# Locomotive Engine Running

AND

# Management

*Showing How to Manage Locomotives in Running Different Kinds of Trains with Economy and Dispatch; Giving Plain Descriptions of Valve-Gears, Injectors, Brakes, Lubricators, and Other Locomotive Attachments; Treating on the Economical Use of Fuel and Steam; and Presenting Valuable Directions about the Care and Management of Locomotives and their Connections; A Brief Chapter on Electric Locomotives, and Complete Cathechism on Modern Air-Brake Operation, and also a Catechism on the Mallet Compound Locomotive*


BY

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# PREFACE TO THE TWENTY-THIRD EDITION

The first edition of Locomotive Engine Running and Management was published in 1885, thirty years ago. Many important changes have been made on the design and operation of the locomotive and its attachments in these thirty years, and in my opinion the time had arrived for a thorough revision of the book which is now offered to the railway world as practically a new book suitable for meeting the needs of modern practice. The changes on air-brake mechanism have been revolutionary and a section on electric mechanism has been added to meet the development of that art.

Locomotive Engine Running and Management has been an intellectual ladder which many ambitious men have climbed on their way to higher positions than those enjoyed in train service. The author cherishes the hope that the revised edition will prove as helpful as those which have gone before it.

In connection with the publication of the twenty-third edition I wish to acknowledge valuable assistance from Mr. George W. Kiehm, the well-known expert on Air Brakes, who wrote the chapter on that subject, which is entirely new; to Mr. James Kennedy, who rendered valuable help on the Valve Motion chapters, and to Mr. Harry A. Kenney, whose help was invaluable in the production of the whole book.

ANGUS SINCLAIR.

NEW YORK,
July 1, 1915.

# PREFACE

WHILE following the occupation of a locomotive engineer, I often observed peculiarities about the working of my engine, while running, that I did not entirely understand. As I was perfectly aware, even before making my first trip on a locomotive engine, that there is no effect without a cause, I never felt satisfied to accept any thing as incomprehensible without investigation, and fell into the habit of noting down facts about the working of the engine, with the view of studying out, at leisure, any thing which was not quite clear. When, some years ago, I abandoned engine-running to take charge of the round-house at the mechanical headquarters of the Burlington, Cedar Rapids, and Northern Railway, in Iowa, the practice of keeping notes was continued. The work connected with the ordinary repairing of running-engines, the emergency repairing executed to get engines ready hurriedly to meet the traffic demands on a road then chronically short of power, and diagnosing the numerous diseases that locomotives are heir to, provided ample material for voluminous notes. Those notes formed the raw material from which this book was constructed.

The original intention was, to publish a book on Locomotive Engine Running alone, and the first portion of the work was prepared with that idea in view; but, before the articles were finished, I joined the editorial staff of the *American Machinist*. The correspondence in the office of that paper convinced me that an urgent demand existed, among engineers, machinists, and others, for plainly given information relating to numerous operations connected with the repairing and maintenance of locomotives. To meet this demand, the chapters on "Valve-Motion" and all the succeeding part of the book were written. Most of that matter was originally written for the pages of the *American Machinist*, but was afterwards re-arranged for the book.

In preparing a book for the use of engineers, firemen, machinists, and others interested in locomotive matters, it has been my aim to treat all subjects discussed in such a way that any reader would easily understand every sentence written. No attempt is made to convey instruction in any thing beyond elementary problems in mechanical engineering, and all problems brought forward are treated in the simplest manner possible.

The practice of applying to books for information concerning their work is rapidly spreading among the engineers and mechanics of this school-spangled country; and this book is published in the hope that its pages may furnish a share of the needed assistance. Those men, who, Socrates-like, search for knowledge from the recorded experience of others, are the men who, in the near future, will take leading places in



our march of national progress. To such men, who are earnestly toiling up the steep grade of Self-help, this book is respectfully dedicated.

ANGUS SINCLAIR.

NEW YORK CITY,
Jan. 1, 1885.

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# LOCOMOTIVE ENGINE RUNNING

## CHAPTER I

### STEAM AND MOTIVE POWER

#### DEFINITION OF A STEAM ENGINE

A STEAM ENGINE is an apparatus through which the potential heat energy of fuel, combining with oxygen from the atmosphere, is transformed into mechanical work. Physically it is a machine whereby the potential or latent energy of fuel is caused to manifest itself in molecular motion or heat, and is eventually converted into that form of external and actual energy known as motive power.

The transformation includes three leading processes:

1. The combustion of carbonaceous fuel and the development of heat therefrom.

2. The transfer of this heat from the material products of combustion to water and the consequent conversion of the water into steam.

3. The expansion of this steam against external resistance and the production of motive power.

The term steam engine in its most comprehensive sense includes all of the appliances used in producing and utilizing the steam.

The locomotive is an engine so designed that the power produced by heat is employed in the transportation of passengers and freight from one place to another on land. The principal parts of a locomotive are the boiler employed to generate steam, and the cylinder and piston used to transform the force of steam into motive power.

### THE LOCOMOTIVE BOILER

Many forms of locomotive boilers have been tried, and the most common form of boiler has survived, because it has proved itself better adapted for the work to be done than any other. It is a horizontal multitubular boiler, consisting of four main portions—that is, the barrel, which is the principal part and has as attachments, the fire-box and the smoke-box. The fire-box consists of two parts, the outer shell and the inner fire-box. In this inner fire-box, which is usually an oblong box, are steel sheets about $\frac{5}{16}$ inch thick, at the bottom of which the grates are secured for carrying the fire. Between the inside and outside shell of the fire-box are spaces about $3\frac{1}{2}$ inches wide for the free circulation of water, the inside box and the outer shell being tied together by stay-bolts.

In the front of the fire-box is a tube-sheet on which is secured a set of flue-tubes, that extend to the front end of the boiler and are then secured in another tube-sheet. With ordinary sized locomotives, these flue-tubes, which are generally 2 inches diameter, number about 200 and are about 18 feet long. The water inside the boiler circulates around these tubes through which the fire gases pass to the smoke-box, thence into the smoke-stack.



The pipes that carry the steam away from the cylinders after it has done its work end in an exhaust-pipe, set central with the smoke-stack, through which the exhaust steam is passed into the atmosphere. The escaping steam passes through the smoke-stack at high velocity and sucks the gases of combustion through fire and flues. The intensity of this draft is regulated to some extent by the size of the exhaust-nozzle employed.

Two important elements are requisite in the design of a locomotive boiler. They are strength and lightness. The boiler must be sufficiently strong to withstand the shocks and strains resulting from carrying steam of high pressure, and it must be as light as circumstances will permit, having to be carried over uneven track frequently at high speeds.

Besides these two considerations of strength and lightness, the boiler must be designed to secure complete combustion of the fuel, without permitting excess of air that wastes heat. To effect that, means must be provided to maintain the fire-box temperature as high as possible.

The heating surfaces must be so arranged that the heat generated will be absorbed by the water without unnecessary obstruction to the draft. The form of the boiler must be such, that it may be constructed without mechanical difficulties or excessive expense. It must also be durable under the action of the hot gases and of the corroding elements acting upon its parts.

Sound designing requires that all parts of the boiler be made accessible for cleaning and repairs. Also that every part be as nearly as possible uniform in strength and in liability to loss of strength, wear and tear. All first-class locomotive boilers possess these qualities.

Nearly all modern boilers are made of steel, but locomotives built for foreign railways have copper inside fire-boxes. The fire-box sheets outside and inside are united to a stout bar, conforming to the shape of the fire-box, called a foundation-ring or more commonly a mud-ring.

All flat surfaces of the boiler are strengthened by means of stay-bolts or braces to resist the pressure. Seams and joints are caulked by having a blunt tool hammered along the edges of the plates. This process turns in the edge of the plate and makes the joints steam or water tight. The crown of the inside fire-box being flat or arched, has to be secured to the outer shell by means of stay-bolts. Crown-bars were formerly used for this purpose, but stay-bolts are now almost universally employed. In the illustrations of a boiler used in this book crown-bars are shown, but they are passing out of use.

## TECHNICAL EXPRESSIONS

In the course of this book, it will be necessary for me to use technical words which may be strange to the readers, so I shall give a few definitions.

*Heat unit* represents 778.3 foot-pounds of work and is the quantity of heat necessary to raise 1 pound of water, slightly above the freezing-point, 1 degree Fahr.

*Boiler pressure* is the pressure shown by the steam gauge, and is 14.7 pounds higher when reckoned from vacuum.



*Absolute pressure* is the steam pressure reckoned from vacuum.

*Mean effective pressure* is the average pressure pushing the piston during the entire stroke in one direction.

*Unit of work* is the foot-pound, or 1 pound raised 1 foot.

*Horse-power* is 33,000 pounds raised 1 foot per minute.

*Saturated steam* is steam containing just sufficient heat to hold the water as steam.

*Superheated steam* is steam holding more heat than that needed to keep it vaporized.

*Latent heat of steam* is the quantity of heat expressed in heat units, required to vaporize water already heated to the temperature of the steam into which it is to be converted.

## CONVERTING WATER INTO STEAM

A satisfactory boiler being provided, it is edifying to study what happens in the process of converting water into steam.

To comprehend clearly all the processes in the generation and application of steam, it is necessary to observe the standard of heat measurement, which is as already mentioned 778.3 foot-pounds, known as the Thermal Unit.

To illustrate and explain the working of the locomotive engine, the first part of the subject can be made plain by following the process of converting water into steam. Suppose we place 1 pound of water in a vessel convenient for measurement and applying heat, record the events of a cycle, similar to that which steam makes in passing through the boiler and cylinders of a locomotive. Let us place the water at a temperature of 32° Fahr. at the bottom of a glass tube of indefinite length, open at the top, and having a cross-sectional area of 1 square foot—144 square inches. At the freezing-point, 1 pound of water measures 27.7 inches, therefore the volume we are going to experiment with will cover the level bottom of the tube to a depth of .1923 inch. If we now apply the flame of a spirit lamp, or other source of regular heat, to the tube beneath the water, the temperature will rise until 212° Fahr., the point at atmosphere pressure, is reached. The water will then be gradually evaporated into steam, but the temperature will remain the same until vaporization is completed. If it took ten minutes for the heat of the flame to raise the temperature of the water from 32° Fahr. to 212° Fahr. the boiling-point, it would take nearly fifty-five minutes longer before the whole of the water would be converted into steam, and the thermometer would show no alteration of temperature. It takes nearly $5\frac{1}{2}$ times the quantity of heat to evaporate water that it takes to raise it from the freezing- to the boiling-point.

When this phenomenon was first discovered, investigators used to say that the heat became *latent*, a vague expression. The explanation is now given that the extra heat had been expended in tearing the particles of the water apart.

When the heat was applied beneath the tube, the power of the flame was first devoted to raising the temperature of the water, and 180 heat units were expended in this manner, increasing the temperature from 32° to 212° Fahr. The heat continues to pass into the water and steam is gradually formed, boiling goes on and when the last drop of water has been evaporated 966 heat units, besides that used to heat the water, having been expended, making a total of 1146 heat units, which is known as the total heat of vaporization. The degrees of heat that have been insensible to the thermometer, viz., 966 heat units, is spoken of as the latent heat of steam at atmospheric pressure.



Steam generated in the way described, where only sufficient heat is applied to evaporate the water, is called saturated steam. Saturated steam contains just sufficient heat to maintain the vaporous condition, and the smallest subtraction of the heat causes the steam to return to water.

If heat had been continued to be applied after the water was all evaporated, the steam would have received more heat than was necessary to evaporate it from water and it would have become superheated. Superheated steam has superior properties for doing work and the trend of present practice is to superheat the steam used by all locomotives. The steam formed by the process described occupies 1644 times the space which held the water, that being the relative volumes of water and steam at atmospheric pressure. Our tube being 1 foot square in area or 144 square inches, the steam forms a column 26.36 feet high. In taking possession of this length of tube, the steam had to work up against the atmospheric pressure of 14.7 pounds to the square inch, that being the atmospheric pressure at sea level. On high levels the pressure would be less.

### APPLYING STEAM PRACTICALLY

As the low tension of steam employed in our example would be useless for purposes connected with railway motive power, we will suppose a case of generating steam at a pressure familiar to persons engaged in railroad engineering. Suppose we again put into our tube 1 pound of water at a temperature of 32° Fahr. and apply heat. Instead of leaving the tube open to the atmosphere, we will put a piston weighing 130.3 pounds to the square inch on the surface of the water, and we further suppose that the piston will be perfectly steam tight and capable of moving upwards with no friction. As the atmospheric pressure will rest upon the upper side of the piston, steam cannot be formed without raising an absolute load of 145 pounds to the square inch.

On heat now being applied, the temperature of the water will keep rising until the thermometer registers 355.6° Fahr., at which point boiling will begin. Heat continuing to pass into the water, boiling will go on, steam will be formed and the piston raised until the last drop of water has been evaporated. When this operation is completed, it will be found that 866.8 heat units beyond that used to raise the water to the boiling-point have been expended in turning the water into steam. Figured from the freezing-point the total heat of vaporization would in this case be 1190.4 heat units as compared with 1164 heat units used when evaporation was performed at atmospheric pressure.

These paragraphs roughly describe the operation of turning water into steam as used in a locomotive boiler.



It may be mentioned that the boiling-point of the water rises with the increase of pressure. Thus at atmospheric pressure the boiling-point is 212° Fahr. and with 200 pounds gauge pressure the boiling-point is 387.5° Fahr.

Steam being raised in the manner described in a good boiler the next practical operation is to use the force of the expanding steam to perform the work of train hauling. The mechanism and means required for performing this duty will be described in succeeding chapters.

## CHAPTER II

# DESIGN AND OPERATION OF LOCOMOTIVES

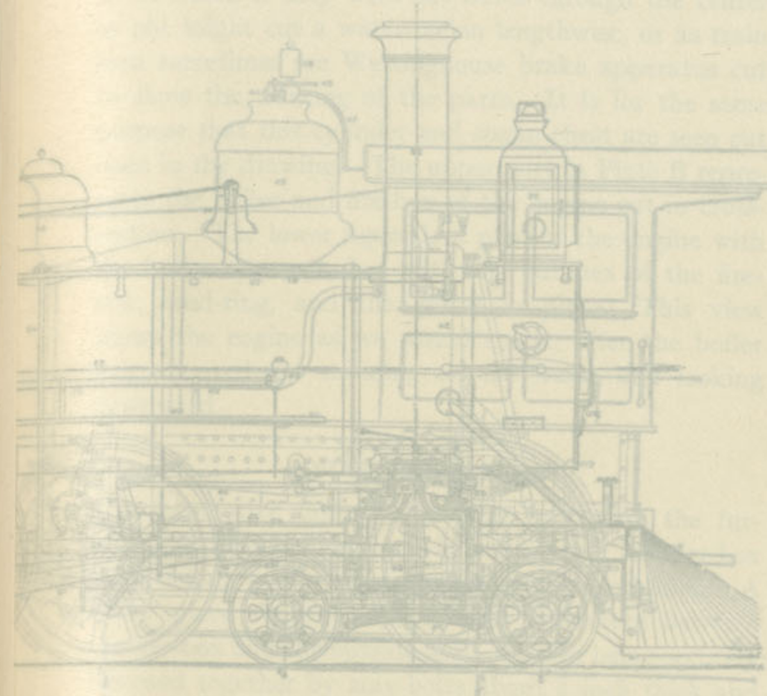
### DESIGNING OF LOCOMOTIVES

THE purpose of the locomotive engine as already mentioned is to transform the energy of fuel by the medium of steam into the work of pulling railroad trains. The leading aim of good designers is to plan locomotives that will do the greatest amount of work with the least expenditure of fuel, and will at the same time be safe, convenient to handle, strong and durable. The two most important parts of the locomotive are the boiler and the cylinders. These are like the stomach and the heart of the human machine. In the boiler the steam is generated, and it is used in the cylinders, transmitting the resulting power to the driving-wheels. In a well-designed locomotive, the boiler is made large enough to supply all the steam required by the cylinders, no matter how hard the engine may be worked or how fast it may be run.

### DESCRIPTION OF ORDINARY LOCOMOTIVE

In most of the engravings to be found at this part of the book, the outlines and principal parts of an ordinary eight-wheel locomotive are shown. Plate A is a side elevation of the engine, and shows all the outside parts that can be seen by a person standing near the engine.





To face p. 10.

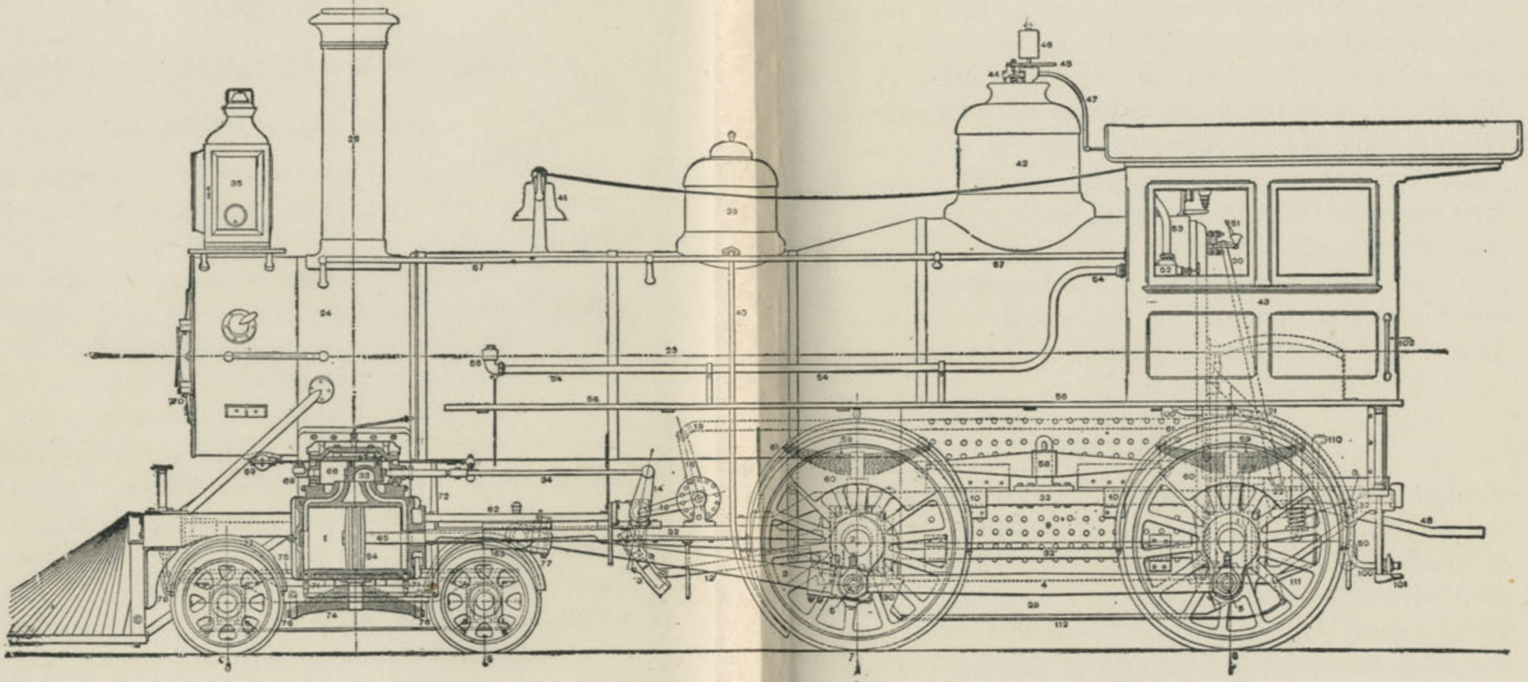


PLATE A.

*To face p.* 10.

The cylinder and steam-chest are, however, shown in cross-section, giving the view of these parts that would be obtained if they were cut down through the center as one might cut a water-melon lengthwise, or as train men sometimes see Westinghouse brake apparatus cut to show the working of the parts. It is for the same purpose that this cylinder and steam-chest are seen cut open in the drawing. The upper part in Plate B represents the boiler and fire-box of the engine cut in cross-section. The lower figure is a plan of the engine with the boiler removed, but with the outlines of the fire-box, mud-ring, and the grates in place. This view shows the engine as we would see it, after the boiler was removed, by standing on the frame and looking downward.

### BOILER AND FIRE-BOX

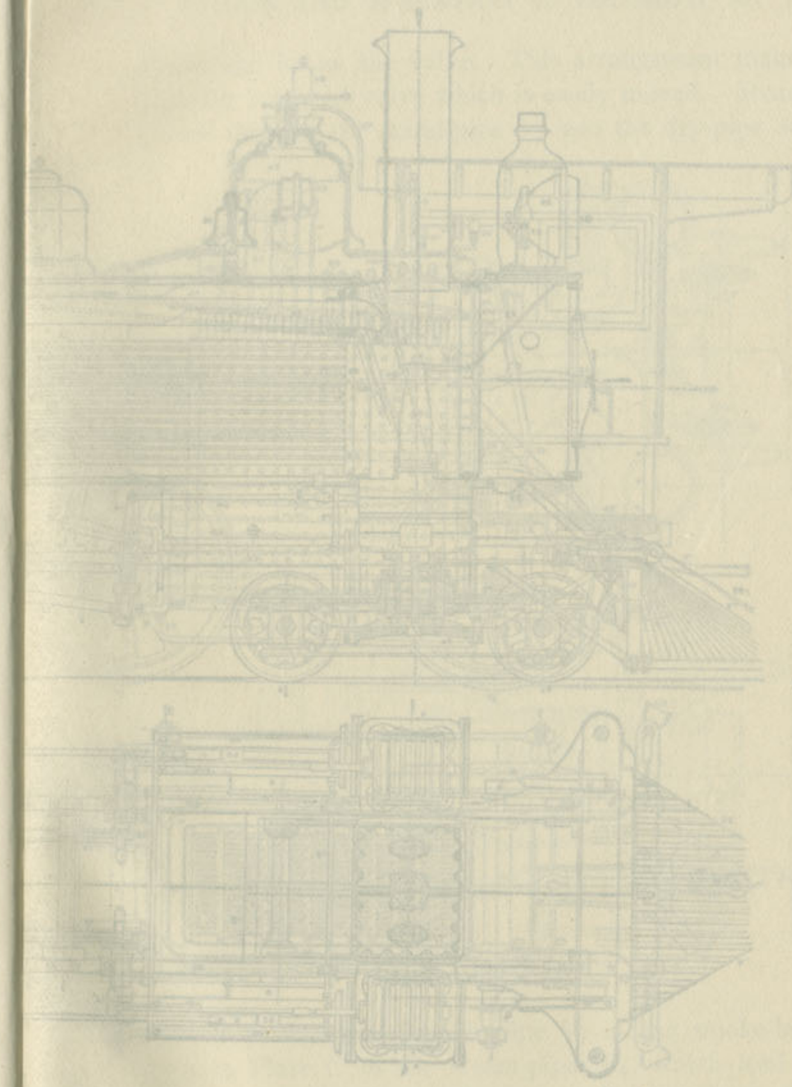
A locomotive boiler is peculiar in having the furnace and boiler all inclosed in one shell. The fire-box is an oblong box of sheet steel about $\frac{5}{16}$ inch thick. A water space about $3\frac{1}{2}$ inches wide intervenes between the fire-box and the outside shell, the two being securely fastened together by stay-bolts about $\frac{7}{8}$ inch thick and 4 inches apart. The small circles seen on the side of the fire-box in the figures represent the stay-bolts.

The boiler of the engine shown is of the wagon-top kind. That is, the waist or barrel of the boiler is straight in the front portion, but towards the fire-box the diameter increases and the top of the fire-box is raised considerably above the boiler. The object of the wagon-top enlargement is to increase the space for holding steam. The dome in this form of boiler is nearly always placed on the wagon-top. The purpose of the dome is to raise the inlet of the "dry-pipe" which carries the steam to the cylinders, away as far as possible above the water level.

### HOW STEAM MOVES THE ENGINE

When a locomotive is ready for raising steam, the boiler is filled with water till the crown-sheet of the fire-box is well covered. When the water in the boiler begins to get low, this crown-sheet is the first part exposed to the fire to become uncovered, and great care must be exercised to prevent this while there is fire in the fire-box, for the dry sheets are quickly destroyed when exposed to a hot fire.

The water being put in to cover the crown-sheet, a fire is started in the fire-box and steam is quickly raised. When the engineer gets ready to move the engine, he puts the reverse lever 20 (Plate B) in forward or back motion, which puts the eccentric-rod 12 or 12′ opposite the bottom rocker-pin and gives one of the rods the power to operate the slide-valve 33 (Plate A) for the direction the engine is intended to be run. This applies specially to engines having link-valve motion, but the movements for other motions are practically the same. The engineer then carefully pulls the throttle-lever 51, which opens the throttle-valve 88 and admits steam into the stand-pipe 87. The throttle-valve which closes this stand-pipe is a double-seated poppet-valve formed of two flat circular pieces joined by a stem, one piece being smaller than the other so that it can pass through the upper hole but close the lower one. When the throttle-valve is moved, steam passes in



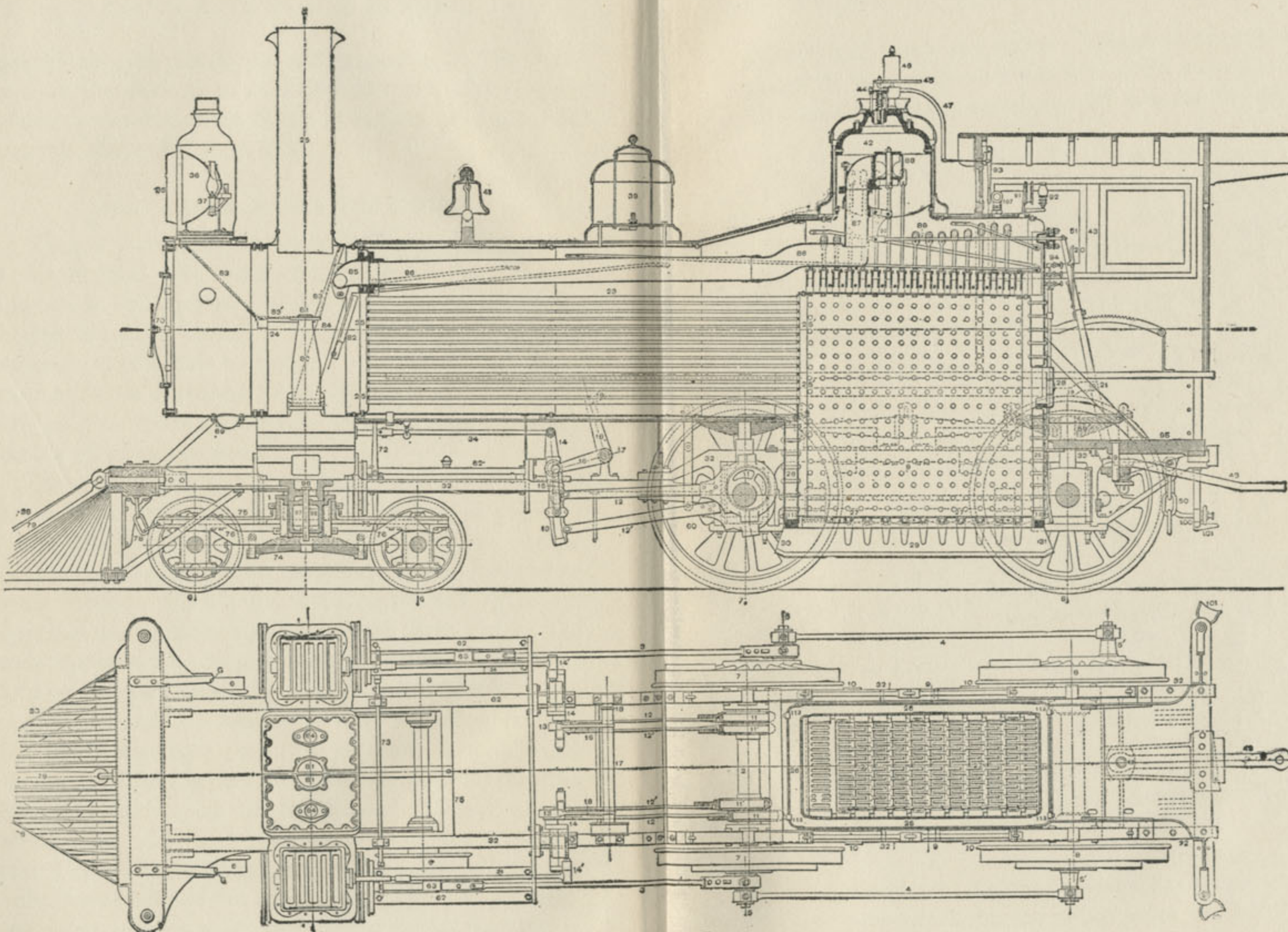


PLATE B.

*To face p.* 12.

above and below the valve. This arrangement makes a partly balanced valve which is easily moved. Steam passes through the stand-pipe 87 into the dry-pipe 86,

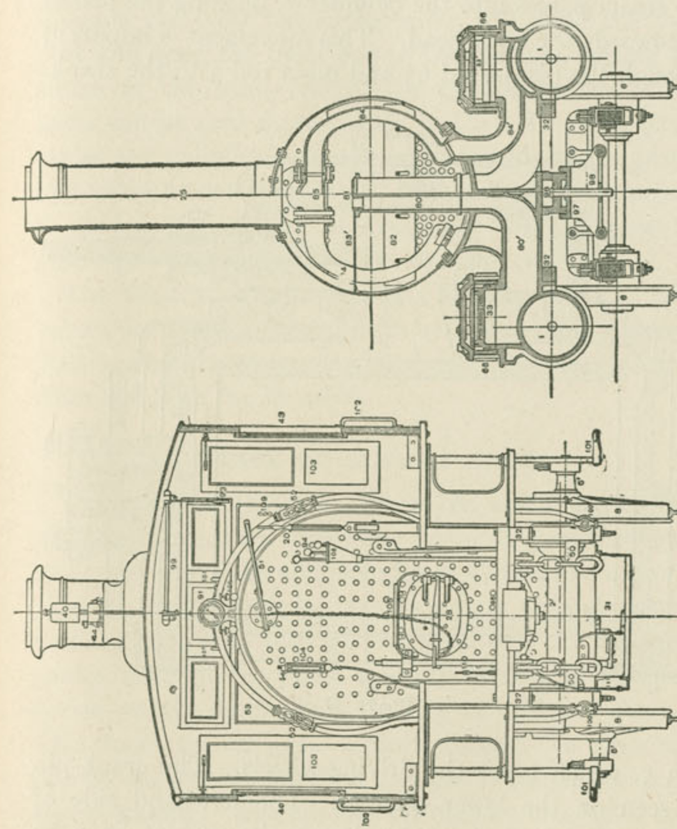


Plate C.

thence through the branch pipe 85 in the smoke-box seen in Plate C to the steam-pipes 84, which lead it through the cylinder-saddle into the steam-chests 66, 33, 33′. The openings where the steam-pipes are jointed upon the saddle are marked 84 in Plate B. In Plate A, the steam-chest 66 is represented with the valve 33 uncovering the forward port, through which the steam passes into the cylinder 1, pushing the piston 64 towards the back head. This movement is imparted through the piston-rod 65 and main rod 3 to the crank-

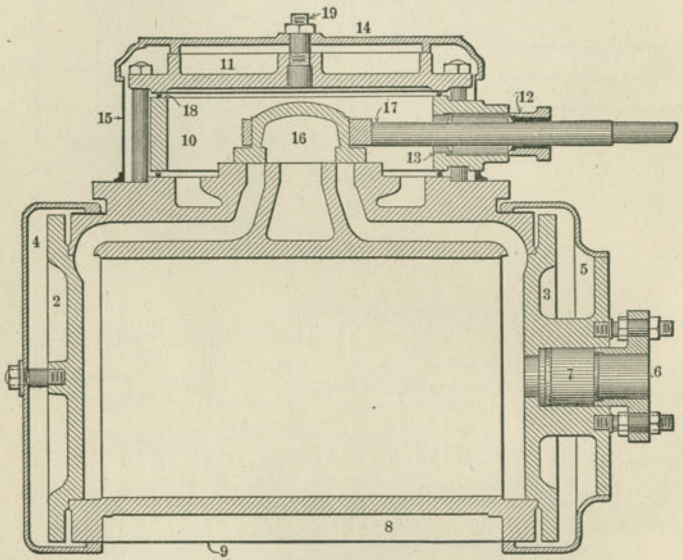



Plate D

pin 5, which turns the driving-wheels. The crank-pin is seen on the lower quarter. The left-hand side of this engine is shown. As the cranks are set at right angles to each other with the right-hand crank leading, the right-hand crank on this engine would now be on the back center.

It will be seen that the back end of the cylinder is



open to the exhaust, as the escaping steam is free to pass through the port shown white up to the cavity under the valve 33 and thence into the opening of the exhaust-pipe. When the piston moves a little farther towards the back head, the valve will close the back port and open the front one to the exhaust, letting the steam in the front end of the cylinder escape. The parts can be seen more clearly in Plate D. If a drawing of the cylinder be made and patterns of the piston and valve be cut out of thick paper, they can be moved so that a student can obtain a clear idea of how the steam gets into and out of the cylinder.

The illustration is known as a D slide-valve. Piston valves are rapidly coming into use; but their action in distributing the steam is practically the same as that described with the D-valve.

## ESCAPE OF EXHAUST STEAM

Returning to Plate B: When the steam passes into the exhaust passage under the valve, it goes through a cavity in the saddle and emerges at 81 into the exhaust-pipe 80, finally escaping at the nozzle 81 and passing to the atmosphere through the stack 25. As each puff passes through the stack it exerts a sort of pumping action on the smoke-box, tending to create a vacuum. This draws the fire-gases rapidly through the tubes and creates the forced draft on the fire required for rapid steam-making. The amount of vacuum created is controlled to some extent by the diameter of the nozzle. If the nozzle is small the steam escapes with increased rapidity, thereby tending to increase the pull on the fire.

People ambitious to learn the details of locomotive operation ought to study this description thoroughly, for I have seen an old engineer very much embarrassed when he was asked how steam gets from the boiler to the cylinders.

### DRAFT ARRANGEMENTS

The locomotive shown has an extension smoke-box the purpose of which is to arrest sparks. Set at an angle in front of the tube openings there is a plate 82 called the diaphragm. The object of this plate is to regulate the draft through the different rows of flues. When the gases from the fire, which tend to fly upwards, are not controlled in their movement, there is a rush through the upper rows of tubes, and the lower ones do not perform their share of steam-making. The diaphragm plate partly obstructs the upper tubes, and if it is set right makes the flow of gases uniform. The petticoat-pipe performs similar functions where it is used. When the sparks pass through the tubes they strike the diaphragm and are projected forward in the extension and lie undisturbed away from the direct line of draft, which is strongest below the smoke-stack. A netting marked 83 83 83 helps to prevent the sparks from being drawn out of the smoke-box. There are various ways of arranging the netting, and it is generally put in to give as much area as possible.

### NAMES OF PARTS

The names of nearly all the parts of the locomotive may be learned by finding the numbers in the first three plates and identifying them by means of the following list:



1. Cylinders; 2. main driving-axle; 3. main rod; 4. side rod; 5. main crank-pin; 6. truck-wheels; 7. main driving-wheels; 8. back driving or trailing wheels; 9. fire-box; 10. expansion braces; 11. eccentrics. 12. eccentric-rods; 13. link; 14. rocker; 15. link-hanger; 16. horizontal arm of lifting-shaft; 17. lifting, or tumbling-shaft; 18. upright arm of lifting-shaft; 19. reach rod; 20, 21, 22. reversing-lever; 23. barrel, or waist of boiler; 24. smoke-box; 25. chimney or smoke-stack; 26. water spaces; 27. grate; 28. furnace-door; 29. ash-pan; 30. front ash-pan damper; 31. back ash-pan damper; 32. frames; 33. main valve; 34. valve-stem; 35. head-light; 36. head-light reflector; 37. head-light lamp; 38. pilot; 39. sand-box; 40. sand-pipes; 41. bell; 42. dome; 43. cab; 44. safety-valve; 45. safety-valve lever; 46. whistle; 47. whistle-lever; 48. draw-bar; 49. coupling-pin; 50. safety-chains; 51. throttle-lever; 52. injector; 53. injector steam-pipe; 54. injector feed-pipe; 55. injector check-valve; 56. running-board; 57. hand-rail; 58. equalizing-lever; 59. driving-springs; 60. counterbalance weights; 61. driving-wheel guard; 62. guide-bar; 63. cross-head; 64. piston; 65. piston-rod; 66. steam-chest; 67. rubbing-plate for balanced valve; 68. steam-chest relief-valve; 69. hopper of extension smoke-box; 70. smoke-box door. 71. cylinder-cocks; 72. cylinder-cock lever; 73. cylinder-cock shaft; 74. truck-spring; 75. truck-frame; 76. truck equalizing-lever; 77. truck wheel-guard; 78. truck check-chain; 79. push-bar; 80. exhaust-pipes; 81. exhaust-nozzle; 82. diaphragm; 83. wire-netting; 84. steam-pipe; 85. T-pipe; 86. dry-pipe; 87. throttle-pipe; 88. throttle-valve; 89. throttle-stem; 90. throttle bell-crank;

91. steam-gauge; 92. steam-gauge lamp; 93. whistle-lever; 94. gauge-cocks; 95. foot-board; 96. truck center-bearing; 97. truck center-plate; 98. truck center-pin; 99. whistle-shaft; 100. suction-pipes; 101. foot-steps of cab; 102. hand-holds of cab; 103. front door of cab; 104. water-gauge; 105. stand for oil-cans; 106. drip for gauge-cocks; 107. injector-valve; 108. oil-cup for oiling main valves; 109. handle for opening valves in sand-box; 110. handle for opening front damper; 111. bell-crank for opening front damper; 112. rod for opening front damper; 113. mud-plugs.

### CYLINDER AND STEAM-CHEST

The leading details of the locomotive's mechanism may be more clearly studied from succeeding plates. Plate C gives a cross-section of the cylinder and steam-chest. The principal parts are;

1. Cylinder; 2. front cylinder-head; 3. back cylinder-head; 4. front casing-cover; 5. back casing-cover. 6. cylinder-gland; 7. cylinder-gland packing; 8. wood-lagging; 9. casing; 10. steam-chest; 11. steam-chest cover; 12. steam-chest packing-gland; 13, gland-ring; 14. steam-chest casing; 15. side of chest-casing; 16. slide-valve; 17. valve-yoke; 18. steam-chest joint; 19. oil-pipe stem.

### PISTONS

The piston which works in the cylinder is shown in enlarged form in Plate D. The purpose of the piston-head is to fill the cylinder bore tight enough to prevent steam blowing through between the walls of the cylinder and the piston-head, and yet be loose



enough to move freely with as little friction as possible. There are various forms of piston-heads, and three kinds are shown in Plate D. Figure 1 is what is known as a solid head with two grooves round the outside into which packing-rings are sprung in. Packing-rings are made of a good quality of cast iron turned a little larger than the bore of the cylinder, and a piece cut out which permits the ring to be compressed when the piston is put into the cylinder. The rings then press the sides of the cylinder and soon form a steam-tight connection.

In Figure 2 a piston-head is shown with what is known as spring packing. The packing-rings are not made to spring, but are kept up to the cylinder-walls by separate small springs secured inside the body of the piston-head and held in tension by a stud.

Figure 3 illustrates the most common form of piston in use. The packing-rings are made with spring to them as in Figure 1, but they are carried on T-ring or bull-ring 9, which fits on the piston-spider and is held in place by the follower-plate 2.

The piston consists of the following parts:

1. Head; 2. follower-plate; 3. follower-bolts; 4. follower-bolt socket; 5. piston-rod; 6. rod key-way; 7. piston-rod nut; 8. packing-rings (cast iron); 9. bull-ring; 10. composite packing-rings; 11. packing-spring; 12. spring stud and nuts.

### LINK MOTION

Plates E and F give a very clear illustration of the link motion and its connections on the right-hand side of a Baldwin locomotive as they appear when the piston is on the forward center, and the engine is in full gear forward.

The principal parts shown are:

1. Axle; 2. eccentric; 3. forward half of eccentric-strap; 4. back half of eccentric-strap; 5. eccentric-rod (forward motion); 6. eccentric-rod (backward motion); 7. expansion link, back half; 8. expansion link, front half; 9. expansion-link filling-block; 10. expansion-link sad-

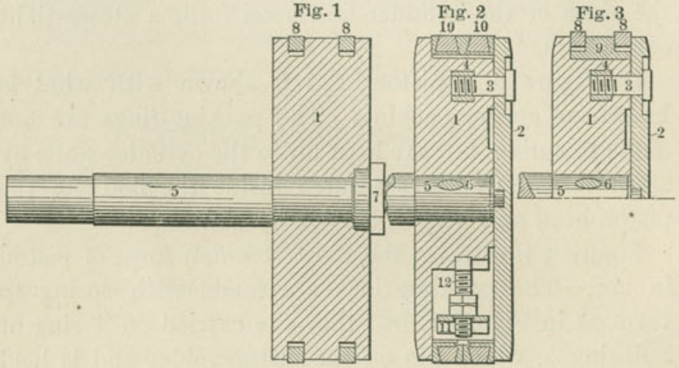



PLATE E

dle; 11. expansion-link sliding-block; 12. link-hanger; 13. tumbling-shaft; 14. counterbalance-spring; 15. tumbling-shaft bracket; 16. reach-rod; 17. upper rocker-arm; 18. rocker-box; 19. valve-rod.

## RUNNING GEAR

Plate G illustrates details of the frames, the arrangement of which requires to be carefully studied by those who are connected with the running of locomotives, for a great part of the failures that happen to modern loco-



motives arise from accidents to some part of the running gear.

By referring back to Plate B, it will be seen that the frames, driving-wheels, and truck with their minor parts form a carriage which carries the boiler and cylinders. When this carriage is properly designed we have a good riding locomotive. To bring this about the whole of the running gear, as this part of the engine is called, must work harmoniously together. Pressing upon the

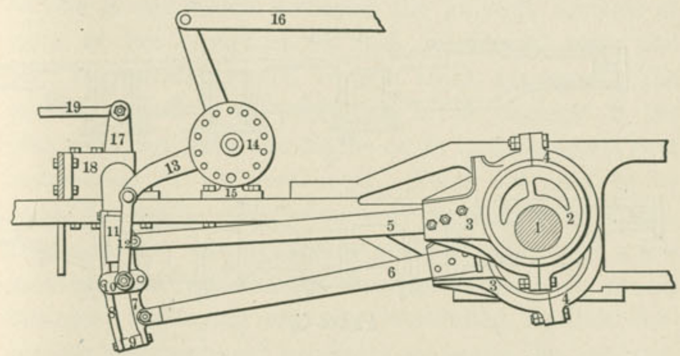


PLATE F

upper half of the different axle-journals are bearings of brass or some other soft metal on which the weight of the engine rests. The bearing is in an axle-box which is made strong enough to protect the brass bearing and to withstand the shocks of the hard service. The driving axle-boxes are held firmly in oblong formations on the frames called jaws, and secured so that the box can rise and fall freely a certain distance. On the top of the axle-box and spanning the frame is a casting called a stirrup, on which the driving-spring rests. On one end hangers connect the spring to the frame, taking their part in holding up the whole of the weight resting on the wheels, and on the other end connecting with the equalizing beam, which tends to transmit any severe shock over all the connecting wheels.

In plate G, class *C* is the frame of an eight-wheel

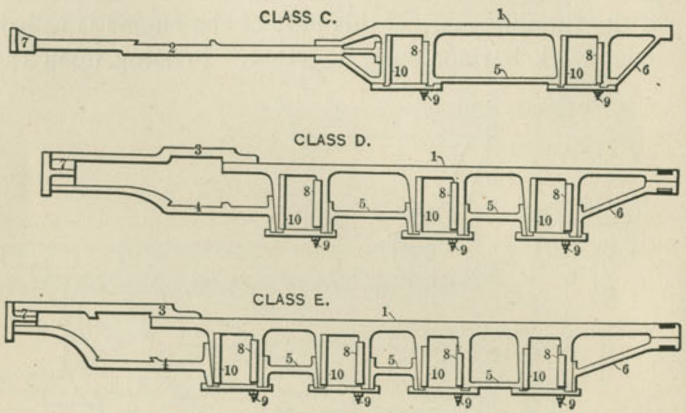



PLATE G

engine, class *D* is the frame of a mogul engine, and class *E* is the frame of a consolidation engine.

The principal parts are:

1. Top rail of frame and pedestals; 2. front rail of frame; 3. front top of mogul and consolidation frame; 4. bottom of mogul and consolidation frame; 5. middle brace; 6. back brace; 7. buffer-block; 8. pedestal-wedge; 9. wedge-bolt; 10. pedestal-shoe

# CHAPTER III

## ENGINEERS AND THEIR DUTIES

### ATTRIBUTES THAT MAKE A GOOD ENGINEER

THE locomotive engine which reaches nearest perfection is one which performs the greatest amount of work at the least cost for fuel, lubricants, wear and tear of machinery and of the track traversed; the nearest approach to perfection in an engineer is the man who can work the engine so as to develop its best capabilities at the least cost. Poets are said to be born, not made. The same may be said of engineers. One man may have charge of an engine for only a few months, and yet exhibit thorough knowledge of his business, displaying sagacity resembling instinct concerning the treatment necessary to secure the best performance from his engine: another man, who appears equally intelligent in matters not pertaining to the locomotive, never develops a thorough understanding of the machine.

There are few lines of work where the faculty of concentrating the mind to the work on hand is so valuable as in that of running a locomotive. A man may be highly intelligent and be well endowed with general knowledge, but on a locomotive he will make a failure, unless his whole attention while on duty is devoted to the duties of taking the locomotive and train over the division safely on time. The man who lets outside hobbies or interests take much of his time while running a locomotive is likely to get into many scrapes. Keen habits of observation and calm judgment are the most valuable attributes in the making of a first-class engineer.

### HOW ENGINEERING KNOWLEDGE AND SKILL ARE ACQUIRED

A man who possesses the natural gifts necessary for the making of a good engineer will advance more rapidly in acquiring mastery of the business than does one whom Nature intended for a ditcher. But there is no royal road to the knowledge requisite for making a first-class engineer. The capability of handling an engine can be acquired by a few months' practice. Opening the throttle, and moving the reverse lever, require but scanty skill; there is no great accomplishment in being able to pack a gland, or tighten up a loose nut; but the magazine of practical knowledge, which enables an engineer to meet every emergency with calmness and promptitude, is obtained only by years of experience on the footboard, and by assiduous observation while there.

### PUBLIC INTEREST IN LOCOMOTIVE ENGINEERS

Ever since the incipiency of the railroad system, a close interest has been manifested by the general public in the character and capabilities of locomotive engineers. This is natural, for no other class of men hold the safe-keeping of so much life and property in their hands.



### IGNORANCE VERSUS KNOWLEDGE

Two leading pioneers of railway progress in Europe took diametrically opposite views of the intellectual qualities best calculated to make a good engineer. George Stephenson preferred intelligent men, well educated and read up in mechanical and physical science; Brunel recommended illiterate men for taking charge of engines, on the novel hypothesis that, having nothing else in their heads, there would be abundant room for the acquirement of knowledge respecting their work. In every test of skill, the intelligent men proved victors.

### ILLITERATE ENGINEERS NOT WANTED IN AMERICA

No demand for illiterate or ignorant engineers has ever arisen in America. Many men who have spent an important portion of their lives on the footboard have risen to grace the highest ranks of the mechanical and social world. The pioneer engines, which demonstrated the successful working of locomotive power, were run by some of the most accomplished mechanical engineers in the country. As an engine adapted to the work it has to perform, the American locomotive is recognized to have always kept ahead of its compeers in other parts of the world. No inconsiderable part of this superiority is due to the fact, that nearly all the master mechanics who control the designing of our locomotives have had experience in running them, and thereby understand exactly the qualities most needed for the work to be done.

### GROWING IMPORTANCE OF ENGINEERS' DUTIES

The safe and punctual operation of our railroads has always depended to a great extent, and always will depend, upon the discriminating care and judgment of the engineer. Every year sees the introduction of new appliances for the purpose of increasing the safety of train operating, but no automatic appliances will ever enable a man to run a locomotive safely if he is deficient in judgment, care, and intelligence. The increasing amount of train mechanism every year imposes new responsibilities upon the locomotive enginemen. The tendency is to require the engineer to understand not only everything about the locomotive, but every detail of air-brake mechanism, and also that of train signals, heating apparatus, lighting appliances and every other train attachment. He is gradually coming to fill on a train the position that a chief engineer holds on a steamer.

### INDIVIDUALITY OF AMERICAN ENGINEERS

Writing on the fitness of various railroad employees for their duties, that eminent authority, Ex-Railroad Commissioner Charles F. Adams, says: "In discussing and comparing the appliances used in the practical operating of railroads in different countries, there is one element, however, which can never be left out of the account. The intelligence, quickness of perception, and capacity for taking care of themselves—that combination of qualities, which, taken together, constitute individuality, and adaptability to circumstances,—vary greatly among the railroad employees of



different countries. The American locomotive engineer, as he is called, is especially gifted in this way. He can be relied on to take care of himself and his train under circumstances which in other countries would be thought to insure disaster."

### NECESSITY FOR CLASS IMPROVEMENT

While American locomotive engineers can confidently invite comparison between their own mechanical and intellectual attainments and those of their compeers in any nation under the sun, there still remains ample room for improvement. If they are not advancing, they are retrograding. The engineer who looks back to companions of a generation ago, and says that we know as much as they did, but no more, implies the assertion that his class is going backward. On very few roads, and in but rare instances, can this grave charge be made, that the engineers are falling behind in the intellectual race. On the contrary, there are signs all around us of substantial work in the cause of intellectual and moral advancement.

### THE SKILL OF ENGINEERS INFLUENCES OPERATING EXPENSES

No class of railroad-men affects the expenses of operating so directly as engineers do. The daily wages paid to an engineer is a trifling sum compared to the amount he can save or waste by good or bad management of his engine. Fuel wasted, lubricants thrown away, supplies destroyed, and machinery abused, leading to extravagant running repairs, make up a long bill by the end of each month, where enginemen are incompetent. Every man with any spark of manliness in his breast will strive to become master of his work; and, stirred by this ambition, he will avoid wasting the material of his employer just as zealously as if the stores were his own property; and only such men deserve a position on the footboard.

The day has passed away when an engineer was regarded as perfectly competent so long as he could take his train over the road on time. Nowadays a man must get the train along on schedule time to be tolerated at all, and he is not considered a first-class engineer unless he possesses the knowledge which enables him to take the greatest amount of work out of the engine with the least possible expense. To accomplish such results, a thorough acquaintance with all details of the engine is essential, so that the entire machine may be operated as a harmonious unit, without jar or pound; the various methods of economizing heat must be intimately understood, and the laws which govern combustion should be well known so far as they apply to the management of the fire.

### METHODS OF SELF-IMPROVEMENT

To obtain this knowledge, which gives power, and directly increases a man's intrinsic value, young engineers and aspiring firemen must devote a portion of their leisure time to the form of self-improvement relating to the locomotive. Socrates, a sagacious old Greek philosopher, believed that the easiest way to obtain knowledge was by persistently asking questions. Young engineers can turn this system to good account. Never feel ashamed to ask for information where it is needed,



and do not imagine that a man has reached the limit of mechanical knowledge when he knows how to open and shut the throttle-valve. The more a man progresses in studying out the philosophy of the locomotive and its economical operation the more he gets convinced of his own limited knowledge. A young engineer who seeks for knowledge by questioning his elders must not feel discouraged at a rebuff. Men who refuse to answer civilly questions asked by juniors searching for information are generally in the dark themselves, and attempt by rudeness to conceal their own ignorance.

### OBSERVING SHOP OPERATIONS

The system in vogue in most of our States, especially in the West, of taking on men for firemen who have received no previous mechanical training leaves a wide field open for engineering instruction. Such men cannot spend too much time watching the operations going on in repair-shops; every detail of round-house work should be closely observed; the various parts of the great machine they are learning to manage should be studied in detail. No operation of repairs is too trifling to receive strict attention. Where the machinists are examining piston-packing, facing valves, reducing rod-brasses, or lining down wedges, the ambitious novice will, by close watching of the work, obtain knowledge of the most useful kind. Looking on will not teach him how to do the work, but interesting himself in the procedure is a long step in the direction of learning. Repairing of air-brake mechanism and injectors is interesting work, full of instructive points which may prove invaluable on the road. The rough work performed by the men who change truck-wheels, put new brasses in oil-boxes, and replace broken springs is worthy of close attention; for it is just such work that enginemen are most likely to be called upon to perform on the road in cases of accident. To obtain a thorough insight into the working of the locomotive, no detail of its construction is too trifling for attention. The unison of the aggregate machine depends upon the harmonious adjustment of the various parts; and, unless a man understands the connection of the details, he is never likely to become skillful in detecting derangements.

### WHERE IGNORANCE WAS RUIN

I knew a case where the neglect to learn how minor work about the engine was done proved fatal to the prospects of a young engineer. A new engine-truck box had been adopted shortly before he went running; and, although he had often seen the cellar taken down by the round-house men when they were packing the trucks, he never paid close attention to how it was done. As the new plan was a radical change from the old practice, taking down the new cellar was a little puzzling at first to a man who did not know how to do it. One day this young engineer took out an engine with the new kind of truck, and a journal got running hot. He crept under the truck among snow and slush to take the cellar down for packing; but he struggled half an hour over it, and could not get the thing down. Then the conductor came along, to see what was the matter; and, being posted on such work, he perceived that the young engineer did not know how to take the cellar out of the box. The conductor helped the engineer to do a job he should have needed no assistance with. The story was presently carried to headquarters with additions, and was the means of returning the young engineer to the left-hand side.



### PREJUDICE AGAINST STUDYING BOOKS

There is a silly prejudice in some quarters against engineers applying to books for information respecting their engines. Engineers are numerous who boast noisily that all their knowledge is derived from actual experience, and they despise theorists who study books, drawings, or models in acquiring particulars concerning the construction or operation of the locomotive parts. Such men have nothing to boast of. They never learn much, because ignorant egotism keeps them blind. They keep the ranks of the mere stopper and starter well filled.

### THE KIND OF KNOWLEDGE GAINED FROM BOOKS

The books on mechanical practice which these ultra-practical men despise contain in condensed form the experience and discoveries that have been gleaned from the hardest workers and thinkers of past ages. The product of long years of toilful experiment, where intense thought has furrowed expansive brows, and weary watching has whitened raven locks, is often recorded on a few pages. A mechanical fact which an experimenter has spent years in discovering and elucidating can be learned and tested by a student in as many hours. The man who despises book-knowledge relating to any calling or profession rejects the wisdom begotten of former recorded labor.

The study of good books relating to the locomotive will teach the young engineer many things about his engine that can be verified by practice. If anything in a book induces an engineer to think for himself, and sets him to observing and investigating, it is certain to do him good.

### MODELS AND CROSS-SECTIONS

A highly instructive and interesting means of self-instruction that can be reached by most ambitious engineers and firemen is the study of models and cut cross-sections of locomotive mechanism. Many division brotherhood rooms used by engineers and firemen have models and cross-sections of valve gear, lubricators, brake mechanism, etc. These appliances offer invaluable aid to men anxious to learn about the working of the parts they represent, and constant use ought to be made of them.

Valve gears are a favorite study with young engineers, and information about their arrangement and action can be studied to the greatest advantage by the aid of a model. The chapters on valve motion, farther on in this book, are made as plain as simple words and clear wood-cuts can make them; but the subjects treated will be much easier understood if they are studied with a model at hand for reference. Two or three studious engineers or firemen can give great help to each other by forming a class to study a model together by the aid of the chapters on valve gear. When that part is mastered, they will be likely to study the



Westinghouse and New York air-brake lubricating appliances and other parts in the same way. The union of two or three together for the purpose of mutual study yields a form of strength that is certain to have a sustaining influence throughout the life of those participating.

When an ambitious student of railway mechanism fails to secure local help, I should advise him to join the International Correspondence School of Scranton, Pa., or some educational establishment of similar character.

## CHAPTER IV

## HOW LOCOMOTIVE ENGINEERS ARE MADE

### RELIABLE MEN NEEDED TO RUN LOCOMOTIVES

Locomotive engine running is one of the most modern of trades, consequently its acquirement has not been controlled by the exact methods associated with ancient guild apprenticeships. Nevertheless, graduates to this business do not take charge of the iron horse without the full meed of experience and skill requisite for performing their duties successfully. The man who runs a locomotive engine on our crowded railroads has so much valuable property, directly and indirectly, under his care, so much of life and limb depending upon his skill and ability, that railroad companies are not likely to intrust the position to those with a suspicion of incompetency resting upon them.

### DIFFICULTIES OF RUNNING LOCOMOTIVES AT NIGHT, AND DURING BAD WEATHER

In the matter of speed alone there is much to learn before a man can safely run a locomotive. During daylight a novice will generally be half out in estimating speed; and his judgment is merely wild guesswork, regulated more by the condition of the track than by the velocity his train is reaching. On a smooth piece of track he thinks he is making twenty-five miles





an hour, when forty miles is about the correct speed: then he strikes a rough portion of the road-bed, and concludes he is tearing along at thirty miles an hour when he is scarcely reaching twenty miles, since the first lurchy spot made him shut off twenty per cent of the steam. At night the case is much worse, especially when the weather proves unfavorable. On a wild, stormy night the accumulated experience of years on the footboard, which trains a man to judge of speed by sound of the revolving wheels, and to locate his position between stations from a tree, a shrub, a protruding bank, or any other trifling object that would pass unnoticed by a less cultivated eye, is all needed to aid an engineer in working along with unvaried speed without jolt or tumult. On such a night a man strange to the business cannot work a locomotive and exercise proper control over its movements. He may place the reverse-lever latch in a certain notch, and keep the steam on; he can regulate the injector after a fashion, and watch that the water shall not get too low in the boiler; he can shut off in good season while approaching stations, and blunder into each depot by repeatedly applying steam; but he exerts no control over the train, knows nothing of what the engine is doing, and is constantly liable to break the train in two. A diagram of his speed would fluctuate as irregularly as the profile lines of a bluffy country. This is where a machinist's skill does not apply to locomotive-running until it is supplemented by an intimate knowledge of speed, of facility in handling a train and keeping the couplings intact, and of insight into the best methods of economizing steam.

These are essentials which every man should possess before he is put in charge of a locomotive on the road. The great fund of practical knowledge which stamps the first-class engineer is amassed by general labor during years of vigilant observation on the foot-board, amidst many changes of fair and foul weather.

As passing through the occupation of fireman was the only way men could obtain practical knowledge of engine-running before taking charge, railroad officials all over the world gradually fell into the way of regarding that as the proper channel for men to traverse before reaching the right-hand side of the locomotive.

### KIND OF MEN TO BE CHOSEN AS FIREMEN

As the pay for firemen rules moderately good, even when compared with other skilled labor; and as the higher position of engineer looms like a beacon not far ahead,—there is always a liberal choice of good men to begin work as firemen. Most railroad companies recognize the importance of exercising judgment and discretion in selecting the men who are to run as their future engineers. Sobriety, industry, and intelligence are essential attributes in a fireman who is going to prove a success in his calling. Lack in any one of these qualities will quickly prove fatal to a fireman's prospects of advancement. Sobriety is of the first importance, because a man who is not strictly temperate should not be tolerated for a moment about a locomotive, since he is a source of danger to himself and others; industry is needed to lighten the burden of a fireman's duties, for oftentimes they are arduous beyond the conception of strangers; and wanting in



the third quality, intelligence, a man can never be a good fireman in the wide sense of the word, since one deficient in mental tact never rises higher than a human machine. An intelligent fireman may be ignorant of the scientific nomenclature relating to combustion, but he will be perfectly familiar with all the practical phenomena connected with the economical generation of steam. Such a man does not imagine that he has reached the limit of locomotive knowledge when he understands how to keep an engine hot and can shine up the jacket. Every trip reveals something new about his art, every day opens his vision to strange facts about the wonderful machine he is learning to manage. And so, week by week, he goes on his way, attending cheerfully to his duties, and accumulating the knowledge that will eventually make him a first-class locomotive engineer.

### FIRST TRIPS

A youth entirely unacquainted with all the operations which a fireman is called upon to perform finds the first trip a terribly arduous ordeal, even with some previous experience of railroad work. When his first trip introduces him to the locomotive and to railroad life at the same time, the day is certain to be a record of personal tribulation. To ride for ten or twelve hours on an engine for the first time, standing on one's feet, and subject to the shaking motion, is intensely tiresome, even if a man has no work to do. But when he has to ride during that period, and in addition has to shovel six or eight tons of coal, most of which has to be handled twice, the job proves no sinecure. Then, the posture of his body while doing work is new; he is expected and required to pitch coal upon certain exact spots, through a small door, while the engine is swinging about so that he can scarcely keep his feet; his hands get blistered with the shovel, and his eyes grow dazzled from the resplendent light of the fire. Then come the additional side duties of taking water, shaking the grates, cleaning the ash-pan, or even the fire, where bad coal is used, filling oil-cans, and trimming lamps, to say nothing of polishing and keeping things clean and tidy. By the time all these duties are attended to the young fireman does not find a great deal of leisure to admire the passing scenery.

### POPULAR MISCONCEPTION OF A FIREMEN'S DUTIES

A great many idle young fellows, ignorant of railroad affairs, imagine that a firemen's principal work consists in ringing the bell, and showing himself off conspicuously in coming into stations. They look upon the business as being of the heroic kind, and strive to get taken on as firemen. If a youth of this kind happens to succeed, and starts out on a run of one hundred and fifty miles with every car a heavy engine will pull stuck on behind, his visions of having reached something easy are quickly dispelled.

Like nearly every other occupation, that of fireman has its drawbacks to counterbalance its advantages; and the drawbacks weigh heaviest during the first ten days. The man who enters the business under the delusion that he can lead a life of semi-idleness must change his views, or he will prove a failure. The man who becomes a fireman with a spirit ready and willing



to overcome all difficulties, with a cheerful determination to do his duty with all his might, is certain of success; and to such a man the work becomes easy after a few weeks' practice.

### LEARNING FIREMEN'S DUTIES

Practice, combined with intelligent observation, gradually makes a man familiar with the best styles of firing, as adapted to all varieties of engines; and he gets to understand intimately all the qualities of coal to be met with, good, bad, and indifferent. As his experience widens, his fire management is regulated to accord with the kind of coal on hand, the steaming properties of the engine, the weight of the train, the character of the road and of the weather. Firing, with all the details connected with it, is the central figure of his work, the object of pre-eminent concern; but a good man does not allow this to prevent him from attending regularly and exactly to his remaining routine duties.

### A GOOD FIREMAN MAKES A GOOD ENGINEER

There is a familiar adage among railroad men, that a good fireman is certain to make a good engineer; and it rarely fails to come out true. To hear some firemen of three months' standing talk, a stranger might conclude that they knew more about engine-running than the oldest engineer in the district. These are not the good firemen. Good firemen learn their own business with the humility born of earnestness, and they do not undertake to instruct others in matters beyond their own knowledge. It is the man who goes into the heart of a subject, who understands how much there is to learn, and is therefore modest in parading his own acquirements, that succeeds.

### LEARNING AN ENGINEER'S DUTIES

When a fireman has mastered his duties sufficiently to keep them going smoothly, he begins to find time for watching the operations of the engineer. He notes how the boiler is fed; and, upon his knowledge of the engineer's practice in this respect, much of his firing is regulated. The different methods of using the steam by engineers, so that trains can be taken over the road with the least expenditure of coal, are engraven upon the memory of the observant fireman. Many of the acquirements which commend a good fireman for promotion are learned by imperceptible degrees, the knowledge of speed, for instance, which enables a man to tell how fast a train is running on all kinds of track, and under all conditions of weather. There would be no use in one strange to train service going out for a few runs to learn speed. He might learn nearly all other requisites of engine-running before he was able to judge within ten miles of how fast the train was going under adverse circumstances. The same may be said of the sound which indicates how an engine is working. It requires an experienced ear to detect the false note which indicates that something is wrong. Amidst the mingled sounds produced by an engine and train hammering over a steel track, the novice hears nothing but a medley of confused noises, strange and meaningless as are the harmonies of an



opera to an untutored savage. But the trained ear of an engineer can distinguish a strange sound amidst all the tumult of thundering exhaust, screaming steam, and clashing steel, as readily as an accomplished musician can detect a false note in a many-voiced chorus. Upon this ability to detect growing defects which pave the way to disaster depends much of an engineer's chances of success in his calling. This kind of skill is not obtained by a few weeks' industry: it is the gradual accumulation of months and years of patient labor.

### LEARNING TO KEEP THE LOCOMOTIVE IN RUNNING ORDER

As his acquaintance with the handling and ordinary working of the locomotive extends, the aspiring fireman learns all about the packing of glands, and how they should be kept so as to run to the best advantage: he displays an active interest in everything relating to lubrication, from the packing of a box-cellar to the regulating of a rod-cup. When the engineer is around keying up rods, or doing other necessary work about his engine, the ambitious fireman should give a helping hand, and thereby become familiar with the operations that are likely to be of service when he is required to draw upon his own resources for doing the same work.

Of late years the art of locomotive construction has been so highly developed, the amount of strain and shocks to which each working part is subjected has been so well calculated and provided against, that breakages are really very rare on roads where the motive power is kept in first-class condition. Consequently, firemen gain comparatively small insight, on the road, into the best and quickest methods of disconnecting engines, or of fixing up mishaps promptly, so that a train may not be delayed longer than is absolutely necessary. A fireman must get this information beyond the daily routine of his experience. He must search for the knowledge among those competent to give it. Persistent inquiry among the men posted on these matters; observation amidst machine-shop and round-house operations; and careful study of locomotive construction, so that a clear insight into the physiology of the machine may be obtained,—will prepare one to meet accidents, armed with the knowledge which vanquishes all difficulties. Reflecting on probable or possible mishaps, and calculating what is best to be done under all contingencies that can be conceived, prepare a man to act promptly when a breakdown occurs.

### METHODS OF PROMOTION ON OUR LEADING ROADS

In the method of promotion of firemen considerable diversity of practice is followed by the different railroads. On certain roads, with well-established business, and little fluctuation of traffic, firemen begin work on switch-engines, and are promoted by seniority, or by selection through the various grades of freight trains, thence to passenger service, from whence they emerge as incipient engineers. A more common practice, and one almost invariably followed in the West, is for firemen to begin as extra men, in place of firemen who are sick or laying off. From firing extra, they get advanced, if found competent and deserving, to regular



engines. Then, step by step, they go ahead to the best paying runs, till their turn for being "set up" comes round. Passenger engines are not fired by any but experienced men, but the oldest firemen do not always claim passenger-runs. For learning the business of engine-running freight service is considered most valuable; and many ambitious firemen prefer the hard work of a freight engine on this account.

### NATURE OF EXAMINATION TO BE PASSED

When a fireman has obtained the experience that recommends him for promotion, on nearly all well-regulated roads he is subjected so some form of examination before being put in charge of an engine. In some cases this examination is quite thorough. The tendency to require firemen to pass such an ordeal is extending, and its beneficial effect upon the men is unquestioned. The usual form of examination is, for officers connected with the locomotive department to question the candidate for promotion on matters relating to the management of the locomotive, and how he would proceed in the event of certain mishaps befalling the engine. Parties belonging to the traffic department propound questions relating to road-rules, train-rights, understanding of time-card, and so on.

A common practice among progressive railroad companies is to subject their firemen to an examination, with questions and answers similar to those given in the form of examination published in another chapter of this book. The questions and answers are given to show to the candidate for promotion the scope of knowledge he is expected to possess. The prevailing practice in carrying on the examination is to vary the questions enough to find out that the fireman has not merely committed the words of the answer to memory without understanding the subject. A careful study of this book will give a candidate for promotion good sound knowledge of all the questions that will be asked, and will enable him to prove to the examiners that his acquaintance with the working of the locomotive is sufficient for dealing with all difficulties likely to arise.

A good practice for firemen who read this book is to note what is recommended to be done in case of accidents or emergencies and study how the recommendations could best be carried out on the locomotives they are acquainted with. Try to give a practical application of every recommendation.

# CHAPTER V

## INSPECTION OF THE LOCOMOTIVE

### LOCOMOTIVE INSPECTORS

On well-managed railroads, where the system of pooling locomotives prevails, there is a locomotive inspector employed, whose duty it is thoroughly to examine every available point about every engine that arrives at his station, and find out what repairs are needed, and to detect the incipient defects which lead to disaster on the road. Some roads that do not practice pooling have an inspector who examines every engine. These inspectors are not employed to exempt engineers from looking over their engines, but merely to supplement their care. In some cases engineers are brought sharply to task if they overlook any important defect which is discovered by the inspector.

### GOOD ENGINEERS INSPECT THEIR OWN ENGINES

The engineer who has a liking for his work, and takes pride in making his engine perform its part so as to show the highest possible record, does not require the fear of an inspector behind him as an incentive to examine his engine properly, and keep it in the best running-order. He recognizes the fact that upon systematic and regular inspection of the engine while at rest depends in a great measure his success as a runner and his exemption from trouble.

### WHAT COMES OF NEGLECTING SYSTEMATIC INSPECTION OF LOCOMOTIVES

The man who habitually neglects the business of inspecting his engine, and leaves to luck his chances of getting over the road safely, soon finds that the worst kind of luck is always overtaking him on the road. A careful man may have a run of bad luck occasionally, but the careless man meets with nothing else. Among a great many men who have failed as runners, I can recall numerous cases where carelessness about the engine was the only and direct cause which led them to failure. One of the most successful engineers that ever pulled a throttle on the Erie Railroad was asked by a young runner to what cause he attributed his extraordinarily good fortune. His reply, was, "I never went out without giving my engine a good inspection." This man had been running nearly half a century, and never needed to have his engine hauled to the round-house.

### CONFIDENCE ON THE ROAD DERIVED FROM INSPECTION

When a locomotive is thundering over a road ahead of a heavy train in which may be hundreds of human beings, the engineer ought to understand that the safety of this freight of lives depends to a great extent upon his care and foresight. As the train rushes through darkened cuttings, spans giddy bridges, or



rounds curves edged by deep chasms, no one can understand better than the engineer the importance of having every nut and bolt about the engine in good condition, and in its proper place. The consciousness that everything is right, the knowledge that a thorough inspection at the beginning of the journey proved the locomotive to be in perfect condition, give a wonderful degree of comfort and confidence to the engineer as he urges his train along at the best speed of the engine.

### INSPECTION ON THE PIT

Between the time of an engine's return from one trip and its preparation for another a thorough examination of all the machinery and running-gear should be made while the engine is standing over a pit. Monkey-wrench in one hand, and a torch in the other if necessary, the engineer ought to enter the pit at the head of the engine, and make the inspection systematically. The engine-truck, with all its connections, comes in for the first scrutiny. Now is the time to guard against the loss of bolts or screws, which leads to the loss of oil-box cellars on the road. This is also the proper time to examine the condition of the oil-box packing. The engineers of my acquaintance who are most successful in getting trains over the road on time attend to the packing of the truck-boxes themselves. Nothing is more annoying on the road than hot boxes. They are a fruitful source of delay and danger, and nothing is better calculated to prevent such troubles than good packing and clear oil-holes. The shopmen who are kept for attending to this work are sometimes careless. They can hardly be expected to feel so strongly impressed with the importance of having boxes well packed as the engineer, who will be blamed for any delay. He should, therefore, know from personal inspection that the work is properly done.

When the engineer is satisfied that the truck, pilot-braces, center-castings, and all their connections are in proper condition, he passes on to the motion. His trained eye scans every bolt, nut, and key in search of defects. The eccentrics are examined, to see that set-screws and keys are all tight. Men who have wrestled over the setting of eccentrics on the road are not likely to forget this part. Eccentric-straps are another point of solicitude. A broken eccentric-strap is a very common cause of break-down, and these straps very seldom break through weakness or defect of the casting. In nearly all cases the break occurs through loss of bolts, or on account of oil-passages getting stopped up. The links are carefully gone over, then the wedges and pedestal-braces come in for an examination which brings the assurance that no bolts are missing or wedge-bolts loose. Passing along, the careful engineer finds many points that claim his attention; and when he gets through he feels comfortably certain that no trouble from that part of the engine will be experienced during the coming trip. The runners who do not follow this practice are not aware of how much there is to be seen under a locomotive when the examination is undertaken in a comprehensive manner.



### OUTSIDE INSPECTION

In going round the outside of the engine the most important points for examination are the guides and the rods. Guide-bolts, rod-bolts, and keys, with the set-screws of the latter, are the minutiæ most likely to give trouble if neglected. In going about the engine oiling, or for any other purpose, it is a good thing to get in the habit of searching for defects. When a man trains himself to do this, it is surprising how natural it comes to make running inspections. As he oils the eccentric-straps, he sees every bolt and nut within sight; as he drops some oil on the rods, he identifies the condition of the keys, set-screws, or bolts; while oiling the driving-boxes, the springs can be conveniently examined; and when he reaches the engine-trucks with the oil-can he is sure to be casting his searching eyes over the portions of the running-gear within sight.

### OIL-CUPS

The oil-cups should be carefully examined to see that they are in good feeding order. A great many feeders have been invented, which guarantee to supply oil automatically; but I have never yet seen the cup which could long dispense with personal attention. And this does not apply to locomotives alone, but to all kinds of machinery. The worst sort of oil-cup will perform its functions fairly in the hands of a capable man, and the most pretentious cup will soon cease to lubricate regularly if the engineer neglects it. The oil-cups should be cleaned out at regular intervals: for mud, cinders, and dust work in; and they sometimes retain glutinous matter from the oil, which forms a sticky mixture that prevents the oil from running. The eccentric-strap cups and the tops of the driving-boxes should receive similar attention.

In looking round an engine it is a good plan to watch the different oil-cups to see that they are not working loose. Many cups that are strewed over the country could be saved by a little more attention. A cup flying off a rod when an engine is running fast becomes a dangerous projectile. I have known several cases where cups went back through the cab window. I have also seen several cases where cups worked off the guides or cross-head, and got between the guides, doing serious damage. One instance was that of an engine out on the trial trip. It smashed the cross-head to pieces, and let the piston through the cylinder-head.

### INSPECTION OF RUNNING-GEAR

A sharp tap with a hammer on the tread of the cast-iron wheel will produce a clear, ringing sound if the wheel is in good order. The drivers can generally be effectively inspected by the eye. If oil be observed working out between the wheel and axle, attention is demanded; for the wheel may be getting loose. Moisture and dirt issuing from between the tire and wheel indicate that the former is becoming loose, and this is a common occurrence when the tires are worn thin. When a wheel is running so that the flange is cutting itself on the rail, something is wrong, which also demands immediate attention. Oblique travel of wheels may be produced by various causes. If the axles of



the driving-wheels are not secured at right angles to the frames, and parallel with each other, the wheels will run tangentially to the track, according to the inclination of the axles. Violent strains or concussions, such as result from engines jumping the track about switches, sometimes spring the frames, and twist the axle-box jaws away from their true position enough to cause cutting of flanges without disabling the engine. Tires wearing unevenly in consequence of one being harder than the other produce a similar effect. Where there are movable wedges forward and aft of the boxes, the wheels are often thrown out of square by unskillful manipulation of these wedges. Engineers running engines of this kind should leave the forward wedges alone. Sometimes the center-pin of the engine-truck gets moved from the true central position, leading the drivers toward the ditch. Diagnosing the cause of wheel-cutting is no simple matter, and it is a wise plan for engineers to allow the shopmen to devise a remedy.

### ATTENTIONS TO THE BOILER

On our well-regulated roads engineers are not required to inspect their boilers; as expert boiler-makers, who can readily detect a broken stay-bolt or broken brace, have to make periodical examinations. But a prudent engineer will keep a sharp lookout for indications that show weak points about any part of the boiler or fire-box. This department cannot receive too much vigilance. A seam or stay-bolt leaking is a sign of distress, and should receive immediate attention. Leaks under the jacket should never be neglected, although they are hard to reach; for they may proceed from the beginning of a dangerous rupture. A leak starting in the boiler-head should make the engineer ascertain that none of the longitudinal braces have broken. I once had some rivet-heads on my boiler-head start leaking, and presently the water-glass broke. After shutting off the cocks, I found that the boiler-head was bulged out. I reduced the pressure on the boiler as quickly as possible. When the boiler was inspected, it was found that two of the longitudinal braces were broken, and the head-sheet was bent out two inches.

### MISCELLANEOUS ATTENTIONS

If an engineer is going to take out an engine the first time after it has been in the shop for repairs, it is a good plan to examine the tank to see if the workmen have left it free from bagging, greasy waste, and other impediments, which are not conducive to the free action of pumps or injectors. Keeping the tank clean at all times saves no end of trouble through derangement to feeding-apparatus. The smoke-box door should be opened regularly, and the draft appliances examined. These things wear out by use, and it is better to have them renewed or repaired before they break down on the road.

### REWARD OF THOROUGH INSPECTION

To go over an engine in the manner indicated requires perseverance and industry. The work will, however, bring its full reward to every man who practices the care and watchfulness entailed by regular and systematic inspection. It is the sure road to success.



He who regards his work from a higher plane than that of mere labor well done, will experience satisfaction from the knowledge, that, understanding the nobility of his duties, he performed them with the vigor and intelligence worthy of his responsible calling.

# CHAPTER VI

## GETTING READY FOR THE ROAD

### RAISING STEAM

It used to be the universal custom, that, when an engine arrived from a trip, the fire was drawn, and the engine put into the round-house for ten or twelve hours before another run was undertaken. During this period of inaction, the boiler partly cooled down. When the engine was wanted again, a new fire was started in time to raise steam. The system of long runs, introduced on many roads, has changed this; and engines are now generally kept hot, unless they have to be cooled down for washing out, or repairs. When an engine comes in off a trip, the fire is cleaned from clinkers and dead cinders, and the clean fire banked. It is found that this plan keeps the temperature of the boiler more uniform than is possible with the cooling-down practice, and that the fire-box sheets are not so liable to crack, or the tubes to become leaky.

Where it is still the habit to draw the fire at the end of each trip, a supply of good wood is kept on hand for raising steam. On some roads the fires in the locomotive fire-boxes are kindled by oil or greasy waste. To raise steam from a cold boiler, some theorists recommend the starting of a fire mild enough to raise





the temperature about twenty degrees an hour. The exigencies of railroad service prevent this slow method from being practicable, and the ordinary practice is to raise steam as promptly as possible when it is wanted.

### PRECAUTIONS AGAINST SCORCHING BOILERS

The first consideration before starting a fire in a locomotive is to ascertain that the boiler contains the proper quantity of water. The men who attend to the starting of fires should be instructed not to depend upon the water-glass for the level of the water, but to see that it runs out of the gauge-cocks. I have known several cases where boilers were burned through those firing up being deceived by a false show of water in the glass, and starting the fire when the boiler was empty. If the boiler has been filled with water through the feed-pipes by the round-house hose, care should be taken to see that the check-valves are not stuck up. Where there is sand in the water, it frequently happens that, in filling up with a hose, all the valves get sanded, and do not close properly. When there is steam on the boiler, this source of danger will generally be indicated at once by the steam and water blowing back into the tank; but, where the boiler is cold, the water flows back so silently and slowly that the crown-sheet may be dry before the peril is discovered.

### STARTING THE FIRE

The water being found or made right, the next consideration is the grates. Before throwing in the wood, all loose clinkers left upon the grates should be cleaned off: care should be taken to see that the grates are in good condition, and connected with the shaker-levers. This is also the time to see that no accumulation of cinders is left on the brick arch, the water-table, or in the combustion-chamber, should the engine be provided with either of these appliances.

### FIREMAN'S FIRST DUTIES

On most roads the engineer and fireman are required to be at their engine from fifteen minutes to half an hour before train-time. A good fireman will reach the engine in time to perform his preliminary duties deliberately and well. He will have the dust brushed off from the cab-furnishing and from the conspicuous parts of the engine, the deck swept clean, the coal watered, and the oil-cans ready for the engineer. His fire is attended to, and its make-up regulated,—the kind of coal used, the train to be pulled, and the character of the road on the start. With a level or down grade for a mile or two on the start the fire does not need to be so well made up as when the start is made on a heavy pull. But every intelligent fireman gets to understand in a few weeks just what kind of a fire is needed. It is the capability of perceiving this and other matters promptly that distinguishes a good from an indifferent fireman. When a young fireman possesses these "true workman" perceptions, and is of an industrious, aspiring disposition, anxious to become master of his calling, he will prove a reliable help to the engineer; and his careful attention to the work will insure comfort and success on every trip. There must be a certain amount of work done on the engine, to get a train along; and if the fireman cannot do his part efficiently it will fall upon the engineer, who must get it done somehow.



### SAVING THE GRATES

An important duty, which is never neglected by first-class firemen, before taking the engine away from the round-house, is that of looking to the grates, and seeing that the ash-pan is clean. When grates get burned, in nine cases out of ten it happens through neglecting the ash-pan. Some varieties of bituminous coal have an inveterate tendency to burn the grates. Such coal usually contains an excess of sulphur, which has a strong affinity for iron, and at certain temperatures unites with the surface of the grates, forming a sulphuret of iron. Neglecting the ash-pan, and letting hot ashes accumulate, prepares the way for bad coal to act on the grates. Keeping the ash-pan clear of hot ashes is the best thing that can be done to save grates, since that prevents the iron from becoming hot enough to combine with sulphur.

### SUPPLIES

Before starting out, the fireman ought to ascertain that all the supplies necessary for the trip are in the boxes; that the requisite flags, lanterns, and other signals are on hand, and that all the lamps are trimmed. He should also know to a certainty that all his fire-irons are on the tender, that the latter is full of water, and that the sand-box is full of sand.

These look like numerous duties as preliminary to starting, but they are all necessary; and the fireman who attends to them all with the greatest regularity will be valued accordingly. Nearly all firemen are ambitious to become engineers. The best method they can pursue, to show that they are deserving of promotion, is to perform their own duties regularly and well. A first-class fireman will save his wages each trip over the expenditure made by the mediocre fireman: a persistently bad fireman should be sent to another calling without delay. Few railroad companies can afford the extravagance of a set of bad firemen.

### ENGINEER'S FIRST DUTIES

Try the water. That is the most important call upon the engineer when he first enters the cab. If the engine has a glass water-gauge, he should ascertain by the gauge-cocks if the water-level shown in the glass be correct. A water-glass is a great convenience on the road, but it should only be relied on as an auxiliary to the gauge-cocks. Many engineers have come to grief through reposing too implicit confidence in the water-glass. Engineer Williams was considered one of the most reliable men on the A. & B. road. With an express train he started out on time one morning; and he had run only two miles when the boiler went up in the air, with fatal results to both occupants of the cab. An examination of the wreck showed unmistakable evidence of overheated sheets. Circumstantial evidence indicated that the glass had deceived the engineer by a false water-level. When he pulled out, the fire-box sheets, which were of copper, became weakened by the heat, so that the crown-sheet gave way, the reaction of



the released steam tearing the boiler to pieces. Numerous less serious accidents originating from the same cause might be cited.

### REACHING HIS ENGINE IN GOOD SEASON

An engineer who has a proper interest in his work, and thoroughly appreciates the importance of it, will reach his engine in time to perform the duties of getting her ready for the road leisurely, without rush or hurry. Although a good fireman may relieve the engineer of many preliminary duties, the engineer himself should be certain that the necessary supplies and tools are on the engine, and that water is in the tank, and the sand-box filled.

### OILING THE MACHINERY

Oiling the machinery is such an important part of an engineer's work, and the success of a fast run is so dependent upon this being properly done, that it should never be performed hurriedly. Although practice with short stoppages at stations may have got an engineer into the way of rushing around an engine and oiling at express speed, it is no reason why the first oiling of the trip should not be carefully and deliberately attended to when there is an opportunity. In addition to filling oil-cups, lubricators, and oil-boxes, this is a good time to complete the inspection, which assures the engineer that everything about the engine is in proper running order. When anything in the way of repairs has been done to the engine since she came off the last trip, special attention has generally to be given to the parts worked at. New wheels require close care with the packing of the boxes; rod-brasses reduced entail an additional supply of oil to the pins for the first few miles; guides closed should insure a free supply of oil till it is found that the cross-heads run cool.

### QUANTITY OF OIL THAT DIFFERENT BEARINGS NEED

While oiling, the engineer should bear in mind that it is of paramount importance that the rubbing-surfaces receive lubrication sufficient to keep them from heating; but, while making sure that no bearings shall run dry, lavish pouring of oil should be avoided. There are still too many cases to be noticed, of men pouring oil on the machinery without seeming to comprehend the exact wants. We are constantly seeing cases where oil-cups waste their measure of oil through neglect in adjusting the feeders. A steady supply, equal to the requirements, is what a well-regulated cup provides. With the ordinary quality of mineral oil, six drops will lubricate the back end of a main rod for one mile when the engine is pulling a load. This applies to eight-wheel engines on passenger service. Heavier small-wheeled engines will require a quarter more oil. Guides can be kept moist with five drops of oil to the mile. A dry, sandy road will require a more liberal supply. With good feeders, properly attended to, the supply can equal the demand with close accuracy. An oil-cup which runs out the oil faster than it is needed, wastes stores, besmears everything with a coating of grease, and is likely to leave the rubbing-surfaces to suffer by running dry before it can be replenished. A cup in that condition also advertises the engineer to be incompetent.



### LEAVING THE ENGINE-HOUSE

Before moving the engine out of the house, the cylinder-cocks should be opened so that water, or the steam condensed in warming the pipes and steam-chest, may escape. After ringing the bell, and giving workmen employed about the engine time to get out of the way, the throttle should be opened a little, and the engine moved out slowly and carefully. If there is a sufficient pressure of steam in the boiler, and the engine refuses to move, something is wrong. Never force an engine. Any work which may have been performed upon it while in the house will probably indicate the nature of the defect. The most common cause of stalling engines in the house is a miscalculation of the piston-travel, permitting it to push against the cylinder-head. Sometimes, however, the setting of the valves is at fault. I knew a case where the machinist connected the backing-up eccentric-strap with the top of the link, and the mistake was not discovered till they attempted to move the engine out of the house. Another blunder, the result of gross carelessness, was where a cold-chisel was left in the steam-chest. But a more representative case was that which happened to Engineer Amos, on the B. & C. road, His engine had the piston-packing set up; and the following morning, when he tried to take it out of the house, it would not pass a certain point. Thinking that the packing was set up rather tight, he backed for a start, determined to make it go over on the run. He succeeded, too, but a hammer which had been left in the cylinder went out through the cover.

While running from the round-house to the train is a good time to watch carefully the working of the various parts of the engine. Should any defects exist, they are better to be detected now than after the engine is out with a train. The brakes can be tested conveniently at this time, and the working of the injectors tried. All these matters are regularly attended to by the successful engineer: they are habitually neglected by the unlucky man, and misfortune never loses sight of him.

# CHAPTER VII

## RUNNING A FAST FREIGHT TRAIN

### RUNNING FREIGHT TRAINS

By far the greater proportion of American locomotive engineers are employed on freight service. On most roads, the freight engines constitute from seventy-five to ninety per cent of the whole locomotive equipment. On this kind of service, locomotive engineers learn their business by years of hard practice in getting trains over the road as nearly as possible on time. On the best of roads, there is much hardship to be undergone, working ahead through every discouragement of bad weather or hard-steaming engines. The man who brings the most energy, good sense, and perseverance to his aid, will come out most successfully above these difficulties.

Every department of locomotive engine running has difficulties peculiar to itself. Every kind of train needs to be handled understandingly, to show the best results; but, I think, getting a heavy fast freight train on time, over a hilly road, having a single track, requires the highest degree of locomotive engineering skill. Therefore, I have selected that form of train as the first subject of description.

### THE ENGINE

The engine that takes the train over the road is of the Pacific type (4-6-2), with cylinders 26×28 inches, driving wheels 62 inches diameter, heating surface 4,100 square feet, boiler pressure 200 pounds gauge, traction power 42,000 pounds. The valve gear is of the Baker type equipped with piston valves. The boiler capacity is supplemented by a Schmidt superheater.

### THE TRAIN

The train consists of 40 loaded cars weighing 2800 tons.

### THE DIVISION

The physical character of the country, which is rolling prairie, makes the road undulatory,—up hill, then down grade, with occasional stretches of level track. Some of the gradients rise to fifty feet to the mile, extending over two miles without sagging a foot. Sound steel rails, well tied, are supported by a graveled road-bed, making an excellent track, and presenting a good opportunity for fast running where high speed is needed. The train is run on card-time, stopping about every twenty miles.

### PULLING OUT

When the engineer gets the signal to go, he drops the reverse lever into the full forward notch, gives the engine steam gently, with due care to avoid breaking couplings, and applies sand. A slight sprinkling of sand only is dropped on the rails, which keeps the engine



from slipping while getting the train under way. A clear, level fire is burning over the grates before the start is made, and this suffices till the most crowded switches are passed; so, when the signal to start is given, the fireman closes the fire-door, and opens the damper, these duties not preventing him from keeping a lookout for signals.

### REDUCING VALVE TRAVEL

As the engine gets the train into motion, the engineer gradually notches up the reverse lever, thereby reducing the valve travel. This is not done by a sudden jerk as soon as the engine will move, with the steam cutting off short. He waits for that till the train is well under the control of the engine, notching up gradually. Some men think that it is best to get the valves up to short travel as soon as possible, without reflecting that it is better for the motion to let the engine be going freely before notching up short. I have often seen men coming into terminal stations with a heavy fire and the safety-valves blowing, and the engine toiling slowly along with the links hooked up to eight inches cut. In cases of this kind, a runner may better work the engine well down, so that the valve will travel freely over the seat. By doing so when the engine is working slowly and heavily, there will be less wear to the valves, and less danger of breaking a valve yoke. It is only in cases where there is an advantage in saving steam, that benefit is derived from working the engine close hooked back. There is a right time for all things, and working steam expansively is no exception to the rule. If, however, the start has been made with a light fire, the engineer ought to lose no time in getting the motion well notched back to give the fireman an opportunity to make up his fire. While starting from stations it is all-important that engineer and fireman should co-operate.

### WORKING THE STEAM EXPANSIVELY

At the right time, our engineer gets the reverse lever notched up; for he knows, that to obtain the greatest amount of work out of the engine, with the least possible expenditure of fuel, with a heavy freight train, the links must be hooked back as far as can be done consistently with making the required speed. Some engines will not steam freely when run close back if they are burning coal that needs a strong draught. This is the exception, however, and most engines will steam best in this position; and many of those that fail to steam well cutting off short are not properly fired, or the draught appliances need adjusting. Most firemen who run with a heavy fire fail worst with engines that steam indifferently when notched close up. Engineers should give this their attention, and do everything possible to make the engine steam while working with the lever as near the center notch as can be done while handling the train.

### ADVANTAGE OF CUTTING OFF SHORT

When the links are notched close towards the center, the travel of the valves is so short that they close the steam-ports shortly after the beginning of the stroke, at six, nine, or twleve inches of the piston's travel,



as the case may be, permitting the steam to push the piston along the remainder of the stroke by its expansive power. Steam at a high pressure is as full of potential energy as a compressed spiral spring, and is equally ready to stretch itself out when the closing of the port imprisons it inside the cylinder; and, by this act of expanding, it exerts immense useful energy, which would escape into the smoke-stack unutilized if the cylinders were left in communication with the boiler till the release took place. Suppose, for instance, that a boiler-pressure of 40 tons which this engine can develop is exerted upon the piston from the beginning to the middle of the stroke, and is then cut off. During the remainder of the stroke, the steam will continue to press upon the piston with a regularly diminishing force, till, at the end of the stroke, if release does not take place earlier, it will still have a pressure of twenty tons. The work performed by the steam during the latter part of the stroke is pure gain, due to its expansive principle. If the steam is cut off earlier, at a third or fourth of the piston travel, the gain will be correspondingly great. With the slide-valve motion used on locomotives, the steam cannot be held to the end of the stroke; but the principle of expansion holds good during the period the steam is held in the cylinders after the cut-off.

The observing engineer of any experience does not require to have the advantages of working his engine expansively impressed upon his attention. His fuel-record has done that more eloquently than pen can write.

### DISADVANTAGE OF CUTTING OFF TOO SOON

Working the steam expansively is, like nearly everything else in engineering, subject to modifications. With some steam-engines the steam cannot be expanded more than two or three times before the loss due to cylinder condensation becomes greater than the gain from expansion. No locomotives can be worked economically cutting off shorter than quarter stroke, and some engines do better if the steam is permitted to follow the piston a little farther before the cut-off takes place.

Locomotives equipped with steam superheaters can be worked with much more steam expansion than the older forms.

### BOILER-PRESSURE BEST FOR ECONOMICAL WORKING

There is a close and constant relation between the boiler-pressure carried and the useful work obtained from expansion of steam. The higher the pressure, the greater elasticity the steam possesses. The tendency of modern steam-engineering is, to employ intensely high boiler-pressure, expanding the steam by means of a succession of cylinders, so that it is reduced to low tension before escaping into the atmosphere, or into the condenser, as the case may be. Wonderfully economical results have been obtained in this manner,—results which can never be approached in locomotive practice while the ordinary slide-valve is used. But, while we cannot hope to rival the record of high-class automatic cut-off engines, their methods can teach us useful lessons.



It is advisable to keep the steam constantly close to the blowing-off point. During a day's trip, considerably less water will be evaporated when a tension of 200 pounds is carried, than will be required with a pressure of 140 pounds or under. And, where less water is evaporated, a smaller quantity of fuel will be consumed in doing the work. Running with a low head of steam is a wasteful practice, for several good reasons. The comparatively light pressure upon the surface of the water allows the steam to pass over damp, or mixed with a light watery spray, which diminishes its energy, since the wet steam contains less expansive medium than dry steam. It requires nearly the same expenditure of fuel to evaporate water at the pressure of the atmosphere alone, that it does to make steam at the higher working tensions: consequently, the work obtained by the expansion of the high-pressure steam is clear gain over the results to be obtained by working at a low pressure. This is a very important principle in economical steam-engineering. Engineers who are accustomed to making long runs between water-tanks, when every gallon is needed to carry them through, know that their sure method of getting over the dry division successfully is to carry steam close to the popping-point, link up to the most economical point of cut-off, and see that no loss occurs through the safety-valves.

### RUNNING WITH LOW STEAM

There are engineers who habitually carry merely sufficient steam to get them along on time, under the mistaken belief that they are working economically.

John Brown runs steadily, and takes as good care of his engine as any man on the A. & B. road; but he dislikes to hear the steam escaping from the safety-valves, and prevents it from doing so by habitually using steam thirty pounds below the blowing-pressure. The consequence is, that he always makes a bad record on the coal-list, compared with the other passenger men.

### MANAGEMENT OF THE FIRE

The engine has moved only a few rods from the station when the steam shows indications of blowing off; and then the fireman sets to work,—not to pile a heap of coal indiscriminately into the fire-box. That is the style of the dunce whose natural avocation is grubbing stumps. Ours is a model train, and a model fireman furnishes the power to keep it going. He throws in from one to three shovelfuls at each firing, scattering the coal along the sides of the fire-box, shooting a shower close to the flue-sheet, and dropping the required quantity under the door. With the quick intuition of a man thoroughly master of his business, our model fireman perceives at a glance, on opening the door, where the thinnest spots are; and they are promptly bedded over. The glowing, incandescent mass of fire, which shines with a blinding light that rivals the sun's rays, dazzles the eyes of the novice, who sees in the fire-box only a chaotic gleam; but the experienced fireman looks into the resplendent glare, and reads its needs or its perfections. The fire is maintained nearly level; but the coal is supplied so that the sides and corners are well filled, for there the



liability to drawing air is most imminent. With this system closely followed, there is no difficulty experienced in keeping up a steady head of steam. But constant attention must be bestowed upon his work by the fireman. From the time he reaches the engine, until the hostler takes charge at the end of the journey, he attends to his work, and to that alone; and by this means he has earned the reputation of being one of the best firemen on the road. His rule is to keep the fire up equal to the work the engine has to do, never letting it run low before being replenished, never throwing in more coal than the keeping up of steam calls for. The coal is broken up moderately fine, a full supply being prepared before the fire-door is opened; and every shovelful is scattered in a thin shower over the fire,—never pitched down on one spot. Some men never acquire the art of scattering the coal as it leaves the shovel; and, as a result, they never succeed in making an engine steam regularly. Their fire consists of a series of coal-heaps. Under these heaps, clinkers are prematurely formed; and between them spaces are created, through which cold air comes, and rushes straight for the tubes, without assimilating with the gases of combustion, as every breath of air which enters the fire-box ought to do.

### CONDITIONS THAT DEMAND GOOD FIRING

Roads that are hilly require far more skillful management to get a train along than is called for on level roads, and the greater part of the extra dexterity is needed from the fireman. To get a heavy train up a steep hill, it is generally run at a high speed before reaching the grade, so that the momentum of the train can be utilized in climbing the ascent. Running for a hill is a particularly trying time on the fireman; for the engine is rushing at a high speed, and often working heavily. This ordeal must be prepared for in advance, by having the fire well made up, and kept at its heaviest by frequent firing. When the engine gets right on to the grade, toiling up with decreasing speed, every pound of steam is needed to save doubling, and steady watchfulness is required to prevent a relapse of steam; but the danger of the engine "turning" the fire is not nearly so great as it was when running fast for the hill.

### HIGHEST TYPE OF FIREMAN

The highest type of fireman is one who, with the smallest quantity of fuel, can keep up a good head of steam without wasting any by the safety-valves. He endeavors to strike this mean of success by keeping an even fire; but it sometimes happens that the closest care will not prevent the steam from showing indications of blowing off. When this is the case, he keeps it back by closing the dampers, or, if that is not sufficient, opens the door a few inches. Immense harm is done to tubes and fire-boxes by injudicious firing.

When the train is ready to start, there is a glowing fire on the grates, sufficient to keep up steam until the reverse-lever is notched back after the train has worked into speed. With heavy freight trains this firing is made sufficient, so that the door has not to be opened until the tremendous exertion of starting is over. When the time for replenishing the fire arrives, the good fire-



man knows either from instruction or by observation that the effect of throwing fresh coal into the burning mass of the fire-box is similar to that of pouring a dipperful of cold water into a boiling kettle. The cold coal cools the fire, and if thrown in in large quantities its tendency is to depress the burning mass for a brief time below the igniting-point. A small quantity of cold water does not check the boiling of a kettle much, and three or four shovelfuls of coal are little felt on the fire of a big locomotive; so our man throws in only a few scoopfuls at a time, is quite deliberate in applying each charge, scattering it over the surface of the burning mass, so that each portion of fresh supply quickly gives up its hydrocarbon gases and becomes a vital addition to the bed of incandescent fuel. This bed of glowing fuel, on which the fresh coal is thrown, being comparatively thin, a supply of air passes through sufficient to provide the necessary oxygen to the hydrocarbons released, and the gases are burnt with the high generation of heat of which they are capable.

### SHAKING THE GRATES

Should indications appear that the fire is not receiving sufficient air, our fireman gently shakes the grates, an operation which is repeated during the trip at intervals sufficient to keep the fire as clean as possible. No act marks the poor fireman so strongly as his method of shaking grates. He does the work so violently and so frequently that a great deal of fuel is wasted. The fire is perniciously disturbed, and unless it is very heavy, holes are made which admit the cold air. Good coal requires no more grate-shaking than what will prevent clinkers from hardening between the grate-openings. Coal that contains a great deal of ash will be burned to greater advantage when the grates are shaken lightly and frequently, and this shaking should be done by short, quick jerks. The long, slow movement that some men give the grates, in shaking, merely moves the clinkers resting upon them. The purpose of shaker-grates is to provide a means of breaking the clinker, so that it will fall into the ash-pan and permit the dead ashes to fall.

### AT STOPPING-POINTS

When approaching a stopping-place, our fireman takes care to have sufficient fuel in the fire-box, so that he will not have to begin firing until the start is made. When this has not been done, a fresh supply of coal should be applied while the engine is standing at the station. The common practice of throwing open the door and beginning to fire as soon as the throttle is open, is very hard on fire-boxes, because the cold air drawn through the door strikes the fire-box sheets and tubes, contracting the metal and tending to produce leakage. Firing just as a train is pulling out of a station is bad for another reason—at that time the fireman ought to be looking out for signals.

### FIRES TO SUIT THE WORK TO BE DONE

The good fireman maintains the fire in a condition to suit the work the engine has to do. At parts of the road where there are grades that materially increase the work to be done, he makes the fire heavier to suit the circumstances, but this is done gradually, and not by pitching a heavy charge of fresh coal into the fire-



box at one time. This system of firing keeps the temperature of the boiler as even as possible, and has the double result of being easy on the boiler and using coal to the best advantage. From the time he reaches the engine until the hostler takes charge at the end of the journey, this fireman attends to his work, and to his work alone. It is only by concentrated attention to the work to be done that a fireman can do it in a first-class manner.

There are circumstances where the method of firing described would not be a success, because certain coals and certain engines require special treatment. But, in a general way, the methods described are those of the most successful firemen.

### SCIENTIFIC METHODS OF GOOD FIREMEN

It is not necessary that a man should be deeply read in natural philosophy to understand intimately what are actually the scientific laws of the business of firing. Mr. Lothian Bell, the eminent metallurgist, somewhere expresses high admiration for the exact scientific methods attained in their work by illiterate puddlers. Although they knew nothing about chemical combinations or processes they manipulated the molten mass so that, with the least possible labor, the iron was separated from its impurities. In a similar way, firemen skillful in their calling have, by a process of induction, learned the fundamental principles of heat-development. By experiments, carefully made, they perceive how the greatest head of steam can be kept up with the smallest cargo of coal; and they push their perceptions into daily practice.

If an accomplished scientist were to ride on the engine, observing the operations of a first-class fireman, he would find that nearly all the carbon of the coal combined with its natural quantity of oxygen to produce carbon dioxide, thereby giving forth its greatest heat-power; and that the hydrocarbons, the volatile gases of the coal, performed their share of calorific duty by burning with an intensely hot flame. He would find that these hydrocarbon gases, although productive of high-power duty when properly consumed, were ticklish to manage just right, for they would pass through the tubes without producing flame if they were not fully supplied with air; and, if the supply of air were too liberal, it would reduce the temperature of the fire-box below the igniting-point for these gases, which is higher than red-hot iron, and they would then escape in the form of worthless smoke. Our model fireman manages to consume these gases as thoroughly as they can be consumed in a locomotive fire-box.

### THE MEDIUM FIREMAN

John Barton is considered a first-class fireman by some men. He works hard to keep up steam, and is never satisfied unless the safety-valves are screaming. He carries a heavy fire all the time; and, when the pop-valves rise, he pulls the door open till they subside, gets in a few shovelfuls more coal, closes the door till the steam blows off again, and repeats the operation of throwing open the door. This man has learned only the half of his business. He has got through his head how to keep up steam, but he has not acquired



the more delicate operation of keeping it down wisely and well. Training with an intelligent engineer anxious to make a good fuel-record, will, in a few months, improve Barton wonderfully. Barton is the medium fireman.

### THE HOPELESSLY BAD FIREMAN

Behind him comes Tom Jackson, the man of indiscriminately heavy firing. Tom's sole aim is to get over the road with the least possible expenditure of personal exertion. He tumbles in a fire as if he were loading a wagon, the size of the door being his sole gauge for the lumps. When the fire-box is filled to the neighborhood of the door, he climbs up on the seat, and reclines there till the steam begins to go back through drawing air; then he gets down again, and repeats the filling-up process, intent only on getting upon the seat-box with as little delay as possible.

Some men are so constituted that they never make good firemen, no matter how much they may try. The average bad fireman is, however, of that quality because he never tries to be a good one. The average bad fireman is careless about how his work is done; indifferent about how his inferiority may cause delay to trains, annoyance to the engineer, or expense to the company. All he cares for is to get through his work with as little personal exertion as possible. It often happens that his efforts to shirk the most necessary part of his work greatly increase his labors before a trip is finished; yet he will go through the same performance on the next run.

When called to go out on a run, the poor fireman reaches the engine-house just as it is time to start for the train. He pitches some coal into the fire-box, and sweeps the cab and waters the coal as the engine is on its way to the starting-point. As soon as the engine pulls out, working hard to force the train into speed, this fireman pulls open the fire-door and throws in a heavy load of coal. Steam begins to go back and the engineer shuts off the injector. As the fire burns through, the steam comes up; and just as the engineer finds it necessary to start the injector again, the fireman jerks open the fire-door and pitches in eight or ten shovelfuls of coal as fast as he can drop it inside the door; then he climbs up on the seat and waits for the black smoke ceasing to flow from the stack as the signal to get down and repeat his method of firing.

Finding that the engine is not steaming freely under his treatment, he gets down reluctantly and tears up the fire by violent use of the shaking-lever. When the train reaches a stopping-place, this kind of fireman occupies himself looking at the sights, and pays no attention to the fire until the signal to start is given, when he throws open the door again and repeats the operation of firing followed at the first start.

By this method of firing small mounds of coal are dropped promiscuously over the grates. In intervening spots the grates are nearly bare, and cold air passes through without meeting carbon to feed upon, and not sufficiently heated to ignite with the volatile compounds distilling from the mounds. The product is worthless smoke. Each mound is a protection for the formation of clinker, which grows so rapidly that the shaking-bar has to be frequently toiled on to let



sufficient air through the fire to make steam enough for making slow time.

The result of this fireman's way of working is irritation all round. Towards the end of the trip he is overworked, throwing the extra coal needed and the hard shaking of grates. At every stopping-place he has to crawl beneath the engine to clean the ash-pan, and is fortunate if the grates are not partly burned. The practical result for this man's employers is that he has burned from 25 to 35 per cent more coal than a first-class fireman would need for doing the same work.

# CHAPTER VIII

## GETTING UP THE HILL

### SPECIAL SKILL AND ATTENTION REQUIRED TO GET A TRAIN UP A STEEP GRADE

In the last chapter, some details were given of the methods pursued in starting out with a heavy fast freight train. Where a train of that kind has to climb heavy grades, special skill and attention are needed in making the ascent successfully.

### GETTING READY FOR THE GRADE

The track for the first two miles from the starting-point is nearly level, permitting the engineer and fireman to get ready for a long pull not far distant. At the second mile-post a light descending grade is reached, which lasts one mile, and is succeeded by an ascending grade two and a half miles long, rising fifty-five feet to the mile.

### WORKING UP THE HILL

At the top of the descending grade, the engineer hooks up the links, using a light throttle while the train is increasing in speed, until the base of the ascent is nearly reached, when he gets the throttle full open, letting the engine do its best work in the first notch off the center. By this time the train is swinging





along thirty miles an hour, and is well on to the hill before the engine begins to feel its load. Decrease of speed is just becoming perceptible when the valve-travel gets the benefit of another notch, and the engine pulls at its load with renewed vigor. But soon the steepness of the ascent asserts itself in the laboring exhausts; and the reverse-lever is advanced another notch, to prevent the speed from getting below the velocity at which the engine is capable of holding the train on this grade. While the engineer is careful to maintain the speed within the power of his locomotive, he is also watchful not to increase the valve-travel faster than his fire can stand it; for, were he to jerk the lever two or three notches ahead at the beginning of the pull, the chances would be that he would "turn" its fire, or tear it up so badly that the steam would go back on him before he got half a mile farther on. Before the train is safe over the summit, it will probably be necessary to have the engine working down to 21 inches; but the advance to this long valve-travel is made by degrees; each increase being dependent upon, and regulated by, the speed. The quadrant is notched to give the cut-off at 6, 9, 13, 17, 23, and 27 inches. Repeated experiments, carefully watched, have convinced the engineer of this locomotive that its maximum power is exerted in the 21-inch notch; so he never puts the lever down in the "corner" on a hill. A great many engines act differently, however, showing increased power for every notch advanced. If the cars in the trains hould prove easy running,—and there are great differences in cars in this respect,—it may not be necessary to hook the engine below 15 inches, or even

12 will suffice for some traims; but this can only be determined by seeing how the engine holds the speed in the various notches.

### WHEEL-SLIPPING

As the engine gets well on to the grade, and is exerting heavy tractive power, the wheels are liable to commence slipping; and it is very important that they should be prevented from doing so. An ounce of prevention is known to be worth a pound of cure; and it pays an engineer to assure himself that no drips from feed-pipes, or cylinder-cocks, or from any other fountain, are dropping upon the rails ahead of the driving-wheels. There is no use telling an engineer of the decreased adhesion which the drivers exert on half-wet rails, from what they do on those that are clean and dry. Knowing the difference in this respect, every engineer should endeavor to prevent the wetting of the rails by leaks from his engine; for hundreds of engines get "laid down" on hills from slipping induced by this very cause.

### HOW TO USE SAND

The first consideration in this regard is to have clean, dry sand, and easy-working box valves. Then the engineer should know how far the valves open by the distance he draws the lever. In starting from a station, or working at a point where slipping is likely to commence, the valves should be opened a little, and a slight sprinkling of sand dropped on the rails. This often serves the purpose of preventing slipping just as well as a heavy coating of sand. And it has none of the



objectionable features of thick sanding. Trains often get stalled on grades by the sand-valves being allowed to run too freely. It is not an uncommon occurrence for engineers to open the valves wide, and let all the sand run upon the rails that the pipe will carry, so that a solid crust covers each rail, and every wheel on the train gets clogged with the powdered silica; and, after the train has passed over, a coating is left for the next one that comes along.

The wheels scatter their burden of powdered sand into the axle-boxes, and it grinds its way inside the rod-brasses, and part of it gets wafted upon the guides; and in all these positions it is matter decidedly in the wrong place. And this body of sand under the wheels increases the resistance in the same way as a wagon is harder to pull among gravel than it is on a clean, hard road: the indiscreet engineer complains about the train being stiff to haul; and the chances are, that he goes twice up the hill before the whole train is got over. Uncle Toby's plan is, when pulling on a heavy grade, to open the valve enough to let the drivers leave a slight white impression on the rails. If they slip, he gives a few particles more sand, but decreases the supply again so soon as the drivers will hold with the diminished quantity. Uncle Toby seldom needs to double a hill.

These remarks are for the use of men running engines with the common sand-boxes and valves. The modern locomotives have automatic devices which place the sand where it will do the most good and do not cause waste and annoyance by dropping an oversupply.

All efficient engineers are careful not to have their sanding-apparatus in the condition that only one sand-pipe is feeding. That is a common cause of broken crank-pins and side-rods.

### SLIPPERY ENGINES

The causes that make an engine bad for slipping are various. Excess of cylinder-power or very hard steel tires, are the most frequent causes of slipping; but badly worn tires sometimes produce a similar effect; or the blame may rest in a short wheel-base, deficiency in weight, or in too flexible driving-springs. To get a slippery engine over the road when the rails are moist and dirty, requires the exercise of unmeasured patience by the engineer. The tendency of an engine to slip may be checked to some extent by working with the lever well ahead towards full stroke, and throttling the steam. This gives a more uniform piston-pressure than is possible while working expansively. Of two evils, it is better to choose the lesser. The smallest in this case is losing the benefits of expansion, and getting over the road.

### FEEDING THE BOILER

Some engineers claim that the most economical results can be obtained from an engine by running with the water as low as possible, consistent with safety. They hold, that, so long as the water is sufficiently high to cover the heating-surfaces, there is enough to make steam from; and the ample steam-room remaining above the water assures a more perfect supply of dry steam for the cylinders than can be had from the



more contracted space left above a high water-line. Old engineers, running locomotives furnished with entirely reliable feeding-apparatus, may be able to carry a low water-level advantageously, especially with light trains and level roads; but with ordinary men, average injectors, and the common run of roads a high water-level is safest. With a high water-level the temperature of the boiler can be kept nearly uniform; for the increased volume of water holds an accumulated store of heat, which is not readily affected by the feed. And the surplus store is convenient to draw upon in making the best of a time-order, or in getting over a heavy grade. Then, if the injectors fail, a full boiler of water often enables a man to examine the delinquent feeding-apparatus, and set it going; whereas, with low water, the only resource would be to dump the fire.

The right-hand injector is used most for feeding the boiler, but several times during each trip the left-hand injector is called into service, a thing necessary to keep it in good working order. On a heavy grade one injector will not supply all the water necessary for steam-making, and the other is put to work. This is generally done when the slow, heavy pull begins and the steam reaches near to the blowing-off point. During the remainder of the ascent, the water is supplied as liberally as it can be carried; and the top of the grade finds the engine with a full boiler. This enables the engineer to preserve a tolerably even boiler temperature; for in running down the long descent which follows, where the engine runs several miles without working steam, the injectors can be shut off, and sudden cooling of the boiler avoided. The preservation of flues and fire-box sheets depends very much upon the manner of feeding the water. Some men are intensely careless in this matter. In climbing a grade, they let the water run down till there is scarcely enough left to cover the crown-sheet when they reach the summit. Then they dash on the feed, and plunge cold water into the hot boiler, which is then peculiarly liable to be easily cooled down, owing to the limited quantity of hot water it contains. The fact of having the steam shut off, greatly aggravates the evil; for there is then no intensity of heat passing through the flues to counteract the chilling effect of the feed-water. If it is necessary to feed while running with the steam shut off, the blower should be kept going; which will, in some measure, prevent the change of temperature from being dangerously sudden. There will probably be some loss from steam blowing off, but this is the smaller of two evils.

Engineers are not likely to feed the boiler too lavishly when working hard, for the injection of cold water instantly shows its effect by reducing the steam-pressure. But this is not the case when running with the throttle closed. The circulation in the boiler is then so sluggish that the temperature of the water may be reduced many degrees, while the steam continues to show its highest pressure.

Writers on physical science tell us that the temperature of water and steam in a boiler is always the same and varies according to pressure; that, at the atmosphere's pressure, water boils at 212 degrees, and produces steam of the same temperature. At 10 pounds



above the atmospheric pressure, the water will not evaporate into steam until it has reached a temperature of 240 degrees, and so on: as the pressure increases, the temperature of water and steam rises. But under all circumstances, while the water and steam remain in the same vessel, their temperature is the same. This is an acknowledged law of physical science; yet every locomotive engineer of reflection, who has run on a hilly road, knows that circumstances daily happen where the law does not hold good.

### CAREFUL FEEDING AND FIRING PRESERVE BOILERS

A case where the conservative effect of careful firing and feeding was strikingly illustrated once came under the author's notice. During the busiest part of the season, the fire-box of a freight engine belonging to a Western road became so leaky that the engine was really unfit for service. Engines, like individuals, soon lose their reputation if they fail to perform their required duties for any length of time. This engine, "29," soon became the aversion of trainmen. The loquacious brakeman, who can instruct every railroadman how to conduct his business, but is lame respecting his own work, got presently to making big stories out of the amazing quantity of water and coal that "29" could get away with, and how many trains she would hold in the course of a trip. The road was suffering from a plethora of freight and extreme scarcity of engines; and on this account the management was reluctant to take this weakling into the shop. So the master mechanic turned "29" over to Engineer Macleay, who was running on a branch where delays were not likely to hold many trains. Mac deliberated about taking his "time" in preference to the engine, which others had rejected, but finally concluded to give the bad one a fair trial. The first trip convinced the somewhat observant engineer that the tender fire-box was peculiarly susceptible to the free use of the pump, and to sudden changes of the fire's intensity of heat. So he directed the fireman to fire as evenly as possible, never to permit the grates to get bare enough to let cold air pass through, to keep the door closed except when firing, to avoid violent shaking of the grates, and never to throw more than two or three shovelfuls of coal into the fire-box at one time. His own method was, to feed with persistent regularity, to go twice over heavy parts of the division in preference to distressing the engine by letting the water get low, and then filling up rapidly. This system soon began to tell on the improved condition of the fire-box. The result was that within a month after taking the engine, Mac was pulling full trains on time; and this he continued to do for five months, till it was found convenient to take the engine in for re-building.

### OPERATING THE DAMPERS

According to the mechanical dictionary, a damper is a device for regulating the admission of air to a furnace, with which the fire can be stimulated, or the draught cut off, when necessary. Some runners regard locomotive dampers in a very different light. They seem to think the openings to the ash-pan are merely holes made to let air in, and ashes out; that doors are



placed upon them, which troublesome rules require to be closed at certain points of the road to prevent causing fires. Those who have made their business a study, however, understand that locomotive dampers are as useful, when properly managed, as are the dampers of the base-burner which cheers their homes in winter weather. To effect perfect combustion in the fire-box, a certain quantity of oxygen, one of the constituents of common air, is required to mix with the carbon and carbureted hydrogen of the coal. The combination takes place in certain fixed quantities. If the quantity of air admitted be deficient, a gas of inferior calorific power will be generated. On the other hand, when the air-supply is in excess of that needed for combustion, the surplus affects the steam-producing capabilities of the fire injuriously; since it increases the speed of the gases, lessening the time they are in contact with the water-surface, and a violent rush of air reduces the temperature of portions of the fire-box below the heat at which carbureted hydrogen burns.

### LOSS OF HEAT THROUGH EXCESS OF AIR

In the fire-boxes of American engines, where double dampers are the rule, far more loss of heat is occasioned by excess of air than there is waste of fuel through the gases not receiving their natural supply of oxygen. The blast from the nozzles creates an impetuous draught through the grates; and when to this is added the rapid currents of air impelled into the open ash-pan by the violent motion of the train, the fire-box is found to be the center of a furious wind-storm. The excess of this storm can be regulated by keeping the front damper closed, and letting the engine draw its supply of air through the back damper. When the fire begins to get dirty, and the air-passages between the grates become partly choked, the forward damper can be opened with advantage. So long as an engine steams freely with the front damper closed, it is an indication that there is no necessity for keeping it open. With vicious, heavy firing, all the air that can be injected into the fire-box is needed to effect indifferently complete combustion; and the man who follows this wasteful practice cannot get too much air through the fire. Consequently, it is only with moderately light firing that regulation of draught can be practiced. Running with the front damper open all the time is hard on the bottom part of the fire-box, and the ever-varying attrition of cold wind is responsible for many a leaky mud-ring.

### LOSS OF HEAT FROM BAD DAMPERS

In Europe, where far more attention has been devoted to economy of fuel than has been bestowed upon the matter this side of the Atlantic, locomotives are provided with ash-pans that are practically air-tight, and the damper-doors are made to close the openings. In many instances, the levers that operate the dampers have notched sectors, so that the quantity of air admitted may equal the necessities of the fire. European locomotives, as a rule, show a better record in the use of their fuel than is found in American practice; and a high percentage of the saving is due to the superior damper arrangements.



Imagine the trouble and expense there would be with a kitchen stove that had no appliance for closing the draught! Yet some of our locomotive-builders turn out their engines with practically no means of regulating the flow of air beneath the fire.

# CHAPTER IX

## FINISHING THE TRIP

### RUNNING OVER ORDINARY TRACK

THE hill which our train encounters nearly at the beginning of the journey is the hardest part of the division. The style in which it is ascended shows what kind of an engine pulls the train, and it tests in a searching manner the ability of the engineer. Our engine has got over the summit successfully; and the succeeding descent is accomplished with comfort to the engine, and security to the train. And so the rest of the trip goes on. The train speeds merrily along through green, rolling prairies, away past leafy woodlands and flowery meadows: it cuts a wide swath through long cornfields, startles into wakefulness the denizens of sleek farmhouses, and raises a rill of excitement as it bounds through quiet villages. But every change of scene, every varied state of road-bed,—level track, ascending or descending grade,—is prepared for in advance by our enginemen. Their engine is found in proper time for each occasion, as it requires the exertion of great power, or permits the conservation of the machine's energy. Over long stretches of undulatory track the train speeds; each man attending to his work so closely that the index of the steam-gauge is almost stationary, and the water does not vary an





inch in the glass. This is accomplished by regular firing and uniform boiler-feeding, two operations which must go together to produce creditable results.

### STOPPING-PLACES

There are few stops to be made, and these are mostly at water-stations. Here the fireman is ready to take in water with the least possible delay; and, while he is doing so, the engineer hurries around the engine, feeling every box and bearing, and dropping a fresh supply of oil where necessary. And, while going thus around, he glances searchingly over the engine, his eye seeking to detect absent nuts, or missing bolts or pins; anything wrong may now be observed and remedied.

At the coaling-stations the fireman finds time to rake out the ash-pan, and the engineer bestows upon the engine and tender a leisurely inspection besides oiling around.

### KNOWLEDGE OF TRAIN-RIGHTS

Next to studying the idiosyncrasies of his engine, our model engineer prides himself on his intimate acquaintance with the details of the time-table. The practice becoming so common on our best-regulated railroads, of examining candidates for promotion to the position of engineer on their knowledge of the time-table, has a very salutary effect upon aspiring firemen, and induces them to acquire familiarity with the rules governing train-service which they never forget.

Our engineer is well posted on all the rules relating to the movement of trains; his mind's eye can glance over the division, and note meeting or passing points; and the relative rights of each train stand blazoned forth in bold relief before his mental vision. This knowledge regulates his conduct while nearing stations; for, although every stopping-point is approached cautiously, those places where trains may be expected to be found are run into with vigilant carefulness, the train being under perfect control. Depending blindly upon conductors and brakemen to keep safe control of the train at dangerous points is opening the gate of trouble. An engineer is jointly responsible with the conductor for the safety of his train, and he should make certain that every precaution is taken to get over the road without accident.

On some roads the rules require the engineer to show his train-orders to the fireman. No rule ought to be necessary to insure this practice being regularly followed. Two heads are better than one when memory of where trains are to be met is concerned. Not a few engineers have escaped forgetting train-orders by showing them to the fireman.

### PRECAUTIONS TO BE OBSERVED IN APPROACHING AND PASSING STATIONS

Running past stations where trains are standing sidetracked, requires to be done with special care, particularly in the case of passenger trains; for, at such points, there is danger of persons getting injured by stepping inadvertently past a car or a building, in front of a moving train. This peril is guarded against



by reducing the speed as far as practicable, after whistling to warn all concerned, by ringing the engine-bell and keeping a sharp lookout from the cab.

### THE BEST RULES MUST BE SUPPLEMENTED BY GOOD JUDGMENT

Rules framed by the officers of our railways for the guidance of employees are always safe to follow as far as they go, and neglect of their behests will soon entail disaster. But circumstances sometimes arise in train-service to which no rule applies, and the men in charge must follow the dictates of their judgment. This happens often, especially on new roads; and the men who prove themselves capable of wrestling successfully with unusual occurrences, of overcoming difficulties suddenly encountered, are nature's own railroaders. It is this practice of acting judiciously and promptly, without the aid of codified directions, which gives to American railroadmen their striking individuality, known to the men of no other nation following the same calling. European railway servants carry ponderous books of "rules and regulations" in their pockets, and these rules are expected to furnish guidance for every contingency; so, when an engine-driver or guard gets into an unusual dilemma, he turns over the pages of his rule-book for counsel and direction. The American engineer or conductor under similar circumstances takes the safe side, and goes ahead.

### ACQUAINTANCE WITH THE ROAD

Next in importance to knowing well how to manage the engine, and intimate familiarity with the time-table and its rules, comes acquaintance with the road. In the light of noonday, when all nature seems at peace, when every object can be seen distinctly, the work of running over a division is as easy as child's play. But when thick darkness covers the earth, when the fitful gleam of the headlight shines on a mass of rain, so dense that it seems like a water wall rising from the pilot, or when blinding clouds of snow obliterate every bush and bank, it is important that the engineer should know every object of the wayside. A person unaccustomed to the business, who rides on a locomotive tearing through the darkness on a stormy night, sees nothing around but a black chaos made fitfully awful by the glare from the fire-box door. But even in the wildest tempest, when elemental strife drowns the noise of the engine, the experienced engineer attends to his duties calmly and collectedly. A cutting or embankment, a culvert or crossing, a tree or bush, is sufficient to mark the location; and every mile gives landmarks trifling to the uninitiated, but to the trained eye significant as a lighted signal. One indicates the place to shut off steam for a station, another tells that the train is approaching a stiff-pull grade; and the enginemen act on the knowledge imparted. And so the round of the work goes. Working and watching keep the train speeding on its journey. Nothing is left to chance or luck: every movement, every variation of speed, is the effect of an unseen control. As a stately ship glides on its voyage obedient as a thing of life to the turn of the steersman's wheel, so the king of inland transportation, the locomotive engine, the monarch of speed, the ideal of power in motion, pursues its way, annihilating space, binding nations into harmonious unit, and all the time submissive to the lightest touch of the engineer's hand.



To get a freight train promptly over the road day after day, or night after night, an engineer must know the road intimately, not only marking the places where steam must be shut off for stations or grades, but every sag and rise must be engraved on his memory. Then he will be prepared to take advantage of slight descents to assist in getting him over short pulls, where, otherwise, he would lose speed; and the same knowledge will avail him to avoid breaking the train in two while passing over the short depressions in the track's alignment, called sags in the West.

### FINAL DUTIES OF THE TRIP

With an engine properly fired, there is but little special preparation needed for closing up the trip without waste of fuel. The fire is regulated so that a head of steam will be retained sufficient to take the engine into the round-house after the fire-box is cleaned out. In drawing the fire, the blower should be used as sparingly as possible; for its blast rushes a volume of cold air through the flues, which is apt to start leaks. Many engineers find flues, or stay-bolts, which were dry at the end of one trip, leaking when the engine is taken out for the next run. In nine cases out of ten, the cause has been too much blower. So soon as the ash-pan is cleaned out the dampers should be closed so that the fire-box and flues may cool down gradually.

### PULLING PASSENGER TRAINS

The enginemen who acquire the art of taking a fast freight train over the road on time will experience no difficulty in handling passenger trains after a little experience. All the rules that apply to handling freight trains are suitable for passenger trains with very little modification.

## CHAPTER X

## SIGHT-FEED LUBRICATORS

THE introduction of sight-feed lubricators for oiling the valves and pistons of locomotives is one of the most important improvements carried out in the last quarter of the nineteenth century.

### EARLY METHODS OF STEAM-CHEST LUBRICATION

When locomotives were first put into service it was supposed that the low-pressure steam employed would supply sufficient moisture to lubricate the rubbing surfaces and prevent cutting. That plan did not work long and oil-cups were put on the steam-chests. A decided improvement on the steam-chest cup was the placing of oil-cups in the cab, with pipes to lead the lubricant to the steam-chest.

All those mentioned were crude methods at the best. The sight-feed lubricator was introduced in the progress of improvement and appealed so strongly to those who appreciated the lubrication requirements of slide-valves and pistons that it soon became a recognized necessity of a properly equipped locomotive.

For several years the merits of the sight-feed lubricator for locomotives were more apparent than real. One watching the regulated number of oil-drops passing each minute from the lubricator into the oil-pipe naturally supposed that the same number of drops were passing with the same regularity into the steam-chest.

### MISTAKES ABOUT ACTION OF SIGHT LUBRICATORS

There is now reason for believing that a great part of the time the oil kept dropping into the oil-pipes, which acted as reservoirs, until a reduction of steam in the steam-chest permitted the steam passing through the lubricator to overcome the pressure in the steam-chest and force the oil into that chest.

The principle of the sight-feed lubricator is that water condensed from a steam connection with the boiler passes below a body of oil standing in the oil-chamber, and owing to the lighter specific gravity of the oil pushes out a drop of oil for every drop of water that passes into the chamber. The water being heavier than oil, naturally keeps the body of oil floating upon it. The oil that is forced towards the oil pipes has behind it the pressure due to the steam connection with the boiler, and it was assumed that the boiler pressure through the lubricator would always be sufficient to overcome the steam-chest pressure. In practice, however, it became known that the steam direct from the boiler operating the lubricator was sometimes so reduced in pressure, through restricted passages and other causes, that the steam in the steam-chest opposed the flow of oil, and pushed it upwards from the steam-chest instead of permitting it to pursue its course. This defect did not become very apparent until extreme steam boiler-pressure became common practice. Several special devices have been perfected to overcome this difficulty, particulars of which will be given later.



### THE NATHAN AND THE DETROIT LUBRICATORS

There are many kinds of sight-feed lubricators in use for different kinds of engines; but for locomotives there are only two varieties, the Nathan and the Detroit, which are well known. Both these lubricators use the Gates invention of the up-feed of a drop of oil rising through a glass tube of water by virtue of its lighter gravity.

Both these lubricators feed oil to the valves and pistons whether the engine is using steam or not. Both require about the same handling to be successfully operated, and I shall ignore all other makes and consider only these two.

### LOCATION

The best location of the lubricator to secure satisfactory results will largely depend upon the style of boiler and the location of cab-fittings. On engines with large foot-plates the best location is over the middle of end of boiler. In this position feeds are in plain view of both enginemen, and irregular working or stoppage will be noticed at once upon engines where the boiler extends well into or through the cab; or with Colburn boilers, where the cab is ahead of the fire-box, the lubricator should be placed with the cylinder feed-glasses in line lengthwise with the boiler and air-pump, feed- and oil-glass facing the engineer. The bracket supporting the lubricator should be sufficiently heavy to prevent vibration.

### STEAM-SUPPLY AND PIPING

The early practice was to connect the steam-pipe of the lubricator to the turret, when one was used. It is now admitted that a better plan is to make an independent connection with the boiler for the lubricator steam-pipe. The favorite plan now is to connect the steam-pipe with the top of the boiler and to make it not less than $\frac{1}{2}$ inch inside diameter.

### "NATHAN" 5-FEED BULL'S-EYE LUBRICATOR

Sectional views of the Nathan 5-feed bull's-eye lubricator, known as type 1912, are shown in figure 1.

This type of lubricator is the latest development in the line of continued improvements in locomotive lubrication on the part of the Nathan Manufacturing Company.

The general construction, operation and use of these types of lubricators are so well known at this date that it will be necessary to refer only very briefly to the general features.

100*A* is the condenser which is connected at (116) for steam supply to the boiler. The water of condensation passes from the condenser, controlled by valve (107) to the bottom of the lubricator body through pipe (119). The oil elevated in the lubricator body passes down through pipe (118) into the channels from which the outlet through nozzles (109*A*) is controlled by the regulating valves (115). Pipes (117) in the condenser are the usual equalizing pipes, and (105) is the choke-plug, the function of all of which parts being familiar do not need any further explanation. The particular



and novel features of the type 1912 lubricator are worthy of attention. In addition to the regular choke-plugs

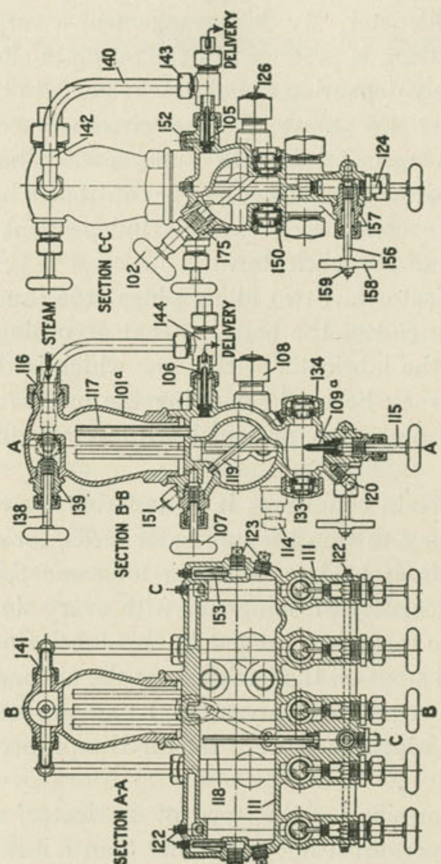



FIG. 1.—Nathan 5-feed Lubricator.

(105) at the delivery ends of the lubricator, auxiliary steam-pipes (140), popularly known as booster-pipes, are provided for which connect to the feeds leading to

the high-pressure valves or high-pressure steam-pipes. At the steam-chest or steam-pipe the usual oil-stud is provided with a final outlet opening of not more than $\frac{3}{32}$ inch in diameter. By this arrangement a very strong current of steam is produced in the oil-pipes effectively and positively delivering the oil to the parts to be lubricated, under the most adverse circumstances, particularly in connection with superheat. The steam admission to the auxiliary pipes is controlled by valve (138) in the condenser, which is independent of the boiler valve of the lubricator.

The lubricator has two filling plugs (102) and (151), one on each end of the body, so that according to the location of the lubricator, either one which is the most convenient may be used for filling the lubricator with oil. These plugs are provided with removable seats (175).

Under certain conditions it is desirable for the sake of oil economy to stop the lubricator feeds, for example when a train is held on a siding for some time. To avoid the necessity of doing this with every single feed a stop-valve (158) is arranged in this lubricator, which when closed stops all the feeds except the air-pump feed, leaving the regulating valves (115) undisturbed in the position in which they were set for the proper rate of feed.

The steam-pipe for this type of lubricator, which is usually copper, must not be smaller than 1 inch outside diameter, and steam valves and their shanks must have openings fully in accordance with this dimension.

The lubricator is also so arranged that by removing plug (123) on the center line of the body an air-cylinder oiler may be attached to feed oil to the air end of the air-pump directly from the body of the main lubricator.



**DETROIT BULL'S-EYE LOCOMOTIVE LUBRICATORS**

*To Start Lubricator*—Always start the lubricator about fifteen minutes before leaving the terminal. Be sure that the regular boiler-valve is open, then open wide the steam-valve " B " at the top of the condenser and keep it wide open while the lubricator is in operation. Allow sufficient time for the condenser and sight-feed glasses to fill with water.

Open the water-valve " D." Three turns will give full port opening.

Open the oil-control valve " C ".

In adjusting the lubricator feeds for a class of service, after the oil-valve " C " is opened, regulate the cylinder and pump feeds by means of valves " E," " E " and " L." After these valves have once been adjusted, do not use them in the ordinary operation of the lubricator. The oil-control valve is employed to throttle the feeds and to shut off part or all of them.

*Setting Feed Valves*—Adjust the feed-valves to the maximum number of drops required for the hardest *level* track service in the class Then the number of drops can be decreased for the lighter service by throttling with the oil-control valve.

*To Shut Down Lubricator*—For short stops, close oil-control valve " C " only.

For terminal stops, close oil-control valve " C " first then water-valve " D ," and last the steam-valve " B."

*Automatic Steam Chest Plugs*—The same automatic steam-chest plugs are used in connection with the No. 22 that were used with the No. 21, and whether they be of the straight, angle or T-angle type, it is equally important to see that their chokes are in place and not

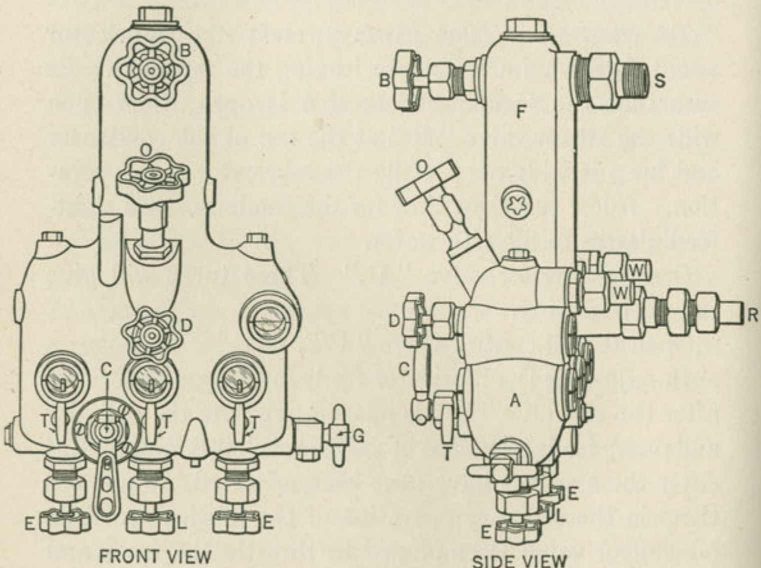



FIG. 2.

E—Indicates Feed Regulating Valves to Cylinders.
L—Indicates Feed Regulating Valves to Air Pump.
WW—Coupling to Right and Left-Hand Cylinders.
R—Coupling to Air Pump.
S—Steam Connection.
F—Condenser.
A—Oil Reservoir.
O—Filler Plug.
G—Drain Valve.
TTT—Sight Feed Drain Stems.
D—Water Feed Valve.
B—Steam Valve.
C—Oil Control Valve.

worn beyond the limit specified. As these chokes retain the balance of the lubricator, frequent attention should be given them. The steel chokes in the steam-chest plugs are reversible and should be replaced by new ones when the holes in both ends are enlarged to an area of



$\frac{7}{64}$-inch. A $\frac{5}{16}$-inch brass ball is employed to balance the feeds to the air pump, intercepting valve and mechanical stoker.

*To Fill or Refill*—Move the oil-control valve " C " to " Closed " position, close water-valve " D " and steam-valve " B." Open drain-valve " G " and fill with clean strained valve-oil. If the lubricator is under pressure, proceed as before, but remove filler plug slowly to allow pressure above the oil to escape and the air to enter. Fill the reservoir full. If there is not sufficient oil for this purpose, use water to make up the required quantity. This method will expel the air and enable the feeds to start without exhausting the water from the condenser or materially lowering its level.

*Steam Valve*—The regular boiler-valve must be left wide open at all times, and the steam valve " B " at top of condenser must be left wide open while the locomotive is in service.

## GENERAL REMARKS ON LOCOMOTIVE LUBRICATORS

The proper manner of applying and operating locomotive lubricators, in a general way is well understood, that when applied and operated in accordance with this general understanding, they perform their functions in most cases in a satisfactory manner. Nevertheless I do not consider it out of place to enumerate a few brief points, which users of lubricators should keep in mind.

*Steam-pipes.*—Before connecting the steam-pipe to the lubricator, especially when it is an iron pipe, it should be blown out thoroughly, to prevent scale and chips from being blown into the lubricator and there to clog up the pipes and other passages.

*Sizes of steam-pipes* must not be less than called for in the "directions for application."

*Steam-valves* used in connection with lubricators must have openings fully in accordance with the sizes of pipes. Pipes of proper size, and steam-valves with improper openings in the valve-seat or in the shank, will not work well together.

Steam should be taken from highest part of boiler, and at a point where dry steam may be obtained, using (when necessary) a dry pipe for the purpose. Turrets or fountains are often not large enough to supply all drains made upon them. Do not allow muddy water to get into the lubricator. It will clog the passages, and cut the valve-seats, causing them to leak.

*Oil-pipes* must have a good steady fall from lubricator toward the steam-chest, to prevent the forming of water-traps. Oil will float upward through water but not downward.

*Irregularity* in the feed of lubricators is usually due to enlarged openings in the choke-plugs. The remedy for this trouble is to use choke-plugs of standard size, and to remove them as soon as they fail to maintain the regularity of the feed.

The restriction of the live-steam supply to the lubricator may also cause irregular feeding. Have the steam-valve wide open. If there is reason to suspect a restricted steam-supply from other causes, examine the steam-pipe, equalizing tubes, and equalizing steam passages for stoppages from scale, torn gaskets, etc.

*Filling.*—The greatest care should be exercised in the filling of the lubricator, to prevent foreign matter of any kind from passing into the lubricator with the oil. To prevent this the oil should be thoroughly strained before using it.



## RAGONNET REVERSE GEAR

### Instructions for the Operation and Maintenance of the Ragonnet Power Reverse Gear

#### *For the Engineer*

*Use Air for Operation.*—See that valve admitting air from main reservoir or supply pipe is *wide open* at all times except in emergency.

*Use Steam Only in Emergency.*—In case of failure of pump, open turret valve, admitting steam to gear. The check valve in the air line will prevent steam flowing into main reservoir, but globe valve must also be closed.

*Always report having turned steam on reverse gear, so* that the cylinder packing may be given attention.

*Use engine oil in cylinder cup* filling cup at least once a trip. In case there is a blow from exhaust, try one ot two cups full of signal oil; then work the gear rapidly forward and back.

*Keep piston rod packing* set up tight—do not allow any blow at this point as it may cause the gear to creep.

*Always look at air gauge* before moving engine. If pump has been shut off, see that full reservoir pressure has been regained before opening bottle.

#### *For the Machinist*

If gear is reported "*creeping*," examine and test cylinder packing, and slide valve also see if piston-rod packing is tight. Both valve and piston may be tested by taking off cylinder head and blocking cross-head against opposite head. Then place reverse lever in the corner which will admit air to end of cylinder next to cross-head. A blow from valve will be felt by holding hand under port where it enters top of cylinder. A blow past cylinder packing may be detected by feeling around the circumference of the piston.

If gear is reported as "*blowing*" from exhaust, examine and test cylinder packing and slide valve.

See the *valve* is free on stem. Nut on end of stem should be so adjusted that valve is free, with as little lost motion as possible.

*Cylinder Packing.*—Use three rings of $\frac{5}{8}$ square "Vulcabeston Mallet Quality" packing. Squeeze up with follower until packing is tight, but not so tight as to cause excessive friction.

*When engineer reports having turned steam on gear* cylinder packing must be tested before engine is returned to service.

After examining or renewing cylinder packing, *grease packing and cylinders* with soft grease (use cylinder oil if no soft grease is furnished).

*The set screws* opposite tappets on valve stem rocker are not to be tampered with unless the stroke of the gear needs changing.

*When stop pins* are used in guide, gear must be so adjusted that cross-head will not touch pins while pressure is turned on.

An easy way to *remove piston from cylinder.* Disconnect each rod and piston-rod. Place hard wood block over end of piston-rod, and use cross-head for a hammer.

# CHAPTER XI

## BOILER FEEDING APPLIANCES

### INJECTORS

Although the injector is not theoretically so efficient as a good pump, practically it has proved itself the best means of feeding water to locomotive boilers that has ever been tried. When a well-made injector is used regularly, it is more reliable than any form of pump, is more easily examined and repaired when it gets out of order, is less liable to freeze or to sustain damage from accidental causes, and it regulates the quantity of water required as well as the ordinary pump, and better than any pump actuated by the machinery of the engine, when the speed of a train is irregular. The injector also possesses the important advantage that it raises the temperature of the feed-water to approach the temperature of the boiler, thereby avoiding shocks and strains to metal that very cold water is likely to impart.

So long as injectors were imperfectly understood, and were used with no regularity, they retained the name of being unreliable; but so soon as they began to be made the sole feeding medium for locomotive boilers, they had to be worked regularly, and kept in order, which quickly made their merits recognized.

### INVENTION OF THE INJECTOR

The boiler-feed injector was invented by Henri Giffard, an eminent French scientist and aeronaut. Its successful action was discovered during a series of experiments, made with the view of devising light machinery that might be used to propel balloons. Although Giffard designed the most perfect balloon that was ever constructed, up to his time, the injector was not used upon it; and the invention was laid aside and almost forgotten. During the course of a sea-voyage, Giffard happened to meet Stewart of the engineering firm, Sharp, Stewart & Co., of Manchester, England. In the course of a conversation on the feeding of boilers, Giffard remembered his injector, and mentioned its method of action. Stewart was struck with the simplicity of the device, and undertook to bring it out in England, which he shortly afterwards did, representing the interests of the inventor so long as the original patents lasted. By his advice, William Sellers & Co., of Philadelphia, were given control of the American patent. Seldom has an invention caused so much astonishment and wild speculation among mechanics, and even among scientists, as the injector did for the first few years of its use. Scientists were not long in discovering the philosophy of the injector's action, but that knowledge spread more slowly among mechanics. It was regarded as a case of perpetual motion—the means of doing work without power, or, as Americans expressed it, by the same means a man could raise himself by pulling on his boot-straps.



### PRINCIPLE OF THE INJECTOR'S ACTION

Although the mechanism of the injector is very simple, the philosophy of its action is not so easily understood as the principles on which a pump raises water and forces it into the boiler. On beginning to investigate the action of the injector, it appears a physical paradox, the finding that steam at a given pressure leaves a boiler, passes through several tortuous and contracted passages, raises several check-valves, and then forces water into the boiler against a pressure equal to that which the steam had when it first began the operation. At first acquaintance, the operation looks as if it had a strong likeness to perpetual motion, but closer investigation will show that the steam which raises and forces the water by passing through an injector performs mechanical work as truly as the steam that pushes a piston which moves a pump-plunger. A current of any kind, be it steam, air, water, or other matter, has a tendency to induce a movement in the same direction of any body with which it comes in contact. Thus, we are all familiar with the fact that a current of air called wind, passing over the surface of a body of water, sets waves in motion, and dashes the water high up on the shore away above its original level. In the same way, a jet of steam moving very rapidly, when injected into a body of water under favorable conditions, imparts a portion of its motion to the water, and starts it with momentum sufficient to overcome a pressure even higher than the original pressure of the steam. The locomotive blast, blowers, steam-siphons, steam-jets, jet exhausters, vacuum ejectors, and argand burners, are all common instances of the application of the principle of induced currents.

### VELOCITY OF STEAM AND OF WATER

At a boiler-pressure of 200 pounds per square inch steam passes into the atmosphere with a velocity of 1960 feet per second. When steam at this speed strikes like a lightning-flash into the tubes of the injector, it becomes the ram which forces the water towards the boiler; but its power is opposed by the tendency of the water inside the boiler to escape through the check-valve. The velocity with which water will flow from a vessel is known to be equal in feet to the square root of the pressure multiplied by 12.19. Accordingly, in the case under consideration, the water inside of the boiler would tend to escape at a speed of 144 feet per second. This represents the resistance at the check-valve. The mechanical problem, then, to be worked out by the injector is to transform the energy of hot steam moving at a high velocity into the momentum possessed by a heavier and colder mass of water. In the operation the steam yields up a portion of its heat and the greater part of its velocity, but it keeps a current of water flowing fast enough to overcome the static resistance at the check-valve.

### TEMPERATURE OF INJECTED WATER

A common delivery temperature of the water forced through an injector is 160° Fahr. Taking the feed-water at 55° Fahr., we find that the steam used in operating the injector imparts 105° Fahr. to the



feed-water before putting it into the boiler. One pound of steam at 140 pounds boiler-pressure contains 1224 heat units reckoned above zero. When the hot steam speeding at a high velocity strikes the feed-water, part of the heat is converted into the mechancial work required to put the water in motion, but there still is left heat sufficient to raise about 11 pounds of water to the temperature of 160 degrees. One pound of steam, therefore, communicates to 11 pounds of water the motion required for overcoming the resistance encountered at the check-valve. The steam moving at a speed of 1920 feet per second having imparted motion to a body eleven times its own weight, itself in the meantime having become a portion of the mass, the velocity of the feed-water would be $1920 \div 12 = 170$ feet per second. When the reduction of speed due to friction of the pipes and other resistances is considered, there still remains momentum enough in the water to raise the check-valve.

Although 160 degrees is about the average heat of the water delivered by lifting injectors, instruments can be designed so that they will heat the water much higher. With non-lifting injectors the feed-water is nearly always delivered at a higher temperature than with the other kind.

### ELEMENTARY FORM OF INJECTOR

There are numerous forms of injectors in use, but they are all developments of the elementary arrangement of parts shown in the annexed illustration, Fig. 2*A*. Steam at a high velocity passes from the boiler into the tube *A*, and striking the feed-water at *B*, is itself condensed, but imparts momentum to the water to send it rushing along into the delivery-pipe *E*, with sufficient force to raise the check-valve against the pressure inside and pass into the boiler. As the current of water could not be started into rapid motion against the constant pressure of the check-valve, an overflow opening is provided in the injector, through which the water can flow unchecked till the necessary momentum is obtained, when the overflow-valve is closed.

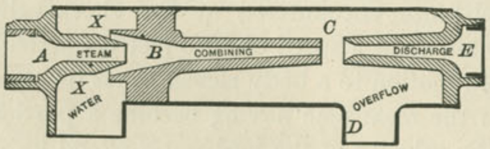



FIG. 2*A*.

In a lifting injector the parts are so designed that, in starting, a jet of steam passes through the combining tube *B* at sufficient velocity to create a vacuum in the water-chamber *XX*, and the water is drawn into this place from the feed-pipe as if by the suction of a pump. The steam-jet then striking the water starts it into motion. If too much steam is admitted for the quantity of water passing, air will be drawn in through the overflow opening, mixing with the water and reducing its compactness, while some uncondensed steam will pass through with the water. This will reduce the force of impact of the feed-water upon the boiler check, and when it becomes so light that the momentum of feed-water is no greater than the resistance inside the boiler, the injector will break. On the other hand, when the quantity of water supplied is too great for



the steam to put into high motion, part will escape through the overflow-valve. In some forms of injectors, separate appliances are used for raising the water from the forcing chamber to the source of supply.

As the successful operating of the injector is dependent on the feed-water promptly condensing the steam which supplies the power, water of a very high temperature cannot be fed by an injector. A certain amount of live steam must be condensed by the feed-water to impart the momentum necessary to make the latter overcome the resistance at the check-valve. When the feed-water becomes hotter than 100° Fahr. a point is soon reached where it takes such a large body of water to condense the steam that there is not the required velocity generated to force the feed-water into the boiler.

## CARE OF INJECTORS

When an engineer finds that an injector refuses to work, his first resort should be the strainer. That gets choked with cinders or other impurities so frequently that no time should be lost in examining it. One day when I was running a round-house, an engineer came in breathless, with the information that his engine was blocked in the yard, and he must dump his fire, as he could not get his injector to work. The thermometer stood at twenty degrees below zero, and an Iowa blizzard was blowing; so the prospect of a dead engine in the yard meant some distressingly cold labor. I asked, the first thing, if he had tried the strainer; and his answer was that the strainer was all right, for the injector primed satisfactorily, but broke every time he put on a head of steam. I went out to the engine, and had the engineer try to work the injector. By watching the overflow stream, I easily perceived that the injector was not getting enough water, although it primed. An examination showed that the strainer was full of cinders, and the injector went to work all right as soon as the obstruction to the water was removed.

### THE MOST COMMON CAUSES OF DERANGEMENT

Sand and cinders are the most common causes of failure with injectors, as they are indeed with all water-feeding apparatus. A very common cause of failure of injectors is leakage of steam through throttle-valve or check-valve, keeping the tubes so hot that no vacuum can be formed to make it prime. A great many injector-checks have been turned out too light for ordinary service, while others are made in a shape that will always leave the valve away from the seat when they stop working. Then the engineer has to run forward and pound the check with a hammer to keep the steam from blowing back, and that soon ruins the casting. Check-valves set in a horizontal position are worthless with water that contains grit.

### HOW TO KEEP AN INJECTOR IN GOOD ORDER

To preserve a good working injector, the engineer should see that the pipes and joints are always perfectly tight. Of course it is difficult to keep them tight when they are subjected to the continual jars a locomotive must stand; but injectors cannot be depended on where there is a possibility of air mixing with the



water. Leaky joints or pipes are particularly troublesome to lifting injectors; for air passes in, and keeps the steam-jet from forming a vacuum. At the first injector will merely be difficult to start; but as the leaks get worse there will be no starting it at all. Then, the air mixing with the water is detrimental to the working of all injectors, as its tendency is to decrease the speed of the water. The compact molecules of water form a cohesive body, which the steam can strike upon with telling force to keep it in motion. When the water is mixed with air it lacks the element of compactness, and the steam-jet strikes a semi-elastic body which does not receive momentum readily. This mixture of steam and air does not act solidly on the check-valve, but makes the water pass in with a bubbling sound, as if the valve were moving up and down; and the stream of water breaks very readily when it is working in this way.

### COMMON DEFECTS

As maintaining unbroken speed on the water put in motion is the first essential in keeping an injector in good working order, anything that has a tendency to reduce that speed will jeopardize its action. A variety of influences combine to reduce the original efficiency of an injector. Those with fixed nozzles are constructed with the orifices of a certain size, and in the proportion to each other which experiment has demonstrated to be best for feeding with the varied steam pressures. When these orifices become enlarged by wear the injector will work badly, and nothing will remedy the defect but new tubes. The tubes sometimes get loose inside the shell of the injector, and drop down out of line. The water will then strike against the side of the next tube, or on some point out of the true line, scattering it into spray which contains no energy to force itself into the boiler. A machinist examining a defective injector should always make sure that the tubes are not loose. Injectors suffering from incrusted water-passages will generally work best with the steam low. In districts where the feed-water is heavily charged with lime salts, it is common for injectors to get so incrusted that the passages are almost closed.

Joints about injectors that are kept tight by packing must be closely watched. Many an injector that failed to work satisfactorily has been entirely cured by packing the ram-gland.

### CARE OF INJECTORS IN WINTER

During severe frosty weather an injector can be kept in order without danger of freezing; but it needs constant watching and intelligent supervision.

To keep an injector clear of danger from frost, it should be fitted with frost-cocks so that all the pipes can be thoroughly drained. Bends in the pipes, where water could stand, should be avoided as far as possible; and where they cannot be avoided, the lowest point should contain a drain-cock.

To operate an injector successfully, thoughtful care is requisite on the part of the engineer; and where this is given, the injector will prove itself a very economical boiler-feeder.

The injectors principally used in American locomotives are the Sellers, the Nathan, the Rue Little Giant,



and the Metropolitan. All are good reliable boiler-feeders, and all are made to wear well under the rough service met with on locomotives.

## INJECTOR

### THE SELLERS INJECTOR

When the Giffard injector was first introduced into this country by William Sellers & Co., Philadelphia,

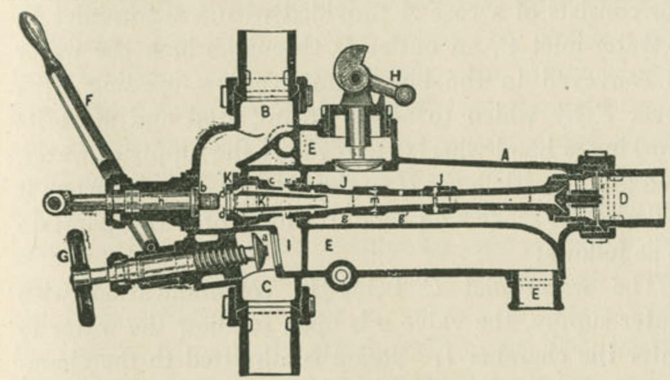



FIG. 3.

it was a rather defective boiler-feeder; but that firm effected great improvements and led the way for making the injector the popular boiler-feeder it is to-day. They made the instrument self-adjusting, and improved its design so that it would feed automatically, however much the pressure of the boiler varied, and finally they perfected it so that, should anything happen to interrupt its working, it would automatically restart itself. The latest development of the injector is shown by a sectional view in Fig. 3.

This instrument will start at the lowest steam pressures with water flowing to it, and will lift the water promptly even when the suction-pipe is hot. At 10 pounds steam pressure it will lift the water 2 feet; at 30 pounds, 5 feet; and at all ordinary pressures, say 60 pounds and over, it will lift from 12 to 18 feet. It can be used as a heater for the water supply by simply closing the waste-valve and pulling out the steam-lever.

By reference to the cut it will be seen that this injector consists of a case *A* provided with a steam-inlet *B*, a water-inlet *C*, an outlet *D* through which the water is conveyed to the boiler, an overflow opening *E*, a lever *F* by which to admit steam, stop and start its working, a hand-wheel *G* to regulate the supply of water, and an eccentric lever *H* to close the waste-valve when it is desired to make a heater of the injector. Its operation is as follows:

The water-inlet *C* being in communication with water supply, the valve *a* is open to allow the water to enter the chamber *I*. Steam is admitted to the chamber *B*, and the lever *F* is drawn out to lift the valve *b* from its seat and permit the steam to enter the annular lifting steam-nozzle *c* through the holes *d d*. The steam issuing from this nozzle passes through the annular combining tube *e* and escapes from the instrument, partly through the overflow opening *f* and partly through the overflow openings provided in the combining tube *g g′*, through the overflow chamber *J* and passage *E E*, and produces a strong vacuum in the water-chamber *I* which lifts the water from the source of supply, and the united jet of steam and water is, by reason of its velocity, discharged into the rear



of the receiving end of the combining tube *g*. The further movement of the lever *F* withdraws the spindle *h* until the steam-plug *i* is out of the forcing-nozzle *K*, allowing the steam to pass through the forcing-nozzle *K* and come in contact with the annular jet of water which is flowing into the combining tube around the nozzle *K*. This jet of water has already a considerable velocity, and the forcing steam-jet imparts to it the necessary increment of velocity to enable it to enter the boiler through the delivery-tube *j* and boiler-check *k*.

If from any cause the jet should be broken—say from a failure in the water supply—the steam issuing from the forcing-nozzle *K* into the combining-tube *g* will escape through the overflows *m* and *n* and intermediate openings with such freedom that the steam, which will return through the annular space formed between the nozzle *K* and combining-tube *g*, and escape into the overflow-chamber through the opening *f*, will not have sufficient volume or force to interfere with the free discharge of the steam issuing from the annular lifting steam-nozzle and escaping through the same overflow *F*, and hence the lifting steam-jet will always tend to produce a vacuum in the water-chamber *I*, which will again lift the water when the supply is renewed, and the combined annular jet of steam and water will be forced into the combining-tube *g* against the feeble current of steam returning, when the jet will again be formed and will enter the boiler as before. In actual practice on a locomotive the movement of the lever *F* in starting the injector is continuous.

This injector is self-adjusting from 40 to 250 pounds steam pressure, without hand adjustment or waste at the drip pipe; this action is caused by the increase of capacity of the annular lifting set as the steam pressure rises. This action is further assisted by the introduction of an inlet valve, No. 309, from the water supply to the overflow-chamber through which a supplemental supply of water is drawn into the injector-tubes and forced into the boiler at pressures above 140 pounds steam. When the feed is stopped, the valve automatically closes, preventing flow of steam back into the suction-pipe and enabling the injector to restart automatically. The special advantage of this valve is that the capacity of the injector is largely increased at 180–225 pounds steam pressure.

The water regulating valve *A* has been changed from a stop valve to a cylindrical plug-cock; this cock rotates one third turn between closure and maximum opening.

### NATHAN MANUFACTURING COMPANY'S IMPROVED INJECTORS MONITOR, TYPE "XX"

One of the most successful and enduring injectors in use is the Monitor, the distinguishing characteristic of which is the independent lifting-jet, which being uninfluenced by any other part of the injector, enables it to make the priming or starting reliable under the most adverse circumstances. The injector shown in Fig. 4 is an improvement on the original Monitor and is provided with removable seats for the steam- and lifting-valves (141) and (142), making the body practically indestructible. The water-valve (119) in this type of injector is an ordinary screw-valve of simple and positive construction.

To start the injector the water-valve must be open.



The lifting jet-valve (113) is opened first to lift the water, when the water begins to escape through the overflow, the steam-valve (108) is opened, which puts the injector working at its full power. The lifting-valve (113) is then closed down. The quantity of feed required is graduated by the water-valve (119).

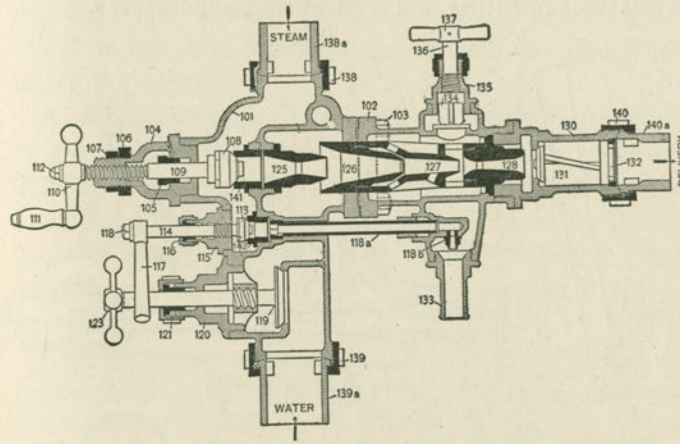



FIG. 4.

When it is desired to use the injector as a heater, valve (134) is closed, and valve (108) opened slightly, at other times valve (134) must be kept open.

### SIMPLEX INJECTOR TYPE "R"

This type of injector, Fig. 5, is designed to meet the most severe requirements of modern locomotive practice. It is simply constructed and contains only a few operating parts. It is self-regulating, that is, after being started at the highest operating pressure the latter may drop down to about 40 pounds before there is any waste at the overflow. It is also restarting, that is, if from any cause the supply of water should be temporarily interrupted, the injector restarts automatically without any further manipulation as soon as the water supply is restored. The reducing capacity is fully 50 per cent of the maximum capacity under ordinary variations of lifting and feed-water temperatures.

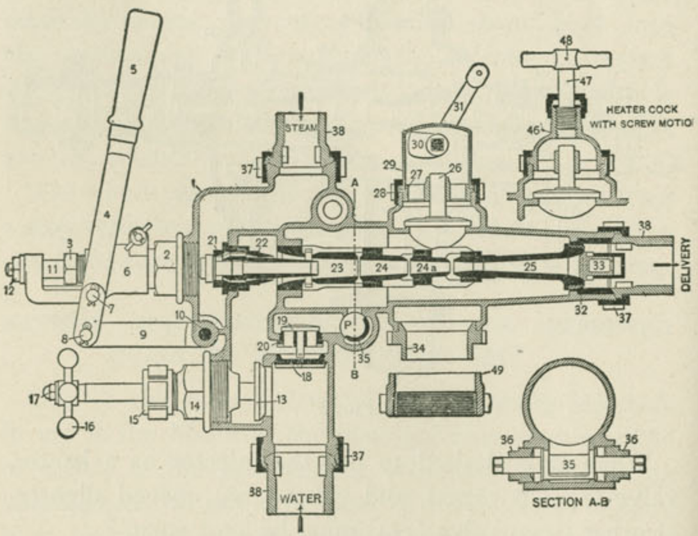



FIG. 5.

The action is as follows; steam from the boiler is admitted to the lifting-nozzle (22) by drawing out the starting-lever (4) slightly, and without withdrawing the plug on the end of the steam-spindle (11) from the steam-nozzle (21). Steam then passes through the small openings around the steam-nozzles and passages into the overflow-chamber, lifts the heater cock-check



(26) and issues from the overflow-nozzle (34) to which the overflow-pipe is attached.

When water appears at the overflow the lever (4) is drawn back as far as it will go, which opens up the steam-nozzle (21) and allows the full supply of steam to enter the intermediate nozzle (23) mixing there with the water and forcing the same through nozzles (24), (24A) and (25), and finally into the delivery pipe leading to the boiler.

A peculiar feature of this injector is the inlet-valve (19) located in water supply passage through which an auxiliary water supply is established directly from the overflow-chamber into the nozzles, which additional water is forced into the boiler, thereby increasing the capacity of the injector under ordinary conditions of operation.

An injector provided with such inlet-valve would not prime properly, or not at all if for some reason the inlet-valve leaks, but in the Simplex injector a cutout or emergency-valve (35) is provided for which in such cases enables the inlet-valve to be cut out and the injector to be operated until there is an opportunity to grind or otherwise repair the inlet-valve.

The quantity of water needed is regulated by means of the water-valve (13)

The heater-cock arrangement is made either in the form of a cam motion, as represented by parts 26 to 31, or in the form of a screw-motion, as represented by parts 46 to 48. The heater-cock check is closed down only when it is desired to warm the water in the tank, at all other times the heater-cock check (26) must be allowed to open to its full extent.

### LITTLE GIANT INJECTOR

This injector, made by the Rue Manufacturing Co., is a highly efficient boiler-feeder, and a very simple apparatus. The construction is clearly seen in the engraving. A unique feature about this injector is the movable combining tube adjusted by a lever, causing the feed to be exactly suited to the service. Moving the lever towards *A* tends to cut off the feed,

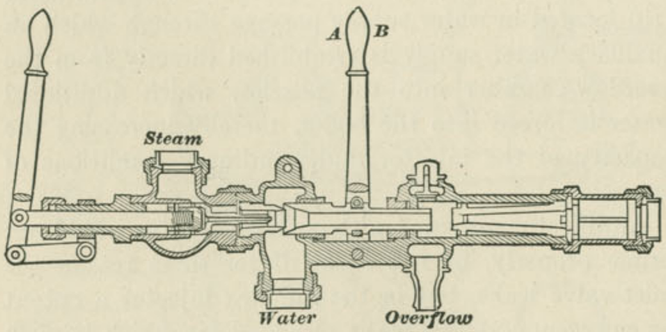



FIG. 6.

and moving towards *B* increases it. To work the injector, the combining tube lever is set in position to admit sufficient water to condense the steam from the starting-valve. The starting-valve is then opened slightly till the water begins to escape from the overflow, when it is opened full. The feed is then regulated by the combining tube lever. To use this injector as a heater, the overflow is closed by the combining tube being moved up against the discharge, and opening the starting-valve sufficiently to admit the quantity of steam required.



The Metropolitan 1898 locomotive injector is a double-tube injector, and great care has been taken in designing same to have the chambers and the form of the shell such as to procure the greatest possible steam range. This injector consists of two sets of tubes,—a set of lifting tubes, which lifts the water and delivers it to the forcing set of tubes under pressure, which in turn forces the water into the boiler. The lifting set of tubes acts as a governor to the forcing tubes, delivering the proper amount of water required for the condensation of the steam, thus enabling the injector to work *without any adjustment* under a great range of steam pressure, handle very hot water, and admit of the capacity being regulated for light or heavy service under all conditions.

The Metropolitan 1898 locomotive injector starts with 30 lbs. steam pressure, and without any adjustment of any kind will work at all steam pressures up to 300 lbs.; in fact, at all steam pressures and under all conditions its operation is the same, and it is impossible for part or all of the water to waste at the overflow.

## CHAPTER XII

### THE VALVE-MOTION

This portion applies to the link motion and to several radial motions.

#### THE LOCOMOTIVE SLIDE-VALVE

The nature of the service required of locomotive engines, especially those employed on fast-train service, makes it necessary that the steam-distribution gear shall be free from complication; and, for convenience in working the engine, it is essential that means should be provided for reversing the motion promptly without endangering the working-parts. The valve-gear should also be capable of regulating the admission and exhaust of steam, so that the engine shall be able to maintain a high rate of speed, or to exert a great tractive force. These features are admirably combined in the valve-gear of the ordinary locomotive. Designers of this form of engine have given great consideration to the merit of simplicity.

#### DESCRIPTION OF THE SLIDE-VALVE

The slide-valve in common use is practically an oblong cast-iron box, which rests and moves on the valve-seat. In the valve-seat, separated by partitions called bridges, are three ports, those at the ends being the openings of the passages for conveying steam

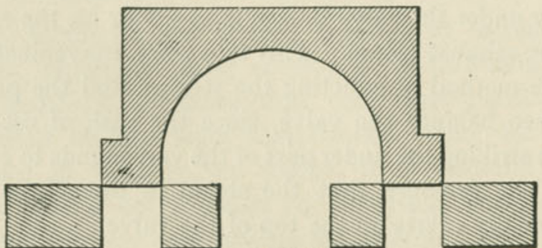




to and from the cylinders, while the middle port is in communication with the blast-pipe, which conveys the exhausted steam to the atmosphere. On the under side of the valve is a semicircular cavity, which spans the exhaust-port and the bridges when the valve stands in its central position. When the steam within the cylinder has performed its duty of pushing the piston towards the end of the stroke, the valve cavity moves over the steam-port, and allows the steam to pass into the exhaust-port, thence into the exhaust-pipe. The cavity under the valve thus acts as a door for the escape of the exhaust steam. This is a very convenient and simple method of educting the steam; and the process helps to balance the valve, since the rush of escaping steam striking the under part of the valve tends to counteract the pressure that the steam in the steam-chest continually exerts on the top of the valve.

#### PRIMITIVE SLIDE-VALVE

In its primitive form the slide-valve was made merely long enough to cover the steam-ports when placed in the central position, as shown in Fig. 7. With a valve of this form, the slightest movement had the effect of opening one end so that steam would be admitted to the cylinder, while the other end opened the exhaust. By such an arrangement steam was necessarily admitted to the cylinder during the whole length of the stroke, since closing at one end meant opening at the other. There were several serious objections to this system. It was very difficult to give the engine cushion enough to help the cranks over the centers without pounding, and a small degree of lost motion was sufficient to make the steam obstruct the piston during a portion of the stroke. But the most serious drawback to the short valve was that it permitted no advantage to be taken of the expansive power of steam. For several years after the advent of the locomotive the boiler-pressure used seldom exceeded fifty pounds to the square inch. With this tension of steam there was little work to be got from expansion with the conditions under which locomotives were worked; but, so soon as higher pres-



*Quarter Size*

FIG. 7.

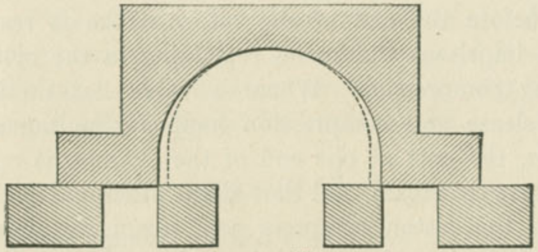
sures began to be introduced, the loss of heat entailed by permitting the full-pressure steam to follow the piston to the end of the stroke became too great to continue without an attempted remedy. A very simple change served to remedy this defect and to render the slide-valve worthy of a prominent place among mechanical appliances for saving power.

### OUTSIDE LAP

The change referred to, which so greatly enhanced the efficiency of the slide-valve, consisted in lengthening the valve-face, so that, when the valve stood in



the center of the seat, the edges of the valve extended a certain distance over the induction ports, as in Fig. 8. This extension of the valve is called outside lap, or simply lap. The effect of lap is to close the steam-port before the piston reaches the end of the stroke, and the point at which the steam-port is closed is known as the point of cut-off. When the steam is cut off and confined within the cylinder, it pushes the piston along by its expansive energy, doing work with heat that would be



*Quarter Size*

FIG. 8

lost were the cylinder left in communication with the steam-chest till the end of the stroke.

When a slide-valve is actuated by an eccentric connected directly with the rocker-arm or valve-stem, the point of cut-off caused by the extent of lap, remains the same till a change is made on the valve, or on the throw of the eccentric, unless an independent cut-off valve be employed. Locomotives having the old hook motion worked under this disadvantage; because the hook could not vary the travel of the valve, which is the method usually resorted to for producing a variable cut-off. The link and other simple expansion gears perform their office of varying the cut-off in this way.

### SOME EFFECTS OF LAP

In addition to cutting off admission of steam before the end of the stroke, lap requires the valve to be set in such a way that it has also the effect of leading to the exhaust-port being opened before the end of the stroke. The point where the exhaust is opened is usually known as the point of release. The change which causes release to happen before the piston completes its stroke, leads to the closure of the exhaust-port before the end of the return-stroke is reached, which imprisons the steam remaining in the cylinder, causing compression. Where a valve has no inside lap, release and compression happen simultaneously; that is, the port at one end of the cylinder is opened to release the steam, and that at the other end is closed, letting the piston compress any steam remaining in the cylinder into the space left as piston clearance.

### INSIDE LAP

In some cases the inside edges of the valve cavity do not reach the edges of the steam-ports when the valve is on the middle of the seat, but lap over on the bridge a certain distance, as shown by the dotted lines in Fig. 7. This is called inside lap, and its effect upon the distribution of steam is to delay the release. By this means it prolongs the period of expansion, and hastens compression on the return stroke. Inside lap is an advantage only with slow-working engines. When high speed is attempted with engines having much inside lap, the steam does not have enough time to escape from the cylinders, and the back pressure



and compression become so great as to be very detrimental to the working of the engine. As locomotive engineers have it, the engine is "logy."

### THE EXTENT OF LAP USUALLY ADOPTED

In locomotive practice, the extent of lap varies according to the character of service the engine is intended to perform. With American standard-gauge engines, the lap varies from $\frac{1}{2}$ inch to $1\frac{1}{4}$ inch. For high-speed engines, the extent of lap ranges from $\frac{7}{8}$ to $1\frac{1}{4}$. Freight engines commonly get $\frac{5}{8}$ to $\frac{3}{4}$ outside lap, and from $\frac{1}{16}$ to $\frac{1}{4}$ inside lap. With a given travel, the greater the lap the longer will the period for expansion be.

### FIRST APPLICATION OF LAP

Lap was applied to the slide-valve in this country before its advantage as an element of economy was understood in Europe. As early as 1829, James of New York used lap on the valves of an engine used to run a steam-carriage; and in 1832 Mr. Charles W. Copeland put a lap-valve on a steamboat-engine, and he further understood that its advantage was in providing for expansion of the steam. Within a decade after our first steam-operated railroad was opened, the lap-valve became a recognized feature of the American locomotive; but the cause of the saving of fuel, effected by its use, was not well comprehended. Many enlightened engineers attributed the saving to early release of the steam while in reality, it was due to increased work due to steam expansion.

### INSIDE CLEARANCE

For high-speed locomotives, where there is great necessity for getting rid of the exhaust-steam quickly, the valves are sometimes cut away at the edges of the cavity, so that, when the valve is placed in the middle of the seat, it does not entirely cover the inside of either of the steam-ports. This is called inside clearance. In many instances, inside clearance has been adopted in an effort to rectify mistakes made in designing the valve-motion, principally to overcome defects caused by deficiency of valve-travel. The fastest locomotives throughout the country do not require inside clearance, because their valve-motion is so designed that it is not necessary. Inside clearance induces premature release, and diminishes the period of expansion. Consequently inside clearance wastes steam, and ought to be avoided.

### LEAD

There are certain advantages gained, in the working of a locomotive, by having the valves set so that the steam-port will be open a small distance for admission of steam, when the piston is at the beginning of the stroke. This opening is called valve-lead. On the steam-side of the valve the opening is called steam-lead: on the exhaust side it is called exhaust-lead. Lead is generally produced by advancing the eccentric on the shaft, its effect being to accelerate every event of the valve's movement; viz., admission, cut-off, release, and compression. In the most perfectly constructed engines, there soon comes to be lost motion in the rod connections and in the boxes. The effect of this lost motion is to delay the movement of the valves; and, unless they are set with a lead opening, the stroke of the piston would in some instances be commenced before steam got into the cylinder. It is also found, in practice, that this lost motion would cause a pounding at each change in the direction of the piston's travel, unless there is the necessary cushion to bring the cranks smoothly over the centers. Without cushion, the change of direction of the piston's travel is effected by a series of jerks that are hard on the working-parts. So long as the lead opening at the beginning of the stroke is not advanced enough to produce injurious counter-pressure upon the piston, it improves the working of the engine by causing a prompt opening for the steam admission at the beginning of the stroke. This is the time that a full steam pressure is wanted in the cylinder, if economical working be a consideration. A judiciously arranged lead opening is therefore an advantage; since it increases the port opening at the proper time for admitting steam, tending to give nearly boiler-pressure in the cylinder at the beginning of the stroke. With the shifting link-motion, the amount of lead opening increases as the links are hooked back towards the center notch; the magnitude of the increase, in most cases, being in direct proportion to the shortness of the eccentric-rods. A common lead opening in full gear with the shifting link is $\frac{1}{16}$ inch, which often increases to $\frac{3}{8}$ inch in the center notch. The tendency of wear and lost motion is to neutralize the lead, so that when a locomotive motion gets worn, increasing the lead will generally improve the working of the engine.

With radial-valve motions such as the Baker, Walschaert, Joy & Southern there is no convenient method of causing increasing lead when the valve-travel is reduced.

### NEGATIVE LEAD

Lead opening, however, has its disadvantages. When the eccentric-rods are short the lead opening increases so rapidly, as the links are notched up towards the center, that it has become the custom on some roads to set the valves of high-speed engines lapping all over the port at the beginning of the stroke. This practice is called setting the valves with negative lead, and it increases the efficiency and power of the engine when running very fast. It is very common to find the valves set with $\frac{1}{16}$ inch negative lead.

### OPERATION OF THE STEAM IN THE CYLINDERS

As the work performed by a steam-engine is in direct proportion to the pressure exerted by the steam on the side of the piston which is pulling or pushing on the crank-pin, it is important that the steam should press only on one side of the piston at once. Hence, good engines have the valves operated so that, by the time a stroke is completed, the steam, which was pushing the piston, shall escape and not obstruct the piston during the return stroke, and so neutralize the steam pressing upon the other side. When an engine is working properly, the steam is admitted alternately to each side of the piston; and its work is done against a pressure on the other side not much higher than that of the atmosphere.



### BACK PRESSURE IN THE CYLINDERS

When, from any cause, the steam is not permitted to escape promptly and freely from the cylinder at the end of the piston stroke, a pressure higher than that of the atmosphere remains in the cylinder, obstructing the piston during the return stroke, and causing what is known as back pressure. There is seldom trouble for want of sufficient opening to admit steam to the cylinders, for the pressure is so great that the steam rushes in through a very limited space; but, when the steam has expanded two or three times, its pressure is comparatively weak, and needs a wide opening to get out in the short time allowed. This is one reason why the exhaust-port is made larger than the admission-ports. Nearly all engines with short ports suffer more or less from back pressure, but the most fruitful cause of loss of power through this source is the use of extremely contracted exhaust-nozzles. Were it not for the necessity of making a strong artificial draught in the smoke-stack, so that an intense heat shall be created in the fire-box, quite a saving of power, now lost by back pressure, would be effected by having the exhaust-opening as large as the exhaust-pipe. This not being practicable with locomotives, engineers should endeavor to have their nozzles as large as possible consistent with steam-making.

Engines with very limited eccentric-throw will often cause back pressure when hooked up, through the valve not opening the port wide enough for free exhaust.

Locomotives suffering from excessive back pressure are nearly always logy. The engine can not be urged into more than moderate speed under any circumstances; and all work is done at the expense of lavish waste of fuel, for a serious percentage of the steam pressure on the right side of the piston is lost by pressure on the wrong side. It is like the useless labor a man has to do turning a grindstone with one crank, while a boy is holding back on the other side. The weight of obstruction done by the boy must be subtracted from the power exerted by the man to find the net useful energy exerted in turning the grindstone. In the same way, every pound of back pressure on a piston takes away a pound of useful work done by the steam on the other side.

Excessive lead opening acts in the same way, since it lets steam into the cylinder to obstruct the piston before it reaches the end of the stroke.

### COMPRESSION

The necessity which requires lap to be put on a slide-valve to produce an early cut-off, in its turn causes compression, by the valve passing over the steam-port, and closing it entirely for a limited period towards the end of the return stroke. As the cylinder contains some steam which did not pass out while the exhaust-port was open, this is now squeezed into a diminishing space by the advancing piston. In cases where too much steam was left in the cylinders through contracted nozzles or other causes, or where, through mistaken designing of the valve-motion, the port is closed during a protracted period, the steam in the cylinder gets compressed above boiler tension, and loss of useful effect is the result. Under proper limits,



the closing of the port before the end of the stroke, and the consequent compression of the steam remaining in the cylinder, have a useful effect on the working of the engine by providing an elastic cushion, which absorbs the momentum of the piston and its connections, leading the crank smoothly over the centre. Where it can be so arranged, the amount of compression desirable for any engine is the degree that, along with the lead, will raise the pressure of the cylinder up to that of the boiler at the beginning of the stroke. When this can be regulated, the compression performs desirable service by cushioning the working-parts, thereby preventing pounding, and by filling up the clearance space and steam passages, by that means saving live steam. Compression probably does some economical service by reheating the cylinder, which has a tendency to get cooled down during the period of release, and by re-evaporating the water, which forms by condensation of steam in the cool cylinder.

Engines that are running fast require more cushioning than those that run slow, or at moderate speeds. The link-motion, by its peculiarity of hastening compression when the links are hooked up, tends to make compression a useful service in fast running.

### DEFINITION OF AN ECCENTRIC

The reciprocating motion which causes the valves to open and close the steam-ports at the proper periods, is, with most locomotives, imparted from eccentrics fastened upon the driving-axle. An eccentric is a circular plate, or disk, which is secured to the axle in such a position that it will turn round on an axis which is not in the center of the disk. The distance from the center of the disk to the point round which it revolves is called its eccentricity, and is half the throw of the eccentric. Thus, if the throw of an eccentric requires to be 5 inches, the distance between the center of the driving-axle and the center of the eccentric will be $2\frac{1}{2}$ inches. The movement of an eccentric is the same as that of a crank of the same stroke, and the eccentric is preferred merely because it is more convenient for the purposes to which it is applied than a crank would be.

The functions performed by eccentrics on link-motion engines are generally performed by a single crank in engines equipped with radial-valve motion.

### RELATIVE MOTION OF PISTON AND CRANK, SLIDE-VALVE, AND ECCENTRICS

When a locomotive is running, the wheels turn with something near a uniform speed; but any part which receives a reciprocating motion from a crank or eccentric travels at an irregular velocity. Fig. 9 shows the relative motion of the crank-pin and piston during a half revolution. The points in the path of the crank-pin marked *A*, 1, 2, *B*, 3, 4, *C*, are at equal distances apart. The vertical lines run from them to the points *a*, *b*, *c*, *d*, *e*, represent the position of the piston in relation to the position of the crank-pin. That is, while the crank-pin traverses the half-circle, *A B C*, to make a half revolution, the piston, guided by the cross-head, travels a distance within the cylinder equal to the straight line *A C*. The crank-pin travels at nearly



uniform speed during the whole of its revolution, but the piston travels with an irregular motion. Thus, while the crank-pin travels from *A* to 1, the piston travels a distance equal to the space between *A* and *a*. By the space between the lines, it will be seen that

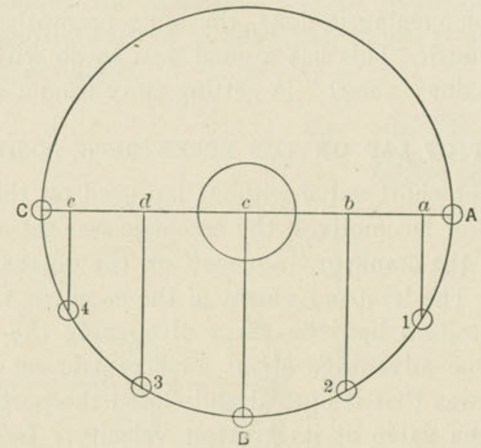



Fig. 9

the piston travels slowly at the beginning of the stroke, gets faster as it moves along, reaches its highest velocity about half stroke, then slows down towards the end till it stops, and is ready for the return stroke.

### VALVE MOVEMENT

The valve travels in a manner similar to the piston; although its stroke is much shorter, and its slow movement is towards the limit of travel. The small circle in the figure shows the orbit of the eccentric's center, and the valve-travel is equal to the rectilinear line across the circle. If the valve opened the steam-ports at the outside of its travel, the slow movement at that point would be an objection, since the operation of opening would be slow: but the valve opens the ports towards the middle of its travel, when its velocity is greatest; and, the nearer to the mid-travel the act of opening is done, the more promptly it will be performed. This has a good deal to do with making an engine "smart" in getting away from a station.

### EFFECT OF LAP ON THE ECCENTRIC'S POSITION

With the short valve without lap used on the earliest forms of locomotives, the eccentric was set at right angles to the crank or "square" on the dotted line *e*, Fig. 10. The least movement of the eccentric from its middle position had the effect of opening the steam-ports. One advantage about an eccentric set in this position, was that it opened and closed the ports when moving the valve at its greatest velocity. Lengthening the valve-face by providing lap entails a change in the location of the eccentric; for, were it left in the right-angle position, the steam-port would remain covered till the eccentric had moved the valve a distance equal to the extent of the lap on one end, and the piston would begin its stroke without steam.

### ANGULAR ADVANCE OF ECCENTRICS

The change made on the eccentric location is to advance it from *e* to *F*, being a horizontal distance equal to the extent of lap and lead, and known as the angular advance of the eccentric. The centers *F* and *B* represent the full part, or "belly," of the forward and



back eccentrics in the position they should occupy, where a rocker is employed, when the piston is at the beginning of the backward stroke. It will be perceived that the eccentrics both incline towards the crank-pin, and the eccentric which is controlling the valve follows the crank-pin. Thus, when the engine is running forward, *F* follows the crank: when she is backing, *B* follows.

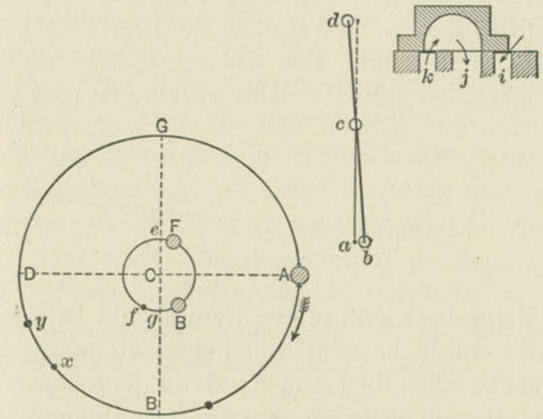



FIG. 10

It is a good plan for an engineer to make himself familiar with the proper position of the eccentrics in relation to the crank, for the knowledge is likely to save time and trouble when anything goes wrong with the valve-motion. With this knowledge properly digested, a minute's inspection is always sufficient to decide whether or not anything is wrong with the eccentrics.

### ANGULARITY OF CONNECTING-ROD

In following out the relative motion of the piston and crank, we discover a disturbing factor in what is called the angularity of the connecting-rod, which has a curiously distorting effect on the harmony of the motion. When the piston stands exactly in the mid-travel point, the true length of the main rod will be measured from the center of the wrist-pin to the center of the driving-axle. If a tram of this length be extended between these points, this will be found correct, as every machinist accustomed to working on rods knows.

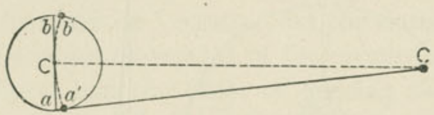



FIG. 11

Now, if the back end of the tram should be raised or lowered towards the points where the center of the crank-pin must be when the crank stands on the top or bottom quarter, it will be found that the tram-point will not reach the crank-pin center, but will fall short a distance in proportion to the length of the main rod. The dotted lines *a′* and *b′* in Fig. 11 show how far a rod $7\frac{1}{2}$ times the length of the crank falls short. A shorter rod will magnify this obliquity, while a longer rod will reduce it.

### EFFECT ON THE VALVE-MOTION OF CONNECTING-ROD ANGULARITY

As the opening and closing of the steam-ports by the valves are regulated by the eccentrics, which are subject to the same motion as the crank, following it at an unvarying distance, it is evident that their tendency will be to admit and cut off steam at a certain position of the crank's movement. If the motion is planned to cut off at half stroke, it will be apparent, that, in the backward stroke, the piston will be past its mid-travel before the crank-pin reaches the quarter, so that end of the cylinder will receive steam during more than half the stroke. On the forward stroke of the piston, however, the crank-pin will reach the quarter before the piston has attained half travel; the consequence being, that in this case steam is cut off too early. The disturbing effect of the angularity of the connecting-rod on the steam distribution thus tends to make the cut-off later in the backward stroke than in the forward stroke, resulting in giving the forward end of the cylinder more steam than what is admitted in the back end. The link-motion provides a convenient means of correcting the inequality of valve opening due to the connecting-rod angularity, the details of which will be explained farther on.



### AIDS TO THE STUDY OF VALVE-MOTION

An engineer or machinist who wishes to study out this peculiarity of connecting-rod angularity, will find that the use of a tram or long dividers will help him to comprehend it better than any letter-type description. All through the study of the valve-motion, there are numerous difficult problems encountered. The use of a good model will be found an invaluable aid to the study of the valve-motion, and every division of engineers or firemen should make a combined effort to furnish their meeting-room with a model of a locomotive valve-motion. In no way can the spare time of the men connected with locomotive running be better employed than in the wide range for study presented by a well-devised model. Great aid can be obtained in the study of the valve-motion from good books devoted to the subject, and they will impart more information than can be obtained by mere contact with the locomotive. The valve and its movements are surrounded with so many complicated influences, that an intelligent man may work for years about a locomotive, doing valve setting occasionally, and other gang-boss work, yet, unless he studies the valve-motion by the aid of the drawing-board, or by models, which admit of changing sizes and dimensions, he may know less about the cause of certain movements than the bright lad who has been a couple of years in the drawing-office. The man who thinks he can study the valve-motion, and understand its philosophy, by merely running the engine, deceives himself. The engineer who never looks at a book or a paper in search of information about his engine, knows very little about anything not visible to the eye. Yet many men of this stamp, by looking wise, and by exercising a judicious use of silence, pass among their fellows as remarkably profound. But let a fireman, in quest of locomotive knowledge, put a question to such a man, and he is immediately silenced with a "You ought to know better" answer.

Where the use of a model cannot be obtained, any one beginning the study of the valve-motion can assist himself by making a cross-section of the valve and its seat, similar to those published, on a strip of thin wood or thick paper. By slipping the valve on the seat, its



position at different parts of the stroke can be comprehended more clearly than by a mere description. With a pair of dividers to represent the motion of the eccentric, and strips of wood to act as eccentric, and valve-rod and rocker, and some tacks to fasten them together, a helpful model can be improvised on a table or board. By the time a student gets a rig of this kind going, he will see his way to contrive other methods of self-help.

# CHAPTER XIII

## THE SHIFTING LINK

### EARLY REVERSING MOTIONS

In the engineering practice of the world, before the locomotive and marine engines came into use, there was no need for devices to make engines rotate in more than one direction. When the need for a reversible engine first arose, it was met by very crude appliances. Locomotives were kept at work, earning money for their owners, which were reversed by the man in charge stopping the engine, and by means of a wrench changing the position of the eccentric by hand. A decided improvement on the wrench was the movable eccentric, which was held in forward or back gear by stops; the operation of reversing being done by a treadle or other attachment located near the engineer's position. A serious objection to this form of reversing gear was, that the abrasion of work enlarged the slot ends, and wore out the stops, leading to inaccuracy and frequent breakage. A somewhat better form of reversing motion was a fixed eccentric, with the means at the end of the eccentric-rod for engaging with the top or bottom of a rocker-shaft, which operated the valve-stem. This was the form of reversing motion used on the early Baldwin engines. Numerous other appliances, more or less defective, were experimented





with before the double fixed eccentric were introduced. Till the link was applied to valve-motion, the double eccentrics—an American invention—were the most important improvement that had been made on the locomotive valve-motion since the incipiency of the engine. The V-hook, in connection with the double eccentrics, made a fair reversing motion in comparison to anything that had preceded it. The objection to the hook was, that, when the necessity arose for reversing the engine while in motion, much difficulty was experienced in getting the hook to catch the pin. As a simple, prompt, and certain reversing motion, the link was readily acknowledged to be far superior to anything that had previously been tried.

### CONSTRUCTION OF THE SHIFTING LINK

As usually constructed for American locomotives, the link is a slotted block curved to the arc of a circle, with a radius about equal to the distance between the center of the driving-axle and the center of the rocker-pin. The general plan of the link-motion is shown in Fig. 12. Fitted to slide in the link-slot is the block which encircles the rocker-pin. The eccentric-rods are pinned to the back of the link; the forward eccentric-rod connecting with the top, and the back-up eccentric-rod with the bottom, of the link. Bolted to the side and near the middle of the link is the saddle, which holds the stud to which the hanger is attached; this, in its turn, connecting with the lifting arm, which is operated by the reversing rod that enables the engineer to place the link in any desired position.

### ACTION OF THE LINK

Regarded in its simplest form, the action of the link in full gear is the same upon the valve movement as a single eccentric. When the motion is working, as in the figure, with the eccentric-rod pin in line with the rocker-pin, it will be perceived that the movement can not differ much from what it would be were the eccentric-rod attached to the rocker. Here the forward eccentric appears as controlling the movement of the valve. Putting the link in back motion brings the end of the backing eccentric-rod opposite the rocker-pin, the effect being that the back-up eccentric then operates the valve. When the link-block is shifted toward the center of the link, the horizontal travel of the rocker-pin is decreased; consequently, the travel of the valve is reduced; for, with ordinary engines, the travel of the valve in full gear equals the throw of the eccentrics, the top and bottom rocker-arm being of the same length. The motion transmitted from the eccentrics, and their means of connection with the link, make the latter swing as if it were pivoted on a center which had a horizontal movement equal to the lap and lead of the valve. The extremities of the link, or rather the points opposite the eccentric-rods, swing a distance equal to the full throw of the eccentric. The variation of valve-travel that can be effected by the link, is from that of the eccentric throw in full gear down to a distance in mid gear which agrees with the extent of lap and lead. The method of obtaining these various degrees of travel is by moving the link so that the block which encircles the rocker-pin shall approach the middle of the link.



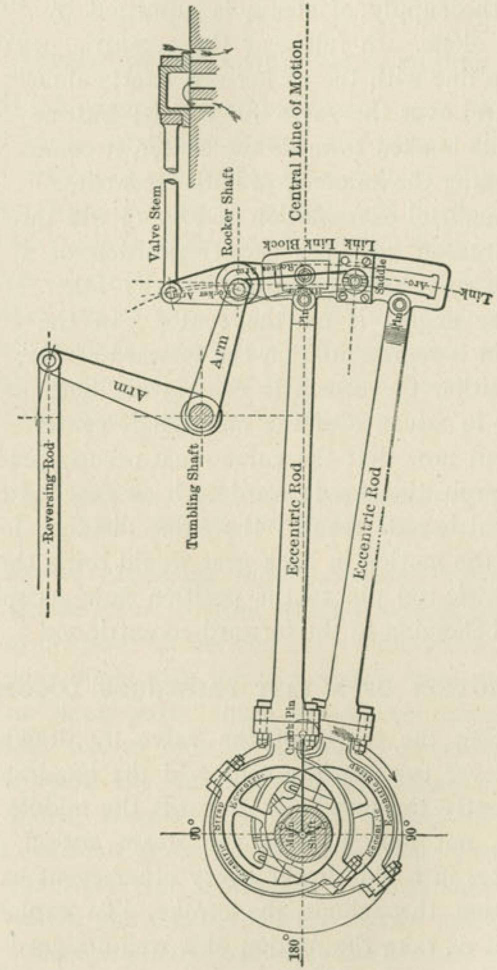



FIG. 12

When an engine is run with the lever in the center notch, the supply of steam is admitted by the lead-opening alone. In full gear the eccentric, whose rod-end is in line with the rocker-pin, exerts almost exclusive control over the valve movement; but, as the link-block gets hooked towards the center, it comes to some extent under the influence of both eccentrics.

A thoughtful examination of Fig. 12 will throw light on the reason why the proper position of a slipped eccentric can be determined by the other eccentric when the engine is on the center. In the cut, the crank-pin is represented on the forward center; and in that position the eccentric centres are both an equal distance in advance of the main shaft center. It will be evident now that the valve must occupy practically the same position for forward or back gear, as each of the eccentric-rods reaches the same distance forward. Putting the motion in back gear would bring the back-up eccentric-rod pin to the position now occupied by the pin belonging to the forward eccentric-rod.

### VALVE-MOTION OF A FAST PASSENGER LOCOMOTIVE

Reducing the travel of the valve by drawing the reverse-lever towards the center of the quadrant, and consequently the link-block towards the middle of the link-slot, not only hastens the steam cut-off, but it accelerates in a like degree every other event of steam distribution throughout the stroke. To explain this point, let us take the motion of a well-designed engine in actual service, which has done good economical work on fast train running. The valve-travel is five-inches, lap one inch, no inside lap. lead in full gear



$\frac{1}{16}$ inch, point of suspension $\frac{9}{16}$ inch back of center of link.

### EFFECT OF CHANGING VALVE-TRAVEL

When this engine is working in full gear, the steam will be freely admitted behind the piston till about eighteen inches of the stroke, when cut-off takes place; and the release or exhaust opening will begin at about twenty-two inches of the stroke, giving four inches for expansion of steam, Now, if the links of this engine are hooked up so that the cut-off takes place at six inches of the stroke, the steam will be released at sixteen inches of the stroke; and at that point compression will begin at the other end of the cylinder.

### WHY DECREASING THE VALVE-TRAVEL INCREASES THE PERIOD OF EXPANSION

Increase of expansion follows reduced valve-travel from a similar cause to that which produces expansion when lap is added to the edge of a slide-valve. When the valve is made with the face merely long enough to cover the steam-ports, there can be no expansion of the steam; for, so soon as the valve ceases to admit steam, it opens the steam-port to the exhaust. When lap is added, however, the steam is inclosed in the cylinder, without egress for the time that it takes the lap to travel over the steam-port. An arrangement of motion which will make the valve-travel quickly over the port, has a tendency to shorten the period for expansion; while making the valve-travel slowly over the port, has the opposite effect, and protracts expansion. A valve with, say, five inches travel, has a comparatively long journey to make during the stroke of the piston; and the lap-edges will pass quickly over the steam-ports,—much more quickly than they will when the travel is reduced to three inches. In a case of this kind, there is more than the mere reduction of travel to be considered. Suppose the valve has one inch lap at each end. When it stands on the middle of the seat, it has a reciprocating motion of two and one-half inches at each side of that point to make. At the beginning of the stroke, it has been drawn aside one inch (we will ignore the lead), but still has one and one-half inch to travel before it begins to return. On the other hand, when the travel is reduced to three inches, the valve has only one and one-half inch to travel away from the center; and, one inch being moved to draw the lap over the port, there only remains one-half inch for the valve to move before it must begin returning. This entails an early cut-off; for the valve must pass over the ports with its slow motion, and be ready to open the port on the other end, before the return stroke. Thus a travel of five inches draws the outside edge of the valve one and one-half inch away from the outside of the steam-ports, three inches travel only draws it one-half inch away, and a greater reduction of travel decreases the opening in like proportion.

### INFLUENCE OF ECCENTRIC THROW ON THE VALVE

As reducing the travel of the valve diminishes the port opening, a point is reached in cutting off early in the stroke where the port opening is hardly any more than the port opening due to the lead. This is what makes long steam-ports essential for a successful high-



speed locomotive. The best-designed engines given an exceedingly limited port opening at short cut-offs, and badly planned motion sometimes seriously detracts from the efficiency of the engine, by curtailing the opening at the point where a very brief time is given for the admission of steam. The magnitude of the eccentric throw exerts a direct influence on the port opening when cutting off early. A long throw tends to increase the opening, while a short throw reduces it. The long-throw eccentric will draw the valve farther away from the edge of the steam-port, when admitting steam for the same point of cut-off, than a short-throw eccentric will move its valve. For an ordinary $19 \times 26$ inch locomotive, the throw of eccentric should not be less than five inches, unless the engine is intended entirely for slow running. There are many engines running with eccentric throw less than five inches, but they are invariably slow unless the valve-lap is very short. With an ordinary lap, an engine having an eccentric throw of $4\frac{1}{2}$ inches needs so much angular advance to overcome the lap, and provide lead, that the rectilineal motion of the eccentric is very meagre at the beginning of the stroke. That is, the center of the eccentric is traveling downward in its circular path, which gives little motion to the valve, just as the crank gives decreased motion to the cross-head when near the centers.

### HARMONY OF WORKING-PARTS

Hitherto we have regarded the link as merely performing the functions of transmitting the motion of the eccentrics to the valves, with the additional capability of reducing the travel at the will of the engineer. Otherwise, the motion of the link is intensely complex; and its movements are susceptible to a multitude of influences, which improve or disturb its action on the valve. A good valve-motion is planned according to certain dimensions of all the working-parts; and any change in their arrangement will almost invariably entail irregularities upon the link's movement, which will radically effect the distribution of steam. A link-motion schemed for an eccentric throw of $4\frac{1}{2}$ inches will not work properly if the throw be increased to five inches; a link with a radius of 57 inches can not be changed with impunity for one of 60 inches. Any change in the position of the tumbling-shaft or rocker-arms distorts the whole motion, and any alteration in the length of the rods or hangers has a similar effect. That the link may perform its functions properly, all its connections must remain in harmony.

### ADJUSTMENT OF LINK

A very important feature of the link is its property of adjustability, which serves to neutralize the distorting effect of the connecting-rod's angularity. As has already been explained, the angularity of the main rod tends to delay the cut-off during the backward stroke, while it is accelerated in the forward stroke. With the ordinary length of connections, this irregularity would seriously affect the working of the engine. But it is almost entirely overcome by the link, which can be suspended in a way that will produce equality for the period of admission and point of cut-off for both strokes in one gear. Perfect equalization of admission



and cut-off for both gears has been found impossible with the link-motion; and designers are generally satisfied to adjust the forward motion, and permit the back motion to remain untrue. The point about the link which exercises the most potent influence on adjusting the cut-off, is the position of the saddle, or of its stud for connecting the hanger. This stud is called the point of suspension. Raising the saddle away from the center of the link will effect adjustment of steam admission; but in locomotive practice the saddle is nearly always located in the middle of the link, there being practical objections against raising it. Equalization of steam distribution is produced by placing the hanger-stud or point of suspension some distance back of the center line of the link-slot, the distance varying from 0 to $\frac{7}{8}$ inch.

Moving the hanger-stud affects the link's movement in a way that is equivalent to temporarily lengthening the eccentric-rod during a portion of the piston-stroke. The length of the tumbling-shaft arms, the length of hanger, the location of the rockers and tumbling-shafts, the radius of link, and length of rods, all exercise influence on the accurate adjustment of the valve-motion.

### SLIP OF THE LINK

In equalizing the valve-motion, and overcoming the discrepancy of steam admission, due to the angularity of the connecting-rod by moving the link-hanger stud away from the center of the slot, a new distortion is introduced. The link-block being securely fastened to the bottom of the rocker-pin, moves in the fixed arc traversed by that pin, which is nearly horizontal.

The action of the eccentric rods on the link, on the other hand, forces the latter to move with a sort of vertical motion at certain parts of the stroke, making it slip on the block. Moving the hanger-stud back tends to increase this slip, which will become excessive enough to seriously impair the efficiency of the motion if not kept within bounds by the designer. Where the slip is very great, the motion will not be serviceable, a consideration which can never be overlooked; for the block will wear rapidly, producing lost motion, a very undesirable defect about any part of a link-gear. With the long rods which prevail in locomotive practice, designers have no difficulty in keeping the slip within practical bounds; but with marine engines it is sometimes necessary to sacrifice equality of steam admission to the reduction of the slip. The greatest amount of slip is in full gear, and it diminishes as the link-block is moved towards the center.

Placing the eccentric-rod pins back of the link-arc, as is almost universally done in this country, has a tendency to make the link slip on the block; and care has to be taken not to locate these pins farther back than is actually necessary for other requirements of the link-motion's adjustment. Auchincloss, who is a recognized authority for designing of link-motion, gives four varieties of alterations capable of reducing the slip when it is found too great for practicable motion. His resorts are, either to increase the angular advance, reduce the travel, increase the length of link, or shorten the eccentric-rods. One or a combination of these methods may be adopted, as the designer finds most convenient.



### RADIUS OF LINK

Among the constructing engineers who plan link-motion, there is considerable diversity of opinion about what radius of link helps to produce the best valve-motion. The distance between the center of axle and center of lower rocker-pin may be accepted as approximately correct, although some designers slightly increase beyond these points. On the other hand, the locomotives sent out from a leading building establishment have the radius of link drawn $\frac{3}{4}$ inch per foot short of the distance between the axle and rocker; and the claim has been made, that the arrangement produces an excellent motion.

A committee of the American Master Mechanics' Association have placed themselves on record on this subject by asserting that the distance between the centers of axle and rocker-pin is the proper radius for the link. That same committee recommended that the link-motion should be planned to give as long a link-radius as possible, subject to the first-mentioned conditions.

It must be noted that the middle of the link-slot is the radius arc. I knew of a case where the links for an altered locomotive were finished out of the true radius through the edge of the slot being taken as the radius-curve.

### INCREASE OF LEAD

Most of the men who are at all familiar with the valve-motion are aware of the fact that, with the shifting link, the lead increases as the link is notched towards the center. Where the valve has $\frac{1}{16}$-inch lead in full gear, it is no unusual thing to find it increase to $\frac{1}{4}$-inch lead opening at mid gear. The phenomenon is better known than its cause is understood.

The relative positions of link and eccentric centers of an engine, when the crank is on the forward center, are shown in Fig. 13; the link being represented with the block in the center, which represents mid gear. It will be observed that the centers of the eccentrics *f* and *b*, from which the rods receive direct influence, are both some distance ahead of the center of the axle, the one above, the other below. The eccentric-

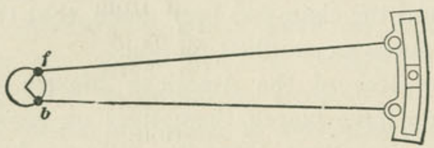


FIG. 13

straps to which the rods are connected sweep round the eccentric circles, and are controlled thereby. When the link is moved up or down, each eccentric-rod pin, where it attaches to the link, describes the arc of a circle with a radius drawn from its own eccentric. If both rods were worked with a radius from the axle-center, the link could be raised and lowered when the engine stands on the dead center without moving the rocker-pin at all; but, under the existing arrangement, the link is influenced directly by one or other of the eccentrics, whatever position in the link the block may stand.

When the engine is standing on the forward center, with the link in mid gear, as shown in Fig. 13, it will be readily perceived that the block stands at its farthest



point away from the axle; for the rods are so placed to reach their greatest horizontal distance ahead, and consequently in this position the lead opening is greatest. If the link be now lowered, the backing eccentric-rod will immediately begin to pull the link back; and, as the pin of the forward eccentric-rod approaches the central line of motion, it will also keep drawing the link back; so that, by the time the link is in full gear, the lead opening will be considerably reduced.

When the engine stands on the back dead center, as shown in Fig. 14, the eccentric centers will be on

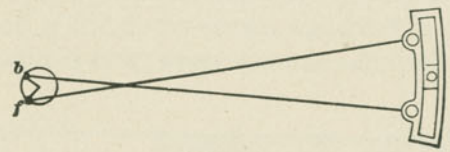


FIG. 14

the other side of the axle, and the eccentric-rods will be crossed. While in mid gear, the link-block is drawn closer to the axle than it would be in any other position of the link; and consequently the lead opening is greatest. If the link be now lowered, the forward eccentric-rod will approach its horizontal position. and consequently reaches farther on the central line of motion, so it will push the link-block away from the axle, thereby decreasing the lead. Pulling the link into back gear has a similar effect.

The tendency of a link-motion to increase the lead towards the center is made greater by shortening the eccentric-rods. Increasing the throw of eccentric inclines to accelerate the lead towards the center, since it throws the eccentric centers farther apart. For slow running, hard-pulling locomotives, where increase of lead is a disadvantage, the tendency to increase the lead is sometimes restrained in forward gear by reducing the angular advance of the backing eccentric. This expedient is, however, not necessary where proper care and intelligence have been bestowed in the original design of the motion.

# CHAPTER XIV

## RADIAL VALVE-GEARS

### THE WALSCHAERTS VALVE-GEAR

In the early days of the steam-engine the necessity for the economical or expansive use of steam, was not so great as it is now, for the reason that steam was used at a much lower pressure at that time, and the loss of steam at the end of the piston-stroke was small in comparison with what it is now, when steam is admitted during the

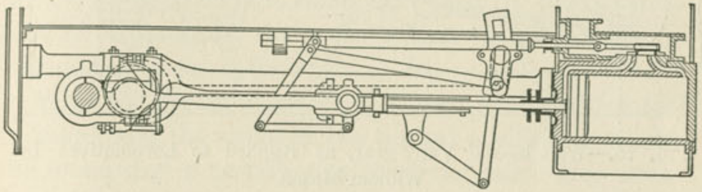


Fig. 15.—Walschaerts' Variable Expansion Valve-motion Applied to Locomotive 98, at Brussels, Belgium, Sept. 2, 1848

entire length of the stroke. Other causes soon arose calling for a variable supply of steam. With the locomotive the difference in grades to be climbed and in loads to be hauled necessitated an increase and a diminution of the steam pressure, and the brightest minds among steam-engineers were early at work on this important problem. As boiler construction improved and higher steam pressure became possible, the necessity for a variable valve-motion increased. Egide Walschaerts, a young Belgian engineer, was among the first, and among the most successful, in solving this intricate mechanical problem. Eccentrics were already in use for the simple purpose of reversing the movement of the engine. This was accomplished by having two eccentrics set in such positions that when their rods were in operation on a rocker that moved the valve-rod, one rod was adjusted so that it would act in advance of

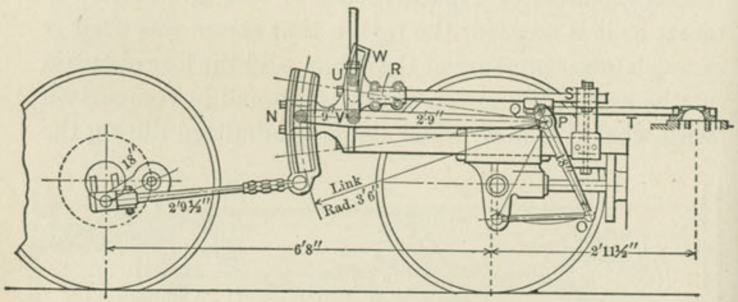



Fig. 16.—Walschaerts' Valve-gear, as Applied to Locomotives by William Mason

the main crank, while the other, when in operation, would follow the crank. One rod could be lifted off the rocker-pin and the other one attached by a simple appliance similar to the lifting-shaft now in use on locomotives, the rods being furnished with hooks adapted to catch the rocker-pin.

This reversing contrivance attached to the early locomotive is alluded to in order that the condition of the valve gearing at the time that Walschaerts brought his keen intellect and engineering skill to bear upon the problem may be understood.



The valve then in use, known as the D-slide valve, the steam-ports leading to the cylinder and the method of exhausting the steam through the inner cavity of the valve were not in any way affected by the work of the young Belgian engineer. The perfect adjustment of an eccentric or crank set at right angles to the main crank is the primal necessity in the construction of the Walschaerts gearing. It can readily be understood that a connecting-rod attached to an eccentric or crank so fixed and so adjusted in point of length that it would reach exactly to the movable valve while the valve was in the central position would, by continuing the movement of the engine, continue to place the valve in the middle of the valve-seat when the piston was at the end of the stroke, and also move the valve to the extreme end of its stroke at the moment that the piston was in the middle of the cylinder.

With the piston at either of the extreme ends of the cylinder and the valve in the central position, it would be found that a certain portion of the valve face overlapped the steam-ports and it would be necessary to move the valve a distance equal to the amount of lap in order that the steam might be readily admitted to act on the piston in the early part of its movement towards the other end of the cylinder. The mechanism invented by Walschaerts in moving the valve the required distance from the center at either end of the piston is one of the cleverest devices in use in steam-engineering and is generally looked upon as the crowning feature of Walschaerts' masterly invention. It should be noted that the overlapping of the valve is an essential requisite in the economic use of steam. If the valve exactly covered the ports any movement of the valve would cause an immediate opening of one port at the instant of the closing of the other port. The amount of lap makes a period of closure of the ports possible, and consequently renders the expansive use of steam already alluded to a mechanical possibility.

The moving of the slide-valve toward the desired point is effected by the engaging of the valve-rod by a coupled combination-lever which is connected to the cross-head by a union-link, and which will be fully described hereafter. The co-relation between the combination-lever and a radius-bar driven by an oscillating radial-link, which is driven by the eccentric-rod, become the determining factor in moving the valve from the central position to the point desired.

The shortening of the valve-stroke making it possible to close the supply of steam at any desired point of the piston-stroke is effected by the oscillating radial-link into which the radial-bar attached to the valve-rod and cross-head is movable by the lifting-shaft, and it will be readily seen that as the radial-link suspended centrally oscillates furthest at the extreme ends the radial-bar will travel further when near the extreme ends of the link, and as it is made to approach the center the motion of the bar will be shortened. At the center of the link it will cease moving altogether, and after passing the center it will move in the opposite direction, thus reversing the movement of the engine. The moving of the valve towards the opening point by the use of the cross-head connection, as well as the intervention of the oscillating radial-link, together with the use of the single



eccentric or crank, are three distinct and separate features of this valve gearing.

It will be noted that the construction of the Walschaerts' valve-gearing as originally applied by the inventor to the locomotives of the Belgian State railways differ somewhat in detail from the forms in which it is now made applicable to twentieth-century locomotives. These changes do not in any way affect the organic principles of the device, but are merely matters of con-

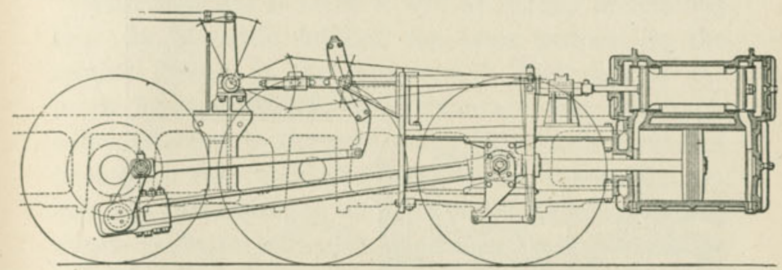


FIG. 17.—Walschaert Valve-gear Used by American Locomotive Company

venience made to suit the increased size of the engines. Among the changes in form it will be observed that the original method of causing the radial-link to oscillate on its central suspension-stud was by an eccentric attached to the main axle to which a rod was attached, one end of the rod being fastened to the eccentric strap, and the other end attached to the lower end of the radial link. This eccentric was set at right angles to the main driving-crank, that is while the piston would be at the extreme back end of the cylinder and the main crank-pin consequently on the back center, the extreme point of the eccentric would be on the top center, or

90° ahead of the main crank while the engine was running forward. It must be borne in mind that the original invention was applied to an outside admission-D-slide valve. In the case of a modern locomotive equipped with an inside admission-piston valve the eccentric would be set 90° behind the main crank, this is on the bottom center. This change of position is made necessary from the fact that an inside admission-piston valve must necessarily move in the opposite direction from that of the ordinary outside admission-slide valve.

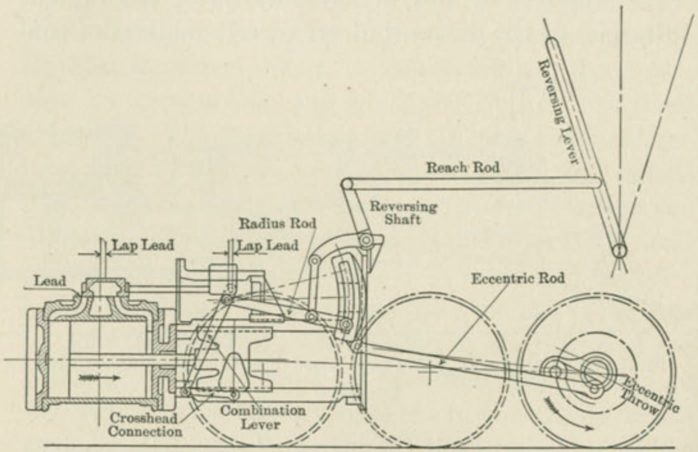



Fig. 18.—Walschaerts' Valve-gear Used by Baldwin Locomotive Works

In addition to the change of position in the eccentric there is also a change necessary in the relative positions of the radius-bar and valve-rod, the outside admission-valve requiring that the valve-rod should be attached to the combination-lever above the radius-bar as in



Walschaerts' original design, whereas with an inside admission-valve, the valve-rod attachment is made beneath that of the radius-bar. The cause and effect of this change of position will be fully explained hereafter, the present reference being merely the need of calling attention in a general way to some apparent changes in the construction of the valve gearing, which in reality are not changes at all, but simply varying modifications of the same general principles.

With this idea in mind it will be readily understood that the eccentric fulfilled the same purpose in the original design as the return-crank does that in the larger locomotives with the advantage that the crank being attached to the outer end of the main crank-pin its motion can readily be imparted to the oscillating-link by a rod moving in the same plane, thereby avoiding the necessity for extended attachments which would be necessary if the eccentric was attached to the main axle inside of the engine frames while the oscillating-link would necessarily be at some distance outside of the frames.

Other changes of less importance have occurred among which is the placing of the lifting-shaft above the same so that the radius-bar is hung by a short hanger or suspended by an adjustable sleeve, instead of being sustained by a bar from beneath which in the case of the modern locomotive would be of considerable length and add to the degree of unwieldiness of the mechanism.

Among the first to adopt the Walschaerts valve-gearing to the expanding form of the modern locomotive was William Mason, an American engineer and locomotive builder. The changes in the position of some of the parts of the mechanism made by him have been closely followed by subsequent engineers. In his application of the device he not only made the valve-rod adjustable by the use of threaded ends on the valve-rods on which nuts were movable to equalize the position of the valve, but he also applied turn-buckles to the eccentric-rods so that inevitable wear of the return-crank bearing could be readily rectified in case of the lengthening or shortening of the rod occasioned by the refitting of the brasses.

It will be noted that in the modern use of the oscillating-link there is an attachment extending beyond and underneath the bottom of the link. This attachment is variable in extent, and is adapted to form a suitable connection for the eccentric-rod. The exact location of the connecting point must be carefully considered by the constructor on account of the relation of the amount of throw of the crank to the travel of the valve. In ordinary practice a locomotive with the piston-stroke of 28 inches would have a valve-stroke of $5\frac{1}{2}$ inches, while the path of the return-crank would describe a circle 12 inches in diameter. The center of the eccentric-rod attachment to the link would thus be describing an arc 12 inches in length, while the radius-bar being considerably nearer the center of the link would move through a smaller arc which continues to grow smaller if the radius-bar is moved toward the center of the link.

In the construction of some kinds of locomotives there are two lifting-shafts connected by a transmission-bar. It will be readily found that variations of this kind are made necessary in order to accommodate the location of other parts of the engine, the additional



lifting-shaft not in any way affecting the action of the valve-gear.

Such briefly are the principal changes in form which have occurred in Walschaerts' valve gearing since its original introduction. These changes illustrate its ready adaptability to changing conditions and stamp it as one of those few mechanical contrivances that have come to us as nearly perfect as any kind of mechanism involving the changing of circular motion in some parts to linear motion in other parts can be expected to be, and not surpassed in the fine quality of reliability.

### THE BAKER VALVE-GEAR

The necessity that we have already referred to of providing a locomotive-valve gear outside the frames induced many clever American engineers to extended experiments with a view to make still further improvements than that already shown to be possible with the introduction of the Walschaerts' valve-gear. The introduction of what was known as the Baker-Pilliod valve-gear was at once acknowledged as an important step in the right direction. In a few years the number of parts composing the mechanism have been reduced in number, thereby avoiding the tendency to lost motion, besides adding to the simplicity and stability of the structure, and in its improved form is now known as the Baker locomotive valve-gear.

It will be readily observed that the device resembles the Walschaerts' valve-gearing in two important particulars. The eccentric-crank, which gives the valve its motion, is attached to the main crank-pin, and a combination-lever deriving its motion from the cross-head gives the valve its position in relation to the steam-ports. The most important variation between the Baker valve-gearing and the Walschaerts' valve-gearing consists in the absence of a radial-link in the Baker gear. As is well known, the link whether sliding or oscillating on a fixed center, is a source of error in all valve-motions, largely on account of the slipping of the link-block, and is more noticeable in the case of the shifting-link as it moves through a longer extended arc than is the case when oscillating on a fixed center. This drawback has been largely overcome in stationary engine practice, but delicately automatic appliances are not suited to locomotive service.

In view of these facts it will be readily understood that if the motion of a sliding-valve can be perfectly controlled, and the length of valve-stroke varied without the intervention of a radial-link, a real gain in the economical use of steam is made. Not only so, but the valve-gearing in locomotive service that readily lends itself to rigidity of movement, and at the same time possesses that flexibility of adaptation essential to the various requirements of the service is all that can be looked for, and these qualities are found in an eminent degree in the Baker locomotive valve-gear.

In regard to the various parts of the valve-gearing it will be observed that the circular movement of the eccentric-crank will impart an irregular linear movement to the eccentric-rod, as also does the cross-head impart a similar varying movement to the combination-lever. The cross-head travels with an increasing degree of rapidity towards the center of the stroke and diminishes in velocity towards the end of the stroke. The same



remarks apply to the eccentric-rod. The cross-head movement is at the swiftest point when the eccentric-crank motion is at the slowest, because they are set at right angles to each other. The union-link attached to the cross-head, and the eccentric-rod are connected to separate ends of a bell-crank. The end of the bell-crank attached to the eccentric-rod describes an ellipse at an irregular velocity. This varying motion is conveyed through the bell-crank to the combination-lever

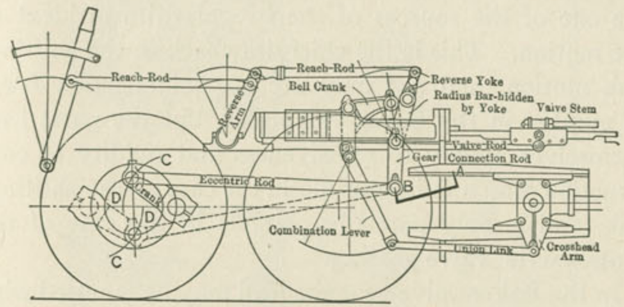



FIG. 19.—The Baker Locomotive Valve-gear

and valve-rod as shown in the detailed drawings. The result of the two motions is that the valve travels very rapidly at the beginning of its stroke, and by the time that the piston has moved one-twentieth of its stroke, the valve is wide open and the valve then moves very slowly during the period when the piston is moving with increasing rapidity. As the piston approaches the release point the valve again travels with increasing rapidity and closes at its highest speed.

The reversing movement is effected by the eccentric-rod being attached to a reverse-yoke, and when the reach-rod is moved backward or forward it changes the position of the bell-crank and effects the position and movement of the valve with a degree of accuracy not obtainable in any motion passing through a shifting or oscillating-link. The rods and bell-crank are so connected and adjusted that the placing of the reverse-lever on any position affects, the position of the bell-crank conveying a corresponding movement on the valve-rod and valve.

The number of joints in all kinds of valve-gearing are one of the sources of the irregularities incident to the motion. This is the chief drawback in the shifting-link motion, and not only are the joints much fewer in number in the Baker valve-gear, but the parts lend themselves readily to massiveness and rigidity of construction which is impossible in the case of the shifting-link, and is only partially possible in the case of the Walschaerts' valve-gearing.

In the Baker valve-gear the lead may be renewed with ease and rapidity that is at once simple and complete. The interchangeability of the parts have proved themselves that the most advanced methods have been used in obtaining perfection in the duplication of all of the parts comprising the Baker valve-gearing.

A particular advantage in running a locomotive with the Baker valve-gear is the perfect ease with which the reverse-lever may be moved. The lever does not act against any direct thrust of the moving parts, but the reach-rod and reverse-yoke acting as a lever and fulcrum moves the bell-crank readily and easily.



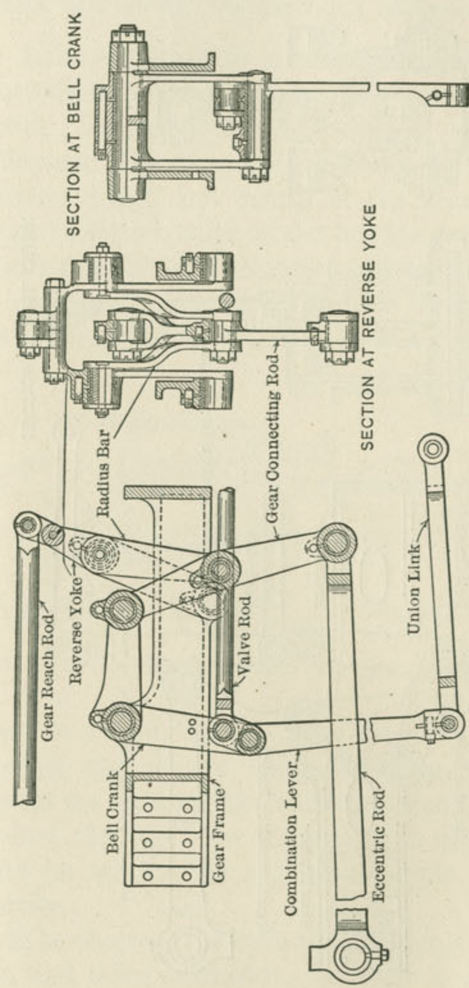



FIG. 20.—Details of Baker Locomotive Valve-gear for Outside Admission

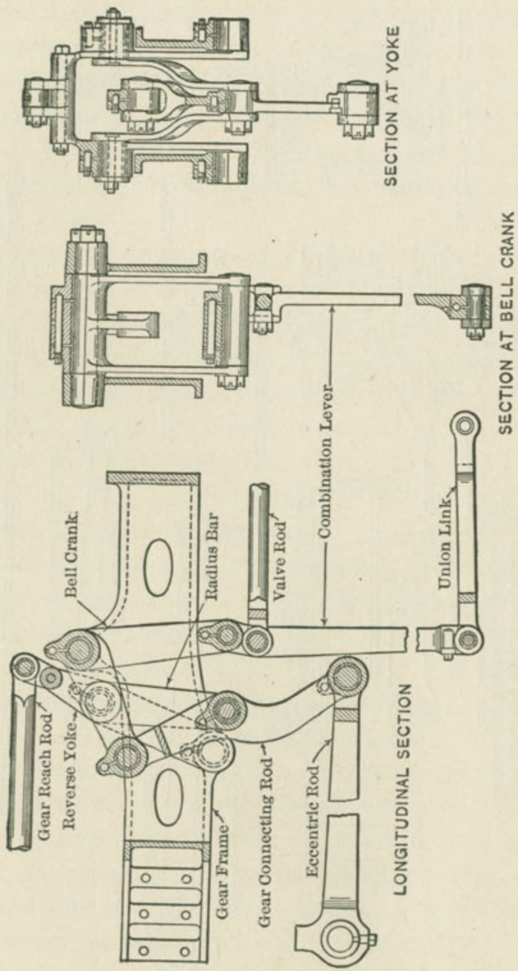



Fig. 21.—Details of Baker Locomotive Valve-gear for Inside Admission



### THE SOUTHERN LOCOMOTIVE VALVE-GEAR

The latest addition to locomotive valve-gears has been introduced on the Southern railway and is eminently successful, especially on the important elements of durability and ease of operation. The illustration shows the general design and details of the gearing. It is simple and compact, and contains but few wearing parts. The usual counterbalance-springs, counter-weights, and also a cross-head connection has been dispensed with, and as a consequence there has been a corresponding

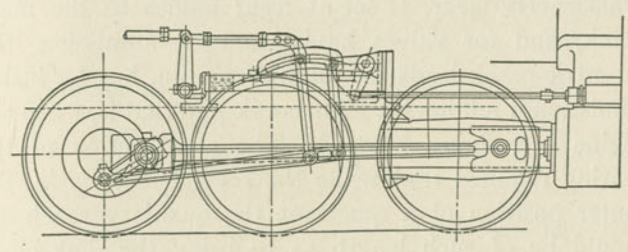


Fig. 22.—Southern Locomotive Valve-gear Assembled

reduction in weight. It has been shown by extensive experiments that if the valves have been properly adjusted at the time that the engine has been constructed or repaired, the gear is so designed as to eliminate the necessity for any further adjustment while the engine is in service.

As will be observed the links are placed in a horizontal position and being stationary, the wear is done away with at this point as the link-block only moves in the link when the reverse-lever is moved to adjust cut-off reverse-gear. What is known as the slip of the link is also avoided. A prominent feature of the gear is the ease with which the reverse-lever is handled. There is literally no stress or strain upon the lever and reach-rod connections. The avoidance of this trouble appeals very strongly to the engineer, as it enables him to adjust the cut-off without any risk of the reverse-lever getting beyond his control, and as a consequence he readily and frequently adjusts the lever to meet the requirements of the situation.

It will be observed from the accompanying illustration that the eccentric-crank, which is similar to that of the Walschaerts' gear, is set at right angles to the main crank, and for valves having outside admission, the eccentric-crank leads the main crank-pin, but for inside admission it follows the main crank-pin, that is, when the engine is running forward. The construction of the gearing requires that while the reverse-lever is in the center position of a quadrant the auxiliary reach-rod should be of such length as to bring the link-block to the center of the link.

It will also be noted that the eccentric-rod has two connections, one of which is attached to the radius hanger from the link, and the other attached by the transmission-yoke to a bell-crank which actuates the valve-rod. As the two connections are relatively near each other, as result is that when the link-block is in the center the movement of the bell-crank is reduced to a minimum, and as the link-block is moved towards either end of the link the distance traversed by the arms of the bell-crank increases, and these parts, with their relative movements, when properly adjusted,



have an abiding degree of correctness not surpassed by any other kind of valve-gearing now in use.

It is not necessary to describe in detail the remedying of any defect that may arise on the gear. The reach-rod, auxiliary-reach rod, eccentric-rod and valve-rod may be readily shortened or lengthened to correct any variation that may arise in the exact opening and closing of the valves. The throw or stroke of the eccentric-crank is also an important factor in the motion. Not

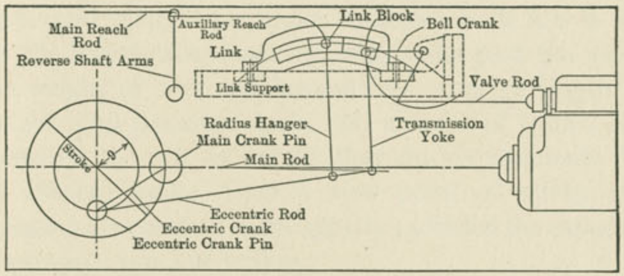



FIG. 23.—Diagram of Southern Locomotive Valve-gear With Names of the Different Parts of the Gear

only must it be set at right angles to the main-crank, as already stated, but it must describe a path coincident with the requirements of the valve-travel. As shown in the annexed diagram the path of the eccentric has a diameter of eighteen inches. This has been found to be convenient for the present form of the most high-powered locomotives. Any increase or diminution would, of course, require a change in the other parts, particularly in the length of the radius-hanger and transmission-yoke as well as in the length of the arms of the bell-crank, but it is almost always safe to assume that the constructing engineer is correct in the proportion of the parts, and those who are at all familiar with other valve-gearings will have no difficulty in correcting any slight variation that may arise in the adjustable parts.

## CHAPTER XV

### MODERN AIR BRAKE EQUIPMENTS.

PREVIOUS editions of this book have contained questions and their answers on the Westinghouse Quick-Action Automatic Brake, embracing the high-speed brake for passenger-service and the combined automatic and straight air brake (Schedule S W A-S W B) for the locomotive, however, within the past ten years the weight of cars and locomotives, average length of freight- and passenger-train and amount of traffic, has increased to such an extent that the requirements for an efficient brake, from a view point of safety and economical operation, have greatly exceeded the capacity of previous types of brakes.

The development of a satisfactory brake for modern railroad operation has constituted an engineering problem of such magnitude that the analysis of the factors involved and technical details in themselves comprise a library in air-brake literature. Our aim will be to offer a brief description of modern brake equipments, and to formulate into questions and answers, the most approved methods of brake manipulation in freight and passenger service and to outline the most practical course to be pursued in the event of a failure in any part of the apparatus.

At no time in the history of railroading has the locomotive engineer been called upon to display the amount of knowledge, skill and care in train-handling that is necessary to successfully handle modern trains, break-in-two of both passenger- and freight-trains have been of frequent occurrence, in fact the air-brake experts have repeatedly demonstrated that it is possible to break up and wreck the modern freight-train by incorrect manipulation of the brake-valve alone.

The fundamental principles of brake operation, with all types of equipment, is the creation of a differential in pressure between two stored volumes on the cars and the increased volume of compressed-air stored in long trains, and on modern locomotives, the increased length of time required to compress and transmit these volumes, the added length of time that must elapse before the necessary differential can be created on the rear cars of a long train, variations in the actual percentage of braking forces obtained on different cars, and in different sections of the train, which are produced by almost innumerable causes emanating from difference in type and design of individual car brakes, variations in brake cylinder-piston travel and in brake-pipe pressure combines to present a very complex condition, and added to this are the retarding and accelerating forces that are produced by changes in grade and curvature of track and increased amount of train slack, creating a braking proposition which cannot be covered by any fixed rule.

While fundamental principles may remain unchanged, and while brake applications must still be largely governed by speed and track conditions, enough additional factors have entered into train handling to necessitate brake applications and methods of release that will conform to make-up of train and type of equipment



as well as speed and distance, and as any train, with draft gear in from fair to good condition, can be handled without causing a break-in-two, it remains for the engineer to so vary the brake valve manipulation that like results will be obtained in stopping different make up of trains.

To do this requires an intimate knowledge of air-brakes and braking conditions, that is, a considerable amount of that air-brake knowledge that begins with the composition and condition of the rail of the track.

If the following will assist the engineer in obtaining a better knowledge of the conditions which necessitated the design and manufacture of improved brake equipments, we shall feel that our efforts have not been in vain

### AIR COMPRESSORS

In order to meet the increasing demands for large capacity air-pumps, the Westinghouse Co. has perfected the 8½ and the 10½ in. cross-compound compressors, and the New York Co. the No. 5 and No. 6 Duplex compressors.

### LOCOMOTIVE BRAKES

All former types of locomotive brakes are now superseded by the Westinghouse No. 6 E.T. brake and the New York L.T. equipment.

### FREIGHT CAR BRAKES

The difficulties encountered in operating the brakes on long freight-trains have been greatly minimized by the use of the Westinghouse K 1 and K 2 triple-valves, and the New York K 5 and K 6 valves.

To provide an efficient brake for large capacity freight-cars in descending heavy grades, the Westinghouse Co. has introduced an empty- and load-brake.

### PASSENGER-CAR BRAKES

When it became obvious that the enormous energy stored in the modern passenger-train, through the weight and velocity of the mass in motion, could not be dissipated or destroyed by the high-speed brake in a comparatively reasonable length of time, thereby lengthening the emergency stopping distances far beyond a desirable figure, the Westinghouse L.N. brake was introduced. The New York Co. also offers the type J equipment, both of which develop a high emergency-braking pressure.

With the advent of the heavy steel car a further demand was made upon the brake builders, the Master Car Builders required a brake that would stop a train from a 60-mile per hour speed on a level track in 1,200 feet. The L.G.N. equipment, an improvement upon the L.N. brake was tested out and failed, thereupon the P.C. equipment was designed with a double-braking power for emergency stops and more than met the requirements.

The abnormally high brake-shoe pressures thus brought to bear against the wheels resulted in the overheating and breaking down of shoes in service, thereupon the clasp type of foundation brake-gear was perfected.

The Pennsylvania R.R, however, did not favor double braking power on some cars and practically a single or service power on other cars for emergency stops during the transition period, and demanded an improvement over the service operation of the triple valve, and in order to supply their requirements the Westinghouse Co. built the U.C. equipment which gives any braking force desired and embodies all improved brake features, or can be arranged to eliminate any or all. The Pennsylvania road has a further desire to eliminate the time element incident to passenger-brake operation and for this purpose the U.E. or U.C.-E. is provided. The U.C. contains all of the pneumatic features and a reserved space for the electric portion, and when the electric current is added it becomes the U.C.-E. or the Electro-Pneumatic brake.



### THE CROSS-COMPOUND COMPRESSOR

The capacity of the cross-compound compressors is about three times that of the 9½ pump, and has about one-third the steam consumption when doing the same amount of work. The C.C. derives its name from the fact that the high-pressure steam-piston is connected to the low-pressure air-piston and conversely the low-pressure steam-piston is connected with the high-pressure air-piston. In operation both piston-rods move at the same time, but in opposite directions. The distribution of steam is controlled by the main valve structure and the reversing gear is identical with that of the direct-acting pumps.

The high-pressure steam-piston operates the reversing-gear while the opposite side is what is termed a floating-piston.

Steam from the boiler operates the high-pressure steam-piston and it is exhausted from the high-pressure cylinder into the low-pressure steam-cylinder and having served its purpose there is exhausted to the atmosphere.

Atmospheric-pressure enters the low-pressure air

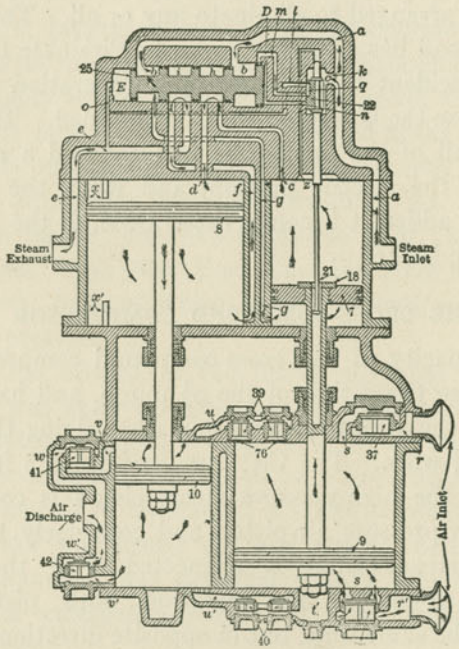



FIG. 24.—Cross-compound Compressor

cylinder through the receiving valves, is compressed from there into the high-pressure air-cylinder under about 40 pounds pressure and from there through the discharge valves into the main reservoir. The combination of 40 pounds air-pressure on the high-pressure air-piston and the high-pressure steam-cylinder exhaust



on the low-pressure steam-piston serves to positively drive the floating-piston the full length of its stroke in the final stage of compression.

### DUPLEX COMPRESSOR

The New York duplex compressor uses steam from the boiler in both steam-cylinders, both steam-pistons

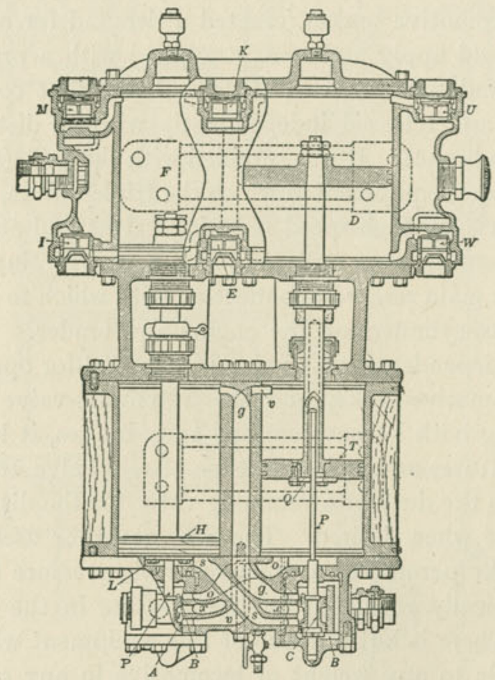


FIG. 25.—New York Duplex Compressor

operate a reversing arrangement whereby each reversing-gear controls the opposite steam-piston from that to which it is attached. While one rod and its pistons are in motion the other side is at rest and as with the cross-compound, atmospheric-pressure is drawn into the low-pressure air-cylinder, is compressed from there into the high-pressure cylinder and from there into the main-reservoir.

### E.T. EQUIPMENT

Numerous cases of break-in-two of passenger- and freight-trains directly and indirectly traceable to inefficient locomotive brakes, created a demand for a brake that would apply and remain applied with a predetermined and fixed braking force and one that could be applied and released independently without disturbing the train brakes. It was supplied with the E.T. (Engine and Tender) equipment in which the triple-valves, auxiliary-reservoirs, high-speed reducing-valves and straight-air apparatus were replaced with a distributing-valve having a main reservoir connection with which to supply the brake-cylinders on the engine and tender.

An independent-brake valve is provided for operating the locomotive-brake, and the automatic-valve is for operating both locomotive- and train-brakes, it has the same features as the former type of G 6-valve and also performs the duty of a retaining-valve for the distributing-valve when desired. The S.F. governor used with this brake permits of a main reservoir pressure that is automatically regulated by the pressure in the brake-pipe. There is but one size of this equipment which is adaptable to any weight of locomotive in any class of service.

It will be understood that a complete description of this brake would occupy more space than is contained in the present edition of this book, in fact an elaboration of any single feature of the improved equipments, with



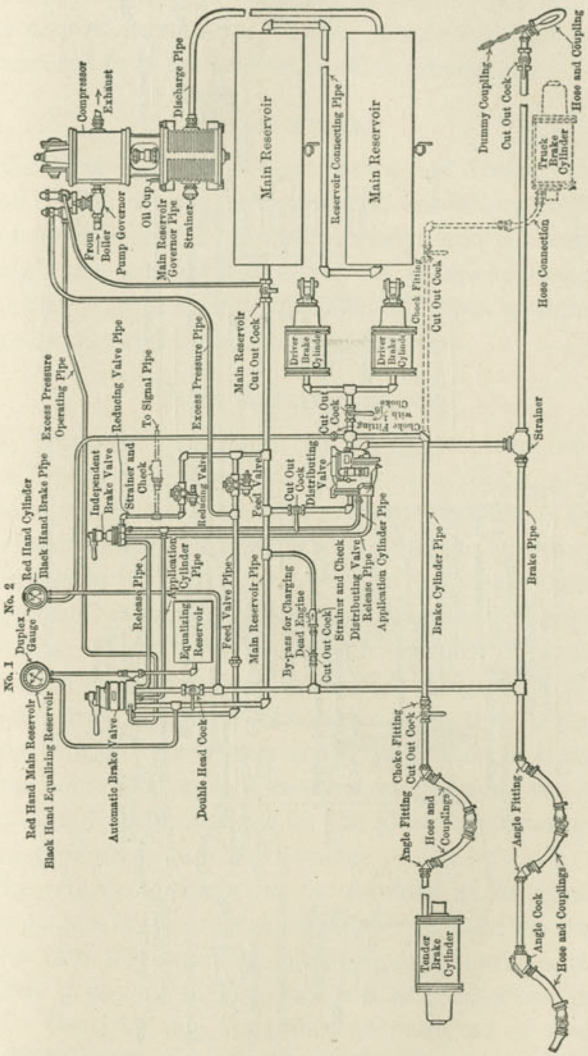



FIG. 26.—Piping Diagram of the E.T. Equipment

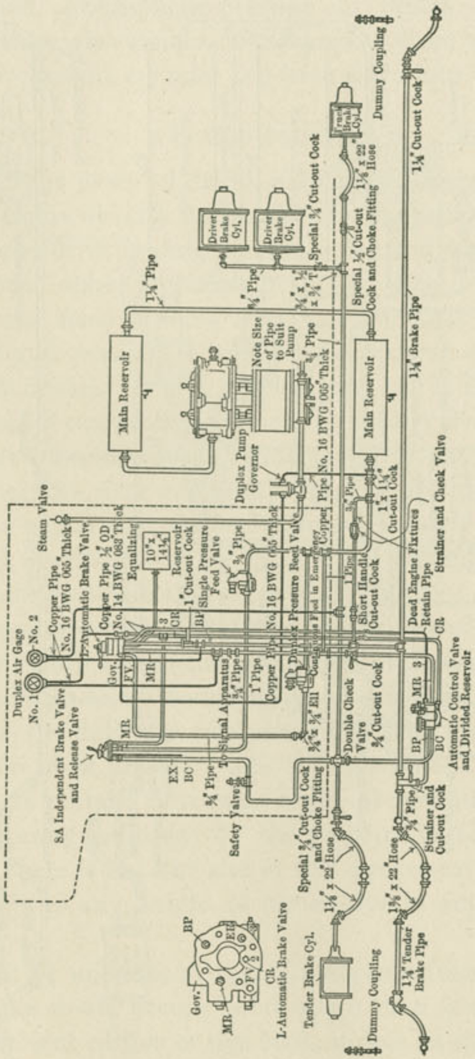



FIG. 27.—Piping Diagram of the L.T. Equipment



a résumé of the tests necessary to disclose the information derived would fill a volume, hence these brakes will be referred to in the briefest possible manner.

### L.T. BRAKE

The New York L.T. (Locomotive and Tender) brake is of similar design, an automatic control-valve being used instead of the distributing-valve and a combined straight-air feature instead of an independent-brake. It is really an independent-brake, and both equipments contain approximately the same features.

### TYPE K TRIPLE-VALVES

K triple-valves possess all of the features of the type H-valves (F 36 and H 49) and in addition, a quick service, retarded release and uniform recharge. Quick service consists of each triple-valve making a brake-pipe reduction as it moves to application position by admitting a small quantity of brake-pipe pressure to the brake-cylinder. This serial reduction enables a 5-pound reduction at the brake-valve to apply every brake in the 100-car train, whereas the same reduction with H-triples will not apply over 40 of the brakes, in fact, all brakes cannot be applied on the average train even with a 20-pound reduction due to the slow rate of drop in brake-pipe pressure with H-valves.

The retarded release can be obtained as far back as 25 or 30 cars in the train, and in order to force the triple-valves into this position, brake-pipe pressure must be at least 3 pounds higher than auxiliary-reservoir pressure. The frictional resistance encountered in forcing the compressed air into the brake-pipe prevents this rise in pressure back of the 25th or 30th car, and the retarding-springs cannot be compressed hence the brake-release from rear cars will be unobstructed.

Uniform recharge is obtained by restricting the auxil-

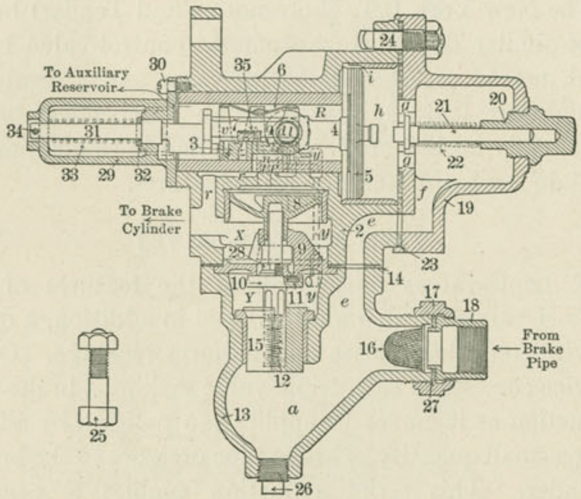



Fig. 28.—Type K Triple-valve

iary-reservoir charging-port when the triple-valve is in retarded release position, thus the reservoirs on the head end absorb less brake-pipe pressure during a release which facilitates the release and recharge of rear brakes, and at the same time prevents the usual high overcharge at the head end.



### EMPTY AND LOAD BRAKE

The standard freight-brake when applied to cars with a carrying capacity 110,000 pounds and over, is manifestly inadequate to provide a factor of safety for heavy grade work. As the maximum permissible braking force of the car is a certain per cent of its light weight, as a protection against wheel sliding, it is a simple geometrical proposition embracing a mathematical equation to demonstrate that in descending a 2 per cent grade the load of, such cars frequently reduces the available braking force to a figure as low as 17 per cent of the weight of car and load, whereas 22 or 23 per cent will be required to prevent an increase in speed after full braking power is obtained. This necessitates the "clubbing down" of a sufficient number of hand brakes to increase the braking power and hold the train, or to mix enough light loads or empties to increase the total percentage of braking power.

In order to obviate this condition, the Westinghouse empty and load-brake is employed wherein a K-2-L triple-valve operates a standard cylinder and standard braking force when the car is empty, and in combination with a change over valve, operates an additional cylinder, with an exceedingly and permissibly short piston-travel, when the car is loaded. This is accomplished without any material addition to the auxiliary reservoir and brake-pipe volume, and for a very good reason that modern operating conditions will not permit of any further increase in these volumes which are encountered in long trains.

The load-cylinder brings the braking power up to

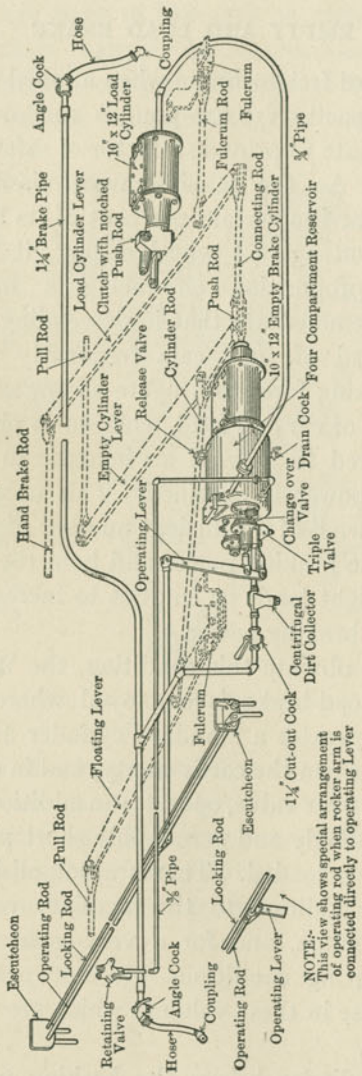



FIG. 29.—Diagram Empty and Load Brake



about 40 per cent of the total weight of car and load, the change over to load position is made manually, but the change back to light will be automatic upon a depletion of pressure, or it can be arranged to remain locked in load position.

### L.N. EQUIPMENT

The L.N. brake consists of the usual auxiliary reservoir, brake-cylinder and type L triple-valve, eliminating the high speed reducing-valve and adding a supplementary reservoir $2\frac{1}{2}$ times the size of the auxiliary with which to produce the high emergency braking power, quick recharge and graduated release.

This valve is of the pipeless type, all connections being made to the brake-cylinder head, and it also contains a quick service and safety-valve feature. With this brake the pressure can be graduated from the brake cylinders as with the distributing-valve by movement of the brake-valve handle between lap and running or lap and holding positions as desired.

When mixed with P.M. equipment the supplementary reservoir may be cut out which deprives it of high-pressure emergency and graduated release, and it will work in perfect harmony with P triple-valves and retain the quick service, and limit the service braking power to the safety-valve adjustment which is the same as the high-speed reducing-valve.

### TYPE J EQUIPMENT

The New York type J brake, dispenses with the compensating-valve and adds the supplementary reservoir and safety-valve. The J triple-valve is of the pipeless

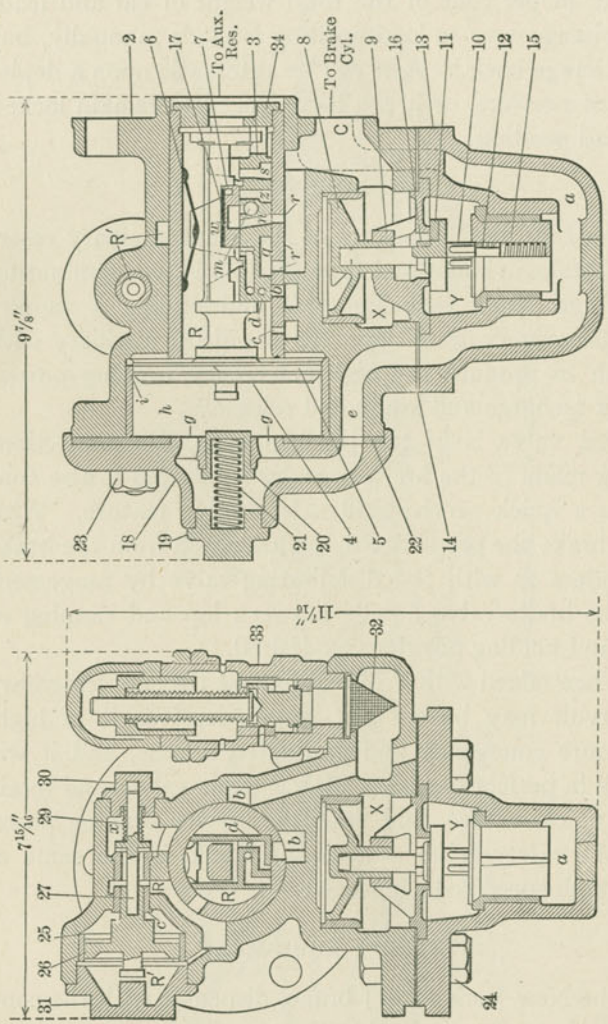


Fig. 30.—Type L Triple-valve



type and its high-pressure cap and cut-off valve arrange for the high-pressure emergency and retains the high-pressure to the point of train stop, while the safety-valve limits the service braking power.

The valve works in harmony with all previous types of brakes, and is considered undesirable, the high emergency pressure feature can be eliminated.

This brake has, however, been superseded by the type L.N. equipment of which a view of the L triple-valve is shown. It is of the same construction and possesses the features of the Westinghouse L.N. brake.

## P.C. EQUIPMENT

In addition to the features of the P triple-valves, and the double-braking power for emergency previously mentioned, the P.C. (Passenger Control) contains certain improvements upon service operation. It will not apply from variations or fluctuations in brake-pipe pressure until a definite brake-pipe reduction is made.

It absorbs no brake-pipe pressure for recharge during a release until after the release is effected. Like a distributing-valve it maintains service brake-cylinder pressure against leakage up to the capacity of the service-reservoir. A second or emergency-reservoir furnishes to stores a supply of compressed-air for the emergency-brake cylinder while a three compartment reservoir contains the control-valve portions, and certain chambers necessary to the operation of the control-valve.

There is but one size of control-valve for all weights of cars and service-brake cylinder pressure is governed

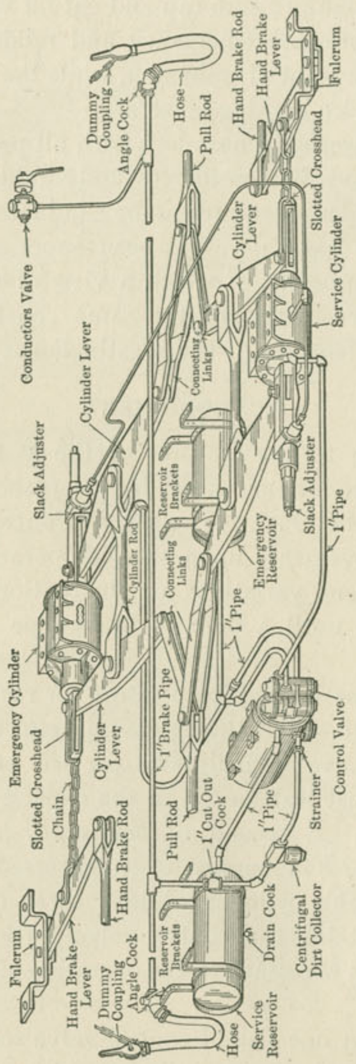



FIG. 31.—General Arrangement P.C. Brake Equipment



by an application portion with chambers of a standard capacity, which insures a predetermined and fixed brake-cylinder pressure for a given reduction regardless of unequal piston-travel. In emergency action it provides for a quick rise in brake-cylinder pressure; full emergency braking power is available at any time during a service application and a protection feature causes an emergency application upon a continued reduction or depletion of brake-pipe pressure.

The equipment is, however, what may be termed solid as it permits of no change in features except in the graduated release which can be eliminated during the transition period.

As all brake devices must necessarily work in harmony if used in the same trains, the equalizing portion of the control-valve embodies triple-valve features, the brake-pipe reduction permits a pressure-chamber air to move the equalizing and release pistons, and flow to the application-chamber and application portion where it moves the application-piston and its attached valves, to admit service-reservoir pressure to the service-brake cylinder. A continued reduction or a sudden reduction causes these pistons to travel their full stroke and cause an emergency application, wherein, the emergency portion admits emergency-reservoir pressure to the emergency-brake cylinder, and the quick action portion transmits the reduction serially. The release is, of course, accomplished by the restoration of brake-pipe pressure.

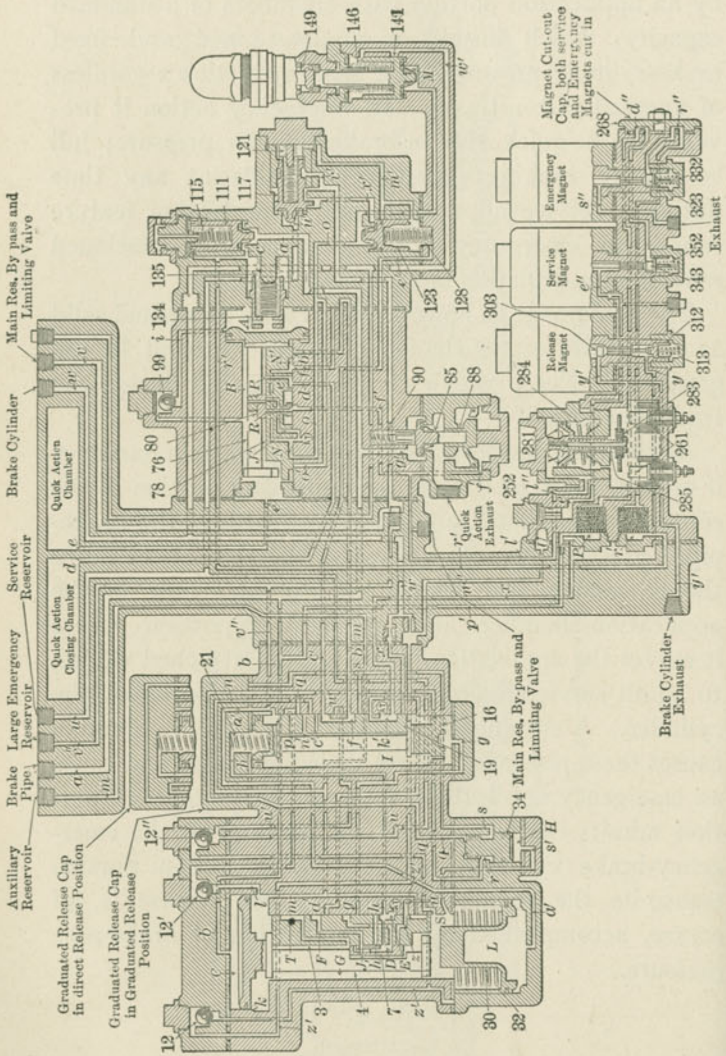



FIG. 32.—Type U Common Standard Universal Valve, Diagramatic



### U.C. EQUIPMENT

The U.C. (Universal Control) equipment is the first stage of the perfect passenger-car brake, and it will eventually be considered as necessary for passenger-cars as the E.T. brake now is for locomotives. This is a built-up type of brake, whereby any known improved feature can be added to those of the plain triple-valve, or rather by a system of addition, elimination and substitution of parts any single feature can be incorporated or dispensed with.

The principal improvements upon triple-valve operation are, certainty of application, positive to release or bleed itself off with an increase of brake-pipe pressure, and will not apply with less than a fixed amount of brake-pipe reduction. It absorbs no brake-pipe pressure during a release of brakes, gives the maximum possible rate of rise in brake-cylinder pressure in emergency, delivers any per cent. of braking power desired, contains a perfect graduation of release and all previous safety and protection features.

Full emergency braking power is available at any time during, or after a service application, and service and emergency features are entirely separated. It operates in perfect harmony with any type of triple-valve, can be used as a single or two cylinder equipment, and improves triple-valve operation whenever mixed with them in trains.

### U.C.—E.

The time element incident to the transmission of large volumes of compressed-air is the insurmountable obstacle to uniform operation with a strictly pneumatic

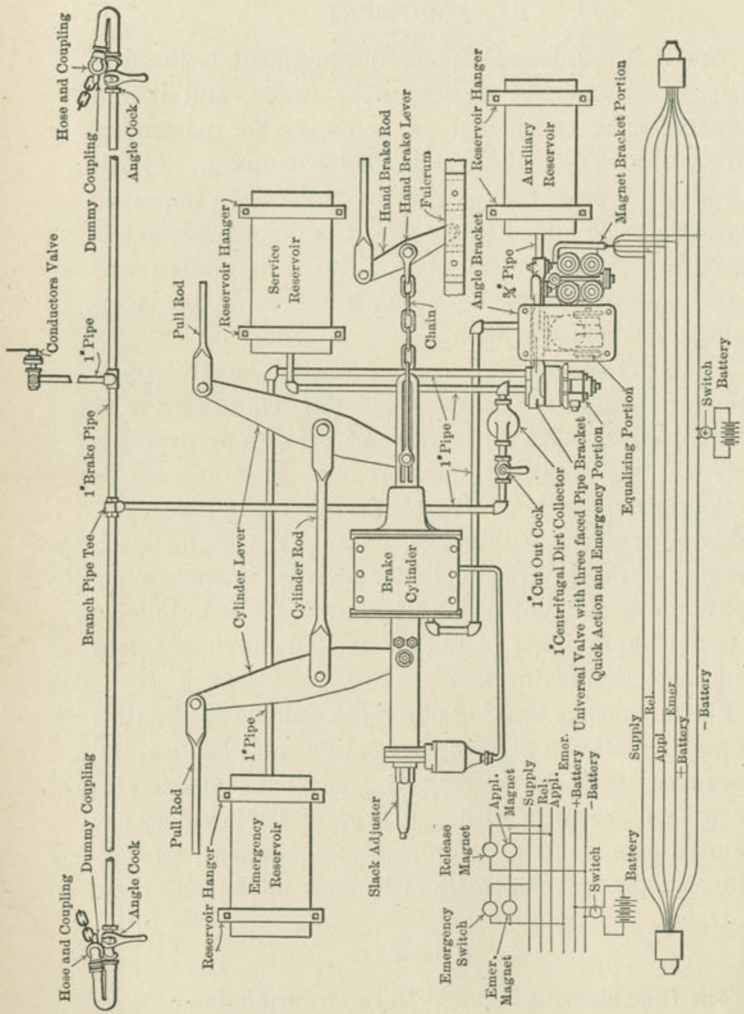



FIG. 33.—General Arrangement of the U.C. Brake



brake, hence the employment of electric current for the transmission of the application and release of brakes. When this is desired an electric portion is attached to the universal-valve and the locomotive-brake valve, and the application of brakes is not only simultaneous but instantaneous. A magnet controlling a magnet-valve causes the brake-pipe reductions at each universal-valve, and the release is controlled by similar magnets which prevent the escape of brake-cylinder pressure until running position of the brake-valve is used.

This is called the Electro-Pneumatic brake, and its use has increased the capacity of the Interborough Company's Subways about 33 per cent. It was perfected for steam-road service for the Pennsylvania R.R.

## OBJECT OF QUESTIONS AND ANSWERS

The foregoing is a mere mentiou of the brake apparatus used in present-day service, and while all of the equipments operate on the same general principle, it is obvious that a good general knowledge of them is absolutely essential to a correct manipulation, however, an exception may be noted in the Electro-Pneumatic brake where an entire train brakes as one car, nevertheless this brake is not as yet in general use in railroad service.

The following questions are not intended for examination purposes, but merely to simplify a multiplicity of technical instructions which are a prerequisite to proficiency in train handling. No attempt will be made to touch upon the construction, operation or disorders of the equipments as this matter along with instructions covering the correct methods of procedure in the event of failure of any part of the equipment, broken pipes, etc., will be found in the standard-air brake publications, these questions are intended for the fireman who is preparing himself for promotion and the engineer who wishes to keep in touch with recommended practices in train braking.

### QUESTIONS AND ANSWERS

1. What are you careful to observe in the way of brake inspection before taking a locomotive away from the engine-house?

*A*. That the air-pressures are correct, that the governor and feed-valve are reasonably sensitive to maintain them, that the brake-cylinder piston travel is correct, and that there is no noticeable leakage in the system.

2. Why are you particular about brake-cylinder leakage when the distributing-valve will maintain it?

*A*. Because excessive leakage may cause a heavy drain on the main reservoir at a time when all the main reservoir capacity may be needed for a release and recharge of train-brakes.

3. Why is standard piston-travel necessary if the braking power remains constant regardless of long travel?

*A*. It might become necessary to make the quickest possible release of the engine-brake with the independent brake-valve in the event of the driving-wheels picking up and sliding, and the longer the piston-travel, the longer the time required to exhaust the pressure from the brake-cylinders.

4. How would you test the feed-valve for sensitiveness?



*A*. Make a $2\frac{1}{2}$ or 3 pound brake-pipe reduction and see that the valve opens promptly and returns the gage-hand to the original figure of adjustment.

5. Would you try the automatic brake-valve before leaving?

*A*. Yes.

6. How?

*A*. By making a 5 pound reduction to see that this operates the distributing-valve, then a 20 pound application to see that 50 pounds brake-cylinder pressure is obtained after which the brake should be released with the independent-valve, then the independent-valve should be placed in slow application position and the automatic in running to note that 45 pounds will accumulate in the brake cylinders.

7. Is it necessary to make any further tests?

*A*. Some instructors specify a more rigid test, but tests to locate different slide-valve leakages, rotary-valve and gasket defects should be made by the air-brake inspectors.

8. Why are you particular to make a release with the independent-valve when the automatic-brake is applied?

*A*. To know that the independent-brake valve exhaust-port is not obstructed, and that the application-cylinder and release-pipes are not wrongly connected.

9. Would the brake release under this condition if these pipes were crossed?

*A*. No.

10. Would the instructor excuse you if you were to flatten the driving-wheel tires on account of this wrong connection?

*A*. No. He would likely say that even if they were crossed, you should have thought fast enough to quickly close the stop-cock under the brake-valve and place the automatic-valve in running position to make a release under this condition.

11. In connection with the subject of driving-wheel tires, why is it necessary to know that the feed-valve and application portion of the distributing-valve are sensitive?

*A.* Because if they are not, and the brake-cylinders and pipe-connections are tight, variations in brake-pipe pressure may result in a number of movements of the distributing valve which might build up enough brake-cylinder pressure against a sticky application-piston to move the pistons out of the cylinders and draw the shoes against the wheels, and overheat and loosen the tires without any brake-cylinder pressure showing on the gage.

12. Is this of frequent occurrence?

*A.* No, but is by no means unheard of.

13. Would you be excused for a case of loosened tires if you could prove that this condition of the distributing-valve did exist?

*A.* Not likely, as the instructor would take the stand that the engineer should know the distributing-valve to be sensitive enough to graduate brake-cylinder pressure out of the cylinders in about 5 pound steps, and if in this condition, the application portion will not have frictional resistance enough to cause the failure to release mentioned.

14. How would you handle the engine in coupling to an uncharged freight-train?

*A.* Make one or two heavy applications with the automatic-brake valve and leave the handle on lap while the hose are being coupled.



15. Why?

*A.* To have a reduced pressure-chamber so that there will be no brakes sticking on the engine if a prompt movement of cars is necessary.

16. After the hose are coupled, what position of the brake-valve is used to charge the train?

*A.* Full release position.

17. When should the valve handle be brought to running position?

*A.* When the brake-pipe pressure is very nearly up to the adjustment of the feed-valve.

18. Why do the compressors stop if the brake-valve is brought to running position while charging a train?

*A.* Because the auxiliary reservoirs absorb brake-pipe pressure faster than main reservoir pressure can expand through the feed-valve into the brake-pipe. The difference in these pressures then unseats the diaphragm valve of the excess pressure-governor.

19. How long will the compressor remain shut down?

*A.* Until the main reservoir pressure reduces to a figure within 20 pounds of the pressure in the brake-pipe.

20. In pumping up a train, how do you know when it is about charged?

*A.* By the position of the gage-hands and the slowing down of the compressor.

21. How could you make a test for brake-pipe leakage?

*A.* Make a 7 or 8 pound reduction and watch the fall of the hand of the brake-pipe gage.

22. What is meant by application and reduction?

*A.* An application dates from the brake-valve movement to the return to release. An application may consist of any number of reductions.

23. After waiting a reasonable length of time in charging the train, what would you think wrong if the pumps stopped every time the brake-valve handle was brought to running position.

*A.* That brake-pipe leakage was in excess of the capacity of the feed-valve.

24. What would you do if the train crew was then to inform you that there was no unusual leakage to be found in the brake-pipe?

*A.* Make a test of the feed valve to know that it is able to deliver the usual amount of compressed-air.

25. How?

*A.* By closing the brake-valve cut out cock and opening the brake-pipe to the atmosphere at the rear of the tender, then release the engine-brake, and with the pressures at 70 and 90 open the brake-valve cut out cock and note the fall of main reservoir pressure.

26. With the ordinary main reservoir capacity of from 70,000 to 80,000 cubic inches, how long should it take for the pressure to fall from 70 to 90 pounds?

*A.* About 30 seconds.

27. What would you think wrong if the governor would not hold the compressor shut down during this test?

*A.* It would indicate that there was a restriction in the brake-valve, or in the brake-pipe, and that because of it, feed-valve pipe pressure was being maintained.

28. What would you do if the feed-valve was working at about its maximum capacity according to the test?



*A.* Insist that the brake-pipe leaks be tightened to a degree that the feed-valve will be enabled to maintain it.

29. What would you do if it took 45 or 50 seconds for the pressure to fall from 90 to 70 pounds?

*A.* Take the engine back to the shop.

30. Why not clean the feed-valve yourself?

*A.* The trouble is not likely to be in the feed-valve, and even if it is, it takes a drill-press to remove a restriction and sometimes necessitates a removal of the supply-valve bushing.

31. Why not proceed with the brake-valve in release position?

*A.* It would not conform to rules of safety first, the train might be parted en route, and with the large capacity compressors the pressure on the engine might be held up to the standard, for the brake-pipe with the angle-cock on the rear end open and the large locomotive would haul a fair-sized train even if a number of the brakes at the rear-end remained applied.

32. If the feed-valve action during the test indicates that the pressure is leaving the main reservoir in a sufficient volume, do you still insist that the leaks be tightened and refuse to leave with the brake-valve in release position?

*A.* Yes. With a leakage that the feed-valve cannot maintain, a fixed reduction of brake-pipe pressure could not be made as this leakage would continue the reduction to a full service application.

33. After the brakes have been tested according to standard instructions and you have pulled the train out of the yard, what do you do if you feel the brakes dragging?

*A*. Make a quick movement to release and back to running position.

34. Why a quick movement?

*A*. To kick off any brakes that may have applied through some temporary irregularity without overcharging the brake-pipe.

35. Do you ever make a few of these movements to release just before ascending a grade to be sure that the brakes are off?

*A*. Under no circumstances except in an actual case of brakes sticking, as several of these movements would be sure to overcharge the head auxiliares and likely result in an application and stall the train.

36. What should be done as soon as the train tips over the summit of the first hill?

*A*. Make a 7 or 8 pound reduction to know that the brakes are holding and that no angle-cocks have been turned.

37. What do you do if you notice that the compressor has stopped for an unusual length of time?

*A*. Notice the positions of the gage hands.

38. What would you think wrong if the hands were more than 20 pounds apart and the brake-pipe hand somewhat below the point of feed-valve adjustment?

*A*. That the stoppage was due to an irregularity of the feed-valve.

39. What if you then moved to release position and the compressor would not start?

*A*. It would indicate that the feed-valve was stuck shut.

40. Why would the compressor remain at rest with the brake-valve in release position?



*A*. Because in release position the feed-valve pipe would receive no supply if the feed-valve was stuck tight shut and the governor diaphragm-valve would be unseated.

41. How would you then keep the compressors in operation, assuming that they again stopped with the hands more than 20 pounds apart, and the brake-pipe pressure still below the standard of feed-valve adjustment?

*A*. Move the brake-valve handle far enough toward release position to partly open, the warning port, in this position the feed-valve pipe will be supplied from the main reservoir and with a little observation of the gage, the handle can be regulated to a position where the brake-pipe leakage will be maintained without keeping the handle in full release position.

42. Suppose that by moving the handle to release position main-reservoir pressure had lowered and brake-pipe pressure had increased until the hands were less than 20 pounds apart and the compressor would not start, what would you then think was wrong?

*A*. That the governor was at fault, or the compressor broken down.

43. What would you first do?

*A*. Move the brake-valve handle to lap position.

44. Why?

*A*. To eliminate the excess pressure top from the disorder, by holding the main reservoir pressure away from it for a sufficient length of time for the compressor to start.

45. What would you then do if the compressor started and stopped every time the handle was returned to

running position, the gage hands still being less than 20 pounds apart?

*A*. Hold the handle in lap position long enough to put a blind gasket in the excess pressure operating pipe.

46. What if the compressor would not start with the brake-valve in any position, and less than standard pressure on the engine?

*A*. Proceed according to standard instructions governing the location of pump and governor troubles.

47. If you found the compressor broken would you attempt to make any repairs?

*A*. Not on the main line of a railroad, and especially not the duplex or cross-compound.

48. Reverting to the subject of train handling, what causes shocks to trains during brake applications?

*A*. Differences in speed between various portions of it.

49. What permits this difference in speed?

*A*. Slack in the coupling.

50. About how much slack is here in a 100-car train?

*A*. About 50 feet.

51. What is the chief consideration in freight-train braking on an approximately level track?

*A*. To stop the train without shock or damage regardless of the distance required.

52. What is the secret of smooth train handling?

*A*. Ability to control the slack action.

53. From a viewpoint of smooth handling only, what would be the ideal stop with a freight-train?

*A*. Close the engine-throttle and allow the train to drift to a stop.

54. What is the next best?



*A*. Gently catching up the slack with a very light application of the independent-brake and allowing the engine to stop the train.

55. Why is it contrary to instructions to use the independent-brake in stopping a train?

*A*. Because an engineer who does not thoroughly understand the art of train-braking would do more damage with it than if it was entirely ignored.

56. What is the effect of a heavy application of the independent-brake?

*A*. A quick change of speed of the engine and a run in from the rear which tends to wreck the train.

57. Allowing the train to drift to a stop or stopping with the independent-brake is not train-braking, therefore what is the best kind of an application to use in stopping freight-trains on a level tracks?

*A*. As a general proposition, with lightest reduction that will run through the train and apply all the brakes.

58. What if the train is running at a high rate of speed?

*A*. Follow with another reduction that will bring the speed down to 18 or 20 miles per hour, then release and recharge for making the stop.

59. How would the next application be made?

*A*. With the same light initial reduction, made far enough away from the point of the desired stop to allow this reduction to make the stop, when the speed is down to a point where the train will stop within an engine length, another somewhat heavier reduction should be made, but not to assist in shortening the stopping distance.

60. What is the idea?

*A*. To bring the train to rest while the brake-valve is discharging air and building up braking power at the head-end.

61. How will the actual stop then be made?

*A*. With one application but two reductions, the last reduction to have no bearing whatever upon the length of stop.

62. What is the object of making a very light initial reduction?

*A*. Not to build up enough braking power in any part of the train to break the couplings.

63. About how much reduction would be required at the brake-valve to run through a 100-car train of about one-half K triples?

*A*. From 6 to 8 pounds.

64. If all were H valves?

*A*. It would require 10 or 12 pounds to obtain any material braking force at the rear portion of the train.

65. What is the most important observation to be made with regard to slack action on the initial reduction of the first brake application?

*A*. To note which way the slack runs.

66. What do you conclude if it runs out, or to the rear?

*A*. That the greater percentage of braking power is at the rear-end.

67. What is meant by percentage of braking power?

*A*. The retarding force of the brake as compared with the total weight of the car.

68. What is meant by the nominal per cent of braking power?

*A*. The calculated brake-shoe pressure as compared with the light weight of the car.



69. Where is the actual per cent found?

*A*. In the measure of retardation obtained between the wheel and the rail as compared with the weight of the wheel on the rail.

70. What is meant by co-efficient of friction?

*A*. The actual pull of the shoe tending to stop the rotation of the wheel, in other words, the pull on the brake-beam hanger.

71. How does this frictional force vary?

*A*. With a constant force acting on the shoe, it can increase only with a decrease in the speed of the wheel, but decreases with an increase in the force pressing the shoe against the wheel, with an increase in the length of time the shoe is held against the wheel, and with an increase in the speed of the wheel.

72. With two 100,000 capacity cars, one empty and the other loaded, about how much more per cent of braking power has the empty car than the load, with the same brake-cylinder pressure?

*A*. About 400 per cent.

73. Then if both cars are started off at the same speed and with the same braking force in pounds pressure, how much further would the load run than the empty before it could be stopped by the brake?

*A*. Roughly speaking about 4 times as far.

74. What does this indicate on a grade?

*A*. That the empty car in descending may stop in a certain distance from a full application of the brake while the load might not stop until it has passed the foot of the grade.

75. Considering this, what is the most difficult make up of train to handle without serious shock, on a level track?

*A*. One of loads and empties, with the empties behind the loads.

76. In making a brake application on a train of this kind, which way would the slack run?

*A*. Out or to the rear.

77. Knowing from the make up of the train that the slack will run out what can be done to prevent it from running out harshly?

*A*. Make the initial reduction before closing the engine throttle.

78. What is the object?

*A*. To keep the train stretched so the slack cannot run out hard.

79. From an air-brake point of view could the train be made up to handle better?

*A*. Yes, by placing a certain per cent of the empty cars ahead of the loads.

80. Why is the next reduction made within an engine length or say 40 feet of the point at which the initial reduction will stop the train?

*A*. To get all the braking power possible on the loads just as the train stops, and to have the head-end stop before the reduction becomes fully effective on the rear.

81. This method can then be used with any make up of train?

*A*. Yes, if the worst make up can thus be successfully handled it will naturally serve for any better make up under ordinary conditions, and could be modified to conform to better conditions.

82. What if the make up of train was the reverse, that is with all the loaded cars behind?

*A*. The throttle would first be closed and the slack



bunched by a very light application of the independent-brake before the initial reduction was made.

83. Why?

A. Because with the loads behind a run in of slack would be expected, hence the slack would be gently gathered up to prevent any run in.

84. Then if empties and loads are mixed throughout the train and there is no way to estimate the direction the slack is going to run, how do you find out?

*A*. By looking for it on the initial reduction.

85. Why are trains of all empties or all loads easier to handle?

*A*. Because the slack can be bunched before the initial reduction as the brakes will start to apply on the head-end first, and thus tend to permit a run in of slack.

86. Would you in all cases use the light initial reduction?

*A*. Yes, in order to be on the safe side of any adverse track condition, or in cases of defective brakes having an influence in change of slack.

87. Would any allowance be made for a case of application when the rear-end of the long train happens to be in a reverse curve?

*A*. Yes. The effect of the curvature would be to add considerable braking power, or rather retarding force to the rear-brakes.

88. How is stop for water made?

*A*. With the light initial reduction made far enough away from the plug for it to stop the train, follow up with the second reduction as outlined, within an engine length of the place the stop will occur, and cut off the engine and run to the plug.

89. What if the speed is high?

*A*. Follow the light reduction with one that will bring the speed down, release and recharge for the stop.

90. How about pulling into a siding?

*A*. Use the same method; it is easier for the brakeman to walk a few hundred feet to open the switch than it is to drag up enough chain to get the train together again.

91. What is a good general rule to follow in this respect?

*A*. Attempt no spot stops with a long freight train.

92. How about backing a train into a siding?

*A*. It should be done in the same general way, but under ordinary conditions the application should be made while the engine-throttle is open and the engine-brake should be held off so as to offset so far as possible, the tendency of the slack at the rear-end to run out while the head-brakes are applying.

93. What should the train-crew do to assist the engineer in making a stop of this kind?

*A*. Set enough hand-brakes on the rear-end to hold the slack in.

94. How is the brake-valve handled in case of an emergency?

*A*. It is placed in emergency position and allowed to remain there until the train stops.

95. How is a release of brakes made after an application?

*A*. By placing the brake-valve handle in release position.

96. For what length of time?

*A*. It depends upon air-pump and main reservoir capacity, length of the train, type of triple-valves in



use and upon the amount of brake-pipe reduction that has been made.

97. Assuming an ordinary reduction on a 100-car train having both H and K triple-valves with the modern large air-pump and main reservoir capacity?

*A*. From 15 to 20 seconds.

98. Why not longer?

*A*. To avoid a heavy overcharge of brakes on the head-end.

99. Why not less than 15 seconds?

*A*. It requires 15 seconds in release to drive all of the K triple-valves possible into retarded release position.

100. Why should they be in retarded release position?

*A*. To assist the engine-brake in holding in the slack while the rear-brakes are releasing.

101. What would be the effect of a heavy overcharge at the head-end?

*A*. It might result in the brake going into quick action and wrecking the train.

102. Explain how this could occur?

*A*. If the brake-valve was allowed to remain in release position for 40 or 50 seconds, the H triple-valves at the head-end may become charged to nearly 100 pounds in the auxiliary reservoirs, while the rear-brakes have not yet had time enough to release, then if the brake-valve handle was brought to running position the drop in pressure at the head end of the brake-pipe due to the flow back to the uncharged cars may be rapid enough to cause a perfectly good triple-valve to work in quick action throwing all the charged brakes in with it. The brake-pipe and auxiliary remaining comparatively high on the head-end would not result in an application on the rear cars, and if it did it would be a light service so that the rear-end might run in hard enough to buckle the train.

103. What will occur at the head-end if the brake-valve is held in release position for 20 seconds on the long train?

*A.* A reapplication of brakes ahead.

104. Is this desirable?

*A.* No, but it cannot be avoided as it requires a high-pressure or driving head in the front-end of the brake-pipe to force the compressed-air back to release the rear-brakes.

105. How are the brakes then released after the reapplication?

*A.* By a second short movement to release, not over 2 or 3 seconds.

106. It is then possible to have a vast difference in pressure between the two ends of a long brake-pipe?

*A.* Yes, it is not unusual to have 90 or 100 pounds in the brake-pipe on the head-cars, and less than 50 on the rear ones. In fact, it is possible to pump the pressure up to standard on the head-end against an open angle-cock, if the brake-valve is in release position.

107. How long would it take for compressed-air under 110 pounds pressure to flow from the main reservoir through a 100-car train and issue from the open angle-cock on the last car?

*A.* About 20 or 25 seconds.

108. Under favorable conditions how long would it then take from the first movement of the brake-valve handle to release the rear-brakes?

*A.* At least one minute.



109. And under unfavorable conditions as to leakage and moderate sized compressors?

*A.* It might require two minutes or even more.

110. After an ordinary application, how long would you wait from the time of movement to release until opening the engine-throttle?

*A.* At least one minute and a quarter.

111. What would you expect to happen if you moved the valve to release position, released the engine-brake with the independent-valve, and opened the engine-throttle about 15 seconds afterward?

*A.* If the locomotive was powerful enough to get away there would likely be two or three sections of the train left?

112. Why would the train likely break in more than one place?

*A.* Because the first break would occur near the point that the brakes were still applied, then quick action would take place at the rear of those that were released which would likely result in another break in two and possibly still another from the same cause.

113. How long would you wait before opening the engine-throttle after having been cut off from the train for some time?

*A.* It would depend somewhat upon pump and main reservoir capacity, and the pressure shown on the brake-pipe gage after coupling up, even if the brake-pipe was considerably depleted, 2 or 3 minutes with proper pump capacity should effect a release.

114. What causes about 90 per cent of the slide flat-wheels in freight-service?

*A.* Starting the train before the rear-brakes have had time to release or in other words, starting cars with set brakes.

115. How do you estimate time required for brake operation on long trains?

*A*. In minutes instead of seconds.

116. When would it be advisable to use a watch in checking up this time?

*A*. When occupying the main track close upon the time of a first-class train.

117. Why?

*A*. Because at such a time 30 seconds seems like about 10 minutes.

118. Is schedule time then of secondary importance to careful operation in freight-train braking?

*A*. Yes, more time may be lost in attempting to hurry a train movement than if ample time was allowed for the release of brakes.

119. Why?

*A*. Because jerking the cars back and forth in trying to get enough slack to start the train will usually start an additional amount of brake-pipe leakage, and still further delay the release of brakes and even if the locomotive is powerful enough to start the train with part of the brakes applied, they will retard the speed to such an extent that no time would be gained in the total movement.

120. Why do air-brake men always emphasize the importance of allowing ample time for a release of brake before starting a train?

*A*. Because more wrecks and break-in-two of trains have been caused by disregarding these instructions than from any other single phase of incorrect train handling on level track.



121. What would be done if running at a low speed with the brakes applied and a signal was given to proceed?

*A*. Allow the train to come to a stop before releasing.

122. Can this ever be varied?

*A*. Yes, if there are enough K triples on the head-end to hold in the slack until the rear brakes release, it may be possible in some cases to get away without coming to a stop.

123. Suppose then that on a slightly descending grade the brake-valve has been in release position for about 15 seconds, what position is it moved to?

*A*. Holding position so that the engine-brake will be held applied with the K triples at the head-end.

124. What about releasing when the rear-end of the train happens to be rounding a sharp curve?

*A*. As a general proposition it should be avoided, as the sharp curve sets up a considerable amount of retarding effect.

125. How is the independent-brake to be handled in connection with train-braking?

*A*. When applied it is to be graduated on, and when released to be graduated off?

126. How does grade braking differ from braking on a level track?

*A*. Trains handled on heavy grades are usually very much shorter and the chief consideration is to hold the train against the possibility of a runaway.

127. What should be done before descending a heavy grade?

*A*. A standing test of brakes should be made according to the instructions covering brake operation on that particular division.

128. In descending, when should the first application be made?

*A.* As soon as the train tips over the summit of the grade.

129. About how much reduction?

*A.* About 7 or 8 pounds.

130. What should be particularly observed at this time?

*A.* That the brake-pipe exhaust is of sufficient length for the number of cars in the train and that the brakes are holding.

131. Why will the brake-pipe exhaust be shorter with K than with H triple-valves?

*A.* Because K valves use a considerable amount of brake-pipe pressure in the brake-cylinders leaving less volume to escape at the brake-valve.

132. What if the first reduction does not materially check the speed of the train?

*A.* Make a further reduction of 5 or 6 pounds.

133. What if this will not hold the train?

*A.* Make 5 or 6 more and call for hand-brakes.

134. What if the first reduction decreases the speed the desired amount?

*A.* Release and recharge.

135. How?

*A.* Move the handle to release position and leave it there until ready to re-apply.

136. Why?

*A.* To have a wide open port for recharge so as to deliver all the compressed air possible to the brake-pipe.

137. What will control the brake-pipe pressure?

*A.* The excess pressure governor top.



138. Why?

*A.* Because the feed-valve pipe will contain brake-pipe pressure as governed by the feed-valve and brake-pipe pressure can rise but 20 pounds higher than this.

139. Why is 20 pounds more pressure necessary for grade-braking? A. To provide a factor of safety by maintaining brake-pipe pressure above 70 pounds at all times for cases of emergency.

140. How is this best done?

*A.* By making the applications as light as possible and recharging as frequently as possible.

141. Will a 10 pound application give more brake-cylinder pressure from a 90 pound brake-pipe than from a 70?

*A.* No.

142. Why not?

*A.* Because the same number of cubic inches of free air leaves the auxiliary reservoir in each case.

143. How can a higher brake-cylinder pressure be derived from the 90 pound pressure?

*A.* By a full service reduction.

144. How much brake-pipe reduction is required to produce full service from 90 pounds brake-pipe pressure?

*A.* About 27 pounds.

145. From 70 pounds pressure?

*A.* About 20 lbs., but in either case 3 or 4 more pounds may be required on account of some unusually long brake-cylinder piston-travel.

146. How is the independent-brake handled in grade-braking?

*A.* It is graduated off as soon as the car brakes are felt to be holding well.

147. Why?

*A*. To prevent overheating the driving-wheel tires.

148. When is it reapplied?

*A*. Just before releasing and recharging the train-brakes.

149. What is the engine-brake then used for?

*A*. To assist in holding the train while the auxiliary reservoirs are being recharged for another application.

150. Why are damaging shocks not as likely to occur in grade-braking?

*A*. Because retaining valves, and possibly set hand-brakes on the head-end, tend to hold the train solid and prevent any rapid change in slack.

151. How is the brake-valve handled on the last application at the foot of the grade?

*A*. The brake-pipe pressure is reduced below the adjustment of the feed-valve, the handle returned to release position and then to running, or holding position, if required.

152. Would it be necessary to carry the handle in release position in descending a light grade?

*A*. No.

153. You understand then that the foregoing is intended in a general way, to refer only to the most severe conditions met or where the capacity of the brake is taxed to its utmost?

*A*. Yes.

154. Why is it that no air-brake expert will attempt to lay down any fixed rules for train-handling?

*A*. To state exactly how any air-brake stop can be made to the best advantage also necessitates an intimate knowledge of every local condition as to grade, curves and location of signals.



155. How does passenger-train braking differ from freight-braking?

*A*. Passenger-train handling demands a smooth and accurate stop, but a shorter brake-pipe, consequently less volume, permits of a more rapid movement of the brake valve handle for different operations.

156. In coupling to a passenger-train, is the governor operation the same as referred to in coupling to freight trains?

*A*. Yes, only that long passenger-trains are usually charged from a test plant before the locomotive is coupled, and at division points they are left practically charged by the incoming engine.

157. When the passenger-train is charged and a signal to apply brakes is given, how much brake-pipe reduction is made?

*A*. 25 or 30 pounds.

158. Upon the signal to release, how is it made?

*A*. Assuming a large air-pump and main reservoir capacity, and an ordinary train, the valve-handle should be placed in release position for about one second and then be returned to running position.

159. Why such a short time in release?

*A*. To prevent the possibility of an overcharge of auxiliary reservoirs which is a pretty serious matter especially with modern equipment.

160. After leaving the station, when will the first application be made?

*A*. If possible, within 1,000 feet of the terminal.

161. Why?

*A*. To know that the angle-cocks are open and that the brakes are holding.

162. How is this application made?

*A*. With a 10 or 12 pound reduction.

163. How is the independent-valve handled during this application?

*A*. It is held in release position.

164. Why?

*A*. To know that the retarding effect is not from the powerful locomotive brake.

165. Why make such a heavy reduction?

*A*. Because a release after the heavy reduction is more positive than after a light one.

166. Why?

*A*. Because the rate at which air will flow through the brake-pipe depends upon the difference in pressure between the main reservoir and the brake-pipe, and after a light reduction it is quite possible for the flow to the rear to be so slow that slight triple-valve packing ring leakage might charge an auxiliary reservoir near the rear without resulting in a movement of the triple-valve to release.

167. Would this not indicate that the brake-valve might be left in release position for more than 1 second?

*A*. No, as there may be an L triple-valve near the head-end that would charge an auxiliary reservoir as fast as the brake-pipe pressure can be raised, hence a longer time in release would overcharge this brake and result in a re-application and a stuck brake.

168. Can this time in release be varied?

*A*. Practically everything in air-brake practice *must* be varied to conform to some peculiar or unusual condition, therefore with a small main reservoir that will equalize with the brake-pipe below the adjustment of the feed-valve, the brake-valve could be left in release position until the brake-pipe gauge would show that brake-pipe pressure had risen nearly to the maximum.



169. How is a stop made from a high rate of speed?

*A*. With a 25 pound application to start with, which, however, may be at times made in two reductions, with a very short interval of time between, and when the speed has reduced to about 15 miles per hour release and make another application for the stop. If the train is of less than 10 cars, the brake can be released before coming to a stop but if more the brake should be held on to the stop.

170. What is the object of the heavy initial reduction?

*A*. To obtain a high brake-cylinder pressure when the speed is high and reduce it as the speed reduces. It also tends toward uniformity of braking power in spite of variations in piston-travel, as the higher cylinder-pressure from short travel would be blown away by the safety-valves and the reducing-valves, while the long travel brake-cylinders would be built up to the adjustment of the safety valves.

171. What about making a stop from a low rate of speed?

A. Never with less than a 12 pound application.

172. What if a 6 or 7 pound reduction stops the train at the desired point?

*A*. Make 6 or 7 pounds more after the train has stopped before releasing.

173. How is a stop made from high-speeds with solid L.N. equipment?

*A*. With the heavy reduction, and when the speed is reduced the brake can be graduated off as desired and with a little practice a very smooth one application stop can be made.

174. How is the graduation made?

*A*. From release to lap position for the first, thereafter from laps to running position.

175. At a moderate rate of speed, or with an exceptionally long train, how is the first application made?

*A*. With a split reduction.

176. What is the disadvantage of a split reduction?

*A*. It tends to lengthen the stop and thus consume a little more time, but results in a smoother stop.

177. What is the disadvantage of a very heavy initial reduction at low speeds?

*A*. It sets up the retarding effect too quickly and shocks the train.

178. At a very low speed, would you ever make less than 6 pound initial reduction?

*A*. No.

179. Why not?

*A*. Because control-valves and universal-valves are designed not to apply with less than a 4 or 5 pound reduction even when in perfect condition.

180. What would you expect to occur if the train happens to be stretched and a 4 or 5 pound reduction is made, and there are some control-valves on the rear?

*A*. A run in from the rear, and the conductors report that the independent-brake was used in making the stop.

181. Would the brake-valve ever be moved to release position when running along the road?



*A*. Not unless the brakes were felt to be sticking.

182. What if the sticking was primarily due to low steam?

*A*. Leave the valve-handle in release position until steam pressure was regained.

183. Why?

*A*. To add the main reservoir volume to that of the brake-pipe so that leakage in the brake-pipe would have to lower both pressures before an application could occur.

184. How would this tend to prevent a brake-pipe leak from applying the brakes?

*A*. Being compelled to reduce a great volume would require more time and a slower rate of reduction would give more time for the auxiliary reservoir pressure to expand through the feed grooves into the brake-pipe without applying the brakes.

185. When would the brake-valve be returned to running position?

*A*. When steam pressure is sufficiently regained to bring the air-pressure up to about the adjustment of the feed-valve.

186. What may be done to maintain the brake-pipe pressure while excess pressure is accumulating in the main reservoir?

*A*. An occasional quick movement to release and return to running position may be made, great care being taken not to overcharge the brake-pipe.

187. What are the chief causes of slid-flat wheels in passenger service?

*A*. Bad condition of rail, unequal braking power, and defective equipment, and incorrect manipulation of the brake-valve.

188. How can unequal braking power cause wheels to slide?

*A*. By momentarily creating differences in speed between various cars in the train.

189. How does the difference in speed cause it?

*A*. A car moving along at a uniform rate of speed with the brake applied, if jerked or pushed to a faster speed, the wheel cannot increase the speed of its revolution against the brake-shoe pressure the same instant that the car body changes speed, hence the adhesion of the wheel to the rail is broken and the wheel locked.

190. Why will heavy reductions at low speeds tend to cause wheel-sliding?

*A*. Because a greater brake-shoe friction is obtained at lower speeds, and as in the case of a bad condition of the rail the adhesion of the wheel to the rail may be broken.

191. Is wheel-sliding affected by very thin brake-shoes?

*A*. The thin shoe tends to a quick rise in temperature and momentarily a greater holding power which at times may result in wheel-sliding, but this same shoe is quickly overheated and then less braking force will be obtained than from the full sized shoe.

192. Given ample time, can a train be stopped on a bad rail without serious injury to the wheels from sliding?

*A*. Yes, but it also requires ample distance and sometimes several applications.

193. Then you understand that in making up time with short stops under all conditions of rail and weather you take a chance on rough stops and wheel-sliding?

*A*. Yes.



194. Is wheel-sliding to be considered in cases of emergency?

*A*. Failure to use the emergency-brake in actual cases of emergency might be construed to appear as criminal neglect, however, there is no doubt but that under some conditions of bad rail and low rate of speed, a shorter stop can be made with a prompt heavy service reduction than with the number of sliding wheels that would be the result of an emergency application.

195. How is an application to steady a train on a curve made?

*A*. Make the application and release before the train goes into the curve. Releasing brakes while the rear end of a long passenger-train is in a sharp curve is a very bad practice.

196. Are there any circumstances under which a series of light reductions are permissible?

*A*. About the only time it would be is in the event of a very rare occurrence in which the heavy reduction would produce undesired quick-action as in the case of a restricted service port in a triple-valve. The use of standard test racks has practically eliminated this disorder.

197. Why will the light reduction ordinarily tend to produce instead of avoid undesired quick action?

*A*. Light reductions tend to cause a slow movement of the triple-valve pistons and they may be stopped by considerable slide-valve friction, and in this position the feed-groove is closed and the auxiliary reservoir pressure bottled up so that by the time enough difference in pressure is obtained to dislodge the slide-valve it may jump against the graduation stem with sufficient force to compress the spring and work in quick action, whereas if the reduction had been heavy enough to move the slide valve as the piston was drawn against it, it would have moved to service position.

198. How many contributing disorders are there, that if working singly or in combinations, may produce quick action when a service application is intended.

*A*. About 45.

199. How would the brake be handled if quick-action occurred every time either a light or heavy reduction is made?

*A*. The train would be run in close to the point of stop and the brake-valve used in emergency position.

200. Why?

*A*. To start the emergency application from the head end, which is not particularly harmful when running at a high rate of speed.

201. Can the second engine in double-heading be of any assistance in charging a train?

*A*. A man with a good general knowledge of air-brakes and braking conditions would almost unconsciously cut in and assist until nearly the standard pressure is accumulated in the brake-pipe.

202. Would the second man ever cut-in to assist in re-charging when descending a grade?

*A*. No; because of the probability of interfering with the brake operation and the possibility of forgetting to again cut-out.

203. How can the second engineer render assistance during the release of brakes on a freight train in motion?

*A*. By placing the independent brake-valve on lap or in application position when the first brake-valve is



moved to release position, thus assisting the first engine and the type K triple-valves on the head end to prevent any rapid change in draw-bar slack.

204. How will the second man know when the brake-valve on the first engine is moved to release position?

*A*. By the escape of application-cylinder air from the distributing-valve through the automatic-brake valve and by the increase of pressure shown on the No. 2 air gage.

205. If the engine brake has been tested as previously outlined and has been found apparently correct in every operation, what could be wrong if the brake on the second engine would not remain applied upon an application from the first engine?

*A*. The graduating-valve of the distributing-valve may be leaking or some combination of pressure-chamber leakage may permit the equalizing-valve of the distributing-valve to be forced to release position.

206. Could there be any other cause of the brake releasing under this condition?

*A*. If the brake has not been tested as specified, the application-cylinder pipe and the release-pipe may be wrongly connected.

207. How can you tell the difference between the two disorders?

*A*. If the pipes are crossed, the application-cylinder pressure will escape through the automatic-brake valve during the reduction, and if the brake applies at all it will be very lightly applied and release as soon as the brake-pipe reduction ceases, whereas if the brake releases from graduating-valve or other pressure-chamber leakage, it will be applied with a degree of force proportionate to the amount of reduction and release a few seconds afterward.

208. Would you be considered responsible for the condition of a brake that would release on the second engine due to graduating-valve or equalizing slide-valve leakage?

*A*. No; the inspector should find this disorder during his test.

209. How is the test made?

*A*. By moving the automatic-brake valve to release position until the pressure-chamber is overcharge by 15 or 20 lbs., then making a 10 lb. brake-pipe reduction and returning the handle to running position. Under this condition, with both brake-valves in running position, the brake should remain applied and a release would indicate a disorder.

210. In shifting a few cars from the head-end of a freight train, the *K* triple-valves are forced to retarded-release position by a movement of the brake-valve to release position, thus sometimes delaying an otherwise prompt movement of cars. Could you release these brakes without forcing the triple-valves to retarded-release position?

*A*. Yes; by a quick movement to running position and back to lap or by a gradual movement from lap position to the shoulder between lap and holding positions or in fact by any admission of pressure into the brake-pipe that would not increase it more than 2 or $2\frac{1}{2}$ lbs. above the auxiliary-reservoir pressure which would permit these triple-valves to release at approximately the same rate as type *H* triple-valves.

# CHAPTER XVI

## ELECTRIC LOCOMOTIVES

### WHAT TO INSPECT AND HOW TO OPERATE

THE electric locomotive is fundamentally different from the steam-locomotive, in that it is not a self-contained power unit but receives its power from the central power source and transmitted to it through overhead wires or a third rail located adjacent to the running rail. Although there are, in reality, two distinct types of electric locomotives, the alternating current and the direct-current, they are similar with the exception of minor details and a general description will apply to all types. The boiler, the air pump, the throttle and the cylinders of the steam-engine are represented by the electric apparatus, the electrically driven air-compressor, the master controller and by the motors respectively of the electric locomotive.

Thus it is clearly seen that the inspection to be made by the engineer, previous to a run, is radically different from that made on the steam-locomotive with two or three exceptions, namely, the inspection as far as adjusting of grease-cups, oiling of driving-boxes, wedge, etc.; the inspection of the air-brake apparatus; and the mechanical parts such as tires, wheels, draft rigging, etc. On all electric locomotives of any capacity the mechanical construction follows, as far as possible, the steam-engine design; the draft rigging is usually standard and the air-brake apparatus a duplicate.

The electric locomotive possesses the great advantage in that it can be run for twenty-four hours a day, and day after day, with only a lay-up of from two to three hours after every fifteen hundred to two thousand miles for shop inspection. The design of the electrical apparatus is such that the inspection on the mileage basis by the shop-man is all that is necessary and all that is required of the engineer is to give the locomotive a general inspection as outlined below. For instance, the electric motors can all be oiled on the mileage basis and no oil should be added by the engineer.

The inspection of the electrical parts then narrows down to the following:

Before starting the motor-driven compressor by closing a hand operated switch, see that the cocks in the pipe leading to the electric governor are open. On a steam-locomotive the pump keeps the air-pressure practically at a constant-pressure. With the motor-driven compressor, the governor, which, in reality, is nothing more than an automatic-electric switch, is so adjusted that there is fifteen pounds difference between the opening- and closing-pressures. With a 110-pound brake-pipe pressure, the governor would be set to open the circuit to the motor of the compressor at 140 pounds main reservoir, and the governor would not close, thus starting the compressor, until the main reservoir pressure had fallen to 125 pounds. It is very essential that the cock be open, otherwise, the compressor will pump up to a very high pressure. The governor should be watched to see that it operates at the proper pressure.



The other necessary air-brake inspection is the same as that on the steam-locomotive.

If the locomotives are equipped with a small battery of 22 volts for operation of electric switches, used to connect power to the main motors, as is the case with all of the locomotives used on the New York, New Haven & Hartford Railroad, the Pennsylvania Railroad and several other railroads, then these batteries should be tested with a small lamp provided for the purpose to be sure that they are in good condition, the light burning dim if the batteries are not properly charged.

The various auxiliary apparatus should be tested such as sanders, light circuit, etc., and if the locomotive is fitted with overhead pantagraph trolleys and third-rail shoes, which can be operated, that is raised and lowered from the cab by means of the electric control-current from the battery, then these should be tested.

On practically all large electric locomotives a motor-driven fan is included for blowing air into, and through, the main motor so as to increase the capacity of these motors. These fans should be tested.

The operation of the electric locomotive is, in principle, the same as the steam-locomotive. It is as necessary that the master-controller be handled as carefully as the throttle so as not to cause damage to couplings, etc. The operation of the air-brake is identical with that on the steam-locomotive.

After releasing the latch, pull the controller-handle step by step, watching the electrical instrument, or ammeter, as it is called, so that the current to the main-motors will not exceed a safe value, until the correct speed is obtained. Due to the necessary apparatus required to control the electric locomotive, every notch on the controller is not a running notch as on the throttle, so that the handle must stop for a certain length of time only on certain notches which are always plainly indicated. It is very necessary in getting the train up to speed that the engineer must be limited *not* by the slipping point of the wheels, which is very high on electric locomotives, but by the amount of current being taken by the motors as shown on the ammeter. To safeguard the electrical apparatus from too fast notching, an electrical-safety valve or circuit-breaker, as it is called, is provided so that when electric current reaches a certain fixed amount it will cut off the main power automatically, and the engineer must throw off the controller before this breaker can be reset.

In the operation of electric locomotives, one important point should be borne in mind. The source of power is of unlimited amount when compared with the capacity of the locomotive, and the work an electric locomotive will do is unlimited providing that the power is fed to it. With the steam-locomotive, a self-contained unit, the maximum draw-bar pull depends upon the diameter of cylinders and the boiler-pressure, both fixed quantities, and it is impossible to overload the engine. In the case of the electric locomotive the work done depends upon the amount of power delivered to the motors, and as this power is practically unlimited the electric locomotive can be overworked, resulting in burned up motors and electrical apparatus. In other words, an electric locomotive will not stall but will continue to work until it burns itself up. This point has not been realized by all steam-operating men, they



going on the assumption, which is true for steam-operation, that any load the locomotive will haul is a safe load.

In general, every employee whose duties are in any way connected with the operation or maintenance of electric locomotives, should have a knowledge of the electrical apparatus. Engineers should familiarize themselves with the name, location and purpose of all of the apparatus, and should know, in general, the principles upon which the operation of the various apparatus depends, the manner in which it should be operated and method of procedure in case of failure.

## CHAPTER XVII

### TRACTIVE POWER AND TRAIN RESISTANCE

#### HOW TO CALCULATE THE POWER OF LOCOMOTIVES

THE practice of tonnage-rating, which has been steadily growing in favor for the last few years, has set many officials, outside of the mechanical departments, to figuring upon the power of locomotives, and on the trains all kinds of engines ought to haul over certain divisions. To meet this demand I have determined to write particulars by which any man, knowing the first four rules of arithmetic, can figure out for himself the tonnage that any locomotive can haul on any grade or curve. The information to be given is found in other engineering-books, but many railroadmen do not know where to look for the technical data they need.

#### HORSE-POWER OF STEAM-ENGINES

The power capacity of steam-engines is generally expressed in horse-power, which is a measurable quantity and is based on the arbitrary measure of one horse-power being equal to the effort of raising 33,000 pounds one foot per minute. That is the unit used for measuring the power transmitted by nearly all kinds of prime motors and machines. It is sometimes applied to locomotives, but for a variety of reasons the horse-





power capacity of a locomotive does not convey to the ordinary railroad mind its capacity for hauling different kinds of trains. The utility of a locomotive for train-pulling has to be expressed in a different way.

#### HOW PRACTICAL RAILROADMEN ESTIMATE POWER OF LOCOMOTIVES

When practical railroadmen know the size of cylinders, the diameter of driving-wheels, the weight resting upon them, and the boiler dimensions, they understand what kind of service the engine is adapted for, and in a general way what weight of train it will haul. A general idea of power is, however, a guess which may be considerably away from the truth. Guessing is not a good basis for designing or estimating the power of a locomotive, and so methods have been devised for figuring out the power and speed that certain dimensions will develop which are as correct and reliable as any other engineering rules. It has become customary to reckon the power of a locomotive by the tractive force the driving-wheels will exert upon the rail—that is, the resisting weight which the engine will start from a state of rest.

#### ADHESION AND TRACTIVE POWER

The tractive force is the power which the pistons of a locomotive are capable of exerting through the driving-wheels to move engine and train. The efficiency of the engine's tractive power is dependent upon the adhesion of the wheels to the rails. When adhesion is insufficient, the power transmitted through the pistons and rods will slip the wheels, and no useful effect will result. To prevent the slipping of locomotive driving-wheels, it is necessary to put resting upon them at least four times in weight the force available for turning them. If the weight is five or six times the piston power, the engine will do its work with less annoyance from slipping than would be the case with less weight. To prevent slipping on unwashed, greasy rails, more than double the adhesion would be necessary for that required on dry, clean rails. This cannot often be done, but the sand-box provides the means for obtaining adhesion when the rails are in bad order.

### FIGURING PARTICULARS OF TRACTIVE POWER

Let us calculate the tractive power of the kind of engine most commonly used for hauling heavy passenger- and fast freight-trains, which has cylinders 19×26 inches, driving-wheels 69 inches diameter, with a working-pressure of 200 pounds to the square inch. The method by which the traction of a locomotive is calculated is to square the diameter of the cylinders in inches, multiply that by the length of the stroke in inches, and divide by the diameter of the driving-wheels in inches. The product of that sum will be the power exerted by the engine for every pound of pressure that reaches the cylinders from the boiler. A rule established by the Railway Master Mechanics' Association makes out that 85 per cent of the boiler-pressure is a fair average of what pressure will be available in the cylinders at slow speed.

Follow that rule and the formula whereby we have



described the method for finding out the tractive power of this particular locomotive would be

$$T=\frac{d^2Lp}{D},$$

which means

$d$ = diameter in inches squared;
$L$ = the length of stroke in inches;
$p$ = the mean effective pressure on piston;
$D$ = the diameter of the driving-wheels in inches;
$T$ = the equivalent tractive force at the rails in pounds.

To apply this rule in practice, we find that $d^2$ means multiply 19 by itself, or square, so we have 19×19 = 361×26 (the stroke in inches) = 9386×170 (mean effective pressure) = 1,595,620÷(the diameter in inches of driving-wheels) = 23,125. This gives 23,125 pounds as the power exerted at the circumference of the wheels, from which a deduction of about 10 per cent. is usually made for internal friction. We have assumed the boiler-pressure to be 200 pounds and have used 85 per cent. of it.

The formula described seems at first sight theoretical, and not based on a good philosophical foundation; but it is merely a short way, and agrees in results with more detailed methods of calculation. It agrees with another plan which is more in favor with civil engineers. That is, to ascertain the foot-pounds of work the engine is doing during each revolution of the driving-wheels. By dividing the total thus found by the circumference of the drivers in feet the force exerted through each foot which the engine moves is found.

### CIVIL ENGINEERS' METHOD OF CALCULATING TRACTIVE POWER

Taking the same engine that we have figured on, with pistons 19 inches diameter, the area of one piston is 283.5294 square inches. This is multiplied by the mean average pressure of the steam, giving 283.5294 $\times$ 170 = 48,199.9980, which gives the aggregate pressure exerted by the steam on one piston. Multiplying that by 2 to take in both pistons, we have 96,399.9960 $\times 4\frac{1}{3}$ feet (the stroke moved in a full revolution of the driving-wheels) = 417.733.3160 ÷ 18.0642 (the circumference of the driving-wheels in feet) = 23,125 pounds tractive force, the same as by the other rule.

There are several other methods of calculating locomotive tractive-power, but they need not be described, as they bring precisely the same figures as those found.

### FINDING THE HORSE-POWER OF A LOCOMOTIVE

When people wish to find the horse-power developed by a locomotive at various speeds, the steam-engine indicator is usually employed to show the mean effective pressure inside of the cylinders. To explain the process to be followed, we will draw on our own experience with a representative locomotive pulling a fast passenger-train.

The writer took indicator-diagrams to find out the amount of work done by the locomotive in taking the Empire State Express over the New York Central Railroad. The details were published in *Locomotive Engineering*, June, 1892. A very common speed was



60 miles an hour. The engine had cylinders 19 $\times$ 24 inches, and driving-wheels 78 inches diameter. The indicator-diagram proved that the average cylinder-pressure at 60 miles an hour was 53.7 pounds per square inch. The horse-power is calculated in the following manner:

283.5294 square inches piston area;
53.7 pounds M.E. pressure;

---

15,225.5 pressure on one piston;
2 pistons;

---

30,451 pressure transmitted from both cylinders;
4 feet piston-travel in each revolution;

---

121,804
260 revolutions per minute;

---

31,669,040 ÷ 33,000 = 959 horse-power.

That method of calculation, of course, applies to all locomotives, and can be used when the area of piston, revolutions per minute, and mean effective cylinder-pressure are known.

In the case recorded the mean effective cylinder-pressure was little more than 33.5 per cent of the boiler-pressure. When the same engine was running at 37.1 miles an hour, making 160 revolutions per minute, the M.E.P. was 59.2 pounds, and 37 was the percentage of boiler-pressure. At 20 revolutions per minute the mean effective pressure would be little short of the 85 per cent of boiler-pressure of the master mechanics' rule, but it would gradually decrease as the piston-speed increased.

The work that a locomotive has to do in pulling a train is described under the heading of Train Resistances.

### TO CALCULATE THE POWER OF COMPOUND LOCOMOTIVES

To calculate the tractive power of compound locomotives, it is necessary first to know what the mean effective pressure on the pistons is in every case, and any attempt at a theoretical exposition of the methods for arriving at this information by calculation is very unsatisfactory and inaccurate, for this reason: In the case of the two-cylinder compound there are too many unknown quantities, among which are the volume of receiver, pressure of live steam through reducing-valve, and the amount of back-pressure. In the case of the four-cylinder compound there is no receiver, but the element of back-pressure is present on the high-pressure piston. For these reasons calculated pressures are not reliable for finding the power of this type of engine. The indicator furnishes the means to arrive at the correct mean effective pressure, and the formula for a two-cylinder compound when the mean effective pressure is known is

$$\frac{d^2 \times \text{M.E.P.} \times s}{2 \times D},$$

in which $d^2$ = diameter of low pressure squared, M.E.P. = mean effective pressure, $s$ = stroke in inches, and $D$ = diameter of driving-wheel. In the absence of indicator-cards showing cylinder-pressures for a given boiler-pressure, approximate results may be had by



taking the mean effective pressure in the high-pressure cylinder at 70 per cent of boiler-pressure, which for 200 pounds boiler-pressure would be 140 pounds. If the reducing-valve gives steam to the low-pressure cylinder so as to equalize the work on both the pistons, the low-pressure cylinder will have a mean effective pressure of about 60 pounds for a ratio of cylinder of 2.3, which is the ratio between 23- and 35-inch cylinders. Referring the mean effective pressure to terms of the low-pressure cylinder, we have

$$60 + \frac{140}{2.3} = 60 + 61 = 121 \text{ pounds.}$$

Placing the values in the formula, the tractive power equals

$$\frac{35^2 \times 121 \times 32}{2 \times 55} = 43{,}120 \text{ pounds.}$$

If a deduction of 7 per cent for internal friction is made, the net tractive power is about 40,000 pounds. The tractive power of the four-cylinder compound is also found by taking mean effective pressures known to have been found in service. These may be taken at 44 and 46 per cent of the boiler-pressure for the high- and low-pressure cylinders, respectively, which for 200 pounds gauge-pressure equals 88 and 92 pounds mean effective pressure. Taking, for an example, an engine with high-pressure cylinders 18 inches diameter, low-pressure cylinders 30 inches diameter, stroke 30 inches, and diameter of drivers 55 inches, the ratio of cylinder areas is 2.77; and again referring the pressures to the low-pressure cylinder we have $92 + \frac{88}{2.77} = 123$ pounds mean effective pressure in the low-pressure cylinders. Placing these values in the formula, which in this case is somewhat different from the other, owing to the fact that there are now two cylinders to consider instead of one, we have

$$\frac{30^2 \times 123 \times 30}{55} = 60{,}300 \text{ pounds.}$$

Taking out 7 per cent for friction, as before, the tractive power is about 56,000 pounds. For their four-cylinder compounds the Baldwin Locomotive Works take $\frac{2}{3}$ of the boiler-pressure for the mean effective pressure in the high-pressure cylinder, and $\frac{1}{4}$ for the mean effective pressure in the low-pressure cylinder; for two-cylinder compounds take $\frac{2}{3}$ of the boiler-pressure for the mean effective pressure for the high-pressure cylinder. The variation between high- and low-pressure cylinders in the two-cylinder type will, of course, be compensated by the reduced mean effective pressure in the low-pressure cylinder.

### RESISTANCE OF TRAINS

The work which a locomotive performs in pulling a train is expended in overcoming the resistance due to wheel-friction, gradients, curves, and atmospheric or wind pressure. Ever since railroad trains began to be operated, engineers have been striving to devise formulæ for showing the train resistance at various speeds. From what we have found out in investigating this subject we do not believe that it is possible to devise a formula that will show an approximation of the resistance due to different kinds of trains at different speeds when train-tons are the basis of calculation.



The character and the load of the cars have a decided influence upon the resistance per ton of the train. Thus records made on the Chicago, Burlington & Quincy by the aid of the dynamometer-car and indicator-diagrams taken from the locomotive showed that with a train of loaded freight cars weighing 940 tons, running at a speed of 20 miles an hour, the average resistance on a straight, level track was $5\frac{1}{2}$ pounds to the ton. A train of empty freight cars weighing 340 tons run at the same speed showed an average resistance of about 12 pounds to the ton.

There is good reason for believing that the heavier the cars in a train are loaded the smaller the ton resistance is, just as was cited in the case of the loaded and empty cars. A particularly heavy train of freight cars, weighing, with engine and tender, 3428 tons, pulled over the New York Central, to test the power of a new type of locomotive, indicated that the resistance at 20 miles an hour was about 4 pounds per ton.

I have collected a great mass of information concerning the resistance of trains, and careful study of the facts convinces us that to show an approximation of the resistance of different kinds of trains it is necessary to treat every one separately.

Nearly all railroads rate the power of locomotives to haul trains according to some formula which is supposed to indicate the resistance of trains or of cars to motion. The oldest formula of train resistance was worked out in the infancy of railway operation by Daniel Kinnear Clark, a Scotch engineer who had devoted much attention to railway problems. Clarks' formula is,

$$\frac{V2}{171}+8=R$$

That is, V representing miles per hour and R resistance per ton. The rule stated in words is: Square the velocity in miles per hour, divide this by 171 and add 8 to the quotient, the result being the resistance at the draw-bar in pounds per ton. American engineers finding that the rule made the resistance more than the fact, substituted 6 for Clark's 8. This formula is still used but it is merely an approximation of the train resistance.

Years ago when Angus Sinclair was a locomotive-engineer he directed attention to the train loads handled and found that applying Clark's formula for train resistance, many of the engines pulled trains that was much heavier than their power made possible.

In 1887 Dr. Sinclair made a series of tests of locomotives belonging to the Burlington, Cedar Rapids & Northern Railway, pulling their limit of freight trains. The resistance of loaded cars varied from 5 to 7 pounds per ton at a speed of 20 miles an hour, and the resistance of empty cars at the same speed varied from 11 to 13 pounds per ton. The impression was received when these tests were going on that no hard and fast rule could be established for train resistance, the condition of each car and that of the track bringing in so many variables that no correct formula could be established. It is certain that the old rule holding that the train resistance increased with the square of the velocity is worthless.

In 1892 Angus Sinclair made a series of tests of locomotives pulling the Empire State Express to ascertain as accurately as possible the power required to pull the train at different speeds. When the record of these



tests was published, Arthur M. Wellington, a well-known civil-engineer who had devoted particular attention to train resistance wrote:

"The observations are among the most important evidences on record of the actual resistance of trains at high speed. Perhaps we might go farther and say that

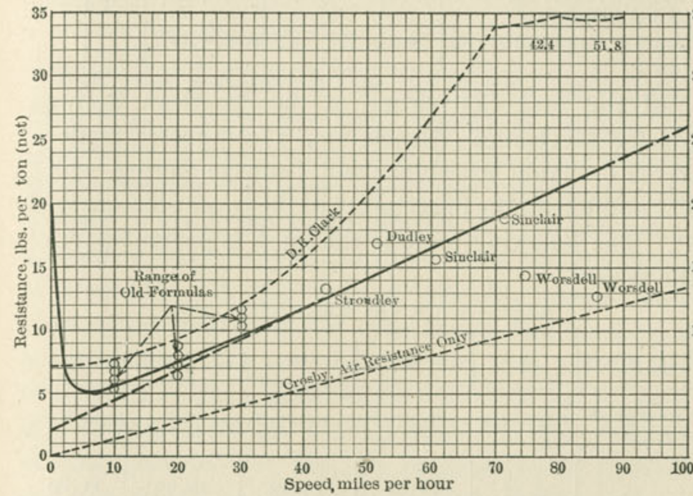



FIG. 34

they are the most important, especially as they are reasonably consistent with the mean of the few other records which have been obtained for speeds of 50 to 75 miles an hour, while presumably far more trustworthy and decisive than any prior records. As such they are a real contribution to technical knowledge."

From the data concerning train resistance obtained, Mr. Wellington plotted the annexed diagram. Fig. 34.

From the facts which we have obtained from dynamometer-car records and other sources that may be relied on as being as nearly correct as the subject will admit of, we have framed the following table:

RESISTANCE PER TON OF 2000 POUNDS

| Miles per hour | 10 | 20 | 30 | 40 | 50 | 60 | 70 |
|---|---|---|---|---|---|---|---|
| Sinclair for heavy passenger train | 4.5 | 6 | 9.5 | 12 | 14 | 17 | 19 |
| Vauclain | | | | | 11 | 13 | 15 |
| Loaded freight cars | 4 | 5.8 | 9.2 | 11.3 | 12.5 | | |
| Empty freight cars | 6 | 7.5 | 11 | 14 | 17 | | |

At the 1914 Convention of the American Railway Master Mechanics' Association, a committee made a report on Train Resistance and Tonnage Rating, which was notable for the uncertainty of the conclusions arrived at. The following table is the most important part of the report:

RESISTANCE OF FREIGHT CARS

| Speed M.P.H. | 6 | 10 | 15 | 20 | 25 |
|---|---|---|---|---|---|
| Weight per Car, Tons. | Resistance per Ton in Pounds from Tests on Penna. Lines West. | | | | |
| 15 | 9.55 | 10.00 | 10.30 | 10.90 | 11.80 |
| 20 | 8.60 | 9.05 | 9.40 | 9.90 | 10.75 |
| 25 | 7.80 | 8.20 | 8.60 | 9.05 | 9.80 |
| 30 | 7.10 | 7.45 | 7.85 | 8.25 | 9.00 |
| 35 | 6.50 | 6.85 | 7.20 | 7.65 | 8.30 |
| 40 | 6.00 | 6.25 | 6.60 | 7.00 | 7.65 |
| 45 | 5.55 | 5.75 | 6.10 | 6.50 | 7.10 |
| 50 | 5.10 | 5.35 | 5.65 | 6.05 | 6.60 |
| 55 | 4.80 | 5.05 | 5.30 | 5.70 | 6.20 |
| 60 | 4.50 | 4.70 | 5.00 | 5.40 | 5.85 |
| 65 | 4.25 | 4.45 | 4.75 | 5.10 | 5.55 |
| 70 | 4.05 | 4.25 | 4.50 | 4.90 | 5.35 |
| 75 | 3.90 | 4.10 | 4.35 | 4.70 | 5.15 |
| 80 | 3.75 | 3.95 | 4.20 | 4.50 | 5.00 |
| 85 | 3.60 | 3.80 | 4.05 | 4.35 | 4.85 |
| 90 | 3.50 | 3.70 | 3.95 | 4.20 | 4.70 |

# CHAPTER XIX

## COMBUSTION

### IMPORTANCE OF COAL ECONOMY

THE coal account of the locomotive department constitutes a very important element in railroad expenditures; it makes a heavy drain upon every railroad in the country. A saving of 15 per cent in the coal account of a railroad might often have been the means of keeping a company solvent that went into the hands of a receiver. A bad fireman generally wastes more than 15 per cent over the quantity of fuel used by a good fireman. We are told that the man who makes two blades of grass grow where one blade use to grow is a benefactor of the human race. As the quantity of coal provided for the use of mankind is limited, and the means of cultivating a fresh supply are not apparent, it would seem that the man who makes one pound of coal do the work that has generally called for the consumption of one and a half pounds is worthy of a share of the admiration accorded to the industrious agriculturist. There are locomotives in the country where the coal consumed, in the generation of steam, is used as economically as knowledge and skill combined can effect, but these cases are not so common as they ought to be. Much has been said and written of late years about proper methods of firing, founded on correct conceptions of the laws that regulate combustion, but a great many of our locomotives continue to be fired in a way that violates Natures' laws, and a senseless waste of coal is the result. The opportunities for firemen mending their ways and earning the distinction of being public benefactors, to say nothing of being better worthy of employment, are innumerable.

There are gratifying evidences that the modern engineer or fireman is striving to acquire the knowledge and the skill that make him thoroughly master of his business. For the help of such men the following chapter has been prepared:

### MASTERING THE PRINCIPLES

To properly conprehend what happens to keep a fire burning, we must understand something about the laws of nature as they are explained under the science of chemistry. Practical men are generally easily repelled by the strange names which they meet with in reading anything where chemical terms are used. An engineer or fireman who is ambitious to learn the principles of his business ought to attack the hard words with a little courage and perseverance, when it will be found that the difficulties of understanding them will vanish.

### SCIENTIFIC FIRING

A man may become a good fireman without knowing anything about the laws of Nature that control combustion. This frequently happens. If he becomes skillful in making an engine steam freely, while using



the least possible supply of fuel, he has learned by practice to put in the coal and to regulate the admission of air in a scientific manner. That is, he puts in the exact quantity of fuel to suit the amount of air that is passing into the fire-box, and in the shape that will cause it to produce the greatest possible amount of heat. When this degree of skill is attained by men ignorant of Nature's laws, it is attained by groping in the dark to find out the right way. A man who has acquired his skill in this manner is not, however, perfectly master of the art of firing, for any change of furnace arrangement is likely to bewilder him, and he has to find out by repeated trying what method of firing suits best. He is also liable to waste fuel uselessly, or to cause delay by want of steam when anything unusual happens.

### KNOWLEDGE IS POWER

A knowledge of the laws of combustion teaches a man to go straight to the correct method, and the information possessed enables him to deal intelligently with the numerous difficulties which are constantly arising owing to inferior fuel, obstructed draft due to various causes, and to viciously designed fire-boxes and smoke-boxes. To illustrate: Engineer West was pulling a passenger-train one day, and his grates got stuck. He ran as far as he could till he could do nothing more for want of steam, then he stopped and cleaned the fire; loss of time over one hour with an important train. Engineer Thomas, on the same road, had a similar experience with the grates; but he understood combustion, and knew that all the fire wanted was air put in so that it would strike the fire before it passed into the flues. He got an old scoop and rigged it in the fire-box door slanting towards the surface of the fire. He did not need to clean the fire, and he went in nearly on time. He could not get air to mix with the fire through the grates, so he devised a plan to inject it above the fire.

### ELEMENTS THAT MAKE UP A FIRE

The nature of fuel, the composition of the air that fans the fire, and the character of the gases formed by the burning fuel, and the proper proportions of air to fuel for producing the greatest degree of heat, are the principal things to be learned in the study of the laws relating to combustion.

All things are composed from about sixty-five elementary substances, which have combined together to form the immense variety of substances found in and around the globe. A simple substance or element is something out of which nothing else can be got, no matter how finely it may be divided, or to what searching tests it may be subjected. Elements unite together to form compounds, or combine with compounds to form other compound substances. When elements or compounds combine to form new substances, they always do so in fixed proportions by weight; and if there is any excess of any substance present it does not combine, but remains unused. It is important to remember this, as it has a direct bearing upon the economy of fuel. A few of the principal elements are oxygen, hydrogen, nitrogen, carbon, sulphur, iron, copper, mercury, gold,



and silver. We will have to deal principally with the four first mentioned.

The elements which perform the most important functions in the act of combustion are oxygen and carbon. Carbon is the fuel, and oxygen is the supporter of combustion. Combustion results from a strong natural tendency that oxygen and carbon have for each other, but they cannot unite freely till they reach a certain high temperature, when they combine very rapidly, with violent evolution of light and heat.

### FUEL AND ITS COMBINING ELEMENTS

All the fuel used for steam-making is composed of carbon, or the compounds of carbon and hydrogen. Carbon is the principal element found in trees and in all woody fiber, and is the fundamental ingredient of all kinds of coal. The ordinary run of American bituminous coal contains from 50 to 80 per cent of fixed carbon, which is the coke, and from 12 to 35 per cent of volatile substances, which burn with a lurid flame, and supply the ingredients of coal-gas. These inflammable compounds are known as hydrocarbons, being combinations of hydrogen and carbon. Anthracite coal differs from other coals in the fact that it consists principally of fixed carbon, with but little volatile matter. Good anthracite contains as high as 90 per cent of pure carbon.

All the air required for furnace combustion is taken from the atmosphere, which consists of a mixture of 1 pound of oxygen to 3.35 pounds of nitrogen; or, by volume, 1 cubic foot of oxygen to 3.76 cubic feet of nitrogen. Nitrogen is an inert, neutral gas that gives no aid in sustaining life or in promoting combustion; but it passes into the furnace with the oxygen, and has to be heated to the same temperature as the other gases.

### SCIENTIFIC MEASUREMENTS

In treating of combustion it is constantly necessary to speak of measuring gases by weight. How air and other gases can be weighed as if they were sugar or tea seems a puzzle to many men not acquainted with laboratory work; but they must take if for granted that these things are done.

Before dealing with the action of the air on the fuel resting on the grates, we might mention that scientists have devised a scale of measurement of heat, which is just as necessary for the comprehension of combustion as ordinary weights and measures are for mercantile purposes. The amount of heat necessary to raise the temperature of one pound of water, at its greatest density, one degree Fahrenheit is called a heat-unit, or sometimes a thermal unit. This is equivalent in mechanical energy to the power required for raising 778 pounds one foot high. The enormous amount of mechanical energy present in each pound of good coal will be understood from a small calculation. A pound of good coal properly burned generates about 14,500 heat-units. Then 14,500 multiplied by 778, the number of foot-pounds in each heat-unit, gives 11,381,000, foot-pounds, which is sufficient energy to raise the weight of one ton more than one mile high. Little more than 10 per cent of this energy is ever utilized by being converted into the work of driving machinery.



### APPLYING THE PRINCIPLES OF COMBUSTION TO A FIRE-BOX

Having mentioned the leading elements that take part in keeping a fire burning, we will now apply the operation to the work done in the fire-box of a locomotive. Let us take a common form of engine, such as that shown in Fig. 35, page 276, with a fire-box 72×35 inches, which makes about 17 square feet of grate area. The engine starts with a fairly heavy train, and has to keep up a running speed of 40 miles an hour. To maintain steam for this work the engine burns 60 pounds of coal per mile, which is equal to 2400 pounds per hour. This requires that about 141 pounds of coal must be burned on each square foot of grate surface every hour, a very rapid rate of combustion, but a rate common enough on many railroads. As shown in the cut referred to, the engine is of the kind most commonly found pulling our passenger-trains, which have no other means of admitting air to the fire except through the ash-pan.

### HEAT VALUE OF THE PROPER ADMIXTURE OF AIR

When the air, drawn violently through the grates by the suction of the exhaust, strikes the glowing fuel, the oxygen in the air separates from the nitrogen and combines with the carbon of the coal. It has been mentioned that elements unite in certain fixed proportions. In some cases the same elements will combine in different proportions to form different kinds of products. If the supply of air is so liberal that there is abundance of oxygen for the burning fuel, the carbon will unite in the proportion of 12 parts by weight (one atom) with 32 parts by weight of oxygen (two atoms). This produces carbonic acid, an intensely hot gas, and therefore of great value in steam-making. If, however, the supply of air is restricted and the oxygen scarce, the atom of carbon is contented to grasp one atom of oxygen, and the combination is made at the rate of 12 parts by weight of carbon to 16 parts by weight of oxygen, producing carbonic-oxide gas, which is not nearly so hot as carbonic-acid gas. It makes a very important difference in the economical us of fuel which of these two gases is formed in the fire.

One pound of carbon uniting with oxygen to form carbonic-*acid* gas generates 14,500 units of heat, or sufficient to raise 85 pounds of water from the tank temperature to the boiling-point. On the other hand, when one pound of carbon unites with oxygen to form carbonic-*oxide* gas, only 4500 heat-units are generated, or sufficient to raise 26½ pounds of water from the temperature of the tank to the boiling-point. The same quantity of fuel, it must be remembered, is used in both cases, the only difference being that less oxygen is in the fire mixture.

### VOLUME OF AIR NEEDED TO FEED A FIRE

Our engine using 2400 pounds of coal per hour has to burn 2⅓ pounds per minute on each square foot of grate. A very large volume of air has to pass through the grates to supply all the oxygen necessary to combine with the quantity of coal mentioned. The combining proportions of carbon and oxygen to form carbonic acid being 12 to 32, the combustion of each



pound of carbon requires 2⅔ pounds of oxygen. It takes 4.35 pounds of atmospheric air to supply one pound of oxygen; therefore at the least calculation it will take more than 11½ pounds of air to provide the gas essential to the economical combustion of each pound of coal. But practice has demonstrated that where combustion is rapid the fuel must be saturated with the air that contains the oxygen, bathed in it, as it were; otherwise a large portion of the furnace-gases will pass away uncombined with the element that gives them their heating value. So it is estimated that at least 20 pounds of air must be passed through the grates of a locomotive to supply the oxygen for each pound of coal burned. At this rate, our engine must draw in $20 \times 2\frac{1}{3} = 46.66$ pounds of air per minute through every foot of grate area. One pound of air, at ordinary temperature and atmospheric pressure, occupies about 13 cubic feet; so it takes over 600 cubic feet of air to pass every minute through each square foot of grate. This volume of air would be sufficient to fill a cylinder $18 \times 24$ inches nearly one hundred and seventy times. Or, to put it another way, if there were no obstruction to the passage of air through each foot of grate, a trunk of air over 600 feet long has to pass into the fire every minute. As more than half the opening is obstructed by the iron and coal, a column at least 1200 feet long has to be admitted each minute. With some forms of grates the openings are much more restricted and consequently the inward rush of air must be faster in proportion.

### VELOCITY OF THE FIRE-GASES

There are several practical objections to the air blowing through the grates like a hurricane. The high speed of the gases lifts the smaller particles of the fuel and starts them toward the entrance of the flues, helping to begin the action of spark-throwing. Where they find a thin or dead part of the fire, the gases pass in below the igniting-temperature, or tend in spots to reduce the heat below the igniting-point, and go away unconsumed, at the same time making a cold streak in the fire-box, chilling the flues or other surface touched, and starting leaks and cracks. Then the great volume of air has, under ordinary circumstances to be heated up to the temperature of the fire-box, and a considerable part of the heat produced from the coal has to be used up doing this before any of it can be utilized in steam-making. When a large volume of gas is employed it must be passed through the furnace and tubes at a high velocity, the result being that there is not sufficient time for the heat to be imparted to the water; consequently the gases pass into the stack at a higher temperature than would be the case if the movement of the gases were slower. One can get a good personal illustration of this by passing his hand through the flame of a gas-burner.

A thoughtless remedy so readily tried with locomotives that do not steam freely is the use of smaller nozzles. That produces bad results in two ways. It causes increased back-pressure in the cylinders through the restrictions put upon the escape of the steam, thus reducing the power that the engine can exert and



causing more steam to be used to perform a given measure of work. It also increases the velocity of the fire-gases, with the result that less of the heat is imparted to the water in the boiler.

Our engine is drawing in 600 cubic feet of air per minute through each square foot of grate, that is, 600×17 equals 11,200 cubic feet for the whole grate area. The act of combustion is turning 40 pounds of coal per minute into gas, adding about 300 cubic feet more to the volume. This cloud of gas has to pass out through 202 two-inch flues, that give a total opening of 485 square inches, equal to 3.36 square feet. The body of gas reduced to this diameter makes a column over 3400 feet long, so it must pass through at a velocity of at least 3400 feet per minute.

### THREATENED LOSS OF HEAT

From these figures it will be understood that in firing loss of heat is threatened from two opposite directions. If there is not enough air admitted, a gas of inferior heating power will be generated, and a waste of heat will take place equal to the difference between $26\frac{1}{2}$ pounds of water evaporated by the heat from one pound of coal burned as carbonic oxide, and 85 pounds of water evaporated when the same weight of coal is burned to carbonic-acid gas. If the admission of air is greater than what is necessary, heat will be wasted in proportion to the quantity needed to raise the temperature of the superfluous air up to the heat of the furnace. Those who have noted the difference in the fuel needed to heat a small and a large room, thirty or forty degrees, may readily understand the quantity of coal that must be wasted raising about 1000 degrees the temperature of the blizzard of extra air that is often passing through the fire-box of a locomotive. Then, as has been mentioned, an extra supply of air causes an increased speed of draft, and this prevents the sheet and flues from abstracting as much heat as they would if the speed of the gases were slower.

### IGNITING-TEMPERATURE OF THE FIRE

The igniting-temperature of the fire has been repeatedly mentioned. Everybody meets daily with illustrations of the fact that fuel will not burn till it has been raised to a certain heat. If you put a piece of wood or coal on the fire it remains unchanged for a time till the temperature at which it combines with oxygen is reached, when it begins to burn. The point of heat at which it begins to burn is called the igniting-temperature. Different kinds of fuel have different igniting-points. Coal-gas does not burn below a red heat of iron, and carbon has a still higher igniting-point. If you take a piece of iron, heated dim red, and try to light an illuminating-gas jet with it you will not succeed. Increase the heat till the iron approaches orange color, and it will then light the gas. From this it will be learned that the igniting-temperture of hydrocarbon-gas is about the cherry heat of iron. As the igniting-temperature of carbon is still higher, it will be understood that coal must be kept at a higher temperature still to make it burn.

When wood, coal, or gas will not begin to burn outside till they have been raised to the heat mentioned, it may be readily understood that they will not



burn in a locomotive fire-box if they are not up to the igniting-temperature. As the active portion of the fire is constantly distilling gases from the fuel that rise upwards, and require a high temperature for their combustion, it will be readily seen that a great waste of heat must happen when the temperature of any part of the fire-box gets so low that the gases pass away unconsumed. So the fireman ought to make it his business to see that the fuel in any part of the fire-box is not permitted to fall below the temperature of combustions. It may be said or believed that the heat in the fire-box is so high that it is always up to the igniting-temperature. This would be a mistake. The rush of cold air is so great that a thin part of the fire readily permits air that is not up to the igniting-temperature to pass through, and it chills all the gas it touches. When a heavy charge of coal is thrown into the fire-box, the cold material reduces for a time part of the fire-box below the igniting-temperature, and the gases distilled by the hot fire beneath are ruined by the cold place they have to go through above, and they pass into the flues in the shape of worthless smoke and coal-gas. The fire-box sheets abstract the heat so quickly that waste will occur from the fuel closer to the sheets, or the gases passing up beside them, getting below the igniting-temperature, unless the fireman watches to see that a bright fire is kept up in the vicinity of the sheets.

### BURNING BITUMINOUS COAL

The burning of bituminous coal is a complex operation. The volatile gases in this kind of coal contain great heat-generating power, but they are difficult to burn so that none of the heating elements will be lost. Average bituminous coal contains 65 per cent of carbon and 25 per cent of hydrocarbons. About $\frac{1}{4}$ by weight of the latter is hydrogen-gas, which makes the hottest fire that can be burned; but it ignites only at a very high temperature, as has been alluded to, and if the fire-box or any part of it gets cooler than this all or a part of the gas passes away unconsumed. In that case there is direct loss by the gas not being used to create heat, and also loss due to the work done by the burning carbon in gasifying the hydrocarbons. To turn a solid into a gas uses up heat in the same way that evaporating water into steam does.

To burn, hydrogen-gas unites in the proportion of two parts by weight (two atoms) to sixteen parts by weight of oxygen (one atom), and the product is water. It may appear strange that water is formed by the burning of a fire; but such is the case, and a tremendous heat is evolved by the operation. The water passes away in the form of colorless steam; but when it touches a cool place the vapor instantly condenses into water. When a fire is newly lighted in the fire-box of a locomotive the drops of water that may be seen oozing out of the smoke-box joints is the water formed from the hydrogen of the fuel.

### HEAT VALUE OF THE VOLATILE GASES

The combustion of each pound of hydrogen-gas, if it combines with eight pounds of oxygen taken from the air, produces about 62,000 heat-units, or enough to raise about 365 pounds of water from the tank



temperature to the boiling-point. It will be noted that one pound of hydrogen calls for eight pounds of oxygen (2 to 16) for perfect combustion, while each pound of carbon requires only $2\frac{2}{3}$ pounds of oxygen (12 to 32). As the hydrocarbon-gases are released at the top of the fire, it is difficult getting this very large volume of air needed for combustion to the proper place, unless means are taken for admitting air above the fire.

Where there is much volatile gas in the coal, it is an economical arrangement to admit air above the fuel; but the means of its admission ought to be under the control of the fireman, or there is likely to be loss of heat by the ingress of cold air when it is not needed.

It is important in the economical combustion of coal to keep the fire as bright on the top as possible.

Experimenters on combustion have found that "the efficiency of fuel to heat by radiation depends directly upon the luminosity of the products of combustion." That means that a smoky or cloudy fire wastes a great part of the heat, because the heat rays cannot strike the heating surfaces. The "luminosity" or brightness of the flames of a fire is said to be due to the free carbon liberated by the hydrocarbons of the flame being heated up to the temperature of the flame itself. The solid particles becoming incandescent act like tiny incandescent gas-lights, each particle of free carbon throwing off heat and light in all directions until consumed and converted into carbonic-acid gas. This free carbon is the last component of the flame to burn, and it only burns at a very high temperature; so if the fire-box is not maintained very hot there will be little bright flame, the volatile gases will pass off as smoke, and those burned will lose part of their value through not being able to send through the mist of smoke their steam-making rays.

### HEAT LOSSES THAT RESULT FROM BAD FIRING

Our engine is laboring along with a heavy, thick fire on the grates. The air that passes up into the fire has the atoms of oxygen seized on by the glowing carbon first encountered, and the heat generated keeps distilling the hydrocarbon-gas from the green coal above. There being no means of admitting air above the fire, and there being very little oxygen left in the air after it has worked up through the body of the burning fuel, the volatile gases fail to receive their supply of oxygen, and with their great steam-making possibilities they pass away in the form of worthless smoke and unconsumed coal-gas. The fire being so thick and compact that the air cannot diffuse freely through the mass, a considerable part of the solid carbon does not receive its full share of oxygen, so it passes away in the inferior heating condition of carbonic oxide.

An inferior fireman, who maintains a thick fire, will often use up an enormous quantity of coal without making an engine steam freely. This is caused by the air failing to reach the 25 per cent of the fuel that exists as hydrocarbons, and which is in consequence utterly wasted; and because part of the solid carbon is burned to carbonic *oxide*, which produces 4500 heat-units, as compared with 14,500 heat-units that would result from the carbon being consumed as carbonic-*acid* gas. A fire run in this wasteful manner is always



smoky, and the fire-box looks dull and cloudy, with a tendency for the sheets to hold a covering of soot. Other losses due to a smoky fire have already been explained.

Some firemen have acquired the habit of firing at times when the fire-door ought to be kept closed. As soon as the engineer opens the throttle to pull out of a station these men begin filling up the fire-box. Cold air is pumped through the flues without any need for it, and the charge of fresh coal put in at the wrong time helps add to the chilling effect. When approaching a heavy pull these men generally let the fire get thin, and then they are ready to begin shoveling industriously when the engine is toiling hard up the grade.

### EFFECT OF SMALL NOZZLES

Thick, heavy firing, with all the losses described, is not always caused by ignorance or want of skill on the part of the fireman. It is very frequently the case that an engine will not steam freely unless a heavy fire is carried. This state of things is nearly always due to the use of very small nozzles, which make the blast so sharp that a thin fire could not be used, as the fierce rush of air would be constantly tearing holes in places through which the cold air would pass directly into the flues. When an engine does not steam freely, the tendency always is to call for smaller nozzles; yet it often happens that the nozzles are already too small for free steaming. The diverse character of the coal supplied on most roads is responsible for great waste of fuel. With the average coal an engine will steam while using a large nozzle. But occasionally some cars of coal will be sent in that contains a large percentage of slate and other incombustible material. When an engine gets a tenderful of this stuff, there will be trouble in making steam freely enough to take the train along on time. The men know that a sharp blast would help them in such a case, and it is natural that they should be ready always to provide against this emergency.

# CHAPTER XVIII

## DRAFT APPLIANCES

### ORDINARY ARRANGEMENTS FOR CREATING DRAFT

THE capacity of the boiler for generating steam with great rapidity was what made high-speed locomotives a possibility. The filling of the boiler with small flue-tubes and the employing of a strong artificial draft were the principal means used in making the locomotive-boiler a success. Various methods were for a time tried in maintaining the strong draft necessary; but it is now generally admitted that the emission of the exhaust-steam through the smoke-stack is the most efficient and simple means of creating the pull on the fire necessary to generate the great volume of steam used by the cylinders of a locomotive.

The ordinary arrangement of draft appliances is as simple as it is efficient. Referring to the illustration Fig. 35, the fuel rests on the grates *uu*, and receives through the grate-openings the air necessary to sustain and stimulate combustion. The gases released from the burning fuel pass up into the body of the fire-box *BB*, thence into the flue-tubes *xxx* to the smoke-box *CC*, from whence they pass to the atmosphere by the smoke-stack *D*. In traversing this route the fuel-gases impart the greater portion of their heat to the water surrounding the sheets and flues; and the greater the proportion of the heat imparted to the water the greater is the efficiency of the boiler. There is a remarkable difference in the faculty of boilers for absorbing the heat of the fire-gases, and not a little of this difference is due to the design and arrangement of the draft appliances.

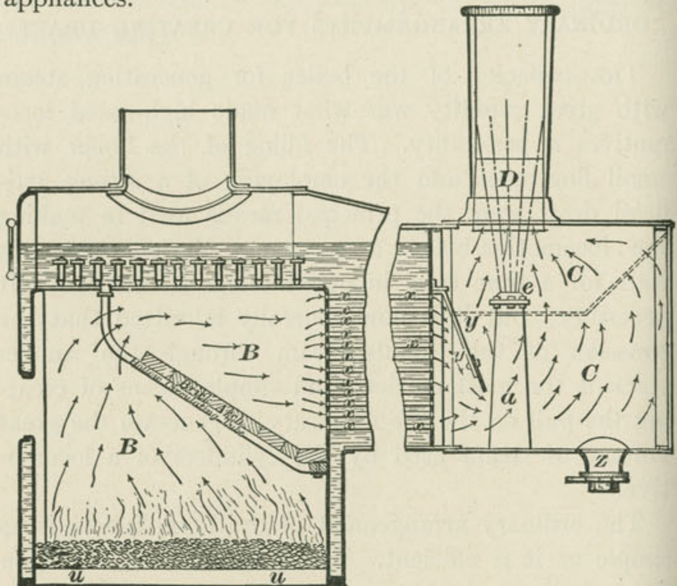



FIG. 35

Locomotive engineers and firemen do not design or make the draft appliances of the engines they operate; but they have a great deal to do with adjustments of the same, and an intelligent study of the action of the draft appliances may often save them from much unnecessary labor, and the company from useless expense.



### ACTION OF THE DRAFT-CREATING FORCES

When a locomotive is at work the steam passes through the exhaust-pipe *a*, through the nozzle *b*, and shoots up through the stack like a projectile, the velocity depending on the pressure of the steam released- and on the size of the nozzle-opening through which it has to pass. The greater the quantity of steam passing through the cylinders, the greater, under ordinary circumstances, will be the draft induced.

Draft by the exhaust-steam passing from the exhaust, pipe through the smoke-stack appears to be created in two ways. The steam acts partly on the surrounding air or gases it passes through to induce a current by friction of the particles; or, on the other hand, its compact volume fills the smoke-stack like a piston, inducing draft by leaving a partial vacuum behind like the action of a pump-plunger. Whether the current be induced by friction or by the piston-like action, the air in the smoke-box is rarefied, and there being only one means of ingress to fill the partial void, the pressure of the atmosphere forces air through the grates into the fire in its passage to the smoke-box by way of the tubes.

Inducing a current by friction is the principle the steam-jets works on, and when that is the mode of the exhaust action in maintaining draft the nozzle is merely an enlarged jet-opening. There is no doubt that when the exhaust-steam acts like a plunger in the smoke-stack to leave a partial vacuum behind, a more perfect draft can be maintained with the same steam velocity than where the draft is created by friction; yet the latter practice of draft induction is largely followed in American locomotives. In ordinary working at moderately high piston-speed the exhaust acts in both ways. At low-speed the plunger-action alone ought to provide the required draft.

## DIFFERENT WAYS OF PASSING EXHAUST-STEAM INTO THE STACK

Under whatever conditions a locomotive is worked, the intensity of draft created by a given volume or velocity of exhaust-steam will depend, to a great extent, upon the way the nozzle or nozzles and their connections pass the steam into the stack. If the steam passes centrally into the stack in a compact form, and expands on its passage just enough to fill the stack at its base, a low tension of exhaust-steam will serve to leave a comparatively high vacuum behind, which will instantly be filled by the gases that pass through the flues. This perfect action of the exhaust-steam in creating draft is not so general as it ought to be.

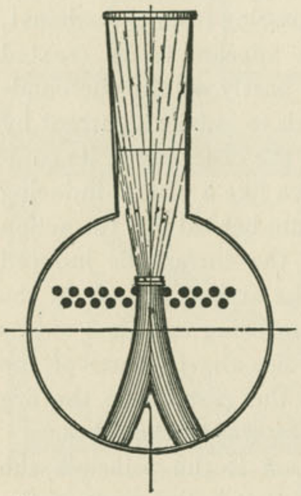


FIG. 36

In Fig. 36 the escaping steam is shown expanding sufficiently to fill the stack just as it enters the base casting. When this happens, the stack acts like a pump-barrel delivering a full charge at each stroke. In such a case, a stackful of gas is pumped out of the



smoke-box with every exhaust, and the vacuum necessary for making steam will be maintained with a low velocity of exhaust-steam, which means that a large nozzle may be employed.

The steam is sometimes delivered in such a form that it does not fill the stack till it is half-way up. The

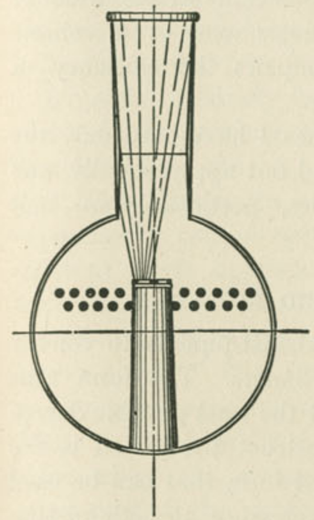


FIG. 37

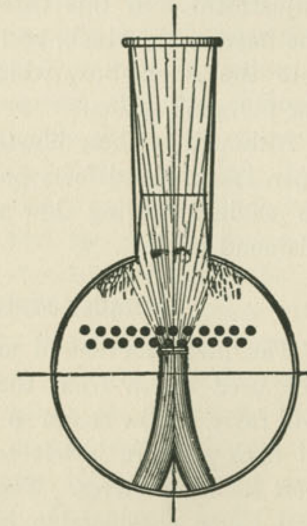


FIG. 38

exhaust-steam in this case will pump only about a half stackful out of the smoke-box with each puff of steam, and the necessary vacuum will be maintained partly by the pumping action and partly by friction of the escaping steam on the gases. A higher steam velocity is required to create the needed draft in this case.

Fig. 37 illustrates a defect of exhaust action very common where double nozzles are used. Its effect is similar to that mentioned in the last paragraph; but in some cases it is much worse, for the exhaust-steam hugs the side of the stack the whole way up, and by that means loses a portion of its draft-creating power. This same effect sometimes comes from a single nozzle being set out of plumb.

Fig. 38 illustrates another pernicious form of bad adjustment. In this case the steam strikes wide at the base of the stack, and delivers some of its volume into the smoke-box, which impairs the efficiency of the pumping action.

Although in these illustrations I have used only the open stack, the defects pointed out apply equally well to engines having low-nozzles, petticoat-pipes, and diamond stacks.

### EXHAUST-PIPES AND NOZZLES

The first function of an exhaust-pipe is to convey the used steam from the cylinders. The form that will carry off the steam so that the least possible degree of back-pressure is left to obstruct the piston is the best for locomotives. The best form that can be used will cause considerable back-pressure at high piston-speeds. When the exhaust-pipe is designed to open at the bottom of the smoke-box, it is necessary to use double-nozzles, to prevent the presence of severe back-pressure in the cylinders caused by the steam passing through the exhaust-pipes from one cylinder into the other. The two pipes come together below in such a shape that this cannot be prevented.

When double-nozzles are used with a high exhaust-pipe, the greatest possible care should be taken to adjust the nozzles to deliver the steam as nearly central in the stack as possible. When an engine having this arrangement is not steaming satisfactorily, it is a good plan to watch how the steam strikes in the stack.



Where a high exhaust-pipe is used, it is best to employ a single nozzle. Careful experiments have proved that a well-designed exhaust-pipe ending in a single nozzle gives the best results in creating draft; but unless the exhaust-pipe is large and properly shaped, the engine is likely to suffer from back-pressure in the cylinders.

It might naturally be supposed that the arrangement of exhaust which produced in the highest vacuum would produce the best results in steam-making; but that is not always the case. Very carefully conducted experiments, carried out to find the relative value of different draft appliances, showed decidedly that a lower smoke-box vacuum would keep up steam with a well-arranged single nozzle than with any form of double-nozzle. The tendency of the double-nozzle was to make an uneven vacuum in the smoke-box. That is, there would be a higher vacuum near the place where the exhaust-steam passed than at any other part of the smoke-box. This would in its turn lead to the gases crowding towards a certain part of the tube-openings, and have the same effects as a badly adjusted diaphragm-plate.

# CHAPTER XX

## STEAM AND MOTIVE POWER

In the previous chapter we have mentioned that the heat value of coal is measured by the number of heat-units it contains, and that each heat-unit represents 778 foot-pounds of work, or the energy required to raise 778 pounds one foot. According to the figures given, each pound of coal contains an enormous amount of possible work energy. The operating of the locomotive, and of all other steam-engines, is a process of transforming the heat energy of coal into mechanical work. In some kinds of engines driven by hot air or gas the operation of converting heat into work is done without the use of steam. A greater proportion of the heat energy can be utilized in that way; but there are mechanical obstacles which prevent such systems from being used where much power is required.

### CONVENIENCE OF STEAM FOR CONVERTING HEAT INTO WORK

Steam, the vapor of water, has been found the most convenient medium for transforming the energy of coal into the useful work of pulling railroad trains, and of driving other kinds of machinery. Water has the greatest heat-absorbing capacity of any known substance, which makes it an excellent means of converting heat into work; but it has some peculiarities





which readily lead to great loss of energy if not carefully controlled. If we follow the circle of operations which the burning of coal for steam-making purposes sets going, we shall meet at every move heat losses which show us why so small a portion of the entire heat energy of coal reaches the crank-pins that turn the wheels of the engine. But an intelligent study of the losses will also help an engineer to restrain them to the lowest possible limit.

### HEAT USED IN EVAPORATING WATER

Suppose we take one pound of water at a temperature of 40° Fahr., and apply heat to it in an open vessel. If we put a thermometer in the water, we shall find that the temperature will rise rapidly till it reaches 212°, the boiling-point at the pressure of the atmosphere. Then the mercury stops rising, but the water keeps absorbing the heat and turning into steam. It takes rather more than $5\frac{1}{2}$ times the quantity of heat to evaporate the whole of the pound of water into steam that it took to raise the temperature from the tank temperature to the boiling-point; for, although it is not shown by the thermometer, the converting of the pound of water from the boiling-point into steam uses up 965.7 heat-units, that being called the latent heat of steam at atmospheric pressure. In raising the water to the boiling-point—from 40° to 212°—172 heat-units were used, and in vaporizing the water 965.7 units, making in all 1137.7 heat-units, which are expended in evaporating one pound of water under the pressure of the atmosphere alone, which is 14.7 pounds to the square inch. Steam formed under this light pressure fills 1644 times the space occupied by the water it was made from. The volume of steam varies nearly inversely as the pressure, so that when the steam is generated under the pressure of two atmospheres it fills only 822 times the space that the water did. Every step in the increase of pressure reduces the volume of the steam in like proportion. Steam at 150 pounds per square inch gauge-pressure is only 173 times the volume of the water. Steam gauge-pressure is the pressure above the atmosphere; absolute pressure is reckoned from the vacuum-line.

### LITTLE EXTRA HEAT NEEDED FOR MAKING HIGH-PRESSURE STEAM

If the pound of water, instead of being left to boil in an open vessel, had been put into a boiler where a pressure of 165 pounds absolute was put upon it, that being equal to a gauge-pressure of 150 pounds, the result would have been different. When heat was now applied, the mercury would keep rising till the temperature of 365.7° was reached before the water would begin to boil. To raise it to the boiling-point under this pressure, 330.4 heat-units would be put in the water, and then the addition of 855.1 more heat-units would convert the whole pound of water into steam, the total expenditure of heat being 1185.5 heat-units. From this it will be seen that while the generating of steam at atmospheric pressure, which gives no capacity to speak of for doing work, calls for an expenditure of 1137.7 heat-units, raising the steam to the high gauge-pressure of 150 pounds takes only 1185.5 heat-units. Steam of 100 pounds gauge-pressure uses up 1177 heat-units, so that it takes very little more heat to raise the steam to the higher pressure where it has the power of doing much more work than to the lower pressures. A study of these facts will show why it is most economical to use steam of high-pressure.



### CONDITIONS OF STEAM

Steam formed in ordinary boilers, where only sufficient heat is applied to evaporate the water, is called saturated steam. It is also sometimes spoken of as dry steam or anhydrous steam. Saturated steam contains only just sufficient heat to maintain it in a gaseous condition, and the least abstraction of heat causes a portion of the steam to fall back into water, when it loses its power of doing work. This is why it is important that steam cylinders and passages should be well protected from cold. The condensation of steam that goes on in badly lagged cylinders wastes a great deal of fuel.

When heat is applied to steam that is not in contact with water, the steam absorbs more heat and is said to be superheated. Superheated steam has a greater energy than saturated steam in proportion to the amount of heat added. The practical advantage of superheated steam is that it does not turn into water in the cylinder so readily as saturated steam.

### METHODS OF USING STEAM

Having got steam raised to 150 pounds gauge-pressure, which is almost 165 pounds absolute, the next move is to use it to the best advantage, so that the greatest possible amount of work will be got out of every pound of steam generated. In ordinary circumstances, the higher the temperature of steam admitted into the cylinders of a steam-engine, and the lower the temperature at which it is passed out by the exhaust, the greater will be the economy, if the reduction of temperature has been due to the conversion of heat into mechanical work.

That the steam passed into the cylinders may be used to the best possible advantage, the ordinary practice is to cause the expansive force of the steam to do all the work practicable. As has been already mentioned in a former chapter, high-pressure steam is like a powerful spring put under compression, and is ever ready to stretch out when its force is directed against anything movable. In that way it pushes the piston when the valve is cutting off admission of steam before the end of the stroke is reached. We shall try to show how such practice is economical.

### THE STEAM-ENGINE INDICATOR

To find out what is going on in the inside of the cylinders of an engine, to show accurately how the steam is distributed, the use of the steam-engine indicator is necessary. The indicator consists essentially of a small steam-cylinder, whose under side is connected by pipes to the main cylinder of the engine under inspection. Inside the indicator-cylinder is a nicely fitting piston, whose upper movement is resisted by a spring of known strength. The piston-rod passes up through the top of the indicator-cylinder: and its extremity is connected with mechanism for operating a



pencil, and marking on a card a diagram whose lines coincide with the movement of the indicator-piston.

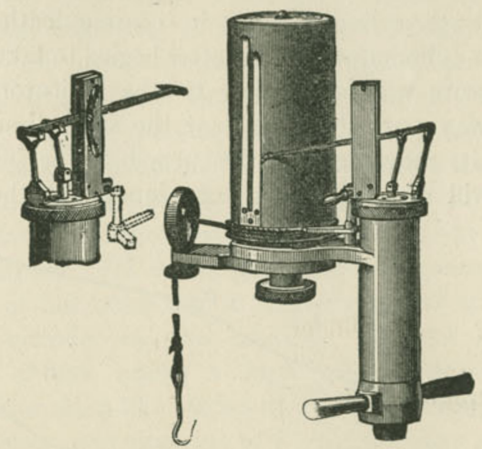


Fig. 39 gives perspective and sectional views of the Tabor indicator, an instrument well adapted for application to locomotives. The card to be marked is fastened in the paper drum attached to the indicator. This drum receives a circular motion from a cord which is operated by the cross-head of the locomotive, and the connection is so arranged that the drum will begin to move round just as the main piston begins its stroke. The circular motion of the

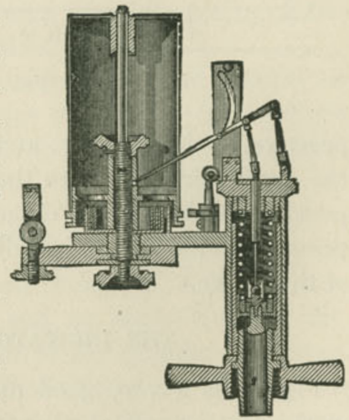


FIG. 39.

drum is continued till the piston reaches the end of its stroke, when the drum reverses its movement, and returns to the exact point from which it started. Now the indicator-cylinder being in communication with the main cylinder, when the latter begins to take steam, the pressure will be applied to the indicator-piston, which was pushed upward, at the same time transmitting its movement to the pencil. The indicator-piston will rise and fall in accordance with the steam

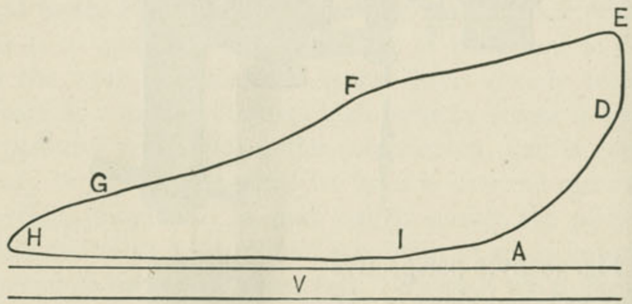



FIG. 40

pressure in the cylinder: and the circular movement of the drum coinciding with the cross-head movement, the pencil will describe a diagram which represents the pressure inside the main cylinder at the various points of the stroke.

### THE INDICATOR-DIAGRAM

Fig. 40 is a very good diagram taken from a locomotive cutting off at about 37 per cent of the stroke and running at 150 revolutions per minute. *A* is the atmospheric line traced before steam is admitted to the indicator. *V* is the vacuum-line traced according



to measurement, 14.7 pounds below the atmospheric line. *DE* is the admission-line, *D* being the point where the valve opens to admit steam. *EF* is the steam-line, beginning at the point of change in direction of the admission-line. The steam-line in this diagram drops down before the point of cut-off is reached, through the steam admission not being rapid enough to keep it up. *FG* is the expansion-line traced after the steam is cut off. At the point *G* the exhaust takes place, and the exhaust-line is from *G* to the end of the stroke. *HI* is the line of counter-pressure, and is high or low according to the quantity of steam left in the cylinder by the exhaust. The use of small nozzles always causes a high counter-pressure line. The compression-line begins at *I*, the point where the valve closes, and runs up to *D*, the pressure rising as the steam left in the cylinder, after the valve closes, gets pressed by the piston into small space.

For an exhaustive and easily understood treatise on the indicator our readers are referred to Hemenway's "Indicator Practice and Steam-engine Economy," published by John Wiley and Sons, New York.

### PRACTICAL ILLUSTRATION OF STEAM-USING

Suppose the steam in our boiler is raised to 165 pounds absolute pressure, and we apply it under different conditions to do work in the cylinder *ZZ* shown in Fig. 41, which is 16 inches diameter and has a stroke of 24 inches. The diagram above the cylinder represents the action of steam in the cylinder. The vertical lines represent the steam at different points of the piston's stroke. If the cylinder were filled with steam at boiler-pressure during the entire stroke of the piston, the diagram of work would resemble the rectangle *ACEB*. Using the steam in this way is impracticable,

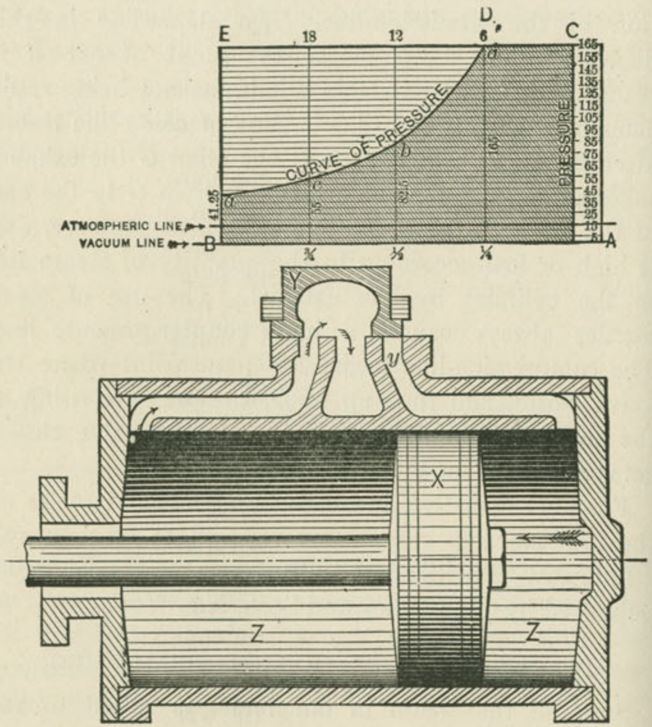



FIG. 41

but an approximation to it is possible, and it will serve to illustrate the subject. Ignoring the quantity needed to fill the clearance-spaces, the steam from one pound of water, which is called a pound of steam, would just be sufficient to fill the cylinder once.



### CURVE OF EXPANDING STEAM

Instead of permitting the steam to follow the piston unimpeded during the whole stroke, we will cut it off at 6 inches or one quarter stroke, as shown in the illustration Fig. 41, where the valve *Y* is closing the port *y*, just as the piston *X* has moved one quarter the stroke. The piston will now be pushed the remainder of the stroke by the expansive force of the steam, the latter falling in pressure as the space to be filled increases, and obeying what is called Mariotte's law, the pressure varying inversely as the volume. By the time the piston has moved to half stroke, the steam is filling twice the space it was in when cut-off took place, and accordingly its pressure has fallen to the point *b*, which represents 82.5 pounds to the square inch. At the end of the stroke, when release takes place, the pressure has fallen to 41.25 pounds. We find by calculation that the average pressure on the piston when the steam was cut off at quarter stroke was 98.42 pounds to the square inch. In this case, just one quarter the quantity of steam was drawn from the boiler that was taken when steam followed full stroke, yet with the small quantity of steam the average pressure on the piston was considerably more than half of what it was when four times the volume of steam was used.

The description of the action of the steam does not represent with any degree of accuracy what actually takes place; but it gives the facts closely enough to indicate how steam can be saved or wasted.

### EFFECTS OF HIGH INITIAL AND LOW TERMINAL PRESSURE

All engineers who have given the economical use of steam intelligent study agree that the proper way to use steam in a cylinder is to get it in as near boiler-pressure as possible, so that the greatest possible ratio of expansion may be obtained while doing the necessary work. Where this practice is not followed, the steam is used wastefully. Locomotives that are run with the throttle partly closed, when by notching the links back it could be used full open, are throwing away part of the fuel-saving advantages that high-pressure offers.

For this practice the engineers are not in every case to blame, for many locomotives are constructed with valve-motion so imperfectly designed that the engines will not run freely when they are linked close up. With the small nozzles made necessary to force the steam-making in small boilers, the back cylinder-pressure is so great that the high compression, resulting from an early valve-closure, prevents the engine from running at the speed required.

From whatever cause it originates, the practice of running with the throttle partly closed causes much waste of fuel. A few examples will be given:

The diagram shown in Fig. 42 was taken from a locomotive running at 192 revolutions per minute. The boiler-pressure was 145 pounds, and the initial-pressure on this card is 136 pounds. This high cylinder-pressure was obtained by keeping the throttle-valve full open. The driving-wheels were 68 inches



diameter, and the engine was running close on forty miles an hour and was developing, with 18×24-inch cylinders, sufficient power to haul a train weighing 300 tons at the rate of fifty miles an hour. Steam was cut off at about seven inches of the stroke, expanded down to 25 pounds above the atmospheric line, and showed an average back-pressure of 4 pounds. The work was done using at the rate of 21.5 pounds per horse-power per hour—very economical work.

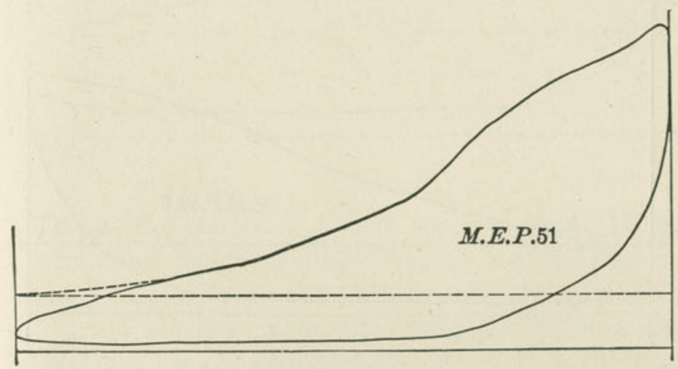



FIG. 42

Diagram Fig. 43 shows about the same power as the other one; but it was taken with the steam partly throttled, and cutting off at $10\frac{1}{2}$ inches. In this case it will be noted that the initial-pressure is only 102 pounds, that the terminal-pressure is 31 pounds above the atmosphere, and that the counter-pressure is 7 pounds. In this case the work is done by using steam at the rate of 25.8 pounds per horse-power per hour, which is 16.6 per cent more steam than was used with the other way of working. There was no reason whatever for working the engine in this manner, except the careless practice that some runners get into.

A still worse case is shown by the diagram Fig. 44. Here the engine, which was running at 176 revolutions per minute, was worked cutting off at half stroke, and the average steam pressure kept down by throttling. Consequently the initial-pressure is low, the terminal-pressure and the back-pressure high. This condition

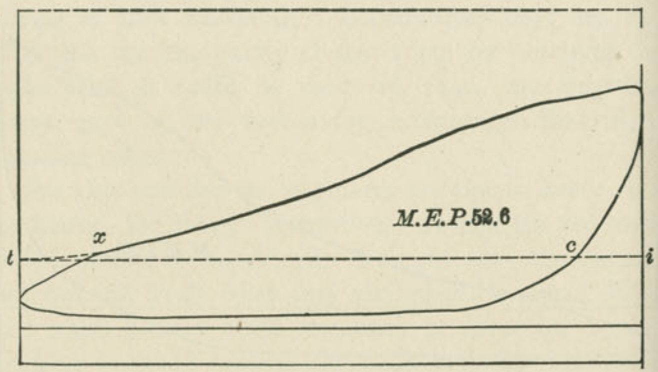



FIG. 43

of working calls for the use of a large volume of steam to perform the work. The initial-pressure is 109 pounds, the terminal-pressure 45 pounds, and the back-pressure 11 pounds. The engine while working this way used steam at the rate of 32 pounds per horse-power per hour, or 33 per cent more than was used in the first case. These are examples taken from the ordinary working of locomotives. They are no mere theories. They are the record of accurate measurements and are as trustworthy as the indications of



the steam-gauge. Using 33 per cent more steam than what is absolutely necessary is just throwing away one-third of the coal put into the fire-box.

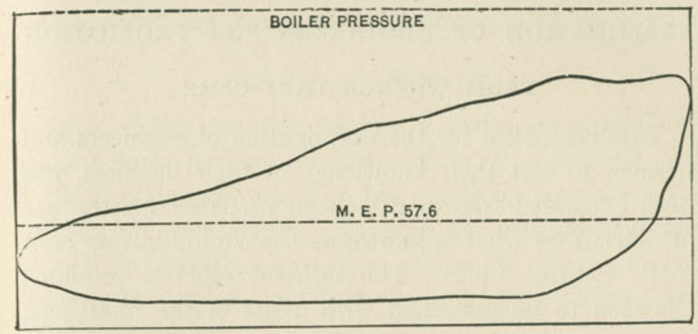



FIG. 44

To put the matter in a more concrete form: If the engine from which diagram Fig. 42 was taken was running 33.3 miles to the ton of coal, only 27.7 miles to the ton would be made when using the steam shown in diagram Fig. 43 and only 22.3 miles when diagram Fig. 44 was the record of the steam consumed.

# CHAPTER XXI

## EXAMINATION OF ENGINEERS FOR PROMOTION

### FROM WHENCE THEY CAME

THIS catechism for the examination of engineers and firemen to test their knowledge of their business, has been expanded from a catechism prepared for the use of officials on what is known as the Vanderbilt or New York Central Lines. The railroad officials provided the men to be examined with a list of the questions; we have worked out the answers, and added other questions and answers that are of general interest.

We advise men studying this catechism to refrain from committing the answers to memory, but to acquire the sense of the answers and to use the actual locomotive as an aid to acquiring the desired knowledge.

These questions and answers have been worked up from a code prepared by the Traveling Engineers' Association, and developed by various writers on railroad machinery matters to suit changes in rolling stock and conditions of operating.

### SECTION I.

### FIRST YEAR EXAMINATION

*General Questions*

*Q.* 1. Do you consider it essential to your success in business to abstain from the use of intoxicating liquors?





Do you consider it to your interest to work to the best of your ability for the interest of your employer, and be economical in the use of fuel and supplies?

*A.* This question will be answered according to the judgment of the man under examination.

### DUTIES OF FIREMEN

*Q.* 2. What are the fireman's duties on arrival at engine-house previous to going out on a locomotive?

*A.* See that the fire is in the condition to make up a proper one for starting. See that the ash-pan is clean. Ascertain that the engine has got on all the necessary tools and supplies, and that the engineer's oil-cans are filled.

*Q.* 3. Is it your duty to compare time with your engineer, and should you insist on seeing all train orders?

*A.* I should consider it my duty to compare time with the engineer and insist on seeing the train orders, if that was the rule of the company I was working for.

*Q.* 4. Give the substance of the various rules pertaining to signals as found in the Book of Rules and Regulations of the operating department.

*A.* This question will be answered by describing the signals described in the book of rules. The meaning of swinging-arms and lanterns in different ways must be explained, and also the meaning that the rules attach to the station-signals used by the road.

*Q.* 5. In addition to any that you have not mentioned, what else do you consider a danger signal?

*A.* Any person near the track violently waving his arms or any sort of light would be regarded as a danger signal; also a fire burning on the track.

### THE STEAM-GAUGE

*Q.* 6. Explain the principle of the steam-gauge.

*A.* There are several kinds of steam-gauges, but all of them are operated on one of two principles. When internal pressure is applied to a bent flat tube, the tendency of the tube is to straighten out. That tendency is made use of in the Bourdon-gauge, the necessary mechanism for operating the dial needle being connected with the tube. The other form of gauge is operated by a double diaphragm of corrugated plate. When pressure is admitted between the plates it forces them outward and the attachments operate the mechanism that moves the gauge needle.

*Q.* 7. What pressure is indicated by the steam-gauge? What is meant by atmospheric pressure?

*A.* The pressure above the atmospheric pressure. The pressure of the atmosphere is that imposed by the body of air surrounding the earth. At sea-level it is 14.7 pounds to the square inch.

### HEAT AND STEAM

*Q.* 8. What is the source of power in a steam-locomotive?

*A.* Steam generated by heat.

*Q.* 9. What quantity of water ought to be evaporated in a locomotive-boiler to the pound of coal?

*A.* From 7 to 10 pounds. It is seldom more than 5 pounds.

*Q.* 10. What is steam, and how is it generated?

*A.* The vapor of water. It is generated by the heat from the fuel burning in the fire-box.



*Q.* 11. At what temperature does water boil?

*A.* On the level of the sea it boils at 212° F.

*Q.* 12. What is the temperature of the water in the boiler when the pressure is 200 pounds?

*A.* At 200 pounds gauge-pressure the temperature of the water is 387.7° F.

### COMBUSTION AND FIRING

*Q.* 13. What is combustion?

*A.* The chemical combination of the carbon in fuel with oxygen.

*Q.* 14. What is the composition of bituminous coal?

*A.* A good quality of bituminous coal contains about 61 per cent fixed carbon, about 31 per cent of volatile matter, known as hydrocarbons, 7 per cent of ash, and 1 per cent of sulphur.

*Q.* 15. What is carbon? From what is oxygen obtained?

*A.* Carbon is one of Nature's elements. Nearly all combustible material, such as wood and coal, consists principally of carbon. Oyxgen for sustaining combustion is obtained from the air.

*Q.* 16. What per cent of oxygen is in the air?

*A.* The atmosphere contains 20.63 per cent of oyxgen.

*Q.* 17. Is air necessary for combustion?

*A.* It is.

*Q.* 18. About how many cubic feet of air are necessary for the combustion of a pound of coal in a locomotive fire-box?

*A.* It takes 2.66 pounds of oxygen to burn 1 pound of coal into carbon dioxide. It takes 4.35 pounds of air to supply 1 pound of oxygen, therefore it will take $11\frac{1}{2}$ pounds of air to provide the oxygen necessary to burn each pound of coal. As some excess of air is necessary, 20 pounds of air should be admitted to the fire for each pound of coal to be burned. One pound of air fills about 13 cubic feet at ordinary temperatures, so we have $13 \times 20 = 260$, equal to 260 cubic feet of air needed for every pound of coal burned.

*Q.* 19. How many cubic feet of air, therefore, would be necessary for the burning of a "fire" of four scoopfuls, assuming each scoopful to weigh 10 pounds?

*A.* For four scoopfuls of coal, each weighing 10 pounds, the quantity of air required for combustion would be $40 \times 260 = 10{,}400$ cubic feet.

*Q.* 20. Why is it necessary to provide for combustion a supply of air through the fuel in the furnace?

*A.* Because it is only by forcing the air through the burning fuel that the proper mixture of the gases will be effected.

*Q.* 21. How can you prove that it is necessary to supply air to the fire-box for combustion?

*A.* By shutting off the air supply.

*Q.* 22. What is the effect upon combustion if too little air is supplied through the fire? If too much air is supplied?

*A.* If too little air is supplied the fire loses activity and combustion produces carbon monoxide, a gas with only about one-third the heating properties of carbon dioxide, the gas formed when the supply of air is sufficient.

If too much air is supplied waste is caused by heating the surplus quantity of air, and the over-supplying tends



to depress the fire-box gases below the igniting temperature.

*Q.* 23. What effect on combustion has the closing and opening of dampers?

*A.* A closing of the dampers cuts off the supply of air and prevents the fire from receiving its proper supply of air. Opening the dampers permits the air to pass through the grates. Under some circumstances it is better to keep one damper closed, unless the engine is working very hard.

*Q.* 24. How is draft created through the fire?

*A.* By the current of air induced by the exhaust through the flues and smoke-stack.

*Q.* 25. Describe a blower and its use and abuse.

*A.* A blower is a jet of steam passed up the smoke-stack to induce an artificial current of air. Its proper use is to prevent smoke when an engine is not working, to draw the fire gases away so that they do not pass into the cab, and to stimulate the fire when necessary.

The abuse of the blower is drawing cold air through the tubes or by forcing the fire when it is not necessary, causing waste of steam through the safety-valves.

*Q.* 26. What effect is produced by opening the fire-door when the engine is being worked?

*A.* It cools the boiler and prevents the rapid generation of steam.

*Q.* 27. What bad effect?

*A.* It causes sudden contraction of the fire-box sheets and flues, tending to cause leakage.

*Q.* 28. In what condition, therefore, should the fire be in order that the best results may be obtained from the combustion of the coal?

*A*. The fire ought to be maintained in the condition necessary to generate the steam required for the way the engine has to be worked. Even firing and even temperature go together.

*Q*. 29. What is the effect of putting too many scoops of coal on a bright fire? Is this a waste of fuel?

*A*. Throwing too much coal into a fire at one time depresses the temperature below the igniting-point and causes the generation of smoke. The practice is wasteful of fuel.

*Q*. 31. What effect has the fire upon a scoopful of coal when it is placed in the fire-box?

*A*. It distills the volatile gases first, then ignites the carbon of the coal.

*Q*. 31. In what condition should the fire be to consume these gases?

*A*. Bright and at a high temperature.

*Q*. 32. What is the temperature of the fire when in this condition?

*A*. About 3000° F.

*Q*. 33. How can the fire be maintained in this condition?

*A*. By regular firing. That is, by keeping up the supply of fuel as nearly as possible at the rate it is burned.

*Q*. 34. What is black smoke? Is it combustible?

*A*. It is unconsumed coal and can be prevented by good firing, if the coal is not too volatile, or the boiler forced beyond the limit where the gases can be properly mixed. It is combustible when mixed with air and kept at a high temperature.

*Q*. 35. Have you made any effort to produce smokeless firing?



*A*. Certainly I have.

*Q*. 36. How can black smoke be avoided?

*A*. By careful firing. With some qualities of coal and a plain fire-box smoke cannot be entirely prevented.

*Q*. 37. Can the firing be done more intelligently if the water-level is observed closely? Why?

*A*. Because regular boiler feeding and regular firing go together. The fireman can work more intelligently when he knows that the boiler is being fed regularly.

*Q*. 38. What advantage is it to the fireman to know the grades of the road and the location of the stations?

*A*. This knowledge enables him to regulate the firing to suit the fluctuating work the engine will have to do.

*Q*. 39. How should the fire and water be managed in starting from a terminal or other station?

*A*. The fire ought to be made up sufficiently heavy to preclude the necessity for firing while passing through the yards. The boiler ought to be as full of water as can be carried without priming.

*Q*. 40. What is the purpose of a safety-valve on a locomotive-boiler? Why is more than one used?

*A*. To relieve the boiler from over-pressure of steam. Two safety-valves are used because one is sometimes unequal to the task of preventing over-pressure.

*Q*. 41. What usually is the cause for steam being wasted from the safety-valve?

*A*. Injudicious firing, or want of co-operation between engineer and fireman.

It is frequently due to want of co-operation between the people who regulate the movement of trains and the enginemen.

*Q*. 42. What is the estimated waste of coal for each minute the safety-valve is open?

*A*. From 15 to 20 pounds.

A systematic test was made of an engine with about 1200 square feet of heating-surface and 27 square feet of grate area to ascertain the volume of steam wasted through the safety-valve. It was found to be 91 pounds of water per minute. As each pound of coal burned will evaporate about 6 pounds of water, the waste of coal in that case would be about 15 pounds per minute.

*Q*. 43. What should be done to prevent waste of steam through the safety-valves?

*A*. The firing should be so regulated when the engine is working that the steam will not rise to the blowing-off point; when steam has to be shut off unexpectedly blowing-off may be prevented by closing the dampers, opening the fire-box door a little and keeping the injector going. The surplus steam may also be blown back into the water-tank.

*Q*. 44. What should be the condition of the fire on arriving at a station where a stop is to be made?

*A*. Bright and clear, so that little smoke will flow from the stack. There must be sufficient fire on the grates to build on when the engine is started.

*Q*. 45. How should you build up the fire when at stations in order to avoid black smoke?

*A*. By putting in small quantities of coal at a time at short intervals and permitting the charges to burn bright.

*Q*. 46. What should be the condition of the fire when passing over the summit of a long grade?

*A*. It should be burned down as low as the requirements of steam-making will permit.



*Q*. 47. If the injector is to be used after passing over summit, how should the fire be maintained?

*A*. The fire ought to be maintained bright and the blower kept in use to create some circulation of the water of the boiler.

*Q*. 48. Is it advisable to take advantage of every opportunity to store in the boiler as much water as possible?

*A*. It is.

*Q*. 49. Why is it that if there is a thin fire with a hole in it, the steam pressure will fall at once?

*A*. Because cold air passes through the hole and has a chilling effect upon the boiler.

*Q*. 50. What would be the result of starting a heavy train with too thin a fire upon the grates?

*A*. Delay for want of steam.

*Q*. 51. How deep a fire should be carried?

*A*. It should be no deeper than necessary to make the required steam. The kind of fire-box and the work to be done would influence the proper depth of fire.

*Q*. 52. Where should the coal, as a rule, be placed in the fire-box?

*A*. It ought to be placed evenly over the entire surface of the grates.

*Q*. 53. Is rapid firing advisable?

*A*. No. Not the rapid firing that puts a heavy charge of fresh coal quickly into the fire-box. The rapid action that puts a scoopful of coal where it belongs, having the door open as short a time as possible, is commendable.

*Q*. 54. When and for what purpose is the use of rake on the fire-bed allowable?

*A*. When the surface of the fire is coking so that combustion is obstructed.

*Q*. 55. Within what limits may steam pressure be allowed to vary, and why?

*A*. When an engine is working the steam pressure ought to be kept as uniform as possible short of blowing-off pressure. When approaching stations the steam pressure should be reduced sufficiently to prevent blowing-off.

*Q*. 56. Is it advisable to raise steam rapidly?

*A*. Not if it can be avoided without causing delay. Rapid raising of steam, especially from cold water, puts destructive strains upon the boiler sheets.

*Q*. 57. Has improper firing any tendency to cause tubes to leak? How?

*A*. It has. Improper firing causes wide variations in the temperature of the fire-box, and sudden reduction of temperature causes the tubes to contract and leak.

*Q*. 58. What would you consider abuse of a boiler?

*A*. Intermittent firing, causing fluctuating variations of fire-box temperature, cooling by means of an open fire-box door and intermittent boiler feeding. Feeding the boiler rapidly when steam is shut off abuses the boiler.

*Q*. 59. How would you take care of a boiler with leaky tubes or fire-box?

*A*. Maintain the temperature as evenly as possible by uniform firing and boiler feeding. I should avoid feeding when steam was shut off.

*Q*. 60. What are the advantages of an arch in the locomotive fire-box?

*A*. It tends to keep the temperature of the fire-box



uniform; it prevents cold air from passing directly into the tubes, and it lengthens the journey of the fire-gases on their way to the tubes. The arch acts also to some extent as a spark-arrester.

*Q*. 61. Why is it very important that coal should be broken so that it will not be larger than an ordinary sized apple before being put into the fire-box?

*A*. Because in that condition it provides the best surface for ignition and provides the proper openings for emission and mixture of the fuel-gases.

*Q*. 62. When and why should you wet the coal in the tender?

*A*. As soon as the supply of coal has been put upon the tender. The wetting is done to keep down the dust. It also tends to keep the mass of fine coal together and prevents it from being drawn into the tubes by the suction of the exhaust.

*Q*. 63. Should coal be allowed to lie on the deck and fall out of the gangway?

*A*. Certainly not.

*Q*. 64. Do you understand that the coal used on the locomotive is property and represents money invested by the company?

*A*. I do.

*Q*. 65. What are the advantages of a large grate surface?

*A*. It permits of slower combustion than would be practicable with smaller grate surface, and slow combustion under proper restrictions promotes economy of fuel.

*Q*. 66. Why are the grates made to shake, and when should they be shaken?

*A*. To break up the clinkers and ashes that close up the grate openings and restrict the supply of air. The grates should be shaken very lightly as soon as the fire shows that the air is too much restricted. With some kinds of coal the grates must be moved frequently to prevent them from "sticking," a condition caused by fused clinker.

*Q*. 67. Why should grates not be shaken too frequently?

*A*. Because good fuel would be wasted and the ash-pan prematurely filled, with danger of burning grates.

*Q*. 68. Is it a fireman's duty to avoid filling up the ash-pan too full?

*A*. Certainly it is.

*Q*. 69. Is it permissible to dump ashes or fire over road-crossings, switches, or around stations?

*A*. It is not.

*Q*. 70. Is it objectionable to fill the tanks too full or spill water at stand-pipes or water-tanks?

*A*. It is a very objectionable and dangerous practice, and should be avoided.

*Q*. 71. What are the duties of a fireman on arriving at a terminal?

*A*. The answer to this question will vary according to the rules of the particular road.

*Q*. 72. Is the engineer responsible for the fireman's conduct while on duty and the manner in which the fireman's duties are performed?

*A*. He is.



## AIR-BRAKE QUESTIONS AND ANSWERS

### FIRST YEAR EXAMINATION

*Q*. 1. What is an air-brake?

*A*. It is a brake operated by compressed-air, and requires special mechanism for the application of the power.

*Q*. 2. How is the air compressed for use in the brake system?

*A*. By means of an air-pump, or compressor, located at some convenient place on the side of the locomotive-boiler.

*Q*. 3. What are the essential parts of the air-brake as applied to a locomotive?

*A*. They are an air-pump or compressor, an air-pump governor, a main reservoir, an engineer's brake, and equalizing discharge-valve; a duplex-air pressure-gauge, a plain triple-valve, an auxiliary reservoir, a brake-cylinder, with a piston in it, and the necessary piping-stop-cocks and angle-cocks.

*Q*. 4. How many kinds of triple-valves are there in use?

*A*. Two; the plain and the quick-action triples.

*Q*. 5. What is the main reservoir used for, and where is it located?

*A*. Primarily for the storage of a large quantity of air, to be used in releasing the brakes and quickly recharging the auxiliaries; and secondarily, to catch the moisture, dirt, and oil which are pumped in along with the air. It may be located in any convenient place about the engine or tender, but it is usually placed under the boiler, just back of the cylinder saddles, or under the running-board.

*Q*. 6. What is the usual standard brake-pipe pressure?

*A*. With the plain quick-action brake 70 pounds, and with the high-speed quick-action brake 110 pounds.

*Q*. 7. What pressure is usually carried in the main reservoirs?

*A*. With the plain brake, 90 pounds; with the high-speed brake, from 130 to 140 pounds.

*Q*. 8. Why is it important that all air-brake apparatus should be kept tight and free from leaks?

*A*. In order that the air-brake mechanism may operate properly and that there may be no waste of air, with its attendant evils, or any unnecessary work required of the pump.

*Q*. 9. Where does the air come from that operates the sand-blower, bell-ringer, air-whistle signal, water-scoop, or other devices?

*A*. From the main reservoir.

*Q*. 10. How should an air-pump be started?

*A*. Very slowly, with all drain-cocks wide open. After the water has drained away, close all drain-cocks, and when a pressure of 35 or 40 pounds has accumulated in the main reservoir, open the pump-throttle sufficiently to run the pump at a speed that will maintain the required pressure and perform the brake work satisfactorily. The steam end of the pump should be lubricated freely during the starting, just after the drain-cocks are closed.



## SECOND YEAR EXAMINATION

### *General Questions*

*Q*. 1. Has there been anything in the past year to interfere with your preparation for this examination?

*A*. The answer to this question will depend upon anything interfering or not.

*Q*. 2. Have there been any new signals introduced during the year or any changes on the old ones?

*A*. This question will be answered according to the knowledge of the candidate about signals.

*Q*. 3. Have you made any improvement in your method of firing, and have you obtained any better results economically and in smokeless firing during the year?

*A*. The answer to this question will also be based on the candidate's experience and progress.

### THE LOCOMOTIVE-BOILER

*Q*. 4. Describe the general form of a locomotive-boiler.

*A*. It is a cylindrical form of varying length and diameter, with a fire-box in the rear and a smoke-box in front. Flue-tubes extend from the front of the fire-box to the smoke-box and carry through the boiler the hot gases generated in the fire-box.

*Q*. 5. How does the wide fire-box boiler with fire-box projecting at each side beyond the wheels differ from the narrow fire-box set between the wheels, and what advantage has the wide fire-box over the narrow fire-box?

*A*. The purpose of the wide fire-box is to provide a larger grate area than what can be obtained with a fire-box set between the wheels. It is also easier to fire properly than a very long narrow fire-box.

*Q.* 6. What is a wagon top fire-box?

*A.* A boiler with that part of the shell above the fire-box raised above the level of the waist or cylindrical part of the boiler.

*Q.* 7. Describe a locomotive fire-box.

*A.* The ordinary fire-box is an oblong or nearly square box secured to the back part of the boiler. It is so constructed that water spaces are provided between it and the outside shell at the sides and the back. The fire-box is secured to the outside shell by stay-bolts, and at the front end of the fire-box is a flue sheet with the flues secured therein. At the bottom part of the fire-box is a bar called the mud-ring, conforming to the shape of the fire-box, to which the outside and inside sheets of the fire-box are riveted. Beneath the grates an ash-pan is secured. The crown-sheet is sometimes supported by bars set on edge but more generally by stays of various kinds.

*Q.* 8. Why have two fire-doors been placed in some of the wide fire-boxes?

*A.* To make it easier to spread the coal over every part of the grates.

*Q.* 9. To what strains is the locomotive fire-box subjected?

*A.* First, to the strains due to high-pressure of steam; second, to the strains that arise from varying temperature with the hot water on one side of the sheets and a hot flame or, perhaps cold air, on the other side. Then the changes of temperature act to lengthen or shorten the sheets, putting great strains upon the material. Varying



temperature of feed-water also puts strain upon the fire-box.

*Q.* 10. How are the side and end sheets of the fire-box supported?

*A.* The sides and back sheet are supported by stay-bolts; the front sheet by the tubes. All these sheets are supported by the mud ring.

*Q.* 11. What purpose is served by the small hole drilled in the outer end of stay-bolts?

*A.* To give indication by leakage when a stay-bolt breaks.

*Q.* 12. In what manner is a crown-sheet supported?

*A.* Sometimes by crown-bars, but generally by stay-bolts.

*Q.* 13. What is a bad feature about crown-bars?

*A.* They impede circulation of water and collect scale and mud.

*Q.* 14. What are the advantages of radial-stayed crown-sheets?

*A.* The radial stays offer little obstruction to the free circulation of the water. They also put less weight on the fire-box than crown-bars; and do away with the need of sling-stays to bind the fire-box to the shell.

*Q.* 15. How are the inside and outside sheets secured at the bottom?

*A.* By the mud ring, or foundation ring, as it is sometimes called.

*Q.* 16. Describe the ash-pan.

*A.* It is a sheet-iron pan that conforms to the outline of the mud ring and is secured thereto. There is a door at each end called a damper for restraining or cutting off the supply of air when necessary and to provide means for removing cinders and ashes that the ash-pan collects.

*Q.* 17. Why are boilers provided with steam-domes?

*A.* The dome provides a location for the throttle-valve removed considerably above the water-level in the boiler. This tends to prevent water from passing into the dry pipe along with the steam.

*Q.* 18. What must be the condition of a boiler in order to give the best results?

*A.* It must be kept as clean as possible and as free from scale and mud as circumstances will permit.

*Q.* 19. What is meant by circulation in a boiler?

*A.* The circulation is the moving of the water from one point to another inside the boiler. Circulation tends downwards at the cooler parts and upwards close to the heating-surfaces. It is strongest about the fire-box and arises from the heated water moving upwards and to the stirring given to the water by the steam rushing away from the heating-surfaces. There is a theory that the water at the sides and end of the fire-box flows downwards at the outside sheet and upwards on the hotter inside sheet.

*Q.* 20. What would be the result if a leg of the fire-box became filled with mud?

*A.* The fire-box side sheet would become overheated.

*Q.* 21. What would be the result if the fire-box sheets became overheated?

*A.* The sheets would bulge between the stay-bolts and would be likely to crack. If they were overheated by becoming dry rupture might ensue.

*Q.* 22. Why are boiler-checks placed so far away from the fire-box?



*A.* The checks are placed at the coolest part of the boiler so that the fire-gases that have been cooled in passing forward may still be able to impart some heat to the incoming water.

*Q.* 23. What part of the locomotive-boiler has the greatest pressure?

*A.* The steam pressure is uniform throughout, but there is a little pressure due to the weight of the water, and that is greatest on the lowest point which is the mud ring.

*Q.* 24. What should be the length of a locomotive smoke-box?

*A.* The ideas of designers vary greatly on this point. Extension smoke-boxes vary from 40 to 60 inches. The most common length on the New York Central Lines is about 65 inches for passenger- and 60 inches for freight-engines.

*Q.* 25. What object is there in having the exhaust-steam go through the stack?

*A.* For the purpose of creating draft.

*Q.* 26. How does this effect the fire?

*A.* The suction or draft created by the exhaust-steam causes a partial vacuum in the smoke-box which draws air through the grates, thereby stimulating the fire.

*Q.* 27. What should be done to prevent black smoke from trailing when the throttle is closed?

*A.* The dampers should be closed, the fire-door partly opened, and the blower started sufficiently to clear away the smoke.

*Q.* 28. What are the adjustable parts in the front end by which the fire is regulated?

*A.* With an extension front the diaphragm-plate in front of the tubes is adjustable. With a diamond stack an adjustable lift-pipe is generally set between the nozzles and the base of the stack. A lift-pipe is sometimes also used with an extension front.

*Q.* 29. Explain what adjustment can be made and the effect of each adjustment on the fire.

*A.* When the diaphragm-plate has the lower part too far away from the tube-plate there is danger of spark-throwing and the fire-gases will pass too freely through the upper rows of tubes. With such a defect the fire is burned more actively on the back part of the grates than in front. If the plate is set with the lower part too near the tube-plate draft will be obstructed and the fire will burn most actively in the front part of the grates.

There is no hard-and-fast rule for the adjustment of the lift or petticoat-pipe. It is usually set with the bottom of the flare level with the top of the nozzle. If the draft cuts the front of the fire too much the petticoat-pipe ought to be raised a little. If the back part of the fire is cut it ought to be lowered. Diaphragm and lift-pipe ought to be set so that the fire-gases will be drawn evenly through all the tubes.

*Q.* 30. What is out of place where the exhaust-steam strikes the side of the stack?

*A.* Generally the lift-pipe. That result will also come from the nozzle being out of plumb.

*Q.* 31. What effect has the stoppage of a number of flues?

*A.* It reduces the steam-making capacity of the boiler. Makes boiler-steam poorly.

*Q.* 32. What is the effect of leaking steam-pipe joints inside the smoke-box?



*A.* It injuriously affects the steaming of the boiler.

*Q.* 33. What causes pull at the fire-door?

*A.* Diaphragm-plate or lift-pipe being set too high.

## FIRING

*Q.* 34. Give briefly your opinion as to the best method of firing locomotives.

*A.* In the manner that will generate steam freely with the smallest quantity of coal. This is done generally by steady firing with the quantity to suit the way the engine is working.

*Q.* 35. If upon opening the fire-door you discover what is commonly called "red" fire what might be the cause?

*A.* The free passage of air through the grates being obstructed.

*Q.* 36. Is it a waste of fuel to open the fire-box to prevent safety-valves from blowing? How can the necessity for this be prevented?

*A.* First, it is a waste of fuel. Closing the dampers and starting the injector are the easiest remedies. Second, escape of steam through the safety-valves bowling may generally be prevented by careful firing and forethought when approaching stopping-places. When blowing off steam cannot be prevented, some of the heat may be saved by blowing the steam into the tender.

## OPERATION ON THE INJECTOR

*Q.* 37. What is an injector?

*A.* An injector is an apparatus in which a jet of steam condensed by water imparts to the latter its velocity, with the result that the final energy of the combined steam and water is greater than that at which the water would issue from the boiler. This difference of energy in favor of the jet passing through the injector enables it to lift the boiler-check and enter the boiler.

*Q.* 38. In a general way what are the two kinds of injectors?

*A.* In a general way, injectors are known as "Single Tube" injectors, when they have a single set of nozzles, and as "Double Tube" injectors when they have two sets of nozzles; one of the latter kind has the function of lifting the feed-water and delivering it to the forcing set, which latter imparts to the water sufficient velocity to cause it to enter the boiler.

*Q.* 39. What is the difference between a lifting and a non-lifting injector?

*A.* A lifting-injector is placed above the highest water-level of the tank from which the feed-water supply is taken, so that the injector has to lift the water up to its own level. A non-lifting injector is placed below the lowest level of the water of the tank from which the feed-water is taken, and it flows to the injector by gravity.

*Q.* 40. What are the essential parts of an injector?

*A.* The essential parts of injectors are, in the first place, the nozzles, which perform the function of delivering or forcing the water into the boiler, and, in the second place, the operating mechanism, such as the lifting-valve, steam-valve, water-valve, etc.

*Q.* 41. How should an injector be started?

*A.* In starting an injector, if it is a lifting one, the lifting-valve should be opened first, and when the water appears at the overflow, the forcing-valve of the injector should be opened gradually to its full extent. In starting



a non-lifting injector the water should be admitted to the injector first, and when it appears at the overflow the steam-valve should be opened gradually to its full extent.

*Q.* 42. Give some of the common causes for failures of injectors to work.

*A.* The most common causes for failure of injectors are the following: leak in the suction-pipe. Obstructed strainer or strainer of insufficient size. Liming up of the nozzles. Loose hose lining. Obstructions in the nozzles, such as pieces of coal, or other foreign matter washed in from the tank. Obstructions in the delivery-pipe, such as a sticking boiler-check which will not open properly. Leaky steam-valve and boiler-check, which will affect the starting of the injector by heating the suction-pipe and the feed-water.

*Q.* 43. What course should be pursued with the check-valve stuck open?

*A.* In case the check-valve is not provided with a stop-valve, it will be necessary to close the heater-cock and water-valve of the injector, to prevent water from the boiler from running out through the injector. In this case reliance for feeding the boiler must be had on the injector, the check of which must be in good condition. If the boiler check has a stop-valve, this can be closed down to shut off the boiler-pressure from the check, in which case the check can be taken out for cleaning or for the removal of the causes which made the valve stick open.

*Q.* 44. How may it be determined whether the check-valve or steam-valve is leaking?

*A.* To determine whether the check-valve is leaking the frost-cock, with which all delivery-pipes and most check-valves are provided, should be opened. If water continues to issue from this frost-cock, the indication is that the check-valve is leaking. To determine whether the steam-valve is leaking, the cap of the heater-cock and the heater-cock check should be removed. If the steam-valve is leaking, steam will issue through the opening.

*Q*. 45. What may be done in this case?

*A*. In such cases the check-valve and the injector must be reported for repair, and the leaky valves ground in. Sometimes the check-valve may be sent to its seat by tapping the case with a piece of wood.

*Q*. 46. What may be done if a combining-tube is obstructed?

*A*. In case the combining-tube is obstructed, it must be removed, the nozzles thoroughly cleaned, and all obstructions removed.

*Q*. 41. How may it be determined if the trouble is on account of a leak in the suction-pipe?

*A*. When the suction-pipe leaks, the injector works with a hoarse, rumbling sound, caused by the air drawn in through the leaks. A leak in the suction-pipe may also be determined by closing the tank-valve, and opening the steam-valve of the injector slightly, with the heater-cock closed. If there is a leak anywhere in the suction-line, the steam under such circumstances will issue through the leak.

*Q*. 48. What should be done in case of obstructed hose or strainer?

*A*. In case of an obstructed hose or strainer, the connection between hose and strainer should be broken, and with the heater-cock closed, steam should be blown back through the strainer. The water allowed to flow through the open hose will usually wash out the obstruction. In most cases it will be sufficient to remove the waste-cap of the strainer, and allow water from the tank to flow through to wash out the obstruction.



*Q*. 49. What should be done in case the feed-water in the tank is too hot?

*A*. In case the feed-water in tank is too hot, it will be necessary to obtain fresh water as soon as possible to reduce the temperature.

*Q*. 50. Will an injector work if all of the steam is not condensed by water?

*A*. An injector will not work properly if all of the steam is not condensed.

*Q*. 51. If it is necessary to take down the tank-hose, how can the water be prevented from flowing out of a tank that has the siphon-connection instead of the old style tank-valve?

*A*. In case a tank is provided with a siphon-connection in place of the usual type of tank-valve, it is better to open the air-vent at the top of the pipe, in order to prevent the water from flowing out when the tank-hose is taken down. The sizes of the siphon-pipes are usually large enough to admit air when the hose is disconnected, so that there is little danger of the water being siphoned out of the tank.

*Q* 52. Explain how the water in the delivery-pipe can be protected from freezing.

*A*. If the injector is not in use for a long period in cold weather, the frost-cock in the delivery-pipe should be opened to prevent freezing.

*Q*. 53. Explain how you would prevent the waste-pipe freezing, either while the injector is working or shut off.

*A*. The waste-pipe contains water only during the short period when the injector is started, and even then it flows through the pipe at a rapid rate, so that the danger of freezing is very remote. When the injector is at rest, the waste-pipe is empty. A gradual freezing as a result of a badly leaking lifting- or steam-valve may be prevented by occasionally opening the lifting-valve slightly, and allowing steam to blow through the waste-pipe.

*Q*. 54. How can the suction-pipe and injector-hose be protected from freezing?

*A*. The suction-pipe and hose may be protected from freezing by using the injector as a heater.

*Q*. 55. Explain how the heater is used on a lever-Monitor injector?

*A*. In connection with the lever-motion injector, it can be used as a heater by closing down the heater-cock and opening the lever very slightly, and fastening it in that position by means of the thumb-screw on the side of the lever.

*Q*. 56. How is the heater used with a screw-Monitor injector?

*A*. With a screw-Monitor injector is can be used as a heater by closing down the heater-cock and opening the steam-valve spindle about half a turn.

*Q*. 57. Is the indication of water-level by the gauge-glass a safe indication if the water-level in the glass is not moving up and down when the locomotive is in motion?

*A*. If the water-level in the gauge-glass of a locomotive is not moving up and down when the locomotive is in motion, the indication of the water-level is not a safe one.



*Q*. 58. Is any more water used when an engine foams than when water is solid?

*A*. When an engine foams, the consumption of water is decidedly greater than when the boiler does not foam.

*Q*. 59. How should an injector be stopped?

*A*. In stopping an injector, the steam-valve should be pressed firmly and gradually on its seat, avoiding (more particularly in the case of a lever mechanism) the closing of the valve with a sudden shock, which injures the valve and its seat, and has a tendency to loosen these seats, where they are inserted in the body of the valve.

## AIR-BRAKE QUESTIONS

### SECOND YEAR EXAMINATION

*Q*. 1. Why is the present brake called the automatic-brake?

*A*. Because it is automatic in its action; that is, its normal condition is when it is held off, due to the maintenance of train-line pressure, and anything which happens to reduce train-pipe pressure will cause the brake to apply of its own accord, or automatically.

*Q*. 2. Where is the compressed-air stored?

*A*. In the main reservoir on the engine; in the train-line which extends throughout the train, under the cars and connects the brake-valve with the triple-valves, and in the auxiliary reservoir under each car.

*Q*. 3. What are the functions of the auxiliary reservoir, train-pipe, triple-valve, and brake-cylinder?

*A*. The auxiliary reservoir holds a storage of compressed-air for supplying the brake-cylinder with pressure with which the brake-piston is pushed out, engaging the system of levers which brings the brake-shoes up against the wheels and supply braking-power. The train-pipe stores a quantity of compressed-air, which holds the triple-valve in release position normally, but when the train-pipe pressure is reduced, the triple-valve will shift and apply the brake. The triple-valve performs a three-fold function. When in release position, it permits a charge of pressure to pass from the train-pipe into the auxiliary reservoir. In application position, it permits pressure to pass from the auxiliary reservoir into the brake-cylinder. In release position, it permits pressure to discharge from the brake-cylinder to the atmosphere. Thus air passes through the triple-valve three times. The brake-cylinder receives pressure from the auxiliary reservoir in service application, and from both train-pipe and auxiliary reservoir in emergency application, which pushes out the piston and applies the brake.

*Q*. 4. Where does the pump deliver the air?

*A*. To the main reservoir on the engine.

*Q*. 5. Where does the main-reservoir pressure begin and end?

*A*. It begins with the discharge-valves of the air-pump and ends at the rotary-valve of the engineer's brake-valve.

*Q*. 6. What is excess pressure?

*A*. That amount of pressure contained in the main reservoir higher than that in the train line, available for releasing brakes.

*Q*. 8. How should a brake be cut out?

*A*. By turning the stop-cock in the branch or cross-over pipe.



*Q*. 9. How should the handle of cut-out cock stand when closed?

*A*. Parallel with the pipe.

*Q*. 10. How should handle of the angle-cock stand when closed?

*A*. At a right angle with the pipe.

*Q*. 11. What does line, or mark, at end of plug-cock indicate, regardless of position of handle?

*A*. This line, or mark, indicates the direction of the passageway through the plug-cock, and by it may be known whether the cock is open, regardless of the handle itself.

*Q*. 12. How should a brake be "bled" off?

*A*. The release-valve should be sharply opened for an instant, then quickly closed. This operation may be repeated until the triple-valve begins to discharge the air, which can be heard at the retaining-valve or exhaust-port of the triple, then no further opening of this valve should be made.

*Q*. 13. When should the brake-valve be used in the emergency position?

*A*. Only in extreme emergency cases to prevent accident, such as loss of life or property, then the handle should be placed in the emergency position and left there until the train stops or the danger of accident is over.

*Q*. 14. What does the red hand on the air-gauge register?

*A*. Main-reservoir pressure.

*Q*. 15. What does the black hand register?

*A*. The pressure above the equalizing piston and in chamber *D*. This pressure may be properly classed with train-line pressure.

### THIRD YEAR EXAMINATION

*General Questions*

**ENGINEER'S FIRST DUTIES**

*Q.* 1. What are the duties of an engineman before attaching the locomotive to the train?

*A.* The duty of the engineman is to thoroughly inspect his engine for possible defects of machinery. He should know the condition of the fire-box, grate-bars, etc.; that gauge and water-glass cocks are open and working freely, and that the crown-sheet is covered with sufficient water to protect it from injury, and that the tender has been supplied with water. He should also know the condition of the engineer's brake-valve and air-pump, and take such other precautions as would prevent an engine failure.

*Q.* 2. What tools should there be on the locomotive?

*A.* The engine should be provided with such tools as are bound necessary in everyday work. This includes also tools with which to make repairs in case of accident. Rake, coal-pick and shovel are classed as tools.

Some companies specify that tools ought to be carried on the engine. Where that is done the answer to this question should be regulated accordingly.

*General Questions*

*Q.* 3. What examination should be made after any work or repairs have been done on valves, brasses, etc.?

*A.* A man should satisfy himself by personal inspection that the work has been properly done, that all movable parts have been returned to place and properly secured by bolts, set-screws or otherwise.



*Q.* 4. How can it be known whether a boiler is carrying the proper steam-pressure?

*A.* By the safety-valves and steam-gauge, which should correspond with the prescribed pressure as established by the company.

*Q.* 5. What attention should be given to boiler attachments, such as gauge-cocks, water-glasses, etc.?

*A.* It should be known that they are open and working freely at all times.

*Q.* 6. Is smokeless-firing practicable?

*A.* It is practicable with certain kinds of coal. With other kinds of coal the best a fireman can do is to fire frequently, keeping the fire as thin as practicable.

*Q.* 7. Trace the steam from the boiler through the cylinders to the atmosphere, and explain how it transmits power.

*A.* Steam enters from the main throttle located in the dome into the dry-pipe, thence to the steam-pipe and into the steam-chest. From the chest it passes through the admission-port into one end of the cylinder and forces the piston to the opposite end. When the piston has very nearly completed the stroke, the movement of the valve, which is in the opposite direction to the movement of the piston, establishes communication with the exhaust-passage and permits the steam to pass through the exhaust-passage into the stack and thence to the atmosphere.

*Q.* 8. How much power have the piston and cross-head on one side to turn the crank-pin, when the center of the wrist-pin, the crank-pin, and the main-driving axle on the same side are in a straight line?

*A.* None whatever.

*Q.* 9. How then is the engine kept going?

*A.* Since a locomotive consists of two complete engines whose main-rods transmit their power to the same driving-shaft upon which the main-pins are at right angles to one another, it follows that the engine whose main-pin is on either top or bottom quarter exerts sufficient power to cause the wheel to rotate, carrying the pin on the opposite side past the dead center to a point where the steam becomes effective to move the engine on that side.

*Q.* 10. What is meant by "working steam expansively?"

*A.* By working steam expansively is meant the process by which the steam is let into the cylinder and cut-off before the piston has finished its full stroke, thereby allowing the expansive force of the steam to exert a certain amount of energy on the piston from the time that cut-off took place up to the point where release occurs.

*Q.* 11. How should the locomotive be started to avoid jerks, and what train-signals should be looked for immediately after starting?

*A.* The engine should be started with the reverse-lever in full gear in the direction in which the locomotive is expected to move, and a gradual admission of steam.

Signals should be carefully looked for towards the rear end of the train to make sure that the entire train has been started.

*Q.* 12. After a locomotive has been started, how can it be run most economically?

*A.* By working steam expansively, that is, with the reverse-lever cut back to a point where the engine will handle the train with a full throttle.



*Q.* 13. If you discovered that a fixed signal was missing or was imperfectly displayed, what should you do?

*A.* Stop. Ascertain the cause and report to the proper official from the first telegraph station as per standard or special rules covering this subject.

*Q.* 14. How rapidly should the water be supplied to the boiler?

*A.* Water should be delivered to the boiler steadily and in just sufficient quantity to replace the water which is being evaporated in doing work.

### FOAMING AND PRIMING

*Q.* 15. What is the difference between priming and foaming of a locomotive-boiler?

*A.* Priming is carrying water along with the steam and is caused by water being carried too high, or from insufficient steam-room in the boiler. Foaming consists of an aggregation of bubbles, or both, which carry the sediment to the surface. In both cases water is carried with the steam to the cylinder. To the ordinary observer priming and foaming are the same thing.

*Q.* 16. What should you do in case of foaming in the boiler?

*A.* The throttle should be either partly or entirely closed for a few moments to ascertain the water-level in the boiler. Where surface-cocks are used, they should be used while the engine is at work, because they will then carry away the scum which has been driven to the surface. When recourse is had to the blow-off cock, it can best be done when the engine has been shut off, as the sediment then settles to the bottom.

*Q*. 17. What danger is there when the water foams badly?

*A*. There is danger of exposing the crown-sheet to the intense heat through the water being too low, and liability of burning it. There is also danger of knocking out cylinder-heads.

### ADJUSTING ROD BRASSES AND SETTING UP WEDGES

*Q*. 18. What work about a locomotive should be done by the engineer?

*A*. He should set up the wedges and key up the rod brasses. Some railroad officials do not permit the engineers to adjust wedges or brasses.

*Q*. 19. How should the work of setting up the wedges be done?

*A*. The engine should be placed with the crank-pin of the right side on the upper-forward eighth, which brings the crank-pin-of the left side on the back upper-eighth. Block the wheels, and with the reverse-lever in the forward motion apply a small quantity of steam. As the action of the steam against the piston has a tendency to move it forward, the strain is thrown against the shoes, permitting a free movement of the wedges. The wedges should be set up with an ordinary wrench as far as possible and then pulled down again about one-eighth of an inch to prevent the box from sticking either from overheating of the box or defective lubrication of the wedge.

*Q*. 20. How should the rod brasses be keyed?

*A*. The key should be driven down just enough to bring together brass to brass. Any greater force would spring the crown of the brass against the pin and cause it to heat.



*Q*. 21. How should an engine be placed for the purpose of keying rod brasses?

*A*. That depends entirely on which rods are to be keyed. If the main-rod is to be keyed, place the side of the engine upon which the work is to be done either on the upper-forward eighth or the lower-back eighth, as these positions present the greatest diameter of the pin to the rod brass and guarantee a free movement at all points without binding.

*Q*. 22. What is the necessity of keeping brasses keyed up properly?

*A*. To prevent unnecessary shocks and heating of rod brasses and pounding in driving-boxes, which in time cause undue strain on the entire motion with disastrous consequences.

*Q*. 23. How should the side rods on mogul and consolidation locomotive be keyed?

*A*. Place the engine on the dead center either forward or back. First key the middle connection, next the ends of rods and observe that the rod moves freely on the pin. Now place the engine on the opposite dead center, and notice if the rods move freely at this point also. This is particularly necessary with rod brasses having keys on both sides of pin and which are apt to be made either too long or too short, throwing the rods out of tram and causing undue strain on rods and driving-boxes, and also danger of broken rods or pins.

*Q*. 24. What is meant by "engine out of tram?"

*A*. By an engine out of tram is meant one whose distance from center to center of axle or rod on one side does not coincide with the similar distance on the opposite side; or it may mean that the distance between two connected crank-pins is not the same as the distance between the two axles to which the crank-pins belong.

### WHY SMOKE-BOX IS KEPT AIR-TIGHT

*Q.* 25. Why is it important that there be no holes through smoke-box sheets or front and none in the smoke-box seams or joints?

*A.* There should be no possible chance for the admission of air to any part of the smoke-box, because it tends to destroy the vacuum necessary to create a perfect draft on the fire and also fans fires in the smoke-box that warp and destroy the sheets or front end.

### VALVES AND PISTONS

*Q.* 26. Describe a piston-valve?

*A.* A piston-valve is a cylindrical spool-shaped device having cast-iron packing rings sprung into place on the valve, and operating in a cylinder of equal diameter. The valve-cylinder is provided with suitable admission and discharge ports and permits the valve to perform the same functions as an ordinary slide-valve.

*Q.* 27. What is a balance slide-valve? How is it balanced and why? For what reason is the hole drilled through the top of the valve?

*A.* A balance slide-valve is one where a certain percentage of the steam pressure exerted on the top of the ordinary slide-valve has been prevented.

The balancing feature is obtained by a steam-table extending beyond the extreme travel of the valve, and either bolted to the steam-chest cover or cast in one piece



with it. The Allen-Richardson valve has its valve grooved for the reception of four snugly-fitting strips, which are supported against the table by semi-elliptic springs, which make a steam-tight joint, and prevent any pressure reaching the enclosed part of the valve. The American balance-valve obtains the same results but uses circular, tapering rings supported by coiled springs.

The small hole in the top of the valve is for the express purpose of allowing any pressure or water which may have accumulated on the top of the valve from whatever cause to escape to the exhaust-port.

*Q.* 28. What is meant by inside and outside admission valves?

*A.* By inside-admission valve is meant one where the steam enters the steam-port of the cylinder from the inside edge of the valve and is exhausted from the outer edge of the valve; by outside admission is meant one where steam enters the steam-port from the outer edge and is exhausted from the inner edge, similarly to our common slide-valve, which is an outside-admission valve.

*Q.* 29. What is the relative motion of main piston and valve for inside-admission valve and for outside-admission valve?

*A.* With inside admission the motion of the valve is in the opposite direction to the piston's motion at the beginning of the stroke. With outside admission the movement of the valve is in the same direction as the piston at the beginning of the stroke.

*Q.* 30. What is the difference in the valve motion for outside-admission valves and inside-admission valves?

*A.* Both may have either direct or indirect motion, according to the position of the eccentrics on the shaft and the type of rocker-arm used.

*Q*. 31. What is a direct-motion valve-gear? What is an indirect-motion valve-gear?

*A*. A direct-motion valve-gear is one that transmits the motion of the eccentric to the valve direct by means of a transmission-bar or its equivalent connecting with the valve-stem.

An indirect-motion valve-gear is one where the power is transmitted from the eccentric to the lower rocker-arm, which gives motion to the upper arm that moves the valve-rod connecting with the valve-stem.

*Q*. 32. What is meant by lead?

*A*. Lead is the amount of opening a valve has when the piston is at the beginning of the stroke.

*Q*. 33. What is meant by steam-side lap?

*A*. By steam-side lap is meant the amount the valve overlaps the steam-ports, when the valve is on the middle fo the seat.

*Q*. 34. What is meant by exhaust-side lap and by exhaust-side clearance?

*A*. Exhaust-side lap is the amount the inner edge of the valve overlaps the steam-ports when the valve is in the middle of the seat.

Exhaust-side clearance is the amount the inside edge of the valve comes short of covering the ports when the valve is in the middle of the seat.

*Q*. 35. With an indirect-valve motion, what would be the position of the eccentric relative to the crank-pins? With direct-motion valve-gear? Why?

*A*. If the valves are the inside-admission indirect, necessitating a rocker-shaft, the eccentrics would lean toward the fire-box when the main-pin is on the forward dead center; while an outside-admission indirect has the belly of the eccentrics leaning toward the main-pin.

With an inside-admission direct and a transmission bar, both eccentrics lean toward the pin; while with the outside-admission direct the eccentrics have the same position as with the inside-admission indirect. With the inside-admission indirect the eccentric-rods are crossed, when the crank-pin is on the forward dead center; the eccentric-rods with the outside-admission direct are also crossed when the crank-pin is on the forward dead center.

These positions of the eccentrics are necessary with the corresponding valve motion to secure correct movement of the valves.

*Q*. 36. What effect would be produced upon the lap and lead by changing the length of the eccentric-rods?

*A*. If the valves are set so that they travel an even distance over the center of the valve-seat, changing the length of eccentric-rods would make the valves travel unevenly, opening the steam-ports too much at one end and too little at the other. Changing the length of the eccentric-rods after the valves have been properly set would produce too much lead on one rod and not enough at the other.

*Q*. 37. Why are eccentric-rods made adjustable?

*A*. To allow for adjustment of the valve-travel, so that even steam admission may be made at both steam-ports.

### CYLINDERS, PISTONS, AND PACKING

*Q.* 38. Why is it necessary to keep the cylinders free from water?

*A.* To prevent rupture of cylinder and head which would necessarily occur should much water which is incompressible remain after the valve had closed all communication and the piston been forced to the end of its stroke.

*Q.* 39. Where is the piston-rod packing located? Cylinder packing?

*A.* The piston-rod packing is located in the back cylinder-head.

Cylinder-packing is to be found in the grooved receptacles provided for that purpose in the circular surface of the piston.

*Q.* 40. How are the metallic packing-rings on valve-stems and piston-rods usually held in place? And what provision is made for the uneven movement of the rods?

*A.* Metallic packing-rings are held in place by stiffened spiral springs pressing against a ring and forcing the packing into a bell-shaped cone.

Suitable provision is made for the uneven movement of the rods in that the cone holding the metallic packing has a ground and steam-tight joint, which permits the cone to have a lateral motion against the face of the packing-gland, and thereby prevents the escape of any steam.

### CAUSE OF TANK SWEATING

*Q.* 41. What is the cause of tank sweating? And what will prevent it?

*A.* Sweating on the tank is caused by the cold water inside condensing the moisture in the air. It can be prevented by raising the temperature of the water in the tank to the temperature of the air.



### FRICTION AND LUBRICATION

*Q.* 42. What is friction?

*A.* Friction is the resistance between two bodies in contact, which resists the sliding of one upon the other.

*Q.* 43. Upon what does the amount of friction depend?

*A.* The amount of friction between two bodies in contact depends on pressure, temperature, speed, kind of material, and quantity and quality of lubricant.

*Q.* 44. What is the effect of the introduction of oil or other lubricants between frictional parts?

*A.* It reduces friction in proportion to the quantity and quality of lubricant used.

*Q.* 45. Explain the principle on which grease-cups operate. What is the objection in using water on a hot pin where grease is used, or a hot pin with babbitted brasses?

*A.* The principle on which grease-cups operate is that of compression and expansion. As grease reduces friction less rapidly than oil, a certain amount of heat is generated, and as grease expands more rapidly than metal, it is forced through the aperture in the cup down upon the pin.

As one of the ingredients of "rod grease" is lye, and as lye will freely dissolve in water, the application of water to a pin will remove the "grease" and destroy lubrication.

The intermittent use of water on hot pins provided with babbitted brasses, where oil is used as a lubricant, has a tendency to clog the feeder with babbitt metal, thereby preventing the flow of oil to the pin. It also produces unequal contraction of the pin, often with disastrous results. There can be no bad effect from the continuous use of water, if used before the brass becomes overheated and before the babbitt starts to melt.

### BLOW-OFF COCK

*Q.* 46. Explain the construction and operation of the blow-off cock?

*A.* A blow-off cock may be either a globe-valve operated by a screw, a taper plug-valve operated by a lever, a sliding disk-valve operated by a lever, or a plunger-valve upon whose upper end either steam or air may be forced to unseat it.

The object of any of these valves when open is to permit the escape of sediment and impurities from the boiler, and for that reason they are located at the bottom of the boiler.

### BELL-RINGER

*Q.* 47. Describe a bell-ringer; and how it may be adjusted?

*A.* The automatic bell-ringer is a device whose mechanism consists of a valve have either a sliding or rotary movement and provided with a suitable admission and exhaust-port, a piston operated in a cylinder, and a piston-rod connected to the bell-crank so as to impart a swinging movement. The motive power is air taken from the main reservoir.

Some types are provided with a threaded stem and a jam nut by which adjustment can be made, while others have a piston-rod operating like a telescope and requiring no adjustment.



### USE OF THE BLOWER

*Q.* 48. How should the blower be used when an engine is on the cinder-pit?

*A.* The blower should be used with just enough force while cleaning the fire to prevent the escape of gases from the fire-door and possible injury to the fire-cleaner.

When the engine is at rest it is sometimes necessary to use the blower to prevent the emission of smoke. In this case the fire-door should be kept on the latch. The blower has sometimes to be used for stimulating the fire when the engine is not steaming freely. In such cases it can be employed to best advantage when descending grades or approaching stations with the steam shut off.

### ENGINE DISABLED ON THE ROAD

*Q.* 49. In case the locomotive in your care became disabled on the road what should you do?

*A.* First, protect the train front and rear by flags the prescribed distance. Make such temporary repairs as are necessary to get the train to the next siding, in order to prevent blocking the main line. When on the siding make all the repairs practicable with the tools at hand. If the breakdown is of such a nature as to prevent the possibility of making even temporary repairs, so as to clear the main lines, arrange to notify the nearest telegraph office of your location and ask for assistance.

*Q.* 50. Suppose a wash-out plug blew out, or a blow-off cock broke off or would not close, what should be done?

*A*. Draw the fire at once to prevent burning of fire-box sheets. In addition to this, in cold, freezing weather, the pet-cocks on all connections where there is any liability of water collecting should be opened to drain the pipes, and in the absence of cocks, the couplings should be slacked off. The tender-hose couplings should be disconnected and special care should be given to the air-pump drain-cocks to prevent the rupture of the steam-cylinder of pump.

If a heavy fire was on the grates it might be necessary to dampen it with earth or water before dumping it.

*Q*. 51. What should be done, should the grates be burned out or broken while on the road?

*A*. Block up the broken or burnt grates, with fish-plates, brick, or anything conveniently at hand, and disconnect the good grate immediately ahead and back of the burnt section in order to prevent disturbing the other grates when shaking down the fire.

#### TO PREVENT SPARK THROWING

*Q*. 52. What precaution should be taken to prevent locomotives throwing fire?

*A*. In order to prevent engines from throwing fire, the netting in the smoke-stack or smoke-box should be carefully looked after, and the cinder slide and hand-hole plates must be in their proper places and securely fastened. Equally important is the knowledge that the ash-pan is clean, otherwise live coals, more dangerous than cinders, will roll out of the pan and start fires on bridges and along the company's property.



#### BURSTED OR LEAKY TUBES

*Q*. 53. What should be done with a badly leaking, or bursted tube?

*A*. Where time and conditions permit, burst flues can be put in condition to bring in train. First, fill the boiler as full of water as it will hold, to compensate for loss. Then blow off steam through the whistle or remove release-valve from chest, open the throttle, and blow off steam and deaden the fire so that the flue can be plugged. If the tube is burst, it must be plugged at both ends. If it is simply a case of leaky tube at tube-sheet, the above method is not necessary. Simply plug the tube. Bran or any starchy substance admitted through the heater-cock on injector after injector has been started will aid in stopping a bad leak.

*Q*. 54. Suppose that, immediately after closing the throttle, the water disappeared from the water-gauge glass, what should be done?

*A*. Disappearance of water from water-glass may be caused in various ways. The water may be bad and foamy, or the engine may have insufficient steam space, thus causing the water to prime, or the engineman may have taken too many chances on low water. As soon as the water disappears from the glass no time should be lost before banking or deadening the fire. Injectors should be kept at work until the water reappears in the glass before fire is rekindled.

#### THROTTLE-VALVE DISCONNECTED

*Q*. 55. What should be done in case a throttle-stem becomes disconnected while the throttle-valve is closed;

and if it becomes disconnected while the throttle-valve is open?

*A*. With a disconnected throttle closed—where the company requires the engineman to make repairs—steam must first be blown off and the dome-cap raised to reach the disconnected rod. Not enough power can be had from the oil-pipes to move the modern engine. If she is equipped with a drifting-valve, she can be made to move herself without train.

If the throttle is disconnected and open, reduce pressure to a point where engine will not slip, and control the train by air-brake.

What is often mistaken for a disconnected throttle is merely a stuck throttle, due to excessive lost motion of parts, and occurs when giving full throttle. Tapping the throttle-rod often releases it from sticking.

### ACCIDENTS TO VALVES OR VALVE MOTION

*Q*. 56. In the event of a slide-valve yoke or stem becoming broken inside of the steam-chest, how can the breakage be located?

*A*. After satisfying myself that the eccentrics and visible parts of the valve motion were intact, consider the type of valve on the engine. With a broken valve-stem or yoke, the valve is always forced to the forward end of chest. With an outside admission piston-valve or a slide-valve, place the lever in the forward gear and watch the steam leaving the cylinder-cocks. Reverse the lever, and if the steam issues from both cocks on one side and from only the back one on the other, the latter has the disabled valve.

With the inside admission, steam would issue from the



front and not from the back cylinder-cock. Where relief-valves are used, remove them first and watch movement of valve.

*Q*. 57. After locating a breakage of this kind, how should one proceed to put the engine in safe running order?

*A*. If the engine had relief-valves on front end of chest, disconnect valve-rod; and, after forcing valve to central position to cover ports, clamp stem from one end and block with a plug driven into relief-valve of sufficient length to hold valve in place, leave up main-rod and proceed. If relief-valve were on back end, the chest cover would not have to be taken up, but back end of main rod would have to be disconnected and cross-head blocked ahead. The disconnected valve-rod would hold the valve against forward end of chest.

*Q*. 58. If a slide-valve is broken, what can be done to run the engine on one side?

*A*. If it is a balanced-valve and broken so that the steam-ports cannot be successfully covered, slip a heavy piece of sheet iron between valve and valve-seat, and block valve front and back. The balance-plate will then come down solid on valve and prevent leakage to cylinder.

With ordinary slide valve and similar conditions, remove valve entirely and block with hard wood, having the grain of the wood crosswise of the seat. With the sheet-iron over the seat and the chest filled with blocking so that the cover will close down on it firmly and make a steam-tight joint, proceed on one side without disturbing anything except the valve-rod.

*Q*. 59. What should be done in case of link saddle-pin breaking?

*A*. Put the lever in a notch forward where one would be safe in starting a train. Then raise the link on the disabled side to the same level as the good one, and block between top of link-block and link. Have another block ready of sufficient length to raise the link enough, should it be necessary to back up the engine.

*Q*. 60. With one link blocked up, what must be guarded against?

*A*. Reversing the engine, unless the disabled side has been changed by raising or lowering to correspond with the good side.

*Q*. 61. How can it be known if the eccentric has slipped?

*A*. By a lame exhaust, or with a bad slip, one of the exhausts disappearing entirely, and by watching the cross-head to note when the exhaust takes place.

*Q*. 62. Having determined which eccentric has slipped, how should it be reset?

*A*. Having located the eccentric, if it is a go-ahead, move the engine so that cross-head will come very near to the end of its travel ahead. Then move the eccentric around pointing in the opposite direction to the back-up, leaning either toward or from the pin—which would depend entirely on the style of valve and whether direct or indirect motion. As soon as steam appears at front cylinder-cock, tighten set-screws.

For back-up eccentric, lever and cross-head will have to be placed in the opposite direction. The best way is to mark eccentrics before starting, by placing the lever in forward notch and having cross-head at front end of travel. Then make a mark on cross-head and guide, doing the same with eccentrics and straps. If from any



cause an eccentric slips and engine is placed so that mark on cross-head corresponds with that on guide, the marks on three of the eccentrics will correspond with those on straps, while the fourth or slipped eccentric's mark will be some distance away from mark on its strap. By this method an eccentric can be set as true as any machinist can set it, and there is no guesswork.

*Q*. 63. What should be done in case of a broken eccentric-strap or rod?

*A*. Take down the other strap and rod, cover ports and leave main-rod intact.

*Q*. 64. How should the engine be disconnected if a lower rocker-arm becomes broken? If a link-block pin?

*A*. Unless the link interferes, all that is necessary is to remove broken part of the arm, cover ports by placing valve in central position and leaving main-rod up; otherwise the eccentric-straps and rods would have to come down. With a broken link block-pin, there is more or less danger of interference between link and rocker-arm. Take down eccentric-straps and rods only, and cover port.

### ACCIDENTS TO RUNNING GEAR

*Q*. 65. What should be considered a bad tender or engine-truck wheel?

*A*. One with sharp flange, or flat or shelled-out spots in tread of wheel, $2\frac{1}{2}$ inches or more in length.

*Q*. 66. What should be done if an engine-truck wheel or axle breaks?

*A*. It should be entirely removed or blocked up so as to have the wheel clear of the rail, and the truck-frame should be securely fastened to the engine-frame with chains.

*Q*. 67. What should be done if a tender-truck wheel or axle should break?

*A*. Pursue the same course as with the engine-truck wheel and fasten the truck-frame with chains to the tender-frame. Move slowly and cautiously to a point where repairs can be made.

*Q*. 68. How should an engine be blocked for broken engine-truck spring or equalizer? For broken tender-truck spring?

*A*. If pilot will not be too low, let truck-frame ride on boxes; otherwise, block between top of boxes and truck-frame.

Blocking for a broken tender spring will vary according to the type of truck used. Some have a coil-spring over each axle-box and are easily taken care of; some have semi-elliptic springs with the spring band against the tender-frame and the ends of spring resting on arch-bar over axle-boxes, while others have elliptic or coil springs supporting the truck-bolster and resting on the sand-plank. With the first, block over the individual box; with the second, between truck-bolster and tender-frame; and with the third, between truck-bolster and sand-plank.

*Q*. 69. If it is not necessary to take down the main-rod or disabled side of the engine, how would one arrange to lubricate the cylinders?

*A*. By removing indicator-plugs, if the engine is equipped with them, oiling through them and replacing plugs.

If the engine has no plugs, shift valve just enough to show a little steam at cylinder-cocks and oil with the lubricator.



*Q*. 70. What should be done if a driving-spring, spring-hanger of equalizer should break?

*A*. Remove broken parts and block over box affected by break; as to blocking equalizers properly, one would have to be governed by the type of spring-rigging used.

*Q*. 71. How can an engine be moved if the reverse-lever or reach-rod were caught at short cut-off by a broken spring or hanger?

*A*. By disconnecting the tumbling-shaft arm and blocking over link block-pin with blocking that would permit sufficient power to be used to start train.

**BLOWS THROUGH VALVES OR PISTONS**

*Q*. 72. How can a blowing of steam past a valve-cylinder, packing or valve strip be distinguished and located?

*A*. When the valve has been placed to cover both steam-ports and no steam escapes from cylinder-cock but escapes through exhaust-port to stack, it indicates that valve strips are down or broken and permit steam to escape through small hole in valve to exhaust-port.

If valve covers ports and steam appears at both cylinder-cocks, it indicates a cut valve or seat.

If piston is at beginning of stroke and valve uncovered and steam escapes from cylinder-cocks at opposite end from which it is admitted, it indicates leaking packing-rings or cut cylinder.

A valve blow continues during the entire travel of valve, while a cylinder blow is strongest when piston is at beginning of stroke and gradually diminishes until cut-off takes place as piston nears end of stroke.

*Q*. 73. If a simple engine should blow badly and be unable to start the train when on the right-hand dead center, on which side would be the blow, generally?

*A*. On the left side, since that is the only power the engine has to move the other side off the dead center.

### LEAKY THROTTLE, STEAM-PIPES OR DRY-PIPE

*Q*. 74. If the throttle were closed and steam came out of the cylinder-cocks what might be the cause?

*A*. Leaky throttle or dry-pipe.

*Q*. 75. Is it possible to distinguish between a leaky throttle and a leaky dry-pipe?

*A*. Yes; a leaky throttle will show dry steam only, while with a leaky dry-pipe more or less water will pass out of the cylinder-cocks with the steam when the engine is standing, and when the engine is working she appears to be working water all the time.

*Q*. 76. What effect has leaky steam-pipes, and how should they be tested?

*A*. They interfere with the draft on the fire and prevent the engine from making steam.

Place the lever in the center, set the air-brake, open throttle, and watch the joints of steam-pipes top and bottom. The proper test is the hydraulic test made in the shop.

*Q*. 77. How should the test for a leaky exhaust-pipe joint or a leaky nozzle-joint be made?

*A*. By placing the lever forward or back, moving the engine slowly with brakes set, and watching the joints. Cinders never accumulate around such leaks and are always driven away from them.



### ACCIDENTS TO VARIOUS PARTS

*Q*. 78. How should hot bearings be treated?

*A*. They should be cooled down gradually, so as to prevent undue strain on the metal. The cause should be ascertained, whether defective lubrication or poor workmanship, in order to guard against a recurrence of the difficulty.

*Q*. 79. What should be done if a steam-chest cracks?

*A*. If the crack is not too serious, temporary relief can be obtained by driving wedges between chest-bolts and chest.

*Q*. 80. What should be done if a steam-chest breaks?

*A*. That depends on the type. With the chest commonly used, take up the chest cover, insert blocking in the steam-passages to chest and bolt the cover down firmly upon them.

*Q*. 81. If a link-lifter or arm were broken what should be done?

*A*. Block the same as for broken link saddle-pin.

*Q*. 82. If the reverse-lever or reach-rod should break, what should be done?

*A*. Follow the same method as for broken link saddle-pin.

*Q*. 83. What should be done if the piston, cross-head, connecting-rod, or crank-pin is bent or broken?

*A*. If the piston is broken or the piston-rod bent, remove both, disconnect valve-stem only, and cover ports.

With a broken cross-head or bent or broken main-rod, the main-rod would have to come down. Then, push piston ahead or back—this depends on the type of engine—and shift valve to force steam against piston in the direction in which it was desired to hold the piston, clamp valve, and block the cross-head as an additional precaution.

With a broken crank-pin the rod would not have to come down, but could rest on the yoke or guide. First, ascertain in the case of a piston-valve whether it is an inside or outside admission before shifting, as the movement of the former is directly opposite to that of the latter.

*Q*. 84. What should be done if a safety-valve spring breaks?

*A*. Remove the spring and block between valve and cap, allowing the other valve to do the work.

*Q*. 85. How can an engine be brought in with a broken front end or stack?

*A*. By boarding up and by protecting it with the canvas curtain on the cab. Placing a barrel on smoke-arch in lieu of a stack will answer the purpose, but on a road with heavy traffic such expedients are not practicable.

*Q*. 86. What should be done when a frame is broken between the main-driver and cylinder?

*A*. The safest plan is to be towed in dead. The other alternative is to disconnect the disabled side and bring the engine in light, because an attempt to bring in part of the train might damage the previously uninjured side.

*Q*. 87. What should be done when there is a loose or lost cylinder-key?

*A*. If the key is loose and can be shimmed up, it is safe to go on. If key is lost and nothing available in its place, disconnect that side to prevent further damage.



*Q*. 88. What should be done if a frame is broken back of main driver?

*A*. Take down side-rods on both sides back of main driver and proceed.

*Q*. 89. In case of broken side-rods, what should be done?

*A*. Take down corresponding rod on opposite side also, and, if it is a consolidation, mogul, or 10-wheel engine, and the intermediate-rod is broken, all side-rods would have to come down.

*Q*. 90. What can be done if the intermediate-side rods were broken on a consolidation engine, having the eccentric on the axle ahead of main wheel?

*A*. There is nothing to be done but to be towed in, unless only one side is broken, when it would be possible to bring the engine in under her own steam on one side, with the disabled side having its valve disconnected and ports covered, but this is not advisable, inasmuch as the engine might slip and break the other intermediate-rod and do incalculable damage. All side-rods ahead of the intermediate on both sides would have to come down.

*Q*. 91. Should one of the forward ties of a 10-wheel engine break, what must be done to bring the engine in?

*A*. Run the wheel upon a wedge so as to clear the rail under all conditions; remove the oil-cellar and fit a block in its place; then place another block between bottom of box and pedestal binder. Also block under the equalizers nearest the disabled wheel to take the weight off the journal.

*Q*. 92. What is a good method of raising a wheel when jacks are not available?

*A*. To run them up on frogs or wedges.

*Q*. 93. How can it be known whether the wedges are set up too tight and the driving-box sticks, and in what manner can they be pulled down?

*A*. If the wedges are set up too tight, the boxes will heat, the engine will ride hard and have a rough, jerky, up-and-down motion.

Drawing down the wedge-bolt snug and running the wheel upon blocks or wedges and off again will generally bring down a wedge as the box drops down. A little oil or kerosene between wedge and pedestal will often be a help.

### REPORTING WORK TO BE DONE

*Q*. 94. In reporting work on any wheel or truck on engine or tender, how should they be designated?

*A*. It should be designated as engine-truck, driver or tender-truck wheel, giving the exact location and side.

Some roads have adopted a method which prevents mistake by numbering the wheels, beginning at the forward engine-truck wheel on right side, going around the tender and ending with engine-truck wheel on left side, in consecutive numbers, as wheel No. 1, No. 2, No. 3, etc. On an 8-wheel engine the right forward engine truck-wheel would be designated No. 1, while the left forward would be No. 16, according to this system.

*Q*. 95. What are some of the various causes for pounds?

*A*. Wedges not properly adjusted, loose pedestal-braces, lost motion between guides and cross-heads, badly fitting driving brasses, improper keying of rod brasses, engine and rods out of tram, loose piston on rod or loose follower bolts.



### POUNDING

*Q*. 96. How can a pound in driving-box wedges or rod brasses be located?

*A*. By placing the right main-pin on the upper forward eighth, which brings the left main-pin to the upper back eighth. Then by blocking the drivers, giving the cylinders a little steam and reversing the engine under pressure, both sides can be tested at the same time.

*Q*. 97. When should cross-heads or guides be reported to be lined?

*A*. When there is sufficient lost motion between cross-head and guides to cause a jumping motion when the pin is leaving either dead center and the cross-head is beginning the return stroke.

*Q*. 98. When should driving-box wedges be reported to be lined?

*A*. When the wedge has been forced up as high as it can go and lost motion appears between wedge and box. It should then be reported lined down. Lining-up is sometimes reported by enginemen, but this is incorrect.

*Q*. 99. When should rod brasses be reported to be filed?

*A*. When there is sufficient lost motion to cause pounding.

*Q*. 100. When should rod brasses be reported to be lined.

*A*. When the key is down to a point where it cannot be forced down further to prevent brass working in strap.

*Q*. 101. When should lost motion between engine and tender be taken up?

*A.* When there is $\frac{1}{4}$ inch or more lost motion between engine and tender, causing an undue strain on the draw-bar, by the forward and backward lurching of the engine while in motion, or the forward lurch in starting. It also causes severe strain on draft-rods.

### HOW THE INJECTOR WORKS

*Q.* 102. Describe the principle on which an injector works.

*A.* The principle on which an injector works is a combination of forces, velocity and an induced current of water passing through suitably proportioned tubes, designated as steam-nozzle, combining tube and delivery-nozzle. Under a given pressure the velocity of escaping steam is much greater than that of water, which would be ejected were a hole opened in the boiler below the water-line. The reduced orifice in the steam-nozzle naturally increases the velocity of the escaping steam as it enters the combining-tube where it entrains the feed-water and condenses. As the escaping steam is being condensed it has lost none of its velocity except that due to friction of the pipes through which it passes, consequently it has a vastly greater penetrating force after condensation than the resisting force in the boiler. Leaving the combining-tube, the condensed steam and feed-water now pass through the delivery-nozzle into the branch-pipe, where the ram-like force imparted to the water by the velocity of the escaping steam unseats the boiler-check and permits the free flow of water to the boiler.

*Q.* 103. What is generally the cause of failure of the second injector, and what should be done to obviate this failure?



*A.* Infrequent use causes the various parts to corrode and check to lime over and stick. Frequent use and a trial before starting on trip will guard against such failures.

*Q.* 104. What are the advantages of the combination boiler-check?

*A.* It reduces the number of boiler-check and injector failures.

*Q.* 105. If an injector stops working while on the road what should be done?.

*A.* First, ascertain the cause before applying the remedy. It may be due to a disconnected and closed tank-valve, clogged strainers, loose coupling in feed-pipe, which destroys the vacuum necessary to raise the water when starting a lifting-injector, stuck-check, etc.

*Q.* 106. How can a disconnected tank-valve be opened without stopping?

*A.* By closing the heater-valve and forcing the steam from injector back into tank to dislodge valve.

### STEAM-HEATING

*Q.* 107. If the steam-heat gauge showed the required pressure, and cars were not being heated properly, how should one proceed to locate the trouble?

*A.* First, make sure that the connections on the cars were all coupled and their respective valves opened to the rear end of train. If no steam appeared at rear car, examine each angle-cock or valve, and if these were open, look for the trouble at the regulator reducing-valve.

*Q.* 108. How does the steam-heat reducing-valve control the pressure?

*A*. By suitably adjusted springs and valves, which restrict the steam-passages in proportion to the amount of tension of the springs exerted upon the valves.

### ABUSE OF AN ENGINE

*Q*. 109. What constitutes abuse of an engine?

*A*. Improper care, running with parts loose that could be readily made tight, working at a longer cut-off than necessary, pumping the water irregularly or in greater quantities than required. Running with fire-door open, unnecessarily neglecting the adjustment of draft-appliances and failing to report needed repairs.

*Q*. 110. How are accidents and breakdowns best prevented?

*A*. By frequent and careful inspection before starting and during each trip.

*Q*. 111. What are the duties to be performed by an engineer when giving up his engine at the terminal?

*A*. To thoroughly inspect the engine and report all defects in an intelligent manner.

*Q*. 112. In what manner should an engine be inspected after arrival at terminal?

*A*. All running gear, frames, cylinders, saddles, bolts, wheels, fire-box, smoke-arch, and any other parts of the engine should be thoroughly examined and all defects correctly reported. No superficial examination is sufficient.

*Q*. 113. In reporting work on an engine, is it sufficient to do it in a general way, such as saying "Injector won't work," "Lubricator won't work," "Pump won't work," "Engine blows," etc.?

*A*. No; he should be explicit and assign a cause for



every failure, so as to assist the shop force in remedying the defect.

### FIRE-BOX QUESTIONS

*Q*. 114. What causes the drumming sound sometimes heard in the fire-box of a soft-coal burning locomotive?

*A*. The combination of the combustion gases in a form that makes a series of minute explosions creating the drumming sound.

*Q*. 115. How can the disagreeable noise be stopped?

*A*. By closing a damper or putting the fire-door on the latch.

*Q*. 116. What are the principal causes that prevent a locomotive-boiler from steaming freely?

*A*. Badly adjusted draft appliances, leaky joints in steam-pipes, tubes choked up, too much piston-clearance, valves and piston-packing blowing, and irregular boiler feeding, or inferior firing, and poor fuel.

### PERIODS OF EXHAUST

*Q*. 117. How often does an ordinary locomotive exhaust steam during a revolution of the driving-wheels, and at what periods do the exhausts take place?

*A*. Four times. Beginning with the right-hand piston moving from the forward center and the left crank set one-quarter behind the right-hand crank. When the right-hand cross-head has moved back to nearly the middle of the guides, the left-hand exhausts on forward stroke; when the right-hand cross-head reaches close to back of guides, the right-hand cylinder exhausts on backward stroke; when the cross-head returning reaches near the middle of the guides, the left-hand cylinder exhausts on backward stroke, and when the cross-head reaches close to the forward end of the guides, the right-hand cylinder exhausts on the forward stroke. That completes the cycle.

### THIRD YEAR EXAMINATION

### AIR-BRAKE QUESTIONS

*Q.* 1. Explain how an air-pump should be started to run on the road.

*A.* It should be started slowly to permit the condensation to be drained off. The lubricator should be started carefully, and the pump worked slowly until about 40 lbs. have been accumulated in the main reservoir to cushion the steam and air-piston of the pump. Then the throttle should be opened wider, giving a speed of about one hundred and thirty or one hundred and forty single strokes per minute. The amount of work being done really governs the speed of the pump.

*Q.* 2. How should the steam end of the pump be oiled?

*A.* By the sight-feed lubricator, with a good quality of valve-oil, and at the rate of about one drop per minute. This amount will vary with the condition of the pump and the work being done,

*Q.* 3. How should air end of a pump be oiled, and what lubricant should be used?

*A.* High-grade valve-oil, containing good lubricating qualities and no sediment should be used. A good swab on the piston-rod will help out a great deal. Oil should be used in the air-cylinder of the pump sparingly but continuously, and it should be introduced on the down stroke, when pump is running slowly, through the little cup provided for that purpose, and not through



the air-suction valves. A connection with the lubricator, such as has recently come into practice, is preferable to hand oiling.

*Q.* 4. When first admitting steam to the $9\frac{1}{2}$-inch pump, in what direction does the main-valve move?

*A.* If the main-piston is at the bottom of the cylinder, as it usually is after steam has been shut off and gravity controls it, the main-valve will move to the position to the right.

*Q.* 5. With the main-valve to the right, which end of the cylinder will receive the steam?

*A.* The bottom or lower end.

*Q.* 6. When the main-piston completes its up stroke, explain how its motion is reversed so as to make the downward stroke.

*A.* When the main-piston reaches and is nearly at the top of its stroke, the reversing-plate engages the shoulder on the reversing-valve rod, moving the reversing-rod and valve to their upper positions, where steam is admitted behind the large head of the main-valve, forcing this main-valve over to the left, carrying with it the slide-valve which admits steam to the top end of the cylinder and exhausts it from the bottom end, thereby reversing the stroke of the pump.

*Q.* 7. Explain the operation of the air end of the $9\frac{1}{2}$-inch air-pump on an up stroke and on a down stroke.

*A.* The air-piston is directly connected with the steam-piston, and when the steam-piston moves up, the air-piston will go with it, thus leaving an empty space or a vacuum in the lower end of the air-cylinder, underneath the air-piston. Atmospheric air rushes through the air-inlet, raising the lower receiving-valve, and filling the bottom end of the cylinder with atmospheric pressure. At the same time the air above the air-piston will be compressed. The pressure thus formed holds the upper receiving-valve to its seat, and when a little greater than the air in the main reservoir, the upper discharge-valve will lift and allow the compressed air to flow into the main reservoir. When the piston reaches the top of the stroke its motion is reversed, and on the down stroke the vacuum in the upper end of the air-cylinder is supplied by atmospheric pressure passing through the upper receiving-valve. The main-reservoir pressure is held by the upper discharge-valve, and the air being compressed in the bottom of the cylinder holds the bottom receiving-valve to its seat, and when compressed sufficiently, forces the lower discharge-valve open and passes to the main reservoir.

*Q.* 8. Give some of the causes of the pump running hot?

*A.* First, air-cylinder packing-rings leaking. Second, discharge-valves stuck closed or the discharge-passages so obstructed that the pump will be pumping against high air-pressure continually. Third, poor lubrication. Fourth, high speed. Fifth, discharge or receiving air-valves leaking. Sixth, air piston-rod packing leaking.

*Q.* 9. If the pump runs hot while on the road, how would you proceed to cool it?

*A.* First, reduce the speed of the pump, and look for leaks in the brake system. Second, make sure that the packing around the piston-rod is not too tight or in bad condition. Third, see that the main reservoir is properly drained. If the pump still runs hot it should be reported at the end of the trip.



*Q.* 10. If the pump stops, can you tell if the trouble is in the pump or in the governor?

*A.* Yes. It may be tested by opening the drain-cock in the steam-passage at the pump, and noting whether there is a free flow of steam; if so, there is a free passage through the governor and the trouble is not there.

*Q.* 11. State the common causes for the pump stopping.

*A.* There are several reasons. First, it may be stopped by the governor being out of order; second, the valves may be dry and need lubrication; third, nuts may be loose or broken on the piston-rod or one of the pistons pulled off. Fourth, the reversing-valve rod may be broken or bent, or the reversing-plate may be loose, or the shoulder on the reversing-valve rod or the reversing-plate may be so badly worn as not to catch and perform their proper functions. Fifth, nuts holding the main-valve piston may be loose or broken off. Sixth, excessive blow past the packing-rings of the main valve.

*Q.* 12. Should a pump make a much quicker down stroke than up, what effect does it indicate?

*A.* An upper discharge air-valve leaking, a lower receiving air-valve stuck to its seat, or stuck open.

*Q.* 13. Should it make a much quicker up stroke, what defect does it indicate?

*A.* The lower discharge-valve leaking badly, or the upper receiving-valve is probably open, or stuck to its seat.

*Q.* 14. Should an engineer observe the workings of a pump on the road, and report repairs needed?

*A.* Yes.

### GOVERNOR

*Q*. 15. What is the function of the air-pump governor?

*A*. To properly regulate the pressure in the main reservoir.

*Q*. 16. Explain how the governor operates.

*A*. The governor is an automatic arrangement for admitting and closing off steam to the air-pump, and is actuated by air-pressure. The steam-valve, which shuts off and opens up the steam-passageway to the pump, is controlled by an air-piston and spring. When air-pressure is admitted above the piston, it forces the piston down, closing off the steam to the pump. When the air-pressure is exhausted from above the piston, the spring and steam pressure forces the piston up and allows steam pressure to pass to the pump. The admission and exhaust of the air to this piston is controlled by a diaphragm and spring. The air from the main reservoir enters the body of the governor underneath the diaphragm, which is held by a spring of given tension, depending on the pressure desired in the main reservoir. While the main-reservoir pressure is less than the pressure the governor is set for, this diaphragm is held down by the spring, and the air can pass no farther than a small pin-valve attached to it, but when the main-reservoir pressure overcomes the tension of the spring, it raises the diaphragm, unseats the pin-valve and allows the air to flow to the top of the air-piston, shutting off the pump. During the time the air is acting on this piston some of it escapes through a large waste-port, which is always open. When the main-reservoir pressure drops below the pressure the spring is adjusted to, the spring forces the diaphragm down, seating the pin-valve and allowing the air on top of the piston to escape to the atmosphere, through the small vent-port.



*Q*. 17. Why is it necessary that the vent-port in the improved governor be kept open?

*A*. If this port is not kept open, the air-pressure, which holds the piston down, cannot escape when the diaphragm-valve closes, and consequently the governor will not operate the pump properly.

*Q*. 18. Where would you look for the cause, if the governor allowed a very high main-reservoir pressure to accumulate, especially in winter weather?

*A*. The main-reservoir pressure may not reach the governor, due to the stoppage in the pipe or in the union at the governor. This may also be due to the space on top of the diaphragm being filled with dirt. If the air is getting to the diaphragm-valve, and is so indicated by the blow at the vent-port, the trouble must then be due to the drip-pipe being stopped up or frozen, thereby preventing the air and steam, which leak in under the air-piston, from escaping.

*Q*. 19. If the pin-valve in the governor leaks, what effect will it have on the pump?

*A*. It will allow a certain amount of air-pressure to flow in on top of the air-piston. If the leak is greater than the escape from the little vent-port, the pressure will accumulate and cause the governor to slow down or completely stop the pump.

*Q*. 20. How can you tell if the pin-valve leaks?

*A*. It will blow continually at the vent-port while the pump is running.

### MAIN RESERVOIR

*Q*. 21. What harm is there in allowing water to accumulate in the main reservoir?

*A*. It reduces main-reservoir capacity or space which should be employed in storing air-pressure for releasing and recharging the brakes. The moisture also is carried in the air, goes back into the brake-pipe and gets into the triples, where it freezes in cold weather.

*Q*. 22. How often should the main reservoir be drained?

*A*. After each trip.

*Q*. 23. Where does the main-reservoir pressure begin and end?

*A*. It begins at the top side of the discharge-valves in the pump and ends on the top side of the rotary-valve of the engineer's brake-valve.

*Q*. 24. What is the main reservoir used for?

*A*. It is a storehouse, or storage-tank, for air-pressure, to charge and recharge the air-brakes.

*Q*. 25. What pressure is usually carried in the main reservoir?

*A*. Ninety, 110, and 120 pounds in freight service and 130 and 140 in passenger service.

### ENGINEER'S VALVE

*Q*. 26. What kinds of engineer's brake and equalizing-discharge valves are used?

*A*. Three forms; the G-6, H-6 and type L. These three forms are all of the equalizing-discharge type, and have the slide-valve feed-valve. The initial and figure designations given the forms of valves are those used in the different catalogues of the manufacturer.



*Q*. 27. How is the amount of excess pressure regulated when the G-6 brake-valve is used?

*A*. The slide-valve feed-valve attachment is adjusted by the regulating spring to control the brake-pipe pressure when the brake-valve handle is in running position. The air-pump governor is adjusted to control the amount of pressure to be carried in the main reservoir. The difference between these two pressures is what is commonly known as "excess pressure," and is used for releasing and recharging the brakes.

*Q*. 28. How is the excess pressure regulated with the H-6 and type L valves?

*A*. In approximately the same manner except that the feed-valve is located in a branch between the main reservoir and the brake-valve.

*Q*. 29. How should the feed-valve of a G-6 brake-valve be cleaned?

*A*. The stop-cock in the brake-pipe under the brake-valve should be closed, and all brake-pipe pressure drawn off the brake-valve with the handle in service position, thus eliminating all chance of the parts being roughly moved or injured when the valve attachment is taken apart. Then remove the large cap-nut, and take out the piston-spring and slide-valve. Clean these parts carefully, taking care that no lint or dirt remains on the parts. Oil the slide-valve and its seat very sparingly with a good quality of oil, then replace the parts carefully. Next remove the diaphragm-valve, clean it carefully, taking especial care not to bruise or scratch its ground surface. The same care should be exercised in cleaning the diaphragm-valve seat, observing that none of the small ports are stopped or clogged with dirt or foreign matter. No oil is necessary on the diaphragm-valve and its seat. As a rule, it is unnecessary to remove the regulating spring and diaphragm, but when it is necessary it should be done by the repair-man, and not when the engine is in service on the road if it can be avoided. In fact, all work possible should be done on the brake-valve by the air-brake machinist, either in the roundhouse or machine-shop.

*Q.* 30. Name the different positions of the brake-valve.

*A.* Full release, running, lap, service application, and emergency application.

*Q.* 31. In what position of the brake-valve is there direct communication between the main reservoir and brake-pipe?

*A.* The first or full release position.

*Q.* 32. Is there no other position of the brake-valve in which the air may pass from the main reservoir to the brake-pipe?

*A.* Yes; running position. However, in running position the air passes indirectly, or through the passages and ports of the feed-valve attachment, in order to get from the main reservoir to the brake-pipe.

*Q.* 33. When making a service application, do you draw air direct from the brake-pipe?

*A.* No. In service application the engineer draws air directly from the small equalizing reservoir and from the chamber on top of the equalizing-piston. This reduction causes a difference in pressures acting on the piston, and the brake-pipe pressure under the equalizing-piston being greater causes the piston to rise and discharge brake-pipe pressure at the angle-fitting of the brake-valve until such time as the latter pressure becomes lower than that



remaining on top of the piston, when the piston will descend, closing off the discharge of pressure.

*Q.* 34. With the G-6 brake-valve in running position, if the black hand of the gauge goes up and equalizes with the red hand, what is the defect?

*A.* As the black hand indicates brake-pipe pressure, and the red hand main-reservoir pressure, the brake-pipe pressure is evidently being increased, due to the leakage of main-reservoir pressure coming into it. This leakage may be due to either a leaky rotary-valve or leaky body gasket. Also, there may be a leakage in the feed-valve attachment past the supply-valve, or in the attachment gasket, or the regulating spring may be improperly adjusted.

*Q.* 35. How can it be ascertained which one of these defects is causing the trouble?

*A.* Discharge all air from the brake-valve. Place the brake-valve handle on lap and start the pump. If there is a leakage of main-reservoir pressure into the brake-pipe, which will be indicated by the rising of the black hand, the trouble is either in the rotary-valve and its seat, or in a defective body gasket. However, if the black hand does not rise while handle is on lap position, but if both hands go up together in running position above the figure the feed-valve adjusting-spring is set for, the trouble is probably either in a faulty supply-valve in the feed-valve attachment, or in the small gasket between the feed-valve attachment and the brake-valve body.

*Q.* 36. What is the effect of leakage from the equalizing-reservoir, or the connections to the small chamber above the equalizing-piston?

*A.* When a service application is made, the leakage from the equalizing-reservoir in the chamber above the piston will cause more air to escape than is desired by the engineer, the equalizing-piston will remain raised off its seat longer than intended, and more pressure will be drawn from the brake-pipe than desired, thus making a heavier application than is wanted. In other words, a continuous, or at least prolonged, application will be made, and the engineer will be unable to reliably regulate the flow of pressure from the brake-pipe in service application. In release and in running positions, this leakage will merely mean a waste of air-pressure. On lap, brake-pipe pressure will continue to escape at the angle fitting, either slowly or rapidly, according to the size of the leak.

*Q.* 37. Should the equalizing-piston fail to seat, how can it be known if it is due to dirt on the seat of the valve or leak of the equalizing-reservoir pressure?

*A.* This question was partly answered in the preceding. If there is dirt between the valve and its seat, there will be a constant flow of brake-pipe pressure through the angle fitting at all times, but if the piston fails to seat, due to leakage from the equalizing-reservoir in the chamber above the piston, there will be no leakage of pressure at the angle fitting with the brake-valve handle in full release, or running position.

### GENERAL

*Q.* 38. If there is a continuous blow at the brake-pipe exhaust-port, or angle fitting, what should be done to stop it?

*A.* If the blow is due to dirt between the valve and its seat, make several service applications and releases. If this does not stop the blow, the valve may be taken apart and cleaned, provided it is known that the trouble is caused by dirt between the valve and its seat. If the piston will not seat on account of leakage from the equalizing-reservoir in the chamber above the equalizing-piston, or the connections, each connection should be gone over carefully with soap suds to detect and locate the leak, and it should then be taken up. A torch blaze is not sufficient. If it is impossible to stop the leaks, on account of breakage of the parts, etc., a blind gasket may be placed in the connection between the chamber *D* and equalizing-reservoir, plugging this opening, and a plug should be placed in the angle fitting of the brake-pipe discharge, and braking be done very cautiously and carefully with the valve handle in emergency position. This latter, however, is an expedient that is very seldom necessary.



*Q.* 39. What is the effect of leaving the handle of the brake-valve in full release position too long, before returning it to the running position, after releasing brakes?

*A.* The brake-pipe and auxiliary reservoirs will be charged higher than the feed-valve is adjusted for, thus permitting the equalization of pressures. Should the handle be then drawn to running position, main-reservoir pressure will be unable to pass through the feed-valve attachment to the brake-pipe until such time as the latter pressure becomes reduced below the point at which the feed-valve is adjusted. Should there be leakage in the train-line, brakes will apply and drag until the brake-valve is thrown to full release position, thus releasing the brakes. The brake-valve handle should not be left in full release position after releasing brakes.

*Q*. 40. If, from any reason, the brakes should drag, how can they be released from the engine?

*A*. If it is found that the brake-pipe is overcharged before leaving a terminal, a fairly heavy application of the brake may be made in service position, and the brake-valve handle placed in running position. Several repetitions of this process may be necessary. However, if the overcharge occurs while the train is running, and brakes will not release in running position, the valve-handle may be placed in full release position and left there until the next stop is made, and then care should be taken to not overcharge again in full release position, but to return to running position in due season, thus preventing this trouble. Sometimes a series of light applications and releases may while made be running to reduce an overcharged brake-pipe; however, this is not practical on fast modern trains.

*Q*. 41. If the brakes apply suddenly, what should the engineer do?

*A*. Place the brake-valve in lap position and ascertain the cause. It will probably be due to a burst or parted hose, to the opening of a conductor's-valve, or the rear angle-cock. However, regardless of the cause, the brake-valve handle should be placed on lap, to save the main-reservoir pressure for releasing the brakes after the brake-pipe opening has been closed.

*Q*. 42. If the pipe connecting the chamber above the equalizing-piston with the equalizing-reservoir should be broken off, what should be done?

*A*. Plug up the connection to chamber *D*, also the angle fitting on the underside of the brake-valve, and brake cautiously and carefully in the emergency application position.



*Q*. 43. What should be done if the pipe leading to the black hand or the air-gauge should break? If the pipe to the red hand should break?

*A*. If the black-hand pipe should break, plug the connection at the brake-valve, using careful judgment in gauging by sound the amount of pressure drawn from the equalizing-chamber in service application. If the red-hand pipe should break, plug the connection at the brake-valve, taking care that the pump governor is operating and observing that sufficient main-reservoir pressure is being accumulated with which to release brakes after each application.

*Q*. 44. How is the brake-pipe pressure regulated to 70 pounds, while the handle of the brake-valve is in running position?

*A*. By the adjusting-nut and spring in the feed-valve attachment.

*Q*. 45. What is the reason for having the equalizing-reservoir on the brake-valve?

*A*. The equalizing-reservoir is used to give an enlarged capacity for the required volume of air-pressure on top of the equalizing-piston, to permit the equalizing-piston to draw pressure gradually from the brake-pipe in service application. If this enlarged capacity were placed in the brake-valve, the valves would be entirely too large and bulky for location in the cab; however, this capacity is obtained by employing a reservoir of suitable capacity, and locating it in a remote and convenient place, and piping it to the brake-valve. If the reservoir was not used, and the chamber *D* capacity was restricted to its present size alone, it would be impossible to reduce pressure sufficiently slow to permit the piston to rise gradually as it now does; but instead the pressure would be exhausted quickly, the piston would rise suddenly and make a heavier application of the brake than was desired.

*Q*. 46. What effect would a leak from the equalizing-reservoir have?

*A*. It would be troublesome to the engineer, inasmuch as he would not be able to control the discharge of brake-pipe pressure, as the leakage of pressure above the piston would cause the piston to discharge more pressure than he intended and desired; hence, he would be unable to properly control brake applications on his train.

*Q*. 47. How can a leak past the packing-ring in the equalizing-piston be located?

*A*. Ascertain that the rotary-valve and body gasket are tight, place the brake-valve handle on lap position and open the angle-cock at the end of the tender. If the black hand now falls, indicating a reduction of pressure in chamber *D* above the piston, that pressure is evidently passing by the piston into the brake-pipe and out at the angle-cock. Another way is to observe whether the black hand rises when the brake-valve has been returned to lap after making a service application. With a long train, a leaky packing-ring would permit brake-pipe pressure to leak past into chamber *D*, which would be indicated by a rise of the black hand on the gauge, during a service application.

*Q*. 48. What danger would there be from a leakage of main-reservoir pressure into the brake-pipe, when the brakes were set and brake-valve was on lap position?



*A*. Such a leakage would increase the train-line pressure and cause the triple-valves to go to release position, thus releasing the brakes.

*Q*. 49. What danger is there in a leak from the main reservoir to the brake-pipe when the brakes are released and handle in running position?

*A*. The train would be overcharged, and no excess pressure could be carried, if the leakage were of such consequence and there were a considerable lapse of time between brake applications. This unduly increased pressure would have a tendency to produce wheel-sliding.

*Q*. 50. What repairs may be made on the road to overcome such leakage?

*A*. It does not pay to make road repairs generally, as frequently more harm is done thereby than good. The four bolts holding together the top and bottom portion of the valve may be carefully tightened, taking care not to break the bolts, and thereby creating a worse condition than existed before. It would be better to exercise unusual care and caution in handling the trouble while on the road, and report it upon arrival at the terminal.

### TRIPLE-VALVE

*Q*. 51. How many kinds of triple-valves are there in general use?

*A*. Two, the plain type and the quick-action type.

*Q*. 52. What is the function of the triple-valve piston, the slide-valve, and the graduating-valve?

*A*. The function of the triple-valve piston is, by variation of pressures on its two sides, to move the slide-valve on its seat to the application, graduating, and release positions, and to open and close the feed-groove in the piston-bush. The function of the slide-valve is, by movement due to triple-valve piston, to make connection between the auxiliary reservoir and brake-cylinder, applying the brake, and to make connections between the brake-cylinder and the atmosphere, releasing the brake. The function of the graduating-valve is, from movement given by the triple-piston, to admit pressure gradually from the auxiliary reservoir to the brake-cylinder, in response to reductions made in the brake-pipe pressure.

*Q.* 53. Explain how the quick-action triple operates when making an emergency application of the brakes.

*A.* A sudden reduction of pressure in the brake-pipe will cause the triple-piston and its parts to be moved to quick-action application-position, which first throws into operation the emergency feature of the triple, admitting brake-pipe pressure to the brake-cylinder, after which auxiliary-reservoir pressure is permitted to pass to the brake-cylinder, where a higher pressure is obtained than in a full service application of the brake.

*Q.* 54. Name the parts of the quick-action triple-valve that are not in the plain triple valve.

*A.* The emergency-piston, the rubber-seated emergency valve, and the non-return check-valve and its spring.

*Q.* 55. Where does the air come from which sets the brakes in emergency with the plain triple-valve?

*A.* From the auxiliary reservoir only.

*Q.* 56. Where does the air come from which sets the brakes when an emergency-application is made with the quick-action triple?



*A.* The first portion of air going to the brake-cylinder is contributed by the brake-pipe, after which the auxiliary reservoir sends in its portion of air to the brake-cylinder.

*Q.* 57. What causes a blow at the triple-valve exhaust, and how may it be located?

*A.* This blow may be from the three sources, the brake-pipe, the auxiliary reservoir, or the brake-cylinder. If the blow is from brake-pipe pressure, it may be detected by closing the stop-cock in the cross-over pipe, and the brake will promptly apply. If the blow is caused by auxiliary-reservoir pressure, there will be a steady leak of pressure at the exhaust-port when the brake is released and the brake will not apply when the cut-out cock is closed in the cross-over pipe. If brake-cylinder pressure causes the blow, it will only happen when the brake is applied and will cease when the brake is released and the brake-cylinder empty of pressure.

*Q.* 58. About how much time is required to charge the auxiliary reservoir to 70 pounds?

*A.* It should be no less than 45 seconds and no more than 70 seconds.

### TRAIN AIR-SIGNALS

*Q.* 59. Explain in a general way the operation of the whistle-signal reducing-valve.

*A.* The valve consists of an adjusting or regulating-spring which limits the amount of pressure which will pass through the valve, a piston and a supply-valve. If the spring is adjusted for 40 pounds, the standard pressure, the piston will descend and permit the supply-valve to close when 40 pounds has been reached, thus shutting off further supply to the signal-line. If the signal-line reduces below 40 pounds, or what the valve is adjusted for, the adjusting spring and piston will permit the supply-valve to open and admit main-reservoir pressure, until the predetermined amount has been accumulated, when the supply-valve will then be closed.

*Q*. 60. Explain how the signals are transmitted from the car to the engine.

*A*. On the engine is a valve containing a rubber diaphragm, on the under side of which is suspended a stem which, when raised, will permit pressure to pass from the signal-valve outward through the air-whistle. When the pressure on the top side of this diaphragm is equal or greater than that on the under side, the stem will remain seated, closing the port to the whistle; however, if a reduction be made in the chamber above the diaphragm, or in the signal-line connected to this chamber above the diaphragm, the greater pressure on the under side will cause the diaphragm and stem to rise, permitting pressure to pass to the whistle producing the blast.

*Q*. 61. If the signal-whistle blows when brakes are released, where would you look for the trouble?

*A*. In the pressure-reducing valve. Dirt or other foreign substance has settled between the supply-valve and its seat, thus permitting main-reservoir pressure to accumulate in the signal-pipe. When brakes are released, main-reservoir pressure falling below the signal-line pressure will permit the signal-line pressure to pass backward into the main reservoir, making a reduction in the signal-pipe and on the top of the diaphragm on the signal-valve, thus producing the blast the same as if a reduction were made at the car-discharge valve.



*Q*. 62. If the proper discharge of air is made at the car-discharge valve, and the whistle on the engine only responds with a weak blast, where would you look for the trouble?

*A*. The diaphragm stem in the signal-valve may be loose, responding poorly to a signal-line reduction. Also, the adjustment of the whistle bowl on the stem should be examined. Sometimes wind blowing across the whistle bowl when running may weaken the blast.

### HIGH-SPEED BRAKE

*Q*. 63. How much pressure is carried in the brake-pipe when using the high-speed brake?

*A*. One hundred and ten pounds is generally adopted as the standard pressure in high-speed brake service.

*Q*. 64. What changes are necessary in the usual quick-action car equipment to convert it into a "high-speed brake"?

*A*. An additional attachment to the brake-cylinder by pipe-connections of the high-speed automatic reducing-valve.

*Q*. 65. What parts are necessary to change the engine and tender equipment to the "high-speed brake"?

*A*. A high-speed automatic-reducing valve for the tender-brake cylinder, another for the driver-brake, and truck-brake cylinders.

*Q*. 66. At what pressure will the auxiliary reservoir and brake-cylinders equalize with an emergency-application using the high-speed brake?

*A.* With a 7-inch piston-travel the equalized pressures will be about 86 pounds.

*Q.* 67. Explain in a general way the operation of the high-speed reducing-valve.

*A.* The valve consists of a piston and stem whose downward movement is regulated by the adjusting-spring. A small slide-valve with a triangular escape-port is attached to the upper side of the piston. If the adjusting-spring is set at 60 pounds, and an emergency-application of the brake be made, the piston will descend when 60 pounds has been accumulated in the brake-cylinder, and the apex or smallest part of the triangular-port will permit brake-cylinder pressure to pass through it and escape to the atmosphere; as the brake-cylinder pressure reduces, the piston will gradually move up a larger part of the triangular-port, thus increasing the opening for the escape of brake-cylinder pressure to the atmosphere. When the brake-cylinder pressure has blown down to 60 pounds, the port will be closed, shutting off further escape of brake-cylinder pressure to the atmosphere. In service application, the larger portion of the triangular port will permit brake-cylinder pressure to escape to the atmosphere when 60 pounds has been accumulated in the brake-cylinder, thus blowing down the pressure quickly and preventing more than 60 pounds being accumulated in the brake-cylinder in service application.

*Q.* 68. If a train with a high-speed brake should pick up a car not equipped for high-speed brake service, what should the engine-man do?

*A.* Usually a small safety-valve is supplied by yard inspectors for cars not equipped with the high-speed



reducing-valve. Sometimes, however, the car in unusual cases is permitted to go without either a reducing-valve and without a safety-valve, care being taken by the engineer in service applications of the brake not to slide the wheels.

*Q.* 69. What is the object of this variable rate of discharge of brake-cylinder pressure?

*A.* To reduce the brake-cylinder pressure to correspond with the reduction of train speed during an emergency application so that the stop may be made with normal cylinder pressure.

*Q.* 70. How does the pressure developed in the brake-cylinder, with the high-speed brake, with a given reduction, compare with pressure developed with the same reduction made with the ordinary quick-action brake?

*A.* If reductions less than that which will cause a full application of the low-pressure brake is made, the resultant brake-cylinder pressures will be the same with the low-pressure brake as with the high-pressure brake; however, if the reduction made should do more than produce an equalization of the low-pressure brake, the cylinder of the high-pressure brake would have the highest pressure, and would give a greater breaking force.

*Q.* 71. How many full applications with the high-speed brake can be made before recharging is necessary, and have left as much pressure as is used with the ordinary quick-action brake?

*A.* The high-speed brake will usually, with proper piston-travel, permit of two full service applications and releases and still have sufficient pressure reserved to make an emergency application as great as the 70-pound brake would give when fully charged.

*Q.* 72. How should the engine-truck or driver-brake be cut out?

*A.* A suitable arrangement of cut-out cocks should be supplied which will permit of the auxiliary reservoir being cut-out when the brake-cylinder is cut-out, thus preventing the brake left cut in having too large an auxiliary-reservoir capacity, which would tend to slide the wheels when brakes were applied.

*Q.* 73. How should both the driver- and engine-truck brakes be cut-out?

*A.* By the stop-cocks arranged for that purpose.

STRAIGHT AIR-BRAKE

*Q.* 74. On what is the straight air-brake designed to operate, and what extra parts are required on engine and tender?

*A.* The straight air-brake is designed to operate on the engine and tender alone, and not on the cars of the train. To operate the combined automatic and straight air-brake, extra parts as follows should be supplied: Reducing-valve for the straight-air system, set at 45 pounds; an engineer's straight air-brake valve; a double-seated check-valve for the driver-brake cylinders; a double-seated check-valve for the tender-brake cylinder; a safety-valve, set at 53 pounds, one for the driver-brake cylinders and one for the tender-brake cylinder; and a straight air-brake hose connection between the engine and tender.

*Q.* 75. What should be done to release the brakes



when they do not release with the handle of the straight air-brake valve in release position?

*A.* The automatic brake-valve handle should be placed in full release position, then returned to running position.

*Q.* 76. What pressure should be developed in the brake-cylinder by this brake?

*A.* About 45 pounds, as indicated by the adjustment of the reducing-valve in the pipe between the main reservoir and straight air-brake valve.

*Q.* 77. Where are leaks in the brake-pipe most likely to occur?

*A.* First, at the hose couplings; second, at the unions in the train-pipe; third, through porous hose; and fourth, at the exhaust-port of the triple-valve.

*Q.* 78. What is the leakage groove of the brake-cylinder for?

*A.* To permit pressure going to the brake-cylinder at the improper time to escape to the atmosphere, past the brake-cylinder piston, instead of accumulating there and pushing out the brake system and applying the brake.

*Q.* 79. As a rule, how great a reduction of brake-pipe pressure is necessary to insure the brake-piston moving out beyond the leakage groove?

*A.* On a train of a few cars, about 5 to 7 pounds is sufficient; but on a long train 10 or 12 pounds will be required. This depends also upon the condition of the triple-valves and the condition of the equalizing-piston in the brake-valve.

*Q.* 80. Should the brakes be tested before leaving the terminal?

*A.* Yes; first by the yard-testing plan to determine the proper piston-travel and condition of the brakes, and second, by the engineer after coupling up to be sure that all angle-cocks are open and that the brakes are operative.

*Q*. 81. What is the proper brake-cylinder piston-travel on freight-cars?

*A*. From 5 to 7 inches is the accepted standard travel.

*Q*. 82. How is the slack taken up on a tender?

*A*. With a brake of the equalized type a dead lever is supplied for taking up the slack. On other types, the slack may be taken up at points where holes are provided for connecting-rods in the brake-rigging. Some riggings are supplied with turn-buckles for this purpose, but the practice is not considered the best for tenders.

*Q*. 83. If a brake is stuck and cannot be released from the engine, how would you proceed to release it?

*A*. Open the "bleeder" cock quickly and close it quickly, thus making a sudden reduction in the auxiliary-reservoir pressure, which will allow the greater train-pipe pressure to shift the triple from application position to release position.

*Q*. 84. What is the proper piston-travel for passenger-cars?

*A*. About 6 inches standing travel.

*Q*. 85. If, when testing brakes, it is found that one will not apply, what might be the cause?

*A*. The brake might be cut out by the cock in the cross-over pipe, the auxiliary-reservoir might not be charged, or the triple-valve piston and slide-valve might be so corroded that they will not move in response to an ordinary train-pipe reduction.



*Q*. 86. Can a brake be operated if the retaining-valve is broken off?

*A*. Yes; the retaining-valve is operated only to hold pressure in the brake-cylinder to prevent a full release of the brake, and has nothing to do with the application of the brake.

*Q*. 87. With a 70-pounds brake-pipe and auxiliary-reservoir pressure, how much of a reduction will be required to apply the brakes fully?

*A*. About 20 pounds, providing the adjustment of piston-travel is as it should be.

*Q*. 88. Has the piston-travel anything to do with the pressure obtained in the brake-cylinder?

*A*. Yes; the longer the piston-travel the greater will be the capacity of the cylinder for consuming the auxiliary-reservoir pressure sent to the cylinder, and consequently the lower will be the brake-cylinder pressure. The shorter the piston-travel, the less will be the volume in the cylinder into which the auxiliary-reservoir pressure must go, and the higher will be the brake-cylinder pressure.

*Q*. 89. With all things uniform, what is the highest pressure that can be obtained in full service application and also emergency application?

*A*. About 50 pounds, with the piston-travel adjusted at about 7 inches travel. Emergency application, about 60 pounds with a 7-inch piston-travel.

*Q*. 90. Is a greater initial reduction required with a 50-car train than with a 10-car train?

*A*. Yes; if a service application be made, for the train-line pressure may leak past a poor fitting ring in the equalizing-piston of the brake-valve and on to the top side, thus causing the piston to descend and close off the escape of brake-pipe pressure before the full reduction has been made. If the train be short, the leakage upward past the piston-ring into chamber D will be less than it will be with a longer pipe, which has a greater volume and a better chance for leakage.

### MISCELLANEOUS (AIR-BRAKE)

*Q.* 91. Explain how a terminal test of the brakes should be made.

*A.* All brake-pipe couplings should be made and angle-cocks opened except the one on the rear of the train, which should be closed. All hand-brakes should be off. The first test made should be for leaks at the hose couplings and other points in the brake-pipe and auxiliary-reservoir connections. A service application of about 10 pounds should be made, and examination be made to learn whether all brakes have applied. Care should be taken that all brakes are cut in. The piston-travel should be adjusted on all cars to about 6 or 7 inches. When brakes are released, care should be taken to know if all brakes are off and that the brake-rigging does not foul at any point on the truck or car framings. The retaining-valves should be known to be in operative condition and all handles turned down when not in operation.

*Q.* 92. What is meant by a running test, and how is this test made?

*A* A running test consists of a light application of the brakes by the engineer when the train is pulling out, and before it has gotten up to speed, to be sure that all angle-cocks are open and that the brakes are operative.



*Q.* 93. At what points on the road should the running test be made?

*A.* At terminals and at all points where the angle-cocks have been manipulated to take in or set out cars, etc. It is also the rule on some roads to make a running test at points where it shall be absolutely necessary for the brakes to perform their functions, such as on draw-bridges, etc.

*Q.* 94. When should the brakes be released when making a stop with a passenger-train of less than ten cars?

*A.* Shortly before coming to a dead standstill, to allow the brakes to right themselves, and thus preventing a shock to the passengers. *b.* Of ten or more cars? *A.* Brakes should be held on until the train comes to a standstill, as releasing to avoid a shock with a long train will frequently break it in two. A two-application stop should be made, and the brakes be held on with a light second application until the train comes to a standstill.

*Q.* 95. When should the brakes be released in making a stop with a freight-train?

*A.* The brakes should be held on until the train comes to a stop, as with a long passenger-train of ten or more cars.

*Q.* 96. Why is it dangerous to repeatedly apply and release the brakes on a long train without giving the auxiliary-reservoirs time to recharge?

*A.* The auxiliary-reservoir pressure will become depleted by repeated applications, and the holding power of the brakes be thereby reduced and be insufficient to control the train.

*Q.* 97. When two engines are coupled together in double heading, which engine should have full control of the brakes, and what should the other engine do?

*A*. The first engine should do the braking, and the second engineer should close the stop-cock under his brake-valve, thus throwing out of service all his air-brake equipment, except the foundation brakes on his engine, which are operated by the leading engine.

*Q*. 98. In case a hose should burst while on the road, what should the enginemen do to assist the trainmen in locating it?

*A*. Place the brake-valve handle in full release position every few seconds, thus causing the escape of air at the bursted hose to manifest itself to the brakemen as quickly as possible, easing the steam-throttle off to reduce speed of the air-pump.

*Q*. 99. How would you apply and release the brakes on a freight-train?

*A*. A reasonable reduction in the train-pipe pressure should be made to apply the brakes, and when the slack of the train has been bunched, which is indicated by the pushing forward sensation when the slack is taken up, then the brakes may be applied with greater force if desired. In releasing, the straight air-brake on the engine and tender should be held on while the train-brakes are being released and the slack allowed to run out. This will prevent the slack running out in a manner which will snap the train in two.

*Q*. 100. What precaution should be taken in starting a long freight-train with all cars equipped with air-brakes, and in operation?

*A*. The slack should be taken easily until the entire train is stretched, thus preventing a break-in-two, which might occur if the slack were taken suddenly.



*Q*. 101. In releasing brakes on a long freight-train, what should the enginemen do to be sure that the brakes have released?

*A*. Leave the brake-valve handle in full release position for a time that will correspond with the length of the train, before bringing the brake-valve handle to running position.

*Q*. 102. How is the slack taken up on the American outside-equalized driver-brake?

*A*. By a slack adjuster feature on the connecting-rod to the bell-crank lever.

*Q*. 103. Are the brake-pipe and auxiliary-reservoir pressures equal at all times?

*A*. No. *b*. What time are they equal? *A*. Before the brake is applied, when the triple-valve has lapped, itself during the application of the brake, and after a release of brakes when the auxiliary reservoir has become fully recharged.

*Q*. 104. How many applications of the brake are necessary to make a stop with a passenger-train, and why?

*A*. The two-application stop is considered the best in modern passenger-train service. The first application should be heavy and sufficient to slow down the train to about eight or ten miles an hour, when the brakes should be released before reaching the point at which the stop is desired, and a second and lighter application should be made to finish up the stop, and should be held on until the train is brought to a standstill. If brakes are released on a long passenger-train before coming to a full stop, the slack of the train will run out, and the train be snapped in two.

*Q.* 105. How would you make a stop on a grade with a passenger-train?

*A.* By the two-application method, holding on the brake for a second application.

*Q.* 106. Explain the operation of the pressure-retaining valve.

*A.* When the handle of the retaining-valve is turned down it is inoperative. When the handle is turned up in a horizontal position, the free exit for air from the brake-cylinder to the atmosphere is cut off and the pressure must pass upward against the weighted valve. All over this amount will raise the valve and blow off, but all below that amount will be held in the brake-cylinder.

*Q.* 107. What benefits are derived from the use of the retaining-valve?

*A.* On mountain grades the pressure retained in the brake-cylinder, by turning up the handle of the valve, will hold the train in check while the auxiliary reservoirs are being recharged for subsequent application of the brake.

*Q.* 108. Name the defects which cause the retaining-valve to be inoperative.

*A.* First, defective packing leather in the brake-cylinder. Second, defective union in the retaining-valve pipe. Third, retaining-valve or pipe broken off.

*Q.* 109. Explain how a stop at a water-tank or coal-chute should be made with a long freight-train.

*A.* The engine should be equipped with a straight air-brake for this purpose. The train-brakes should be used until the speed of the train has been brought down to three or four miles an hour, then released and the straight air-brake applied to cover the last few feet of the distance to the desired stop. If the engine is not equipped with the straight air-brake it would be better, with a long train of all air-braked cars, to stop, holding on the brakes, and to cut off the engine while taking coal and water, as considerable time and damage will be saved by this method.



*Q.* 110. Do you think it poor policy to reverse the engine while the driver-brakes are applied?

*A.* Yes; tests have proven this.

*Q.* 111. Should the brake-pipe be blown out before leaving the engine-house?

*A.* Yes; as cinders or sparks are likely to be gathered in the coupling head or hose.

*Q.* 112. Are the brakes any more liable to stick after an emergency application than after a service?

*A.* Yes; as dirt in the brake-pipe might work between the emergency-valve and its seat, permitting brake-pipe pressure to pass to the brake-cylinder.

*Q.* 113. If, in making a service application, you notice some wheels slide, do you think it good policy to drop sand to start them turning again?

*A.* No; a wheel once stopped cannot be started to turning again by sand dropped on the rail, and that process will only cut the wheel worse and make the flat spot longer.

*Q.* 114. Explain the principle of the duplex governor applied to freight-trains.

*A.* The high-pressure head of the duplex governor is connected direct to the main-reservoir pressure and is usually set for 110 pounds. The low-pressure head is connected to port *f* in the brake-valve, and is set at 90 pounds. When the brake-valve handle is in full release position or running position, the low-pressure head is operative, but when placed on lap, there being no main reservoir in port *f*, the high-pressure head must govern, thus permitting the pump to compress air during the time the brake-valve handle is on lap while making a brake application.

*Q.* 115. Are the results from shocks on passenger-trains likely to be expensive and give the road a bad reputation?

*A.* Yes.

*Q.* 116. Do you understand the importance of watching the air-gauge closely?

*A.* Yes.

*Q.* 117. When descending a grade, how much should the speed be reduced before releasing the brake to recharge?

*A.* The speed of the train should be brought down to about 10 or 12 miles per hour before recharging. Frequent recharge is preferable to long runs between periods of recharging.

*Q.* 118. What is meant by application of the brakes?

*A.* The operation by which brake-pipe pressure is reduced to permit of triple-valve movement, which will send pressure to the brake-cylinder.

*Q.* 119. Do you understand that the braking power is considerably more on passenger than on freight cars, and on this account greater care must be exercised in handling them?

*A.* Yes.

# CHAPTER XXII

## MALLET COMPOUND LOCOMOTIVE

In 1831, Horatio Allen built an engine at the West Point Foundry which was the forerunner of the articulated system, the idea being to distribute the weight of a locomotive over a number of wheels, and at the same time retain a sufficient degree of flexibility to adapt its motion to the curves incidental to railroads. Mr. Allen's efforts were not particularly successful, but his ideas were adopted by Robert F. Fairlie, an energetic Irish engineer, who, thirty years afterwards brought out the design of an articulated locomotive which bears his name. The locomotives were known as the Fairlie double-enders, and were really two independent locomotives, the boilers of which were placed back to back and supported on more or less elaborate framing. Their usefulness was confined to crooked mountain roads where speed was not a consideration. William Mason also built some locomotives that were known as the Mason-Fairlie type, which had but one boiler, and two sets of engines, and had many friends in their brief day.

Meanwhile Anatole Mallet, a Frenchman, who endeavored to develop a successful compound locomotive, built in 1888 the first of the articulated locomotives which became known as the Mallet Articulated Compound Locomotives. He made important improvements which led to real achievements, the chief of which is allowing the forward engine to swing on a pivoted frame, and avoided the lack of stability, the real defect in the Fairlie type of locomotive. In the Mallet locomotives the steam at high-pressure cylinders is carried to the other cylinder in flexible jointed pipes, so that leakage is practically avoided. It has been demonstrated that low-pressure pipes can be kept tight. In the Mallet locomotive the low-pressure cylinders are made the movable ones, and to provide for curving the boilers are placed high enough to allow the driving-wheels to move transversely. The first of these engines used in America were built by the American Locomotive Company for the Baltimore and Ohio Railroad, in 1904, and was exhibited at the Louisiana Purchase Exposition, and this type has come into extensive use, especially in heavy freight service in mountainous districts.

The chief mechanical peculiarity consists in the flexibility of the frames, which is accomplished by a hinge connecting the two frames, and is a very simple device, consisting of pins or bolts in both upper and lower bars of frames, usually placed immediately in front of the high-pressure cylinders, and are necessarily strong and firmly attached. The front-end of the boiler rests on slides, the upper half being riveted to the boiler and the lower half bolted to the frames of the low-pressure engine. The upper slides are usually of steel and the lower bearings of cast iron.

With the adjustment of frames it will be readily seen that the conveying of the steam from the high-pressure



to the low-pressure engines or cylinders must be made by pipes having some flexible adjustment. This is readily accomplished by the use of a ball and sliding joint. The exhaust pipe is similar in construction, but has one additional ball joint. Considerable ingenuity has been shown in the use of starting valves and intercepting valves which it is not necessary to describe in detail, but it can be readily imagined that the starting valve in the case of the low-pressure cylinders must be closed as soon as the steam from the high-pressure cylinders becomes effective..

In 1914 the Baldwin Locomotive Works constructed for the Erie railroad a locomotive of the Mallet type having two high-pressure cylinders and four low-pressure cylinders, one high-pressure cylinder supplying steam for each pair of low-pressure cylinders. The advantage of a locomotive of this type may briefly be said to be in the use of the weight of the tender as an adhesive part of the engine, and a utilization of its weight as a part of the tractive force of the locomotive. As is well known the basic factor controlling the hauling capacity of any locomotive depending on the frictional adhesions of the driving-wheels to the rails is the total weight on the driving-wheels, which is usually from four to four and one-half times the tractive power. Therefore an increase in tractive power demands a corresponding increase in weight on driving wheels and thus adds to the weight of the engine as a whole. It is generally believed that in the construction of the Erie's Triplex compound locomotive the limit has been reached both in weight and adaptation of steam as a factor in locomotives, but this thought is not new, and it may be safely accepted that new forms in steam locomotives will arise in the future as in the past, to meet new conditions.

### CATECHISM

*Q.* What is a Mallet articulated compound locomotive?

*A.* It is a locomotive having two separate and distinct engines under one boiler, the boiler being rigidly attached to the rear engine, but simply resting on bearing pieces on the forward engine, thereby allowing the forward engine to swing or curve laterally, independent of the rear engine. The rear engine taking steam direct from the boiler and exhausting it into a receiver, the steam is then conveyed to the cylinders of the forward engine.

*Q.* What two types are commonly used in this country?

*A.* The Baldwin and the American Locomotive Company types.

*Q.* In what manner do these differ in construction?

*A.* In the manner in which steam is admitted to the low-pressure cylinders in starting; the Baldwin locomotive having a starting valve that consists simply of a pipe conveying steam direct to the receiver from the boiler, the American locomotive being equipped with an intercepting, reducing and separate exhaust valves.

*Q.* Describe the Baldwin type of Mallet locomotive.

*A.* In the Baldwin type, the rear engine, connected rigidly to the boiler, receives steam direct through the



live steampipes. This steam, after being admitted through the valves to the high-pressure cylinders, is exhausted from them into a receiver from whence it is conveyed, by means of flexible connections, to the low-pressure steam chests. After being again expanded in the low-pressure cylinders, it is finally exhausted through the stack. The starting valve on this type of locomotive consists of a valve operated from the cab which is connected to a pipe that admits steam direct to the receiver, from which it passes to the low-pressure cylinders, this starting valve pipe being so proportioned with reference to the receiver pipe that the pressure of the steam from the boiler admitted to the receiver through the starting valve is reduced to the desired amount.

*Q.* Describe the American type of Mallet compound.

*A.* The general construction of this locomotive is practically the same as that of the Baldwin type, the difference being in the manner in which live steam is conveyed to the low-pressure cylinders in starting. In the American type, instead of having a manually operated starting valve, an intercepting valve is employed, so designed that when the throttle is open, live steam passes by the intercepting valve, through the reducing valve, and into the receiver; from thence to the low-pressure steam-chests, and will continue to pass to the low-pressure steam-chests in this manner until the pressure in the receiver has been built up to about four-tenths boiler pressure, when the intercepting valve automatically closes, allowing the engine to work strictly compound thereafter. The American locomotive also has a separate exhaust valve, so that either in starting or to prevent stalling on a heavy pull, the steam from the high-pressure cylinders can be exhausted direct to the atmosphere, thus reducing the back pressure against the high-pressure pistons, thereby increasing the power of the locomotive in the same proportion. The low-pressure cylinders, during this time, receiving live steam direct through the reducing and intercepting valves.

*Q.* What difference is there in the power of the two types of locomotives on hard pulls attributable to the different methods of admitting live steam to the low-pressure cylinders?

*A.* It is claimed that there is quite an appreciable difference in favor of the American Locomotive Company's design owing to the fact that with their design of intercepting and separate exhaust valves, the full power can be obtained in the low-pressure cylinders, and, at the same time, the back pressure can be eliminated in the high-pressure cylinders, due to the separate exhaust valve allowing the back pressure to escape to the atmosphere, while in the Baldwin type, the starting valve being so arranged as to connect both ends of the high-pressure cylinders, it is evident that the back pressure in the high-pressure cylinders will practically equalize with the initial pressure, thereby throwing the burden of the work on the low-pressure cylinders.

*Q.* What are the advantages and disadvantages claimed for the two methods employed to admit steam to the low-pressure cylinders?

*A.* In the American type the advantages consist in increased power when starting, or when necessary to cut the engine into simple, to avoid stalling on



heavy pulls. The disadvantages consist in a greater number of parts, thereby, in a measure, increasing liability of failure. In the Baldwin type the advantages are simplicity and decreased liability of getting out of order. The disadvantages are, that the power of the locomotive is only appreciably increased momentarily; that is, only when starting a train, as after the train has been started, if left working simple, the pressure on each side of the pistons in the high-pressure cylinders becomes almost balanced, and as the pressure to the low-pressure cylinders is reduced, the power of the engine is not augmented to any extent above what it can develop working strictly compound.

*Q.* Where and how do the high-pressure engines of the Mallet compound type get steam?

*A.* Direct from the boiler through the steam pipes leading to the steam chests, when the throttle is open.

*Q.* How do the low-pressure engines obtain their steam?

*A.* From the exhaust of the high-pressure engine, conveyed through a flexible receiver, except when working simple; that is, with the starting valve open; in which case the exhaust steam from the high-pressure cylinders is augmented by a certain amount of live steam direct from the boiler, conveyed to the receiver pipe either through the starting valve, as in the Baldwin type, or through the intercepting and reducing valves, as in the American type.

*Q.* Which is the high-pressure engine, and why?

*A.* The rear engine, or the engine rigidly attached to the boiler, is in all cases the high-pressure engine. This in order to avoid the use of a flexible steam pipe for the purpose of conveying the steam from the boiler to the high-pressure valve chambers.

*Q*. What other reasons are there for making the rear, or rigidly connected engine, the high-pressure engine?

*A*. As the steam in its final exhaust must pass through the stack in order to create a draft on the fire, if the rear engine were the low-pressure engine, it would require an extra length of exhaust pipe, thereby increasing the back pressure in the cylinders. It would also involve quite a complication of steam pipes, in that both the live steam and the exhaust pipes, together with the receiver pipes, would necessarily have to be of a flexible construction.

*Q*. How are both engines secured to the boiler?

*A*. The rear, or high-pressure engine is rigidly attached by means of a cylinder saddle; the frames being attached by means of expansion pads or expansion links. The forward, or low-pressure engine, is not attached to the boiler at all, the boiler simply resting on heavy bearings so as to allow the boiler to swing laterally over the forward engine when the locomotive is passing through a curve.

*Q*. As the forward engine is not attached to the boiler, what holds this engine in place when pulling or working steam?

*A*. The forward engine is held in position by having the rear end of the frames connected to the front end of the high-pressure engine by means of a flexible connection similar to a draw bar.

*Q*. How is the power of the forward or low-pressure engine exerted to the draw bar at the rear of the tank?



*A*. Through the frames of the rear engine, to which the forward engine is flexibly connected.

*Q*. Would it be safe to try to handle a train if the pin connecting the forward to the rear engine became lost or broken?

*A*. No; as in this case the forward engine might be pulled out from under the boiler.

*Q*. What would you do in case the pin or connection connecting the forward with the rear engine became broken?

*A*. If the pin simply dropped out, would get it and replace it. If the pin or any other part of the connection was broken, would chain the rear engine to the forward engine with heavy chains. In case no heavy chains were available, would use any kind of a chain that I could get of sufficient strength to hold the low-pressure engine in place, set out train and come in light.

*Q*. Why is the forward or low-pressure engine not rigidly attached to the boiler, the same as the rear or high-pressure engine?

*A*. Because in this case it would make both engines rigid, thereby increasing the rigid wheel base of the locomotive to such an extent that the locomotive could not negotiate anything but the longest curves, and would be apt to be derailed in entering turnouts such as passing tracks, etc.

*Q*. Trace the steam from the boiler to the atmosphere.

*A*. When the throttle is opened, steam passes through the standpipe into the steam-pipes to both high-pressure steam chests; thence, by the movement of the valves, it is admitted alternately to the ends of the cylinders and exhausted from the opposite ends, through the valves to the exhaust channel in the cylinder saddle; thence to the receiver pipe; from whence it is conveyed to the low-pressure steam chests; where, by the movement of the valves, it is admitted to and exhausted from the low-pressure cylinders, the final exhaust passing through the exhaust pipe and out through the stack to the atmosphere.

*Q*. What would you do in case of an accident to the main exhaust pipe?

*A*. If the exhaust pipe was broken off so that all the exhaust steam would escape through the break before it passed to the exhaust nozzle, would block up the end of the exhaust pipe leading to the nozzle and depend upon the blower to furnish sufficient draft to make steam enough to handle the locomotive. If the main exhaust pipe simply leaked bad, would go on with the train, using the blower to aid in creating a draft, if necessary.

*Q*. What would you do if the exhaust pipe from the high- to the low-pressure cylinders broke?

*A*. As this is the receiver pipe conveying steam to the low-pressure cylinders, it is evident that the low-pressure engines would be cut out and useless, so far as furnishing power is concerned; and as the draft on the fire is created by the exhaust from the low-pressure cylinders, it is evident that if the low-pressure cylinders receive no steam, there would likewise be no exhaust to create a draft. It would, therefore, be necessary to reduce the train to what could be handled by the high-pressure engine, and depend upon the blower for creating sufficient draft to make steam.



*Q*. In a case of this kind, would you disconnect anything on the forward or low-pressure engine?

*A*. No, it would not be necessary.

*Q*. In a case where either the low-pressure exhaust, or receiver pipe broke, what would you do to prevent the escaping steam from obscuring your vision?

*A*. Nothing could be done. It would simply be necessary to shut off frequently in passing through stations, in order to see that the line was clear.

*Q*. Would it not be safer, then, in a case of this kind, to set out the entire train and allow engine to be towed in?

*A*. Yes; but engineers, as a rule, do not like to be towed in as long as their locomotive is not absolutely helpless.

*Q*. What would you do in case the starting-valve pipe on a Baldwin Mallet compound broke?

*A*. Apply a blind gasket in the union where pipe connects to steam ports.

Q. What would you do in case the reach rod to the forward engine broke?

*A*. Remove or tie up the broken parts to a point where they would not interfere, block the link blocks in the links at a point that you are satisfied engine would handle train—preferably about half stroke—and proceed.

*Q*. What would you do in case the reach rod to the rear engine broke?

*A*. As this reach rod is connected to the reverse lever, and since the forward reach rod is connected to the rear reach rod, in case the rear reach rod broke, it would be necessary to raise the blocks in the links of both the forward and rear engines to a point where the train could be handled. This could be done either by means of blocking or chains.

*Q*. How are Mallet compounds reversed? Why?

*A*. Usually by means of a power reversing gear, as with this type of engine it is necessary to move about four valves, together with their tumbling shafts and their mechanism—something that would be very hard to do by hand.

*Q*. What type of reversing gear is commonly used?

*A*. A power reversing gear, operated by compressed air; or, in case of emergency, steam. This consists of a small auxiliary reverse lever, pivoted to the main reverse lever and moving with it. The movement of the auxiliary lever, operating an air valve, admitting air to one end of the cylinder of the reversing gear, moving the main lever in the same direction that the auxiliary lever is moved until the desired cut-off has been reached, when the latching of the auxiliary lever automatically latches the main lever also, and, at the same time, closes the air valve, preventing any further movement of the piston in the cylinder.

*Q*. With this type of reversing gear, what provision is made to prevent a rapid movement of the lever?

*A*. A cylinder filled with oil and containing a piston attached to the piston in the air cylinder is fastened to and worked in harmony with the air cylinder. The movement of the auxiliary lever which opens the air valve, likewise opens the valve in the oil cylinder, establishing cummunication between the two ends of this cylinder. This valve, having small ports, will allow the piston in the oil cylinder to move only as fast as the oil can move through the ports, thereby preventing sudden movement or " slamming " of the reverse lever.



*Q*. Is there any other type of reversing gear used?

*A*. Yes. On some of the late designs of locomotives, a screw reversing gear is used instead of the air-operated, power reversing gear.

*Q*. How would you test for a blow in the low-pressure valve?

*A*. The same as on any ordinary locomotive, by placing the engine on either quarter on the side to be tested, with the reverse lever in the center of the quadrant; open starting valve on Baldwin type of engine, and main throttle on American type, and cylinder cocks. If steam escapes from either cylinder cock, the low-pressure valve being tested is blowing.

*Q*. How would you test for a high-pressure valve blow?

*A*. Place engine on either quarter on the side to be tested, reverse lever in the center of the quadrant, open cylinder cocks and open main throttle. Steam escaping from either cylinder cock will indicate that the valve is blowing.

*Q*. How would you test for a blow in the low-pressure cylinder packing?

*A*. Leave engine in the same position; that is, on either quarter; cylinder cocks open, driving brakes set, but place the reverse lever in full gear forward or back instead of in the center. Now, with the Baldwin type open the starting valve and wait until sufficient pressure has accumulated in the low-pressure cylinders to give you a good test. With the American type, open the main throttle. If steam now escapes from both cylinder cocks at the cylinder being tested, cylinder packing is defective.

*Q.* How would you test for a blow in the high-pressure cylinder packing?

*A.* Leave the engine in the same position as before, namely, on either quarter; reverse lever in either corner, driving brakes set, cylinder cocks open, open main throttle. If steam escapes from both cylinder cocks at the cylinder being tested, the cylinder packing is defective.

*Q.* How would you test for broken low-pressure valve seat?

*A.* Same as for a cut valve, except in this case, after the valve has been tested with reverse lever in the center of the quadrant, the lever should be moved first to the forward end and then to the back end of the quadrant. A loud blow at the stack, with the reverse lever at either the forward or back end of the quadrant, but not in both positions, would indicate a broken valve or a broken bridge. If there was a blow at the stack, however, with the reverse lever both in the forward end of the quadrant and in the back end of the quadrant, it would probably indicate broken cylinder packing.

*Q.* How would you test for a broken high-pressure valve or seat?

A. The same as for a broken low-pressure valve or seat, except that instead of opening the starting valve, as would be necessary with the Baldwin type of engine, the main throttle should be opened; while on the American type, in addition to the main throttle, the separate exhaust valve should be opened. Now, in case the high-pressure valve or valve seat is broken on the Baldwin type engine, the steam flowing by the broken valve or seat will pass into the cylinder, then out through the exhaust port of the valve, when the lever is in either corner, and so on to the receiver; from whence it passes to the low-pressure steam chests. Now, if the low-pressure valves and seats are all right, there would be no blow at the stack, and, consequently, the only way that you could determine that the valve is defective would be by a strong escape of steam from the low-pressure cylinder cocks, or by the relief valves in the low-pressure steam chests raising and seating. With the American type of locomotive, however, the steam escaping by the broken valve or valve seat, would pass out through the separate exhaust valve, and thence to the stack; and the defective valve could, therefore, be located by the sound of the steam escaping.



*Q.* What would be the effect on the working of the engine in case one of the low-pressure valves or seats was broken?

*A.* There would be a continual blow at the stack when the engine was working, and the engine would lose power.

*Q.* What would be the effect in case one of the high-pressure valves or seats was broken?

*A.* The steam escaping by the broken valve would pass into the receiver, thereby increasing the receiver pressure, causing the pop valves on the low-pressure cylinders and steam chests to open. It would also reduce the power of the locomotive.

*Q.* What would be the effect of broken cylinder packing in one of the low-pressure cylinders?

*A.* It would cause a blow when steam was being admitted to the cylinder having the defective packing, the blow being strongest at the beginning of the stroke, and gradually decreasing towards the end of the stroke.

*Q.* What would be the effect of broken packing in one of the high-pressure cylinders?

*A.* Same as a broken high-pressure valve or seat, in that the steam escaping by the broken cylinder packing would increase the pressure in the receiver, thereby causing the cylinder and steam-chest pop valves to unseat.

*Q.* Would broken high-pressure cylinder packing cause a blow at the stack?

*A.* No; except on the American type of Mallet compound with the separate exhaust valve open.

*Q.* Which would affect the power of the locomotive to the greatest extent, and how?—broken high- or broken low-pressure cylinder packing?

*A.* Broken low-pressure cylinder packing, as this would practically destroy all the power of the steam in the low-pressure cylinder having the defective packing, thereby decreasing the power of the locomotive. Broken high-pressure cylinder packing would increase the amount of power being developed in the low-pressure cylinders, and would, therefore, not affect the power of the locomotive to the same extent as broken low-pressure packing.

*Q.* What is a by-pass valve, and why is it used in connection with this type of locomotive?

*A.* The by-pass valve is a valve establishing communication between both ends of the cylinders when the engine is not working steam. It is used in connection with the low-pressure cylinders in order to enable the engine to drift more freely, and to prevent the compression of air in the cylinder when drifting, as on account of the large diameter of these cylinders, the air compressed ahead of the piston would have quite a retarding effect.



*Q.* How would you test for a stuck or broken by-pass valve?

*A.* Place the engine on either top or bottom quarter on the side to be tested. Now place reverse lever first in either full gear forward or full gear back; and, with the Baldwin type of locomotive, open the starting valve. With the American type of locomotive, open the main throttle. This will admit steam to one end of the low-pressure cylinder. If the by-pass valve at that end is either stuck or broken, it will allow part of the steam to pass through the by-pass valve into the other end of the cylinder; from thence through the exhaust port and out of the stack, causing a blow similar to broken cylinder packing or broken valve seat. It can also be determined, when running, by a blow occurring between exhausts; as, for instance, if but one of the by-pass valves was stuck-up or broken, you would have three normal exhausts at the stack and one blow. If both by-pass valves on one side were stuck-up or broken, however, there would be a continuous blow at the stack. The broken valve can be located by testing as above; and when the engine is placed in the position where the blow occurs, place the reverse lever in the opposite corner. If the blow stops, it will indicate that the defective valve is at that end of the cylinder that was in communication with the steam-chest pressure through the ports, when the lever was in its first position; as, for instance, say that the test was being made for a defective by-pass valve at the right low-pressure cylinder, and the locomotive was spotted with the main-crank pin upon the upper quarter. Now, if the blow occurs with the reverse lever in the forward corner but not in the back corner, it is evident that the back by-pass valve on that side is either stuck or broken.

*Q.* How would you proceed in the case of a stuck or broken by-pass valve?

*A.* After locating the defective valve, take off the valve cap, remove the valve, and if it was simply stuck, clean it off thoroughly; oil it with headlight oil, and replace it. If the valve is broken, and broken in such a manner that it will still make a seat if blocked down, block it in place, holding it with the valve chamber cap. If it is so broken, however, that it can not seat, either slip a blind gasket between the by-pass valve chamber and the port communicating to the steam port; or, with some types of by-pass valves, slip a blind gasket into the connecting steam pipe.

*Q.* Will a Mallet compound locomotive burn more coal than a simple locomotive having the same amount of grate area? Why?

*A.* No. In fact, it will not burn as much coal; as, owing to the steam being compounded, the exhaust and, consequently, the draft on the fire is much lighter.

*Q.* What is the object in building this type of locomotive?

*A.* To obtain more adhesive power, as the tractive power of a locomotive is governed largely by its adhesion, and the adhesion depends upon the weight upon the



drivers; and as the amount of weight permissible on a journal is limited, it is evident that increasing the number of drivers allows a greater weight to be carried, thereby increasing the adhesive power, thus permitting an increase in cylinder power. The articulated feature is necessary in order to reduce the rigid wheel base, and allow the locomotive to take ordinary curves.

*Q.* How is the additional weight on the drivers obtained?

*A.* By increasing the length and size of the boiler, using in addition to direct heating surface, feed-water heaters, reheaters, etc., which can all be carried in or made a part of the boiler, the total weight resting on the two engines.

*Q.* What is a feed-water heater? Where located, and how operated?

*A.* A feed-water heater is a storage space where the feed-water is heated prior to its being forced into the boiler. It is largely used in connection with this type of locomotive, and is generally located in the forward part of the boiler, ahead of the flues proper. The heat is imparted to the water by the gases from the firebox after passing through a number of tubes in the feed-water heater before they finally emerge at the stack; the water in the feed-water heater taking up considerable of the heat of the gases passing through it.

*Q.* Are the feed-water heaters kept full of water at all times? Why?

*A.* Yes; as the feed-water heater must be filled before any water can be forced into the boiler, the injectors being connected to the heater and not to the boiler proper.

*Q*. When superheaters are used in connection with this type of locomotives, where are they located, and how operated?

*A*. In some types of Mallet compound locomotives the superheater consists of what is termed the smoke-tube type, wherein the superheater elements are located in large tubes or flues, extending from the front to the back flue sheets, and the steam, before reaching the high-pressure cylinders, is passed through these superheater elements, and there superheated. In other types of locomotives, the superheater consists of a large drum, practically the same size as the boiler proper, and located just ahead of the boiler proper. The drum is filled with tubes, or flues, running parallel with the boiler, so that the hot gases, after passing through the boiler proper, must pass through these flues in the superheater before they can escape to the stack. The steam to be superheated surrounds these flues, and, by means of baffle plates, is compelled to circulate all around these flues before it is finally admitted to the high-pressure steam chests. On other types of locomotives, the superheater consists of a series of pipes of small diameter, taking the place of the steam pipes in the front end, the steam obtaining its superheat from the front-end gases. The first type of superheater mentioned is termed the "High degree," the second the "moderate," and the third the "low" degree superheater.

*Q*. What is a reheater used in connection with this type of locomotive? Where located, and how operated?

*A*. A reheater is built practically the same as the "moderate" or "low" degree superheater, and can be located either in boiler extension, ahead of the boiler proper, or in the front end. Its purpose is to reheat the exhaust steam from the high-pressure cylinders before it passes on to the low-pressure cylinders. It operates automatically, and practically the same as a superheater, in that the steam to be reheated obtains its additional heat from the gases passing from the firebox, through or around the reheater elements on their way to the stack.



*Q*. What would you do in case of a broken low-pressure piston or head?

*A*. Disconnect the valve stem on that side, clamp the valve to cover the ports. In case the piston was broken and the head not punched out, remove the broken parts, if they are liable to interfere or cause more damage, leaving the cylinder head off. If, after removing the cylinder head, you find that the broken parts can do no further damage, leave the head off and go on. The open end of the cylinder will enable you to keep the piston oiled, and, at the same time, prevent the compression of air.

*Q*. What would you do in case of a broken high-pressure piston or head?

*A*. Handle the same as for broken low-pressure piston or head.

*Q*. What would you do in case of a broken low-pressure cylinder or cylinder head?

*A*. Disconnect the valve stem at that cylinder, clamp the valve to cover the ports. If the cylinder is so broken that it would not be safe to allow the piston to work up and back in it, it would, of course, be necessary to disconnect the main rod also. If the cylinder is simply cracked, however, remove the cylinder relief valves so that the piston can be kept lubricated through the openings, and compression of air can be relieved through the same openings. If the cylinder head is knocked out, simply disconnect the valve stem and clamp the valve to cover the ports.

*Q.* What would you do in case of a broken high-pressure cylinder or cylinder head?

*A.* Handle the same as for broken low-pressure cylinder or cylinder head.

*Q.* What are cylinder relief valves? Why used, and where?

*A.* Cylinder relief valves are valves fashioned similar to the ordinary pop or safety valves; that is, a valve screwed into the end of the cylinder or cylinder head, having a spring that can be adjusted to the tension desired so as to hold the desired amount of pressure in the cylinder, and to raise and relieve any excess pressure. These valves are usually screwed into the lower part of the front- and back-cylinder heads.

*Q.* What would you do in case one of the cylinder relief valves blew out?

*A.* If noticed the moment it blew out, would stop, pick it up and screw it in again. If it could not be found, would endeavor to plug the opening with any kind of a plug available. Frequently one of the compression grease plugs out of one of the rod cups can be used for this purpose. If not, a wooden plug can be used, although these burn out very rapidly.

*Q.* How would you lubricate the valves and cylinders on a locomotive of this type?

*A.* If the lubricator is connected to both high- and low-pressure steam chests, would use about six drops



per minute to each high-pressure valve, and three drops per minute to each low-pressure valve when working steam, reversing the operation when drifting.

*Q.* What would you do in case of a broken frame on the forward engine?

*A.* If the frame was broken ahead of the main driver and both rails were broken, would disconnect the valve stem on that side, clamp the valve to cover the ports, remove the cylinder relief valves from both ends of that cylinder, and proceed with the three cylinders working. In this case, the engine could only handle three-fourths of its rating. If but one rail of the frame were broken, so that there would not be much danger of further damage, or if but one rail of the frame were broken back of the main drivers, would proceed with the engine as it was. If both rails of one frame were broken between the main and rear drivers, however, would disconnect the back sections of both side rods, and proceed.

*Q.* What would you do in case of a broken frame on the rear- or high-pressure engine?

*A.* If but one rail of the frame were broken, would proceed without disconnecting. If both rails on one side were broken, however, and broken just back of the cylinders so that a pull on the frame would be apt to tear off the guides, etc., would set out the train and go in light. If both rails of the frame were broken back of the guide yoke connection, or back of the rear drivers, would disconnect the valve stem on that side, clamp the valve to cover the ports, and go in with one high-pressure and two low-pressure cylinders working. In this case it would not be advisable to handle more than half a train.

*Q.* What would you do in case of some defect arising to the valve gear of the low-pressure engine?

*A.* As locomotives of this type are usually equipped with the Walschaerts gear, it would depend upon what broke. The breakage, however, could be handled the same as a similar break on a simple engine.

*Q.* What would you do in case it became necessary to disconnect both low-pressure valves? Could the engine be handled under its own steam?

*A.* With the American type of locomotive there would be no trouble in bringing the engine in under its own steam, as it would simply be necessary to open the separate exhaust valves, and come in with the high-pressure engine working. With the Baldwin type it would be rather a difficult matter, however, especially if the locomotive was fitted with the common "D" or slide valve at the low-pressure cylinders. If the locomotive was fitted with piston valves, the front-valve chamber heads could be removed and the valves pushed forward enough to uncover the back steam port and also part of the exhaust port, so that the exhaust steam escaping from the high-pressure cylinders and passing through the receiver to the low-pressure steam chest, could find an outlet through the open ports. If the engine was fitted with the "D" or slide valve, however, the only way that the engine could be brought in under its own steam, with both low-pressure valves disconnected, unless the valves could be pushed forward enough to uncover the exhaust port, would be to take up both steam chests, remove the balance strips out of the top of the valves; then raise up the valves and block them off their seats with iron blocks or



wedges, replacing the steam-chest covers. This will allow the steam exhausted from the high-pressure cylinders to pass into the low-pressure steam chests under the valves, and on out through the exhaust.

*Q.* What would you do in case of failure of a portion of the valve gear on the rear engine?

*A.* Handle practically the same as for a similar breakdown on a simple engine.

*Q.* Would it be possible to bring the locomotive in under its own steam in case it became necessary to disconnect both valves on the rear engine? If so, how?

*A.* Yes; the engine could be brought in under its own steam with the low-pressure cylinders by simply opening the starting valve on a Baldwin locomotive. On the American type locomotive, the intercepting and reducing valves would supply steam to the low-pressure cylinders when the throttle was opened.

*Q.* What would you do in case of broken rods, pins or guides on either engine?

*A.* Handle practically the same as for a similar breakdown on an ordinary engine of the ordinary simple type.

*Q.* What would you do in case either engine started slipping when working steam?

*A.* Would drop sand and keep throttle open, as if the high-pressure engine were slipping; it would soon develop so much back-pressure in the receiver pipe as to choke the high-pressure engine down; whereas, if the low-pressure engine was slipping and the high-pressure was not, the low-pressure engine would soon use up all the steam in the receiver, thereby stopping the slipping. This will not apply, however, with the

American type locomotive, if the separate exhaust valve was open, as in this case the high-pressure engine would continue to slip unless the throttle was eased off or partially closed.

*Q*. Would you consider it necessary to oil the front engine bearers?

*A*. Yes. These should be kept lubricated the same as any other part of the locomotive, in order to enable the boiler to swing freely.

*Q*. When inspecting this type of locomotive, what portion would you consider most important to inspect thoroughly?

*A*. The connections between the two engines, as failure of these connections—that is, the draw bar rigging and pin—is liable to cause serious damage by the forward engine running out from under the boiler.

*Q*. How would you start a locomotive of this type?

*A*. Always open the cylinder cocks before opening the throttle. With the Baldwin type, if the train is heavy, open the starting valve. With the American type, try to start the train with the reverse lever down in the corner. If the engine can not start the train in this way, open the emergency operating valve in the cab by pointing the handle to the rear.

*Q*. After the train is started, how would you handle the locomotive?

*A*. After a speed of three or four miles per hour has been reached, close the starting valve on the Baldwin type, and close the emergency valve on the American type, as you would simply be burning more coal with these valves open without getting any more power out of the engine.



*Q*. How would you proceed if you were about to stall on a grade?

*A*. With either engine, if the speed is below three or four miles per hour, proceed the same as when starting a heavy train.

*Q*. In what position would you carry the reverse lever when drifting?

*A*. At about three-quarters stroke or more.

*Q*. What attention should be given the power reversing gear?

*A*. Keep the oil cylinder full of oil, and the piston-rod packing on the oil and air cylinders tight. Always see that the latches of both reverse levers mesh in the teeth of the quadrant. Whenever they do not, report it.

*Q*. What attention should be given by-pass valves?

*A*. They should be reported to be cleaned periodically, in order to keep them from getting gummed up and sticky.

*Q*. What would be the effect if a by-pass valve were stuck open or stuck shut?

*A*. If stuck open, they will cause the engine to blow. If stuck shut, they will cause the engine to pound when drifting.

*Q*. What attention should be given the relief valves on low-pressure steam chests and cylinders?

*A*. They should be tested about once a month, in order to see that they open at the proper pressure.

*Q*. How would you handle the intercepting valve used in connection with the American type locomotive, so far as lubricating it, etc., is concerned?

*A*. Give it a liberal feed of oil for about one minute before starting, and occasionally during long runs where the throttle is not shut off for a considerable length of time. Except for this one drop of oil about every four or five minutes, when running, is ample.

*Q.* Beside the intercepting valve, what other parts of an articulated compound locomotive should be oiled that are not found on the ordinary locomotive?

*A.* The sliding boiler-bearing on the front engine; the ball joint in front of the high-pressure cylinder; the upper- or rear-ball joint of the exhaust pipe; the lower- or front-ball joint of the exhaust pipe (these ball joints need only be oiled before starting, as one oiling should be sufficient for the trip); the bolt in the flexible connection connecting the two engines; the ball bearing of the vertical suspension or trim bolts, which connect the upper rails of the front frames with the lower rails to the rear frames; the ball bearing of the floating columns, if any; the piston-rod packing of the cylinders of the power-reversing gear; the air cylinder of the power-reversing gear, by means of the plug in the top of the cylinder; about once a week will be often enough for the air cylinder.

*Q.* What is the arrangement of cylinders on Mallet compound engine.

*A.* High-pressure cylinders rigidly attached to the boiler and rear engine; low-pressure cylinders rigidly attached to the frames of the forward engine, but not attached to the boiler.

*Q.* Describe the make of valves used on high-pressure engines and on low-pressure engines.

*A.* As a rule, piston valves are used on the high-pressure engines and " D, " or slide, valves on the low-



pressure engines. (The following questions and answers apply to American type engines only except as noted.)

*Q.* Does the engine work simple or compound when first started?

*A.* Simple.

*Q.* When does the Mallet engine work compound?

*A.* When the receiver pressure has reached the desired amount, which is about four-tenths boiler pressure, thereby closing the intercepting valves.

*Q.* When the engine is working compound, what change is necessary to make the engine work simple?

*A.* Open the emergency valve in the cab, which causes the separate exhaust valve to open. This takes the pressure off the end of the intercepting valve, allowing it to open and live steam to pass through the reducing valve direct to the low-pressure cylinders.

*Q.* How would you determine if the intercepting valve was stuck open? If stuck closed?

*A.* If the intercepting valve was stuck open, the engine could not be converted from compound to simple, as, in this case, opening the separate exhaust valve would allow part of the steam from the receiver to pass out through the separate exhaust, and, consequently, but a small portion would pass to the low-pressure cylinders and the engine would lose power and, if on a hard pull, would probably stall. It might also be noticed by the high-pressure engine slipping.

If the separate exhaust valve was stuck closed, the locomotive could not be converted from simple to compound and, unless the separate exhaust valve was opened, the pressure would bank up in the receiver until it balanced on both sides of the high-pressure piston, and, in this case, as before, if the engine was on a hard pull it would probably stall. You could tell if the intercepting valve stuck closed by first opening the separate exhaust valve and noticing if the engine picked up speed, then closing the separate exhaust valve, by means of the emergency valve in the cab, and noting if the speed reduced quickly.

*Q.* Describe how steam is conveyed from high to low-pressure cylinders.

*A.* As the steam is exhausted from the high-pressure cylinders it passes on into what is termed the receiver pipe, which connects the exhaust chamber of the high-pressure valve with the steam chamber of the low-pressure valve, and when the engine is working compound the movement of the low-pressure valve allows the steam from the high-pressure cylinders to enter direct into the low-pressure cylinders. When the engine is working in simple position the low-pressure engines operate with live steam direct from the boiler, while the steam exhausted from the high-pressure cylinders into the receiver passes by way of the separate exhaust valve direct to the nozzle.

*Q.* In starting the locomotive, if the forward engine does not take steam, what is the trouble?

*A.* The reducing valve is stuck shut, as, with this type of engine, unless the reducing valve is open there would be no steam in the low pressure-cylinders until after the high-pressure cylinders have exhausted.

*Q.* What would you do if a by-pass valve was stuck open or stuck closed?

*A.* If one of the by-pass valves should stick open it would cause a severe blow, and, if it could not be closed in any other manner, the cap on the end of the chamber should be removed and the valve forced into closed position with the handle of the coal pick. At the same time, while the cap is removed, see that the small port at the end of the by-pass valve chamber is open. If the valve is stuck shut the engine would not drift freely, and, if necessary to do considerable drifting before reaching the end of the terminal, it is advisable to take off the valve chamber cap, remove the by-pass valve, clean it with coal oil and replace. The sticking of the by-pass valves is generally caused by the smokebox gas being sucked into the cylinder, on account of the reverse lever being carried too high up when the engine is drifting. The reverse lever should always be carried at about three-fourths cut-off when the engine is drifting, as this will allow the engine to drift more freely and there will be less smoke and gas sucked into the cylinder.



*Q.* Describe the course taken by the steam from the time it leaves the boiler until it is exhausted from the stack, when starting and when working compound?

*A.* Ordinarily, when starting without the separate exhaust valve being open, steam, upon opening the throttle, passes from the throttle standpipe to the dry pipe and to the steam pipes leading to the high-pressure steam chests, thence, as the high-pressure valves open and close the steam ports, it passes to the high-pressure cylinder and is exhausted into the receiver, from which, by the movement of the low-pressure valves, it is admitted to, and exhausted from, the low-pressure cylinder, the exhaust passing out through the exhaust nozzle the same as in an ordinary locomotive. At the same time, when starting, live steam is admitted to the low-pressure steam chest through the reducing valve, this steam taking the same course into and out of the low-pressure cylinder as the receiver steam, or exhaust from the high-pressure cylinder. After the engine has made a few revolutions the exhaust steam from the high-pressure cylinder will bank up in the receiver, causing the reducing valve to close, and thereafter the engine will work compound, the steam taking the same course as before, with the exception of the live steam passing through the reducing valve. If the engine is started with the separate exhaust valve open, however, the exhaust from the high-pressure cylinder, instead of banking up in the receiver, is exhausted direct to the exhaust nozzle through the separate exhaust valve, the steam used in the low-pressure cylinder and admitted through the reducing valve taking the same course as before.

*Q*. How are the simple and compound features controlled in Mallet engine?

*A*. In the Baldwin type, by means of an emergency valve in the cab, which, when opened, allows high-pressure steam to flow direct from the boiler into the receiver and from the receiver into the low-pressure cylinders. In the American type, by means of an intercepting valve and an emergency valve. When the emergency valve is opened it throws the intercepting valve in such a position as to allow high-pressure steam to flow from the high-pressure steam chests direct into the receiver pipe, and from thence to the low-pressure cylinders.

*Q*. Should the high-pressure engine become disabled, how would you get the locomotive in?

*A*. By opening the emergency valve in the cab, so



as to allow high-pressure steam to flow to the low-pressure engine.

*Q*. Under what conditions should the emergency or starting valve be used?

*A*. Only when starting, and to prevent stalling on a heavy grade.

*Q*. What are the duties of the intercepting valve?

*A*. To supply steam to the low-pressure cylinders when starting, and to cut off the supply when the reservoir pressure has reached the desired amount.

# CHAPTER XXIII

## OPERATION OF SUPERHEATER LOCOMOTIVES

A REPORT on Fuel Economy prepared by a committee of which Mr. William Schlafge, General Mechanical Superintendent of the Erie Railroad, was Chairman, and read before the 48th Convention of the American Railway Master Mechanics' Association, embodied largely the matter in this chapter in regard to the efficient operation of superheater locomotives.

When properly maintained and efficiently operated, the superheater is by far the most valuable mechanical aid to fuel economy ever applied to locomotives. By its use savings of 20 to 25 per cent in coal and water are obtainable in actual service. But if maintenance is neglected and careless handling of the device in service is permitted, the superheater may become almost useless, as far as performing its regular function is concerned. The question of superheater operation is extremely vital to the subject of fuel economy, and should be given careful consideration.

The general operation of superheater locomotives is the same as the ordinary saturated steam locomotive. Attention is directed to a few items in connection with superheater locomotives which need careful consideration.

Cylinder cocks should be kept open when standing, and, as far as possible, when starting, until dry steam appears.





The lubricator must be started at least fifteen minutes before leaving time, in order that the valves and cylinders may be thoroughly lubricated when starting on the trip. The oil supply to the cylinders should be constant, as there is no water in the steam to assist in the lubrication, and, on this account, the superheater locomotive requires more careful lubrication for valves and cylinders than the saturated steam locomotive.

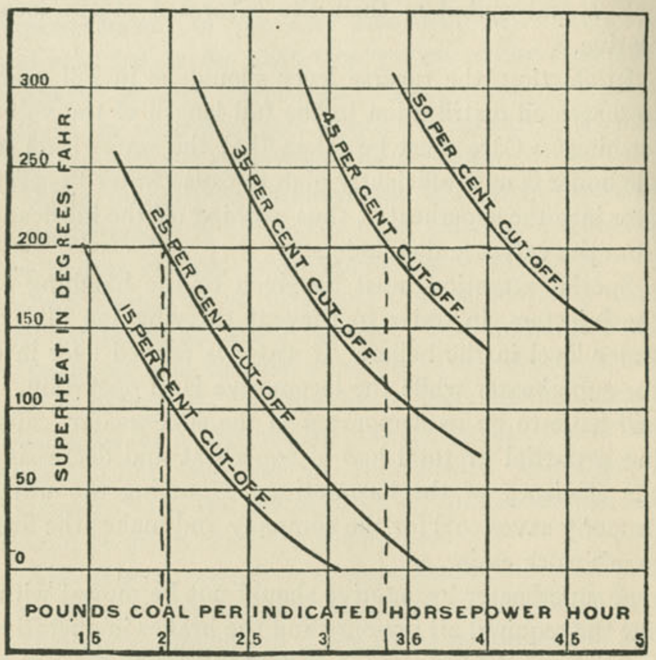
In starting, the reverse lever should be in full gear, to insure oil distribution to the full length of the valve bushings. Care must be taken that the water level in the boiler is not sufficiently high to cause water to carry over into the superheater, thus washing off the lubricant from the valves and cylinders.

Special attention must be given to the handling of the injectors, in order to prevent carrying too high a water level in the boiler. If water is carried over into the superheater while the locomotive is in operation, it will have to be re-evaporated in the superheater, causing a partial or total loss of superheat and decreasing the efficiency of the locomotive. Handling the water properly saves coal for the company and makes the fireman's work easier.

A superheater locomotive should not be moved without the required air pressure and the brakes in operative condition. When water is carried over into the superheater, part or all of it will flash into steam, even after the throttle is closed. Under the above condition the locomotive is not under control, because the valve chamber is filled with steam.

Superheater locomotives should be operated with a full throttle opening and reverse-lever control, as far as service conditions will permit, the exceptions being: When starting a train, when using a very small quantity of steam, and when drifting. The chart shown illus-

**Variation in Coal Consumption with Varying Superheat at Different Cut-offs.**




trates the point in question, and shows the variation in coal consumption with various degrees of superheat for each of the following cut-offs: Fifteen per cent, 25 per cent, 35 per cent, 45 per cent and 50 per cent. The figures were taken from tests of a large Pacific type



locomotive, but they apply with equal force to all superheater locomotives. For example, take the curve for 25 per cent cut-off at 200 deg. of superheat. The coal consumption is about 2 lb. per indicated h-p. hour. Then take the curve for 45 per cent. cut-off at 200 deg. of superheat. The coal consumption is about 3.3 lb. per indicated h-p. hour. This clearly shows why it is better to operate with a full throttle and reverse-lever control rather than with a partial throttle and long cut-offs. The difference for the example taken is 1.3 lb., or 39 per cent over the incorrect method. The chart also shows the advantages of a high degree of superheat at any cut-off in reducing the coal consumption per indicated h-p. hour.

It is advisable, in order to avoid the suction of hot gases from the smoke box into the steam chest and cylinders, to keep the throttle slightly open when drifting or making stops, as by passing a very slight amount of steam through the cylinders, the front-end gases can not be drawn into the exhaust column. The throttle must be completely closed just before coming to a full stop.

The firing should be light and regular, to produce as high flame temperature and as perfect combustion as possible in the firebox. A high firebox temperature results in high superheat, which will be obtained by a small coal consumption. A heavy, black fire means low temperature, low superheat and large coal consumption. Firemen who carefully follow the above outlined practice will save coal for the company and make their own work easier.

The engineman should be sure that the superheater damper is open while using steam, and closed when steam is shut off. This can be ascertained by observing the counterweight on the right-hand side of the smoke box attached to the damper. When the counterweight is up the damper is open, and when down the damper is closed. When the locomotive is shut off and the blower is used, the engineer should observe that the damper is in a closed position. If the damper is open with the blower on, the superheater tubes are apt to be burned out, due to no steam circulating through the superheater tubes. When using steam, the piston in damper cylinder should always move its entire stroke and stop against its seat, in order to prevent loss of cylinder lubrication past the piston. A leak at this point will permit steam to escape at end of drip pipe attached to damper cylinder, and should be reported promptly.

Leaks in front end of superheater units, steam pipes and exhaust column, fire tubes stopped up, and derangement of draft appliances not only interfere with the proper steaming of the locomotive, but reduce the degree of superheat. Blows in cylinder and valve packing will cause scoring, due to removal of oil from the wearing surfaces. All leaks such as those mentioned above should be reported promptly by the engineman, because, if neglected, they seriously affect the economical operation of the locomotive.

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