6	123.1	118.9
40	40–8–200	191.0	182.0	183.0	183.0	184.7	125.0	135.0	125.0	127.0	128.0
41	50–2–200	205.2	206.7	207.5	193.0	203.1	112.8	126.1	111.3	120.5	117.7
42	50–4–200	194.1	194.6	190.8	180.6	190.0	99.4	111.6	98.4	107.7	104.3
43	50–6–200	195.0	184.0	184.0	184.0	186.7	94.0	99.0	87.0	100.0	95.0
44	60–4–200	198.0	185.0	185.0	175.0	180.7	83.0	85.0	75.0	77.0	80.0
45	60–6–200	186.0	171.0	183.0	171.0	177.7	84.0	96.0	84.0	99.0	90.7
46	20–2–180	177.3	171.0	173.3	177.3	174.8	117.7	128.3	125.8	133.7	126.3
47	20–4–180	171.5	168.5	167.7	171.2	169.7	117.6	125.4	123.7	131.3	124.5

TABLE 15.—*Pressures from indicator-cards*—Continued.

Designation of tests.		Indicator results—Pressure above atmosphere.									
		Initial.					At cut-off.				
		Right side.		Left side.		Average	Right side.		Left side.		Average
Number.	Laboratory symbol.	H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	76	77	78	79	80	81	82	83	84	85
48	20–6–180	169.1	164.5	167.3	170.8	167.9	121.8	129.9	119.5	132.8	125.9
49	20–8–180	173.0	166.0	166.9	173.2	169.7	126.2	130.8	126.7	134.5	129.5
50	20–10–180	173.0	170.0	167.0	178.0	172.0	129.0	147.0	137.0	151.0	141.0
51	30–2–180	175.5	170.9	178.0	174.6	174.7	115.9	124.4	117.2	121.0	119.6
52	30–4–180	172.4	168.8	178.3	157.2	169.2	111.5	120.8	115.7	109.4	114.4
53	30–6–180	162.8	157.4	164.8	154.7	159.9	104.3	109.7	108.8	100.0	105.7
54	30–8–180	172.2	166.1	168.5	167.9	168.8	113.3	123.8	115.3	125.5	119.5
55	30–10–180	174.0	169.0	170.0	177.0	172.5	118.0	132.0	122.0	140.0	128.0
56	40–2–180	188.5	175.3	184.2	179.0	181.7	101.6	111.6	100.4	106.0	104.9
57	40–4–180	169.9	167.7	176.2	173.6	171.8	101.4	106.1	101.4	102.2	102.7
58	40–6–180	174.2	168.8	173.4	173.3	172.4	107.6	114.3	107.3	113.3	110.6
59	40–8–180	165.5	164.3	164.0	164.8	164.6	103.4	107.0	102.1	108.7	105.3
60	40–10–180	167.0	164.0	163.0	173.0	166.7	116.0	112.0	112.0	127.0	116.7
61	50–2–180	193.6	187.2	191.3	188.4	190.1	90.8	103.7	95.1	97.6	96.7
62	50–4–180	185.4	177.4	185.5	180.8	182.3	90.0	99.5	89.0	98.0	94.1
63	50–6–180	176.0	172.6	175.5	176.1	175.0	88.3	93.6	86.5	94.6	90.8
64	50–8–180	162.0	164.0	159.0	166.0	162.7	95.0	102.0	97.0	105.0	99.7
65	60–4–180	177.0	168.0	167.0	163.0	168.7	69.0	57.0	64.0	77.0	66.7
66	60–6–180	172.0	162.0	161.0	158.0	163.2	72.0	74.0	77.0	83.0	76.5
67	20–4–160	153.8	150.6	145.8	149.8	150.0	108.9	121.5	107.7	118.3	114.1
68	20–6–160	155.2	154.9	147.8	150.9	152.2	111.6	128.2	113.0	123.4	119.1
69	20–8–160	144.3	147.6	147.8	151.4	147.8	110.4	111.8	110.8	118.3	112.8
70	20–10–160	154.0	151.0	150.0	158.4	153.3	125.0	132.0	129.0	136.0	130.5
71	30–4–160	159.0	150.7	151.5	147.2	152.1	107.9	112.2	102.3	106.8	107.3
72	30–6–160	155.2	146.7	148.8	147.6	149.6	102.5	110.9	97.7	108.0	104.8
73	30–8–160	158.3	152.6	152.9	153.9	154.4	101.7	107.0	103.6	107.0	104.8
74	30–10–160	159.0	154.0	154.0	160.0	156.7	101.0	105.0	104.0	107.0	104.2
75	30–12–160	152.0	154.0	150.0	158.0	153.5	120.0	126.0	114.0	121.0	120.2
76	40–4–160	155.6	156.4	149.9	154.4	154.1	90.5	96.7	85.2	99.4	90.3
77	40–6–160	151.3	153.3	148.7	153.1	151.7	92.6	102.6	86.2	100.0	95.3
78	40–8–160	151.1	151.8	150.8	152.0	151.4	89.2	93.7	91.3	95.4	92.4
79	40–10–160	148.0	149.0	144.0	152.0	148.2	102.0	113.0	107.0	113.0	108.7
80	50–4–160	165.0	163.9	160.7	160.0	162.4	82.7	100.4	77.0	91.3	87.8
81	50–6–160	150.0	152.0	145.3	149.7	149.2	76.1	90.9	73.3	91.3	82.9
82	50–8–160	145.0	147.0	140.0	146.0	144.5	89.0	83.0	83.0	95.0	87.5
83	60–4–160	160.0	150.0	151.0	152.0	153.2	61.0	61.0	57.0	66.0	61.2
84	60–6–160	160.0	146.0	144.0	144.0	148.5	74.0	68.0	71.0	76.0	72.2
85	20–4–120	115.0	112.5	109.4	112.2	112.7	79.7	85.4	78.5	84.2	81.9
86	20–8–120	114.3	111.3	108.5	111.0	111.2	81.0	86.8	81.0	87.7	84.1
87	20–12–120	109.9	111.4	109.1	111.5	110.5	89.8	93.9	89.2	98.5	92.9
88	30–4–120	119.3	112.6	113.6	112.1	114.4	73.9	80.4	72.4	77.7	76.1
89	30–8–120	115.0	111.7	111.3	109.6	111.9	71.4	79.2	72.3	80.6	75.9
90	30–14–120	104.0	108.2	102.9	103.2	104.5	84.3	87.5	84.3	90.2	86.5
91	40–4–120	118.5	118.2	117.8	118.0	118.2	66.6	74.2	65.6	74.3	70.2
92	40–8–120	111.9	112.6	107.4	106.3	109.5	64.8	70.0	63.6	73.0	67.8
93	40–12–120	105.8	113.4	107.1	104.1	107.6	71.6	82.1	69.5	81.2	76.1
94	50–4–120	115.6	125.9	121.1	122.5	121.3	58.0	68.5	55.3	65.0	61.6
95	50–8–120	116.9	113.0	109.2	109.8	112.2	64.3	66.9	58.6	68.4	64.5
96	50–11–120	103.5	97.7	95.0	99.5	98.9	62.7	67.7	63.2	69.5	65.8
97	60–8–120	115.0	106.0	106.0	104.0	107.7	68.0	62.0	62.0	72.0	66.0

TABLE 16.—*Pressures from indicator-cards.*

Designation of tests.		Indicator results—Pressure above atmosphere.									
		At release.					At compression.				
Number.	Laboratory symbol.	Right side.		Left side.		Average	Right side.		Left side.		Average
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	86	87	88	89	90	91	92	93	94	95
1	20-2-240	52.5	56.8	46.1	50.4	51.4	17.8	18.0	18.5	19.6	18.5
1a	20-2-240	....	....	....	....	....	....	....	....	....	....
2	20-4-240	57.3	59.6	58.0	56.7	57.9	19.7	21.6	18.6	18.2	19.5
3	20-6-240	75.0	73.7	68.1	76.1	72.6	9.2	10.1	9.6	10.7	9.9
3a	20-6-240	....	....	....	....	....	....	....	....	....	....
4	20-8-240	82.5	82.5	81.0	87.0	83.2	7.5	12.0	7.5	10.5	9.4
5	30-2-240	44.8	51.6	44.5	53.0	48.4	16.9	19.3	18.8	27.1	20.5
5a	30-2-240	....	....	....	....	....	....	....	....	....	....
6	30-4-240	53.0	55.5	54.0	53.6	54.0	12.4	13.6	13.0	14.4	15.8
7	30-6-240	65.3	65.0	61.3	60.7	63.1	10.3	11.3	10.0	11.7	10.8
8	40-2-240	41.2	46.4	40.9	40.4	42.2	26.0	27.8	22.8	27.3	25.9
9	40-4-240	47.7	53.0	50.7	50.0	50.3	13.9	14.8	12.4	14.8	13.5
10	40-6-240	57.0	54.0	50.0	53.0	53.5	16.0	18.0	13.0	16.0	15.7
11	50-2-240	33.3	45.3	35.0	36.6	37.5	21.3	27.3	22.5	20.5	22.9
12	50-4-240	40.0	40.0	43.0	40.0	40.7	22.0	21.0	18.0	20.0	20.2
13	20-2-220	44.3	47.3	42.3	44.9	44.7	27.4	31.6	29.6	33.3	30.4
14	20-4-220	49.3	54.1	47.6	55.4	51.6	36.0	37.5	28.5	37.3	34.8
15	20-6-220	61.4	66.5	56.9	70.0	63.7	26.9	41.6	27.7	37.4	33.4
16	20-8-220	81.7	78.0	74.2	86.3	80.0	24.0	28.1	21.7	26.6	25.1
17	30-2-220	37.2	43.0	35.9	40.2	39.1	32.7	34.5	30.4	36.1	33.4
18	30-4-220	47.9	51.1	46.6	50.1	48.9	26.3	34.0	25.1	28.8	28.6
19	30-6-220	54.7	60.5	52.9	61.5	57.4	28.0	36.7	27.4	32.1	31.0
20	30-8-220	70.0	68.0	67.0	70.0	68.7	15.0	15.0	12.0	14.0	14.0
21	40-2-220	33.7	37.0	35.7	34.2	35.1	34.2	35.7	35.2	35.2	35.1
22	40-4-220	44.6	43.3	40.0	44.6	43.1	34.8	35.6	33.5	27.6	32.9
23	40-6-220	55.5	52.5	51.0	53.0	53.0	15.0	16.5	13.5	15.0	15.0
24	50-2-220	26.4	33.7	29.1	31.2	30.1	30.6	36.4	32.7	35.7	33.8
25	50-4-220	39.0	43.0	38.0	42.7	40.6	31.7	41.0	32.3	37.0	35 5
26	50-6-220	51.0	45.0	44.0	47.0	46.7	20.0	19.0	12.0	17.0	17.0
27	60-4-220	35.0	33.0	35.0	38.0	35.2	14.0	15.0	12.0	16.0	14.2
28	60-6-220	47.0	41.0	46.0	48.0	45.5	24.0	21.0	20.0	22.0	21.7
29	20-2-200	38.6	42.6	38.1	41.0	39.9	25.2	27.0	29.4	25.2	26.8
30	20-4-200	43.2	50.4	45.0	49.1	46.9	29.1	35.7	25.3	29.0	29.8
31	20-6-200	58.7	57.5	58.6	59.7	58.6	7.4	10.3	7.3	10.2	8.8
32	20-8-200	69.8	71.8	65.2	78.7	71.4	22.4	26.3	20.3	25.9	23.7
33	30-2-200	32.0	39.5	33.4	35.3	35.0	28.4	34.3	27.5	29.9	30.0
34	30-4-200	42.0	44.0	42.8	41.6	47.6	9.4	11.0	9.8	11.0	10.3
35	30-6-200	48.5	51.6	46.2	56.2	50.6	31.6	35.5	32.4	35.2	33.7
36	30-8-200	64.0	63.0	57.0	70.0	63.5	14.0	16.0	10.0	18.0	14.5
37	40-2-200	29.4	33.5	28.8	30.6	30.6	32.3	31.9	31.5	34.5	32.5
38	40-4-200	38.7	40.3	34.6	37.9	37.9	18.3	21.5	17.2	20.3	19.3
39	40-6-200	42.5	51.2	40.6	52.9	46.8	36.8	46.8	35.9	46.2	41.4
40	40-8-200	63.0	57.0	57.0	64.0	60.2	20.0	20.0	16.0	18.0	18.5
41	50-2-200	26.8	30.4	26.6	27.9	27.9	26.5	29.7	31.8	32.0	30.0
42	50-4-200	30.7	37.7	34.4	34.7	34.3	34.0	33.9	32.2	37.7	34.4
43	50-6-200	45.0	43.0	40.0	48.0	44.0	14.0	15.0	10.0	16.0	13.7
44	60-4-200	31.0	32.0	30.0	32.0	31.2	11.0	12.0	10.0	13.0	11.5
45	60-6-200	39.0	31.0	39.0	34.0	35.7	15.0	18.0	12.0	16.5	15.4
46	20-2-180	38.3	39.5	39.1	39.9	39.2	5.5	6.6	6.6	7.6	6.6
47	20-4-180	43.2	43.5	43.4	44.4	43.6	7.5	7.7	7.6	7.9	7.7

TABLE 16.—*Pressures from indicator-cards*—Continued.

Designation of tests.		Indicator results—Pressure above atmosphere.									
		At release.					At compression.				
Number.	Laboratory symbol.	Right side.		Left side.		Average	Right side.		Left side.		Average
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	86	87	88	89	90	91	92	93	94	95
48	20–6–180	50.2	50.0	50.3	55.4	51.4	6.8	8.3	7.7	8.1	7.7
49	20–8–180	60.6	57.8	61.1	68.0	61.8	6.7	7.1	6.6	8.0	7.1
50	20–10–180	70.0	70.0	68.0	81.0	72.2	7.0	11.0	7.0	10.0	8.7
51	30–2–180	32.0	32.2	32.5	33.5	32.5	6.0	6.7	6.9	7.0	6.6
52	30–4–180	35.4	37.3	41.6	38.8	38.3	7.6	9.0	8.2	9.6	8.6
53	30–6–180	40.8	40.8	45.3	40.7	41.9	7.4	6.8	8.0	9.0	7.8
54	30–8–180	54.0	56.4	54.7	60.6	56.4	9.1	10.1	9.0	10.3	9.6
55	30–10–180	65.0	64.0	60.0	75.0	66.0	12.0	15.0	12.0	15.0	13.5
56	40–2–180	26.3	28.1	29.9	28.2	28.1	8.8	8.5	9.1	9.3	8.9
57	40–4–180	32.3	32.4	35.7	33.5	33.4	8.9	8.9	8.5	10.1	9.1
58	40–6–180	42.4	46.2	43.2	46.3	44.5	9.8	11.5	11.4	12.2	11.2
59	40–8–180	49.4	47.5	49.1	53.1	49.7	16.4	17.0	15.1	16.7	16.3
60	40–10–180	60.0	60.0	59.0	68.0	61.7	16.0	19.0	16.0	20.0	17.7
61	50–2–180	23.8	25.2	27.5	26.6	25.7	9.41	9.9	9.5	9.5	9.5
62	50–4–180	29.5	28.5	32.6	30.9	30.3	10.5	10.4	10.5	11.8	10.8
63	50–6–180	36.8	35.8	38.5	39.3	37.6	11.0	11.0	12.0	12.5	11.6
64	50–8–180	42.0	44.0	42.0	50.0	44.5	14.0	18.0	13.0	17.0	15.5
65	60–4–180	26.0	22.0	24.0	27.0	24.7	8.0	7.0	7.0	10.0	8.0
66	60–6–180	32.0	29.0	32.0	36.0	32.2	12.0	13.0	8.0	14.0	11.7
67	20–4–160	35.1	36.6	35.2	39.4	36.6	20.6	26.7	21.0	24.0	23.1
68	20–6–160	42.5	47.6	41.9	48.0	45.0	23.3	31.9	21.3	25.6	25.5
69	20–8–160	51.8	47.7	52.4	56.7	52.1	5.0	7.0	5.5	7.6	6.3
70	20–10–160	62.0	60.0	59.0	73.0	63.5	5.0	7.0	4.0	6.0	5.5
71	30–4–160	28.7	31.4	29.4	31.9	30.4	27.0	28.6	25.4	29.3	27.6
72	30–6–160	36.2	38.8	35.0	43.3	38.3	25.0	28.6	22.8	31.7	27.0
73	30–8–160	46.1	47.3	46.3	53.4	48.3	10.5	11.1	9.1	11.1	10.4
74	30–10–160	54.0	57.0	54.0	64.0	57.2	8.0	13.0	10.0	10.0	10.2
75	30–12–160	61.0	62.0	62.0	76.0	65.2	11.0	14.0	10.0	14.0	12.2
76	40–4–160	26.4	32.5	24.5	32.6	28.9	24.5	31.2	26.3	35.1	29.1
77	40–6–160	30.9	38.3	30.5	41.1	35.2	34.5	42.6	31.4	39.6	37.0
78	40–8–160	40.6	43.8	43.1	47.5	43.7	13.4	13.5	13.4	15.3	13.9
79	40–10–160	48.0	51.0	50.0	60.0	52.2	16.0	15.0	12.0	16.0	14.7
80	50–4–160	22.7	26.2	23.3	27.7	25.0	31.2	39.7	28.0	33.2	33.0
81	50–6–160	28.3	35.8	28.0	38.7	32.7	33.1	38.8	31.2	42.0	36.3
82	50–8–160	36.0	40.0	40.0	44.0	40.0	12.0	15.0	12.0	15.0	13.5
83	60–4–160	23.0	18.0	20.0	22.0	20.7	9.0	11.0	10.0	12.0	10.5
84	60–6–160	28.0	25.0	26.0	29.0	27.0	10.0	10.0	8.0	13.0	10.2
85	20–4–120	22.7	25.1	21.9	26.1	23.9	21.1	26.5	21.6	26.0	23.8
86	20–8–120	34.8	35.9	35.8	41.2	36.9	14.4	19.8	15.8	22.6	18.2
87	20–12–120	49.9	51.0	50.2	60.0	52.8	15.2	18.4	13.7	16.8	16.0
88	30–4–120	19.2	21.7	18.3	22.7	20.5	23.7	26.2	22.0	28.7	25.1
89	30–8–120	27.8	32.6	28.3	35.3	31.0	18.3	25.6	16.5	23.5	21.0
90	30–14–120	52.1	54.2	53.2	61.8	55.3	22.8	25.0	24.1	26.3	24.5
91	40–4–120	16.4	20.5	17.1	20.3	18.6	24.9	37.1	25.4	34.7	30.5
92	40–8–120	25.4	28.5	25.4	32.8	28.0	26.2	29.2	21.2	25.8	25.6
93	40–12–120	39.9	50.6	40.5	50.8	45.4	27.9	36.7	26.5	33.0	31.2
94	50–4–120	13.4	21.1	13.8	18.4	16.7	27.6	34.9	24.3	30.1	29.2
95	50–8–120	29.1	26.5	24.3	32.8	28.1	30.0	26.7	27.0	28.9	28.1
96	50–11–120	33.7	34.5	32.0	40.0	35.0	31.5	32.2	34.7	33.0	32.8
97	60–8–120	21.0	19.0	23.0	27.0	22.5	13.0	12.0	14.0	13.0	13.0

TABLE 17.—*Pressures from indicator-cards.*

Designation of tests.		Indicator results—Pressure above atmosphere.									
		Least back.					Mean effective.				
Number.	Laboratory symbol.	Right side.		Left side.		Average.	Right side.		Left side.		Average.
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	96	97	98	99	100	101	102	103	104	105
1	20–2–240	3.0	1.7	3.2	2.4	2.6	60.75	61.22	65.69	53.08	60.19
1a	20–2–240	...	...	...	...	...	55.50	52.07	61.81	52.73	55.53
2	20–4–240	2.3	2.3	2.0	2.6	2.3	84.99	82.15	82.53	81.04	82.67
3	20–6–240	2.0	3.0	2.0	3.0	2.5	101.49	97.75	96.27	100.46	99.05
3a	20–6–240	...	...	...	...	...	98.46	94.92	95.35	94.17	95.72
4	20–8–240	5.0	3.0	1.0	5.0	3.5	126.60	113.80	120.60	121.00	120.50
5	30–2–240	3.1	2.8	2.0	9.6	4.9	54.33	53.10	53.45	48.29	52.29
5a	30–2–240	...	...	...	...	...	50.84	51.19	55.63	47.53	51.30
6	30–4–240	1.0	2.2	2.6	2.3	2.0	65.21	67.80	67.63	64.66	66.36
7	30–6–240	3.3	4.7	5.0	6.0	4.7	83.66	82.90	83.85	82.06	83.12
8	40–2–240	2.0	2.3	2.1	3.6	2.5	45.07	46.85	46.39	40.30	44.64
9	40–4–240	3.8	4.1	4.0	3.0	3.7	57.26	64.62	59.64	58.75	60.06
10	40–6–240	8.0	7.0	6.0	8.0	7.2	68.70	66.40	68.50	65.10	67.17
11	50–2–240	2.0	7.8	2.5	4.3	4.1	38.92	43.20	38.48	33.79	38.59
12	50–4–240	5.0	7.0	5.0	6.0	6.0	51.70	57.60	56.30	49.20	53.70
13	20–2–220	1.0	1.3	1.4	1.8	1.3	55.83	53.13	53.60	54.54	54.27
14	20–4–220	2.5	0.8	1.5	2.5	1.8	71.67	71.33	68.41	78.17	72.39
15	20–6–220	1.0	2.3	1.0	2.3	1.6	92.32	88.00	85.35	99.16	91.23
16	20–8–220	6.8	3.8	4.1	4.0	4.7	114.15	107.62	108.82	117.10	111.92
17	30–2–220	1.3	1.0	1.0	1.5	1.2	44.80	44.96	45.61	45.22	45.15
18	30–4–220	2.5	2.5	2.5	2.5	2.5	64.50	60.99	61.89	64.16	62.88
19	30–6–220	3.0	3.5	2.4	4.8	3.4	80.39	76.48	75.97	82.84	78.89
20	30–8–220	6.0	7.0	6.0	6.0	6.2	100.12	93.20	94.04	100.40	96.94
21	40–2–220	1.4	1.3	1.1	1.1	1.2	38.14	41.41	40.40	36.68	39.16
22	40–4–220	5.0	4.8	4.0	4.3	4.5	55.22	51.83	53.50	54.70	53.81
23	40–6–220	7.0	7.5	7.5	9.0	7.7	73.78	67.41	70.80	70.40	70.60
24	50–2–220	0.1	2.5	0.9	1.9	1.3	30.96	33.16	32.19	31.86	32.04
25	50–4–220	2.3	3.0	3.0	4.7	3.2	48.88	46.68	48.27	46.44	47.56
26	50–6–220	9.0	9.0	7.0	12.0	9.2	65.55	57.93	62.23	61.68	61.85
27	60–4–220	6.0	6.0	5.0	8.0	6.2	44.00	41.33	43.65	44.00	43.24
28	60–6–220	13.0	11.0	9.0	13.0	11.5	56.40	52.36	55.95	58.09	55.70
29	20–2–200	1.0	1.6	1.0	1.3	1.2	48.09	46.36	47.65	47.39	47.25
30	20–4–200	1.9	2.0	1.7	1.7	1.8	58.90	59.38	62.49	63.42	61.05
31	20–6–200	1.0	1.3	1.0	1.9	1.3	79.96	75.94	80.82	80.54	79.31
32	20–8–200	2.2	4.0	2.3	4.1	3.2	101.98	95.05	96.66	106.73	100.10
33	30–2–200	2.0	1.5	1.5	1.8	1.7	36.87	37.76	39.05	37.85	37.88
34	30–4–200	1.0	1.8	1.8	2.0	1.6	50.84	52.09	53.02	50.81	51.69
35	30–6–200	1.8	2.1	1.1	3.2	2.0	71.34	65.90	67.00	71.37	68.90
36	30–8–200	7.0	8.0	5.0	9.0	7.2	89.10	83.88	85.60	92.74	87.83
37	40–2–200	1.1	1.0	1.0	1.4	1.1	31.82	33.95	32.82	31.08	32.42
38	40–4–200	4.5	3.1	1.9	3.9	3.3	49.25	47.98	47.27	45.19	47.42
39	40–6–200	3.9	5.5	2.5	6.0	4.5	60.22	62.65	58.86	68.17	62.47
40	40–8–200	10.0	10.0	7.0	11.0	9.5	78.40	73.19	75.40	79.22	76.55
41	50–2–200	1.0	1.0	1.4	1.7	1.3	28.59	28.57	28.23	25.89	27.82
42	50–4–200	3.1	4.3	3.3	5.0	3.9	37.73	39.81	41.61	37.55	39.18
43	50–6–200	9.0	6.0	7.0	9.0	7.7	59.92	55.80	57.13	55.34	57.05
44	60–4–200	4.0	5.0	5.0	6.0	5.0	37.20	35.73	37.69	36.09	36.68
45	60–6–200	10.5	8.5	9.0	12.0	10.0	45.12	43.47	48.54	48.95	46.52
46	20–2–180	0.8	0.5	1.3	1.5	1.0	37.73	39.80	41.83	40.93	40.42
47	20–4–180	1.5	1.5	1.5	1.5	1.5	54.82	53.42	57.91	55.78	55.48

TABLE 17.—*Pressures from indicator-cards*—Continued.

Designation of tests.		Indicator results—Pressure above atmosphere.									
		Least back.					Mean effective.				
Number.	Laboratory symbol.	Right side.		Left side.		Average.	Right side.		Left side.		Average.
		H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	96	97	98	99	100	101	102	103	104	105
48	20-6-180	0.2	0.7	0.3	1.1	0.6	70.12	67.37	71.15	72.84	70.65
49	20-8-180	0.5	1.5	1.7	2.0	1.4	85.94	83.18	86.40	91.57	86.77
50	20-10-180	2.0	3.0	2.0	4.0	2.7	102.74	96.75	100.26	115.47	103.81
51	30-2-180	1.4	0.9	1.2	1.3	1.2	31.70	33.91	33.29	33.17	33.01
52	30-4-180	1.5	1.5	1.5	1.5	1.5	43.25	45.28	49.70	41.65	44.97
53	30-6-180	1.6	3.0	2.9	2.7	2.5	53.81	54.70	59.64	53.62	55.44
54	30-8-180	2.2	3.8	2.5	3.9	3.1	74.95	75.64	75.76	82.81	77.29
55	30-10-180	6.0	6.0	6.0	9.0	6.7	91.80	86.77	86.72	101.61	91.72
56	40-2-180	1.5	0.6	1.8	1.9	1.4	21.74	31.90	28.46	27.48	27.39
57	40-4-180	1.0	1.3	2.2	2.1	1.6	38.78	40.43	43.98	39.65	40.71
58	40-6-180	2.2	4.1	2.6	4.6	3.4	53.54	55.74	56.01	59.28	56.14
59	40-8-180	7.1	6.0	6.2	6.9	6.5	63.93	62.77	63.33	66.61	64.16
60	40-10-180	10.0	11.0	10.0	12.0	10.7	79.30	76.33	76.87	87.67	80.04
61	50-2-180	0.8	1.6	1.9	1.5	1.4	20.37	23.59	24.51	22.13	22.65
62	50-4-180	1.8	2.4	2.9	2.9	2.5	31.40	35.52	35.81	36.69	34.85
63	50-6-180	6.3	4.6	4.8	6.8	5.6	42.81	46.51	45.93	49.16	46.11
64	50-8-180	8.0	8.0	8.0	11.0	8.7	57.66	54.35	58.09	63.73	58.46
65	60-4-180	4.0	3.0	4.0	6.0	4.2	29.97	28.27	31.56	34.13	30.98
66	60-6-180	6.0	7.0	7.0	8.0	7.0	40.42	38.22	44.06	46.28	42.24
67	20-4-160	1.0	1.0	1.4	1.9	1.3	47.73	43.22	45.95	48.82	46.43
68	20-6-160	1.2	2.6	1.3	1.1	1.5	63.88	58.62	61.76	67.55	62.95
69	20-8-160	2.1	3.0	2.4	4.1	2.9	72.34	68.89	73.76	76.74	72.92
70	20-10-160	2.0	1.0	1.0	3.0	1.7	93.93	88.08	90.01	105.69	94.43
71	30-4-160	1.0	1.0	1.5	1.2	1.2	38.78	36.03	38.07	40.69	38.39
72	30-6-160	2.0	2.0	2.0	2.0	2.0	54.22	50.84	52.80	58.47	54.08
73	30-8-160	1.6	2.9	1.9	3.5	2.5	63.24	64.19	64.90	69.78	65.58
74	30-10-160	3.0	5.0	3.0	4.0	3.7	78.04	77.33	77.21	85.29	79.47
75	30-12-160	6.0	5.0	6.0	9.0	6.5	90.75	85.97	86.98	97.84	90.38
76	40-4-160	1.2	2.7	1.3	2.1	1.8	32.61	32.85	31.85	36.66	33.49
77	40-6-160	2.0	2.9	2.5	3.3	2.7	44.53	43.84	44.03	50.20	45.65
78	40-8-160	3.5	4.4	3.7	6.6	4.5	53.45	56.76	56.65	61.44	57.02
79	40-10-160	7.0	7.0	6.0	10.0	7.5	69.89	67.83	69.43	79.56	71.68
80	50-4-160	1.1	2.7	2.1	3.0	2.2	28.37	26.77	27.94	31.25	28.58
81	50-6-160	3.3	4.3	2.8	5.5	3.9	39.11	39.83	37.55	44.28	40.19
82	50-8-160	6.0	6.0	6.0	8.0	6.5	51.08	48.02	51.72	56.80	51.91
83	60-4-160	2.0	1.5	2.0	3.0	2.1	24.40	22.72	25.99	28.72	25.46
84	60-6-160	5.0	4.0	4.0	6.0	4.7	34.58	34.12	36.93	40.43	36.51
85	20-4-120	1.1	1.1	2.1	1.1	1.4	29.20	26.72	28.75	28.80	28.36
86	20-8-120	1.0	1.2	1.2	1.2	1.1	54.62	49.40	52.46	57.87	53.59
87	20-12-120	2.0	2.0	2.0	2.1	2.0	75.21	71.73	76.41	79.44	75.69
88	30-4-120	0.5	0.5	0.5	0.5	0.5	23.48	23.87	24.13	24.89	24.09
89	30-8-120	1.0	1.2	1.0	1.6	1.2	45.73	43.87	46.03	47.65	45.82
90	30-14-120	4.0	4.5	5.7	5.9	5.0	72.51	69.80	71.30	76.65	72.56
91	40-4-120	1.0	1.4	1.5	1.0	1.2	18.94	19.03	19.50	20.23	19.42
92	40-8-120	1.8	3.1	1.8	3.6	2.6	40.00	38.42	40.35	45.49	40.94
93	40-12-120	5.7	11.0	6.4	7.6	7.7	58.23	55.07	57.25	63.10	58.41
94	50-4-120	1.0	2.9	1.1	2.0	1.7	14.34	15.40	14.47	16.97	15.29
95	50-8-120	7.7	3.8	3.5	5.5	5.1	35.19	33.79	35.42	40.22	36.13
96	50-11-120	7.2	7.5	7.2	8.5	7.6	45.24	43.70	45.04	51.17	46.26
97	60-8-120	4.0	4.0	5.0	7.0	5.0	30.69	27.15	31.42	35.90	31.29

TABLE 18.—*Engine performance.*

Designation of tests.		Engine performance.											
		Indicated horsepower.					Steam per I. H. P. per hour.		Coal per I. H. P. per hour.	B. t. u. supplied.			
		Right side.		Left side.						To engine per min.		Per I. H. P. per min.	
Number.	Laboratory symbol.	H. E.	C. E.	H. E.	C. E.	Total.	By tank.	By indicator.		Actual calculated from observed temperature of feed-water.	Comparative, assuming temperature of feed equal to temperature of exhaust.	Actual.	Comparative.
1	2	106	107	108	109	110	111	112	113	114	115	116	117
							Lbs.	*Lbs.*					
1	20–2–240	70.15	68.61	77.15	60.54	276.45	26.29	16.16	3.40	138,921	122,274	502.5	442.3
1a	20–2–240	65.96	60.06	74.73	61.90	262.65	....	....	....	.....	.....	....	....
2	20–4–240	101.49	95.21	100.24	95.58	392.52	25.33	17.21	3.30	191,716	167,135	488.4	425.8
3	20–6–240	120.41	112.44	116.19	117.78	466.82	24.09	18.34	....	219,097	189,296	469.3	405.5
3a	20–6–240	116.29	108.81	114.56	109.60	449.26	....	....	....	.....	.....	....	....
4	20–8–240	150.04	130.90	145.41	141.69	568.04	...	18.34	....	.....	.....	....	....
5	30–2–240	97.01	92.03	97.08	85.17	371.29	25.48	17.00	3.29	180,087	157,761	485.0	424.9
5a	30–2–240	90.43	88.37	100.65	83.50	362.95	....	....	....	.....	.....	....	....
6	30–4–240	116.33	117.63	122.73	113.94	470.64	24.43	17.34	....	223,182	191,739	474.2	407.4
7	30–6–240	136.78	131.54	139.46	132.52	540.30	....	17.83	....	.....	.....	....	....
8	40–2–240	107.09	107.99	112.12	94.58	421.78	24.16	16.55	3.33	194,858	171,200	461.9	405.9
9	40–4–240	136.17	147.73	144.38	138.02	566.30	23.86	17.42	....	262,459	225,387	463.4	398.0
10	40–6–240	173.74	163.01	176.25	162.62	675.62	....	18.02	....	.....	.....	....	....
11	50–2–240	118.14	127.26	118.80	101.30	465.50	24.97	16.95	3.07	222,095	194,579	476.9	418.0
12	50–4–240	153.88	166.51	170.47	144.66	635.52	....	15.75	....			....	....
13	20–2–220	66.06	61.02	64.51	63.74	255.33	27.65	16.72	3.24	135,552	118,958	538.0	465.9
14	20–4–220	85 45	82.36	82.97	92.07	342.85	25.80	16.89	3.18	170,233	149,825	496.0	437.0
15	20–6–220	109.82	101.55	103.51	116.56	431.44	25.51	17.54	3.62	209,864	185,337	486.0	429.6
16	20–8–220	137.70	124.81	132.28	138.23	533.02	25.86	19.30	3.89	262,684	229,784	492.0	431.1
17	30–2–220	79.95	77.86	82.80	79.71	320.32	26.60	16.00	3.41	164,475	143,471	513.0	447.9
18	30–4–220	115.18	105.71	112.43	113.17	446.49	24.23	16.95	3.29	206,173	182,123	484.4	407.9
19	30–6–220	143.48	132.66	137.11	146.24	559.49	23.59	17.53	3.34	253,655	220,495	451.6	394.1
20	30–8–220	185.96	168.46	177.68	183.19	715.28	....	19.55	....	.....	.....	....	....
21	40–2–220	91 01	95.91	98.07	86.46	371.46	25.58	16.43	3.27	184,120	159,989	495.6	430.7
22	40–4–220	131.37	119.67	129.48	128.55	509.07	23.68	16.21	3.15	231,158	200,828	454.0	394.5
23	40–6–220	176.71	156.63	172.48	166.43	672.65	....	18.14	....	.....	.....	....	....
24	50–2–220	92.09	95.63	97.39	93.68	378.79	26.29	16.42	3.45	192,609	167,577	508.0	442.4
25	50–4–220	145.17	134.66	146.02	136.44	562.30	24.08	16.71	3.57	259,960	226,494	462.3	402.8
26	50–6–220	195.11	167.47	188.43	181.35	732.36	....	18.39	....	.....	.....	....	....
27	60–4–220	157.31	150.16	151.50	155.22	614.19	....	17.84	....	.....	.....	....	....
28	60–6–220	201.64	181.50	203.29	204.95	791.38	....	18.89	....	.....	.....	....	....
29	20–2–200	57.06	53.38	57.50	55.53	223.47	28.32	17.14	3.47	120,669	105,925	541.0	474.0
30	20–4–200	69.79	68.29	75.31	74.23	287.62	26.24	16.92	3.51	144,015	126,697	501.0	440.5
31	20–6–200	95.27	87.81	97.95	94.79	375.82	26.01	18.85	....	189,134	164,083	503.0	436.6
32	20–8–200	121.16	109.63	116.84	125.27	472.90	26.31	19.13	3.52	237,035	207,744	502.0	439.3
33	30–2–200	65.87	65.43	70.91	66.73	268.95	27 01	16.86	3.48	139,024	122,184	517.0	454.3
34	30–4–200	90.80	90.30	96.34	89.65	367.09	25.70	18.36	....	181,466	157,371	494.0	428.7
35	30–6–200	127.40	114.22	121.70	125.89	489.21	24.91	17.59	3.40	235,366	207,621	489.0	424.4
36	30–8–200	162.21	148.21	158.54	166.78	635.73	....	19.35	....	.....	.....	....	....
37	40–2–200	75.73	78.30	79.48	73.07	306.58	26.88	16.94	3.35	159,350	124,196	520.0	450.1
38	40–4–200	117.24	110.87	114.49	106.28	448.88	24.66	17.17	3.28	209,841	184,708	470.0	412.6
39	40–6–200	148.01	154.64	142.42	160.18	605.25	24.43	17.35	3.47	281,077	246,458	464.0	407.2
40	40–8–200	187.76	170.06	183.70	187.41	728.93	....	19.63	....	.....	.....	....	....
41	50–2–200	85.14	82.46	85.40	76.05	329.05	25.74	16.27	3.23	162,653	142,281	494.0	432.4
42	50–4–200	112.43	115.37	126.11	110.51	464.20	25.78	16.98	3.27	228,162	199,838	491.0	430.5
43	50–6–200	178.35	161.31	173.00	162.70	675.36	....	18.08	....	.....	.....	....	....
44	60–4–200	132.99	123.85	136.93	127.33	521.10	....	18.45	....	.....	.....	....	....
45	60–6–200	161.17	150.69	176.37	172.70	[illegible]0.93	....	18.02	....	.....	.....	....	....
46	20–2–180	46.73	46.13	50.82	48.28	191.97	28.78	19.08	....	107,443	92,533	560.0	482.0
47	20–4–180	65.53	61.98	70.42	65.86	263.59	26.76	17.49	....	137,239	118,000	520.6	447.6

TABLE 18.—*Engine performance*—Continued.

Designation of tests.		Engine performance.											
		Indicated horsepower.					Steam per I. H. P. per hour.			B. t. u. supplied.			
		Right side.		Left side.						To engine per min.		Per I. H. P. per min.	
Number.	Laboratory symbol.	H. E.	C. E.	H. E.	C. E.	Total.	By tank.	By indicator.	Coal per I. H. P. per hour.	Actual calculated from observed temperature of feed-water.	Comparative assuming temperature of feed equal to temperature of exhaust.	Actual.	Comparative.
1	2	106	107	108	109	110	111	112	113	114	115	116	117
							Lbs.	*Lbs.*					
48	20–6–180	83.71	78.05	86.40	85.91	334.07	25.44	18.79	....	164, 617	142, 775	492.7	427.4
49	20–8–180	102.55	96.34	104.88	107.93	411.70	25.91	19.64	....	206, 793	178, 796	502.2	434.3
50	20–10–180	123.02	112.40	122.13	136.89	494.44	....	20.38	....	.....	.....	....	....
51	30–2–180	56.97	59.08	60.84	58.86	235.15	26.54	19.28	....	122, 021	104, 947	517.8	445.1
52	30–4–180	77.02	78.06	89.80	73.07	317.15	25.36	18.28	....	155, 986	135, 300	490.5	426.6
53	30–6–180	95.78	94.68	108.33	94.48	393.27	24.62	18.84	....	187, 092	161, 255	475.0	410.0
54	30–8–180	134.40	131.64	136.12	144.10	546.26	24.61	19.33	....	260, 293	223, 808	476.5	409.7
55	30–10–180	167.12	153.31	160.60	182.73	663.77	....	20.46	....	.....	.....	....	....
56	40–2–180	51.78	73.74	68.95	64.66	259.13	25.89	19.05	....	130, 004	112, 314	477.6	433.4
57	40–4–180	92.45	93.55	106.79	93.38	386.18	24.08	18.20	....	180, 963	155, 450	468.0	402.5
58	40–6–180	126.76	128.09	132.81	136.42	524.08	23.68	18.74	....	240, 941	206, 287	459.7	393.5
59	40–8–180	153.66	146.43	154.88	154.94	609.91	25.85	19.63	....	305, 058	260, 566	500.1	427.2
60	40–10–180	189.94	177.34	187.28	207.40	761.96	....	21.17	....	.....	.....	....	....
61	50–2–180	60.61	68.13	74.22	65.05	268.02	26.61	19.63	....	138, 777	119, 506	517.2	445.9
62	50–4–180	93.19	102.33	107.57	107.58	410.62	24.43	19.16	....	195, 685	167, 367	475.2	407.6
63	50–6–180	129.24	136.27	141.14	146.65	553.30	24.87	18.43	....	266, 663	227, 794	481.8	411.7
64	50–8–180	171.62	157.11	175.89	187.38	692.00	....	19.22	....	.....	.....	....	....
65	60–4–180	107.04	97.99	114.67	120.41	440.11	....	18.15	....	.....	.....	....	....
66	60–6–180	144.37	132.48	160.08	163.26	600.19	....	18.63	....	.....	.....	....	....
67	20–4–160	56.75	49.87	55.59	57.31	219.52	28.03	17.61	3.29	117, 708	103, 052	538.0	469.4
68	20–6–160	76.04	67.77	74.84	79.76	298.41	26.14	18.72	3.20	149, 343	130, 537	500.4	437.5
69	20–8–160	86.03	79.55	89.27	90.20	345.05	27.52	20.17	....	183, 020	158, 183	530.5	458.4
70	20–10–160	112.47	102.36	109.65	125.02	449.50	....	20.86	....	.....	.....	....	....
71	30–4–160	69.16	62.35	68.92	71.68	272.11	26.86	18.01	3.24	140, 050	122, 386	514.6	449.7
72	30–6–160	96.79	88.08	95.89	103.10	383.86	25.28	18.20	3.05	185, 718	164, 597	483.8	428.8
73	30–8–160	113.14	111.46	118.13	123.32	465.05	25.69	19.75	....	231, 593	195, 954	498.0	421.3
74	30–10–160	139.41	134.07	140.31	150.50	564.29	....	20.38	....	.....	.....	....	....
75	30–12–160	166.33	152.93	162.16	177.14	658.56	....	22.41	....	.....	.....	....	....
76	40–4–160	77.81	76.01	77.30	86.40	317.52	26.48	17.50	3.39	160, 550	142, 246	506.0	447.9
77	40–6–160	105.94	101.22	106.54	117.96	431.66	25.82	18.32	3.45	212, 645	185, 991	492.0	430.8
78	40–8–160	127.91	131.81	137.91	145.24	543.87	26.44	19.66	....	277, 611	236, 291	510.0	434.5
79	40–10–160	163.96	154.44	165.70	184.38	668.48	....	21.45	....	.....	.....	....	....
80	50–4–160	84.45	77.31	84.63	91.88	338.27	27.01	17.91	3.39	174, 730	152, 879	516.0	451.9
81	50–6–160	116.54	115.19	113.82	130.32	475.87	26.12	18.36	3.61	238, 441	205, 128	501.0	431.5
82	50–8–160	152.01	138.81	156.58	167.00	614.40	....	20.24	....	.....	.....	....	....
83	60–4–160	87.24	78.74	94.44	101.32	361.74	....	17.95	....	.....	.....	....	....
84	60–6–160	123.61	118.26	134.17	142.61	518.65	....	18.92	....	.....	.....	....	....
85	20–4–120	34.73	30.84	34.61	33.82	134.00	32.47	19.65	3.99	82, 864	72, 597	624.5	541.7
86	20–8–120	64.80	56.88	63.30	67.81	252.79	28.40	20.50	3.52	136, 930	119, 790	541.7	473.8
87	20–12–120	89.17	82.54	92.16	93.04	356.91	28.88	22.45	3.64	195, 008	171, 250	547.6	480.0
88	30–4–120	41.93	41.36	43.83	43.90	171.02	30.63	18.15	3.52	99, 672	87, 510	582.9	511.6
89	30–8–120	81.71	76.15	83.77	83.86	325.49	27.46	20.06	3.32	170, 178	148, 819	522.8	457.1
90	30–14–120	129.19	120.70	129.22	134.90	514.01	30.31	25.24	4.28	297, 524	256, 769	578.8	499.5
91	40–4–120	45.13	44.01	47.28	47.62	184.04	30.18	19.93	3.52	105, 712	92, 609	571.3	503.1
92	40–8–120	95.32	88.85	97.80	107.07	389.05	27.51	19.91	3.41	203, 898	177, 335	525.6	455.7
93	40–12–120	139.17	127.76	139.12	148.72	554.77	28.52	23.66	4.11	302, 109	258, 949	543.9	466.7
94	50–4–120	42.72	44.50	43.83	44.98	176.03	33.84	23.04	3.91	113, 320	99, 022	643.7	562.5
95	50–8–120	104.68	97.55	107.18	118.18	427.59	28.12	21.60	3.67	228, 676	197, 695	534.8	462.1
96	50–11–120	136.01	127.52	138.01	151.99	553.53	29.17	25.85	4.08	307, 342	264, 117	555.2	477.0
97	60–8–120	109.62	94.12	114.16	126.67	444.57	....	22.22	....	.....	.....	....	....

TABLE 19.—*Steam shown by indicator.*

Designation of tests.		Engine performance.									
		Pounds steam at cut-off by indicator.					Pounds steam at release by indicator.				
Number.	Laboratory symbol.	Right side.		Left side.		Total.	Right side.		Left side.		Total.
		H. E.	C. E.	H. E.	C. E.		H. E.	C E.	H. E.	C. E.	
1	2	118	119	120	121	122	123	124	125	126	127
1	20-2-240	0.2538	0.2355	0.2662	0.2091	0.9646	0.2957	0.2756	0.2743	0.2407	1.0863
1a	20-2-240	....	....	....	....	....	....	....	....	....	....
2	20-4-240	.3271	.3093	.3300	0.2992	1.2656	.3589	.3438	.3609	.3434	1.4070
3	20-6-240	.4044	.3624	.3746	0.3897	1.5311	.4502	.4110	.4149	.4398	1.7159
3a	20-6-240	....	....	....	....	....	....	....	....	....	....
4	20-8-240	.5051	.4396	.4861	0.4851	1.9159	.5166	.4746	.5077	.5141	2.0130
5	30-2-240	.2496	.2389	.2511	0.2511	0.9907	.2617	.2653	.2730	.2801	1.0801
5a	30-2-240	.3451	....	....	....	....	....	....	....	....	....
6	30-4-240	.2864	.2744	.2943	0.2692	1.1243	.3089	.3118	.3266	.3098	1.2571
7	30-6-240	.3451	.3270	.3444	0.3373	1.3538	.3675	.3637	.3794	.3684	1.4790
8	40-2-240	.2203	.2204	.2248	0.1938	0.8593	.2423	.2404	.2497	.2287	0.9609
9	40-4-240	.2614	.2751	.2789	0.2619	1.0773	.2896	.3107	.3024	.2948	1.1975
10	40-6-240	.3228	.2984	.3117	0.3098	1.2427	.3409	.3396	.3400	.3313	1.3518
11	50-2-240	.2115	.2150	.2117	0.1867	0.8249	.2258	.2416	.2341	.2124	0.9139
12	50-4-240	.2594	.2411	.2826	0.2411	1.0242	.2772	.2581	.2956	.2327	1.0636
13	20-2-220	.2409	.2189	.2354	0.2179	0.9131	.2673	.2506	.2624	.2531	1.0334
14	20-4-220	.2881	.2785	.2794	0.3033	1.1493	.3182	.3083	.3077	.3312	1.2654
15	20-6-220	.3800	.3420	.3484	0.3961	1.4665	.3957	.3764	.3688	.4125	1.5534
16	20-8-220	.4893	.4096	.4675	1.4987	1.8651	.5454	.4549	.4836	.5031	1.9870
17	30-2-220	.2111	.2051	.2175	0.2077	0.8414	.2353	.2292	.2345	.2315	0.9305
18	30-4-220	.3007	.2639	.2797	0.2729	1.1172	.3027	.2796	.2971	.2919	1.1713
19	30-6-220	.3386	.3182	.3281	0.3511	1.3367	.3582	.3458	.3510	.3617	1.4167
20	30-8-220	.4538	.4054	.4267	0.4605	1.7464	.4680	.4331	.4375	.4625	1.8011
21	40-2-220	.2020	.2070	.2074	0.1848	0.8012	.2219	.2187	.2337	.2038	0.8781
22	40-4-220	.2612	.2506	.2514	0.2501	1.0134	.2838	.2597	.2744	.2694	1.0874
23	40-6-220	.3379	.3053	.3295	0.3214	1.2941	.3538	.3298	.3411	.3427	1.3674
24	50-2-220	.1915	.1886	.1909	0.1760	0.7470	.1906	.2049	.2052	.1944	0.7951
25	50-4-220	.2417	.2406	.2438	0.2405	0.9666	.2594	.2490	.2594	.2562	1.0231
26	50-6-220	.3205	.2621	.3046	0.3373	1.2245	.3358	.3041	.3224	.3175	1.2798
27	60-4-220	.2397	.2162	.2424	0.2310	0.9293	.2574	.2383	.2536	.2625	1.0118
28	60-6-220	.3132	.2760	.3078	0.3092	1.2062	.3305	.2899	.3213	.3321	1.2738
29	20-2-200	.2136	.2022	.2136	0.1984	0.8278	.2420	.2340	.2403	.2307	0.9470
30	20-4-200	.2455	.2466	.2660	0.2572	1.0153	.2768	.2712	.2854	.2712	1.1046
31	20-6-200	.3512	.3107	.3409	0.3299	1.3327	.3634	.3371	.3752	.3672	1.4429
32	20-8-200	.4450	.3909	.4171	0.4572	1.7102	.4582	.4162	.4309	.4644	1.7700
33	30-2-200	.1890	.1905	.2013	0.1809	0.7617	.2092	.2090	.2182	.2037	0.8401
34	30-4-200	.2442	.2279	.2433	0.2198	0.9352	.2602	.2617	.2719	.2617	1.0555
35	30-6-200	.3098	.2828	.2975	0.3138	1.2039	.3225	.3016	.3126	.3254	1.2621
36	30-8-200	.4115	.3710	.3921	0.4282	1.6028	.4242	.3929	.3915	.4486	1.6572
37	40-2-200	.1871	.1835	.1794	0.1708	0.7208	.2016	.2004	.1997	.1929	0.7946
38	40-4-200	.2343	.2270	.2290	0.2192	0.9095	.2609	.2415	.2405	.2452	0.9881
39	40-6-200	.2903	.2931	.2750	0.3142	1.1726	.2993	.3052	.2912	.3243	1.2200
40	40-8-200	.3862	.3508	.3679	0.3880	1.4947	.3951	.3739	.3716	.4067	1.5473
41	50-2-200	.1778	.1709	.1773	0.1616	0.6876	.1899	.1793	.1982	.1794	0.7467
42	50-4-200	.2072	.2093	.2108	0.2038	0.8311	.2181	.2239	.2369	.2146	0.8935
43	50-6-200	.2989	.2654	.2829	0.2803	1.1275	.3108	.2772	.2918	.2978	1.1776
44	60-4-200	.2152	.1977	.2188	0.2070	0.8387	.2311	.2149	.2319	.2285	0.9064
45	60-6-200	.2617	.2338	.2412	0.2709	1.0076	.2849	.2335	.2892	.2562	1.0638
46	20-2-180	.2024	.1860	.1991	0.1794	0.7669	.2328	.2180	.2333	.2285	0.9126
47	20-4-180	.2361	.2128	.2384	0.2266	0.9139	.2587	.2512	.2677	.2584	1.0360

TABLE 19.—*Steam shown by indicator*—Continued.

Designation of tests.		Engine performance.									
		Pounds steam at cut-off by indicator.					Pounds steam at release by indicator.				
		Right side.		Left side.		Total.	Right side.		Left side.		Total.
Number	Laboratory symbol.	H. E.	C. E.	H. E.	C. E.		H. E.	C. E.	H. E.	C. E.	
1	2	118	119	120	121	122	123	124	125	126	127
48	20-6-180	0.3116	0.2812	0.3059	0.3027	1.2014	0.3247	0.3065	0.3325	0.3437	1.3074
49	20-8-180	.3805	.3417	.3788	.3862	1.4872	.3954	.3664	.3998	.4234	1.5850
50	20-10-180	.4724	.4211	.4558	.5305	1.8798	.4751	.4323	.4647	.5360	1.9081
51	30-2-180	.1884	.1722	.1857	.1637	0.7106	.2037	.1910	.2074	.2023	0.8044
52	30-4-180	.2205	.2075	.2369	.1989	0.8638	.2339	.2261	.2685	.2348	0.9643
53	30-6-180	.2588	.2431	.2774	.2440	1.0233	.2732	.2602	.3006	.2684	1.1024
54	30-8-180	.3441	.3360	.3414	.3600	1.3815	.3555	.3520	.3594	.3748	1.4417
55	30-10-180	.4342	.3972	.4142	.4970	1.7426	.4436	.4129	.4146	.4994	1.7709
56	40-2-180	.1676	.1696	.1801	.1521	0.6694	.1782	.1815	.1998	.1841	0.7435
57	40-4-180	.2115	.2012	.2234	.1972	0.8333	.2221	.2163	.2438	.2264	0.9086
58	40-6-180	.2651	.2425	.2732	.2696	1.0510	.2747	.2794	.2892	.2976	1.1360
59	40-8-180	.3219	.2992	.2973	.3272	1.2456	.3326	.2979	.3384	.3470	1.3159
60	40-10-180	.4035	.3837	.3959	.4549	1.6380	.4035	.3960	.4138	.4607	1.6743
61	50-2-180	.1620	.1531	.1712	.1472	0.6335	.1690	.1694	.1853	.1766	0.7004
62	50-4-180	.1968	.1877	.2092	.1917	0.7854	.2066	.2000	.2269	.2159	0.8494
63	50-6-180	.2424	.2353	.2455	.2486	0.9718	.2552	.2444	.2588	.2660	1.0244
64	50-8-180	.3077	.2776	.3111	.3280	1.2244	.3110	.2825	.3120	.3359	1.2415
65	60-4-180	.1893	.1713	.1924	.1885	0.7415	.2088	.1790	.2080	.2139	0.8104
66	60-6-180	.2356	.2140	.2769	.2449	0.9714	.2498	.2290	.2505	.2671	0.9966
67	20-4-160	.2204	.1975	.2147	.2133	0.8459	.2411	.2247	.2121	.2439	0.9218
68	20-6-160	.2809	.2549	.2756	.2880	1.0994	.2975	.2885	.2971	.3067	1.1898
69	20-8-160	.3280	.2996	.3334	.3362	1.2972	.3511	.3170	.3586	.3705	1.3972
70	20-10-160	.4339	.3804	.4131	.4746	1.7020	.4438	.3997	.4303	.4967	1.7705
71	30-4-160	.1951	.1840	.1966	.1968	0.7725	.2129	.1987	.2214	.2149	0.8479
72	30-6-160	.2519	.2328	.2442	.2618	0.9907	.2661	.2529	.2606	.2764	1.0560
73	30-8-160	.3054	.2884	.3073	.3110	1.2131	.3137	.3072	.3237	.3480	1.2926
74	30-10-160	.3736	.3600	.3710	.4055	1.5101	.3736	.3724	.3871	.4139	1.5470
75	30-12-160	.4598	.4100	.4379	.5096	1.8173	.4574	.4314	.4547	.5160	1.8595
76	40-4-160	.1872	.1836	.1741	.1890	0.7339	.1932	.1966	.1903	.2053	0.7854
77	40-6-160	.2292	.2255	.2228	.2512	0.9287	.2390	.2357	.2401	.2628	0.9776
78	40-8-160	.2805	.2750	.2856	.2994	1.1405	.2870	.2928	.3027	.3186	1.2011
79	40-10-160	.3606	.3354	.3557	.4023	1.4540	.3661	.3520	.3761	.4154	1.5096
80	50-4-160	.1695	.1662	.1752	.1817	0.6926	.1827	.1793	.1912	.1954	0.7498
81	50-6-160	.2169	.2169	.2084	.2336	0.8758	.2260	.2197	.2208	.2433	0.9098
82	50-8-160	.2814	.2529	.2763	.2927	1.1033	.2897	.2622	.2852	.3069	1.1440
83	60-4-160	.1684	.1541	.1684	.1672	0.6581	.1811	.1625	.1773	.1871	0.7080
84	60-6-160	.2158	.1875	.2169	.2237	0.8439	.2181	.2024	.2264	.2368	0.8837
85	20-4-120	.1630	.1471	.1607	.1519	0.6227	.1816	.1650	.1813	.1792	0.7071
86	20-8-120	.2727	.2293	.2432	.2712	1.0164	.2717	.2480	.2791	.2867	1.0855
87	20-12-120	.3903	.3425	.3756	.4098	1.5182	.3860	.3535	.3846	.4164	1.5405
88	30-4-120	.1456	.1412	.1480	.1452	0.5800	.1675	.1597	.1613	.1367	0.6252
89	30-8-120	.2343	.2146	.2283	.2474	0.9246	.2381	.2302	.2424	.2551	0.9658
90	30-14-120	.4127	.3744	.4048	.4386	1.6305	.4153	.3869	.4187	.4435	1.6644
91	40-4-120	.1379	.1349	.1402	.1332	0.5462	.1523	.1481	.1570	.1601	0.6175
92	40-8-120	.2205	.2078	.2158	.2380	0.8821	.2225	.2163	.2259	.2399	0.9045
93	40-12-120	.3269	.3186	.3213	.3581	1.3249	.3296	.3313	.3330	.3664	1.3603
94	50-4-120	.1343	.1331	.1207	.1331	0.5213	.1412	.1552	.1454	.1464	0.5882
95	50-8-120	.2272	.2042	.2112	.2337	0.8763	.2459	.2053	.2236	.2393	0.9144
96	50-11-120	.2818	.2509	.2756	.3086	1.1170	.2902	.2707	.2870	.3146	1.1625
97	60-8-120	.1988	.1752	.2045	.2062	0.7847	.2053	.1872	.2161	.2318	0.8404

TABLE 20.—*Cylinder performance.*

Designation of tests.		Engine performance.										
Number.	Laboratory symbol.	Pounds steam at compression by indicator. Right side. H. E.	Right side. C. E.	Left side. H. E.	Left side. C. E.	Total.	Weight of steam per revolution, by tank.	Weight of mixture in cylinder per revolution.	Per cent of mixture present as steam at cut-off.	Per cent of mixture present as steam at release.	Reevaporation per revolution.	Reevaporation per I. H. P. per hour.
1	2	128	129	130	131	132	133	134	135	136	137	138
							Lbs.	*Lbs.*			*Lbs.*	*Lbs.*
1	20–2–240	0.0771	0.0708	0.0785	0.0719	0.2982	1.2819	1.5801	61.0	68.7	0.1217	2.4958
1a	20–2–240	....	....	....	....	....	....	....	....	....	....	....
2	20–4–240	.0667	.0621	.0666	.0629	.2583	1.6940	1.9523	64.7	72.1	.1414	2.1122
3	20–6–240	.0638	.0597	.0596	.0634	.2465	1.9300	2.1765	70.3	79.0	.1848	2.3000
3a	20–6–240	....	....	....	....	....	....	....	....	....	....	....
4	20–8–240	.0563	.0571	.0508	.0587	.2229	....	....	....	....	.0972	0.9957
5	30–2–240	.0868	.0838	.0869	.1026	.3601	1.0790	1.4391	68.7	75.0	.0894	2.1110
5a	30–2–240	....	....	....	....	....	....	....	....	....	....	....
6	30–4–240	.0818	.0803	.0818	.0818	.3257	1.3120	1.6377	68.6	76.7	.1328	2.4700
7	30–6–240	.0677	.0709	.0702	.0698	.2786	....	....	....	....	.1252	1.8619
8	40–2–240	.0934	.0894	.0922	.0875	.3625	0.8735	1.2360	69.5	77.7	.1016	2.8105
9	40–4–240	.0886	.0850	.0891	.0905	.3532	1.1565	1.5097	71.4	79.3	.1212	2.4700
10	40–6–240	.0978	.0973	.0919	.0846	.3716	....	....	....	....	.1091	2.0055
11	50–2–240	.0936	.0984	.0995	.0929	.3844	0.7801	1.1645	70.7	78.4	.0890	2.8490
12	50–4–240	.1050	.0876	.0941	.0920	.3787	....	....	....	....	.0394	0.9062
13	20–2–220	.0758	.0745	.0763	.0721	.2987	1.3028	1.6015	56.9	64.5	.1203	2.7382
14	20–4–220	.0714	.0700	.0671	.0685	.2770	1.5110	1.7880	64.3	70.8	.1161	1.9911
15	20–6–220	.0651	.0679	.0603	.0613	.2546	1.8839	2.1385	68.6	72.8	.0869	1.1769
16	20–8–220	.0646	.0568	.0564	.0558	.2336	2.3496	2.5832	72.2	76.9	.1219	1.3419
17	30–2–220	.0861	.0808	.0822	.0965	.3456	0.9726	1.3182	63.8	70.6	.0891	2.7350
18	30–4–220	.0775	.0772	.0773	.0761	.3081	1.2225	1.5306	72.9	76.5	.0541	1.0624
19	30–6–220	.0742	.0784	.0730	.0729	.2985	1.5033	1.8168	73.8	78.2	.0800	1.2549
20	30–8–220	.0750	.0593	.0648	.0690	.2681	....	....	....	....	.0547	0.6974
21	40–2–220	.0934	.0857	.0942	.0837	.3570	0.8110	1.1680	71.7	75.2	.0769	2.4257
22	40–4–220	.0907	.0792	.0982	.1129	.3809	1.0320	1.4131	71.7	77.0	.0740	1.6990
23	40–6–220	.0869	.0797	.0801	.0832	.3299	....	....	....	....	.0733	1.2815
24	50–2–220	.0923	.0935	.0947	.0887	.3692	0.6819	1.0511	71.0	75.7	.0481	1.8545
25	50–4–220	.0924	.0913	.1040	.0919	.3796	0.9270	1.3066	74.0	78.3	.0564	1.4663
26	50–6–220	.0975	.0917	.0858	.0831	.3581	....	....	....	....	.0553	1.1035
27	60–4–220	.1012	.0991	.0917	.0949	.3869	....	....	....	....	.0825	2.3548
28	60–6–220	.1143	.1021	.1017	.1033	.4214	....	....	....	....	.0676	1.4974
29	20–2–200	.0748	.0728	.0752	.0685	.2913	1.0865	1.3778	60.0	68.7	.1192	3.1160
30	20–4–200	.0692	.0704	.0657	.0636	.2689	1.2979	1.5668	64.7	70.5	.0893	1.8065
31	20–6–200	.0592	.0597	.0544	.0590	.2323	1.6730	1.9073	69.8	75.5	.1102	1.7130
32	20–8–200	.0597	.0594	.0529	.0540	.2260	2.1325	2.3585	72.7	75.2	.0598	0.7378
33	30–2–200	.0832	.0810	.0831	.0755	.3228	0.8288	1.1516	66.1	72.9	.0784	2.5524
34	30–4–200	.0745	.0715	.0710	.0705	.2875	1.0756	1.3631	68.7	77.5	.1203	2.8700
35	30–6–200	.0716	.0682	.0702	.0706	.2806	1.3896	1.6702	72.1	75.5	.0582	1.0432
36	30–8–200	.0744	.0730	.0602	.0737	.2813	....	....	....	....	.0544	0.7650
37	40–2–200	.0922	.0845	.0877	.0857	.3501	0.7053	1.0554	68.3	75.2	.0738	2.8136
38	40–4–200	.0856	.0805	.0822	.0803	.3286	0.9471	1.2757	72.0	78.2	.0786	2.0468
39	40–6–200	.0841	.0828	.0754	.0779	.3202	1.2658	1.5860	74.0	76.9	.0474	0.9147
40	40–8–200	.0868	.0798	.0780	.0864	.3310	....	....	....	....	.0526	0.8500
41	50–2–200	.0906	.0854	.0939	.0913	.3612	0.5800	0.9412	73.0	79.3	.0591	2.6440
42	50–4–200	.0939	.0858	.0893	.0853	.3543	0.8183	1.1726	70.8	76.2	.0624	1.9606
43	50–6–200	.0930	.0811	.0800	.0881	.3422	....	....	....	....	.0501	1.0842
44	60–4–200	.0925	.0887	.0916	.0853	.3581	....	....	....	....	.0677	2.2773
45	60–6–200	.1092	.0904	.0949	.0902	.3847	....	....	....	....	.0562	1.4912
46	20–2–180	.0721	.0659	.0711	.0680	.2771	0.9472	1.2243	62.7	75.3	.1457	4.4555
47	20–4–180	.0634	.0579	.0639	.0636	.2506	1.2016	1.4522	62.9	71.3	.1221	2.7116

TABLE 20.—*Cylinder performance*—Continued.

Designation of tests.		Engine performance.										
		Pounds steam at compression by indicator.										
		Right side.		Left side.								
Number.	Laboratory symbol.	H. E.	C. E.	H. E.	C. E.	Total.	Weight of steam per revolution, by tank.	Weight of mixture in cylinder per revolution.	Per cent of mixture present as steam at cut-off.	Per cent of mixture present as steam at release.	Reevaporation per revolution.	Reevaporation per I.H.P. per hour.
1	2	128	129	130	131	132	133	134	135	136	137	138
							Lbs.	*Lbs.*			*Lbs.*	*Lbs.*
48	20–6–180	0.0598	0.0552	0.0595	0.0586	0.2331	1.4510	1.6841	71.4	77.6	0.1060	1.8601
49	20–8–180	.0538	.0482	.0500	.0521	.2041	1.8234	2.0275	73.3	78.2	.0978	1.3910
50	20–10–180	.0466	.0503	.0486	.0489	.1944	....	....	....	....	.0283	0.3365
51	30–2–180	.0745	.0683	.0746	.0726	.2900	0.7105	1.0005	71.0	80.4	.0944	3.5300
52	30–4–180	.0800	.0651	.0839	.0687	.2997	0.9275	1.2272	70.4	78.6	.1005	2.7615
53	30–6–180	.0700	.0563	0649	.0645	.2557	1.1050	1.3607	75.2	81.0	.0791	1.7630
54	30–8–180	.0619	.0625	.0586	.0581	.2411	1.5480	1.7891	77.2	80.6	.0602	0.9720
55	30–10–180	.0621	.0628	.0602	.0662	.2513	....	....	....	....	.0279	0.3758
56	40–2–180	.0874	.0714	.0844	.0782	.3214	0.5737	0.8951	74.8	83.1	.0742	3.3500
57	40–4–180	.0806	.0719	.0794	.0754	.3077	0.7940	1.1017	75.6	82.4	.0753	2.2822
58	40–6–180	.0749	.0687	.0763	.0718	.2917	1.0673	1.3590	77.3	83.6	.0859	1.9030
59	40–8–180	.0789	.0720	.0727	.0771	.3007	1.3354	1.6361	76.1	80.4	.0703	1.3611
60	40–10–180	.0747	.0732	.0751	.0796	.3026	....	....	....	....	.0360	0.5556
61	50–2–180	.0869	.0809	.0892	.0832	.3402	0.4880	0.8282	76.4	83.5	.0668	3.6400
62	50–4–180	.0861	.0776	.0853	.0802	.3293	0.6885	1.0177	77.2	83.4	.0640	2.2706
63	50–6–180	.0880	.0789	.0849	.0841	.3359	0.9280	1.2639	76.9	81.0	.0526	1.4090
64	50–8–180	.0902	.0770	.0864	.0780	.3316	....	....	....	....	.0170	0.3592
65	60–4–180	.1022	.0854	.0835	.0839	.3550	....	....	....	....	.0690	2.7495
66	66–6–180	.0996	.0915	.0859	.0817	.3587	....	....	....	....	.0250	0.7302
67	20–4–160	.0654	.0661	.0655	.0629	.2599	1.0536	1.3135	64.4	70.2	.0759	2.0100
68	20–6–160	.0587	.0647	0561	.0555	.2351	1.3245	1.5595	70.5	76.3	.0903	1.7701
69	20–8–160	.0508	.0478	.0492	.0510	.1988	1.6229	1.8217	71.2	76.7	.1000	1.6930
70	20–10–160	.0455	.0437	.0431	.0433	.1756	....	....	....	....	.0685	0.8960
71	30–4–160	.0717	.0701	.0743	.0709	.2870	0.8323	1.1192	68.9	75.7	.0764	3.2400
72	30–6–160	.0670	.0678	.0632	.0622	.2602	1.0071	1.3713	72.7	77.0	.0653	1.4913
73	30–8–160	.0635	.0613	.0611	.0612	.2471	1.3594	1.6065	75.6	80.0	.0805	1.5204
74	30–10–160	.0638	.0586	.0564	.0575	.2363	....	....	....	....	.0369	0.5737
75	30–12–160	.0555	.0544	.0549	.0550	.2198	....	....	....	....	.0422	0.5767
76	40–4–160	.0780	.0806	.0738	.0789	.3113	0.7176	1.0289	71.3	76.4	.0515	1.9013
77	40–6–160	.0785	.0772	.0697	.0738	.3002	0.9541	1.2543	74.0	77.9	.0489	1.3153
78	40–8–160	.0758	.0705	.0692	.0755	.2910	1.2237	1.5147	75.3	79.3	.0606	1.3094
79	40–10–160	.0636	.0717	.0635	.0663	.2651	....	....	....	..	.0556	0.9580
80	50–4–160	.0801	.0845	.0843	.0861	.3351	0.6251	0.9602	72.1	78.1	.0572	2.442
81	50–6–160	.0796	.0793	.0753	.0778	.3120	0.8497	1.1617	75.3	78.2	.0340	1.0453
82	50–8–160	.0851	.0708	.0709	.0628	.2896	....	....	....	....	.0407	0.9643
83	60–4–160	.0978	.0787	.0850	.0762	.3377	....	....	....	....	.0499	2.4181
84	60–6–160	.0901	.0758	.0795	.0788	.3242	....	....	....	....	.0398	1.3458
85	20–4–120	.0608	.0649	.0659	.0638	.2552	0.7450	1.0004	62.2	70.7	.0844	3.6830
86	20–8–120	.0491	.0498	.0483	.0475	.1947	1.232	1.4267	71.1	76.1	.0691	1.6120
87	20–12–120	.0462	.0403	.0378	.0390	.1633	1.7710	1.9343	78.6	79.8	.0223	0.3637
88	30–4–120	.0725	.0688	.0627	.0671	.2711	0.5973	0.8684	66.8	72.0	.0452	2.3178
89	30–8–120	.0567	.0559	.0539	.0559	.2224	1.0720	1.2944	71.4	74.6	.0412	1.1122
90	30–14–120	.0458	.0452	.0450	.0453	.1813	1.7813	1.9626	83.1	84.7	.0339	0.5771
91	40–4–120	.0741	.0772	.0765	.0744	.3023	0.4747	0.7770	70.5	79.5	.0713	4.5000
92	40–8–120	.0638	.0641	.0576	.0588	.2443	0.9145	1.1588	76.1	78.0	.0224	0.6771
93	40–12–120	.0598	.0698	.0545	.0560	.2401	1.3503	1.5904	83.2	85.5	.0354	0.7475
94	50–4–120	.0801	.0835	.0707	.0765	.3108	0.4074	0.7182	72.5	80.5	.0669	5.5500
95	50–8–120	.0774	.0698	.0660	.0689	.2821	0.8232	1.1053	79.2	82.7	.0382	1.3160
96	50–11–120	.0658	.0624	.0602	.0648	.1932	1.0936	1.2867	86.8	90.3	.0455	1.2137
97	60–8–120	.0762	.0692	.0644	.0672	.2770	....	....	....	....	.0557	2.1974

TABLE 21.—*Performance of the locomotive as a whole.*

Designation of tests.		Locomotive performance.						
Number.	Laboratory symbol.	Draw-bar pull.	Dynamometer horse-power.	Machine friction. M. E. P.	Machine friction. Per cent I. H. P.	Machine friction. Horse-power.	Steam per D. H. P. per hour.	Coal per D. H. P. per hour.
1	2	139	140	141	142	143	144	145
		Lbs.		*Lbs.*			*Lbs.*	*Lbs.*
1	20–2–240	4690	242.41	7.41	12.31	34.04	29.99	3.87
1a	20–2–240	....	....	....	....	....	....	....
2	20–4–240	6690	357.59	7.36	8.90	34.93	27.77	3.63
3	20–6–240	7626	405.02	13.16	13.30	62.08	27.77	5.01
3a	20–6–240	....	....	....	....	....	....	....
4	20–8–240	....	....	....	....	....	....	....
5	30–2–240	4554	364.04	1.02	1.95	7.25	25.99	3.35
5a	30–2–240	....	....	....	....	....	....	....
6	30–4–240	4897	391.08	11.21	16.90	79.56	29.39	4.68
7	30–6–240	....	....	....	....	....	....	....
8	40–2–240	3370	358.46	6.70	15.00	63.32	28.42	3.92
9	40–4–240	4259	453.45	12.06	19.90	112.80	29.80	4.81
10	40–6–240	....	....	....	....	....	....	....
11	50–2–240	2979	404.73	6.02	13.00	60.77	28.73	3.61
12	50–4–240	....	....	....	....	....	....	....
13	20–2–220	4431	234.73	4.37	8.06	20.60	30.16	3.55
14	20–4–220	Engine on blocking.						
15	20–6–220	Engine on blocking.						
16	20–8–220	9190	491.63	8.68	7.76	41.39	28.04	4.23
17	30–2–220	3360	268.42	7.31	16.20	51.90	31.75	4.08
18	30–4–220	4764	380.86	9.38	14.92	65.63	28.14	3.86
19	30–6–220	6239	499.14	8.50	10.78	60.35	26.43	3.74
20	30–8–220	....	....	....	....	....	....	....
21	40–2–220	2927	312.97	6.14	15.70	58.49	30.37	3.88
22	40–4–220	3963	406.20	10.87	20.20	102.87	29.68	3.95
23	40–6–220	....	....	....	....	....	....	....
24	50–2–220	2255	300.24	6.71	20.70	78.55	23.18	4.35
25	50–4–220	3617	481.62	6.81	14.34	80.67	28.07	4.17
26	50–6–220	....	....	....	....	....	....	....
27	60–4–220	....	....	....	....	....	....	....
28	60–6–220	....	....	....	....	....	....	....
29	20–2–200	3571	189.64	7.18	15.20	33.83	33.38	4.08
30	20–4–200	4943	262.21	5.37	8.80	25.41	28.79	3.85
31	20–6–200	6309	337.07	7.95	10.30	38.75	29.01	4.38
32	20–8–200	8375	445.50	5.86	5.80	27.40	27.93	3.73
33	30–2–200	2965	237.41	4.43	11.70	31.54	30.66	3.94
34	30–4–200	3847	307.40	8.37	16.20	59.69	30.69	4.39
35	30–6–200	5380	430.09	8.33	12.09	59.12	28.33	3.87
36	30–8–200	....	....	....	....	....	....	....
37	40–2–200	2257	240.46	6.97	21.50	66.12	34.27	4.28
38	40–4–200	3622	386.13	6.59	13.90	62.75	28.68	3.82
39	40–6–200	....	....	....	....	....	....	....
40	40–8–200	....	....	....	....	....	....	....
41	50–2–200	1799	239.49	7.56	27.20	89.56	35.73	4.44
42	50–4–200	3434	458.02	5.60	1.43	6.40	26.14	3.45
43	50–6–200	....	....	....	....	....	....	....
44	60–4–200	....	....	....	....	....	....	....
45	60–6–200	....	....	....	....	....	....	....
46	20–2–180	2814	150.47	8.74	21.61	41.49	36.71	4.86
47	20–4–180	4195	224.50	8.22	14.83	39.09	31.42	4.26

TABLE 21.—*Performance of the locomotive as a whole*—Continued.

Designation of tests.		Locomotive performance.						
Number.	Laboratory symbol.	Draw-bar pull.	Dynamometer horse-power.	Machine friction.			Steam per D. H. P. per hour.	Coal per D. H. P. per hour.
				M. E. P.	Per cent I. H. P.	Horse-power.		
1	2	139	140	141	142	143	144	145
		Lbs.		*Lbs.*			*Lbs.*	*Lbs.*
48	20–6–180	5377	287.33	9.89	13.99	46.74	29.58	4.17
49	20–8–180	6900	268.60	9.08	10.47	43.10	28.94	4.36
50	20–10–180	....	....	....	....	....	....	....
51	30–2–180	2179	174.92	8.48	25.70	60.83	35.77	4.24
52	30–4–180	3283	261.05	8.05	17.90	56.95	31.00	4.45
53	30–6–180	4188	334.48	8.26	14.90	58.79	28.95	5.00
54	30–8–180	5856	470.15	10.74	13.90	76.11	28.60	5.33
55	30–10–180	....	....	....	....	....	....	....
56	40–2–180	1726	181.57	8.20	29.93	77.56	36.90	4.34
57	40–4–180	2890	308.54	8.18	20.09	77.61	30.15	3.73
58	40–6–180	4039	427.88	10.31	18.36	96.20	28.98	4.94
59	40–8–180	5142	553.30	5.95	9.28	56.61	28.50	5.22
60	40–10–180	....	....	....	....	....	....	....
61	50–2–180	1305	173.80	7.96	35.13	94.18	40.47	4.82
62	50–4–180	2249	298.89	9.48	27.21	111.77	33.56	4.27
63	50–6–180	3355	453.44	8.35	18.11	99.96	30.36	4.57
64	50–8–180	....	....	....	....	....	....	....
65	60–4–180	....	....	....	....	....	....	....
66	60–6–180	....	....	....	....	....	....	....
67	20–4–160	3281	174.69	9.48	20.42	44.83	35.25	4.14
68	20–6–160	4731	252.20	9.76	15.50	46.22	30.94	3.79
69	20–8–160	5939	316.42	6.07	8.32	28.65	30.01	4.36
70	20–10–160	....	....	....	....	....	....	....
71	30–4–160	2655	211.90	8.49	22.11	60.18	34.50	4.15
72	30–6–160	3786	302.50	11.45	21.18	81.30	32.08	3.87
73	30–8–160	5130	410.86	7.61	11.62	54.19	29.07	....
74	30–10–160	....	....	....	....	....	....	....
75	30–12–160	....	....	....	....	....	....	....
76	40–4–160	Engine on blocking.						
77	40–6–160	Engine on blocking.						
78	40–8–160	4466	478.44	6.79	11.90	64.43	30.06	4.78
79	40–10–160	....	....	....	....	....	....	....
80	50–4–160	1918	255.60	6.97	24.40	82.70	35.75	4.36
81	50–6–160	Engine on blocking.						
82	50–8–160	....	....	....	....	....	....	....
83	60–4–160	....	....	....	....	....	....	....
84	60–6–160	....	....	....	....	....	....	....
85	20–4–120	1960	104.50	6.25	22.04	29.50	41.64	5.12
86	20–8–120	2700	143.39	23.15	43.20	109.41	50.03	6.21
87	20–12–120	6157	326.73	6.40	8.45	30.18	31.56	3.98
88	30–4–120	1277	102.08	9.71	40.31	68.94	51.30	5.90
89	30–8–120	3369	269.46	7.89	17.21	56.03	33.17	4.01
90	30–14–120	6258	500.58	1.89	2.61	13.43	31.13	4.41
91	40–4–120	1190	126.95	6.04	31.10	57.10	43.78	5.12
92	40–8–120	2697	287.68	10.60	25.80	100.24	37.20	4.60
93	40–12–120	5060	540.81	1.49	2.55	14.16	29.27	4.22
94	50–4–120	866	115.44	5.26	34.40	60.59	51.62	5.93
95	50–8–120	2804	373.45	4.55	12.60	54.14	32.22	4.20
96	50–11–120	3513	472.90	6.74	14.56	80.63	34.15	4.80
97	60–8–120	....	....	....	....	....	....	....

TABLE 22.—*Comparative performance of the locomotive assuming irregularities in the results of individual tests to have been eliminated.*

Designation of tests.		Corrected locomotive performance.											
Number.	Laboratory symbol.	Equivalent steam to engine per hour. Feed-water at 60°F.	Equiv. evap. per pound of dry coal by equation E=11.305—221 H.	Dry coal fired per hour corrected by equation.	Dry coal per I. H. P. per hour.	Equiv. steam per I. H. P. per hour.	Machine friction. M. E. P.	Machine friction. H. P.	Machine friction. Per cent I.H.P.	Dynamometer horse-power.	Draw-bar pull.	Coal per D. H. P. per hour.	Equivalent steam per D. H. P. per hour.
1	2	146	147	148	149	150	151	152	153	154	155	156	157
				Lbs.		*Lbs.*					*Lbs.*	*Lbs.*	*Lbs.*
1	20–2–240	8803	9.835	895	3.24	31.84	6.5	30.8	11.1	245.6	4600	3.64	35.86
1a	20–2–240	....	....	....	....	....	...	....	....	....	....	....	....
2	20–4–240	12008	9.298	1291	3.29	30.59	8.5	40.2	10.2	352.3	6610	3.66	34.08
3	20–6–240	13614	9.029	1508	3.23	29.12	9.3	44.0	9.4	422.8	7930	3.56	32.20
3a	20–6–240	....	....	....	....	....	...	....	....	....	....	....	....
4	20–8–240	....	....	....	....	....	...	....	....	....	....	....	....
5	30–2–240	11444	9.392	1218	3.28	30.82	6.5	46.1	12.4	325.2	4060	3.74	35.19
5a	30–2–240	....	....	....	....	....	...	....	....	....	....	....	....
6	30–4–240	13888	8.983	1546	3.28	29.51	8.5	60.4	12.8	410.2	5127	3.77	33.85
7	30–6–240	....	....	....	....	....	...	....	....	....	....	....	....
8	40–2–240	12320	9.245	1333	3.16	29.20	6.5	61.5	14.6	360.3	3379	3.69	34.19
9	40–4–240	16320	8.576	1903	3.36	28.82	8.5	80.5	14.2	485.8	4550	3.91	33.59
10	40–6–240	....	....	....	....	....	...	....	....	....	....	....	....
11	50–2–240	14066	8.953	1571	3.37	30.21	6.5	76.9	16.5	388.6	2910	4.04	36.19
12	50–4–240	....	....	....	....	....	...	....	....	....	....	....	....
13	20–2–220	8533	9.878	864	3.38	33.42	6.5	30.8	12.0	224.5	4210	3.84	38.01
14	20–4–220	10681	9.519	1122	3.27	31.15	8.5	40.2	11.7	302.6	5670	3.71	35.29
15	20–6–220	13294	9.082	1463	3.39	30.81	9.3	44.0	10.2	387.4	7260	3.77	34.31
16	20–8–220	16653	8.521	1954	3.66	31.24	8.4	39.8	7.5	493.2	9250	3.96	33.76
17	30–2–220	10286	9.585	1073	3.35	32.11	6.5	46.1	14.4	274.2	3430	3.91	37.51
18	30–4–220	12976	9.136	1420	3.20	29.06	8.5	60.4	13.5	386.1	4820	3.68	33.60
19	30–6–220	15915	8.644	1841	3.29	28.44	9.3	66.0	11.8	493.5	6170	3.73	32.25
20	30–8–220	....	....	....	....	....	...	....	....	....	....	....	....
21	40–2–220	11471	9.387	1222	3.29	30.87	6.5	61.5	16.5	310.0	2910	3.94	37.00
22	40–4–220	14549	8.873	1638	3.21	28.57	8.5	80.5	15.8	428.6	4020	3.82	33.94
23	40–6–220	....	....	....	....	....	...	....	....	....	....	....	....
24	50–2–220	12017	9.296	1292	3.41	31.72	6.5	76.9	20.3	301.9	2260	4.28	39.80
25	50–4–220	16343	8.573	1906	3.39	29.08	8.5	100.6	17.9	461.7	3460	4.13	35.40
26	50–6–220	....	....	....	....	....	...	....	....	....	....	....	....
27	60–4–220	....	....	....	....	....	...	....	....	....	....	....	....
28	60–6–220	....	....	....	....	....	...	....	....	....	....	....	....
29	20–2–200	7632	10.029	761	3.40	34.14	6.5	30.8	13.8	192.7	3610	3.94	39.61
30	20–4–200	9100	9.784	930	3.23	31.64	8.5	40.2	14.0	247.4	4640	3.75	36.78
31	20–6–200	11774	9.337	1261	3.35	31.33	9.3	44.0	11.7	331.8	6220	3.80	35.48
32	20–8–200	15011	8.795	1707	3.60	31.74	8.4	39.8	8.4	433.1	8120	3.94	34.66
33	30–2–200	8768	9.839	891	3.31	32.60	6.5	46.1	17.1	222.8	2780	4.00	39.35
34	30–4–200	11354	9.406	1207	3.29	30.92	8.5	60.4	16.4	306.7	3830	3.93	37.02
35	30–6–200	14685	8.850	1659	3.39	30.00	9.3	66.0	13.5	423.2	5290	3.92	34.70
36	30–8–200	....	....	....	....	....	...	....	....	....	....	....	....
37	40–2–200	9934	9.644	1030	3.36	32.40	86.	61.5	20.0	245.1	3300	4.22	40.53
38	40–4–200	13361	9.071	1473	3.28	29.76	9.5	80.5	17.9	368.4	3450	4.00	36.27
39	40–6–200	17822	8.321	2142	3.54	29.54	2.3	88.0	14.5	517.2	4850	4.14	34.46
40	40–8–200	....	....	....	....	....	...	....	....	....	....	....	....
41	50–2–200	10206	9.599	1074	3.26	31.02	6.5	76.9	23.4	252.1	1890	4.26	40.48
42	50–4–200	14431	8.892	1623	3.49	31.08	8.5	100.6	1.6	363.6	2730	4.46	39.69
43	50–6–200	....	....	....	....	....	...	....	....	....	....	....	....
44	60–4–200	....	....	....	....	....	...	....	....	....	....	....	....
45	60–6–200	....	....	....	....	....	...	....	....	....	....	....	....
46	20–2–180	6638	10.195	651	3.40	34.57	6.5	30.8	16.0	161.2	3020	4.04	41.18
47	20–4–180	8475	9.888	858	3.25	32.15	8.5	40.2	15.2	323.4	4100	3.84	37.94

TABLE 22.—*Comparative performance of the locomotive assuming irregularities in the results of individual tests to have been eliminated.*

Designation of tests.		Corrected locomotive performance.											
							Machine friction.						
Number.	Laboratory symbol.	Equivalent steam to engine per hour. Feed-water at 60° F.	Equiv. evap. per pound of dry coal by equation E=11.305—221 H.	Dry coal fired per hour corrected by equation.	Dry coal per I. H. P. per hour.	Equiv. steam per I. H. P. per hour.	M. E. P.	H. P.	Per cent I.H.P.	Dynamometer horse-power.	Draw-bar pull.	Coal per D. H. P. per hour.	Equivalent steam per D. H. P. per hour.
1	2	146	147	148	149	150	151	152	153	154	155	156	157
		Lbs.		*Lbs.*	*Lbs.*	*Lbs.*					*Lbs.*	*Lbs.*	*Lbs.*
48	20–6–180	10226	9.595	1066	3.19	30.61	9.3	44.0	13.2	290.1	5440	3.67	35.25
49	20–8–180	12833	9.157	1401	3.40	31.17	8.4	39.8	9.7	371.9	6970	3.77	34.51
50	20–10–180	....	....	....	....	....	...	....	....	....	....	....	....
51	30–2–180	7523	10.047	749	3.18	31.91	6.5	46.1	19.5	189.6	2370	3.95	39.68
52	30–4–180	9722	9.680	1004	3.16	30.65	8.5	60.4	19.1	256.7	3210	3.91	37.87
53	30–6–180	11633	9.360	1243	3.16	29.58	9.3	66.0	16.8	327.3	4090	3.80	35.54
54	30–8–180	16156	8.604	1878	3.44	29.57	8.4	59.6	10.9	486.7	6080	3.86	33.20
55	30–10–180	....	....	....	....	....	...	....	....	....	....	....	....
56	40–2–180	8069	9.956	810	3.12	31.14	6.5	161.5	23.7	197.6	1850	4.10	40.84
57	40–4–180	11177	9.436	1184	3.07	28.94	8.5	80.5	20.8	305.7	2870	3.87	36.56
58	40–6–180	14907	8.813	1691	3.23	28.44	9.3	88.0	16.8	436.1	4090	3.88	34.18
59	40–8–180	18949	8.137	2329	3.82	31.07	8.4	79.5	13.0	530.4	4970	4.39	35.73
60	40–10–180	....	....	....	....	....	...	....	....	....	....	....	....
61	50–2–180	8578	9.871	869	3.24	32.01	6.5	76.9	28.7	191.1	1430	4.55	44.88
62	50–4–180	12061	9.288	1299	3.16	29.37	8.5	100.6	24.5	310.0	2320	4.19	38.90
63	50–6–180	16567	8.535	1941	3.51	29.94	9.3	110.1	19.9	443.2	2320	4.38	37.40
64	50–8–180	....	....	....	....	....	...	....	....	....	....	....	....
65	60–4–180	....	....	....	....	....	...	....	....	....	....	....	....
66	60–6–180	....	....	....	....	....	...	....	....	....	....	....	....
67	20–4–160	7396	10.068	734	3.34	33.69	8.5	40.2	18.4	179.3	3360	4.09	41.25
68	20–6–160	9379	9.737	963	3.27	31.87	9.3	44.0	14.9	250.4	4690	3.85	37.44
69	20–8–160	11392	9.400	1212	3.51	33.02	8.4	39.8	11.5	305.2	5720	3.97	37.33
70	20–10–160	....	....	....	....	....	...	....	....	....	....	....	....
71	30–4–160	8785	9.836	893	3.28	32.28	8.5	60.4	22.2	211.7	2640	4.22	41.50
72	30–6–160	11663	9.355	1246	3.25	30.38	9.3	66.0	17.2	317.9	3970	3.92	36.69
73	30–8–160	14347	8.906	1611	3.46	30.85	8.4	59.6	12.8	405.4	5070	3.97	35.39
74	30–10–160	....	....	....	....	....	...	....	....	....	....	....	....
75	30–12–160	....	....	....	....	....	...	....	....	....	....	....	....
76	40–4–160	10106	9.615	1051	3.31	31.83	8.5	80.5	25.4	237.0	2220	4.43	42.64
77	40–6–160	13406	9.065	1478	3.43	31.05	9.3	88.0	20.4	343.7	3220	4.30	39.00
78	40–8–160	17246	8.421	2048	3.76	31.70	8.4	79.5	14.6	464.4	4350	4.41	37.14
79	40–10–160	....	....	....	....	....	...	....	....	....	....	..	....
80	50–4–160	10982	9.469	1160	3.43	32.47	8.5	100.6	29.7	237.7	1773	4.89	46.20
81	50–6–160	14940	8.807	1696	3.56	31.39	9.3	110.1	23.1	365.8	2740	4.64	40.84
82	50–8–160	....	....	....	....	....	...	....	....	....	....	....	....
83	60–4–160	....	....	....	....	....	...	....	....	....	....	....	....
84	60–6–160	....	....	....	....	....	...	....	....	....	....	....	....
85	20–4–120	5215	10.433	500	3.73	38.92	8.5	40.2	30.0	93.8	1760	5.33	55.59
86	20–8–120	8592	9.869	871	3.44	33.99	8.4	39.8	15.7	213.0	3990	4.09	40.34
87	20–12–120	12329	9.244	1333	3.73	34.52	5.0	23.7	6.5	333.2	6250	4.00	37.00
88	30–4–120	6269	10.257	611	3.57	36.69	8.5	60.4	35.4	110.6	1380	5.52	56.68
89	30–8–120	10683	9.519	1122	3.45	32.80	8.4	59.6	18.3	265.9	3320	4.22	40.18
90	30–14–120	18654	8.186	2278	4.43	36.29	3.0	21.3	4.1	492.7	6160	4.62	37.86
91	40–4–120	6649	10.193	652	3.54	36.13	8.5	80.5	43.7	103.5	970	5.30	64.24
92	40–8–120	12796	9.166	1396	3.59	32.89	8.4	79.5	20.4	309.5	2900	4.51	41.34
93	40–12–120	18942	8.138	2328	4.20	34.12	5.0	47.3	8.5	507.5	4760	4.58	37.32
94	50–4–120	7129	10.113	704	4.00	40.51	8.5	100.6	57.2	75.4	560	9.34	94.55
95	50–8–120	14371	8.902	1614	3.77	33.61	8.4	99.4	23.2	328.2	2460	4.91	43.79
96	50–11–120	19317	8.075	2391	4.32	34.90	6.0	71.0	12.8	482.5	3620	4.95	40.04

APPENDIX III.

DATA CONCERNING LOCOMOTIVE BOILERS.

For the purpose of securing information concerning the weight of boilers designed for different pressures and for different capacities, the assistance of the Schenectady Locomotive Works, as represented by Mr. J. E. Sague, was sought and generously given. The following from the correspondence shows the nature and extent of the information request.

1. *Weight of boilers for different pressures.*—Locate the general lines of a representative radial stay, moderately wide fire-box boiler having 2000 feet of heating-surface as shown by fig. 120. By general lines of the boiler is meant the outline and dimensions without any reference to thickness of plates or character of joints. Making use of this outline, the following information is desired:

(*a*) Weight of complete boiler when designed for 160 pounds pressure.
(*b*) Weight of complete boiler when designed for 190 pounds pressure.
(*c*) Weight of complete boiler when designed for 220 pounds pressure.
(*d*) Weight of complete boiler when designed for 250 pounds pressure.
(*e*) Cubic feet of water when filled to middle gage.
(*f*) Cubic feet of steam space when the water is at middle gage.

An alternative plan.—If the data on file should be sufficient, it is possible that work can be saved and the information desired obtained by plotting the weight per foot of heating-surface of certain existing boilers in order that the relation between weight of boiler and the pressure to be carried may be shown. This is the relation which it is desired chiefly to establish.

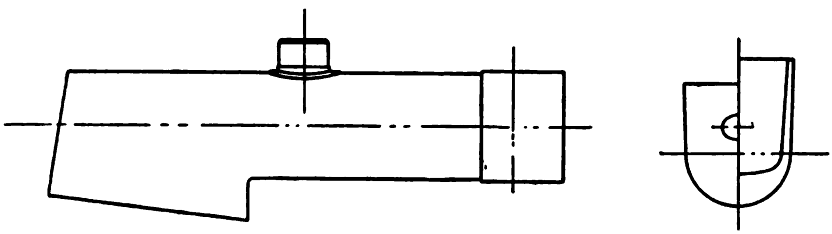


FIG. 120.—Proportions of boiler accepted as typical for purposes of comparison.

2. *Weight of boilers for different capacities.*—Design four boilers for a steam-pressure of 160 pounds, all to be of the same type and to agree in general layout with the boiler covered by paragraph 1, except that in this case the following information is required.

(*g*) Weight of boiler having approximately 2000 feet of heating surface.
(*h*) Weight of boiler having approximately 2500 feet of heating surface.
(*i*) Weight of boiler having approximately 3000 feet of heating surface.
(*j*) Weight of boiler having approximately 3500 feet of heating surface.
(*k*) Cubic feet of water in each of above boilers when filled to middle gage.
(*l*) Cubic feet of steam space when the boiler is filled to middle gage.

Explanation.—The information asked for under paragraphs 1 and 2, when taken in connection with results from the laboratory, should permit a logical development of the question as to whether it is better to build larger boilers or stronger boilers when it is desired to increase the power of a locomotive.

3. *Cylinders.*—The diameter and weight of cylinders, including pistons and valves which could be employed in connection with a boiler having 2000 feet of heating-surface, assuming the boiler to carry each of the following pressures: (*m*) a pressure of 250 pounds; (*n*) a pressure of 220 pounds; (*o*) a pressure of 190 pounds; (*p*) a pressure of 160 pounds.

Explanation.—The purpose of this information is to determine the saving in weight of the machine parts resulting from the use of high steam-pressures.

The response to this inquiry, as prepared by Mr. F. J. Cole, mechanical Engineer, assisted by Mr. C. D. Hilferty, covered the following particulars:

The information requested is covered by the several tables accompanying, values for which were obtained as follows:

For table 23 the boiler used on order S–155 was taken as a basis and tubes were made 14 feet long.

The actual weight of the boiler *b* was known as designed for 190 pounds pressure. The weights for the other pressures were obtained by figuring the change in weight of boiler parts as thicknesses were modified to suit the various pressures, subtracting this change of weight from boiler *b* for boiler *a* and adding it for boilers *c* and *d*.

The volume of the water was figured from actual weight in boiler *b* at 190 pounds pressure with two gages and approximate corrections made for variations of sheet thicknesses in boilers *a*, *c*, and *d*. Steam volumes were obtained by multiplying the area of segment of circle above water line in second ring by the mean length of steam space. The volume of dome was neglected as balanced by bracing, etc.

Verbal request was made for the addition of the column of ratios showing weight of boiler per square foot of heating-surface and a comparison of this figure with that of a number of boilers of similar type.

Satisfactory figures for the latter part of the request can not be given except as special boilers are chosen because of the large variation in the percentage of heating-surface involved in the tube area. The boilers of engines 5377 and 5508 are examples. They carry the same pressures, have same diameter first ring; 5,377 is 11.66 and 5,508 is 19.57.

TABLE 23.—*Boilers for different pressures.*

[See fig. 120 for general design.]

Boiler.	Pressure.	Weight.	Cubic feet of water.	Cubic feet of steam.	Weight of boiler per square foot of heating-surface.
a	160	30679	262	71.5	15.16
b	190	32913	265	72.5	16.26
c	220	36076	267	73.2	17.85
d	250	38953	270	74.4	19.22

Table 24 is based on boiler-cards, as noted in table of miscellaneous information, and weights and volume were figured same as for Table I.

Table 25 is based on weight of actual cylinders of boiler *c* with parts. Other weights are estimated, employing same method as used with boilers. In changing cylinder diameters, the tractive power of engine is considered as a constant, and cylinders changed to offset pressure changes.

TABLE 24.—*Boilers for different capacities.*

[See fig. 120 for general design.]

Boiler.	Extent of heating-surface, feet.	Weight.	Cubic feet of water. *e*	Cubic feet of steam. *f*	Weight of boiler per square foot of heating-surface.
g	2000	30679	262	71.5	15.16
h	2500	36321	310	72.8	14.31
i	3000	41013	322	74.2	13.61
j	3500	42894	352	82.7	12.26

TABLE 25.—*Cylinders.*

Cylinder.	Boiler.	Pressure.	Cylinder diameter. *Inches.*	Weight of cylinders including valves and pistons.
m	*d*	250	16½	11,620
n	*c*	220	18	11,990
o	*b*	190	19	12,240
p	*a*	160	20½	12,580

TABLE 26.—*Dimensions of boilers designed for different pressures.*

Boiler.	Based on card No.	I. D. 1st Ring. *Inches.*	Tubes.			Grates.		
			No.	Size. *Inches.*	Length. *Feet.*	Length. *Inches.*	Width. *Inches.*	Area. *Sq. ft.*
a	138 S 5250	63	252	2	14	90	60	37.5
b	Do.	63	252	2	14	90	60	37.5
c	Do.	63	252	2	14	90	60	37.5
d	Do.	63	252	2	14	90	60	37.5

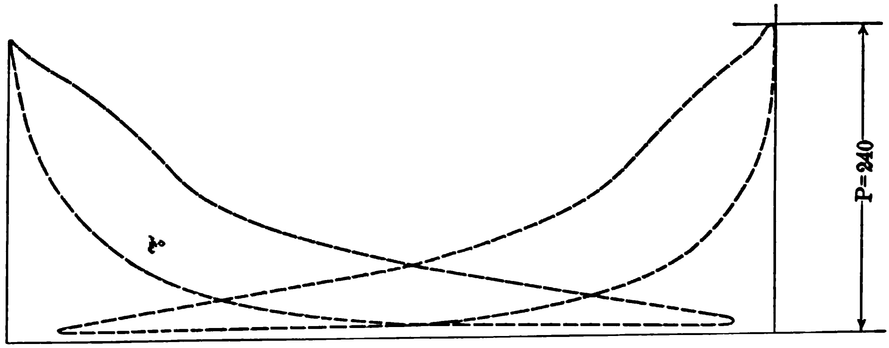
TABLE 27.—*Dimensions of boilers designed for different capacities.*

Boiler.	Based on card No.	Order No.	I. D. 1st ring. *Inches*	Tubes.			Grates.		
				No.	Size. *Inches.*	Length. *Feet.*	Length. *Inches.*	Width. *Inches.*	Area. *Sq. ft.*
a	138 S 5250	121	63	258	2	14	90	60	37.4
b	Do.	155	69	326	2	14	102	65	46.1
c	599	Eng.5613	67	338	2	16	102	65	46.1
d	138 S 5040	135	70⅝	396	2	16	96	75	50.0

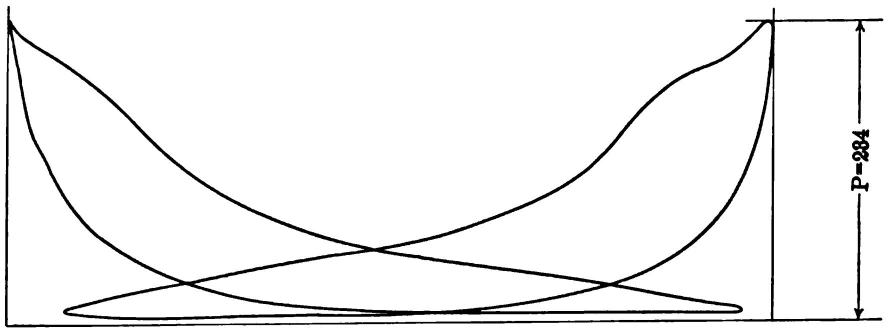
APPENDIX IV.

AN EXHIBIT OF TYPICAL INDICATOR DIAGRAMS.

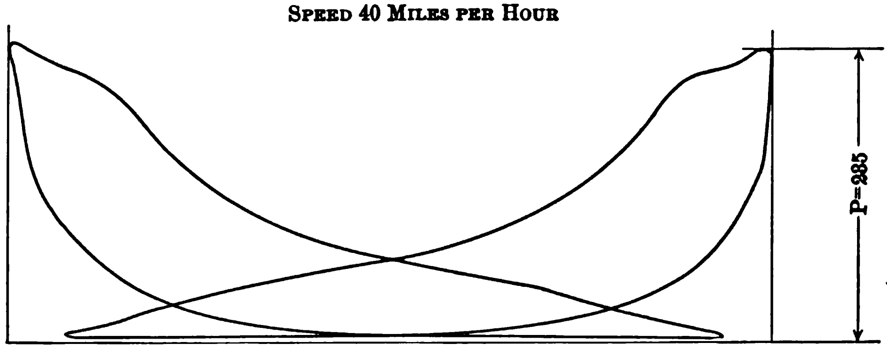
This exhibit consists of cards representing eight different tests for each of the several pressures. The diagrams are designed to be accurate reproductions at full size of actual cards as taken.



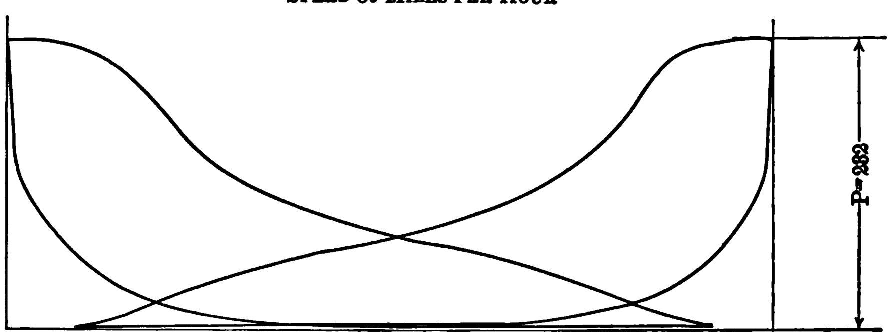
SPEED 50 MILES PER HOUR



SPEED 40 MILES PER HOUR



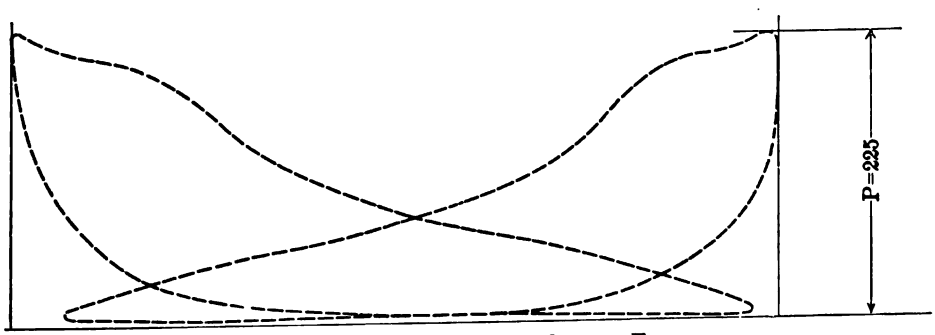
SPEED 30 MILES PER HOUR



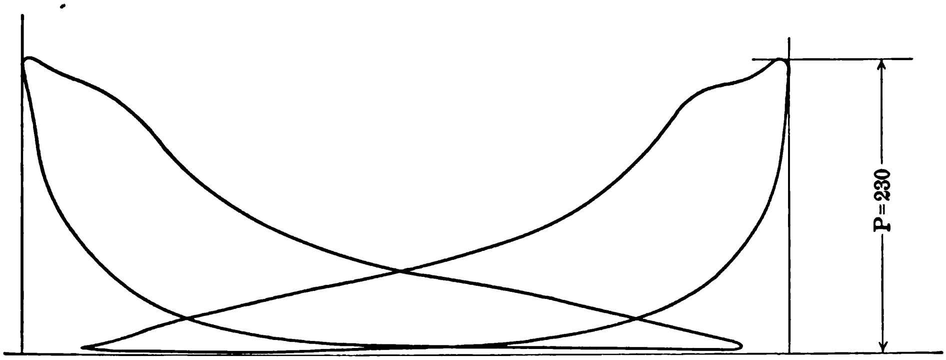
SPEED 20 MILES PER HOUR

BOILER PRESSURE 240 POUNDS. REVERSE LEVER 4TH NOTCH FROM CENTER FORWARD.

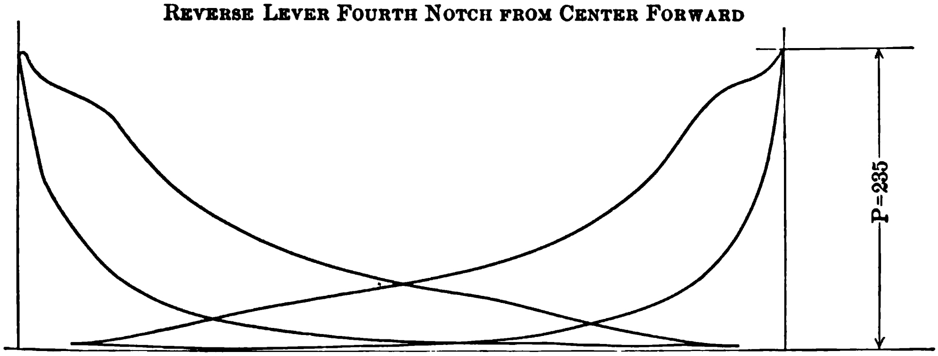
REVERSE LEVER EIGHTH NOTCH FROM CENTER FORWARD



REVERSE LEVER SIXTH NOTCH FROM CENTER FORWARD

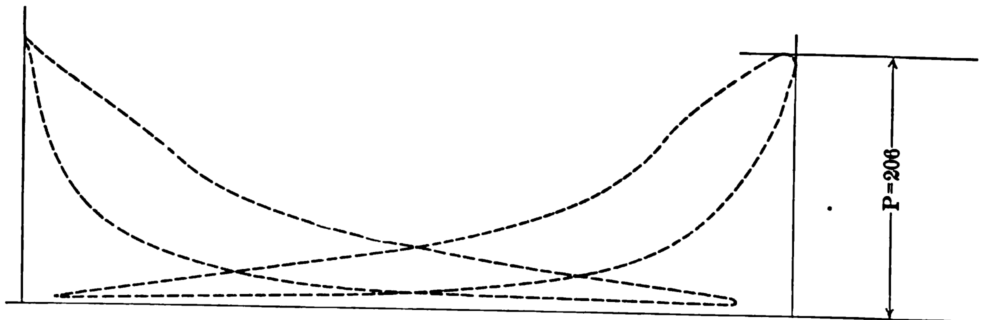


REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD

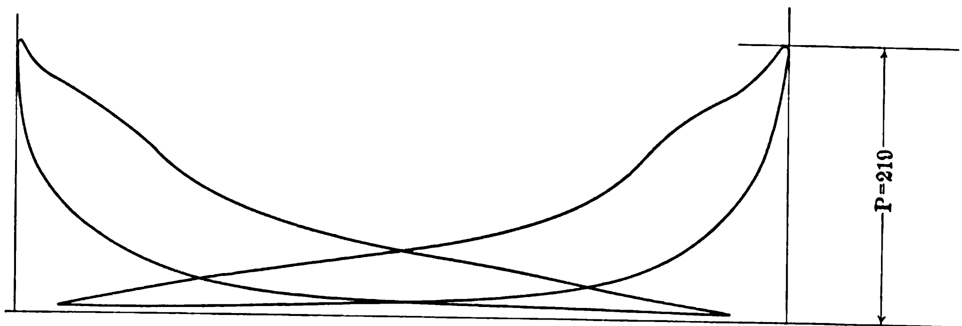


REVERSE LEVER SECOND NOTCH FROM CENTER FORWARD

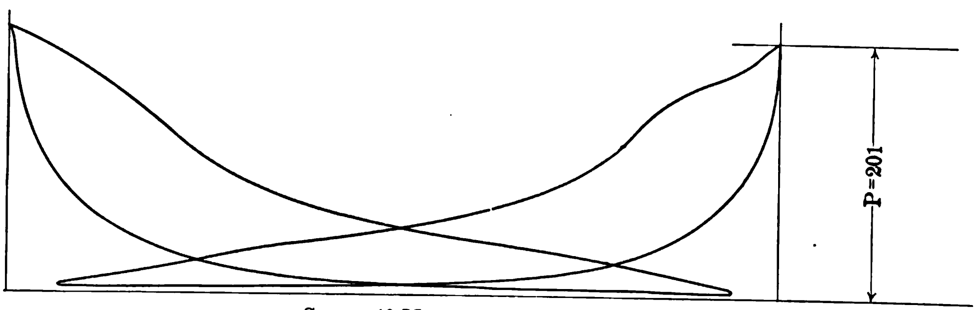
BOILER PRESSURE 240 POUNDS. SPEED 30 MILES PER HOUR.



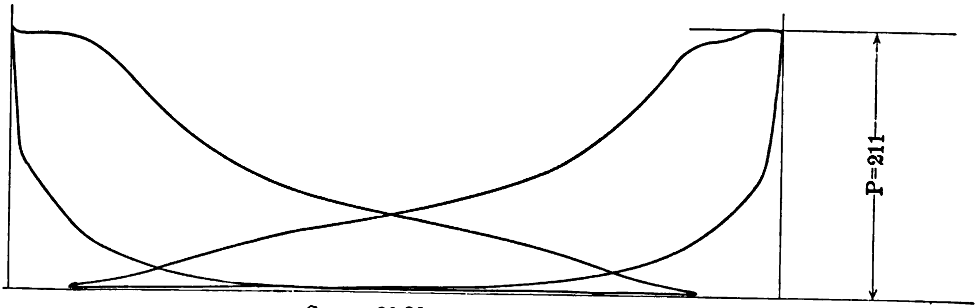
SPEED 60 MILES PER HOUR



SPEED 50 MILES PER HOUR

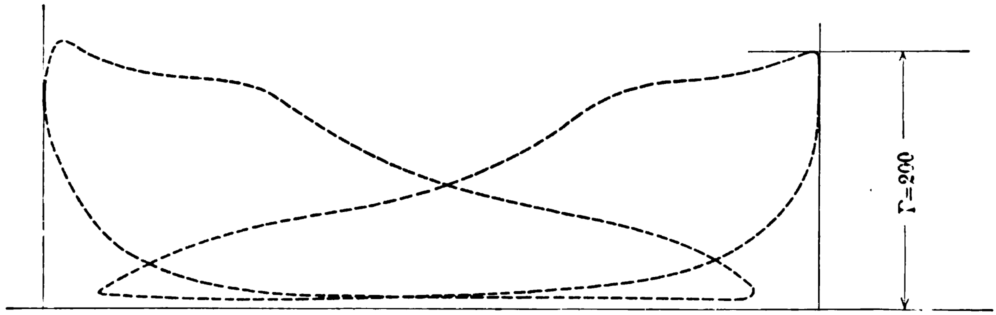


SPEED 40 MILES PER HOUR

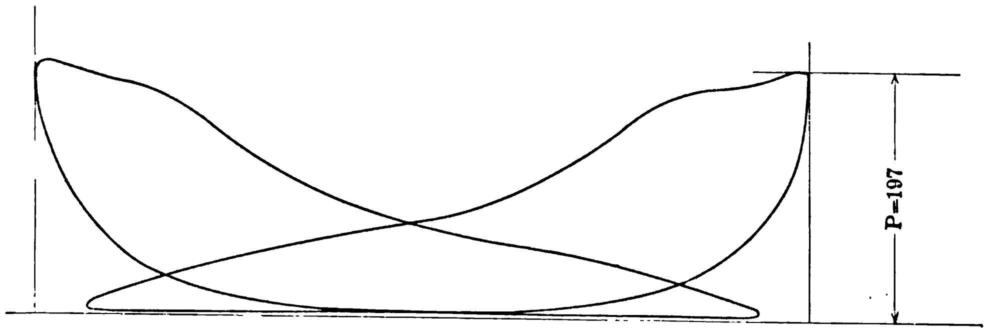


SPEED 20 MILES PER HOUR

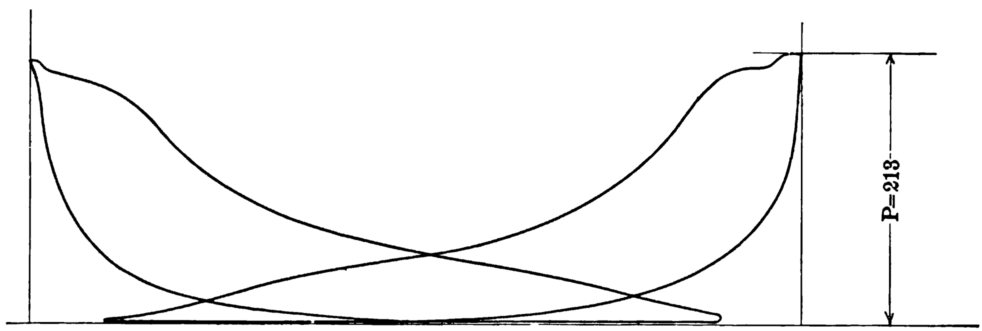
BOILER PRESSURE 220 POUNDS. REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD.



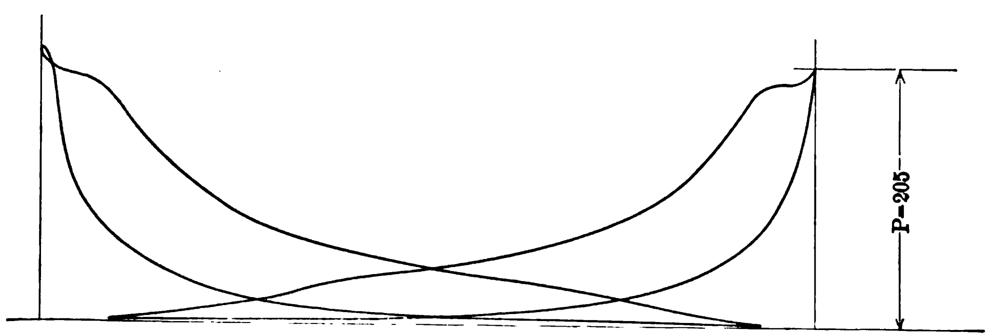
REVERSE LEVER EIGHTH NOTCH FROM CENTER FORWARD



REVERSE LEVER SIXTH NOTCH FROM CENTER FORWARD

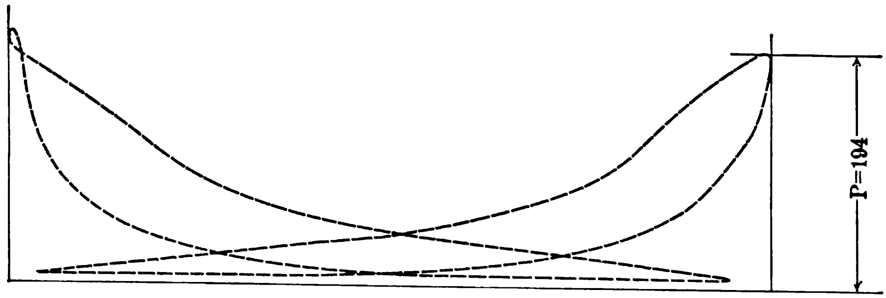


REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD

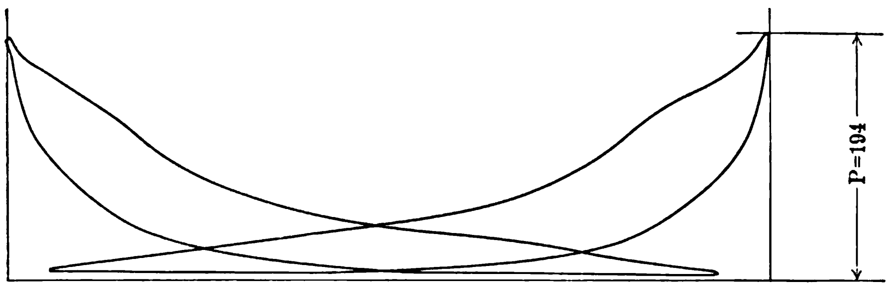


REVERSE LEVER SECOND NOTCH FROM CENTER FORWARD

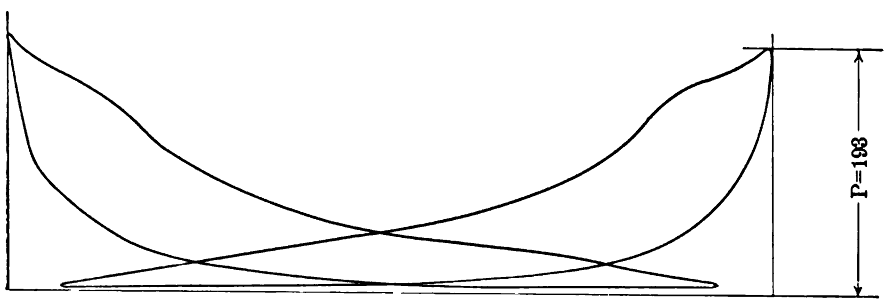
BOILER PRESSURE 220 POUNDS. SPEED 30 MILES PER HOUR.



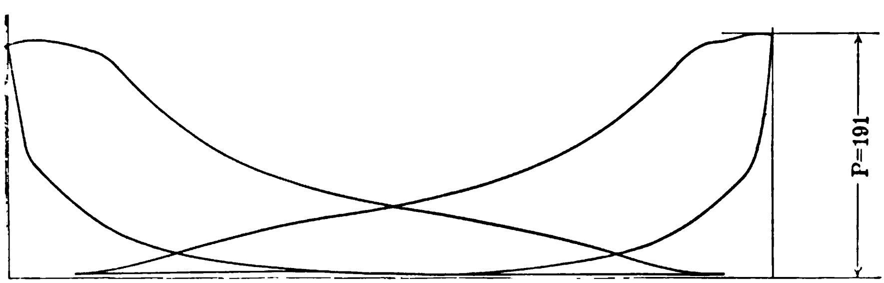
SPEED 60 MILES PER HOUR



SPEED 50 MILES PER HOUR

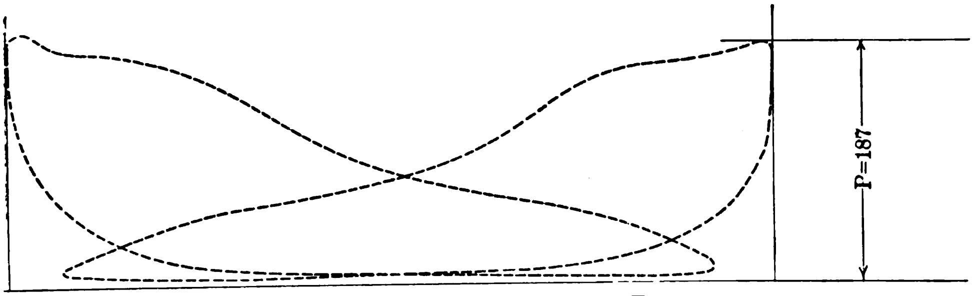


SPEED 40 MILES PER HOUR

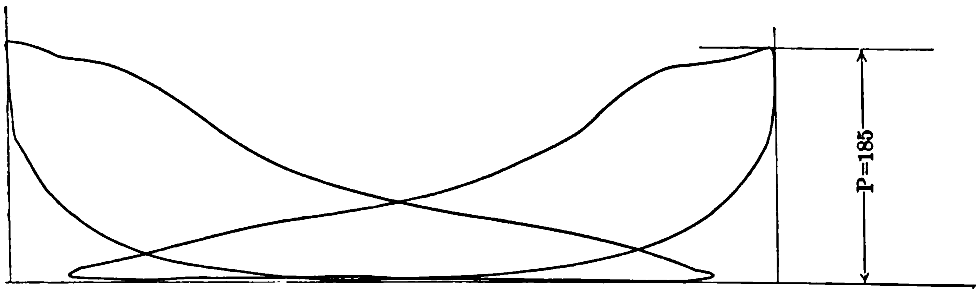


SPEED 20 MILES PER HOUR

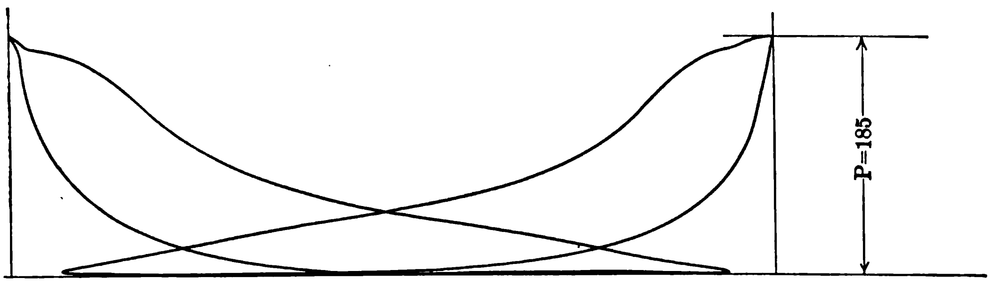
BOILER PRESSURE 200 POUNDS. REVERSE LEVER 4TH NOTCH FROM CENTER FORWARD.



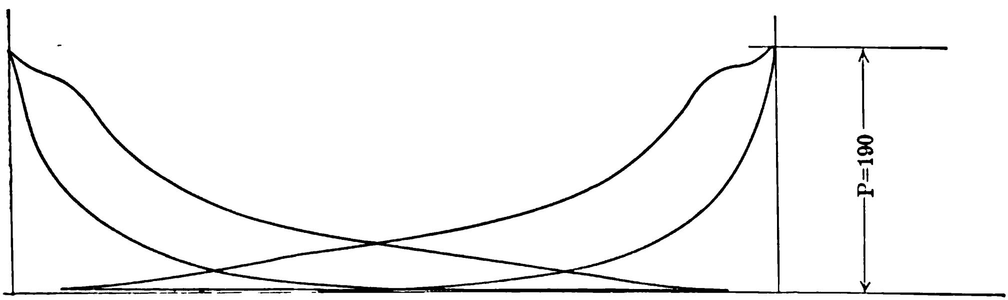
REVERSE LEVER EIGHTH NOTCH FROM CENTER FORWARD



REVERSE LEVER SIXTH NOTCH FROM CENTER FORWARD

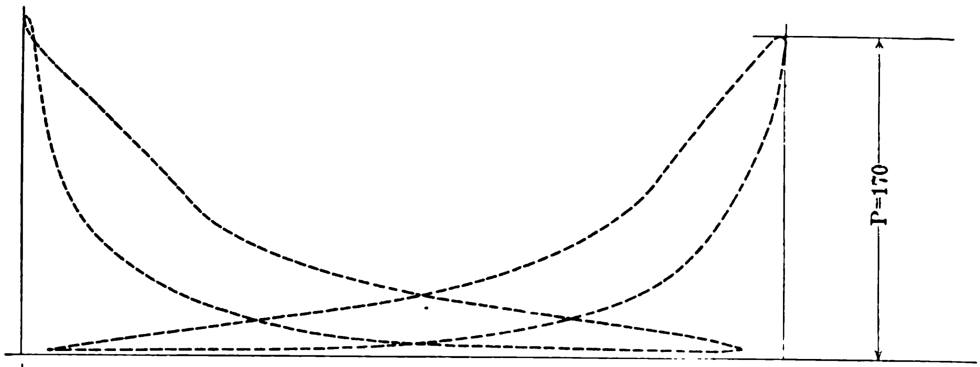


REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD

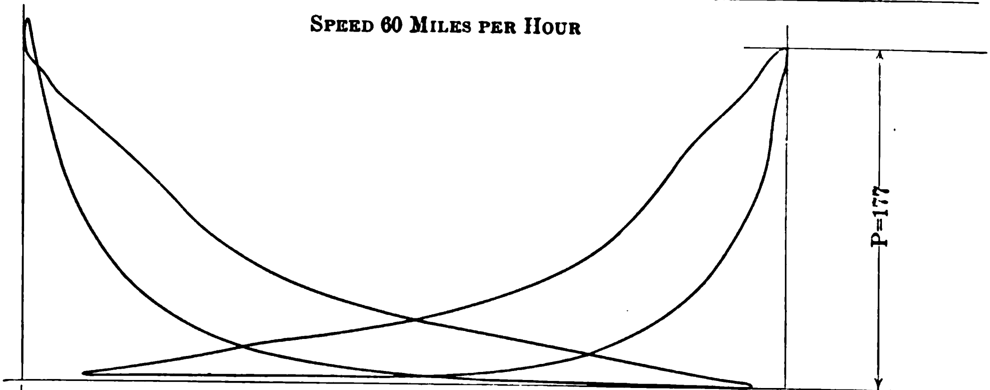


REVERSE LEVER SECOND NOTCH FROM CENTER FORWARD

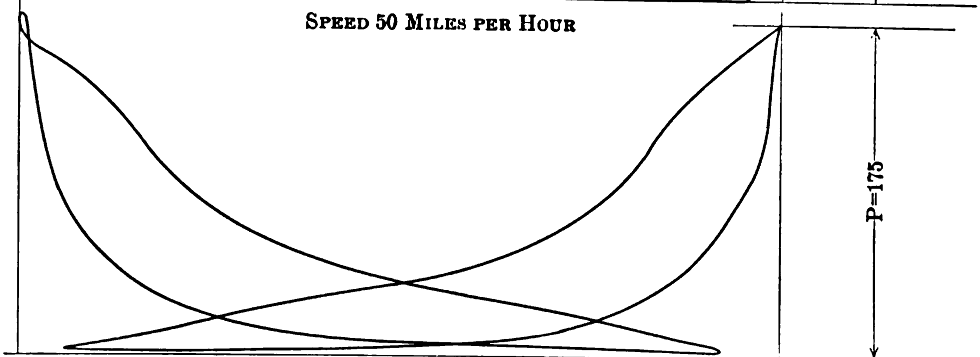
BOILER PRESSURE 200 POUNDS. SPEED 30 MILES PER HOUR.



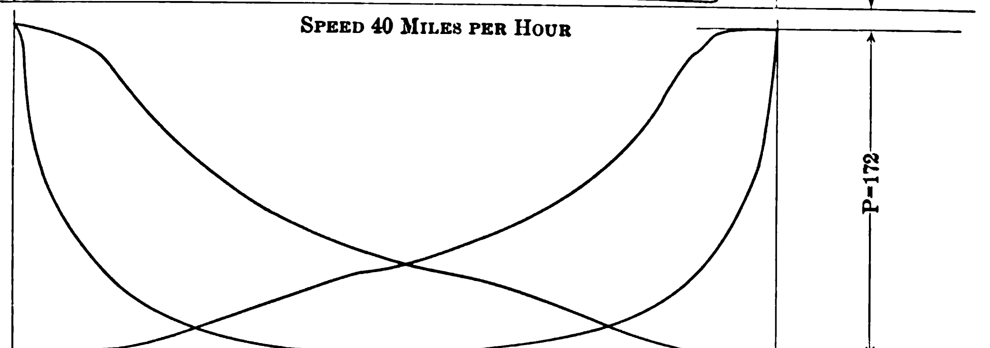
SPEED 60 MILES PER HOUR



SPEED 50 MILES PER HOUR

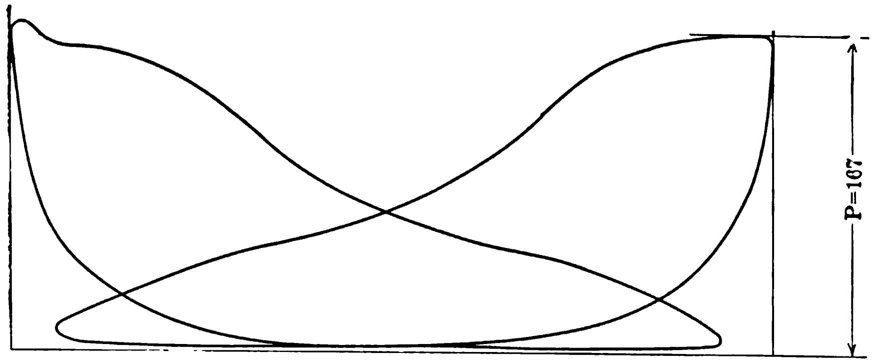


SPEED 40 MILES PER HOUR

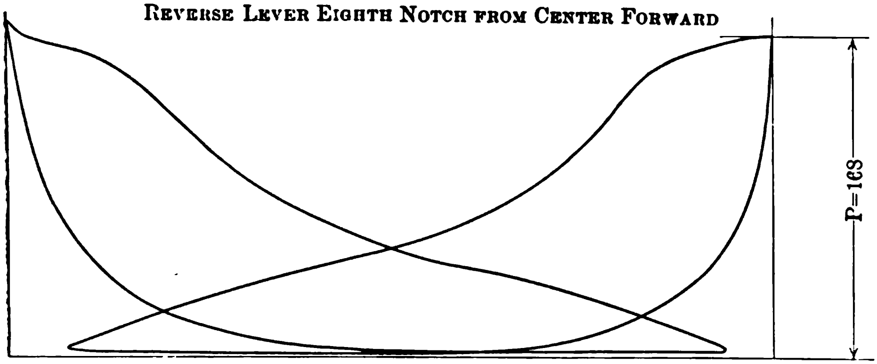


SPEED 20 MILES PER HOUR

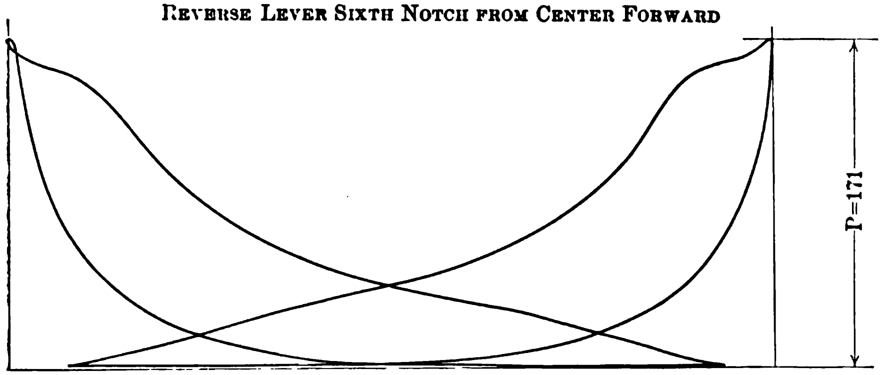
BOILER PRESSURE 180 POUNDS. REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD.



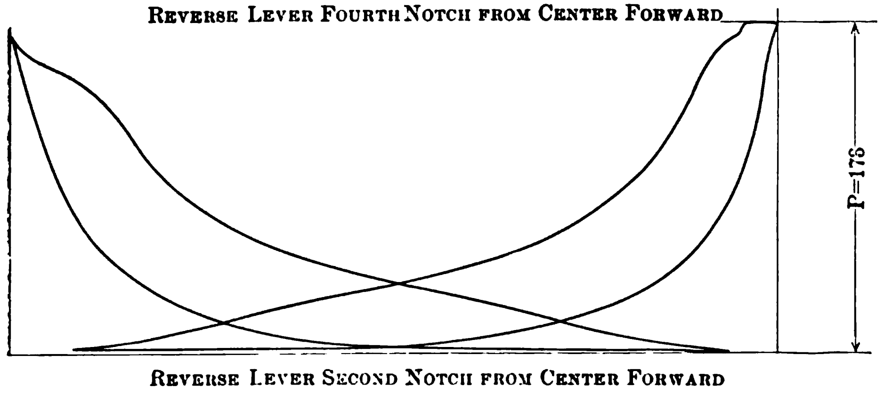
REVERSE LEVER EIGHTH NOTCH FROM CENTER FORWARD



REVERSE LEVER SIXTH NOTCH FROM CENTER FORWARD

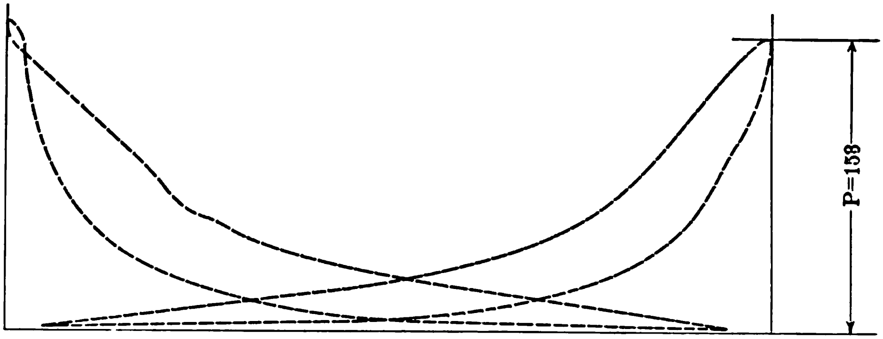


REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD

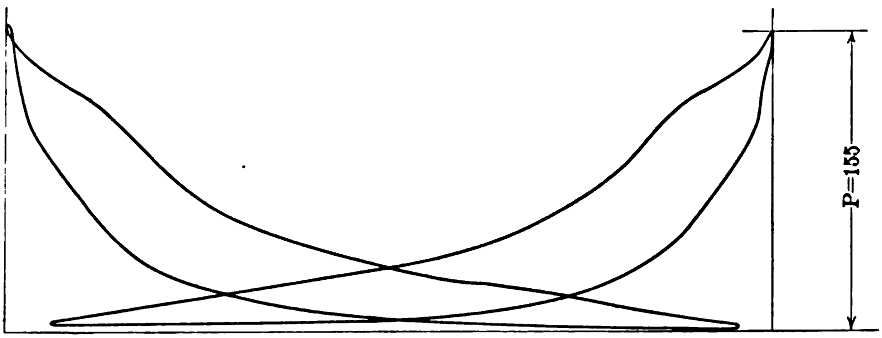


REVERSE LEVER SECOND NOTCH FROM CENTER FORWARD

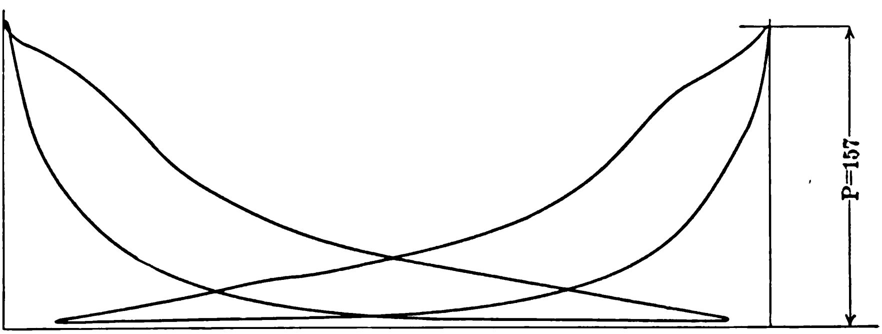
BOILER PRESSURE 180 POUNDS. SPEED 30 MILES PER HOUR.



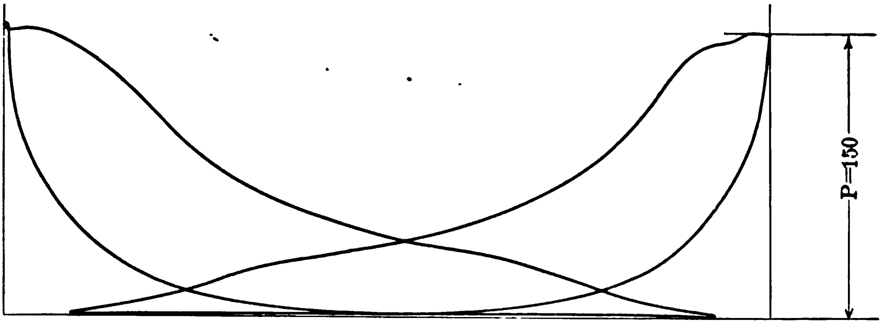
Speed 60 Miles per Hour



Speed 50 Miles per Hour

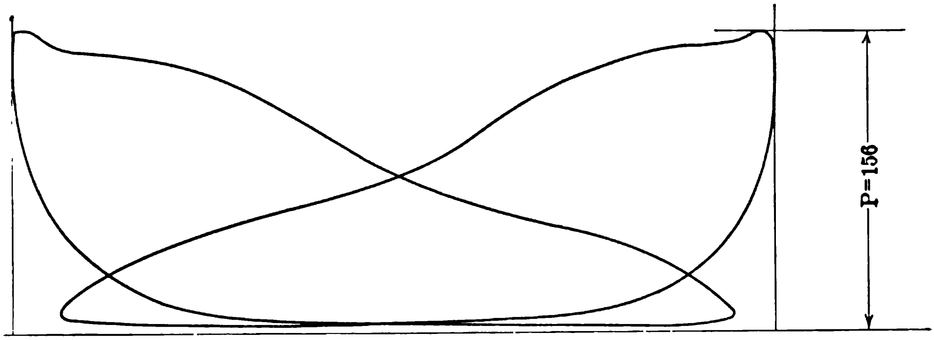


Speed 40 Miles per Hour

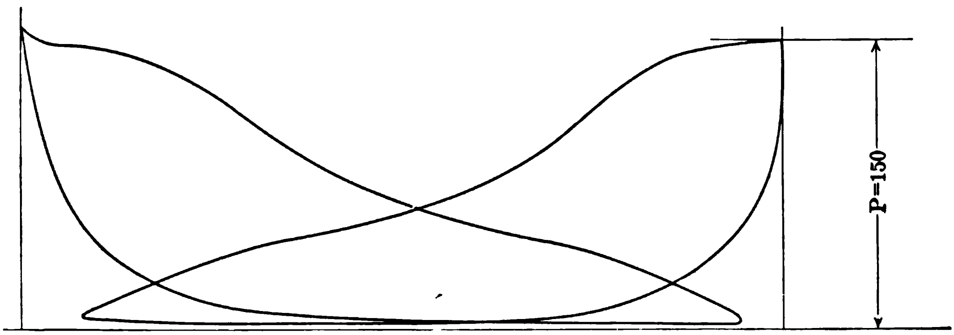


Speed 20 Miles per Hour

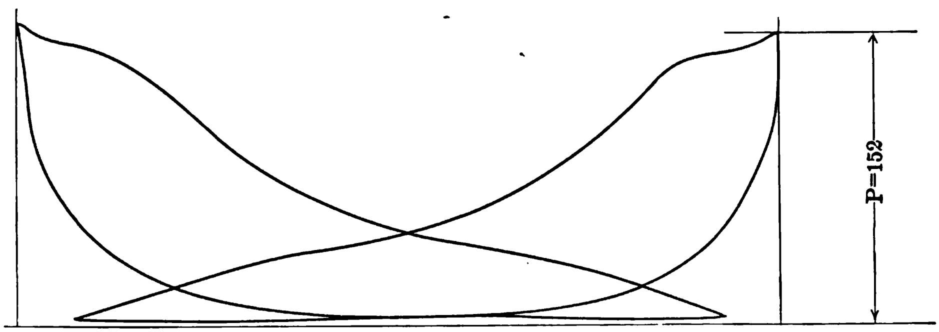
Boiler Pressure 160 Pounds. Reverse Lever 4th Notch from Center



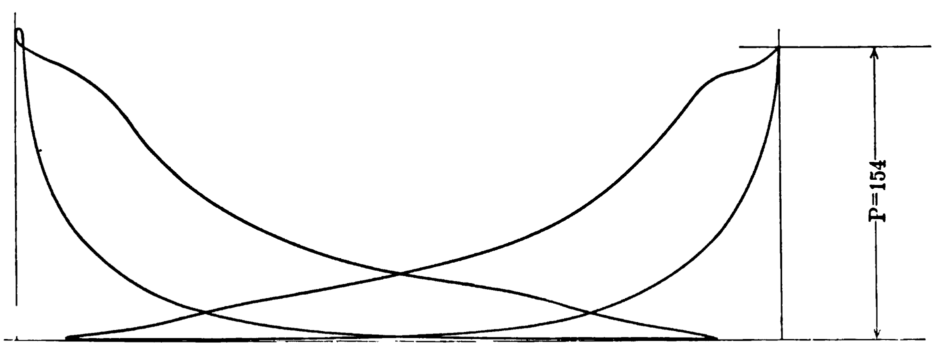
REVERSE LEVER TENTH NOTCH FROM CENTER FORWARD



REVERSE LEVER EIGHTH NOTCH FROM CENTER FORWARD

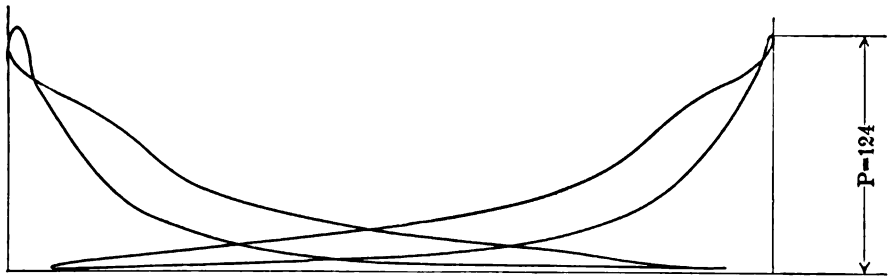


REVERSE LEVER SIXTH NOTCH FROM CENTER FORWARD

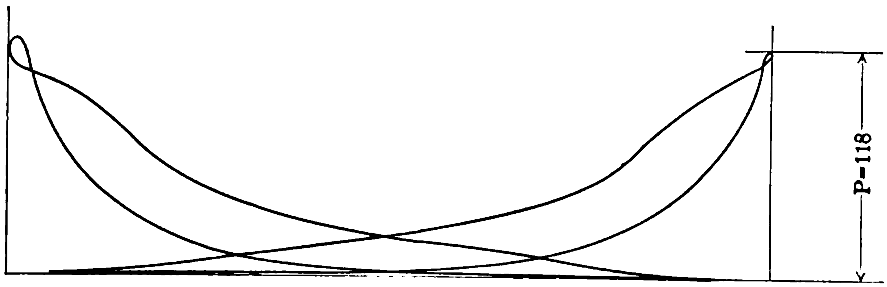


REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD

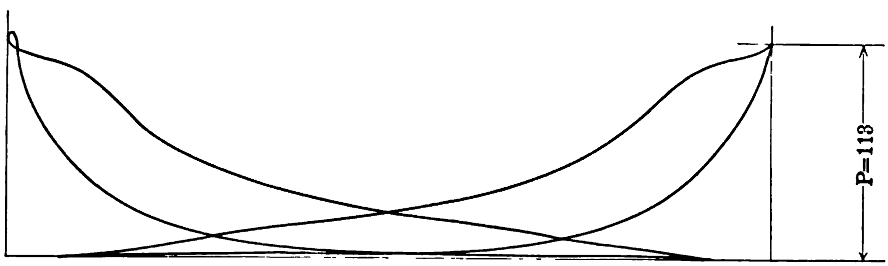
BOILER PRESSURE 160 POUNDS. SPEED 30 MILES PER HOUR.



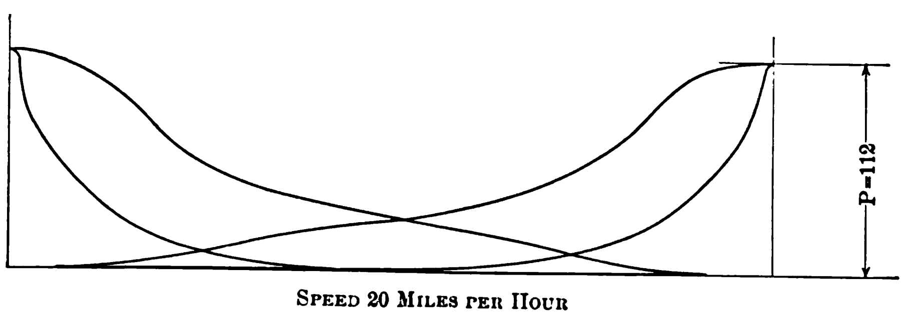
SPEED 50 MILES PER HOUR



SPEED 40 MILES PER HOUR

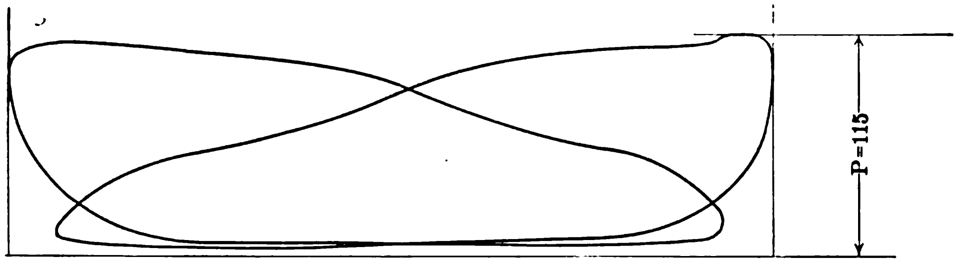


SPEED 30 MILES PER HOUR

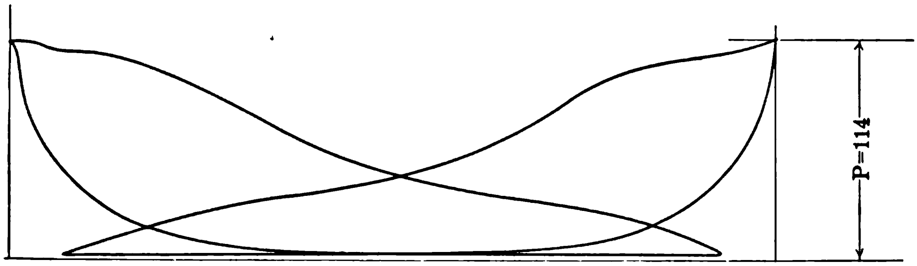


SPEED 20 MILES PER HOUR

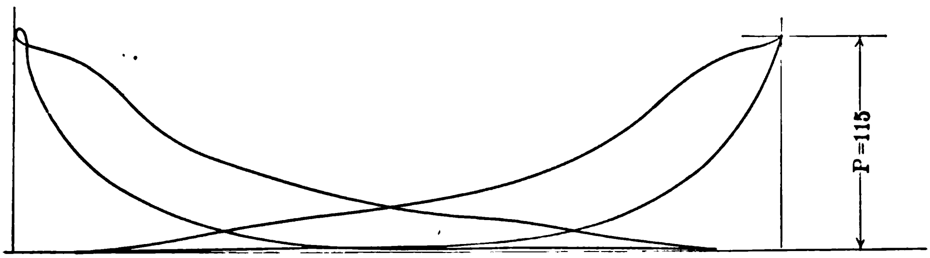
BOILER PRESSURE 120 POUNDS. REVERSE LEVER 4TH NOTCH FROM CENTER FORWARD.



REVERSE LEVER FOURTEENTH NOTCH FROM CENTER FORWARD



REVERSE LEVER EIGHTH NOTCH FROM CENTER FORWARD



REVERSE LEVER FOURTH NOTCH FROM CENTER FORWARD

BOILER PRESSURE 120 POUNDS. SPEED 30 MILES PER HOUR.

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HARVARD ENGINEERING SCHOOL