Easy Steps
TO
Locomotive Engineering

A Series of Eight Easy Explanatory Lessons Covering the
Construction and Operation of the Locomotive, the
Qualifications and Duties of Firemen, the Auto-
matic Airbrake, Fuel and its Combustion, Steam
Expansion and Velocity, the Locomotive
Boiler, Adhesion and Tractive
Power, Block Signalling.

By
FREDERICK J. PRIOR

Author of "Operation of Trains," "Making Good as an
Engineer," "Construction and Maintenance of Railway
Roadbed and Track," "What Stops a Moving
Train," "Running a Modern Locomotive," Also
Regular Staff Contributor to the Locomotive
Firemen and Enginemen's Magazine.

Issued and Published
Exclusively by the Educational Department
of the
AMERICAN JOURNAL OF RAILWAYS
AND RAILROADING
CHICAGO, ILLINOIS

LESSON I

THE LOCOMOTIVE

Its Parts and Their Operation

LESSON I.

THE LOCOMOTIVE.

Its Parts and Their Operation.

1. The locomotive is a trinity of mechanical mastery; three things in one: First, a vehicle; second, a steam generator; third, a steam engine. From fuel, placed in the firebox, it generates heat through combustion; this heat converts the water in the boiler into steam; the steam acting in the cylinders, operates the mechanism—with a variety of operations taking place within the machinery itself. And besides that, the locomotive moves along the rails and hauls enormous loads at great speed. Variations in climatic conditions, weather, water, fuel—all affect the locomotive, but it must meet these conditions, do its work, and perform its duties in a definite time.

2. The locomotive is what may be called an "evolution," that is, it has come into its present form because experience has pointed the way. Every part of it has a certain shape because the shape itself has been formed to meet definite requirements. Its frame must withstand the weight of the boiler and minor parts; the strains of internal stresses, the alternation of heat and cold—the effect of curves and grades—and the loads that are hauled. Every part must perform some duty—and the locomotive as we know it today is different in numerous respects from the earlier types. Appliances, to do certain necessary things, have been added—and each part is important in the performance of the entire duty of hauling trains of vast weight and capacity at a high rate of speed.

3. The novice, who stands idly by and admires this breathing thing of steel and iron and brass, is moved by a desire to understand it better—and maybe to operate it. Before he can reach that point he must first familiarize himself with every part—its purpose, what it does, how it is managed and cared for. To place before the student the things he should know we have adopted charts and will carry the instruction through careful, simple description. Chart A is the anatomy—or skeleton—of a simple type of locomotive, commonly referred to as the eight-wheel engine. Note the numbers used, so that you can make reference to this chart and associate the description with the parts themselves. Bear in mind, also, that this is a study—not simply an interesting article. Go through these facts and examine the chart many times until you know exactly what each part looks like—what its purpose is, and what function, or duty, it performs.

4. THE FIREBOX: Let us begin our study in that part where the heat is generated, for heat is the first necessity of a locomotive to make it useful. In Chart B will be found a sectional view of the boiler—as though the boiler had been sliced lengthwise through its middle, with an enormous knife. There are four divisions to the boiler, which are: (1st) the firebox; (2nd) the barrel or cylinder; (3rd) the tubes or flues; (4th) the smoke-arch and stack.

5. The firebox is rectangular in form and is constructed of steel plates, from ⅜ to 9-16 inch thick. The inner shell (G-G) is enveloped with an outside shell (H-H) that is also built of steel plates. Between the inner and outer shells there is a space of 2½ to 4½ inches, surrounding the firebox completely—on four sides. This is termed the water-

leg. At its bottom edge it is closed by the mud-ring (F), made of wrought iron or soft steel. It extends around the whole space that exists between the inner and outer shells and is riveted to the plates, the rivets extending through this mud-ring. The enormous heat and the pressure of the steam affect every side of the firebox, and unless special precautions were taken in construction, the steel plates would bulge, water would leak in upon the fire, and there would be an explosion. Note the letters J-J, which represent the stay-bolts that will be found along both front and back edge of the firebox. Around the letter A will be seen small holes in the side of the firebox, which are other stay-bolts. The best quality of wrought iron is used in the manufacture of these stay-bolts, they have a screw thread throughout their length and they have a diameter of about one inch.

6. Every part of the steam-generating part of a locomotive must be water and steam-tight as far as possible, and the stay-bolt used is the safest means thus far discovered for holding the plates together. These stay-bolts are about 4 or 4½ inches apart, screwed through inner and outer plates, binding the plates together. The distance between them is measured from the centers of the bolts. In addition to this precaution, of using many stay-bolts and having them threaded, the ends of these stay-bolts are riveted down onto the plates, adding to their firmness.

7. The flat, top sheet of the firebox, known as the crown-sheet, must have particular care, for a very large part of the heating of the water in the boiler depends on this plate. Crown bars, radial

stays and the Belpaire system constitute the three methods of strengthening this crown-sheet.

8. Note the letters K-K, shown on Chart B, which indicate the ends of the crown-bars. These bars extend across the top of the firebox, in the crown-bar method of strengthening the crown-sheet —above which they are run. They are double girders with a space between them and the top of the crown-sheet to permit of the free circulation of the water. Special castings support the ends of these crown-bars, the castings resting on the upper edges of the fire-sheets and the crown-sheet's flange. Crown-bolts are driven every 4 or 5 inches (center to center), with their heads on the crown-sheet's under side, the nut bearing on a plate that is on the top of the crown-bar. Each crown-bolt passes through a ring, or thimble, between the bottom of the crown-bars and the top of the crown-sheet. These rings give and hold the proper distance between crown-bars and crown-sheet.

9. Note, as shown in Chart B, the crown-bars between K and K. On the under side of the crown-sheet will be seen the heads of the crown-bolts, while on top of the crown-bars are the nuts. When a locomotive runs down a steep grade, the water might leave the back part of the crown-sheet, which would be dangerous, for the sheet is hot, and blisters easily unless it is covered completely with water. To avoid this, crown-sheets generally slope backward; usually several inches. Boiler-heads must also be stayed, and the smaller chart illustrates the method. Keep in mind that the boiler itself extends to M—embracing all the space that surrounds the firebox and the tubes.

10. Note, in Chart B, the letters S-S-S-S, repre-

senting braces or stays, to strengthen the boiler-head. These run diagonally, with one end riveted to the shell, and the other connected to the proper part of the head.

11. Notice the letters B-B in Chart B, that stands for the barrel, or cylinder, of the boiler. The tubes, or flues, are C-C, with a diameter usually of 2 inches, inside. The flue-sheet N in the firebox, and the smoke-box sheet M are braced by the flues. Because of the holes drilled into these sheets for the tubes, they are thicker than the shell of the boiler. Fully three-fourths of the space taken up by the barrel of the boiler is accounted for by these tubes, and the space between them is just sufficient to permit of an unobstructed circulation of the water between them.

12. Turn to S-S in Chart B. These are diagonal braces or stays, with one end riveted to the boiler-shell and the other to the flue-sheet M that requires bracing. The bracing of the back boiler-head (above the crown-sheet) is similarly accomplished—shown by S-S, the braces.

13. Added steam space is desired, so the dome O is provided, as shown in Chart B. This is accomplished by extending the top-sheet upward. Not only is more steam space thus given, but the steam is held free from the water. It is "dry," meaning that water particles do not saturate it. For this same reason also the throttle and dry-pipe inlet are placed in the topmost part of the dome.

14. The next point of consideration is the front end—particularly the smoke-arch. Beyond the front flue-sheet the outer sheets of the boiler are extended several feet. This space is equipped with a cast-iron front, having a circular, air-tight front

door. In this interior are the draft appliances—which will be taken up at once.

15. In D (Chart B) we find the smoke-stack that carries the smoke and fumes to the outer atmosphere. But with those gases sparks are also carried —and to prevent this danger a netting is adjusted in the front end, arresting the sparks.

16. Turn now to Chart A and follow the numbers carefully. In Figs. 27 and 28 you will note the edge of the strong metal diaphragm or deflector-plate, extending entirely across the front of the flues. Immediately above the top row of tubes, the upper edge of the diaphragm is bolted to the sheet. At the bottom the plate stands away from the sheet from 20 to 25 degrees. It has been named "deflector-plate," because it "deflects" (turns aside) the onrushing gases and smoke, which must pass under its bottom edge before they gain the stack. From the diaphragm to the top of the front end is the netting, or spark-arrester, Fig. 26.

17. The exhaust stand and exhaust pipes, shown in Fig. 31, are very important factors in draft arrangements. The exhaust pipes extend from the two steam cylinders, carrying the exhaust steam through them. To create a very strong force the exhaust nozzle tips, Fig. 32, are used, the openings being smaller than those of the pipes themselves. Above the exhaust arrangement, note Fig. 36, which is known as the petticoat-pipe. This pipe concentrates the force of the exhaust nozzles, and extends direct into the smokestack. But these draft appliances are for the locomotive when it is running, and very frequently it stands in the yards or at stations, so there is no exhaust steam from the steam cylinders. In the cab of the locomotive is a valve, and

the fireman may turn this and let a jet of steam into the blower-pipe, Fig. 30. This creates a draft—and the draft is necessary to the proper combustion (burning) of the coal in the firebox. But whatever creates, draft is necessary, so in Fig. 29 we find another draft aid in the form of an exhaust pipe from the air-pump, emptying into the petticoat-pipe. There are two steam pipes, of which Fig. 33 is one, connected to the T or nigger-head, Fig. 34. There is a connection with the front end of the dry-pipe, Fig. 35.

18. PASSAGE OF STEAM: Thus far we have considered those features that relate to the firebox, but the purpose of this firebox is to boil the water in the boiler (above the crown-sheet around the sheets of the firebox, and all the space between the flues), thus generating steam. The first operation in liberating the steam is found in the action of the throttle-valve, shown in Fig. 195. It is located high in the steam-dome at the termination of throttle-pipe, shown in Fig. 194. There is a bell-crank, Fig. 196, with which is connected a rod that extends downward from the throttle. The bell-crank's lower arm is connected with a long rod, running back through the boiler and boiler-head into the cab. The engineer operates this mechanism by means of the throttle-lever, shown in Fig. 215. Naturally, there must be no leakage of steam where this rod passes through the boiler-head, and so there is a gland and a stuffing-box, where the rod is carefully packed. In this diagram the throttle is closed.

19. Now, the engineer receives his orders to go ahead, and he pulls back the throttle-lever from the boiler-head, and this moves the long rod back a ways. The bell-crank, Fig. 196, is moved and the

upper arm lifts the throttle off its seat. Steam then enters the throttle-pipe, Fig. 194, passing downward through stand-pipe, Fig. 192, through the dry-pipe, Fig. 191, to the T or nigger-head, Fig. 34, where are steam pipes branching to the two steam chests, one on either side of the locomotive. Fig. 33, Chart A, illustrates one of these pipes. In Fig. 41 is found the cylinder-saddle, a heavy casting to which is connected the steam chest and the cylinder on either side, heavy bolts making the fastening secure. Sometimes they are cast in a single piece.

20. There is conformity of the top of the cylinder-saddle to the curve of the boiler (this is at the front end), and the boiler itself rests on the saddles. Through this casting there is a passageway, connected with steam pipe, Fig. 33. The direction of this passageway is first downward, then horizontal for a short distance, and finally upward to the steam chest, which is represented by Fig. 44. The steam chest rests on the cylinder, Fig. 57. There is a cover, 43, to the steam chest and also an outer shell or casing, Fig. 42.

21. The cylinder is where the actual performance of the tractive duties takes place in the locomotive. Study Chart A and note carefully the various parts of the cylinder. Fig. 47 is known as the balance slide valve that is moved backward and forward on its valve-seat, Fig. 52, connected through the valve-stem, Fig. 49, with valve-yoke 48, by the force of the steam. The balance plate that is directly over the valve is shown by Fig. 46. This plate prevents the steam pressure from keeping the valve on its seat—which would naturally give rise to undue friction. To each end of the cylinder, Fig. 57, there are two steam ports, Fig. 56. In the center of the

valve-seat is the exhaust port, Fig. 54. Through a separate passageway in the saddle casting there is a connection with the exhaust stand in the front end, shown by Fig. 31. The arrows, 53, point out the bridges between the steam and exhaust ports. Screwed into the front end of the steam chest, and acting as a safety valve for the steam chest and cylinder with the throttle closed, and while the engine is "drifting," is the relief-valve, Fig. 45. When the slide valve is in the center of its travel, as it is shown in this chart, steam can not enter at either steam port.

22. In this cylinder, Fig. 57, there are other parts that are necessary in the development and transmission of power. Standing near midstroke is the piston, Fig. 61, fitted with packing-rings, Fig. 62, that conform closely to the bore of the cylinder, prohibiting the steam from blowing past the piston. Fig. 58 indicates the back cylinder-head, and Fig 64 is the front cylinder-head. Fig. 60 is the piston rod. One end is connected to the piston head; the other end to the cross-head, Fig. 96. Packing rings, Fig. 59, inclose the piston rod—and these rings are held by the gland in the back cylinder head, in the stuffing box. Thus, as the rod runs rapidly back and forth there is no loss or blowing of steam past the rod. As indicated in Fig. 50, the valve stem is likewise equipped, at the back end of the steam chest. Great care must be taken in packing any part that might lead to the escape of steam, and this is not simply because of the loss of steam itself. Steam is expansive, and a leak around a working rod would soon lead to trouble—with the head itself blown out, and the efficiency of the engine correspondingly impaired. Keeping in mind that both sides of the

locomotive are similarly equipped we can see how each cylinder is constructed and fitted.

23. A locomotive would be of small value if it would travel in only one direction. It must go forward or backward at the will of the engineer, and to assist him there is a lever close to his hand on the right hand side of the cab that is represented in Chart A by Fig. 217, known as the reverse lever. This lever is held in position by a latch, fitting into notches in the quadrant, Fig. 220. By the dotted lines in Fig. 118 we find the reach-rod that connects the reverse lever with the tumbling shaft lever, Fig. 114. Fig. 113 is the tumbling shaft, and its arm, Fig. 112 extends forward and at right angles to the lever, Fig. 114. The link hanger, Fig. 111, is connected to this arm, the lower end of this link hanger connecting with the suspension stud on the link saddle—a plate that spans the center of the link to which it is bolted securely. The link block is shown by Fig. 108, and this block, as well as the link and link hanger, are all inside the frame. In Fig. 158 is shown the go-ahead eccentric, and Fig. 159 is the back-up eccentric, which are secured inside the frame on the driving axle. These eccentrics impart the swinging, vibrant motion to the link. A rod, Fig. 160, connects the go-ahead eccentric to the top end of the link, and the back-up eccentric is connected to the lower end of the link by means of rod, Fig. 162. These rods (often referred to as "blades") are connected to the eccentric strap from which they receive their motion from the eccentric. These heavy straps are made of two parts and are of heavy cast iron. The parts are bolted together and are bored out to fit the eccentrics revolving within them and giving to them a reciprocating motion.

Fig. 161 is the go-ahead eccentric strap and Fig. 163 is the back-up eccentric strap. From the eccentrics the motion is transmitted to the eccentric rods, connected to the link. The rocker shaft, Fig. 116, moves within the rocker box, Fig. 117, one arm of the rocker shaft extending upward, to which the valve stem rod is connected. The other rocker shaft arm extends downward, connecting with the link block, Fig. 108. The connections are affected by means of steel pins, free to move or rock, and fitted in bored-out bearings.

24. THE OPERATION OF THE ENGINE: Thus far we have dealt in cast iron and steel chiefly, and have observed the patterns of the different parts. But the question, "Why does the locomotive move?" is one that brings before us the essentials of the actual operation. Not only does each part have some special duty, but every part must work in harmony with every other part—must come up to its needs at the right interval, and never fail. With this locomotive speeding over the rails at the rate of fifty or sixty miles an hour the action is too rapid to permit of any experiment—and strength, as well as accuracy, is called for. In the large chart the slide valve, Fig. 47, in the cylinder, admits steam to neither port. It must be moved by hand to one end or the other, and so the engineer pulls the reverse lever down toward the forward end of the quadrant, Fig. 220. What does this do? First, it lowers the link, that then slides down on the link block, to which is connected the lower arm of the rocker shaft. The action of the link moves this lower arm forward, as the link moves down the block, and the upper arm, Fig. 116, is moved backward, bringing

the slide valve with it. The forward steam port, Fig. 56, is then uncovered.

25. This action, just described, would, with the opening of the throttle valve, admit steam to the cylinder so that the engine would operate forward, but it is frequently necessary to back up. To accomplish this end the engineer would push the reverse lever toward the back end of the quadrant. This would raise the link, moving the lower arm of the rocker backward—and the top arm forward, and with it the slide valve. Then the back steam port, Fig. 56, would be opened.

26. The engineer, however, has received orders to go ahead, so he moves the reverse lever forward along the quadrant, opening the forward steam port in the cylinder. He then grasps the throttle lever, Fig. 215, and pulls it out a short distance. This action raises the throttle off its seat, admitting steam to the dry-pipe—through the passages already described—into the steam chests; thence through the ports into the cylinders. Port, Fig. 56, now being opened, steam passes through it to the front end of the cylinder, Fig. 57. The steam pressure, acting on the piston head, Fig. 61, moves it toward the rear end of the cylinder and the area of the piston determines the amount of pressure the steam exercises against the piston head. There is a great weight against the piston in its travels. Let us say that the piston has a diameter of 22 inches; then the area of one side will be 380 square inches. Throughout the piston's stroke we may say that the steam pressure averages 80 pounds to the square inch of surface. Multiply 380 by 80 and the answer is 30,400, meaning pounds, or more than fifteen tons at each stroke of the piston. Perhaps the boiler pressure is 150

pounds, and at the beginning of the stroke there is this much pressure on the piston, but as the piston moves, the slide valve also moves. When the piston has reached the middle of its stroke the travel of the valve is completed, and has reached the point where it cuts off the admission of steam to the cylinder. The expansion of steam must be depended upon, therefore, to carry the piston the balance of its stroke. By the time the stroke is finished the pressure in the cylinder has dropped noticeably below 80 pounds, averaging the pressure against the piston at about 80 pounds throughout the stroke.

27. Now, we have found how the piston operates; what the steam does toward creating definite mechanical motion. As the piston moves it also pushes the cross-head, Fig. 96 in Chart A, and this cross-head pushes the main rod, Fig. 92, its front end being connected to the cross-head, and the back end to the crank pin on the forward driver. In Fig. 152 we see the side rod, or parallel rod, that connects this crank pin with that on the rear driver. Both driving wheels are actuated by the piston's travel at the same instant, revolving harmoniously. When the piston has reached the end of its stroke near the back of the cylinder, the crank pins and rods have likewise reached the rear with the centers of the piston rod, cross-head pin and crank pins forming a straight line. This is known as a "dead center," and in this position it would be impossible for the steam to exert any pressure on them, that would transmit motion. Right here the exhaust occurs. The slide valve has now moved forward, opening the forward steam port, Fig. 56, as well as exhaust port 54. The exhaust steam passes under the valve,

through the exhaust passage, through the exhaust nozzle, and out of the stack.

28. We can see that—with the engine operating—it is necessary for the cylinder to be completely exhausted of the old steam before new steam is fed in to the opposite surface of the piston. When the piston completes its forward stroke the exhaust steam in the back end of the cylinder escapes through the back steam port, Fig. 56, under the valve to the exhaust, Fig. 54.

29. Speed is always a factor in the operation of the engine and its parts. While running fast the dead-center condition obtains for too small a fraction of a second to easily compute, but when a train is being gotten under way, or is climbing a grade, this central position remains longer. Were there only one engine, or were both set the same, it is plain that the locomotive would frequently be caught on the dead-center, but provision has been made to guard against this. The crank pins of the engine on the other side of the boiler are set quartering—or at an angle of 90 degrees, as compared with the opposite engine. Keep clearly in mind that the "engine" is not the entire locomotive, but that part which utilizes the steam, causing the piston rod to travel and transmit its motion to the drivers; together with other necessary parts, which we have covered. Hence, an ordinary simple locomotive, such as the one under consideration, has two engines.

30. The engine we are studying in Chart A was, as we mentioned before, just ready to be started. Hence, the piston head of that opposite engine was at the extreme forward termination of its stroke. The crank pins pointed directly forward, in line with the cross-head pin and center of the piston rod. In

other words, the opposite (left-hand) engine was on dead-enter. As the right-hand engine moved and the drivers turned, a like movement took place in the left-hand engine and drivers. By the time the left-hand crank pins were on the lower quarter and the piston was near the middle of its stroke, with the full steam pressure acting on it, the right-hand engine was at the dead-center. Then the right-hand crank pins were up—past the center—the slide valve has moved so that it has opened the back steam port, Fig. 56, with steam entering the back end of the cylinder, ready to move the piston toward the front. Then dead-center again occurs, but the left-hand engine is past the back dead-center, on the top quarter, and exercises its full pressure, insuring continuous operation.

31. Inventive genius can provide against many things, but even the most skilled designer has to stop short occasionally and admit that the "human element," or the engineer, counts for considerable. Suppose, by way of illustration, that the locomotive should meet with an accident, and that there should be total disability of one side—such as the left-hand engine. The right-hand engine is working properly, and so long as the locomotive is in motion, the momentum (weight plus speed) will always carry that engine over the dead-center. But if the engineer, in stopping, should permit his engine to pause on dead-center, he can not move it by steam power. He must either use a pinch-bar, or have another locomotive supply the force.

32. We have been studying Chart A in this discussion of the locomotive, and we mentioned that this was an eight-wheel locomotive. It has four driving wheels and four truck wheels. A ten-wheel

engine would have six drivers—three on each side—and four truck wheels. Where there are six driving wheels there must be an additional side rod; with eight drivers, there must be two extra side rods on either side.

33. While the frames may not appeal to the student as particularly interesting, a few words may be said about them, the locomotive frame is separate from its firebox, boiler and engines. It is made of bars (although plates are used in England and some other countries), which must be perfectly rigid. In a word, when the locomotive rounds a curve the frame forms a tangent to the curve. It does not bend. And where there are more than four driving wheels (two on a side), the centrally located drivers may be "blind," which means without a flange, so they will slide on the rail and prevent undue stresses. The frame must withstand the work done within the mechanism, as well as the unevenness of the rails, defects in the roadbed, and so on.

34. Instead of having a four-wheel forward truck some of the large engines have "pony" trucks of only two wheels. All drivers have tires of steel, which are shrunk onto the wheel proper by slightly heating the tires and dropping them over the wheel. In cooling they shrink and become rigidly fixed. When the tires have worn to any considerable degree they are turned—trued up in a large lathe.

QUESTIONS.

The following are test questions—not examination questions. They are simply reminders—and the number of each question corresponds with the paragraph number in the preceding text where the instruction covers the point or points involved:

1. What are the three chief features of a locomotive? What functions must the locomotive perform? What conditions affect it?

2. What conditions have dictated the size, shape and material of various parts of the locomotive? What is expected of its frame? What two duties, above all others, must be met by the locomotive?

3. How should the student engage in a study of the locomotive? What is the difference between reading and study?

4. How many divisions are there to the boiler? Name them.

5. What is the prevailing shape of fire boxes? What is the thickness of the metal used? Name the parts of the firebox. What is the water-leg? Of what use is it? What is at the bottom of the water-leg? What precautions had to be taken in firebox construction—and why? How are the plates fastened? Describe the method.

6. Explain the requirements of the steam generating part of a locomotive. What are stay-bolts and how are they used?

7. What is the crown-sheet? What methods are employed for strengthening this crown-sheet?

8. What are crown-bars and how are they used? How are they supported? What method of fastening is used? Describe it.

9. What construction is required to meet the changes when a locomotive runs down grade?

What must be done to boiler-heads? How far does the boiler extend?

10. How is the boiler-head strengthened?

11. Describe the flues. What are the sheets at both ends of the tubes? How much of the space in the barrel does the tubing take up?

12. How are the flue-sheet and back boiler-head braced?

13. What provision is made for more steam space? Describe it. Why is this space placed as it is? What else are also located in the same space?

14. What is in the front end? How is this space equipped?

15. What precaution and disposition concern the smoke and gases?

16. What is the deflector-plate? Describe its purpose, position and location of the spark-arrester.

17. What equipment is used to take advantage of the exhaust? Where are these placed? What pipe extends direct into the smokestack? What provision is made to force the draft while the engines are idle and the locomotive is standing still? Is anything else used to help create a draft? If there is, describe it.

18. What is the first operation in liberating the steam that has been generated—and that is to be used to propel the machinery? What is the bell-crank? How does it operate? How is leakage of steam prevented?

19. When the engineer receives orders to go ahead, what does he do? Then what operation occurs? Trace the steam to the cylinders. What is the cylinder-saddle?

20. Upon what does the boiler rest? What passageways are drilled through this casting? What is

their course? What is the relationship of steam-chest to cylinder?

21. Where does the actual performance of work occur? What are found within the cylinder itself? How is the pressure of steam prevented from holding the slide-valve to its seat? Why is this necessary? Where is the exhaust-port? Where is the steam-port? What separates them? What device is used when the locomotive is drifting—and where is it located? What position of the slide-valve prevents steam from entering either port?

22. What is the piston, and what is used so that steam does not escape around it? How many cylinder heads are there? What is connected direct with the piston? What method of packing is employed? Why must great precautions be taken to prevent escape of steam?

23. What lever is used in making the locomotive back up? How is it held in position and across what does it move? Name the parts that connect this lever with the reversing mechanism and gearing. How many eccentrics are there? Describe the connections. Describe how the motion is transmitted. What is the rocker-shaft? How are connections made?

24. What does the engineer do when he wishes to have steam enter the cylinder? Trace the action involved from the reverse-lever to the slide-valve.

25. Suppose the locomotive is to back up; what does the engineer do to bring this about? Show the action involved.

26. The engineer receives orders to go ahead. What does he do first of all? What is the next lever he grasps and what does he do with it? What does this bring about? Where does the steam now

go? Show how the steam passes into the cylinder. What action does the steam then have? Tell something about the weight against the piston. Is this pressure equal throughout the piston's travel? Suppose there is a boiler-pressure of 150 pounds to the square inch, and the diameter of the piston is 22 inches; what is the first pressure exerted and on how many square inches? Then what pressure does the steam exert? Where is the piston in its travel when the slide-valve has completed its travel? What does the slide-valve then do? Upon what does the piston depend to complete its travel? How does this concern an average pressure?

27. As the piston moves what motion does it impart, and what mechanism has been devised to use that motion? How does the power move the driving wheels? Describe what is meant by dead-center, telling the position of each part during dead-center. What becomes of the exhaust steam?

28. Why is it necessary for the cylinder to be completely emptied of old steam before new steam is admitted? When the piston completes its forward stroke, what occurs?

29. What is a big factor in the operation of the engine and its parts? What is the effect on the dead-center? When is the interval of the dead-center most noticeable? Why does the locomotive not stop entirely when dead-center is reached? What is really meant by the term "engine?"

30. With the engine just ready to be started—meaning the one on the right-hand side of the locomotive, what was the condition in the engine on the left-hand side? Now, as the right-hand engine moves, what occurs in the left-hand engine? What

is the position of the parts in the left-hand engine when the right-hand engine is on dead-center?

31. If one engine is out of commission, what must the engineer guard against? What happens if he does not succeed?

32. What is meant by an eight-wheel engine? What is a ten-wheel engine? When there are six driving wheels, how are they connected; what are the connections with eight driving wheels?

33. In a few words, tell what the frames are—what they are for. Are they flexible or rigid? Why? What occurs on curves? Suppose there are several driving wheels; what provision is made to keep their flanges from binding on the rails as the locomotive rounds curves. What stresses does the frame have to withstand?

34. Do all locomotives have four wheels on the front truck? What is the other kind of forward truck called? What kind of tires do driving wheels have? How are they put onto the wheels? What is done with tires as they wear?

OPERATIONS IN THE CAB.

35. Thus far we have been looking at the mechanical construction of the locomotive. We have studied its skeleton, and have noted the action of the gears, the piston, etc. But back in the cab where the fireman and engineer work there are many appurtenances, or appliances, that help these men do their work. Some of these appliances are automatic; others are partly automatic. But all of them require the strictest attention on the part of both fireman and engineer, because every moment, as the locomotive speeds over the rails, it meets varying conditions. Its rate of speed, its load, grades, curves, stops—all these things dictate largely what the men in the cab must do. There are two main factors in making a locomotive operate; and these are fuel and water. Sometimes the fuel is coal and sometimes it is petroleum, but the coal-burners are by far the greater in numbers. As the locomotive is moving out of a station and accumulating speed, the fireman must keep adding coal—frequently and in small amounts—for the drafting arrangements tend to tear the fire to pieces and leave bald spots in it. When the locomotive has reached a good rate of speed, the engineer then hooks the reverse-lever back near the quadrant's center, shortening the travel of the slide-valves, and lessening the "cut-off."

36. What is meant by the cut-off may be explained as follows: When the engines are being started the steam is permitted to enter the cylinder while the piston is traveling a large part of its stroke, but with the reverse-lever up toward the center of the quadrant the steam is cut off by the slide-

valve when the piston has traveled a fourth or a fifth of its stroke the steam then expanding until the stroke is completed. By the time the steam has reached its lowest pressure and the piston is at the end of its stroke the steam exhausts.

37. When the locomotive is speeding along as we have thus explained the fireman scoops in about two shovelfuls at a time, always waiting till the black smoke has cleared from the stack before shoveling in more coal. He places the coal on the brightest spots, because that is where the fire is thinnest, because of the sharp exhaust. The fireman is also cautious about closing the door as soon as he has placed coal in the firebox. The cold air, rushing in above the fire, has a bad effect on it.

38. In our study thus far we have seen that in the front end of the locomotive there are various draft appliances to utilize the exhaust steam and exhaust air so that the blast from the stack will be sharp. This leaves a vacuum, creating suction. Hence, the air and whatever it carries, such as gases, must be supplied through the tubes—and as the tubes connect with the firebox, it follows that from somewhere in the fiebox the air must come. Fig. 139 is the ash-pan, and through this the air rushes, coming up through the grates upon which the coal rests. Sometimes the supply of air is too great or too little, because the oxygen in the air is what supports the combustion of the carbon and volatile gases in the coal. There must be a proper mixture of these elements, and dampers are provided in the ash-pan so that the fireman can regulate the amount of air fed into the firebox. Fig. 228 is the damper-handle, which is convenient to the fireman. The rocking grates are illustrated in Chart A by dotted lines,

Fig. 165, which are near the bottom of the firebox. The grate-shaking rig is shown by Fig. 164. The lever extends up into the cab on the fireman's side. Occasionally he shakes the grates, breaking up the clinkers and clearing them of obstructing ash, all of which fall into the ash-pan, which may be cleaned at the first considerable stop the locomotive makes.

39. While the fireman is attending to his duties the engineer has many things to look after. He carefully watches the water-gauge glass, Fig. 251, and tries the gauge-cocks, Fig. 219, so that he may ascertain the height of the water in the boiler. Should the water get lower than the crown-sheet the addition of more water would likely cause an explosion, because the water coming into contact with this hot metal would turn into steam immediately, causing vast pressure. If the water gets too high or if there are foreign substances, such as minerals in the water, it is apt to foam; that is, froth up. When this occurs there is danger of "priming," which is the carrying of unevaporated water up through the steam dome, down the dry-pipe, into the steam chests and cylinders, which cuts out the lubricants in the cylinders, and is apt to break a piston or knock out a cylinder-head. But let us also remember that within the boiler there is a steam pressure of perhaps 150 to 200 pounds to the square inch. Water that is put into the boiler must be forced in against this tremendous pressure.

40. The device employed for the purpose of forcing water into the boiler is known as the injector, Fig. 179, in Chart A. There are usually two of these on a locomotive, so that should one become disabled during a trip the other will be ready for use. One is usually located on the fireman's side; the other on the

engineer's side—within the cab. Water from the tank comes up through pipe, Fig. 181, and steam is used to force this water into the boiler, the velocity being so great that it overcomes the pressure exerted against it. The water and steam (the steam then becoming condensed) are forced into the boiler through branch pipe, Fig. 119, that connects the injector with the check-valve, Fig. 121, that is near the front end of the boiler. The steam used in the injector comes from the steam-turret that is found in Fig. 209. It travels through the injector-throttle, Fig. 210, and steam-pipe, Fig. 182. The engineer usually leaves the injector-throttle wide open, starting the injector, as he wishes, by using steam-valve, Fig. 183.

41. Let us say the engineer has determined that more water should be injected into the boiler. He now opens the primer, Fig. 184, about a quarter of a turn. A reduced blast of steam now passes through to the overflow, Fig. 180. The engineer next opens the water-valve, Fig. 185, that is located immediately below the primer. The steam passes across the space so rapidly that a vacuum results in water-pipe, Fig. 181. The feed-pipe, Fig. 236, and the feed-pipe hose, Fig. 237, complete the connections between the injector and the tank on the tender. The vacuum, or suction, now lifts the water from the tank, and the water flows up through the hose and pipe into the overflow, Fig. 180. The moment the water appears at the overflow the engineer opens steam-valve, Fig. 183, feeding the water into the boiler. Were it not for the check-valve, Fig. 121, the water from the boiler would pass out into the branch-pipe, Fig. 119, the moment the injector ceased operation. Usually the water in the tank is kept warm by steam

from the boiler so that its temperature is not so low that it will greatly chill the boiling water within the boiler.

42. It is necessary for the fireman and engineer to know how much steam the boiler is carrying; that is, its pressure to the square inch. For this purpose we find the steam-gauge, Fig. 208, having a dial face, not unlike a clock. The numbers begin at zero and extend up to 250 or 300, each figure representing one pound of pressure to the square inch. The principal part of this gauge is a thin tube, curved and flattened and closed at either end; and enclosed within the case that has the dial on its exterior. Both ends of this tube are free to move. Small levers and arms connect these two ends with a geared rack and pinion, moving the pointer with the movement of the ends of the tube or the spring. About half way the length of this curved tube there is a connection with a small bent pipe that communicates with the steam space in the boiler. The reason for the bend in this small pipe is so that it may be filled with water and prevent the steam from having direct contact with the curved tube. The pressure, increasing in the boiler, seeks to straighten this tube, the movement communicating with the geared rack and pinion—causing the pointer to move across the dial's face, indicating the actual pressure to the square inch in pounds—and showing precisely what the pressure is on every square inch of the inside of the boiler, the various pipes, the steam-chest and the cylinder at the beginning of the travel of the piston. There is a slight loss in this pressure by the time the steam has reached the cylinder, because the metal, the outside air, the speed of the locomotive, etc., bring about an escape of heat through radiation.

43. There is another gauge in the cab to indicate the air-pressure, and this has two pointers and two sets of numbers on its dial. It is known as a "duplex" gauge, showing two varieties of pressure—the red hand pointing to the pressure in the main reservoir and the black hand showing the air-pressure in the train-pipe. With the exception that the pressure is compressed air instead of steam, the action of the air-gauge is the same as that of the steam-gauge.

44. Now we shall take up the matter of lubrication. When metal parts are rubbing against one another rapidly, such as the pistons in the cylinders, there must be plenty of oil, or else the parts would run hot and cease operating altogether. Turn to Chart A and find Fig. 224, which is the lubricator that is attached to the boiler-head inside the cab. This distributes oil to the pistons, valves, air-pump, cylinders, etc. On the engineer's side, in front of the cab and attached to the boiler itself, is the air-pump. On top of it is a steam-cylinder. Fig. 176 is the steam-pipe that leads to it. To this pump, fed a drop at a time, oil passes through the small pipe from the valve, Fig. 206, that connects with the lubricator. From the valves and pistons the passage of the oil is through the oil-pipe, Fig. 123, extending to the steam-chest, there being two oil pipes—one for each side. These pipes are beneath the jacket of the boiler, so that the oil will be kept warm; and the supply is regulated by the fireman, as it is required.

45. Control of the compressed air that operates the air-brakes is made possible by the engineer's brake-valve, Fig. 218, in Chart A, and which is convenient to the engineer. In Fig. 99 is the main reservoir, or air-drum, constructed of boiler steel, and strong enough to withstand a pressure of 180 to 200

pounds to the square inch. The actual pressure seldom goes above 90 or 100 pounds. As soon as it reaches that point the governor, which regulates the air-pump, stops the pump as soon as the pressure is about 90 pounds to the square inch in the main air reservoir. From the air-cylinder through pipe, Fig. 100, the air-pump forces air to the main reservoir. This cylinder is the lower one shown. The train-pipe connection is found in Fig. 101, leading from the main reservoir back to the engineer's brake-valve; the air passes thence to the train-pipe, Fig. 231, this latter pipe leading from the brake-valve beneath the cab, through train-pipe hose, Fig. 232, to the train-pipe beneath the tender. Connections by hose are made to the first car and between all the cars, no matter how many there may be.

46. An auxiliary reservoir is located beneath each car, having direct connection to the train-pipe and always kept filled with compressed air of about the same pressure as that in the main reservoir. When the engineer sets the brakes the compressed air passes from these auxiliary cylinders into the brake-cylinders. A triple-valve is also located beneath each car with connections to the train-pipe, the auxiliary reservoir and the brake-cylinder. There is a piston in each brake-cylinder, its rod being connected to the brake-levers. The piston moves outward under the air-pressure, the brake-levers are moved and the brakes are set on each car at the same moment. Setting the brakes is caused by the movement of the brake-valve handle by the engineer to Application position; the brakes are released when he moves the handle to Release position. The Release position stops the flow of compressed air into the brake-cylinder, the triple-valve automatically per-

mitting the air to exhaust from that side of the brake-cylinder piston. Then air, at a lower pressure, flows into the other end of the brake-cylinder, pushing the piston back to its original position before Application, or Running position, with the brake-shoes not in contact with the wheels. When the train is under way the brake-valve handle is always in Running position. Each time the brakes are used the compressed air supply has been diminished and the air-pump again starts, supplying the deficit in the main reservoir which, through its connections, has fed compressed air to the auxiliary reservoirs to the brake-cylinders. The pump operates automatically. There is always a reserve supply of air in the auxiliary and main reservoirs. It is necessary that the brake-shoes should not press on the wheels at any other time than when the brakes are applied, and so the pressure against the opposite side of the piston in the brake-valve is maintained continuously. When the engineer makes an application this pressure is reduced, the pressure in the brake-cylinder is increased and the brakes are set.

47. Now the locomotive itself must have independent brakes, and in Chart A you will notice that outside the cab and beneath the engineer's seat, Fig. 242, is the engine brake auxiliary reservoir. Connected with it, Fig. 241, is the engine brake triple-valve. These operate the driver brakes, Fig. 140. The engine truck brakes, Fig. 86, are operated also, the connections being to the truck-brake cylinder, Fig. 243, and to the driver-brake cylinder, Fig. 244. Fig. 140 covers the driver-brake cylinder, the brake-lever, brake-rod, brake-shoes.

48. There are many small steam connections necessary to operate the various appurtenances,

such as the air-pump, the injectors, lubricator, etc., and to supply this steam there is provided steam-turret, Fig. 209.

49. The engineer must control the cylinder cocks, Fig. 68, located underneath the cylinders. He uses the lever, Fig. 223, that extends up to the cab, for this purpose. Part of this equipment is lever, Fig. 69. In Fig. 211 is found the blower-valve, located inside the cab so that the fireman can turn steam into the blower when the engine is standing, and more draft is required.

50. Many times it is necessary for the engineer to receive communications from the conductor who may be in any car of the train. For this purpose there is provided a small whistle located near the boiler in the forepart of the cab, and this is operated by compressed air, a code of signals being employed. The whistle is Fig. 213, and its valve, Fig 229.

51. Through air-pressure the bell-ringer valve, Fig. 246, automatically rings the bell. The compressed air passes through the valve into the small cylinder of the bell-ringer, and the bell continues to ring until the valve is closed. Note, Fig. 133, which is the bell-ringer. Fig. 247 is the pipe through which the air passes from the valve to the ringer.

52. The air-pump governor is shown in Fig. 177 on Chart A, the air passing through the pipe, Fig. 248, that connects with the train-pipe connection, Fig. 101, located in the cab. The governor regulates the speed of the air-pump.

53. In Fig. 175 we find the exhaust connection for the air-pump. A pipe, Fig. 168, follows the running board connecting the pump with the front end of the steam-chest, which it enters in front and

above. Within the smoke-arch, Fig. 29 represents this pipe, showing where it leads up to the petticoat-pipe, as previously explained; its purpose being to add to the draft.

54. Occasionally where there are steep grades or heavy loads—or both—it is necessary to couple engines "double-header," and for this purpose there is a pipe, Fig. 103, located beneath the boiler and near its front end, branching off from the main train-pipe near the air-pump, and continuing to the pilot. Hose, Fig. 5, connects this train-pipe with the air-brake pipe on the tender of the forward locomotive, the air passing back to the train. The air-brakes are then always operated by the engineer in the front locomotive. Operated in this fashion cut-out cock, Fig. 55, is opened, but when the locomotive is operated singly, it is closed, except when an engine is coupled to a train from the rear, pushing it, as in switching—or pulling it, tender foremost. The train-brakes are then operated through train-pipe, Fig. 103.

55. Other details are: Cock, Fig. 84, and Signal hose, Fig. 4, connected to the front end of the locomotive, for air-signalling purposes. Figs. 66 and 67 illustrate the cylinder lagging and casing that retain the heat within the cylinder. A washout plug, located near the front end and on the bottom of the boiler, is shown in Fig. 104. Boiler lagging, which is generally of asbestos, and the object of which is to prevent escape of heat from the boiler by means of radiation, will be noted in Figs. 126 and 127.

56. When the rail is "bad," meaning covered with frost or slippery, it is necessary to have the track sanded, so the drivers will grip the rails. On Chart A is found the sand-box, Fig. 134, and the

sand-pipe, Fig. 136, connects the sand-box with a point preceding the front driver and just above the rail. Fig. 135 is the sand-lever, operated by the engineer in the cab. Fig. 240 are counter-balance weights, secured within the rims of the drivers, thus counter-balancing, or offsetting and equalizing the weights of the crank, crank-pins, connecting rods, etc. Fig. 188 represents radial stay-bolts extending within the boiler to the crown-sheet for support—and Fig. 189 shows the sling-stays. There is a cut-out cock, Fig. 245, on the truck-brake air-pipe, so as to shut off air from the truck-brake when it is not needed. The pilot-brace is found in Fig. 254.

57. Now we have seen that the locomotive is a truly complicated machine, having mechanical operations all its own, and also moving over a great space in a short time. Time and hauling power are the two purposes that the locomotive meets. Its air-brakes give the engineer control of the train, not alone in stopping, but in rounding curves, and when an emergency arises he can place his brake-valve handle over to the emergency notch with high pressure thrown against the brake-shoes.

58. How much can a locomotive haul? Its weight will tell us that. Let us say that the locomotive and tender have a total weight of 400,000 pounds, of which 300,000 pounds is carried on the driving-axles. This is the weight that counts in hauling, for the drivers must grip the rails and thus propel the train. Now, with a rail in ordinary condition, the engine can pull about one-fourth the number of pounds that rest on the drivers, sometimes a little more, and again a little less, depending on the rail condition. Hence, in the case we have cited the locomotive could haul about 75,000 pounds, possibly at a rate

of fifty miles an hour on a level track. There may be fifty cars in the freight train, and perhaps about 1,200 pounds will be required to get each car under way at this high rate of speed. Fewer cars, calling for less tractive or hauling force, could be pulled along at a greater speed.

59. There is always a great deal of friction within and outside that tends to stop the speed and detract from the tractive force of a locomotive. Internal friction is partly overcome by lubrication, but the pressure of the train against the atmosphere also not only tends to retard its progress, but also absorbs considerable of the heat from the locomotive. The vestibuling of trains was brought about largely to reduce this atmospheric friction, so that the air could not get in against the ends of cars. Naturally, freight trains can not be vestibuled. The friction of the flanges on the rails at curves, also slows up trains considerably, so that the locomotive is fighting continuously against conditions that would stop it. The force of gravity itself is one of these.

60. The condition of water is likewise a factor in locomotive operation. What we would call perfectly good—even delicious—water may be unfit for the boiler, because of its minerals. These sometimes cause foaming and priming, and usually leave a scale, or hard deposit, that gathers around the staybolts, and tends to force them from the sheets and loosen them—or that collects on the crown-sheet, separating it from the water. This looses a great deal of heat, and also blisters the crown-sheet. Hence, boilers must be washed out frequently, and special devices are installed in Round-houses for this purpose. About three-fourths of the cost of repairs

on locomotives may be checked up to the boilers. We have now seen that a locomotive is a vehicle, because it moves along on wheels. It is a steam-generator, because it burns fuel and boils water, changing it into steam. It is a steam engine because it uses that steam for driving machinery.

QUESTIONS.

The following are mind exercises—not examination questions. Each question number will be found to correspond with the subject covered in the preceding paragraph number:

35. What must fireman and engineer have to assist them in controlling the locomotive? What two chief factors are concerned with the actual operation of a locomotive? Where and how and why does the fireman put coal into the firebox? What does the engineer do when the locomotive has attained a good rate of speed?

36. Describe what is meant by the cut-off. When the reverse lever is hooked up near the center of the quadrant, what action takes place in the cylinders? What becomes of the steam still enclosed in the cylinders?

37. What rules does the fireman observe in firing when the train is making speed? What precaution does he always exercise—if he is a capable fireman?

38. What do the draft appliances in the front end do? Where does the air come from? Explain why there must be control of the air supply. How does the fireman control this supply? What attention does he pay to the grates? When are the grates dumped?

39. Name some of the things the engineer must look after in addition to keeping a lookout on the

track ahead. What shows him the height of the water in the boiler? What may be said about the height of the water? What dangers lurk in both too high and too low a water level? What pressure must be met and conquered in introducing a new water supply into the boiler?

40. What device is used to force water into the boiler? When the engineer decides it is time to have more water in the boiler, tell what he does, and follow the action through the several parts of this device.

41. Explain how each part of the injector works. What is the check-valve?

42. How do the fireman and engineer know how much steam pressure the boiler is carrying? Explain the principal parts of this device. Describe its operation. Is the pressure in the boiler identical with that on the pistons in the cylinders? Why?

43. What other gauge is there in the cab? How does it operate and what does it show?

44. How are the working parts oiled? Give a brief description of this device. Describe its operation.

45. What is the engineer's brake-valve? Describe the various parts of this system.

46. With what is each car supplied for braking purposes? How is the air applied and what occurs in each part? How is it released and what takes place? What is Running position? What occurs each time after the brakes have been used? When an application is made what becomes of the brake-pipe pressure?

47. Describe the braking system used exclusively on the locomotive.

48. What is the steam-turret and its value?

49. How are the cylinder-cocks and blower operated?

50. How does the conductor communicate with the engineer while the train is in motion? Give a brief description of this device.

51. Describe the automatic bell-ringer and its operation.

52. What connections are there to the air-pump governor?

53. Trace the exhaust connection of the air-pump.

54. If the locomotive is to be run double-header, what air connections are made? Which engineer operates the air? What is the cut-out cock for and how is it used?

55. Explain some of the other parts of the locomotive. How is the radiation of heat in both cylinders and boiler reduced?

56. Of what use is the sander and what are its parts? What are the counter-balance weights and what is their value? How is the air shut off from the truck-brake?

57. What facts are true in general about a locomotive? How does the engineer stop the train in case of an emergency?

58. How does a locomotive perform the function of hauling loads? What part of the weight counts, and which portion of the locomotive bears this weight? Suppose there is a total of 300,000 pounds on the driving wheels, how much of a load can a locomotive haul? Does this ratio ever vary?

59. What kinds of friction tend to retard a locomotive? How is this friction partly overcome?

60. What may be said about the effect of water in the boiler? What is done to minimize this effect? How much of the repair cost of a locomotive is

usually checked off against the boiler? Again name the three things that a locomotive really is—and why?

EXAMINATION QUESTIONS.

The following questions are designed to test the advancement the pupil has made in his study of the facts contained in these lessons. The value of knowledge is in being able to think out conditions and, therefore, in the following questions the brain power of the student is put to the test. The answers should be written in ink on one side of the paper, and should be made as clear in their description as possible. Use as much space in answering as you think the reply merits.

Question 1. The engineer has started on his run and a fair rate of speed has been attained. He knows that he will need a great deal of steam and he wants to get the most value out of it because that will save money for the company, as well as time and labor for himself and the fireman. Now, tell what the engineer does, then trace the result of what he does through the parts of the locomotive concerned, and explain how and why the steam is economized.

Question 2. From the time the fuel in the firebox begins to burn trace the effect and action of draft (telling what creates the draft), the effect of the draft on the fire, the source of the air supply and its control, and the passage of the heat and hot gases.

Question 3. There are two engines to a locomotive—one on the right-hand side and one on the left-hand side. The locomotive is in motion—going forward. The drivers make one complete revolution. Explain the several positions of the gears during this revolution, and trace the dead-centers, at the same time describing what position the gears and slide-valve have on the opposite side.

Question 4. There are certain parts to the air-brake system. Name them and show how they are connected. Now the engineer desires to stop the train. What does he do and what follows his action? After the train is stopped what does the engineer do, and what occurs in the several parts of the air-brake system?

Question 5. We assume the locomotive is running along at a fair rate of speed. Tell how the engineer knows there is need of water in the boiler. He has a certain device near his hand to put that water into the boiler, and he does certain things. There is a chain of operations in the mechanism itself and the water takes a certain course. Tell all about this entirely in your own words.

Question 6. The locomotive is going down a steep grade. What relation is there between this grade and the water in the boiler, and what provision has there been made to overcome the results? What would the results be otherwise?

Question 7. Fuel costs money and firing calls for much physical labor and skill. But apart from what the fireman can do there is still a loss of heat. There is also a loss of power. Explain where this heat and this power are lost, and what has been done to try to prevent that loss.

Question 8. Sometimes the locomotive at the head of the train has another coupled to and immediately ahead of it to assist in pulling the train. How are the air-brake connections made with this other locomotive, and which engineer operates the air-brake system.

Question 9. The locomotive is traveling forward and in order to prevent running into a team that is crossing the track the engineer puts on the emergency brakes. At that instant the left-hand engine breaks down. What must the engineer now look out for in addition to the obstruction—and why?

Question 10. There is frost on the rails and the engineer suddenly sees an open switch. What he does must be done rapidly. In your opinion what should he do? Think carefully and give your reasons for each operation; also tell what you believe occurs as he performs every duty.

LESSON II

DUTIES AND QUALIFICATIONS
OF
LOCOMOTIVE FIREMEN

LESSON II.

DUTIES AND QUALIFICATIONS OF LOCOMOTIVE FIREMEN.

FOREWORD.

First of all let us understand that the railway fireman must be physically fit to engage in these duties, which are filled with many hazards. He must be sound of body and mind, and all of his faculties must work properly. His eyes must detect the different colors and his ears must be keen enough to catch the different sounds. Any young man suffering from physical incapabilities would not be able to pass the physical examination imposed by the different railway companies upon their firemen.

Any young man who seeks a position of this nature should bear in mind that he is working for something more than the liberal pay he receives. He should consider his position the most important on the road, and simply because he is one of a great many thousand employes, this should not be any excuse for him to shirk his duty or neglect his education. The individual who can do a thing a little better than anybody else may rest assured that he will be promoted.

The fireman should always keep in mind that just as the boy is father of the man, so is the fireman father of the engineer. In other words, every engineer was a fireman, and the better a fireman a man is the better engineer he is going to be.

THE FIREMEN'S QUALIFICATIONS AND DUTIES.

NOTE—The paragraphs of this section are numbered, and at the end of the section are questions which the fireman should be able to answer correctly. If unable to answer off-hand, turn to the paragraph number that corresponds with the question number to find the correct answer.

1. Before the man who works for a large corporation there is ever present a great temptation to consider himself only one of innumerable thousands. This is particularly true of railway employes, not merely because of the vast endeavors of modern railroading, but because the men themselves, from necessity, are ever in charge of different equipment. And yet, if each man were to give the mechanism under his temporary charge the best of care, the result would be of untold benefit to the company, to the transportation business and to the employes. The man who does his best at all times betters himself far beyond the contents of his pay-envelope. No work is menial; no task unworthy. Men who dug a ditch better than other men found themselves steadily progressing. They did their best, and they got into the habit of always doing their best, which is, after all, the big thing in individual progress. Mr. G. M. Basford, formerly editor of the American Engineer and Railroad Journal, and

later an executive of the American Locomotive Company, said, during an address before the Mechanical Engineering Society of Purdue University: "There is no field of mechanical work so full of opportunity as this, and much depends upon those who are now fitting themselves for the leadership of tomorrow. These leaders may now be in the ranks, but wherever they are their preparation must be thorough for their work is to be great, and it will grow to be still greater." He said further: "A young man makes his record by the work he does. He should seek opportunities to do things that somebody wants done. In that way, he attracts attention, first to the things he does and the way in which he does them, and second, to himself because of what he does."

2. It has been truly said that as the boy is father of the man, so is the fireman father of the engineer. The fireman has charge of the operations in railroading that mean the highest expense, with the single exception of the pay-roll. The fuel proposition is a big one, and while the individual waste caused by one careless fireman might not affect the company to any considerable degree, the aggregate of loss through carelessness climbs into millions. Each fireman should consider it his special duty to do his best—and not to slip up on his obligations simply because he knows other firemen who have that fault. It has been said that "firemen are born—not made," and while this is relatively true, every art can be cultivated—because firing is an art, founded on very definite commercial truths. Good firing means greater fuel consumption, or performance, and better work for the locomotive. Poor firing means pouring out, in the form of gases and smoke, a wealth of unconsumed fuel, particles that constitute the railway's greatest loss.

3. The fireman faces certain contingent duties from the moment he steps into the cab. He is not simply the means toward keeping the engine steaming properly, but he is also the deputy of the engineer, and at all times he must be able to temporarily take the place of the engineer in event some accident disables his chief. Again, the fireman faces stringent physical requirements. His muscles must respond to his mind. This is impossible with intemperance. The nice combination of physical fitness and mental grasp is what makes firemen good, and brings them the more readily to the coveted position in the right side of the cab.

4. While performing his own duties properly, the fireman should also be educating himself, which means through learning what human experience has taught about every detail of his vocation, and through acquiring knowledge relative to the performance of the locomotive at every stage of its travel, under all conditions, by day and by night. The fireman who balks at "book learning" because it presents "too much head work," would better bear in mind that the brain, like the body, grows through cultivation—through exercise, and beyond this is the fact that the world pays little for physical perfection, but very much for mental ability.

5. Briefly the fireman's duties are as follows: He must be at his post in sufficient time before starting to make such disposition of the fuel as conditions and rules dictate; he must see that the oil cans are filled and ready for service; he must care for the proper building of the fire; he must have his engine clean; he must be sure that the supplies for the trip are in their proper places; he must be sure that flags, lanterns and other signals are on hand; he must take care to see the lamps are trimmed; he must make certain

that the ash-pan is clean, that the necessary tools are on hand for caring for the fuel and fire; that water-tank and sand-box are full; that no delay is occasioned in taking water on the road; that cinders and clinkers are removed from the grates and the ashes cleared from the pan, when stops are made at coaling stations; that the fire is kept up to the standard of the engine's requirements; and that the fuel is utilized so as to secure the greatest amount of heating qualities it possesses; and in addition to all this, the fireman must ever be on the lookout for signals, and must always make prompt reports to the engineer of anything the latter should know.

6. It is well for firemen to bear in mind that there is a growing tendency, not only on the part of railway companies, but also on the part of all large corporations, to reward service by promotion as vacancies occur. Time was when outsiders usually got the reward, but the men who have been trained to the business, know its every detail and who have demonstrated their ability, are the ones now more generally selected for promotion.

7. The various duties imposed on the fireman may be included in instructions of what to do and what not to do. Knowing how and when to do the right thing and how and when to avoid the wrong thing, are big points to keep in mind.

8. One of the first duties of the fireman prior to starting, is to fill the lubricator with valve oil. Be sure that the feed-valves on the bottom of the lubricator are shut off by turning them to the right (incidentally opening is achieved by turning the valves to the left). The next thing is to shut off the condensing valve on the side and then the steam valve on the top. The drain-cock on the bottom of the lubricator

should then be opened, and all the water should be drained out of the bowl, which may necessitate the loosening of the filling-plug at the top of the lubricator. The filling-plug at the top of the bowl should then be removed, the drain-cock at the bottom shut, and the bowl of the lubricator filled with oil. When the lubricator is full, replace the filling plug, and after a few moments, open the steam valve at the top of the lubricator, permitting the condensation of the steam that has been turned into the lubricator. The condensing-valve on the side of the lubricator should then be opened, and after the oil has become thoroughly heated, the feed-valves may be opened slightly, permitting the oil to pass through the sight-feed glasses at the rate of about three drops a minute. The feed in the air-pump should be much slower.

9. Having cared for the lubricator, the fireman should see that the cab is thoroughly swept out, the boiler-head wiped off and the windows cleaned. The engine is then ready to back out of the round-house, and after backing out, the fireman should be sure the fire is in condition for the trip. As to the matter of firing, this will be taken up later, for the simple reason that understanding fuel and combustion is an essential to good firing. The fellow who "happens to hit" something that is right never succeeds like the one who really knows. On the road, the fireman should take water and coal and assist the engineer in making repairs to the engine whenever necessary.

10. At the end of the trip it is the fireman's duty to take the engineer's supplies off the locomotive, draw the proper amount of oil for the next trip, seeing that they are placed as previously assigned.

11. Familiarity with train rules at all times is absolutely necessary, and in addition to this it is some-

times essential to use personal judgment and in short time—which may be brought about by contingencies not covered by any train rules.

12. The fireman reports to and receives his instructions from the Road Foreman of Engines, or the Master Mechanic. While in the round-house, he is under the supervision of the Engine House Foreman, and when on the engine he is subject to the orders of the engineer as to the proper use of fuel and the performance of his duty. The fireman must assist in making up the train and take charge of the engine during the engineer's absence, but he should never run the locomotive unless so ordered by the conductor or somebody else in authority, except in case of an emergency. It is also necessary that the fireman be familiar with all signals.

13. When the locomotive starts on its run, it is the duty of the fireman to keep the bell ringing while the engine is moving through the yards. He should also keep an eye on the switches that will be passed, to see that they are properly lined up. He should watch the steam-gauge and water glass. For a fireman new in the service, his attitude should always be to receive as many suggestions as possible from the engineer, and at all times by working in harmony with the engineer, both men get more and better work done. The fact that the engineer himself was first a fireman is a point worth keeping in mind.

14. The fireman should study all parts of the engine, not waiting until the time that experience will point out the functions of the various parts. This may be illustrated by the exhaust-nozzle. The exhaust has been aptly described as the "life-breath" of the locomotive. Its value inheres in the great velocity of the steam that issues from the cylinders, and this carries the air

and gases in the front end out of the stack, causing a partial vacuum, and thereby sucking in the air and gases from the fire-box. The fresh air being continuously supplied to the fire-box through the grates, gives the necessary supply for combustion—points that will be fully covered a little later on. The principle of the blower is similar, but its scope is more restricted. The blower should be used while cleaning the fire, as it carries the cinders and ashes from the flues.

15. In the matter of acquiring useful knowledge, the fireman should make a complete study of the locomotive and its parts and appliances, as well as of the requirements of the railway company for which he works.

16. It has been stated previously that coal is the largest item of railway expense apart from wages. This may be strengthened by another statement that applies very largely to the firemen themselves, although not entirely. Improper firing not only wastes coal, but it causes burned-out plates, leaky flues and the other ills that make the boiler the cause of eighty per cent (or more) of the entire repair bills a railway company has to meet. Some of the fault lies in the heavy demands made on rolling stock, and the short periods left for boiler washing. At the same time, certain care can be exercised so that water can be made to give the minimum trouble, and while transportation concerns are still experimenting in this regard, the fireman should know what has been proved and profit by the experience of others—experience that has cost millions of dollars through experimentation and correcting errors.

17. The position of the fireman is very similar to other positions encountered in the world's work. The attentions given by the fireman to his duties must essentially impress the engineer, who is usually appre-

ciative. To illustrate these points the following may be of value: When approaching stations at which stops are to be made, keep the coal out of the gangway, and if there are duties to perform (as a rod-cup to fill or a journal to pack), have the necessary tools ready in anticipation of the service to be rendered. Or, when the locomotive is pulling out over the switch with a string of cars and the signal is given to stop, the fireman should at once impart this knowledge to the engineer, and instead of keeping his seat, he should get down, drop the necessary amount of coal into the fire-box, and be back on his seat in time to get the signal to start.

18. Getting signals promptly is a big thing for the firemen to keep in his brain. A train crew soon notices the locomotive crew that gets orders promptly and acts on them without delay. Signals, once given, should be followed by as prompt action as possible, and it is also well to remember that superintendents, traveling engineers and other officials often ride their trains to see how the different crews are performing their duties, and how each individual is behaving.

19. There are times when the fireman can assume duties that ordinarily repose on the engineer, such as pumping the engine. While this is a case of taking on more work than requirements demand, it prepares the fireman just that much more for the time when he will be promoted—a period he should never lose sight of.

20. Should the boiler be full of water to the working level, it is well to put the heater on, getting steam back into the feed water in the tender. The pop-valve always wastes heat and energy, and whenever any force can be utilized instead of wasted, it works just that much greater saving to the company, and rein-

forces the fireman to that extent. Sometimes at stations there is a heavy rumbling in the locomotive that rattles the windows of the passenger coaches and causes annoyance generally. This is caused by the chemical action of the coal and air during combustion—the formation of oxyhydrogen gas. Opening the firedoor on the latch or dropping a damper will overcome this as a general thing.

21. Special consideration should be given to the front end, and if the engine is not steaming properly, the report should show the cause. Firemen can add to their knowledge and value a great deal by studying these conditions.

22. There are some things over which the fireman has no control, and an engineer can make a locomotive smoke despite all the fireman attempts to do. This is also true of the conductor or train crew generally, and time wasted at a station will mean a smoky fire in spite of all the fireman can do.

23. The fireman must remember that in case of accidents that injure persons or livestock or destroy property, the inquiry is always directed against the train crew. If the fireman gets down from his seat to put in coal after the engineer has whistled for a crossing, the ringing of the bell may be too late. It is always hard enough to convince railway officials or a jury that the bell was ringing anyway, so it is the best policy to be sure.

24. If the fireman understands the train orders absolutely, the likelihood of accidents is lessened. When everybody forgets, something happens. If the fireman is responsible for the information given to the engineer, nothing more should ever be said about it. That is part of the fireman's duty.

25. It is of interest to know what firemen and en-

gineers expect of one another, and the standard, based on their own desires to progress, will be found in the requirements, aims and purposes of the Brotherhood of Locomotive Firemen and Enginemen. Protection, charity, sobriety and industry enter very largely into the motives of this order. The applicant for membership to the Brotherhood is obliged to have served at least six months prior to the time of applying for the honor, and must also be actively engaged at the time. It is necessary that he be white, of good moral character, sober, industrious, sound in body and limb, have normal eye-sight, be able to read and write English, not under eighteen years of age, and be, in general, a credit to the human family. As this Brotherhood insures its members, it adds to the requirements much more than would be the case were the benefits purely social.

26. The fireman will be called upon, after each year of service, to answer questions formulated to ascertain his fitness and progress. It is always well to learn everything by experience and study, and then no question is apt to arise that will cause more than momentary hesitation. The fireman who knows what to do under any contingency, is not going to "fall down" on the examinations. After serving for a year, the fireman is asked many questions relative to signals and a considerable number pertaining to fuel performance, but after that the questions become more complicated, for not only is the fireman putting in time and drawing his pay, but he is going to school and expects to "graduate" some time and become an engineer, with greater pay and more agreeable work.

27. As the fireman proceeds and time passes, he will be expected to tell, in examinations, what every part of the boiler is and what it is for. He will be expected

to give a very good explanation of combustion and should know exactly how and why fuel burns, or fuel is wasted. Knowing what effect the air has, and what the result of a fresh supply of coal in the fire-box will be, are essentials. The fireman will be expected to tell about the draft appliances used on his road and how to adjust them to get the best results. The fireman will find that his previous conception of being one among the many is wrong, and that the company has singled him out to ascertain his standing without respect to that of all others. He will be expected to not only know just what fuel his locomotive has burned, but what the average is for the road. He will have to be able to explain what causes the numerous troubles and how they may be remedied or overcome. He must understand the various types of boilers, their strong points and their weak points—what the brick arch is for, and in fine, everything that deals in any way with fuel performance.

28. As the fireman progresses he will be expected to learn more as he experiences more. By understanding how a locomotive is built, what every part is for, and what every function is, he will then be able to intelligently discuss breakdowns, and should be able to not only be an economical factor in the operation of the system, but also a man to depend on in an emergency.

SOME NECESSARY DONT'S.

There are things to do; there are other things not to do. By taking both the positive and negative positions, the points can be more thoroughly covered. Following are some of the very essential "dont's" for the fireman:

29. Don't imagine that a little carelessness will go unobserved and that the company is wealthy anyway and doesn't need your economy. Small savings, through persistent performance of duty, always depend on the individual—and this is true no matter how many individuals there are.

30. Don't neglect to be at the round-house in sufficient time to examine the firing tools and see that all duties of the fireman are attended to insofar as is possible before starting.

31. Don't fill the boiler full of water as soon as the locomotive is on the road. A space should be left so that the injectors may be worked to stop popping, while the air-pump exhaust is fanning the fire, in pumping air to make the terminal air-brake test. The train will then be in better condition to pull out with. The sound of the safety-valve in operation interferes with the trainmen in locating leaks.

32. Don't neglect to start the lubricator a few minutes before leaving a terminal. It should be set to feed regularly, for proper lubrication of valves and cylinders saves fuel.

33. Don't neglect to use the blow-off cock because it keeps the boiler clean and the water in good con-

dition, insuring also a better circulation in the boiler. The result is an engine that steams better and saves coal.

34. Don't forget that the sand supply is essential, because the slipping of the drivers will mean a loss of power and a loss of fuel.

35. Don't neglect the fire after the engine has stood a while at a station, and save time and trouble through attention of this kind.

36. Don't put too much coal into the fire-box at one time.

37. Don't permit popping if possible to prevent it, because the waste is worse than throwing the coal on the ground. Tests have shown a tremendous waste in this direction.

38. At the same time, don't open the fire-box door to prevent popping when engine is working. Dropping the dampers is a better practice. When the steam stops blowing off, open the dampers again, replenishing the air supply to the fire.

39. Don't have too much pressure if the load is light and the demands are not sufficient to justify it.

40. Don't lose sight of the fact that when the engine is shut off for stations, the dampers should be dropped, the fire-box door opened slightly, and the blower pressed into service to carry away the black smoke.

41. Don't blame the engine for consuming too much coal and supplying too little steam unless it is clearly demonstrated that the engine is at fault. See to it that the injector is not supplying more water than is being used, and that the firing is neither too light nor too heavy.

42. Don't wait for the signal to pull out before building up the fire.

43. Don't permit the water to get so high in the

boiler that it is carried over into the valves and cylinders. This generally happens in pulling out of stations, and the result is that the water carries off the oil, resulting in cut valves and cylinders and extra friction damages to the entire valve motion.

44. Don't fail to take advantage of excess steam before the engine is about to pop, as the injector can be employed as a heater, with which the steam can be blown back into the tank to warm the cold water, but don't get it so hot that the injector will fail to lift it. This care prevents the locomotive from popping.

45. Don't put too much coal under the arch of engines with sloping fire-boxes, as these engines naturally put the coal ahead, resulting in the sticking of the forward sections of the grates and their clinkering.

46. Don't throw in large chunks of coal because the coal-house men have failed to break it properly. Report the instance, but use enough personal effort to break up the coal before burning it.

47. Don't put in a heavy fire about the time the engine is shut off for a station or down-grade. Service, grade and weather conditions, coupled with observation, will show the fireman when to stop firing.

48. Don't forget that different qualities of coal and different makes of grates govern the shaking of grates.

49. Don't fail to clean the fire on locomotives that are on the road for long hours. The first opportunity for cleaning the fire will insure better service, less effort and flues that are not leaking.

50. Don't take coal or water more frequently than necessary. It only adds to the burden the engine must haul.

51. Don't forget that it takes coal to make steam and that leaks in the air pressure are kept up by like steam pressure.

52. Don't try to put more coal on the tank than will lie on safely, because all coal dropped is wasted. Coal should also be kept from falling off the gang-way when running.

53. Don't fail to co-operate with the engineer when he makes out his work slip.

54. Don't try to save coal to the detriment of service. Use judgment in all things.

Note: The above "Don'ts" are taken from those compiled by Mr. Robert Quayle, Superintendent of Motive Power of the Chicago and Northwestern Railway.

Following are some other "Dont's" and attention is directed to the fact that in the above, as well as in those that follow, some of these instructions relate more particularly to the engineer and his duties, but such only as directly concern the fireman. Hence, he should familiarize himself with the needs that pertain to his part of the work.

55. Don't imagine that an engine will steam better "hooked-up" so close to the center that the exhaust does not work the fire. The fire should be kept heavy, thick and alive.

56. Don't feel that during the last three hours of the trip the only reason for cleaning the ash-pan is to prevent the burning of the grates. There must be room for the air to get through the pan to the fire, because air that comes through the door means a loss of steam; air that comes through the coal means better combustion.

57. Don't talk one method and try another. The locomotive, unlike man, cannot believe, but just acts. Be sure of being right—and then apply it.

58. Don't imagine that because compressed air will operate the blower when firing up, or move a locomo-

tive around the round-house, it will likewise work the injector and force water into the boiler against the air-pressure that is to be used to work the injector.

59. Don't forget that a big clinker forming on the grate will offset the value of a large fire-box and big grate area.

60. Don't be impertinent to those whose help and suggestions are needed. Never be insulting to the men who can assist.

61. Don't stop at every water-tank along the line because complaint was once made of going without sufficient water. The right amount is determined with judgment and practice, and saves time and load.

62. Don't feel that the orders of the despatcher, even when inconvenient, call for revenge in the form of wasted time and fuel.

63. Don't wait for the preparation for examination until "the day before." Let every day bring its education and count that day lost in which some useful knowledge has not been gained—and retained.

64. Don't feel discouraged at not learning everything right away. Knowledge of machinery is embodied in the "why" and the "how" and is not learned very rapidly.

65. Don't complain about buying good technical books that teach something. Knowledge is power—and also advancement's vanguard.

66. Don't forget that the practice received during the day should be supplemented by hard study—not casual reading. To learn something, there must be left a record on the brain—a record that is embedded in the intricate convolutions of the brain in the form of "gray matter." Get these records properly recorded, and learn authentic facts—not haphazard information, theory or hearsay. A truth once learned is a steady

tenant of the mind, but a half-truth or a falsehood stored up as fact is harder to eradicate than a new truth is to learn. Start right and stay right.

67. Don't think that a fireman is at liberty to go on a run when he "feels like it" and lay off when he feels like it. Railroading is serious business and hard work, and serious and hard-working men are the ones who win.

68. Don't think that even the call-boy isn't observing. He learns human nature—and also learns to distinguish good reasons from excuses.

69. Don't feel that firing is simply a means to getting bread and butter. Have dignity, self-reliance. Work up, for many professional men make less than engineers, and firemen, as previously stated, are the material from which engineers are made.

70. Don't become too self-reliant, to the point of being arrogant, for that is a disease, and it brings adverse comments from fellow-workers.

71. Don't feel that the desire to lay-off is the touch of the finger of fate that saves railway men from wrecks. The business is one of hazards, and only brave, willing men are wanted.

72. Don't try to dodge the necessity of keeping up with modern methods in railroading. As truths are demonstrated, learn them and apply them.

73. Don't forget that the purpose of examinations is not to help incompetent men to "slide through," but to provide safety to all through a high average of knowledge and ability.

74. In the above, only casual mention has been made of the actual work of firing. The fireman may feel that chemistry to him is as useless as a knowledge of the planets—and in a general sense it is so. However, nature provides a means of making coal burn. There

is a reason why steam is generated and possesses power. Knowing how to do these things is very important, but the mere practice is only part of the work. Understanding the truths that underlie the processes of combustion and steam generation, is to be able to start from a reason and figure out just why and how the work of firing is really an art.

75. Some men would never make capable firemen, while others are always learning, reasoning from what they have learned and applying it to their daily labors. Thus, small, wiry men of moderate weight are sometimes very successful firemen, whereas large men of great physical strength are less successful. This is because the one studies his position and its requirements, and the other imagines that "heaving coal" is the beginning and the end of the fireman's duties.

76. Don't attempt to pass judgment on this subject until going into it, and don't merely read it as one would read an interesting article in a magazine. The world is paying for what men can do, plus what they know. The more they know, the better they can do—and the more capable they are at their work, the more rapidly they are advanced, and the larger the remittance in the pay envelope. Therefore, every fireman and every engineer should learn the truths as rapidly as possible, because every year finds higher standards and greater requirements in the business of railroading.

REVIEW QUESTIONS

Covering the Preceding Treatise upon the Firemen's Qualifications and Duties, Numbered to Correspond with the Paragraph Numbers for Quick Reference

QUESTIONS.

The answers will be found in the preceding text under corresponding paragraph numbers.

1. Should the fireman regard himself as only one among the many and his work as unimportant? Why are the fireman's duties of importance to himself and to the company for which he works?

2. What relationship does the fireman bear to the railway system?

3. What contingent duties confront the fireman?

4. Why is education an essential thing for the fireman?

5. Name the principal duties of the fireman.

6. Are companies paying more attention to ability than they previously did?

7. What is essential besides knowing what to do?

8. What is the fireman expected to do with regard to the lubricator? How is this usually done?

9. Having cared for the lubricator, what next does he do?

10. What should the fireman do at the end of the trip?

11. What should the fireman do with relation to train rules? Is he expected to use his judgment at times?

12. Under whom is the fireman, and from whom does he receive instructions?

13. When the locomotive begins to move, what must the fireman do?

14. Should the fireman understand the various parts of the engine? Illustrate by explaining the exhaust and its functions.

15. What knowledge should the fireman seek to acquire?

16. What relation does the cost of fuel and firing bear to the expenses of the railway?

17. How can the fireman do little things to assist the engineer?

18. Why is it essential to get signals promptly and act upon them?

19. Should the fireman ever assume duties that are supposed to be cared for by the engineer?

20. What work can the steam do instead of wasting itself popping? What causes rumbling and how is it prevented?

21. Why should the front-end receive attention?

22. Can the engineer assist the fireman in any way?

23. Should the fireman do his duty at all times? Explain the answer.

24. Why should the fireman understand the train orders perfectly?

25. Show what engineers and firemen expect of one another by referring to the requirements of the Brotherhood of Locomotive Firemen and Enginemen?

26. What may the fireman expect to encounter in his first examination?

27. What other facts will the fireman have to explain in examination?

28. How does this knowledge gradually lead him up to the position of engineer?

29. Why are little acts of carelessness unwise?

30. Why should the fireman be at the round-house in ample time?

31. Should the boiler be filled with water as soon as the locomotive is on the road?

32. What attention does the lubricator need before leaving a terminal?

33. What use should be made of the blow-off and why?

34. How about the sand supply? Does it save the company any money?

35. What attention should be given the fire after the engine has stood a while at the station?

36. Should much coal be put into the fire-box at one time?

37. Does popping actually result in waste?

38. Should the fire-box door be opened to prevent popping? What is the best way to stop it?

39. Is high pressure always advisable?

40. When the engine is shut off for stations, what should be done?

41. Should the engineer be blamed for consuming too much coal? Should the injector supply much water?

42. When should the fire be built up?

43. Why is high water in the boilers dangerous? What results?

44. How can the injector relieve the steam pressure and do good service with the steam otherwise wasted in popping?

45. Where the fire-box is sloping, how should the coal be distributed?

46. What should be done relative to large lumps of coal?

47. How will the fireman know when to stop firing?

48. What conditions govern the shaking of the grates?

49. What about cleaning the fires?

50. What may be said about taking coal and water?

51. What keeps up air-pressure leaks?

52. How much coal should be put on the tank?

53. Should co-operation be extended to the engineer when he makes out his work slip?

54. Should the habit of coal saving be carried very far?

55. Can the engine be hooked up so that the exhaust will not work the fire? What sort of fire is advisable?

56. Why should the ash-pan be kept clean at all times?

57. How about theory and practice?

58. What mistakes might be made about compressed air?

59. What will offset the value of large grate area and big fire-box?

60. What attitude should be maintained toward others?

61. Should stops be made at every water tank along the line?

62. Do the orders of the despatcher warrant a revengeful spirit?

63. When should the fireman begin to prepare for examinations?

64. Should knowledge be gathered in a hurry?

65. How about good technical books?

66. How should the practice of the day be supplemented?

67. What should a fireman do about being "on hand"?

68. Does the call-boy cut any figure?

69. Should firing be a dignified position?

70. Is self-reliance liable to go too far?

71. What foolish notions may prompt the desire to lay off?

72. Should the fireman keep up with the times?

73. What is the purpose of examinations?

74. Does firing call for any special knowledge?

75. Of what value is "head work" to the fireman?

76. Why are firemen and other employes advanced?

GRAPHIC ILLUSTRATIONS OF DIFFERENT WAYS OF THROWING COAL INTO THE FIREBOX.

No. 1

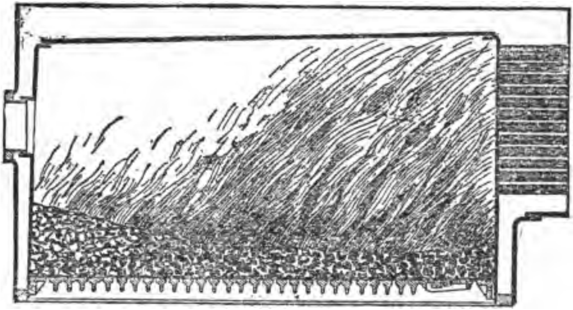

Figure No. 1 shows the system of Heavy Firing at the Furnace Door, resulting in a Bright Fire over a portion only, with a consequent reduction of Fire Box Temperature.

No. 2

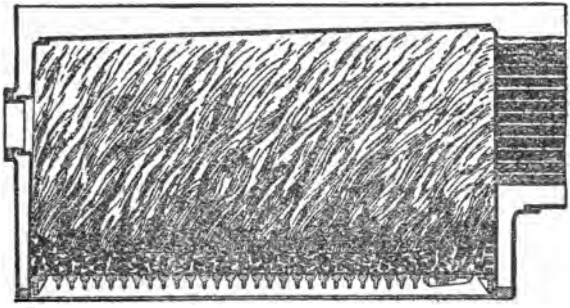

Figure No. 2 shows a system of Shallow and Level Cross Firing with slight building up around the edges, producing a Bright Fire throughout, with High Temperature within the whole Fire Box.

No. 3

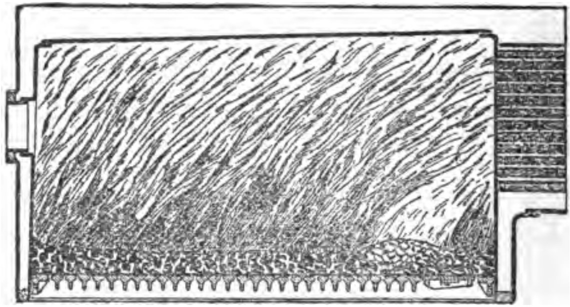

Figure No. 3. shows the effect of the temporary reduction in Fire Box Temperature when a shovel full of coal is introduced.

No. 4

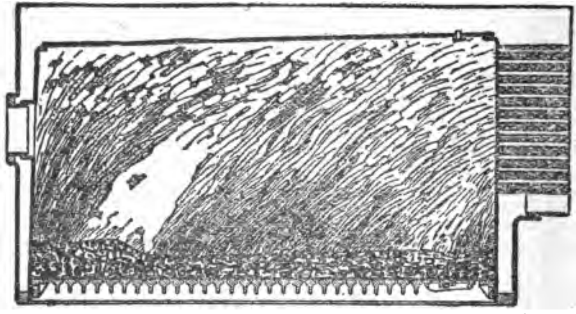

Figure No. 4 shows the reduced temperature restored at the time the second shovelful is introduced, as would be the case with the system of Cross-Firing.

No 5

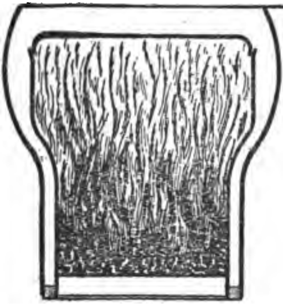

Figure No. 5 shows the piling of the coal on the side as would be the result of Cross-Firing.

No. 6

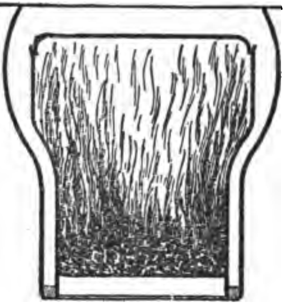

Figure No. 6 shows the action of the draft in thinning fire along the walls of the Fire Box and the edge of fire unless piled, as per figure No. 5.

No. 7

Figure No. 7 shows the method of Cross-Firing as indicated by successive numbers on the arrows, first firing on one side and then the other, along the walls of Fire Box.

LESSON III

THE AUTOMATIC AIR BRAKE

Its Parts and Their Uses

LESSON III.

THE AUTOMATIC AIR BRAKE—ITS PARTS AND THEIR USES.

* DEFINITIONS OF TERMS.

1. Believing it of the greatest importance to the student that he should have a complete understanding of the terms used in air-brake practice, we preface this lesson with a few of the many such terms which by custom and long usage have come to be associated with the construction and operation of the Air-Brake, the meaning of which should be thoroughly familiar to everyone studying the subject.

Application. The operation of applying the brakes by creating a pressure in the brake cylinder and forcing the brake shoes against the wheels.

Graduated Application. An application of the brakes in which the brake-cylinder pressure is increased in a series of steps or graduations.

Service Application. A gradual smooth application of the brakes such as is made in an ordinary stop or slow down; so called because it is the usual application in ordinary service.

Full-Service Application. The most powerful service application of the brakes that can be obtained.

Partial Application. Any service application of the brakes less than a Full-Service Application.

---

*These "definitions" are as given in the lesson papers of the Locomotive Firemen and Enginemen's Brotherhood Correspondence Schools.

Emergency Application. The quickest and most powerful application of the brakes that can be made, in order to stop in the shortest possible distance and avoid a collision or save life.

Reduction. The lowering of the air pressure in the brake pipe below that usually carried in order to cause an application of the brakes. A specified amount is generally referred to, as, for example, "A ten-pound reduction," " a service reduction of fifteen pounds," etc.

Service Reduction. A moderate gradual reduction of brake-pipe pressure to cause a service application of the brakes.

Full-Service Reduction. A service reduction which causes a full-service application of the brakes.

Over-Reduction. Any service reduction which is greater than a Full-Service Reduction.

Emergency Reduction. A sudden rapid reduction of brake-pipe pressure to cause an emergency application of the brakes.

Release. The operation of releasing the brakes by discharging the pressure from the brake cylinder and pulling the brake shoes away from the wheels.

Graduated Release. A release of the brakes in which the brake cylinder pressure is reduced in a series of steps or graduations instead of being completely discharged at one time. (A characteristic of the newer types of passenger triple valves only.)

Charging. Building up the pressure, in that part of the air-brake system which is normally under pressure, to the proper amount that is specified for that particular system.

Recharging. The term used to designate the charging up during the release after an application.

Lap. Generally speaking, this term means the closing or blanking of an opening or passage; in connection with the air brake it is used to designate the preventing of any change of pressures in the various parts of the system as far as such change is controlled by operating valves or devices. Mostly it refers to a certain position of a valve in which the connection between all different pressures is closed.

Quick-Action. That effect of the operation of a triple valve which causes an emergency application to pass rapidly from car to car throughout the train, by causing a local reduction at each triple valve.

Equalized Pressure, or Pressure of Equalization. That pressure at which two volumes, originally at different pressures, will become equal if they are connected together and allowed to remain connected.

Port. The name usually given to the machined holes in a valve or valve seat, placed so as to control the flow of air from one volume to another when the valve is in different positions on the seat.

Register. When a port in a valve comes directly over a port in the valve seat making the connection between them fully open, one port is said to register with the other. If either port is not fully open, they are said to partially register.

Braking Power. As generally used, this term expresses the relation between the total pressure of all the brake shoes against the wheels, and the total weight of the car on the rails. It is expressed by dividing the total brake-shoe pressure by the total weight of car and giving the result in per cent. For example, if the total brake-shoe pressure is 25,000 pounds, and the total weight of car is 50,000 pounds, the former divided by the latter gives ½, which is 50 per cent. braking power.

Retarding Force. The actual frictional force between the brake-shoe and the wheel, which tends to reduce the speed of the moving car or locomotive.

Piston Travel. The actual distance, measured on the piston rod, through which the brake-cylinder piston is forced during an application of the brakes.

Standing Travel. The piston travel that results from a brake application when the car is not moving.

Running Travel. The piston travel that occurs in a brake application when the car is in motion, running over the road. It is greater than the standing travel because the motion of the car and the unevenness of the track allow all loose journals and joints to take up more lost motion than when the car is standing.

False Travel. A rather indefinite term often heard in connection with air-brake matters, sometimes referring to the difference between standing and running travel, and sometimes to an extra excessive travel momentarily caused by some unusual temporary strain.

Foundation Brake Gear. A system of rods, levers, supports, brake beams, hangers, etc., which serve to connect the piston rod of the brake cylinder with the brake shoes, to transmit and multiply the pressure obtained in the cylinder to the shoes.

Automatic Devices. The term automatic means "self-operating." The automatic air-brake devices are self-operating, due to changes in air pressure in parts of the system.

A Manual Device is one operated by hand, that is, not automatic. It should be noted that, although the automatic air-brake devices are set into operation by changes in pressure in parts of the system, these changes in pressure are most generally produced by a manual device, such as the brake-valve, conductor's valve, angle cock, etc.

The Manipulation of the Brake is the term used to cover the handling of the manual devices so as to cause the automatic devices to operate.

1. There are seven distinct types of Standard Air-brake equipment of the Westinghouse and New York designs, as follows: (1) The Westinghouse G-6 Automatic Engine Equipment, in which only one brake-valve is used, and which does not give any independent control of the locomotive brakes; (2) the Westinghouse Combined Automatic and Straight Air Equipment, consisting of the G-6 brake-valve and the old straight air-valve, which gives partial independent control of the locomotive brakes; (3) the Westinghouse No. 6 E. T. Locomotive Brake Equipment, requiring two brake-valves and a distributing valve; (4) the New York B-1 Engine Equipment, consisting of one brake-valve, which does not give any independent control of the locomotive brakes; (5) the New York B-1 Brake-Valve in connection with a straight air-valve, giving partial independent control of the engine brakes; (6) the New York B-2 and B-3 Locomotive Brake Equipment, consisting of a combined automatic and straight air brake-valve and an independent release-valve, giving a partial independent control of the engine brakes; (7) the New York L. T. Automatic Control Equipment with the type L automatic brake-valve.

2. There are also two other types, not in general use. The Dukesmith No. 4 Locomotive Brake Equipment, and the Dukesmith No. 6 Locomotive Brake Equipment.

THE PRINCIPAL PARTS.

3. The principal parts of both the Westinghouse and the New York systems are: The Air-pump, which compresses the air; the Governor, which governs the pump and regulates the amount of air to be compressed; the Main Reservoir, in which an excess supply of compressed air is stored to promptly release and recharge the brakes; an Engineer's Brake-valve, which regulates the flow of air into the Train-pipe and Auxiliary Reservoirs, to charge the train and release brakes, and which also regulates the flow of air from the train-pipe to the atmosphere for applying the brakes; the Duplex Air-gauge, which shows simultaneously the pressure in the Main Reservoir and the Train-pipe; the Train-pipe, which leads from the Engineer's valve through the train, supplying air to the apparatus on each car, and by varying the air pressure in this pipe the brakes on each car automatically apply and release; the couplings and angle-cocks that connect the train-pipe air from one car to another.

4. Other parts are: The Plain Automatic Triple-valve, which is used only on the engine and tender, controlling communication between the train-pipe and the auxiliary reservoir, the reservoir and the brake-cylinder, and from the brake-cylinder to the atmosphere; the Quick Action Automatic Triple-valve, used on cars—a duplicate of the plain triple-valve, with certain additions that are inoperative unless an emergency requires that the train be stopped in the shortest possible distance.

5. Other parts of the equipment include: The Auxiliary Reservoir (one for each brake), which stores a sufficient amount of compressed air under

each car and engine, to instantly operate the brakes thereon; in the application of brakes, the air from the auxiliary reservoir flows into the brake-cylinder, the quantity admitted depending on the braking power desired, or the train-pipe reduction made; the Conductor's Valve, placed in passenger cars, and providing a means for the trainmen to apply the brakes and stop the train when essential to do so very quickly; the Brake Cylinder, where the air is finally admitted when the brakes are applied; the Foundation Brake gear, through which the brake cylinder transmits its force to the Brake-shoes; the Pressure Retaining-Valve, which is used by the trainmen for holding fifteen pounds' pressure in the brake-cylinder while (engineer recharges on) descending grades; the Automatic Slack Adjuster, which automatically maintains a constant travel of the piston in the brake-cylinder by taking up the slack of the foundation brake-rigging as the brake-shoes wear.

QUESTIONS.

The answers will be found in the preceding text under corresponding paragraph numbers.

1. How many types are there of the Westinghouse and New York equipment? Name them.

2. What two other types are there?

3. Name some of the principal parts of both the Westinghouse and New York equipments and tell what their functions are.

4. Enumerate other parts and explain what they are for.

5. Name the balance of the parts and tell what their duties are.

LESSON IV

COMBUSTION OF FUEL IN LOCOMOTIVES

LESSON IV.
*COMBUSTION OF FUEL IN LOCOMOTIVES

Bearing in mind the truth that the capable fireman is the one who knows, who understands causes and effects, it follows that a certain portion of technical knowledge is essential.

1. Combustion of fuel in locomotives means heat, and that spells energy. It is well to keep in mind that matter in any form implies two or more elements in chemical activity, and that in the process of combustion, certain chemical reactions occur, changing the coal in the firebox to one of two gases, known as carbon dioxide and carbon monoxide. One of these gases makes an intensely hot fire, because of perfect combustion, the other a far less satisfactory fire because of imperfect combustion. One fire is economical, profitable, the other is wasteful, unprofitable. The locomotive's power depends on the heat obtained from the coal, and differs according to the kind of combustion —so that one fireman may get more heat out of a small fire than another man gets out of one that consumes a vast quantity of coal.

2. The composition of coal—meaning the elements it contains and in what proportions; the temperature at which these different elements ignite; the proportions in which the different elements combine (burn) when conditions are favorable; the quantity of air required and at what particular place in the firebox it should

---

*Note: Copyrighted as a contributed article to the Locomotive Firemen and Enginemen's Magazine, Feb., 1911, by Frederick J. Prior.

be admitted; the number of heat units a pound of coal will yield under perfect combustion, and the number yielded under imperfect combustion—all form subjects with which the fireman should become familiar if he is to be a capable fireman.

3. An important point to keep in mind is, that when elements or compounds enter into combination to form a new substance they always do so in fixed proportions by weight, but if there is any excess beyond this fixed proportion of either element no combination is effected.

4. The elements concerned in combustion are oxygen, hydrogen, nitrogen, carbon and sulphur. Letters and figures are used in conjunction to designate proportion. Thus, one atom of oxygen combines with one atom of carbon and forms carbon monoxide—CO. Two atoms of oxygen combine with one of carbon and make carbon dioxide—CO_2. The theory of combustion is that the principle of affinity (attraction of certain kinds of atoms for certain other kinds) draws the atoms together with such violent contact that heat is produced.

5. Carbon and oxygen are the most important elements in combustion. Carbon is the fuel and oxygen is the supporter of combustion. They have a natural tendency for one another, but cannot unite freely until they have reached a high degree of temperature. A violent evolution of light and heat then ensues. Combustion goes on either more slowly (as the rusting of iron) or more rapidly (as the explosion of gunpowder), thus showing the scope of the burning process.

6. All the fuel used for making steam is composed of carbon, or the compounds of carbon and hydrogen. Bituminous coal contains besides carbon, certain volatile products, very inflammable, and known as hydrocarbons, being combinations of carbon and hydrogen. Anthracite consists chiefly of fixed carbon, with little volatile, or gaseous substance, the better grades running as high as 90 per cent. carbon.

7. The following table shows the principal constituents of the coal used by the leading railways, the only percentages not shown in the table being made up of ash, moisture and sulphur:

	Average Fixed Carbon	Volatile Matter	Average Heat Units Per Pound
Anthracite.			
Average of four districts	83.77	3.86	13,169
Semi-Bituminous.			
Average of six districts in Pennsylvania and West Virginia	73.75	18.15	14,673
Pocahontas	74.39	21.00	15,070
Bituminous.			
Average of eighteen districts in Pennsylvania, Ohio, West Virginia, Kentucky, Tennessee, Illinois	52.25	34.75	13,000
Highest of above	60.99	32.53	15,200
Lowest of above	37.10	35.65	13,800
Illinois Bituminous.			
Thirty-seven districts	48.02	35.58	12,210
Iowa Bituminous.			
Five districts	37.47	38.44	13,400
Missouri Bituminous.			
Five districts	48.73	37.67	14,150

8. The quantity of fixed carbon contained in fuel and the volatile matter of an inflammable nature it

contains comprise its heat value. In the foregoing table reference is made to a heat unit, commonly referred to as B. T. U.—British Thermal Unit—and repetition is made here as to what it is. The greatest density of water is at 39.1 degrees Fahrenheit. To raise this one degree in temperature represents a certain amount of mechanical work to each pound of water thus heated—which is 778 foot pounds. In other words, if the mechanical energy represented by the heating of one pound of water from 39.1 degrees F. were applied to lifting a weight, a body of 778 pounds could be raised one foot; or, if this body fell one foot, the heat resulting would raise the pound of water the one degree.

9. Various examples could be given to prove that heat and mechanical work can be converted one into the other. This should be kept in mind, as it of service in the consideration of combustion. In a word, the heat produced on iron struck by a steam hammer is equal to the force used in making the hammer strike the blow. The combustion of fuel in the firebox of a locomotive produces the mechanical action necessary to get a train under way and keep it in motion. In stopping, the air-brakes are applied and the entire energy must be changed into heat, which is done by the friction between the brakeshoes and the wheels.

10. It is always necessary to refer to gases as having weight, and although it may be puzzling to know how gases can be weighed like sugar or coffee, it is done, but for the purposes of this article, the demonstration is not required. Science has proved it, and the fireman may feel perfectly safe in taking it for granted.

11. The air, which is a combination of elements in a gaseous state, has weight and the weight of a column of air one inch square at sea level is 14.7 pounds, or 15 pounds in round figures. This atmospheric pressure performs very important functions in combustion. By weight, there are 3.35 pounds of nitrogen to every pound of oxygen in the air; by volume, there are 3.76 cubic feet of nitrogen to every cubic foot of oxygen.

12. While nitrogen does not support combustion, it passes into the firebox with the oxygen of the air, and must be heated to the same temperature as the other gases. The following facts have also been proved by science: One pound of hydrogen combining with oxygen to form water produces about 62,000 heat units. One pound of solid nitrogen, of the density forming a constituent of coal, combining with oxygen, liberates about 50,000 heat units. One pound of gaseous carbon, on combining with 2 2/3 pounds of gaseous oxygen, forming carbon dioxide, liberates about 20,000 thermal units. One pound of solid carbon, on uniting with oxygen to form carbon dioxide, produces about 15,000 heat units. One pound of solid carbon, combining with 1 1/3 pounds of oxygen to form carbon monoxide, generates about 4,500 heat units. Different methods of firing form these combinations, and by referring to the vast differences in the heat units produced it is easy to see how important it is to understand what makes firing good, or makes it poor.

13. One authority on the subject of firing, and who was at one time a fireman himself (and so good that he continued to rise), says that experience proves that the engine may consume a large quantity of fuel

without perfect combustion occurring, and when it does take place the heat from only a portion of the fuel is utilized. Several causes of loss of heat may occur: First, small pieces of unburned coal falling through the grates or being carried through the flues by the blast; second, the unburned gases passing off in a gaseous state or as smoke; third, the heat of the hot gases when they pass out of the stack; fourth, the loss of heat by convection and radiation from the boiler, because the boiler is not sufficiently covered with lagging to prevent radiation and convection of heat from the hot boiler-plates. These losses cannot be entirely prevented, but a great reduction can be achieved in the matter of gaining more heat out of the fuel and the gases. By permitting the proper amount of air for combustion to pass through the firebox much of this loss can be eliminated.

14. Other means of prevention deal with the way in which the coal itself is handled. Broken into lumps (not so small as to drop through the grates), and properly wet, the coal will do more duty. Again, keeping the fire of a thickness too great for the draft to carry away the small pieces also assists. The amount and distribution of air admitted to the firebox helps keep down loss through unconsumed gases and smoke.

15. Just how great these losses are may be summed up approximately as follows: By radiation and convection, 5 per cent. to 10 per cent.; ash, clinkers, coal falling through the grates or being drawn through the flues, from 5 per cent. to 15 per cent.; gases escaping at a high temperature through the smokestack, from 25 per cent. to 30 per cent.; incomplete combustion, 5

per cent, to 15 per cent. In a word, about 45 per cent. of the fuel consumed makes steam; the other 55 per cent. is lost.

16. On a single trip a fireman handles from 6 to 20 tons of coal. Out of every 10 tons he lifts and puts into the firebox he gets steam out of 4.5 tons. This fireman may average 10 tons of coal a trip and make 300 trips a year, handling 3,000 tons. Of this amount 1,650 tons are wasted. If 10 per cent of this loss can be prevented, through good firing that is 165 tons an engine, or 16,500 tons a year for 100 locomotives, amounting to $33,000 at $2 per ton.

17. Much depends on how the locomotive steams. If it is a poor steamer, the fireman becomes discouraged; if a good one, he is pleased to do his best—or should be. Given a locomotive designed for the development of a practical maximum power with a grate area involving the burning of 14,000 B. T. U. coal at a rate of 180 pounds a square foot per hour, it cannot be made to furnish steam at an equivalent rate of working with 10,000 B. T. U. coal; or, a locomotive designed for a certain rate of working with a grate area intended for the use of 10,000 B. T. U. coal at a combustion rate of 100 pounds per square foot an hour proves wasteful of fuel with 14,000 B. T. U. coal at this rate of working because of the small nozzle required to induce sufficient draft to overcome an impractically low rate of combustion when working at half maximum power. Firemen have sometimes observed that below a combustion rate of 50 pounds to a square foot of grate area an hour the fire does not remain in that state of incandescence necessary in locomotive practice. It bakes and lies dead on the surface.

18. A considerable range in the use of coal is permitted in most modern locomotives, provided the drafting arrangements are varied to correspond with the variations in the coals. When engineers report at the roundhouse that the engine is "not steaming," that indicates but very little, because any one of a number of causes may be the reason—and the same type of engines burning the same kind of coal steam well. Reasonably good condition of the engine is always necessary, but the consideration being herein set forth deals not with the remedying of locomotive ills but the question of proper firing under right conditions.

19. This authority contends that the amount of the ashpan opening, as well as the grate opening between the fingers thereof, are matters of experiment that have generally been decided by the traveling engineer, and are usually neglected by the crew. The staybolts and boiler-tubes, with relation to leaking, comprise the next essential points of inspection, which is not so important in good water districts as in those where the water is poor. Where staybolts and boiler-tubes are addicted to leaking, a better water supply must precede considerations of fuel economy. Getting the train over the division supersedes the matter of saving fuel. Where a locomotive is given to leaking, the secret of success is in keeping it hot—up or down grades, or sidings—everywhere. But where the tubes and staybolts are spurting, it is better to run the locomotive into the roundhouse, for the trip would be a failure. But mere "seeping" is often temporarily overcome by a hot fire that expands the metal and stops the leakage. Keep-

ing up the temperature so that contraction will not occur prevents a recurrence of the leaking.

20. The temperature of steam or water at 200 pounds pressure is 387 degrees. F. D. K. Clark gives the temperature of 14,700 B. T. U. coal as follows, when burning at certain rates:

Pounds of coal per sq. ft. of grate area per hour.	Temperature of surface of fire in degrees Fahr.
40	1,857
80	2,009
120	2,097
160	*2,137
200	*2,157

---

*Would be "about."

Unless the water takes the temperature away from the sheet as rapidly as it is delivered the temperature of the sheet will rise very quickly above that of the surrounding water, and the expansion will be in proportion. The temperature of the fire does not drop very rapidly until the coal consumption is below 80 pounds of coal a square foot of grate area an hour. The blower usually enables a combustion rate of more than 40 pounds an hour to be maintained, which is enough to prevent a drop of temperature sufficient to start a "tender" set of tubes to leaking, when getting over the road becomes more important than fuel economy. Firemen recognize that an engine that stops leaking when working hard starts when shut off, unless the blower is put on. It will be seen from the above facts what difference good water and bad water make on the relationship of heat in the plates to the heat of the water; that is, bad water, being filled with sediment, permits a cake to form near the sheets—and this scale does not allow the heat to escape from the metal into the water; hence the excessive expansion of the metal and its distortion.

21. For illustration of firing requirements, take a common form of locomotive with a firebox 72x35 inches, with about 17 square feet of grate area. She starts with a fairly heavy train and has to maintain a running speed of forty miles an hour. The steam necessary to be furnished would call for 60 pounds of coal a mile, or 2,400 pounds an hour. This means that there must be burned 141 pounds of coal on each square foot of grate surface an hour—a very rapid rate of combustion, but common enough on many railroads. Let it be assumed that the locomotive is of the kind ordinarily used in hauling passenger trains, where the only means of admitting air to the fire is through the ashpan. When the air is drawn violently through the grates by the suction of the exhaust, it strikes the glowing fuel and the oxygen in the air separates from the nitrogen and combines with the carbon of the coal and with the hydrocarbon gases distilling from the coal, these gases possessing intense heating properties.

22. While elements unite in certain fixed proportions, under certain conditions they will unite in different proportions, but in cases of this kind the products themselves are different. If the air admitted to the firebox is liberal in quantity, meaning an abundance of oxygen for combustion, the carbon will unite in the proportion of 12 parts by weight with 32 parts by weight of oxygen, and the combination is carbon dioxide, which is an intensely hot gas of great value in steam-making.

23. Should there be a restriction of the quantity

of the air admitted to the firebox, with the oxygen scarce, the 12 parts of carbon will unite with but 16 parts of oxygen, producing carbon monoxide, a gas having less intensity of heat. It follows that the proper admixture of the oxygen in the air and the carbon in the fuel determines which gas is to be formed and what heat value is to be secured.

24. One pound of carbon, uniting with oxygen to form carbon dioxide, will generate 14,500 B. T. U., or heat units sufficient to raise 85 pounds of water from the tank temperature to the boiling point.

25. When one pound of carbon unites with oxygen to form carbon monoxide, only 4,500 heat units are generated. These heat units are only sufficient to raise 26.5 pounds of water from the tank temperature to the boiling point. In each case the same quantity of coal is used. The quantity of oxygen, therefore, is the determining factor.

26. The locomotive in the example consumes 2,400 pounds of coal an hour, or 2 1/3 pounds a minute for each square foot of grate area. The combining proportions of carbon and oxygen to form carbon dioxide (the hottest gas) must be 12 to 32. Therefore, the proper combustion of each pound of carbon calls for 2 2/3 pounds of oxygen. It takes 4.35 pounds of atmospheric air to supply one pound of oxygen, meaning that more than 11.5 pounds of air will be required to give the most economical combustion of one pound of coal. But where the combustion is rapid, the coal must be bathed in the oxygen—saturated in it—and to prevent loss, fully 20 pounds of air should be consumed to each pound of coal. At this rate the locomotive would have to draw every minute through

every foot of grate area 20x2 1/3, or 46.66 pounds of air. At ordinary temperatures, one pound of air occupies about 13 cubic feet, implying that over 600 cubic feet of air would have to pass through each square foot of grate area every minute. A cylinder 18x24 inches could be filled about 170 times with this volume of air. As the grate openings are more restricted, the column of air passing in must be longer—meaning a continuous rush of the atmosphere into the firebox and through the coal.

27. Smoke-preventing furnaces are designed so as to supply air to the surface of the fire, but unless the supply is restricted to the few moments while the distillation of the gases is going on, and the supply is automatically shut off at the right time, there will be a waste of fuel, as the air will be admitted where and when it is not wanted, showing why hollow staybolts and other inventions for admitting air above the fire have not proved economical.

28. If the coal is not rich in hydrogen a thin fire will permit the oxygen to circulate among the coal particles and lumps, although there are numerous practical objections to a very strong draft through the grates. The smaller particles are caught in the hurricane and are taken up to the tubes and result in spark throwing, and when there is a thin or dead part of the fire the gases pass in below the igniting temperature, tending to reduce the heat in places below the proper temperature and escape unconsumed. Thus there are chilling areas here and there, reducing the efficacy of the combustion, cooling the tubes and sheets and starting cracks and leaks. A large part of the air under ordinary circumstances must be heated up

to the temperature of the firebox, and this heat is not available for steam making. When a large volume of gas is employed it must be passed through the furnaces and tubes at a high velocity, not giving time for the imparting of the heat to the water, and going out through the stack at a higher temperature than would be the case were the speed of these gases less. Passing one's hand through the flame of a gas burner illustrates this point aptly.

29. Through the area of the grate in the locomotive under consideration there is being drawn 600 cubic feet of air to every square foot each minute, and as the total area of the grate is 17 square feet the total is 600 × 17, or 10,200 cubic feet. In addition to this gas (for air is gaseous) there is the product of combustion, or about 300 cubic feet more each minute for the 40 pounds of coal converted into gas. This continuous stream of gas must pass out of the firebox through 202 two-inch flues, affording an opening of 485 square inches, or 3.36 square feet, making a column (for this diameter) 3,400 feet long and calling for a speed of 3,400 feet a minute, and these figures are based on a comparatively small locomotive.

30. Loss of heat is threatened from two directions: if the quantity of air admitted to the firebox is not sufficient to furnish abundant oxygen, then carbon monoxide is generated, with its smaller heating power, the difference between which and carbon dioxide has been previously explained. If the air admitted be greater than needed there is a waste of heat equal to the heat units required to raise the temperature of this air to the heat in the firebox. An extra quantity of air calls for watchfulness because of excessive draft.

with the higher speed of the gases and another waste from that source. Continuously raising the temperature 1,000 degrees is a heavy drain on the heating powers of the locomotive.

31. The temperature of the firebox is one of the basic requisites of good firing, meaning perfect combustion. When the locomotive is properly fired and the consumption is at the ratio of about 20 pounds of air to each pound of coal the firebox temperature will be about 2,000 degrees F., the ideal temperature for perfect combustion. The ignition temperature of coal is between 1,800 degrees and 1,900 degrees F., and the maximum firebox temperature should be between 2,000 and 2,500 degrees F. The following shows the colors for the various degrees of heat:

1,300 degrees F.	Fire in dull red.
1,600 degrees F.	Fire in full cherry red.
1,850 degrees F.	Fire in bright red.
2,200 degrees F.	Fire in bright orange.
2,400 degrees F.	Fire in white heat.
2,600 degrees F.	Fire in welding heat.

32. In combustion the evolution of light and heat takes place, and the rate of vibration of the molecules is astounding, scientists having calculated the molecular motion of incandescent fire to be about 600,000,000 a second. The heat generated by the atoms as they unite is sufficient to throw off minute points of light, and this process, continuing in every part of the firebox, produces what is known as flame. Bright flames indicate that the gases which are being set free are properly burned, while dull flame indicates the opposite.

Before ignition can take place the kindling temperature of any inflammable substance must be reached. Place a small piece of wood or coal on a fire and note that for some moments it is not affected by the fire. Finally, reaching its kindling temperature, it bursts into flame. The flame creeps up slowly because no part starts to burn until that portion just ahead of it reaches the kindling temperature. Different classes of fuel have different igniting points. Coal gas does not burn below the red heat of iron, and the kindling point of carbon is still higher. A piece of iron heated red will not light a gas jet, but heated orange it will. Thus the igniting temperature of hydrogen gas is about the orange heat of iron. With carbon still higher in the scale, the necessity of a very hot firebox is apparent. When a heavy charge of fuel is thrown into the firebox the temperature is temporarily reduced below the kindling point, and the gases distilled by the hot fire beneath escape unused.

33. A bright fire next to the sheets is necessary because these sheets take up the heat so rapidly that the heat or gases passing along the sheets will be cooled below the igniting temperature, and waste occurs. An incandescent fire of whitish gray color shows rapid combustion, and that the elements are combining properly to produce the heat of utility and economy, carbon dioxide, yielding 14,500 heat units to each pound of carbon. Contrast this with improper mixture of the elements, the black, sooty appearance of the fire and the 4,500 heat units to each pound of carbon when carbon monoxide is being produced.

34. The coal thus far considered has been soft, or bituminous, but in some sections of the country anthra-

cite is used. This anthracite burns more slowly than bituminous and calls for a larger grate area. Cylinders of a given size draw the same volume of steam each minute from the boiler, and soft coal, burning rapidly, produces about the same quantity of steam per pound consumed as anthracite, which burns slowly. Anthracite must be fired to suit the size of the lumps used, and if the lumps are thick (about eight pounds each) a thick fire must be carried, because the lumps lie so open the air mixes with them readily, and there is danger of chilling the firebox. A thin fire of this kind is not practicable any more than it would be in a stove with several large lumps lying on the fire. Keeping the fire best close to the sheets stops the danger of the passage of air in that vicinity, and the sheets are kept continuously hot—necessary to good steaming.

35. Where the anthracite is burned in small pieces a very large grate area is required, and the fire must be burned thin. A sharp exhaust would be ruinous unless the blast is distributed over a large area. The capable fireman who uses anthracite is ever on the lookout for thin spots where the air is working through, and coal is constantly supplied at the proper points.

36. A locomotive is laboring along with a heavy, thick fire on the grates, and the air entering the firebox has the oxygen atoms seized by the glowing carbon first encountered, and the heat thus generated keeps distilling the hydro-carbon gas from the green coal above. There is very little oxygen left in the air after it has worked through the fire beneath, and the volatile gases (very essential to good steaming) pass out

of the tubes and stack unused; and with less air than is required much of the carbon is not consumed, and carbon monoxide is the result. Fully 25 per cent. of the coal, in the form of the hydrocarbon gases, is thus wasted.

37. Sometimes an engine will not steam freely unless a heavy fire is carried, due to the use of very small nozzles, making the blast so sharp that a thin fire would be torn asunder by the onrush of air. When an engine does not steam properly there is always a tendency to call for smaller nozzles, but the nozzles may be too small for good steaming. With the average coal an engine will steam with a large nozzle, but coal that contains slate or similar material will alter the value of the draft. Small nozzles are also objectionable because they prevent the proper escape of steam exhausted from the cylinders, the piston thus working against back pressure and wasting energy.

38. Let it be assumed that the locomotive under consideration is equipped with the best draft appliances, and it is possible to carry a medium light fire even when doing heavy work. When the fireman throws a shovelful of coal on the fire the effect is similar to throwing a dipperful of cold water into a pot of boiling water. That is, there is a general reduction in temperature. Just as a small quantity of cold water will not check the boiling, so will the small amount of coal not affect the combustion. But part of the heat must be absorbed in raising the new coal to the igniting point. This is done in an instant and the hydrocarbons are released, and if ample oxygen is present, combustion results immediately. But if great masses of coal

are heaved into the fire box it is easy to see the effect, with too much heat required to bring up the temperature of the newly added coal to the kindling point, and with too little oxygen getting to the new coal and the gases to form proper combustion.

39. When soft coal is used, the practice is to carry as heavy a fire as the engine will steam with, and at each firing six or seven shovelfuls are thrown into the firebox. When the door is closed a stream of black smoke pours out of the stack, showing the escape of unconsumed hydro-carbon gases. Want of oxygen at the point where these gases are distilled is the cause of this waste. The fireman watches the stack, and as soon as the smoke has subsided he begins firing again, thus throwing away about 30 per cent of the entire fuel value. The reason for this is usually because it calls for the least amount of personal attention.

40. The proper method of firing is to keep enough fire on the grates to suit the needs of the engine and its work. A shovelful or two at brief intervals, and properly distributed, will do this. The result is the maximum amount of steam with the minimum amount of fuel, and incidentally with the smallest amount of actual labor.

41. The draft in a locomotive fire box is produced by the pressure of the atmosphere—about 15 pounds to the square inch. The flue passages connect the firebox with the stack. The exhaust steam traveling swiftly through the nozzle and shooting out through the stack produces a partial vacuum, which is contrary to nature's liking, and the air coming through the grates is ever rushing on to fill this

vacancy. When the exhaust is working hard on the fire it is creating a partial vacuum in the smokebox, and the air pressure is working itself through the grates.

QUESTIONS.

The answers will be found in the text of the preceding article under corresponding paragraph numbers.

1. What does combustion of fuel in a locomotive mean? What occurs in the act of combustion? Why does one fireman get much heat and another little heat?

2. Name the subjects with which the fireman should become familiar in order to intelligently follow his vocation.

3. When elements or compounds enter into combination to form new substances what rule does nature follow?

4. What elements are concerned with combustion? How is carbon dioxide formed? How is carbon monoxide formed? What is chemical affinity?

5. What are the most important elements in combustion? Which is the fuel and which is the supporter of combustion? Does combustion ever occur rapidly or slowly?

6. What is the composition of fuel used for steam making? What does bituminous coal contain? What are the constituents of anthracite coal? How much carbon does it contain?

7. Give an idea of the principal constituents of coal used by the leading railways.

8. What comprise the heat value of coal? Explain a heat unit. How are heat and mechanical energy interchangeable?

9. Give examples of this relationship between energy and heat. What does combustion in the firebox accomplish? What must happen before a train is stopped?

10. Do gases have weight?

11. What is the weight of air? By weight what are the proportions of the different gases in the atmosphere? By volume what is their relationship?

12. What does nitrogen do in the firebox? Show how the different combinations of oxygen, hydrogen and gaseous and solid carbon produce different degrees of heat, and name the work units actually liberated. What do these facts prove with relation to the firing of a locomotive?

13. Can the engine actually consume fuel without getting the heat value from it? What are the losses of heat? Can these be prevented? Can they be diminished?

14. Name some other means of preventing this loss of heat.

15. Show what percentages of losses may be accredited to each source that has been named. How much energy (heat) does the fireman ordinarily get out of his coal?

16. Show how this waste foots up at the end of the year for one locomotive. Show how it totals for 100 engines, and then give an idea of the actual money that might be saved the company with better firing in vogue.

17. Does the steaming power of the locomotive

cut any figure? Can certain types of locomotives waste heat when fired with different fuel? Explain the answer by an example. What is the lowest rate of combustion that permits of incandescence?

18. Are locomotives usually designed to cover this difference in fuel? Does the report "not steaming" imply anything?

19. What parts of the draft arrangement are matters of experiment, and who usually decides them? What are the next important points of inspection? Does water supply mean anything? What is sometimes more important than the cost of coal? How can a leaky engine be made to work properly? What should be done if the leaks are spurting? What should be done if they are simply seeping? What is the object sought by high temperature?

20. What temperature has steam and water at 200 pounds pressure? With 14,700 B. T. U. coal what consumption per square foot of grate area per hour will produce different degrees of heat in the firebox? How may expansion occur? What consumption of fuel permits the retention of the temperature? What does the blower do? Can the blower be of service when the engine is shut off if it is given to leaking? What does poor water do with regard to heating and leaking?

21. Given a common firebox 72x35 inches, with about 17 square feet of grate area, give an idea of the coal consumption usually required. What effect does the air have?

22. Can the elements, uniting in proportions other than those fixed by nature, produce anything

at all? With plenty of air admitted to the firebox what takes place? What is the value of this gas?

23. If there is a restriction in the quantity of the air admitted to the firebox what results? What determines the best product of combustion?

24. What is the result if one pound of carbon unites with oxygen to form carbon dioxide?

25. What is the result when a pound of carbon unites with oxygen to form carbon monoxide? Has there been any difference in coal consumption? What decides the heat value?

26. Taking the locomotive above referred to, show how much air will be required to carry on the proper combustion. What would this volume of air amount to?

27. Do smoke preventing devices work economies? What may be said of inventions for admitting the air above the fire?

28. If coal is deficient in hydrogen how will the oxygen circulate? Is a strong draft desirable? Why? How can the firebox be deprived of much of its duty in combustion? What may be said of a high velocity of the gases?

29. What is the total volume of air required in this locomotive? What other volume is added to this?

30. How is loss of heat threatened? What does an extra quantity of air call for?

31. What is the great requisite of good firing? What is the average air consumption for good steaming? What should be the firebox temperature and what is the ignition temperature of coal? What average temperatures should be maintained? Give

an idea of what sorts of heat and colors are produced by different temperatures in the firebox of the engine.

32. What takes place during combustion? What is the vibration rate of the atoms? What is flame? What is indicated by a bright flame? What by a dull flame? Illustrate the kindling temperature by an example. Why does the flame creep up slowly when the combustion is slow, and what must always take place before fuel will burn? Illustrate the different heats required for different substances before they will burn.

33. Where should a bright fire be maintained always, and why? What sort of fire implies rapid combustion? If the elements are not properly mixed what results?

34. What may be said about anthracite coal? What effect do cylinders of a given size have? How must anthracite be fired? What may be said of a thin anthracite fire and what must be guarded against?

35. Where anthracite is burned in small pieces what is required? Is a sharp exhaust good under these circumstances, and why? What does the capable fireman always look out for?

36. If a locomotive is working under a heavy, thick fire what takes place as the air enters through the grates? What is the result? What is the percentage of waste?

37. Is a heavy fire ever necessary? What may be said about the size of the nozzles? What effect may a small nozzle have on the cylinder and does this affect the working power of the engine?

38. With an engine equipped with the best draft appliances what occurs when the fireman throws fresh coal into the firebox? What must part of the heat do? If great masses of coal are used what is the result?

39. When soft coal is used, about how much coal is thrown in at a time? What does black smoke indicate? What causes the waste? How great it is?

40. What is the proper method of firing and what is the result?

41. What produces the draft? What happens when the exhaust is working hard?

LESSON V

STEAM
EXPANSION AND VELOCITY

LESSON V.

STEAM EXPANSION AND VELOCITY.[*]

1. There are numerous facts about steam worth understanding, even though the exact nature of steam itself is still more or less a conjecture. There is a certain heat contained in the steam that will be recorded by the thermometer, and some other heat to which the thermometer is not sensitive, known as latent heat.

2. Proof of the existence of latent heat is possible. To illustrate, take one part (by weight) of steam at 212 degrees, and mix it with nine parts of water (by weight) at 62 degrees. One cubic foot of steam at 212 degrees weighs .037928 pound. Taking one part (by weight) of steam at 212 degrees = .037928 pound, and nine parts (by weight) of water at 62 degrees, the nine parts (by weight) of water would, of course, weigh $.037928 \times 9 = .341352$ pound. The latent heat of vaporization of the steam is 966.6 degrees, and the total heat of steam above 32 degrees is $180 + 966.6 = 1146.6$ degrees. The heat of the water above 32 degrees is 62 degrees minus 32 degrees = 30 degrees. Then

$$\frac{W_1 t_1 + W_2 t_2}{W_1 + W_2} = t.$$

Or,

$$\frac{.037928 \times 1146.6 + .341352 \times 30}{.037928 + .341352} = \frac{53.7288}{.37928} = 141.66 \text{ deg.}$$

equals temperature of the water. That is, each of the nine parts of water has received $141.66 - 30 =$

---

[*] Contributed to the Locomotive Firemen and Enginemen's Magazine as a copyrighted article, July, 1911, by Frederick J. Prior.

111.66 degrees of heat, and the total (this amount multiplied by 9) is 1004.94 degrees minus 70.34 degrees (212 — 141.66), or 934.6 degrees of heat.

Take a pound of water at 212 degrees and mix it with a pound of water at 32 degrees, and the temperature of this mixture will be 212 plus 32, or 244, divided by 2 (to designate the equal number of parts), giving 122 degrees as the temperature of the two pounds of water. But, if a pound of ice at 32 degrees is mixed with a pound of water at 212 degrees, the result is not a temperature of 122 degrees for the two pounds of fluid, as above. It will be 50.675 degrees, because experiments show that the water gave up 161.325 units of heat to bring both ice and water to a common temperature. Of this number of degrees or units, 142.65 degrees were used to convert the pound of ice at 32 degrees into a pound of water at 32 degrees—whereas 18.675 degrees more raised the water resulting frôm the melted ice to a temperature of 50.675 degrees in common with the other pound of water. This phase of latent heat (known as the latent heat of fusion) proves that even the thermometer cannot always detect certain heat that actually exists. Therefore, the word "latent" is employed to designate this hidden heat. Experiments have proved that the latent heat in steam varies from 940 degrees to 1044 degrees, the ratio of accumulation advancing from 212 degrees as the steam becomes more dense and has greater elastic force.

3. Ordinary examples of the latent heat of steam are shown by its usefulness in boiling, drying and heating. In heating, there is condensation of the steam in its course throughout a building, and in this process, the latent heat is given out to the pipes and

radiators. Boiling can be altered by air-pressure; thus, on high mountain-tops, it is sometimes necessary to condense the atmosphere in the boiling vessel so as to get the proper degree of heat.

4. Steam used expansively in a steam engine may be illustrated as follows: When steam of a uniform force is used throughout the entire length of the piston's stroke, the amount of the resultant effect is as the quantity of the steam expanded. If the steam be shut off at any portion of the stroke (as at one-half), it expands by degrees until the stroke terminates, when it exerts half its original force.

5. By employing links, and a lever to shift their relation of position and motion to the rocker-arm or eccentrics, the travel of the valve on its seat is altered to meet the requirements by a long or short cut-off of steam admission. Let it be assumed that a cylinder 24 inches long is filled half its length with steam at 90 pounds' pressure to the square inch. By the time this had expanded (were it permitted to do so) until it filled the entire cylinder, its volume would be doubled, but its pressure would be decreased in inverse ratio, amounting to only 45 pounds to the square inch.

6. Suppose an engine has a 26-inch piston travel or stroke, and is cutting off at 18 inches, with an absolute pressure of 120 pounds to the square inch. To find the pressure after expansion, the following calculations may be indulged in: Multiply the amount of the pressure (120) by the length of the cut-off (18) and the result is 2,160. Now, divide this by the total piston travel (26), and the final result is 83, the number of pounds of pressure after complete expansion. The lever might be changed so that the cut-off would occur at 8 inches. To learn

the total pressure take (120), and multiply it by the length of the cut-off (8), and the result is 960. This divided by the total stroke (26) would give 37—the number of pounds of pressure to the square inch after expansion.

7. An efficient and simple rule to use in calculating the final absolute pressure is to take the original pressure and multiply it by the length of the cut-off. Divide the result by the full length of the piston-stroke and the final result is the steam pressure to the square inch in the cylinder after expansion.

8. By absolute pressure is meant effective pressure plus atmospheric pressure. It is also well to remember that a loss of heat in steam implies a loss of power. If the steam cooled perceptibly in expanding, it would lose in force far beyond the ratio quoted.

9. The economy of steam's utility in a locomotive also involves its expansive force after it has left the cylinders. By the use of nozzles the final expansion is used to assist in the combustion of the fuel in the firebox, thereby making the steam not only serve its tractive requirements, but compelling it to help generate more steam as well.

10. Steam pressure is equal in all directions, and its pressure is usually measured with relation to the atmospheric pressure—14.7 pounds to the square inch of surface at sea-level. There is a difference between vapors, of which steam is a member, and permanent gases, where the volume of a given weight is inversely as the pressure. Between the pressure, the density and the temperature of steam there exists a constant relation, so that pressure cannot be raised above a given maximum without also raising the temperature.

11. If the volume of steam is forcibly reduced and the vapor compressed without any change of temperature, the pressure is not augmented by the compression, as would be the case with air. To the contrary, a portion of the steam is liquefied, and no gain is made in pressure without increasing the temperature.

12. When the vapor attains the limit of density and pressure, corresponding to the temperature, the steam is referred to as saturated—and this state of saturation always continues when it is in contact with water. There is one density and one temperature for one pressure—and pressure, density and temperature increase together.

13. When out of contact with water, as in the cylinder of an engine, a quantity of steam may be expanded and again compressed to the limit of saturation. The pressure is nearly in the inverse ratio of the volume. That is, when the volume is doubled, the pressure diminishes to about one-half, and if the volume is trebled, the pressure is reduced to about one-third.

14. In superheated steam the laws of permanent gases are obeyed, and the steam acts as one of them. That is, it expands and contracts in the inverse ratio of the pressure, so long as the temperature is constant, without any condensation.

15. In a steam boiler, therefore, one density, and one pressure are attained with relation to one temperature. The steam is in a state of saturation, and these three qualities possess a relative equilibrium. So long as the saturation corresponding to a given temperature is not attained, evaporation progresses; when it is attained evaporation ceases.

16. With increased capacity of the boiler, evaporation is resumed, continuing until the steam again becomes saturated. With a fall in the temperature, there is also a decrease in pressure and density. With the boiler closed, and the steam at the same temperature, the conditions remain unaltered. With an opening for the egress of steam, the pressure falls, evaporation is taken up again and continues until saturation is re-established. As this new steam generation is very rapid, there is no noticeable change in the temperature, density or pressure in the boiler as steam is withdrawn for each stroke of the pistons.

17. Gases and vapors behave the same as liquids in flowing through tubes and openings. The velocity of liquids also applies to gases and vapors.

18. The pressure of gas or vapor is equal to that of a column of the gas, the weight of which is equal to the pressure. Divide the pressure to the square inch by the weight of a prism of the gas one foot high and one inch square, and the quotient is the height in feet of the equivalent column of gas, from which the velocity of the flow will be calculated. This velocity applies to the discharge of the gas into a vacuum. Ordinarily, the medium into which the gas escapes exerts a counter-pressure; therefore the counter-pressure must be deducted from the total pressure, the difference being the net pressure.

19. Steam under a total pressure of 100 pounds to the square inch would flow from a boiler into steam of a total pressure of 58 pounds to the square inch as readily as into the atmosphere. Thus, the resisting pressure above 58 per cent. of the total pressure must be taken into consideration. The fol-

lowing table shows a few examples of the velocity of the efflux of steam of absolute pressure, varying from 25.37 pounds to 100 pounds to the square inch, into the atmosphere. The velocity is calculated as for steam of the initial density and unexpanded.

Total Pressure in Pounds per Square inch.	Velocity of Efflux in Feet per Second.
25.37	863
30	867
45	877
60	885
75	891
100	898

The velocities calculated in terms of simple pressure and density are greater than in practice, as there are various hindrances to the flow of steam in engines. In well-constructed engines, however, the flow of steam is sufficiently rapid for the proper performance of the steam passing into and out of the engine.

20. As there are retarding influences to the flow of steam, as contraction and friction, the lengths of pipes and passages are reduced as much as possible and the sectional areas are increased; sudden changes in the direction of parts and passages are avoided; and steam is used as dry as possible.

21. Should the lead of the valve be too late, the maximum pressure of the steam in the cylinder is not secured until after the piston has traversed a portion of its stroke. If the lead of the valve is too early, the steam is admitted so suddenly as to be temporarily compressed, causing a pulsation of the

steam. Total absence of lead of the valve likewise causes a pulsation within the cylinder.

22. The value of dry steam inheres in the fact that when steam condenses in the cylinder or it is charged with water, as in priming, there is back-pressure and loss of power.

23. For scientific purposes, a uniform zero is essential, as zero in Centigrade is the freezing point of water, while the zero of Fahrenheit is 32 degrees below freezing. Thus, the zero of absolute temperature is 460 degrees below the Fahrenheit zero and 273 1-3 degrees below the Centigrade zero. To express Fahrenheit degrees in degrees of absolute temprature, add 460. The boiling point of water is 212 degrees F., to which add 460 degrees, making it 672 degrees absolute temperature.

24. In converting Fahrenheit degrees into Centigrade, subtract 32, multiply the remainder by 5 and then divide by 9.

25. Converting degrees of Centigrade into Fahrenheit degrees, multiply by 9, divide by 5 and add 32.

26. The specific heat of a substance is the ratio of the amount of heat necessary to raise the temperature of a substance one degree to the amount of heat necessary to raise the temperature of an equal weight of water one degree. With the exception of hydrogen, water has the highest specific heat; that is, more heat is required to raise the temperature of a given amount of water than any other substance excepting hydrogen. The specific heat of metals is the lowest.

27. If a pound of cold water in a closed vessel is heated until it becomes warm, its weight remains unchanged, even though the temperature has advanced. If the heat is continued until the water has

been converted into steam, and none of the steam escapes, its weight is the same as the water from which it is generated.

28. This means that the heat is without weight—not a material substance. It is supposed to be some sort of vibration—some form of energy.

29. A heat unit is the amount of heat essential to raise the temperature of one pound of water one degree F., when the water is at its greatest density—from 39 to 40 degrees F.

30. The proportion of the difference of temperature between a cold body and a hot one regulates the rate of the transfer of heat. The greater the difference in temperature, the greater the rate of the transmission of the heat.

31. Radiation, convection and conduction are the three means of heat transmission. Hot bodies give out heat by what may be termed rays of radiation. In a furnace, for example, the heat is transferred from the burning coal to the furnace sides and crown by radiation; through the furnace plates the process of transmission is conduction. Water is heated by convection. When heat passes from a hot body to a colder body in contact with it, or from hot parts to cold parts of the same body, the process is conduction. These facts relative to heat, its transmission, its effect on water, the conversion of water into steam, the elasticity, velocity and characters of steam generally, are all related to the engine features of the locomotive—and while many of the theories concerning steam are still hazy, it is doubtful if more definite knowledge would make the application of steam any better than it is today. At any rate, the use of steam, like the use of electricity, is considered far more important than the scientific facts concern-

ing it—but brief knowledge of these truths is not amiss as it gives a very clear reason why the engines and their parts have taken on their present form; it tells why they undergo certain acts in the performance of their functions.

QUESTIONS.

The answers will be found in the preceding text under corresponding paragraph numbers.

1. Is there any other form of heat in steam than that which can be registered by the thermometer?

2. Give examples to show how this heat is detected, and approximately what it amounts to in degrees.

3. Give some other examples of the value of latent heat in steam.

4. How is steam used expansively in a steam engine?

5. How is the cut-off regulated? Show how volume and pressure are related—and how they differ.

6. Give an example as applied to an engine having a total piston-stroke of 26 inches, and cutting off at 18 inches; also at 8 inches.

7. Give an efficient rule for calculating the final absolute pressure.

8. What is absolute pressure? What is effective pressure?

9. How is the economy of the expansion of steam further utilized?

10. What peculiarity is there to steam pressure?

11. Does the reduction of the volume of steam effect its pressure?

12. What is saturation?

13. How does pressure pertain to volume?

14. What difference is there between superheated steam and saturated steam?

15. How do density, pressure and temperature correspond in the boiler?

16. What continuous change is in progress within the boiler as steam is withdrawn for the cylinders?

17. How do gases and vapors behave in flowing through tubes or openings?

18. What is counter-pressure?

19. What consideration is devoted to resisting pressure?

20. What effect do contraction and friction have on steam, and how are these partly overcome?

21. Describe what changes follow different actions of the lead of the valve.

22. Wherein lies the value of dry steam?

23. Describe absolute temperature.

24. How are Fahrenheit degrees converted into Centigrade?

25. How are Centigrade degrees converted into Fahrenheit?

26. What is specific heat?

27. What change does heat make in weight of water?

28. What does this mean with relation to heat?

29. What is a heat unit?

30. What is the deciding point of the regulation of transfer of heat from a hot body to a cold one?

31. How is heat transmitted? Give examples of each class of transmission.

LESSON VI

CARE OF A LOCOMOTIVE BOILER

LESSON VI.

CARE OF A LOCOMOTIVE BOILER.

In locomotive operation the difficulties that are continually met with are numerous. Boiler troubles in road service are, perhaps, the most frequent source of difficulty, certainly the most vital. What is the nature of the boiler troubles most likely to be encountered, and what should be done in each instance, forms the basis of important and practical information for firemen and engineers. The most pronounced troubles, with suggestions in regard to them, are therefore tabulated as follows:

1. Priming and foaming are the chief causes for the carrying of water from the boiler into the cylinders.

2. The cause of foaming is the presence of foreign matter in the water, such as alkali or oil, forming a light, soapy mixture. Corn meal, used to stop leaks, and other substances also cause foaming.

3. The cause of priming is usually traced to forcing the boiler, or because the steam space is too restricted to care for the steam being generated. Defective circulation is also a cause, with the steam driving the water ahead of it through restricted spaces. In any event, water is carried into the cylinders in conjunction with the steam.

4. Foaming is usually detected by the appearance of water at the top of the stack. The steam should then be shut off gradually and the water be per-

mitted to settle. If there are three gauges of water the trouble is usually too much water in the boiler. If the water settles down so there is only one gauge, foaming is the trouble. The whitish appearance of the steam escaping from the stack also indicates foaming. The same appearance of the steam in escaping from cylinder cocks and water gauges, and the noise made in escaping—a sort of flutter—also indicates foaming.

5. With the detection of, and proof of, foaming, the cylinder cocks should be opened, thus preventing the knocking out of cylinder heads. If there is a surface blow-off it should be opened. The left and right injectors should be put to work to raise the water level. At frequent intervals the steam should be gradually shut off and the water permitted to settle. This will determine the true level—which should be neither too high nor too low. Reduction of speed may also be necessary. At the first stop there should be enough solid water in the boiler to permit its being blown down for two gauges.

6. When a boiler is priming the injector should be shut off, the water level lowered and the fire checked, thus reducing the rate of evaporation.

7. Should the level of the water in the boiler fall so low as to leave the crown-sheet uncovered the engine should be stopped and the fire banked with earth, thereby preventing the burning of the crown-sheet. When the boiler has cooled and the steam pressure has fallen, the injector should be started and the water level raised. With the appearance of water at the first gauge, the fire may be cleaned and the locomotive is again ready for the run.

8. Where boilers are fitted with a fusible plug, which has melted because the water has fallen too

much, the engine is generally disabled and has to be towed in. Should another fusible plug be available, this may be inserted after the steam pressure has been lowered. The boiler can be refilled through the safety valve opening and the fire may be rekindled. This generally involves too much time to make it practicable.

9. If a flue is leaking badly, nothing can be done if the leak is at the tube-sheet where the tube has been expanded into place. Should the cause be a defective tube so that the water is blowing through to the firebox, the tube may be plugged. A wooden plug, hammered in and broken off, will usually suffice to complete the run. While the end will be burned off, the part within the tube will usually be protected. There are plugs made especially for this purpose, but they are rarely supplied to locomotives.

10. Should the blow-off cock become clogged in blowing down the boiler so that it can not be closed, the result will usually be the emptying of the boiler to such a degree that the crown-sheet will be bared. The fire, in this case, should be drawn without delay. If the fire is light it may be possible to bank it up with earth, thus keeping the heat away from the crown-sheet.

11. Where a locomotive has a shallow ashpan, and the drop-grate should become broken or burned out, the fire should be drawn back from the broken part and the space beneath filled with stones to the top of the gates. Coal should be thrown over it, so as to prevent the drawing up of an excessive amount of air.

12. Where a locomotive has a deep hopper ashpan, and the drop grate becomes broken or burned, the locomotive should be run to the first place where

splice bars or other pieces of iron or steel of suitable length can be secured. After pulling back the fire the break can be bridged with these pieces of iron.

13. Locating leaky joints in an exhaust pipe, where the air brake pump exhausts into the passages of the saddle, is accomplished by plugging the nozzle and starting the pump with an angle-cock opened to prevent accumulation of pressure in the main reservoir. This will cause the escape of steam from any joints that may be leaking. If the air pump does not so exhaust, the locating of the leak is more difficult, unless the steam pressure is low—around 25 or 30 pounds. In this event, the nozzle may be plugged and the wheels blocked. The throttle may be opened slightly and the reverse lever moved backward and forward. This will cause a pressure in the exhaust pipes and passages.

14. The best time for the inspection of a locomotive for leaky steam pipes in the front end is after the fire has been drawn and the boiler has been permitted to cool.

15. Boilers that have been standing some time under pressure have been known to explode with the opening of the throttle, caused, it is believed, by the superheating of the water. The opening of the throttle causes the outflow of steam and the liberation of the steam from the water, with a sudden increase in pressure. The danger seems to exist mostly in boilers having some weakness.

16. The form of boiler seams sometimes has a deteriorating effect on the sheets. The application or removal of pressure should in no wise affect the shape of the metal. This weakness leads to groov-

17. There is danger in making repairs on a boiler under pressure, because if there is any grooving or weakness anywhere in the metal the disturbance is apt to cause an explosion.

18. Cracked sheets occur frequently, and generally at the throat-sheet, the tube-sheet or the side-sheets of the fire-box, but this does not imply an explosion will follow. If an explosion were going to occur, it would be simultaneous with the cracking. The pressure should be reduced immediately, as by throwing earth on the fire or starting the injector. The movement of the train should not proceed without a careful inspection, so as to determine the extent of the injuries.

19. While blistered sheets are not as frequent in steel as they were in iron, they sometimes occur, and usually in the firebox where the greatest heat is exerted. In size they vary from a small spot to more than a foot in diameter. The same precautions should be taken as in the case of a cracked sheet, and if the blister has not raised away from the sheet more than two or three inches across, the locomotive may move under reduced pressure. Repairs are necessary before it is again fit for service.

20. In the explosion of a boiler, the first break occurs at some point of weakness. Through this vent the onrush of the steam tears the materials asunder, accomplishing the complete explosion in a remarkably short space of time. Grooving along a lap, lines of rivet holes or the edge of a welt is generally the place of the initial rupture.

21. The source of energy in boiler explosions is the heat in the water. Thus, the more water in the boiler, the worse the explosion will likely be. This force is sometimes over 2,600,000,000 foot pounds,

tive to a height of two and one-half miles. The energy, however, is spread in all directions.

22. While a boiler may not burst when tested at hydraulic pressure, it is still possible it may explode at the same steam pressure, due to differences in temperature and to differences also in the nature of the stresses.

23. Some of the causes of locomotive boiler explosions may be traced to the deterioration due to age, or to the carelessness of the engineer. Thinness of plates through corrosion, their continued bending under expansion and contraction, their subsequent breakage, and the breaking of the stay-bolts in the firebox, are all causes. Low water through neglect may also be a cause. In a word, whatever causes pressure greater than the boiler can withstand is liable to result in an explosion.

24. Stay-bolts are most apt to break in the upper rows of the front end of the firebox. The inside sheet, subjected to the greatest heat, usually expands the most. This continued bending causes the trouble.

25. Broken stay-bolts may be detected by striking on the outer end with a light hammer, and listening. If the noise is similar to that produced by a solid substance, the stay-bolts are likely intact; but if the sound is hollow, it is probable the stay-bolts are damaged. Practice and observation alone make this inspection of value.

26. The most ordinary forms of boiler deteriorations are corrosive grooving, external corrosion of firebox sheets, repeated rolling of the tubes, or neglect generally. Sometimes structural weaknesses are present, quite beyond the scope of the engineer, but vigilance is necessary in detecting the signs of depreciation.

27. The over-heating of a crown-sheet is usually due, first, to the continued effect of the heat, resulting in a loss of tensile strength; and, second, to the more severe action when the sheet is permitted to become bare. At a welding heat there is no resistance and no load can be sustained.

28. The cause of grooving, which occurs at the edge of a lap of a seam in the face of a sheet, is traced to the continued exposing of the new metal and the resultant corrosive action of water. Thus, bending stresses followed by corrosion, weaken the plate and cause the groove.

29. Bulging sheets in a firebox may usually be traced to the oil or scale that covers the sheets. Forcing of the fire is also a cause.

30. Should a sheet bulge, the fire should be checked immediately and the locomotive worked under a reduced pressure.

31. In event a handhole plate or plug is blown out, the fire should be drawn or deadened immediately. If the plate can be found, a new bolt will secure it in place. Sometimes a block of wood will take its place temporarily. A soft pine plug will often answer for the one blown out. After the repairs are made the fire may be built, the steam raised and the locomotive put into operation.

32. Where a boiler has become emptied, filling is sometimes a laborious task. Use of pails is the most common, and the water may be poured into some convenient opening, such as whistle or safety valve.

33. Where the road is a busy one and trains are running at frequent intervals, it is always better to be towed in than attempt to make repairs that consume a great deal of time.

34. The constant supervision of the engineer and fireman will prevent many accidents and break-

downs, even due to weaknesses in the boiler itself. Thus the very weight of the boiler and the continued stresses in operation due to the rapid movement of the locomotive and the effect of heat will cause the boiler to bend and result in numerous groovings. All of these deteriorating effects are at work continuously, and eternal vigilance is the best plan—for even with that breakdowns occur.

35. When an engine is not working steam, the use of the blow-off cocks for the removal of sediment is accomplished by the onward rush of steam and water through the blow-off pipe. The engine should be blown off as frequently as possible, as it helps keep the boiler free from the accumulated sediment.

36. The same care is seldom shown to crown-bar braces and bolts that is bestowed upon the staybolts, partly because the former are more difficult of access and partly because they are less liable to breakage.

37. The scale, however, may be so thick and compact on crown-bar braces that they sound solid when struck by a hammer, while in reality they are broken.

38. The safest rule to follow in the case of a boiler liable to leak on the road, is to keep a light, hot fire at all times. Soda ash should be used freely in the tank and the boiler should be blown out frequently. The above facts have been given in brief form, without the theory. These are conditions learned from practice, and under the stress of circumstances the engine crew wants to know what to do rather than caring about the theoretical situation.

QUESTIONS.

The answers will be found in the preceding text under corresponding paragraph numbers.

1. What are the principal causes of carrying water from the boiler into the cylinders?

2. What is the cause of foaming?

3. What causes priming?

4. How is foaming detected?

5. When foaming occurs what should be done?

6. Tell what is to be done when a boiler is priming.

7. In event the level of the water in the boiler falls so low as to leave the crown-sheet bare, what is best to be done?

8. When a fusible plug melts, what should be the procedure?

9. What is done in case of a leaky flue?

10. If the blow-off cock becomes clogged in blowing down a boiler, what is best to be done?

11. If the drop-grate in a shallow ashpan is broken, how is it to be temporarily mended?

12. If the drop-grate of a deep hopper ashpan is broken, or burned, how are temporary repairs effected?

13. How are leaky joints in an exhaust pipe located?

14. When is the best time for inspecting a boiler for leaky steam pipes in the front end?

15. What is supposed to cause explosion of boilers that have been standing under pressure?

16. Does the form of boiler seams affect endurance of plates?

17. Is there danger in making repairs on a boiler under pressure? Give the reason in the answer.

18. Where do cracked sheets usually occur and what is done upon their discovery?

19. What is done in event of blistered sheets?

20. What causes many boiler explosions?

21. What is the source of energy in a boiler explosion?

22. Does the hydrostatic pressure test always indicate ability to withstand steam pressure? Why?

23. What are some other causes of boiler explosions?

24. Where do stay-bolts usually break, and why?

25. How may broken stay-bolts be detected?

26. What are the most common forms of boiler deterioration?

27. What generally causes overheating of crown-sheet?

28. What is the principal cause of grooving?

29. What causes bulging sheets in a firebox?

30. What is done in case a sheet bulges?

31. If a hand-hole plate or plug blows out, what is best to be done?

32. How is refilling of a boiler accomplished when it is emptied at some remote point along the road?

33. Should time be taken for repairs on a busy road?

34. Why is continuous vigilance of fireman and engineer necessary?

35. When should the blow-off cocks be used, and should an engine be blown out frequently?

36. Is the same care shown to crown-bar braces and bolts as to stay-bolts? Why?

37. What is sometimes the effect of scale on crown-bar braces?

38. What rule is best to follow if a boiler is liable to leak on the road?

LESSON VII

ADHESION

LESSON VII.

*ADHESION.

1. The term adhesion means simply the friction that exists between the driving wheels and the rails so as to prevent the slipping of the wheels.

Where the train resistance exceeds the adhesion, the drivers will simply slip and turn around without pulling the load.

2. In the matter of relationship, the engines must exert a pull greater than the resistance of the train and the adhesion must exceed the pull of the locomotive. This rests with the weight placed upon the driving wheels.

3. Given a dry rail in good condition the adhesion is about a fifth of the weight on the drivers, but this diminishes with a "bad rail" caused by rain, sleet, mud or similar conditions. Sanding the rails is purely to increase the friction.

4. It is possible to figure out this relationship by knowing the train resistance or the adhesion. By knowing the weight placed upon the drivers, it is possible to ascertain the adhesion and to learn the available force in overcoming the resistance of the train. Thus, if the weight on the drivers is 60,000 pounds the adhesion is 12,000 pounds.

5. Knowing the train resistance, multiply its force in pounds by five and the result is the necessary weight to be placed on the drivers. In other

---

*Note: Copyrighted as a contributed article to the Locomotive Firemen and Enginemen's Magazine, June, 1911, by Frederick J. Prior.

words, if the train resistance is 10,000 pounds there must be 50,000 pounds on the driving wheels in order for the locomotive to haul its load.

6. There are many conditions governing the weight that can be safely placed on any one driver. The rails, the condition of the roadbed, the bridges, etc., are all factors entering into this part of the subject.

7. It is figured by some authorities that where a rail is light, weighing but 28 pounds to 48 pounds to the yard, the limit of safety in weight on each driving wheel will be 4,000 pounds; and that, in case of heavier rails, weighing from 65 pounds to 80 pounds to the yard, the weight can be 10,000 to 15,000 pounds to each driving wheel.

8. The weight that marks the safety point decides the number of drivers. Thus, if the limit of safety is 10,000 pounds, and the weight required is 40,000 pounds, there must be four driving wheels. This would make the adhesion about 8,000 pounds. If the same weight limit obtains, and it is necessary to have 60,000 pounds on the driving wheels there must be six drivers, and the result would be an adhesive force of practically 12,000 pounds.

9. In some countries the coefficient is not figured the same as it is in the United States, which is one-fifth the weight placed on the driving wheels. England usually bases its calculations on about one-sixth, but conditions vary, because climate always plays an important role in the matter of locomotive adhesion.

10. This friction is not exactly like the kind implied in the general use of the word. Friction

usually means rubbing, but there is no rubbing in a locomotive driver unless it slips. When the engine is working smoothly, the train going at any speed, and the load being hauled without difficulty, the tire is always virtually at rest on the rail. While science may not have classified this kind of friction, railroading must move onward and practical tests determine the solution more than theory. Every device that has offered an answer to the increase of adhesion and the prevention of slipping has received attention. The coupling of drivers has thus far been found the most serviceable.

11. The method that prevails in this coupling is by crank pins, to which rods are attached extending from one crank-pin to another. On the opposite side of the locomotive these pins are set at a variance of 90 degrees, so that when one set of pins is on the dead center, the others are alive. Any number of wheels may be coupled, and the adhesion is benefited just that much.

12. It has been estimated that while the adhesion is increased the fuel consumption is also heightened to sometimes 5 per cent., due to what is known as the rolling resistance of the locomotive. This seems to be increased with the coupled drivers.

13. In coupling the drivers it is well to remember that the wearing of the wheels is different—that is, no two wheels are worn exactly the same, but the coupling makes it necessary that they turn the same. This stricture on the free movement of the locomotive interferes with its lateral flexibility, and to this cause may be directed the need of greater power to propel the vehicle. Given a loco-

motive running on slippery rails, assume that sand is applied to the track and note the effect on coupled drivers. One is brought up suddenly, catching its adhesion, but another does not catch and continues to slip.

14. A severe stress results on the crank axle, and in some instances it is twisted and broken. Advances have been made in the manner of applying the sand, so that it is shot out in a jet to the point where it is most needed. It is sometimes claimed that large driving wheels result in greater coefficient of adhesion, but the class of work to be done and the speed to be maintained play no small part in this consideration.

15. The altering types and the changing needs have continuously affected the locomotive, but, no matter what changes have been made in cylinders, boilers or frames, the adhesion has never been lost sight of, for on this depends the efficiency of all other portions of the locomotive.

QUESTIONS.

The answers will be found in the preceding text under corresponding paragraph numbers.

1. Define adhesion.
2. How are resistance, adhesion and pulling power related?
3. What is the ordinary ratio of adhesion to weight on driving wheels? What is the object of sanding rails?
4. Give a simple method of figuring adhesion.

5. How is necessary weight on drivers figured if train resistance is known?

6. What conditions offset safety of weight to be placed on any one driver?

7. Give some illustrations of answer to question No. 6.

8. What element decides the number of drivers?

9. What is meant by the term "coefficient"?

10. Does adhesion differ from friction?

11. How are driving wheels ordinarily coupled?

12. How does increased adhesion through coupling also heighten coal consumption?

13. What other detrimental effects are brought about by coupling?

14. Where are these stresses most severe?

15. Is adhesion ever overlooked in making other advances in locomotive construction?

LESSON VIII

RAILWAY BLOCK SIGNALS
AND
SIGNALLING

LESSON VIII.

QUESTIONS AND ANSWERS UPON BLOCK SIGNALS AND SIGNALLING.

Ques.: What is a block?

Ans.: A certain length of track that is controlled by a block signal.

Ques.: What is a positive block?

Ans.: A block in which but one train at a time is permitted to enter.

Ques.: What is a permissive block?

Ans.: A block in which two or more trains are permitted to enter at one time.

Ques.: What is a block station?

Ans.: A tower or other place from which block signals are operated.

Ques.: What is a block signal?

Ans.: A fixed signal for controlling the use of a block.

Ques.: What is a home block signal?

Ans.: A fixed signal located at the entrance of the block to control trains entering the same.

Ques.: Describe a distant signal and its uses.

Ans.: It is a fixed signal used in connection with the home signal and is used to indicate that the home signal may be at "Stop" when the distant signal is at "Caution" or that the home signal is clear when the distant signal is clear.

Ques.: What is an advance block signal?

Ans.: A fixed signal used in connection with a home block signal to subdivide the block in advance.

Ques.: What is a block system?

Ans.: A division or a whole railway line arranged in a series of continuous blocks.

Ques.: What is a telegraph block system?

Ans.: A series of blocks in which the movement of trains is governed by signals operated by hand upon information received by telegraph, or telephone.

Ques.: What is a controlled manual block system?

Ans.: A block system in which the signals are operated by hand, but are so constructed that it requires the co-operation of the signalmen at both ends of the block to display a clear signal.

Ques.: What is an automatic block system?

Ans.: A block system in which the signals are operated by electric, pneumatic, or some other agency set in motion by a train when it passes a certain spot, or by certain conditions affecting the use of the block.

Ques.: What do block signals control?

Ans.: The admission of trains to certain blocks.

Ques.: Do they affect the movement of trains under timetable or train rules?

Ans.: They do not.

Ques.: Does a block signal relieve the conductor or engineer in any way from protecting their train by flagmen in the usual manner?

Ans.: It does not.

Ques.: Describe the position of a block signal when shown at "Clear" and at "Stop."

Ans.: When shown at "Clear" a diagonal arm denotes it by day and a green light denotes it at night. When shown at "Stop," or "Danger" by a horizontal arm by day and by a red light at night.

Ques.: When the signal is shown at "Clear" to what point does it give a clear track?

Ans.: To the outer approaching switch at the next station.

Ques.: What is meant by the outer approaching switch at a station?

Ans.: The first switched reached.

Ques.: Do block signals control trains when they are standing on side tracks?

Ans.: They do not.

Ques.: Before a train standing on a side track can proceed what authority is necessary?

Ans.: Authority from the signalman.

Ques.: What constitutes this authority?

Ans.: A caution card and release. The release stamped "Block is Clear" or a train order stamped "Block is Clear," or train orders and a caution card.

card authority how must the engineer expect to find the main track?

Ans.: Occupied by trains in that block.

Ques.: When two or more trains coupled together enter a block when can they be uncoupled?

Ans.: Only at a block station and when uncoupled the signalman should be notified.

Ques.: What is necessary before a train may cross from one main track to another?

Ans.: A crossover permit.

Ques.: What instructions are necessary before re-entering a block or backing into one after it has been cleared?

Ans.: Instructions or authority from the signal man without which the train must not be backed within three hundred feet of the block.

Ques.: How long are train men required to watch a block signal to see that its position does not change?

Ans.: Until the whole of the train has passed it.

Ques.: If a block is approached where a signal man is regularly employed, but none is found there what should be done?

Ans.: Would wait ten minutes and then proceed to the next block station and make an immediate report of the fact to the train dispatcher. This applies to an intermediate station where there are no sidings.

Ques.: When a train that has parted is recoupled who should the conductor immediately notify?

Ans.: The signalman.

Ques.: May hand signals be accepted against block signals?

Ans.: They may not.

Ques.: When the track is obstructed between block stations, what is the duty of the conductor?

Ans.: He should immediately notify the nearest block signalman.

Ques.: When a siding is entered at a block station what notice must the conductor give to the signalman when the train is clear of the main track and the switch is locked?

Ans.: He must personally notify the signalman that his train is clear of the main track.

Ques.: What is an intermediate siding?

Ans.: A side track between two open block stations.

Ques.: What is required of an inferior train, which accepts a clear signal and proceeding on its right intends to proceed to the next block station, but which, owing to some delay, cannot be reached, provided there is an intermediate siding located between the blocks? Under like conditions, what is required of a superior train?

Ans.: The inferior train must take the intermediate siding, but if unable to reach it immediate steps should be taken to protect the train by flags. The superior train would proceed by authority of the caution card.

Ques.: When two trains are scheduled to meet at an intermediate siding what form of release is necessary?

Ans.: A release showing that the train order signal is displayed for these two trains to meet at the intermediate siding.

Ques.: In case the inferior train fails to reach the meeting point how is the superior train governed?

Ans.: The superior train will proceed on its time table rights and the same as on a caution card.

Ques.: When two trains meet by special order at an intermediate siding, what besides the order is necessary before entering the block?

Ans.: A release, stating that the signal is displayed for such trains to meet at the intermediate siding.

Ques.: In districts not controlled by telegraph block how far apart must trains keep when going in the same direction?

Ans.: Ten minutes apart.

Ques.: If your train is passed by any train at an intermediate siding in a district not controlled by telegraph block how long should you remain there before proceeding?

Ans.: Ten minutes.

AUTOMATIC BLOCK SIGNALS.

Ques.: What signals are used in connection with the automatic block system?

Ans.: Either the semaphore or the enclosed disc.

Ques.: How are the signal indications given by day and by night?

Ans.: By not more than two positions of an arm or disc, and at night by light of prescribed colors.

Ques.: Where would you look for these signals on single, double and three tracks?

Ans.: Over or upon the right of the track to which they refer, and on double track to the left of the track to which they refer, for one or two tracks the signals may be attached to the same mast. For three tracks, usually over the running track.

Ques.: When these signals are on bracket posts what signal would you read for the track on which you were running?

Ans.: The signal on the right hand mast refers to the track furthest to the right, the next signal to the left refers to the next track to the left and so on.

Ques.: To what side of the signal mast are semaphore arms displayed as seen from an approaching train?

Ans.: To the right of the mast.

Ques.: When a distant block signal is set at caution what does it indicate?

Ans.: A distant block signal indicates the position of the Home signal ahead.

Ques.: When the indicator disc is visible at a main track switch what does it indicate?

Ans.: That the head of an approaching train had reached a point within 1,000 feet in advance of the block signal protecting the switch.

Ques.: By what signal are the indications for the main running track given?

Ans.: By a high home signal.

Ques.: In what direction do even numbered signals govern?

Ans.: South or East.

Ques.: Odd numbered signals?

Ans.: North or West.

Ques.: Where a semaphore signal is used where are the arms displayed and how many positions are there?

Ans.: To the right of the mast. There are two positions.

Ques.: How at night?

Ans.: It will show a green light when at clear and a red light when at danger.

Ques.: Where a signal disc is used how are the indications given?

Ans.: By a position of a red or clear disc.

Ques.: How are they given at night?

Ans.: By the light of the same color.

Ques.: What is the "Stop" and "Proceed" signal on a Home Semaphore by day and by night?

Ans.: When at stop it will show a horizontal arm to the right of the mast and at night a red light. When "Clear" it will show a diagonal arm by day and a green light by night.

Ques.: Where two signals are displayed from the same mast what does the upper arm indicate?

Ans.: The upper one is the Home block signal for the block in advance.

Ques.: What does the lower arm indicate?

Ans.: It is the distant signal for the second block in advance.

Ques.: What is a caution signal on a Distant Semaphore signal?

Ans.: The arm displayed in a horizontal position and at night a green and red light.

Ques.: What is a Clear signal on a distant Semaphore signal?

Ans.: The arm displayed diagonally and at night a green light.

Ques.: What is a Stop signal on a Home Disc signal by day and by night?

Ans.: A red disc and at night a red light.

Ques.: What is a Clear signal on a Home Disc signal by day and by night?

Ans.: The red disc withdrawn from view and at night a green light.

Ques.: What is the Caution signal on a Distant Disc signal by day and by night?

Ans.: A green disc with a white cross on its face or a red and green light at night.

Ques.: What does this Caution signal indicate?

Ans.: To proceed with caution to the Home signal.

Ques.: What is a "Clear" signal on a Distant Disc signal?

Ans.: The disc withdrawn from view and at night a green light.

Ques.: When a train is stopped by an automatic block signal when may it proceed and how will it run?

Ans.: When the signal is cleared, or after waiting one minute for signal to clear. It should run with caution to the next clear signal.

Ques.: What is the indication when a signal is out of service and how will you proceed?

Ans.: It will be covered with a white shield. Would proceed with caution to the next signal.

Ques.: What is necessary when you find a signal out of order?

Ans.: Would notify superintendent.

Ques.: When a Home signal indicates "Stop" what does it mean?

Ans.: It indicates that the block is occupied, that a switch is wrong in the block, that a car is foul of the main track or that the signal apparatus is out of order.

Ques.: If you desire to pass from a side track to the main track and you find a red disc visible in the indicator box, what would you do?

Ans.: Would not open switch until red disc disappeared from view.

Ques.: Can a switch be opened to permit a train to move from the main to a side track when the red disc is visible in the indicator box at the switch?

Ans.: Yes.

INTERLOCKING SIGNALS.

Ques.: What is a high signal?

Ans.: A signal supported on a mast 20 feet or more high.

Ques.: What is a mast?

Ans.: An upright to which signals are attached.

Ques.: What is a Home signal?

Ans.: A fixed signal at which trains are required to stop when the route is not clear.

Ques.: Describe a Distant signal?

Ans.: A fixed signal used in connection with the Home signal to indicate that the Home signal may be at "Stop" when the Distant signal is at "Caution" or that the Home signal is at "Clear" when the Distant signal is "Clear."

Ques.: What is a Dwarf signal?

Ans.: A low Home signal.

Ques.: What signal is used at interlocking plants?

Ans.: The Semaphore signal.

Ques.: How are the indications given by day and by night?

Ans.: By semaphore arms by day and lights of prescribed color by night.

Ques.: Where are these signals located on single, double and three tracks?

Ans.: On single track they are either over or to the right of the track to which they refer, on double track they are located to the left of the track to which they refer, on three tracks usually over the running track

Ques.: To what side of the mast are the arms displayed as seen from an approaching train?

Ans.: To the right.

Ques.: Explain the position of signal on bracket posts and what track they control?

Ans.: The signals on the right hand mast refer to the track furthest to the right; the signals on the next mast to the left refer to the next track to the left, and so on.

Ques.: When the train service on one main track is superior to that of another how will the signals be displayed?

Ans.: The signals for the superior track will be placed six feet higher than those for the inferior track.

Ques.: By what will the indication for main running track in the established direction be given?

Ans.: By the Home signal.

Ques.: At junction points where two signals are located on the same mast what route will the top signal govern?

Ans.: The superior route.

Ques.: What is the indication for a diverging movement from the main running track in the established direction to a secondary or side track?

Ans.: It is indicated by a Dwarf signal.

Ques.: Where are Dwarf signals located?

Ans.: To the right of the track to which it refers, and either at the foot of or opposite the high Home signal.

Ques.: How does the light on the Dwarf signal show to indicate a diverging movement?

Ans.: It shows either a diagonal arm or a green light.

Ques.: How does the high Home signal show?

Ans.: It indicates "Stop."

Ques.: By what signal will the indication for a reverse movement from the established direction on or from a main running track, or for a movement to or from a side track in either direction be given?

Ans.: By a Dwarf signal.

Ques.: What does a Home signal in a horizontal position or a red light by night denote?

Ans.: It denotes Stop.

Ques.: When the arm is inclined diagonally downward or a green light is shown, what does it mean?

Ans.: It means Proceed.

Ques.: When the Distant signal is in a horizontal position or a red and green light is shown what does it mean?

Ans.: It means that the Home signal may be at danger so should proceed with caution and be prepared to stop before the Home signal is reached.

Ques.: When Distant signal is in a diagonal position or a green light is shown what does it indicate?

Ans.: That the Home signal is at clear.

Ques.: When a signal indicates "Stop" where must the engine be stopped?

Ans.: Before signal is passed.

Ques.: If after receiving a "Clear" signal the

semaphore is placed in the "Stop" position what should be done?

Ans.: The locomotive should be immediately brought to a stop.

Ques.: To whom should a report be made of same?

Ans.: It depends upon the rules, usually to the Superintendent.

Ques.: In case you experience an unusual delay at an interlocking plant should a report be made of same?

Ans.: Yes.