THE
BALTIMORE AND OHIO RAILROAD
COMPANY

GOOD FIRING

A TEXT BOOK FOR ENGINEERS
AND FIREMEN

ON

LOCOMOTIVE MANAGEMENT

No.........................

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GOOD FIRING

A TEXT BOOK FOR ENGINEERS AND FIREMEN ON LOCOMOTIVE MANAGEMENT

CONTENTS

INTRODUCTORY

The following instructions are issued for the information and guidance of engineers and firemen on all lines operated by The Baltimore and Ohio Railroad Company.

The principal object of these instructions is to prevent the waste of fuel, to promote good methods of firing and good practice in the operation of locomotives.

With the single exception of the item "wages," the greatest expense in operating a railroad is for fuel, and every employee will be interested in the matter of fuel economy as it offers a chance for very large savings which would materially add to the prosperity of the Company and react to the benefit of the employee.

Including the cost of haul, The Baltimore and Ohio Railroad Company uses about $10,000,000 worth of coal in a year. If the average weight per scoopful be reduced from fifteen to thirteen pounds, and no more or less scoops used per mile, the aggregate saving of two pounds of coal per scoop will amount to over $1,000,000 a year.

The question of labor is of more particular interest to the fireman. It is an indisputable fact that the easiest and most economical way to fire an engine is in accordance with the correct principles of combustion.

HAND FIRING

Qualifications of a Fireman

1. An efficient fireman is a man possessing the skill and knowledge that enable him to make the fuel which he supplies to a furnace burn so hot that it evaporates into steam as much water as possible and to burn no more fuel than necessary. That is, he makes the fuel perform its maximum duty. There are other attributes which increase the value of a man as a fireman, but the ability to keep up steam with the minimum amount of coal is the first consideration.

2. It is not essential that a man should know all about the science of combustion to make a first-class fireman, and while a good fireman may not always understand the reasons why he is firing in a certain manner, some knowledge of the science of combustion will enable him to overcome difficulties and produce the best results under all conditions. With this in mind, therefore, a brief outline of heat and combustion will be presented hereinafter.

Starting on the Trip

3. When preparatory time is allowed the fireman should make an examination of all parts of the locomotive with which he may have to deal, blower, ash pan, grates, etc., and know that they are in good working order before commencement of the trip. The coal on the tender should be wet down enough to prevent the loss of the fine

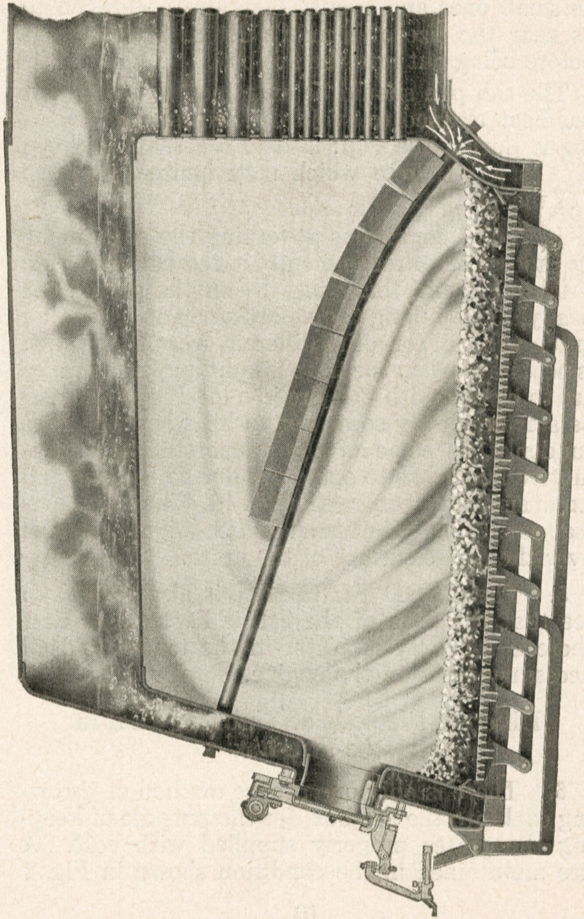

FIG. 1

Light, level fire—giving uniform air supply through fuel bed and resulting in high temperature and complete combustion Note gas mixing eff ect of arch.

coal. Large lumps do not make steam as well as small ones and should therefore be broken to as near the size of a man's fist as is consistent before being put into the fire-box.

The ash pan should be examined to see that it has been cleaned to avoid the necessity of dumping it during the trip; also to see that no green coal is left therein which may ignite and warp the sheets.

4. Local conditions governing the start make it impossible to recommend a fixed rule covering the kind of fire that must be on the grates. A heavy, hard-pulling train starting on an ascending grade will call for a fire different from that which is necessary when the train is light and easy grades are to be met with. A fire in a locomotive should be started slowly so as not to heat any one part suddenly, as some of the worst strains a locomotive boiler has to stand are due to the unequal expansion and contraction of its different parts (see par. 134). The fire should be bright and level over the entire surface of the grate.

5. The GOOD FIREMAN is also careful to see that the deck of the cab is kept clean, that there is a supply of water in the tender and all necessary tools on the engine.

Different Methods of Throwing Coal in the Fire-Box

6. There is only one proper method of throwing coal into the fire-box, for the purpose of keeping the grates properly supplied with coal. A fire maintained in the condition shown in Fig. 1

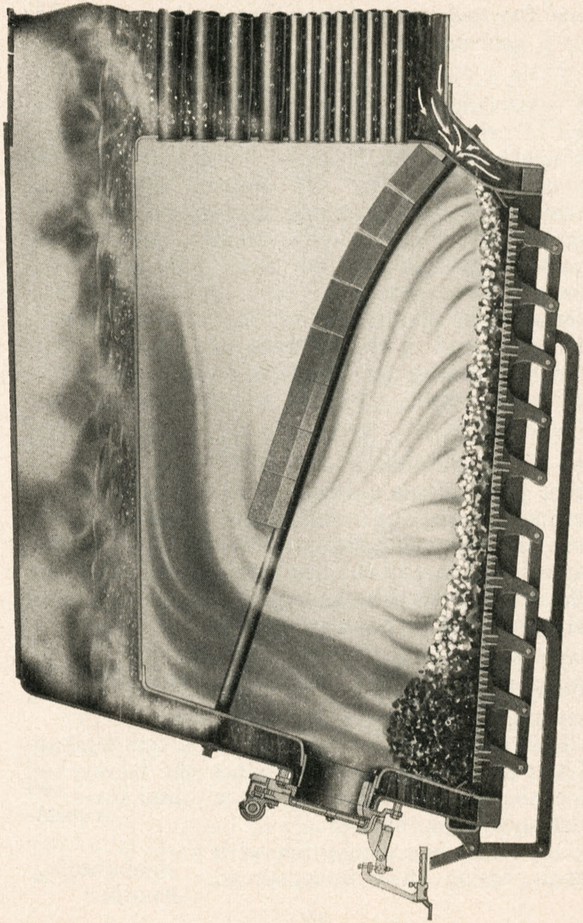

FIG. 2

Bank under fire-door reduces air supply through grates and reduces the temperature. Note large volume of hydrocarbon gases being driven off escaping partly unburned is best for steam making. It is known as the level fire and is more used than any other, and is the proper method.

7. A GOOD FIREMAN follows the practice of scattering the coal over the parts where the bed of fire is thinnest, always firing as light and as nearly level as possible, consistent with the steam requirements. Of course, the fireman must cover any thin spots that may appear. A good many of our heavier freight engines of the present time can be fired successfully with from three to five scoops of coal to the fire. The furnace door should be closed between each scoop of coal placed in the fire-box, and under no circumstances should be left wide open while placing in a fire.

8. The fire is built with a slightly heavier bed along the side sheets than there is on the other parts of the grates. This is good practice, because unless done, too much air will pass up here along the side sheets reducing the temperature of this part of the fire-box below the igniting temperature, thereby causing a waste of fuel and being responsible for cracked fire-box sheets.

9. Fig. 2 illustrates the effect of heavy firing under the door, commonly known as "the banking method."

This method of firing lowers the temperature of the fire-box at the door, since the heavy bed of coal does not allow the air required for combustion to pass through.

One result is a smoky fire with part of the fuel gases passing away unconsumed. Another is a

reduction in the evaporation of water from the fire-box heating surfaces. The evaporation around the fire-box depends almost entirely upon the temperature of the fuel bed. When a bank of green fire is carried under the door, the temperature of that part of the fuel bed is lowered, reducing the radiation from the fuel bed, and the evaporation from the heating surfaces.

It is also one of the contributing causes of clinker and "honeycomb," and it is now believed by those who have made scientific studies of "honeycombing" that a light and level fire with plenty of air through the grates will minimize the likelihood of its formation.

In order to get the greatest evaporation, it is absolutely necessary to carry a light, level fire, through which the air passes uniformly, thereby keeping all parts of it at a white heat.

10. Fig. 3 illustrates the result from firing thick on spots. The thick spot is cooler than the other parts and generates smoke until it slowly burns bright, so that the steam making capacity of the fire is greatly reduced. The man who fires in this uneven fashion always has trouble with banks in his fire, and resorts to the rake which causes clinkers to form on the grates.

11. On the ready track the fire should only be built up to raise 160 pounds of steam pressure to permit test of the injectors and air brakes. Between the ready track and the point where engine is coupled to the train the fire should be so prepared as to have maximum pressure by the time the train is to be started. This practice

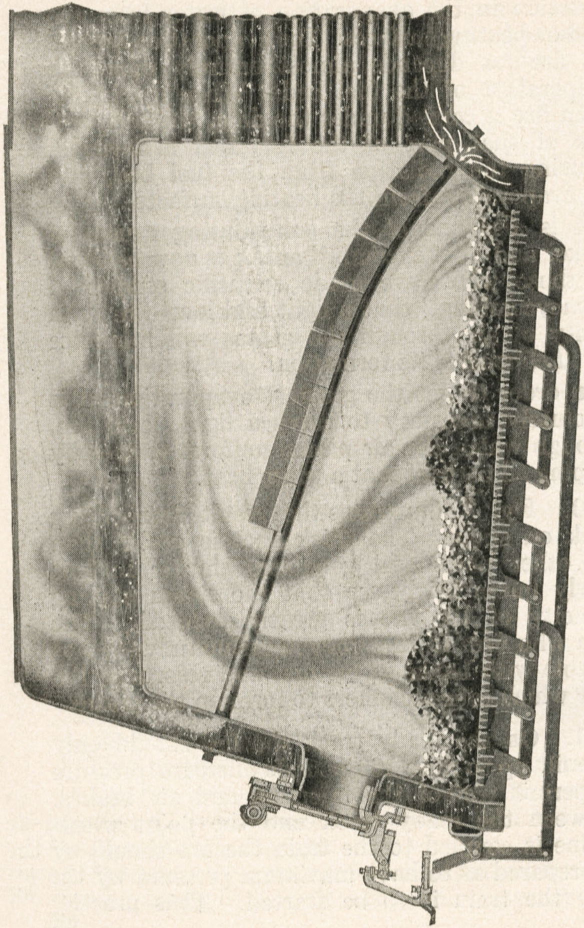

FIG. 3

Uneven firing results in bank being formed. This causes a reduction in air supply and a lowering of the temperature and fire-box evaporation. Note large volume of hydrocarbon gases being distilled off and partly mixed with other gases at the top of arch

will avoid popping of engines and waste of coal on the ready track and between the ready track and the yard.

12. The waste of steam from the pop is so obviously under the control of the engineer and fireman that it seems unnecessary to refer to it, but when it is remembered that some engineers look upon it as something of small importance evidently mention of it should be made. If engineers were aware that every time the pop valve is allowed to open unnecessarily, it is equivalent to displaying a placard with the inscription ''This engine is operated by a careless and wasteful crew,'' their attitude would be altered. At 200 pounds boiler pressure a 4 inch safety valve can discharge in a minute 210 pounds of steam which is equal to 200 pounds of water or 30 pounds of coal per minute. For various sizes of locomotives and pop valves and for various boiler pressures and strength of popping it is estimated that an average of 20 pounds of coal is lost for every minute a locomotive pop valve is blowing. The large saving, which would result if engine crews would not permit waste of steam through the pop valve, would be well worth the little care required. A little self-examination will answer the question: ''Is it worth the effort?'' for YOU!

Prevention of Smoke

13. The absence of smoke when a fire-box or furnace is at work converting water into steam is not an infallible sign that the coal or other fuel is being burned under conditions which will

produce the greatest economy, but it is fair to assume that ''smokeless firing is economical firing.''

14. Some locomotives are fired as if smoke prevention were not a possibility, and an immense waste of money results from the work of the careless fireman whose efforts are directed to converting coal into smoke. When some engineers are told that it is possible to burn bituminous coal in the fire-box of a locomotive without producing any black smoke, they look upon the statement as that of a crank or theorist and promptly reply that it cannot be done. Most men actively engaged in locomotive service have read book and pamphlet descriptions of how bituminous coal can be burned in a locomotive fire-box without causing smoke, but they regard the information as impracticable theories worked out by men who know nothing about the real work of firing locomotives.

15. Many good books published on firing have been prepared by men engaged in the OCCUPATION OF FIRING LOCOMOTIVES, and they give faithful descriptions of the methods followed by men who make the steam required with the least expenditure of coal and at the same time reduce to a minimum the emission of black smoke from the stack.

What is Necessary for the Prevention of Smoke

16. A thin, clean fire should be maintained, so that the fuel can be supplied with sufficient air through the grates for proper combustion, and

the production of a clear, bright flame. Cross-firing should be practiced to maintain an even bed, free from holes. Coal should be scattered first over front grates, gradually working back to the rear grates, in order to permit as clear a view of the fire bed as possible. Heavy firing should be avoided, as the latter method does not permit sufficient air to pass through the fuel and results in dense black smoke and clinkers. The use of the rake should be resorted to only when absolutely necessary to spread an uneven fire caused by improper firing.

17. The grates must be kept clean, in good working order, and well supplied with coal at the sides, ends and corners of the fire-box, and not more than two or three scoops of coal should be applied at any one time, in a narrow fire-box, scattering the coal. The same operation is successful in the prevention of smoke on the larger class of freight engines, only that the number of scoops to the fire is increased to from three to five according to the work being performed.

18. Air admitted above the fire is effective in preventing smoke, and if the fire-door is left ajar about an inch or two for a few seconds after each scoop of coal, the smoke will disappear from the stack when the current of fresh air is drawn into the fire-box.

19. For cleanly as well as economical reasons, engines are not permitted to emit smoke while about stations and depots and should be prevented from doing so by leaving the fire-door ''cracked'' and using the blower slightly, or if the engine is working, by light and careful firing.

Smoke trailing back from the engine on either freight or passenger trains, is very objectionable and will not be permitted. On freight trains it obscures the vision of the trainmen, and on passenger trains it enters the coaches through the ventilators and open windows.

The Good Fireman

20. All men will not make first-class firemen but with attention to the instructions of supervising officers and of the engineer, application to work and a study of this booklet "GOOD FIRING," any able bodied, intelligent man will become a good fireman.

21. When the train is ready to start, the good fireman has 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, and he then maintains the fire in a condition to suit the work the engine has to do. With heavy freight trains this firing is made sufficient so that the door does not have to be opened until the tremendous exertion of starting is over. 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 be throwing a heavy charge of fresh coal into the fire-box at one time. This system of steady firing keeps the temperature of the boiler more uniform, and has the double benefit of being easy on the boiler and using coal to the best advantage. It is only by concentrated attention to the work to be done that a fireman can perform it in a first-class manner.

22. From various causes the fire does not burn evenly all over the grate surface, but thins rapidly in spots. The good fireman, upon glancing into the fire-box, knows where these spots are and loses no time in filling them. The fire is maintained nearly level; but the coal is supplied so that the sides and corners are just a little heavier than other portions of the fire-box, for there the likelihood of drawing in excess air is greatest.

Avoid Rapid Firing

23. Like heavy firing, rapid firing is wrong, and for the same reason. A much easier and more economical way is to commence in time and put in the "fire" in a LEISURELY manner, allowing the door to remain closed between each shovelful, for the fresh coal to start burning and for the furnace to regain its temperature. When the time for replenishing the fire arrives, the good fireman knows either from instructions or by observation that the effect of throwing a fresh charge of coal into the burning mass is similar to that of pouring a dipperful of cold water into a boiling kettle. A small quantity of cold water does not check the boiling of a kettle much, just as one or two shovelfuls of coal are little felt on the fire of a big locomotive; so the good fireman throws in only two or three scoops at a time, is quite deliberate in applying each charge, scattering it over the surface of the burning mass along the sides of the fire-box and corners so that each portion of fresh supply quickly gives up its hydocarbon gases and becomes a vital addition to the bed of incandescent fuel.

Shaking the Grates

24. Should indications appear that the fire is not receiving sufficient air, the good fireman lightly shakes the grates, an operation which is repeated during the trip at intervals sufficient to keep the fire as clean as possible. Rocking grates must be shaken *lightly* and more frequently instead of violently at long, intermittent periods. Grates should not be shaken while using steam unless it is necessary. When the engine is working steam hard, grates should not be shaken nor should the hook be used to an extent that would disturb the fire bed and allow the draft to draw the particles of unburned fuel and ash over the arch onto the flue head, which would result in the formation of honeycomb on the flue head and stoppage of the flues. Ordinarily coal requires no more grate-shaking than that which 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 only when required, and this shaking should be done by short, quick jerks. This will allow the dead ashes to fall into the ash pan and keep the grates and fire clean.

At Stopping Points

25. When approaching a stopping place, the good fireman takes care to have sufficient fuel in the fire-box so that he will not have to begin firing until after the start is made. The firing should be stopped long enough before steam is shut off to prevent smoke and the waste of coal,

and when making station stops the fire should be in such condition that more coal need not be added until after the start is made. It is a bad practice to commence firing as soon as the throttle is opened, because the deadening effect of the fresh coal, together with the use of large quantities of steam and a sudden circulation of cooler water in the boiler, will cause quite a reduction in the steam pressure. Firing just as a train is starting out of a station is not good practice for another reason—at that time the fireman ought to be looking out for signals.

The Poor Fireman

26. Failure to perform properly the necessary work at the beginning of a trip greatly increases the fireman's labors before the trip is finished, yet he will often repeat the same performance the next time. Practicing the best methods until they become habits is the easiest way to increase one's efficiency, or in other words, to reduce his labor.

27. When called to go out on a run, the poor fireman reaches the locomotive just as it is time to start for the train. He places some coal into the fire-box, sweeps the cab and waters the coal as the locomotive 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 throws in a heavy charge 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 opens the

door and adds eight or ten scoops of coal to the fire; then climbs up on the seat and waits for the black smoke to cease as the signal to get down and repeat the operation.

28. Finding that the engine is not steaming freely under this treatment, he gets down reluctantly and tears up the fire by the violent use of the hook and grate shaking lever. No act marks the poor fireman so strongly as his method of using the hook and shaking the grates. He does the work so violently and frequently that a great deal of fuel is wasted. The fire is badly disturbed, and unless it is very heavy, holes are made which admit cold air.

29. 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 with which to unite and without becoming sufficiently heated to ignite with the volatile compounds distilling from the piles. The product is worthless smoke. Each mound is the protection for the formation of a clinker, which grows so rapidly that the shaking bar has to be frequently used.

Draft

30. Dratt in a locomotive boiler is produced by the exhaust steam from the cylinders passing through the exhaust pipe and smoke stack. This action removes a certain amount of the gases and smoke (either burned or unburned) from the smoke-box at each stroke of the engine, creating a partial vacuum in the smoke-box which the air pressure on the outside fills by

passing through the grates, fire and tubes. This flow of air to fill the partial vacuum in the smoke box furnishes the oxygen necessary to support combustion in the fire-box.

Draft Appliances

31. What are known as the draft appliances of a locomotive include the ash pan, the grates, the appliances inside the smoke-box and the smoke-stack. The ash pan and grates ought to be so constructed that the air will pass to the fire with as little obstruction as possible, permitting fire gases to pass uniformly through the different rows of tubes. It is to regulate this flow of gases through the tubes that a lift pipe or diaphragm is placed in the smoke-box. Without this the tendency of the unrestrained gases is to pass through the upper rows of tubes losing the use for heating surface of the lower tubes, and permitting them to choke up with cinders and soot.

Effect of Small Nozzle

32 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 steam better when a heavy fire is carried. This condition is nearly always due to the use of very small nozzles which make the blast so sharp that a thin fire cannot be used, as the strong rush of air will tear holes in places through which it can pass directly into the flues. When engines do 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.

33. With the average coal, an engine will steam better while using a large nozzle. Small nozzles are also objectionable because they prevent the exhaust steam from escaping freely out of the cylinders, and the piston working against back pressure, reduces the amount of useful work it is capable of doing.

Good Judgment

34. Although a man may become a good and skillful fireman without any scientific knowledge, there is one attribute which he must develop or he will succeed only witb difficulty, and that is GOOD JUDGMENT. Good judgment is a locomotive fireman's second important need. Good judgment is an aid to success in every calling, but it seems essential for a fireman, because he must depend to so large an extent upon his own resources after learning how the coal ought to be supplied to a fire-box.

35. In the course of a run over any division, a locomotive pulling a heavy train has to meet so many varying conditions in the demand for steam, that the successful fireman must exercise good judgment to have his fire just right for the demand to be put upon it.

Study and Promotion

36. All those accepting employment in locomotive service and who intend to make the work of railroading their vocation, should study and understand the principles and best practices of

locomotive firing, as this knowledge is a necessary acquirement of a good locomotive fireman and ultimately of a good engineer. The vast amount of literature regarding locomotive engineering which has been written during the past few years and placed upon the market, makes an education along these lines within easy reach of all.

37. Firemen desiring to make their work as easy as possible, especially those desiring promotion, should try to cultivate and give early evidence of the possession of this necessary acquirement of a good engineer.

SCIENTIFIC THEORY OF GOOD FIRING

Chemistry of Combustion

38. While it is not necessary that an engineer or fireman should be thoroughly familiar with the chemistry of combustion in order to attain a high standard of efficiency, yet if any man would combine a knowledge of the theoretical part of any subject with the practical, he is bound to get better results than he would with the theoretical alone or practical alone. If he can know when he throws a shovelful of coal into the firebox what takes place from the time the coal strikes the bed of fire until the results from it are indicated by the pointer on the steam gauge, surely he can come nearer complying with the conditions necessary for better results than can be obtained in the absence of that knowledge.

39. Chemically, everything in the world and about us comes under one of two great heads or divisions of matter, called ELEMENTS and COMPOUNDS.

40. An ELEMENT is a substance that cannot be decomposed or broken up into separate substances by any known means. Some of the more common elements are oxygen, hydrogen, nitrogen, carbon, sulpur, tin, lead, iron, copper, zinc, gold, silver, etc. Of these the first four are the chief constituents of air, water, coal and wood and are the ones that will be here considered.

41. A COMPOUND is formed by the chemical combination of two or more elements and therefore can always be decomposed into separate substances or elements. Examples of compounds are water, wood, salt, lime, etc.

42. Another class of substances are called MIXTURES. The difference between a MIXTURE and a COMPOUND is that a compound is formed by the chemical combination, while the mixture is simply mixed together mechanically two or more elements or compounds. Air is a mixture, not a compound, for the reason that the two elements, oxygen and nitrogen, are not chemically combined. Coal is a mixture of several compounds and elements.

Air

43. The atmosphere consists of a gas called AIR, that completely surrounds the earth to an estimated height of about 50 miles. It is held in place by gravity. The weight of the atmosphere is such that it exerts a pressure of 14.7 pounds per square inch at sea level. This pressure is sufficient to force the air into all crevices and porous substances, so that it penetrates the earth to a considerable depth, its density increasing with the depth. Air is the most familiar mixture with which we deal. It is composed of two elements, *i. e.*, OXYGEN and NITROGEN.

Oxygen

44. Oxygen is one of the principal parts of the air, although not the largest, forming only about

one-fifth of it by volume. Nitrogen is the other and forms about four-fifths of it. When any other element for which oxygen has a liking or affinity is surrounded by the air, the oxygen will leave the nitrogen and chemically combine with the other element. If this combination takes place slowly without rise in temperature, it is called slow oxidation or rusting. If it is rapid and generates heat or light, this chemical action is called COMBUSTION.

Nitrogen

45. Nitrogen, which forms about four-fifths of the atmospheric air, plays no active part in combustion. It is not chemically combined with oxygen, but only mixed with it mechanically, so it is easily separated.

It acts as a diluent in the air, and renders burning less active than it would be in oxygen alone. It is well that it does; for in an atmosphere of pure oxygen, combustion would be so rapid and temperatures would be so high that it would be impossible to maintain a fire-box, and grates would burn up almost as readily as our fuel.

The nitrogen in the air absorbs heat from the fire; and in passing through the flues gives up a large part of its heat in the same manner as the gases of combustion.

Elements that Make up a Fire

46. The nature of fuel, the composition of the air that fans the fire, 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 known in studying the laws of chemistry relating to combustion.

Carbon

47. Carbon is the chief constituent of coal. It forms the larger part of the solid portion which remains on the grate after the volatile matter has been driven off; and also forms part of the volatile matter.

In the volatile matter, it is in combination with hydrogen in different proportions, forming a series of what are known as hydro-carbons. Under the influence of heat, these hydro-carbons are driven off in the form of gas, and as they are very inflammable, burn readily when mixed with oxygen. If mixed with large quantities of air, these inflammable gases are completely burned with a transparent blue flame, producing carbonic acid and steam. When raised to approximately a red heat before being mixed with sufficient quanity of air for perfect combustion, they disengage the carbon in fine powder, and the higher the temperature, the greater is the proportion of carbon thus disengaged. This disengaged carbon maintained at a red or greater heat gives the inflammable gas the red, yellow or white flame. If, however, the carbon is maintained at the temperature of ignition and supplied with sufficient air, it burns while floating in the gas. On the other hand if this disengaged carbon is cooled below the temperature of ignition before coming iu contact with oxygen, it constitutes, while floating in the gas, smoke; and when coming in contact with cold surfaces, deposits on them and gradually builds up an insulating layer of soot.

Hydrogen

48. The most of the hydrogen contained in coal exists in combination with carbon, forming the hydro-carbon series. A part of the hydrogen also exists in combination with oxygen in the proportion to form water, which part adds nothing to the heat value of the coal. There is very little hydrogen contained in coal, but the heat value of hydrogen is very high—about 62,100 heat units per pound.

Composition of Fuel

49. The heat value of fuel depends upon the fixed carbon and upon the volatile matter of an inflammable nature it contains. Following is a table giving the principal constituents of the leading coals burned in the United States, also the number of heat units that ought to be generated for each pound of coal burned. The quantity of water evaporated from tank temperature to boiler pressure varies from 4 to 10 pounds per pound of coal:

Anthracite	Average Fixed Carbon	Volatile Matter	Average Heat Units Per Pound
Average of 4 districts	83.77	3.86	13,160
Semi-Bituminous			
Average of 6 districts in Pennsylvania and West Virginia	73.75	18.15	14,673
Pocahontas	74.39	21.00	15,070
Bituminous			
Average in 18 districts in Pennsylvania, Ohio, West Virginia, Kentucky, Tennessee, Illinois	52.25	34.75	13,000
Highest of above	60.99	35.65	14,450
Lowest of above	37.10	32.53	10,490
Illinois Bituminous			
37 districts	48.02	35.58	12,210

The remainder of the percentage is made up of ash moisture and sulphur.

Burning

50. "Burning," as it is popularly called, is a very rapid combination of oxygen of the air with any combustible material, producing both heat and light. Oxygen has a strong affinity for most elements, and especially for carbon, with which it combines very rapidly whenever they come in contact with each other at a sufficiently high temperature. The more rapid the combination, the greater the quantity of heat given off in a unit of time, and, consequently, the higher the temperature produced.

51. The combustible substances in coal are CARBON and HYDROGEN. The combustion of fuel, therefore, **is the rapid chemical combination**

of the carbon and hydrogen in the fuel with the oxygen of the air. Carbon combines with oxygen in two proportions, forming distinct substances having different chemical properties. One atom of carbon may combine with two atoms of oxygen and form CARBON-DIOXIDE, represented by the formula CO_2; or, one atom of carbon may combine with but one atom of oxygen and form CARBON-MONOXIDE, whose formula is CO. When carbon and oxygen combine to form carbon-dioxide, COMPLETE COMBUSTION is said to have been procured. When it combines with oxygen and forms carbon-monoxide, there is said to be INCOMPLETE COMBUSTION.

52. Carbon-dioxide is formed when carbon is burned in a sufficient supply of air, that is, when the oxygen is present in such quantities that each atom of carbon can have two atoms of oxygen with which to combine. Carbon-monoxide is formed by burning in an insufficient supply of air. (See paragraph 62.)

53. When green coal is heated, the hydrocarbon gases are driven off. This action begins with a temperature of about 300°F.; and most of the gases are driven off when a temperature of 1100°F. is reached. On issuing from the coal, the gases readily ignite if a supply of oxygen is available, at a temperature of 1100°F or higher.

The hydro-carbon gas, methane (CH_4), is the one generally present in the largest quantity; and is the one responsible for the ignition of the coal. In the presence of sufficient oxygen, the

hydrogen burns, forming water; and giving off 62,100 heat units per pound of hydrogen burned.

The carbon is set free, and floating in the gas, at a high temperature, gives the flame its bright, luminous color. If sufficient oxygen is present, the fine particles of carbon are burned completely to carbon-dioxide. If there is not sufficient oxygen available, fine particles of carbon escape through the stack, causing smoke; or, coming in contact with the comparatively cold heating surfaces, they deposit on them and gradually build up an insulating layer of soot.

This hydro-carbon, methane (CH_4), has a heat value of 23,850 B. T. U. To burn it completely requires 17⅛ pounds of air per pound of gas; or 9⅓ cubic feet of air per cubic foot of gas.

As this hydro-carbon is distilled from green coals thrown in on top of the fire, it is very evident that in order to burn it successfully, a supply of oxygen above the fire is absolutely necessary. On account of the high heat value of this gas, the escape of even a small portion of it, unburned, means quite a fuel loss, and also is the reason why some volatile coals, even with a high percentage of ash, have a higher heat value than the burning of pure carbon.

This is another important reason why a light, level fire should be carried at all times—in order that sufficient air may pass up through it, to completely burn the hydro-carbon gases; and is another good reason why "the banking method" of firing should not be used—since placing a bank of green coal across the back end of the fire-box will cause a large volume of these gases to be driven off at one time, and in such a manner as to prohibit their mixing intimately with the ogygen that might be available, and being burned before they escape from the fire-box.

When the fresh coal is scattered uniformly over the level fire, the gases are distilled off uniformly, and have a much better chance of coming in contact with the oxygen required for combustion.

Air Required for Complete Combustion

54. The proper supply of air to the fire is one of the most important factors connected with economical firing. It takes about 250 cubic feet of air to supply the oxygen for the complete burning of one pound of ordinary soft coal, and as one shovelful of coal weighs about 15 pounds, it will take 3,750 cubic feet of air to supply the oxygen necessary for its complete combustion, for every particle of carbon and hydrogen must be embraced by a liberal supply of oxygen to get results. An ordinary box car contains about 2,300 cubic feet, which will give you some idea of the vast amount of air that must pass through the fire-box for proper combustion. As this supply of air comes into the fire-box when the door is shut, at a uniform rate, it may be readily seen that the coal should be supplied at a uniform rate. If the coal is supplied faster than the proper amount of air can get to it, the fire will cool off instead of getting hotter.

55. In addition to having the air and gases above the fire at the proper temperature, they must be mixed. Oxygen and hydrogen combine

during combustion in only one proportion, that is, two volumes of hydrogen and one of oxygen, and this combination gives an intense heat, over four times as hot as the same amount of carbon will make. Oxygen and carbon can combine in either of two proportions during combustion. If there is sufficient oxygen present where it can touch the carbon, one part of carbon will combine with two parts of oxygen and make an intense heat; if the supply of oxygen is not sufficient, the oxygen and carbon will combine in another proportion, one part of each, and makes less heat. It is very important that we understand that the amount of oxygen, or air supply, determines, in a manner, the amount of heat that will be produced. Oxygen is free to us; it costs us nothing excepting the work of drawing it into the fire, therefore it should be used in the best proportions.

56. There is another point to be mentioned in relation to the hydro-carbon gases, and that is, being a compound they must be decomposed or split up into their elements of free carbon and hydrogen before the oxygen will combine with either of them. The temperature at which they will separate is 1100° F., and unless this temperature is maintained, the volatile matter in the coal will not be burned.

Igniting Temperature

57. Oxygen does not combine with many substances at ordinary temperatures to produce combustion. Usually, before it will combine, the temperature of the substance must be raised to a certain degree, which varies for different

substances. Some substances require but a slight increase in temperature before they will combine with oxygen, while others require heating to a very high temperature. Phosphorus, for example, combines with oxygen at a temperature of only 150° F.; sulphur at 500° F.; wood at about 1000° F., and coal at about 1200° F. While the temperature at which substances combine with oxygen differ, yet it is always the same for the same substance; that is, a given substance always combines with oxygen at a certain temperature, called its IGNITING TEMPERATURE. In all commercial fuels, the igniting temperature is lower than the temperature produced by the combustion of the fuel.

Effect of a Shovelful of Coal in the Fire-Box

38. Since the tearing-down process absorbs heat from the fire-box, it is evident that the introduction into the fire-box of any compound which requires this tearing-down process will result in reduction of fire-box temperature.

Water is such a compound. When a pound of hydrogen burns, it combines with 8 pounds of oxygen and forms 9 pounds of water; and generate 62,100 heat units.

If this 9 pounds of water is introduced into the fire-box, either as self-contained moisture in the coal or as water sprinkled on the coal, it is broken down in the presence of the highly heated carbon, and absorbs 62,100 heat units—or the same amount of heat produced when the water was originally formed.

When this breaking-down process takes place in the presence of highly heated carbon, the oxygen combines with the carbon to form carbon monoxide (CO), while the hydrogen is set free.

If these gases are again brought into contact with a sufficient quantity of oxygen, at a high enough temperature, the (CO) burns to carbon dioxide (CO_2), and the hydrogen unites with oxygen to form water.

These two reactions give off heat equal in amount to that absorbed when the water was broken down. However, the water so formed passes out the stack as superheated steam, carrying with it an appreciable amount of heat, which is wasted.

At a front end temperature of 600° F., every pound of water escaping carries with it about 1300 heat units; or, a gallon of water so escaping will carry away about 11,000 heat units—or as much as is contained in a pound of many of our commercial coals.

It is evident that care should be used as to the quantity of water that we place in the fire-box. While it is necessary at times to sprinkle down the coal on the tender—in order to reduce the loss of fine coal passing out the fire-box unconsumed, as well as for the comfort of the engine crew—there is a point at which the loss due to the water on the coal will more than counterbalance the loss due to the escape of fine particles of coal unconsumed.

59. When fresh coal is placed in the fire, it begins to absorb heat at once, which reduces the

amount of heat available for making steam. This fresh coal must be heated up to between 300° F., and 400° F., before the hydro-carbon gases begin to pass off as they are roasted out of the coal. The fixed carbon left begins to burn at 1200° F. If the supply of air is just sufficient for the fixed carbon and combines with it on the grates first, the gases that are roasted out of the coal will have no air for their share and will pass away without burning.

60. A temperature lower than 1200° F. in the fire-box will waste the gases, and as they form about 30% of the coal and a much larger percentage of its heating value, it will be seen that when a fresh charge of coal cools the fire-box temperature below the igniting temperature of the gases, that about one-half of the heat value of the coal is wasted. This is one of the reasons when the steam pressure drops when a heavy charge of coal is placed in the fire-box; it is also the reason why so much smoke passes away from a heavy fire. The fire-box temperature has been reduced by the loss of heat going into the fresh coal, so that it does not leave enough to ignite the hydro-carbons being expelled from the fresh coal. In addition, a heavy charge of green coal causes a large volume of hydro-carbon gases to be driven off, with an insufficient supply of oxygen available for combustion. The result is a dense volume of black smoke, high heat loss and drop in steam pressure.

61. One or two scoops of coal at a time will not reduce the temperature of the fire-box below the igniting point and will produce some heat in

a few seconds to be ready to warm up the next charge. A high fire-box temperature is absolutely necessary to promote a complete combustion of the bases; as soon as the temperature drops below their igniting point, the fixed carbon on the grates must alone be depended upon to produce the heat, while the hydro-carbon gases pass out of the stack unconsumed.

62. The most difficult part of the chemistry of combustion for the fireman to understand is that carbon and oxygen can combine in one proportion and produce heat, while the combination in another proportion will produce not quite one-third as much heat. Heat is measured by the effect it has on a certain quantity of water. A heat unit is the amount of heat necessary to raise the temperature of one pound of water at 39° F. up to 40° F., or one degree higher. When it is understood how heat units are measured, it is easier to understand how it may be determined that a pound of carbon contains a certain number of heat units. When sufficient air passes through the grates to give the burning carbon all the oxygen needed, each pound of carbon will produce 14,500 units of heat and will, of course, raise the temperature of the water correspondingly high; to do this takes two portions of oxygen and one of carbon. But if the supply of air is restricted so that the burning carbon does not get the necessary full supply of oxygen, it will combine in another proportion, one of carbon and one of oxygen. In the first instance, one part of carbon combines with two parts of oxygen and forms carbon-dioxide, which produces a

greater amount of heat—14,500 heat units—sufficient to convert 15 pounds of water into steam; and in the second instance, when one part of carbon combines with only one part of oxygen, instead of two, it forms carbon-monoxide, and gives off only 4,500 heat units, or just enough to convert 4¾ pounds of water into steam—less than one-third as much as when all the oxygen needed is supplied. When only half the necessary amount of oxygen is supplied less than one-third (⅓) of the work is done that would be possible with the full amount of oxygen supplied. In each case the same amount of coal will be used, but on account of the limited supply of oxygen, and the imperfect burning, less than one-third the proper amount of water will be turned into steam and steam is what is wanted. At the same time by having incomplete combustion, the carbon from the hydro-carbons (see paragraph 53) will cause an excessive amount of smoke, and smoke is not wanted.

NOW, DO YOU UNDERSTAND THE REASON FOR LIGHT, BRIGHT, LEVEL FIRING?

Instructions to Engineers

63. The instructions thus far have been devoted almost exclusively to firemen, but the engineer, who uses the finished or manufactured product, can, by close cooperation with and intelligent direction of the fireman, make it possible to obtain the best results, so he is an important factor in any scheme of fuel economy and elimination of the black smoke.

64. The engineer is in charge of the locomotive. *His instructions must be followed, for he is responsible for the economical use of fuel and other supplies used on the locomotive.* He will give suggestions to the fireman, based on his experience, and which, in his opinion, will produce the best results.

65. A large proportion of a good coal record can always be traced to the engineer, who, by intelligent interest in performing his duties, accomplishes smooth, steady running. On the contrary, if the engineer takes but little interest the fireman will soon be compelled to take things as they are and may be blamed for the lack of skill and carelessness of the engineer. This is especially important when an estimate is made of the saving that would be realized were each engine crew to save, say, twenty-five dollars monthly, or $300 yearly (which it is thought can easily be done), on an annual expenditure of about $4,200 per year, for the coal used by each engine crew.

Important Knowledge about Locomotives.

66. While the successful engineer does not entirely depend upon fuel saving to determine his value to the company employing him, yet fuel saving is considered one of his most important duties. The question of taking care of his engine, making proper inspection, both on line of road and at terminals, also seeing that suitable and intelligent reports of work needed on the locomotive are properly made on arrival at final terminal, are quite important and cannot be neglected.

67. Standing instructions provide that water gauge and column must be blown out and gauge cocks tried before each trip on a locomotive. It is particularly important that this be done and that it be repeated frequently on line of road with careful notice of the time it takes for the water to rise in the glass to the point at which it stood before the drain cock was opened. The gauge cocks should be tried frequently to be sure that the water glass and gauge cocks are functioning properly.

68. The most economical method of feeding the boiler is to leave the injector on continuously or as nearly so as possible and adjust the feed according to the conditions of the run.

69. Careful attention must be given to the use of the injector and the height of water level in the boiler. The proper handling of the injector is a very important matter in fuel economy. The best fireman cannot make a showing if the engineer does not carry his water at a steady uniform height in the boiler.

70. No one is qualified to operate a locomotive who does not know in advance what should be done and how to do it quickly, in every emergency in train service, because in case of accident or mishap there is not time to study up situations and remedies. Every engineer should be able to act instantly and should be familiar with the best methods of meeting any situation. He should studiously avoid the necessity of wiring the Road Foreman of Engines, Master Mechanic or Superintendent for information that he ought obviously to be posted about and able to act

upon without delay. However, he should ask for instructions whenever he feels he is not thoroughly conversant with the situation.

71. When an engineer does not know in advance what engine he is to run (when the locomotives are pooled), he should, upon taking charge, exercise special care to see that his locomotive is provided with the necessary tools and appliances.

72. Leaks have a very detrimental influence on fuel economy and should be stopped. Leaking valves, cylinder packing, piston rod and valve stem packing, flues, staybolts, etc., will receive prompt repairs when properly reported by the engineer upon arrival at the terminal.

73. Another matter which is not given the careful consideration and attention by many engineers that it deserves is the matter of slipping the driving wheels of the locomotive when starting a heavy train. Not only is this practice very hard on the machinery of the locomotive and on the rails, but it causes a waste of fuel by throwing unburned coal from the stack on account of the violent exhaust, and by the waste of steam, from which no useful work is derived. In addition to the above, the fire is badly torn up and disturbed and holes are often formed which require the fireman to throw in fresh fuel at the very time the doors should be closed. Also the adhesion of the driving wheels is very much reduced, so that the engine cannot possibly start as heavy a train when the wheels are allowed to slip as it can when care is exercised by the engineer to prevent the wheels from slipping.

74. Avoid dropping sand on the rails when the wheels are slipping, without first shutting off the throttle. The strain put on the machinery by the sudden grip of the wheel on the rail is very severe and is apt to twist the crank pins and tear off the rods, for all the strain comes from the wheel that first catches the sand. It is a good practice to drop sand on the rails while making a stop, in order that the start may be made without slipping. On engines equipped with rail washers, they are to be used enough to clean the rails at all times while the engine is in motion when hauling a train except when using the brake to make final stops and through interlocking plants in freezing weather.

Fuel Standards

75. A record is kept of the coal used on every trip by each engine. This amount is then placed on the engineer's and fireman's fuel record. A standard amount of fuel for every run and type of power has been determined from average amounts used. At the end of each month the total of actual and total of standard amounts are added and the total standard divided by the total actual amount. This figure will represent the fuel performance of the engineer or of the fireman. These fuel performance records will be posted on bulletins and copies retained and will be considered when men are proposed for promotion.

Instructions for the Operation of Superheater Locomotives

76. In general the same operating practice approved for saturated locomotives holds good

for superheater locomotives. The superheater is merely a series of steam tubes located in the large flues in order to deliver hotter steam to the cylinders. The fact that a superheater engine uses hotter steam in the cylinders than a saturated steam locomotive is the only essential difference between the two. The best economy of steam and coal will be obtained when the locomotive is worked with full throttle where conditions require and the speed regulated by changing the reserve lever until a cut-off of about 30 per cent. is reached, provided that the cut-off should not under any conditions be shortened enough to result in excessive compression, causing the rods and boxes to pound and the engine to ride hard. Any reduction in speed after that proper operating cut-off has been reached should be made by reducing the throttle opening. In drifting down grade or in slowing down for a stop, enough steam must be admitted to the cylinders to prevent air and smoke-box gases from being drawn into the cylinders to destroy the lubrication. This should be done by cracking the throttle when drifting or by the use of the drifting valve.

77. In the operation of a superheater locomotive, the following suggestions should be carried out:

(a) The lubricator should be started at least fifteen minutes before moving locomotive 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 the superheater locomotive, due to the higher temperature of the cylinder walls, requires more careful lubrication than a saturated engine.

(b) Move engine from ready tracks by use of the drifting valve, supplemented by the use of the throttle when necessary, in order that the engine may be moved slowly, allowing condensation to work out of superheater and cylinders before throttle is opened. Trains should be started with the drifting valve when possible. The throttle should not be used to start unless it is found that the drifting valve will not start the train.

(c) Start engine carefully with cylinder cocks open until dry steam appears. In starting the reverse lever should be in full gear to insure oil distribution the full length of the valve bushings.

(d) Keep water level as low as in saturated steam locomotives. Actual tests with a pyrometer show that the temperature is 40° higher with two gauges of water than with three.

(e) The man who carries the boiler on a superheater locomotive full of water is using the superheater units for a boiler to boil water and not to superheat steam; therefore the engine will not steam as well, as these superheater units with proper operation add 25% greater capacity to be boiler.

(f) Do not close the throttle entirely on a superheater locomotive; leave the throttle cracked enough to keep steam in the steam chests and cylinders while drifting unless

equipped with a drifting valve. If the engine is equipped with a drifting valve it should be kept open while the engine is running to prevent fouling and carbonizing the cylinders in case it is necessary for any reason to close the throttle quickly. This will also prevent damage to cylinder packing. Keep the drifting valve open from the time the engine starts until 100 feet from stop, in order to avoid the accumulation of condensation in the drifting feature pipe between the superheater header and the drifting feature operating valve. Otherwise if this valve is opened suddenly it will cause a sudden flow of water through the units, which will cause the units to leak and will destroy lubrication. Also be sure the reverse lever is dropped as far down as necessary while drifting.

(g) Do not put engine oil on the pistons of a superheater locomotive.

(h) 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 stem 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 engineer, because if neglected, they seriously affect the economical operation of the locomotve.

(i) In order to get the highest temperature, most steam, stronger and quicker locomotive, all-around higher efficiency, burn less coal and use less water, keep the water level as low as possible and fire according to the correct principles of firing illustrated in the forepart of this book.

Operation of Corner (Muffler) Blow-off Cock

78. On engines equipped with the back corner (muffler) blow-off cock it will be opened when passing over each wooden structure where sparks might start fire, regardless of weather conditions, and also at any point where ties are seen to be on fire. Under ordinary conditions the muffler blow-off cock will be opened not less than 15 seconds in every 15 minutes that the engine is in motion and more than this if necessary, to overcome foaming conditions. Due to the various qualities of water and the differences in water treatment on different divisions, the blowing down of boilers will be handled in accordance with local instructions.

Operation of Flue Blower

79. Full boiler capacity can only be secured by keeping flues clean. Soot is an effective insulator; $\frac{1}{5}$ inch reduces heat transmission as much as 1 inch of asbestos.

The flue blower, operated while the locomotive is in service—

(a) Keeps flues clean.
(b) Saves and keeps arch in good condition.
(c) Keeps superheater units clean and reduces chances of their burning or warping.

(d) Saves fuel.
(e) Makes a better steaming engine.
(f) Lessens labor of the enginemen.

On locomotives equipped with the "Superior Flue Blower" the following instructions will govern the handling and operation of the Flue Blowers:

The blowers should be used wide open, one set at a time, for fully two minutes while getting your engine ready for the trip. This should be done as soon as possible after the boiler pressure reaches its maximum. (This cleans out all soot accumulated during the firing of the engine in the engine house.)

During the run, when the throttle is shut off or the drifting throttle is used, each blower should be operated not less than two minutes. Best results are obtained if this is done AFTER maximum firebox temperature is reduced to a point somewhere near that of the boiler. (Keep in mind the fact that when the engine is working hard, any accumulation on the flue sheet is heated to the extremely high temperature maintained in the firebox, therefore, it is almost impossible to dislodge it; but when throttle is closed, the firebox temperature lowers very quickly, and the lower the firebox temperature, the better are the results obtained.)

Use the blowers wide open, two minutes on each side, approaching the yard at the end of the trip. (This will assure a clean combustion chamber for the proper firebox inspection by the engine-house forces.)

The stack blowers MUST be kept wide open during the full operation of the flue blowers.

Heavy honeycomb, gradually closing the tube openings, causes the engine to lag in steam pressure, and possibly fail; therefore, prevent heavy formation by the use of the Flue Blowers at frequent intervals BEFORE formation becomes heavy. Begin early on the trip and use it as outlined above.

Brick Arches

80. Since most of our engines are now equipped with brick arches, it is well to consider the functions of this device. Its advantages are well understood by all engineers—but just how it affects these advantages is not so well understood.

81. The brick arch is interposed as a barrier between the fuel bed and the flues, thereby forming a combustion chamber. On the Baltimore and Ohio the arch is run solid against the flue sheet to prevent any short circuiting of the gases from the front of the fire into the lower flues and compelling all of the gases to pass around back of and over the arch before entering the flues.

82. As is clearly indicated in Fig. 1, this forcing of all the gases to pass through the restricted opening above the arch causes an intimate mixture of the various combustible gases with the oxygen that might be present, and tends to promote combustion and to prevent the escape of any combustible matter into the flues unconsumed.

83. The arch also acts as a baffle, and holds the fine particles of coal and coal-dust in the

fire-box until they can be burned—thereby reducing the losses due to sparks and cinders. The heat loss from this source is very high, amounting to as much as 25% on stoker-fired engines, where fine Run of Mine coal or screenings are used.

84. Tests on hand-fired engines indicate that the arch will effect a saving of more than 40% on the cinder loss alone. On stoker-fired engines the saving will be greater, due to the grade of coal used; but will be governed to some extent by the length of the arch—the long arch being more efficient than the shorter one.

85. The arch increases the fire-box temperature and maintains it at a more constant level, thereby increasing the evaporation from the fire-box heating surfaces and protecting the flues. By making all the flames pass back and over the arch, the flame-way is increased, the radiating surfaces are increased and the evaporation from the fire-box is increased.

86. The statement is sometimes made that the arch causes honeycombing on the flue sheet. This is erroneous. There is nothing used in the composition of the fire-brick that will cause slag or honeycomb; in fact, the arch tends to decrease the honeycomb on the flue sheet.

87. Perhaps the most important function that the arch performs is the intimate mixing of the gases. As shown in Fig. 2, the ill effects of "bank firing" under the doors are partly neutralized by the action of the arch, as it compels the hydro-carbon gases (distilled off in large quantities from the green coal) to mix intimately

with the oxygen and other gases present, and increases the probability of these gases being completely burned in the fire-box.

88. Fig. 4 shows what would happen under the same conditions without an arch. The hydro-carbon gases driven off in the coal under the door, pass in a stream up along the crown sheet and into the upper flues—to a large extent unburned, due to the absence of any efficient mixing with the oxygen that might be present.

89. Fig. 3 illustrates the same mixing effect which takes place when large volumes of hydro-carbon gases and smoke are being driven off, due to uneven firing

90. Fig. 5 illustrates the protection that the arch affords the flues from cold air shafts entering through the fire-door or through holes in the fire. The mixing of the cold air with the hot gases insures a more nearly uniform temperature above the arch, and protects the flues from wide variations in temperature—which are responsible for most flue leaks. Without an arch, a hole in the fire would result in a rush of cold air into the flues as shown in Fig. 4. This would result in leaky flues and a possible steam failure.

91. The arch, by causing the fine particles of coal to be more thoroughly burned, reduces the amount of accumulation in flues and the amount of flue blowing generally necessary.

92. When spacer blocks are used against the flue sheet, the arch is self-cleansing; but when run tight against the sheet (as is the practice on the

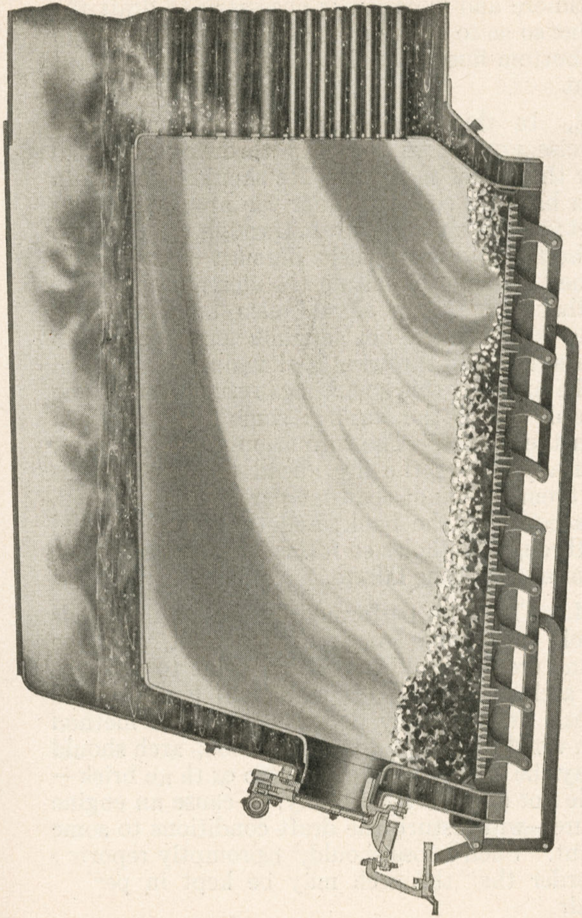

FIG. 4
Note hydrocarbon gases being distilled off from back of green coal under door. See how they escape unconsumed for the most part when arch is not used. Also note hole in fire and cold air rushing into lower flues, causing them to contract and leak

Baltimore and Ohio), it is necessary to draft the engine so as to insure a free flow of gases through the bottom flues, in order to keep the arch swept clean.

93. In this connection, the fireman should exercise great care to avoid throwing any coal over the top of the arch. He should also refrain from banking coal up under the arch, on throat sheet; as this shuts off draft through that portion of the fire and reduces the amount of coal being burned, thereby impairing the steaming qualities of the engine. He should also be careful, in firing shallow fire-box engines equipped with arches, to avoid throwing coal against the bottom of the arch, as this sometimes results in forming a bank across the fire-box some distance back from the throat. The formation of such a bank naturally causes the fire ahead to burn out, as the fireman cannot see that part of his fuel bed, on account of the bank; and the inrush of cold air through the holes so formed is often sufficient to cause an engine failure.

94. The work performed by the arch depends largely upon the length of the arch, and the engine crews should make it a point to see that the arch is run full (or standard) length at all times. Its efficiency depends upon the method with which it is kept up—and a 100% arch should always be used. The loss of two or three brick—while not sufficient, generally, to cause an engine failure—will disturb the draft conditions to some extent. Such a loss should be promptly reported in order that the arch may be kept in perfect repair.

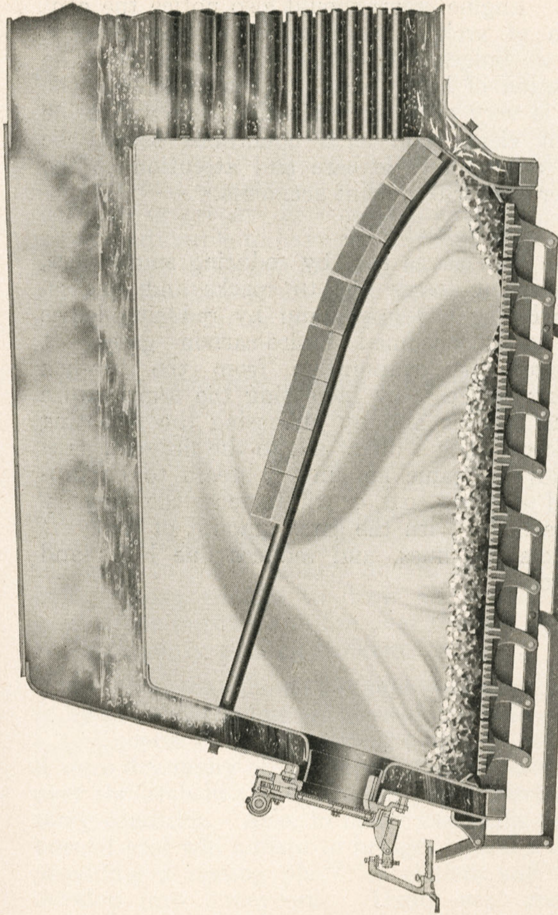

FIG. 5

Note how the arch deflects and mixes the shafts of cold air entering through the open fire-door and through holes in the fire. This mixing produces a more uniform temperature of the gases entering the flues and prevents the contraction of flues that cause them to leak

95. Engine crews should also notice the condition of arch tubes and report any defects, such as bulges, blisters or warped tubes. The formation of heavy scale on the outside of the tube is very often an indication that the inside is not clean, and such conditions should be reported, as a little care and attention at the proper time will prevent accidents.

96. To Summarize:

The arch saves coal by reducing smoke loss, by reducing losses due to sparks and cinders, by reducing CO losses and by reducing losses due to unconsumed hydro-carbon gases. It increases the evaporation from the fire-box heating surfaces, by increasing the temperature in the fire-box and by increasing the radiating surfaces. It is a direct aid to the fireman, as it enables the same amount of steam to be produced with less coal, or will increase the capacity of the boiler with the same amount of coal. It protects the flues, and reduces flue leaks and failures.

STOKER FIRING.

97. A stoker-fired engine requires a light, thin fire so as to be productive of best results. The fire in a stoker-fired engine should be uniformly level and burned through. Best results are obtained by using the shovel to prepare the fire for the trip, and stoker should not be used to build, maintain or prepare fires in engine terminal. It may be advisable to have the fire slightly heavier at the back end when starting out so as to compensate for heavy draught through the back portion of the fire on some engines equipped with an arch.

98. In preparing the fire for stoker-equipped locomotives, the blower should be used as sparingly as possible and the fire should be burned through properly, adding coal to bright spots where needed with the shovel—this in order to avoid raising the fire-box temperature too rapidly. Where strong blower draft is used, it has a tendency to cause clinkers due to the draft not being strong enough to draw air through the grates, but burning the fire over the top surface and frequently causing clinkers.

99. The coal should be kept well dampened, as by so doing the fine particles of coal will adhere to the coarse coal and reach the fire bed while if it were dry many of the fine particles would pass over the arch in the draft in a partly burned or tarry condition. Also, in many cases this partly burned coal will adhere to bridges between flues, providing a resting place for cinders and later develop into honeycomb. Damp coal reduces

stack loss and saves coal. After the fire has been burned through and is uniform on the grates, and the engine is coupled to the train the stoker should be started in advance of the opening of the throttle by engineer in starting the train so as to avoid pulling ash from the grates and heating same while in suspense, which is likely to cause honeycomb to form on the flue-sheet.

100. After the train departs from the terminal and the fireman has the stoker jets adjusted to distribute the coal properly, he should watch the stack and steam gauge closely. By observing the steam gauge closely the fireman can determine just what amount of coal is necessary to apply to the fire-box to maintain the proper pressure. The stack should also be watched closely and the emission of dense smoke be avoided, as this indicates that too much coal is going to the fire-box which will result in the fire being banked and clinkered. There is also a possibility of this same condition creating honeycomb on the flue sheet due to particles of fine coal being carried off the banked fire in a partly consumed condition.

101. At points where closing the throttle is anticipated the fireman should shut off the operating valve of the stoker far enough in advance to prevent the pop valve opening. This matter should also be watched closely by the engineer, who should give the fireman warning when he intends to close the throttle.

In order to make stoker firing a success and economical, there must be close cooperation between engineer and fireman.

The throttle, reverse lever and injector should be handled with the same regard for economy that is exercised with hand-fired engines.

102. The same general principles that pertain to hand firing apply to stoker operation; that is, to maintain a thin, level, light fire and a uniform distribution of fuel over the entire grate area at all times.

The stoker should be run slowly and continuously, just fast enough to supply the proper amount of coal to the grate area. It should never be speeded up and then shut off. Running the stoker as stated above, will prevent black smoke, save coal and produce more heat.

103. The use of the rake and shaker bar should be avoided as far as possible.

Grates should not be shaken unless absolutely necessary, as it is better to have some accumulation of ash over the grates, which in many cases will prevent clinker formation.

104. To do a good job of firing, a fireman must use good judgment in supplying coal to the fire-box in accordance with the way the engine is being worked, and in seeing that his distributor jets are set so that the coal is distributed where needed.

Frequent observation of the fire is necessary to guard against heavy firing, creating "banks," or insufficient coal creating "thin" spots.

The amount of coal fired is determined by the speed of the stoker engine, control of which is manual and under direct supervision of the fireman. Its distribution to the various parts of the fire-box is effected by manipulation of the valves controlling the steam supply to the jets.

105. If banks form in the fire-box it is best to burn them out by cutting out the jets or elevator supplying that particular part of the fire-box. The practice of shaking grates to get rid of a bank is wrong. It is also wrong to use the rake to get rid of a bank unless it is caused by arch brick or clinker, in which case the rake should be used to remove the cause of trouble.

Correct adjustment of the distributing jet valves will give proper distribution of coal in the firebox at all times, which makes the use of the fire hook unnecessary; but if a bank should form, it should be disposed of as soon as possible. This can be accomplished by readjustment of the jets.

If thin spots develop in the fire bed, it will be found more convenient to supply the required coal by hand firing. Then adjust the distributor jets.

Bear in mind that early treatment saves trouble.

Inspect the coal on the tender frequently and do not allow pieces of rock, iron, wood or other foreign matter to feed through the stoker.

106. If the stoker stops while the train is running and cannot be started readily, the fire should be maintained by hand until the first stop. If the stoker can be started without delay

to the train, it should be done. If not, the train should be brought in by hand firing the engine to the terminal.

107. The jets on stokers should be kept turned on enough at all times to keep the firing plates cool. Cooling holes under the Duplex and Lower distributors should be kept open at all times to prevent over-heating, and burning or warping of distributors when engine is working. When starting the trip, if the engine starts to lag for steam, it would indicate that the engine is not getting proper distribution of coal in the fire-box and the stoker should be closed off while the fireman makes a close observation of the fire-box to locate the trouble so that it can be corrected promptly. It is not a good practice to use the rake for this purpose as use of the rake disturbs the fire bed and causes clinkers. If, however, the fire is uniformly level it would indicate that the trouble is not with the distribution of the coal, and the rate of firing should be increased slightly. Care should be exercised in crowding the fire to avoid banks and to avoid filling any part of the fire-box with green or unburned coal which aggravates a bad condition.

108. Care should be exercised approaching or passing through tunnels—stoker should be shut off or run so as to fire as little as possible while passing through tunnels.

109. Account of the fire being light in stoker-fired engines, it is good practice to keep a small amount of coal going into the fire-box particularly when drifting or when engine is being worked lightly, as this permits uniform steam pressure

without excessive smoke. If light firing is not done under these conditions the fire gets low, making it necessary to operate the stoker too fast which results in objectionable smoke and possible banks. At points where engine has been standing for some time the stoker should be started slowly shortly before starting the train to build up fire-box temperature enough so it will not be necessary to crowd the fire after starting.

110. At the completion of the trip, the fireman should deliver the engine to the fire track with fire burned down. Any banks or heel which may have accumulated in the fire-box should be levelled over and no more coal should be placed in the fire-box.

Stoker slides in tank should be closed far enough in advance of arrival at the terminal to insure all coal being worked out of trough, this being especially important in the winter season.

111. Stoker jets should never be entirely closed off except when fire is drawn. If jets are closed off it results in stoker table or distributors being overheated and warped.

Any condition observed in connection with the stoker or any part of the locomotive which results in excessive fuel consumption will be called to the attention of the engineer who will report it for correction.

DUPLEX TYPE STOKER

112. The Duplex stoker consists of a flexible screw conveyor below the shovel sheet flexibly connected to a hopper below the locomotive cab deck. The coal delivered to the hopper by the screw conveyor is lifted by two elevator screws to two points, one on either side of the fire-door. From these points the coal is delivered to the fire-box by a system of steam jets and distributor mechanism located inside of the fire-box.

113. The stoker engine mechanism consists of an 11″ cylinder controlled by a reversing head similar to that used on the Westinghouse 11″ air pump, and operates in about the same manner. The power is obtained through a piston and rod coupled to a driving rack located in what is commonly called the rack housing, through which power is transmitted from the cylinder to the elevator gears which mesh with the elevator side of the rack and drive the two elevator screws located in the casings at the back head of the boiler.

114. A pinion gear mounted on a shaft meshes with the top portion of the main rack. Through this shaft power is transmitted to a head where a series of pawls are located, which control the screw conveyor in operative, neutral and reverse positions. The power is transmitted to gearing at rear end of the conveyor by a flexible shaft, which is located underneath the shovel sheet of the tender.

Operation

115. To start the stoker the fireman should make sure that the main steam supply valves are

all open to the throttle valve and steam jets and that the lubricator is feeding not to exceed two drops of valve oil per minute to the stoker engine. The two jets which blow the coal from the distributors should be turned on to about 15 to 20 pounds, depending on the size of the coal, after which the ½″ stoker throttle valve should then be opened slowly, allowing the pressure to build up in the stoker cylinder so that the condensation will drain slowly for a few strokes or revolutions of the elevators, after which the steam pressure may be gradually increased until the stoker is operating at its required capacity.

116. The proper method of operating the stoker is as follows:

The fireman should first see that the stoker has been properly oiled at all bearings or wearing surfaces, after which the stoker should be tested to see that it is in proper operating condition to make a satisfactory trip. After this has been determined, the fire should be built up gradually with the shovel until it is thoroughly burned through, raising the steam pressure gradually while maintaining the proper level of fire.

117. During the preparation of the fire, the blower should not be used excessively, otherwise the fire will be built up too rapidly, causing steam to be generated too rapidly and wasted through the safety valve before the engine leaves the ready track, thereby causing an unnecessary waste of coal.

118. The stoker should not be used either in the roundhouse to maintain the fire or to assist in the building up of the fire on the ready track. The firing should be done by hand until the engine is coupled to the train ready to begin the trip. After coupling to the train, during the air test the fire should be burning very brightly over the entire grate area, with the steam pressure near the maximum, and the water at its proper level in the boiler. When the engineer is ready to start the train the stoker should be turned on a little in advance of the start and should be operated very carefully while the train is being gotten under way. The fireman should observe his fire very closely for several miles to see that the coal is being delivered properly to all parts of the grate area, otherwise banks will form, which will cause clinker formations on the grates, and will lead to possible steam failure unless proper adjustments are made on the stoker mechanism, such as the dividing rib in the transfer hopper below the cab deck, or the steam jet pressure which should be raised or lowered, depending on the part of the fire-box at which bank formation may have started. By observing this operation for several miles at the start of the trip and making any necessary adjustments on the stoker, a minimum amount of coal will be required. The smoke can be kept down to a minimum also by careful observation on the part of the fireman.

119. When this procedure is not followed, and if banks are allowed to form, causing clinkers, it may eventually become necessary to shake

the grates and possibly clean the fire and the ash pan, which will require excessive time and hard work plus an unnecessary consumption of one to two tons of coal.

120. After the engine cuts off from the train in the terminal, the tank slides should be closed over the conveyor opening from the rear end of the coal space forward to the coal gate, and the coal left in the conveyor and elevator should gradually be fed to the fire so that on arrival at the inspection pit the conveyor and elevators will be free of coal.

121. Before leaving the engine the fireman should advise the engineer just what work is required on the stoker so that the necessary work can be reported and repairs can be made before the engine is again dispatched.

LOWER STOKER

122. The Lower stoker consists of flexible conveyor jointed at the front end to an inclined elevator located beneath the cab deck and ending at the bottom portion of the fire door. A conveyor screw is driven by gearing at the rear end of the conveyor and is connected by a universal joint at its forward end to an elevator screw which ends at or near the fire door.

123. The Lower stoker is driven by a two-cylinder double-acting high-speed engine located either directly below the fireman's seat underneath the cab or in the front left-hand corner of the tender.

124. A number of oil pipes lead to the various bearings in both the engine and the gear case. These should be filled before leaving the ready track, engine oil being used in all except one oil cup. This is equipped with a large container or cup leading directly to the crank case. For lubricating this part of the stoker engine valve oil may be thinned down by using one-half machine oil; otherwise ordinary valve oil should be used.

Operation

125. The fire should be built up with the shovel by hand, using the blower lightly in the same manner as that employed with the Duplex stoker.

126. Before starting the stoker for test on the ready track the main steam valves should be opened, including the control valve leading to the

jets; the jet valves should be turned on with the jets blowing about 8 to 10 pounds to the back corners, about 15 to 20 pounds for the bottom jets between the ribs on the firing plate, the upper jets should be turned on to 30 or 40 pounds, depending on the size of coal. The ½ throttle valve should be turned on slowly until the engine has made a few revolutions, permitting the condensation to pass out of the drain cocks, after which the engine may be turned on to see that the stoker mechanism is in proper operating condition.

127. The bottom steam jets should be kept turned on very light to keep the firing plate from becoming too hot when the stoker is not in use. Also it is very important that the fire be kept at least 6″ to 8″ below the firing plate at all times, otherwise it will become very hot and be destroyed, whereas with proper manipulation of the stoker and jets the firing plates will last for several months.

128. Figure 6—Descriptive Chart and Instructions for Maintaining Fires with the Lower Type Stoker illustrates the proper method, also the improper method of firing as well as maintaining fires with this type of stoker.

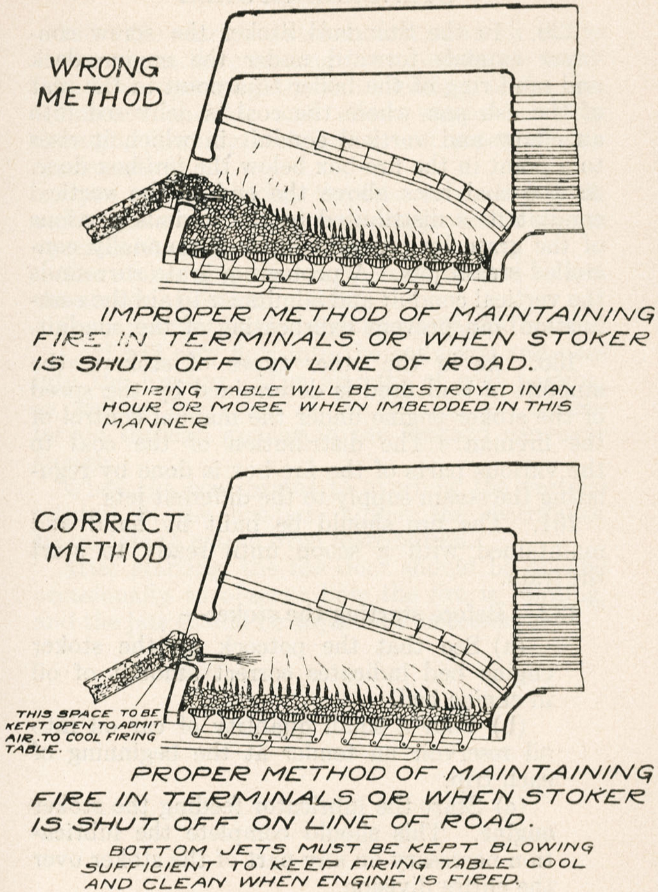

FIG 6

129. In the Standard Stoker the screw conveyor extends forward under the engine deck and mud ring of the boiler to a point in the rear of the ash pan where the coal is delivered into an elbow and vertical conduit in which it rises to a point in the fire-box below the fire-box door. As the coal rises above the end of the vertical conduit it is distributed to the various portions of the grate by properly directed manually controlled steam jets. A protecting grate surrounds the vertical conduit and admits air to aid the combustion and prevent overheating of the conduit.

130. As in the other types of stokers, the amount of coal fired is determined by the speed of the stoker engine under the manual control of the fireman. The distribution of the coal to the various parts of the fire-box is done by regulating the steam supply to the different jets.

131. The fire should be built by hand and maintained with a scoop until ready to start the train.

132. Before starting the stoker—

(a) See that the petcock on the stoker engine bed indicates correct amount of oil in engine bed.

(b) Pour a small quantity of car oil into oil reservoir on tender at the beginning of each trip.

(c) Start the lubricator feeding the stoker engine. This should complete the lubrication necessary on any part of the stoker over the entire division.

Operation

133. To start the stoker, first open all valves the steam lines leading *from* distributor manifold, then open slightly valve leading *to* the distributor manifold, and allow steam to blow through, cleaning distributor and pipes of any condensation.

Open stoker engine throttle valve slowly in order that condensation may escape before engine operates at speed.

The stoker throttle can then be opened to run the stoker at desired speed.

Open the first tender slide by pulling it forward.

Coal will now flow into the conveyor and pass into the fire-box. The amount of coal passing, as well as the speed of the stoker, can be observed through grating in the forward conveyor trough.

When the coal begins to overflow the vertical conduit in the fire-box, adjust the distributor steam jets to get an even distribution.

After starting, the fire door should be opened occasionally to observe how the fire is burning, and the jets should be adjusted if necessary.

IMPORTANCE OF STEADY STEAM PRESSURE

134. The most destructive influences which affect locomotive boilers are expansion and contraction; these actions being the result of variation of temperature—expanding when heated and contracting when cooled. One of these actions takes place with every variation of temperature, and the repeated stretching and shrinking movements of the different parts of the boiler are generally the cause of leaking flues, broken staybolts and damaged fire-box sheets.

In the following table we see that steam of different pressures has different temperatures to correspond therewith. A variation of pressure is always accompanied by a variation of temperature of the steam and water contents of a boiler, and of the metal of the boiler also. To maintain an even temperature of a boiler and thus avoid the damaging effects of expansion and contraction, it is absolutely necessary to maintain an even steam pressure. The steam pressure should be kept within the limits of ten pounds.

Pressure Shown on Steam Gauge	Temperature in Boiler
0 (Boiling point).	212 Degrees.
10	240 "
20	259 "
30	274 "
40	287 "
50	298 "
60	307 "
70	316 "
80	324 "
90	331 "
100	338 "
110	344 "
120	350 "
130	355 "
140	361 "
150	366 "
160	370 "
170	375 "
180	380 "
205	390 "
235	401 "
245	404 "

TOOLS AND SUPPLIES

135. In closing these instructions it will be proper to call attention to the necessity of wise and economical use of tools and supplies. Engineers and firemen cannot hope to make a satisfactory record otherwise. Questions affecting the use of tools and supplies grow more important every day, because measures for ascertaining the care exercised are becoming more effective from time to time. The subject is, therefore, one of importance to the engineers and firemen.

DONT'S

DON'T SLUG.

DON'T OVERLOAD TENDERS.

DON'T OVERFILL SCOOPS.

DON'T SHAKE GRATES OR USE THE HOOK WHEN IT MAY BE AVOIDED.

DON'T ALLOW POPS TO OPEN UNNECESSARILY.

DON'T PERMIT A DIRTY DECK OR APRON, ALLOWING COAL TO RATTLE OFF.

DON'T KNOCK COAL OFF BY CARELESS HANDLING OF TOOLS.

DON'T THROW LARGE LUMPS INTO THE FIRE —CRACK THEM.

DON'T USE BLOWER, EXCEPT WHEN NECESSARY.

DON'T PERMIT FIRE TO GET TOO HEAVY AND DIRTY.

DON'T BRING LOCOMOTIVE TO TERMINAL WITH A HEAVY FIRE.

DON'T ALLOW FIRE TO DIE OUT IN FRONT OF FIRE-BOX, CAUSING LEAKY FLUES.

DON'T BANK FIRES AND LEAVE DOORS OPEN WHEN DESCENDING GRADES OR STOPPING.

DON'T FIRE ON GREEN COAL OR ANY SPOT UNLESS WHITE.

DON'T PERMIT BANKS.

DON'T LEAVE FIRE DOOR OPEN WHEN ENGINE IS WORKING HARD.