FIREMAN'S PREPARATORY INSTRUCTION

Part Two

RAILWAY EDUCATIONAL ASSOCIATION

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Preparatory Instruction

PART TWO

FIRING WITH BITUMINOUS COAL

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FOREWORD.

The proper management of locomotives must always be for the expeditious movements of trains ON TIME. Compared with this necessarily CHIEF SERVICE—every other consideration except SAFETY must be secondary.

But a great deal can be done by every locomotive engineer and fireman to CONSERVE fuel—while compelling their engines to promptly do their duty. For this—CARE and SKILL in the performance of their important respective duties are necessary, based on full and correct KNOWLEDGE of the concealed activities of forces that are always at work in the operations of every locomotive.

This knowledge is easy to understand when plainly presented—but it can NEVER BE LEARNED in the practical work of firing and running locomotives. The first steam engine builders GROPED IN THE DARK for a hundred years for lack of this knowledge. In all that time and with all that EXPERIENCE they did not learn it. Consequently the engines they built could not make more than a dozen effective strokes a minute, and could only pump water.

All the improvements in steam engines which brought them to their present stage of perfection—that enables them to so splendidly do the work of the world—were accomplished by the builders LEARNING and conforming with the later ascertained LAWS OF NATURE which govern the operations of all steam engines.

What is the Science of locomotive management? A definition of "Science" is—"KNOWLEDGE of principles and causes—ASCERTAINED truth or facts"—and this indicates that the facts were CONCEALED.

Then the Science of locomotive management is the ASCERTAINED TRUTH AND FACTS about the concealed activities of the principal matters of locomotive operation—the actions of fire in creating heat—of heat in changing water into steam—and of steam in propelling the engine.

On every locomotive such secret forces are always at work—and a clear and correct knowledge of them is NECESSARY to every locomotive engineer and fireman who wants to be 100 per cent. efficient in his work. This knowledge is presented herein in an EASILY UNDERSTANDABLE WAY for every engineer and fireman.

What is the POWER of locomotives? It is HEAT. The fuel they consume is but the means to obtain the HEAT—and the Water they use is but the Agent through which the power in the HEAT is EXERCISED, in the form of Steam, to propel the engines.

Whence cometh the HEAT? From the fuel? Yes, and NO. We burn the fuel and HEAT is produced—but it was formally STORED in the fuel by the sunshine that illuminated the Earth millions of years before the advent of Man. The HEAT of the Sun was invested in the growth of vegetation and the building of great forests, which through changes in the land, and earthquakes, were buried in the soil and turned into coal.

Also the HEAT of the Sun caused the growth of vegetation in the sea which supported life in shoals of marine creatures—which "lived and died throughout millions of years, and filled the cavities of the sea with an OILY substance that had taken the place of countless trillions of once living little bodies." This finally reached the surface of the dry land as—PETROLEUM, or fuel oil!

Every coal or oil burning locomotive is running today on ANCIENT SUNSHINE—by the power of the HEAT of the Sun that reached the Earth millions of years ahead of Man—and stored his mines with COAL and wells with OIL in anticipation of his need for these fuels when—in the far future—he learned enough of Nature's Laws to enable him to build and operate steam engines successfully.

G. H. B.

New York, June, 1927.

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LESSONS ON ECONOMICAL FIRING

LESSON 1.

IMPORTANCE OF FUEL ECONOMY.

NOTICE TO EVERY FIREMAN:—It is necessary for you to understand that the cost of fuel for locomotives is a Railroad's GREATEST SINGLE EXPENSE. Therefore you should be very careful in your work as a fireman to AVOID all wastes of coal—and keep up steam on the engines you fire with AS SMALL consumption of coal as possible. SAVE EVERY POUND of coal you can. By so doing you will greatly lessen your labor in firing and avoid wasting the Railroad's most expensive supply.

1—Necessities of Skillful Firing.

FOUR NECESSITIES require locomotive firemen to be especially skillful in their work. First, so sufficient steam may be produced to make the engine work as wanted. Second, so no more fuel shall be burned than is necessary. Third, so smoke about stations shall be avoided; and Fourth, so the labor of firing may be lightened.

That the importance of these necessities may be fully understood, respectively, they will be explained in the order named:—

FIRST—Sufficient steam for the engine at all times is the first necessity of every locomotive, as its power of movement and usefulness depends altogether upon its motive power—STEAM.

SECOND—Careful economy in the use of fuel is required because this most expensive supply costs the railroads of North America about Seven Hundred Million Dollars ($700,000,000) a year— about Two Million Dollars ($2,000,-000) A DAY—and an average of about Ten Thousand Dollars ($10,000 a year for each locomotive in service.

The Engineers and Firemen control the consumption of this great wealth of fuel. The portion of it that each engine crew can save or waste each day, although not noticeable to a careless observer, amounts in the daily aggregate on all of any Railroad's engines to many tons—and the total possible saving extends into many thousands of dollars annually.

A Railroad's property consists not only of its right of way and roadbed, cars, engines and buildings, but also of each article of supply purchased for its needs. The fuel supply for locomotives—IS PROPERTY—exceeding in value many cars and many engines. Engine men who waste fuel destroy the Company's property in a different way but with similar net results as if they smashed cars and engines. So it is important that every engineer and fireman shall direct earnest attention and efforts to economize fuel in every practicable way and avoid every unnecessary waste or loss.

THIRD—SMOKE is evidence of imperfect burning and waste of fuel. It is especially objectionable when emitted from locomotives while they are entering, standing about or leaving stations or the vicinities of offices and residences. Locomotive smoke befouling the air in these places brings the Company into disfavor with its patrons and the public, and results in damage and loss. Therefore the necessity of avoiding smoke as much as possible at all times—but always when its presence is a NUISANCE.

FOURTH—Any saving of coal in firing results directly and immediately in lightening the labor of the fireman. If by careful and intelligent management of his fire he burns less coal—just so much easier becomes his work. His intelligence saves his muscles the labor of handling unnecessary fuel.

2—Importance of Good Firing.

These are the main reasons why it is necessary that firemen shall understand the Science and best methods of firing, so they may produce the greatest amount of steam with the least smoke and the least consumption of fuel. These requirements show that a fireman's work is of GREAT IMPORTANCE in the movements of trains.

Many firemen take too little interest in their work to discover its interesting features. They regard the work as dirty, because coal is black, though really a clean substance; as laborious because careless firing often makes it so, and as uninteresting because not understood and not done with sufficient care and pride.

Pride in good work is as inspiring and honorable in a fireman as in an engineer or any officer of the Company. A first-class fireman will realize the importance of his work in generating the MOTIVE POWER for the movements of trains —study its Science to improve his skill—and be proud of perfect work.

3—Harmonious Co-operation.

Every engineer and fireman should "work together" to operate their engine successfully and economize fuel in every reasonable way. The difference between their doing so, or not, can affect the coal consumption of the engine—one or two tons a day.

Many firemen IMPOSE UPON THEMSELVES as much extra and entirely unnecessary work as this, either through ignorance of the best methods of firing, or through carelessness, or because they do not work harmoniously with their engineers.

Absence of harmony between an engineer and fireman insures reduced pleasure in their work, increased anxiety and labor—and LOSSES for the Company.

LESSON 2.

ESSENTIAL QUALITIES OF ENGINEMEN.

Regard for Safety. Sobriety. Good Judgment. Loyalty. Willingness. Cleanliness and Orderliness.

4—Regard for Safety.

A proper regard for SAFETY is the first requirement of an engineman. A railroad is built from its foundation up—for SAFETY. Every detail of its equipment of cars and locomotives is planned and built for safety, and every Rule for the guidance of employees in the operation of the road has for its main object the safety of the passengers and commerce carried and men employed, and the safety of the cars and engines used in the trains by which the whole work of the railroad is accomplished.

Carelessness and disobedience of Rules cause most railroad accidents. The steadfastly careful and obedient employee exempts himself from nearly all dangers. Therefore—

ALWAYS OBEY THE RULES—

and conform to the requirements of Safety for yourself, your associates, and the engines and trains with whose movements you are connected.

5—Sobriety.

Sobriety is the main essential virtue of a railroad man. Every man connected with the movements of trains needs a clear head and steady nerves for the correct judgment that will prompt the right action at the right time to avert danger and secure safety. Strict sobriety is necessary to these conditions of head and hands.

Actual railroad experience confirmed by scientific tests have proved that intoxicating drink:—First, slows the power to see signals. Second, confuses prompt judgment. Third, hastens fatigue. Fourth, lessens resistance to exposure and disease. Fifth, increases shock from injuries.

The responsible men in engine service—of all men—must especially abstain from intoxicants. The doors of railroad employment are closed against the intemperate man, because intoxicating drink makes him LESS A MAN.

There is no place on a railroad for any one who gives a part of himself over to the slavery of liquor. The responsible duties of railroad service require A WHOLE MAN—not part of one. Not one who is a man only part of the time, but one who is a whole man with his complete senses—ALL THE TIME.

6—Good Judgment.

Good judgment correctly measures all the prevailing conditions in an engine's daily work—quickly when necessary—and prompts the right action at the right time.

No matter how much a man may KNOW—if he does not exercise his knowledge with a good comprehension of ALL the conditions involved in his work—he will blunder as a result of POOR judgment. Another man having perhaps less knowledge, but zealous to consider and take advantage of all the conditions under which his engine is working—will exercise GOOD judgment, and save himself much labor and save his Company much expensive fuel.

So the VALUE of the Instructions given in these Lessons about firing and running locomotives ECONOMICALLY will depend largely on the faithfulness and GOOD JUDGMENT with which you carry them out in your daily work.

If you want to SUCCEED in locomotive service and win advancement—and make your work as easy as possible—STRIVE to exercise GOOD JUDGMENT in all you do, and show that you possess this VITALLY important requirement of a good engineman.

7—Loyalty.

The Company's managing officers are charged with the general conduct of its business and maintenance of its property so that the Railroad's operation may yield the best service to its patrons, fair pay to its employees, and a fair return in dividends to the share owners whose capital investments in the property have made the Railroad what it is.

The viewpoint of the Management is the SUCCESS of the COMPANY in these three supreme ways. This should also be the common viewpoint of every man in the Company's service.

Regard the performance of your duties, and your relation to the successful and economical operation of the road—the same as if you were an officer of the Company, with its best interests at heart. This will insure your greatest efficiency in your work, and your personal success. Advise and encourage this attitude in others also.

8—Willingness.

The best way to succeed is to always DO GOOD WORK—and show complete WILLINGNESS to do whatever duty you are called upon to perform—the BEST you can.

If such work should be other than firing—you may learn something by it that will be of advantage to you in your railroad career. Do not consider any kind of engine work as beneath you. It is all necessary and honorable, if well done. You will be fortunate if your early experience brings you in contact with every phase of the work of caring for and repairing locomotives and preparing them for service.

Consider that the work, whatever it is, is a good chance to learn some useful and practical knowledge that you may be fortunate in having later on. In your career in the Motive Power Department you may come to superintend the work of others. You will then regard as fortunate the necessity that once required you to do that work for awhile with your own hands.

9—Cleanliness and Orderliness.

Cleanliness and orderliness should be the guiding principles of a fireman's work. The tools, lamps, signal flags and other articles of an engine's equipment should be kept in perfect order all the time.

The signal lamps, and the steam-gauge and water-gauge lamps should be kept filled, with wicks trimmed and in good order and in perfect condition of cleanliness. The safety of trains often depends on the proper burning of signal lamps.

The large oil cans, used for carrying the necessary supply of oils, should be kept clean and free from leaks; and the small oil cans, used for oiling the engine, should be kept filled and clean and in good order.

LESSON 3.

THE FORMATION OF COAL.

First Growth of Vegetation. Burial of Vegetation by Earthquakes. Burial of Vegetation by Rivers. Composition of Coal.

Before we begin to study the most economical methods of firing locomotives we must learn what A FIRE IS, and what goes on in this wonderful process of "Burning." Probably most people think they know "what a fire is"; and yet, if questioned closely, comparatively few could tell more than that a fire burns fuel and gives off heat. But HOW it does this is a fascinating study, and of utmost importance to engineers and firemen.

To learn the processes of burning—or COMBUSTION—we must first study the nature of the fuel we burn—COAL—how it was formed and of what it is composed, and to do this we must go back to the Earth's beginning.

10—First Growth of Vegetation.

Science teaches that the Earth was once a great ball of flaming gases, as the Sun is now. After ages of burning, the gases condensed to incandescent (red-hot and white-hot) liquids, and finally these cooled and became solid on the surface so that a crust was formed over our globe.

It is the nature of every fire in perfect burning to create—STEAM—and CARBONIC ACID GAS. Thus WATER is formed IN and produced BY FIRE. Perhaps no action of Nature is of more striking interest than the fact that FIRE CREATES its greatest common antagonist and destroyer—WATER.

The great conflagration of the substances of which our Earth is composed that raged for unknown Ages—produced vast quantities of STEAM and CARBONIC ACID GAS which mingled with the Earth's atmosphere.

The steam thus formed played an important part in hastening the formation of a crust over the globe. In rising to a great height from the Earth's surface it was cooled by the cold of high altitude, condensed, and fell in showers of rain upon the red hot surface of the Earth, where it was immediately re-evaporated and forced to rise as steam again to the cold of the mountain tops.

This re-evaporation repeated over and over again exerted a powerful influence in cooling the surface of the Earth and hastening the formation of a thick crust. The rain acted to absorb the heat from the gradually thickening crust, to carry it away, and thus cool the world sufficiently for the existence upon it of vegetable and animal Life.

When this purpose was accomplished, so far as to permit the beginning of vegetable life, the other product of the great fire—CARBONIC ACID GAS—began its operations to transform the surface of the Earth from a barren crust of cinder, dust and ashes, into the fit and beautiful habitation for Mankind it finally became.

By some means that yet lie hidden from our knowledge the carbonic acid gas, acting together with the sunshine and the rain, entered into CHEMICAL COMBINATIONS with the DUST of the Earth's crust—and VEGETATION sprang into existence. The warmth of the yet thin crust was favorable to the rapid and luxuriant growth of vegetation, and the atmosphere was so richly charged with carbonic acid gas that great plants and trees flourished and grew to gigantic sizes.

11—Burial of Vegetation by Earthquakes.

In this early period, probably millions of years before the creation of Man, the Earth's crust of rock and soil was yet comparatively thin, and volcanic disturbances often caused much greater earthquakes than we now know. In such upheavals of the soil whole forests were buried. In time the new soil gave birth to fresh growths of trees and vegetation, and sometimes these in turn were later swallowed up and buried by the earthquakes, or the shifting of the soil through the action of the waters and winds.

The buried wood became a soft black substance that contained all the elements of the wood, only in changed form This was compressed and hardened by the immense pressure of the ever-increasing layers of soil above it, sometimes hundreds and even thousands of feet deep—and finally became the COAL that we burn today.

Successive ages brought successive layers of forest, rock and soil deposits—so that we find in some coal regions today several beds or layers of this ancient vegetable matter. Originally it was all deposited flat, but later earthquakes distorted the surface so that we often find the layers of coal in the mines—distorted, bent and folded just as if they had once been so many layers of moist blotting-paper crumpled up in the hand.

12—Burial of Vegetation by Rivers.

Also the rivers in their flow to lakes and to the seas carried great quantities of drift wood, which in the lapse of time became piled along the banks near their mouths, and were buried in the mud.

In these ways the rivers laid up beds of coal to become available for the uses of Man ages afterward—when the surface of the country was so changed by volcanic action that no one would suspect this or that high hill or ridge had once been the BOTTOM OF A SEA!

13—Composition of Coal.

All coal was formed during the Earth's early ages in the ways described. Thus the CARBONIC ACID GAS of the atmosphere passed into the form of WOOD through the growth of vegetation, becoming CARBON—and the carbon passed into the form of COAL.

CARBON forms the chief part of all kinds of coal. It is the SOLID part that burns as glowing coals on the grates. It is the "coke" of coal and the "charcoal" of wood.

BITUMINOUS or "soft" coal is composed of carbon, gaseous matter and moisture mixed with such impurities as soil, rock and sulphur—which form its ash or incombustible matter. These substances are usually found in ordinary soft coal about as follows:

FIXED CARBON	50 per cent.
GASEOUS MATTER and moisture....	40 per cent.
ASH (incombustible matter)	10 per cent.

ANTHRACITE or "hard" coal is nearly all "fixed" carbon. It burns on the grate in the SOLID state, as red hot or white hot coals. But bituminous coal is usually about half GASEOUS matter that burns above the fire as FLAME or else produces SMOKE.

All anthracite coal was originally formed as bituminous coal, but being afterward subjected to intense heat by volcanic action—this caused nearly all its gaseous matter to escape. It contains only about 5 per cent. of gaseous matter—and this is why in burning it makes very little flame and no smoke.

THE VALUE OF COAL.

"COAL in truth stands not beside but entirely above all other commodities. It is the material energy of the country—the universal aid—the factor in everything we do. With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times."

JEVONS.

LESSON 4.

THE COMBUSTION OF COAL.

{ "FIRE — greatest of discoveries — enabling Man to live in various climates—use many foods—and compel the Forces of Nature to do his work." }

Fire is Man's Greatest Gift. Air in Combustion. The Inactivity of Nitrogen.

14—Fire is Man's Greatest Gift.

FIRE, according to an ancient fable, was the gift that the gods gave to Man alone, of all Earth's creatures—so that he might become the powerful Ruler of the world.

Lord Francis Bacon, writing about the meaning of this fable over 300 years ago, said:—

"Man seems to be the thing in which the whole world centres, with respect to final causes, so that if he were away all other things would stray and fluctuate, without end or intention, or become perfectly disjointed and out of frame; for all things are made subservient to Man, and he receives use and benefit from them all.

"Thus the revolutions, places and periods of the celestial bodies serve him for distinguishing time and seasons, and for dividing the world into different regions * * * the winds sail our ships, drive our mills and move our machines; and the vegetables and animals of all kinds either afford us matter for our houses, clothing, food, physic; or tend to ease, or delight, or support, or refresh us, so that everything in Nature seems not made for itself—but for Man.

"Man, however, in his first origin, seems to have been a defenseless, naked creature, slow in assisting himself, and standing in need of numerous things. Providence, therefore, hastened to the invention of FIRE, which supplies and administers to nearly all human uses and necessities * * * for hence proceed numberless operations—HENCE ALL THE MECHANICAL ARTS—and hence infinite assistances are offered to the sciences themselves."

This great philosopher lived and gave expression to these ideas two centuries before the invention of the first practically successful steam engine by James Watt, in which FIRE was destined to exert its greatest power for the good of Man, by enabling him to multiply his powers of production and transportation from the puny efforts of his physical strength, or that of his friend, the horse, or dependence upon the uncertain wind, to the magnificent results accomplished today through the tremendous work of countless steam engines in mills and shops and factories, on locomotives, and on ships that sail the seas.

Then if Man is the Chief of the creations of the Earth, for whom all else is, and as FIRE is his Chief Gift—through the operations of which his power is successfully exerted and maintained over the world—how necessary it is that engineers and firemen—those who actually LIVE by FIRE—and draw their life support from the conversion of its power into useful work, should study and understand its NATURE, and the interesting activities in the processes of COMBUSTION.

15—Air in Combustion.

To produce combustion, or cause the burning of a fire—anywhere—it is as necessary to have a supply of AIR as a supply of coal. One is as necessary as the other.

Our AIR or atmosphere is composed chiefly of two invisible gases—OXYGEN and NITROGEN. About four-fifths of the volume of the air is nitrogen, and only one-fifth—oxygen.

It is the OXYGEN in the air that makes our fire burn. It is just as much the "FUEL" of a fire as the coal. In burning, BOTH are "consumed," or apparently so—but neither is destroyed. Both simply COMBINE CHEMICALLY to produce a new substance—an invisible GAS. The coal disappears as coal and the oxygen disappears as oxygen, but if their union is perfect they reappear as CARBONIC ACID GAS.

Although contrary to the popular idea—the oxygen in the air is IN FACT the SUPERIOR FUEL of every coal fire—because, as we shall see, it changes and controls, by its presence in the fire in varying QUANTITIES—the chemical actions in and the HEAT of the fire.

16—The Inactivity of Nitrogen.

NITROGEN, although by far the larger part of the air, takes no part in combustion except to modify and RESTRAIN the activity of the oxygen, which without such restraint would be a disastrous destroyer, as impressively described by the great English philosopher, Michael Faraday, as follows:—

"This other part of the air is by far the larger portion, and it is a very curious body when we come to examine it. It is remarkably curious, and yet you say, perhaps, that it is very uninteresting. It is uninteresting in some respects because of this—that it shows no brilliant effects of combustion. If I test it with a taper as I do oxygen and hydrogen, it does not burn like hydrogen nor does it make the taper burn like oxygen. Try it in any way I will, it does neither the one thing nor the other; it will not take fire; it will not let the taper burn, it puts out the combustion of everything. There is nothing that will burn in it in common circumstances.

"And you might say—'It is nothing; it is not worth chemical attention. What does it do in the air?' Ah! then comes our beautiful and fine results shown by an observant philosophy. Suppose, in place of having nitrogen, or nitrogen and oxygen, we had pure oxygen as our atmosphere—and what would become of us?

"You know very well that a piece of iron lit in a jar of oxygen goes on burning to the end. When you see a fire on an iron grate—imagine where the grate would go if the whole of the atmosphere were oxygen. The grate would burn up more powerfully than the coals, for the grate itself is even more combustible than the coals which we burn on it.

"A fire put into the middle of a locomotive would be a fire in a magazine of fuel, if the atmosphere were oxygen. The nitrogen lowers it down and makes it moderate and useful for us; and then, with all that, it takes away with it the fumes you have seen produced * * * dispenses them throughout the whole of the atmosphere, and carries them away to places where they are wanted to perform a great and glorious purpose of good to man—for the sustenance of vegetation."

What Professor Faraday so gracefully said is true, and we must regard the nitrogen as being a safe envelope for the very active and destructive oxygen. What he said of iron being a combustible substance is true, and all that is required to make it burn is the presence of pure oxygen and a high temperature.

LESSON 5.

BURNING OF THE GASEOUS PART OF COAL.

Knowledge of the importance of SUFFICIENT AIR in a fire, and of the processes of Combustion as explained in Lessons 4, 5 and 6, is NECESSARY for an understanding of the IMPORTANCE of right firing methods—and the WASTEFULNESS of wrong practices.

Chemical and Mechanical Mixtures. How the Gases Burn. How Fire Forms Water.

17—Chemical and Mechanical Mixtures.

COMBUSTION or "BURNING" is a CHEMICAL process. The elements of Nature have two ways of mixing or combining—mechanically and chemically.

The mixing of sand and sugar, or milk and water, would be a MECHANICAL mixture. During the mixing nothing of particular interest would occur—and afterward they would still be simply sand and sugar, or milk and water.

But when substances capable of doing so combine CHEMICALLY—they cease to exist in their individual forms—DISAPPEAR—and join together to form A NEW and DIFFERENT substance!

Considering the mixtures mentioned (sand and sugar, and milk and water), if we should dissolve the sugar—the sand would remain solid; and if we should evaporate the water from the milk—the milk would resume its former state. Such are MECHANICAL mixtures.

But when the two gases—oxygen and hydrogen "burn" or unite CHEMICALLY in the proportion of TWO atoms of hydrogen and ONE atom of oxygen—A HOT FIRE results, and the fire CREATES from the two invisible gases A NEW SUBSTANCE—totally unlike either of them—WATER!

If we put a spoonful of sugar in a cup of tea, the sugar dissolves and mixes with the tea. It is a MECHANICAL mixture. If we let the tea evaporate we shall find every grain of the sugar at the bottom of the cup.

But if we take a piece of charcoal and heat it red-hot—its particles, or atoms, will combine CHEMICALLY with the atoms of the oxygen gas in the air—and A HOT FIRE will result; and the fire will produce A NEW substance—unlike either the oxygen gas or the charcoal—CARBONIC ACID GAS.

It is not for us to discuss WHY there are these different kinds of mixtures, with their wonderfully different results. In viewing the facts we face Nature's ETERNAL AND UNIVERSAL LAWS—by which not only all Earthly changes and operations are governed, but also everything in the surrounding Universe.

18—How the Gases Burn.

We learned in Lesson 3 that bituminous coal is nearly half gaseous matter. This is composed chiefly of carbon vapor, moisture and hydrogen gas. As soon as the coal becomes heated by the fire these gases are expelled from it, and if sufficient AIR is present to furnish the needed oxygen, and the temperature of bright red-hot iron (1,800 degrees) exists in the furnace, the gases "catch fire" and burn. At this temperature, called the "TEMPERATURE OF IGNITION," the chemical attractions between the atoms of the gases from the coal and oxygen in the air become so great that they CLASH

TOGETHER—and FLAME and light and HEAT are the results of their collisions.

Under all conditions of coal burning the following processes take place:—

FIRST:—The hydrogen gas SEPARATES itself from the carbon vapor and combines with the oxygen gas in the air in the fire—TWO atoms of hydrogen with ONE atom of oxygen—forming STEAM. When this condenses it is WATER.

SECOND:—Then the carbon vapor combines with the oxygen in the air in the fire—ONE atom of carbon with TWO atoms of oxygen—forming CARBONIC ACID GAS.

In this manner the GASEOUS portion of the coal is expelled and burned, leaving most of the CARBON of the coal upon the grates—as glowing red or white hot coals.

IMPORTANT:—If the fire is thereafter supplied with SUFFICIENT AIR, so that TWO atoms of oxygen can unite with EACH atom of carbon in the burning coals—PERFECT combustion will result, and produce—CARBONIC ACID GAS. A pound of carbon so burned will yield 14,500 units of heat.

A "unit of heat" is the regular basis for MEASURING different quantities of heat. It is the amount of heat that will warm A POUND (a pint) of water ONE DEGREE in temperature. It is about as much heat as is made by burning half an ordinary match, or that portion of a match usually used to "light" a pipe or cigar.

THIRD:—But if the supply of air is RESTRICTED in any way, as by ashes or clinkers clogging the openings between the grates, so not enough oxygen can get to the fire to give EACH carbon atom TWO oxygen atoms—then EACH atom of carbon will unite with ONE atom of oxygen, resulting in IMPERFECT combustion, and the formation of—NOT carbonic acid—but carbonic OXIDE gas. A pound of carbon so burned will yield only 4,452 units of heat—10,000 units or TWO-THIRDS LESS HEAT than if sufficient OXYGEN had been supplied to the fire.

In burning coal it is of the UTMOST IMPORTANCE to understand and be guided by these FACTS, so that the

GREATEST amount of HEAT shall be obtained from the coal we burn.

To accomplish this it is of FIRST IMPORTANCE to INSURE the free passage of sufficient AIR to the burning coal, so all the oxygen needed to form carbonic ACID gas may be supplied, and thus avoid the great loss sustained when, because of restricted AIR supply, only enough oxygen reaches the coal to form carbonic OXIDE gas—when TWO-THIRDS of the HEAT which we should get from the coal will be LOST.

19—How Fire Forms Water.

Hydrogen gas forms about 5 per cent. or a 20th part of the weight of bituminous coal. But in burning, it gives off 62,000 heat units per pound—over FOUR TIMES more heat than is given off by the perfect burning of the same weight of carbon, so a large part of the total heat of burning coal comes from the hydrogen gas it contains and gives up in the fire.

As stated, the burning of hydrogen gas CREATES STEAM—IN THE FIRE. When steam cools and condenses—we have WATER. It seems strange that fire should form water. But there is no other way in which water can be formed except BY FIRE—by the burning of hydrogen and oxygen gases.

When we consider the vast oceans of water on the earth, every pound or pint of which in forming generated 62,000 units of heat—enough to boil away 50 pounds of ice water—we can form some faint conception of the fierceness of the heat of the great conflagration that raged for ages when the Earth was A SUN of liquid FIRE—instead of the temperate and beautiful abode we find it now, with so many abundant provisions for our needs—among the chief of which are AIR and COAL and WATER!

LESSON 6.

BURNING OF THE SOLID PART OF COAL.

The Burning of a Diamond. How the Sun Keeps Hot. Why Coal Should be Broken Into Small Pieces. Rate of Combustion.

20—The Burning of a Diamond.

The liberation and burning of the gases from the coal act like KINDLING to heat up and set on fire the "fixed" CARBON of the coal, which afterward burns on the grate without flame or smoke—as glowing red and white hot coals. This SOLID part of the coal is the larger portion of it, from which we get the most heat—so it deserves our special attention.

How this part of the coal burns on the fire is beautifully illustrated by the burning of a diamond in oxygen gas, as described by Professor John Tyndall, another great English philosopher, as follows:—

"This brilliant gem is composed of the same substance as common charcoal, graphite, or plumbago. A diamond is pure CARBON—and carbon burns in oxygen. Here is a diamond held fast in a loop of platinum wire. Heating the gem to redness in this flame, I plunge it into this jar, which contains oxygen gas.

"See how it brightens on entering the jar of oxygen, and now it glows, like a little star, with a pure white light. How are we to figure the action here going on? Exactly as you would present to your minds the idea of meteors showering down upon the Sun.

"You are to figure the atoms of oxygen—SHOWERING against this diamond on all sides! They are urged toward it by what is called "Chemical affinity"; but this force, made clear, presents itself to the mind as pure ATTRACTION—of the same mechanical quality as Gravity.

"Every oxygen atom as it strikes the diamond's surface and has its motion destroyed by its COLLISION

with the carbon, assumes the motion we call HEAT—and the heat is so intense, the attractions exerted at these molecular [immeasureably small] distances are SO MIGHTY that the crystal is kept white hot, and the compound formed by the union of the diamond's atoms with those of the oxygen—flies away as CARBONIC ACID GAS."

21—How the Sun Keeps Hot.

What Professor Tindall said of "meteors showering down upon the Sun" refers to a belief that the Sun's heat is partly maintained by the BLOWS of meteors striking it on being drawn to it by its powerful attraction, as bodies are drawn to the Earth by Gravity.

It is known that there has been no perceptible reduction of the Sun's heat in the last 2,000 years. How is it kept so hot? We know that BLOWS of any kind will produce HEAT. A nail placed on an anvil can be hammered too hot to hold. A "pound" in any part of an engine produces great heat.

Knowing the weight of an object and the velocity of its movement—the force and heat of its BLOW on striking a target can be calculated. The blow of a lead bullet, fired from a gun with sufficient force to strike a target at a velocity of 1,500 feet a second—generates enough heat to partly melt the bullet.

The velocity of the Earth, in speeding through space on its annual journey around the Sun, is about 19 miles or 100,000 feet—a second. Should this great flying ball strike an object strong enough to stop it—the BLOW would make as much HEAT as could be obtained by burning FOURTEEN globes of solid coal—each as large as the Earth.

Should the Earth change its course and fall into the Sun, it would, gaining speed as it fell, strike the Sun at a velocity of about 300 miles a second. It has been estimated that such a TREMENDOUS BLOW would generate more HEAT than the burning of 5,600 worlds of coal, or enough to keep up the great heat of the Sun for a hundred years!

22—Why Coal Should Be Broken Into Small Pieces.

Whether the heat of the Sun is maintained by the blows of meteors or other causes—it is surely true that the HEAT of COMBUSTION is due to the BLOWS of the CLASHING ATOMS of the substances that in burning enter into CHEMICAL UNION.

"Dusky diamonds" in a furnace, after their gaseous matter is expelled, are burned exactly like the diamond in the jar of oxygen. The intensity of heat depends upon the rapidity of combustion, which in turn depends largely upon the SURFACE of the coal exposed to the attacking atoms of oxygen.

Therefore all large lumps of coal should be broken to small sizes (about like apples) before being spread over the fire, so as to EXPOSE the LARGEST POSSIBLE SURFACE for contract with the oxygen gas in the air.

Some careless firemen dislike and neglect doing this, but they thus waste fuel and only ADD to their work finally, because every wrong practice in firing—injures the fire, burns more coal, and increases the labor of firing.

23—Rate of Combustion.

The term "rate of combustion" means the weight of fuel burned in any furnace on each SQUARE FOOT of its grate surface—in an HOUR.

A fire may burn slowly because of a weak draft or small supply of coal, and consume but five pounds of coal on each square foot of its grates in an hour. This would be its rate of combustion—five pounds.

Or, because of a strong draft and heavy supply of coal, a furnace might burn 100 pounds of coal per hour on each square foot of its grates, as is done on locomotives. Then this would be its rate of combustion—100 pounds.

When coal is burned so rapidly it is burned very wastefully, because not sufficient TIME is given for the meeting and combining of the carbon and gases of the coal with the OXYGEN in the air to produce perfect combustion, and the greatest amount of HEAT.

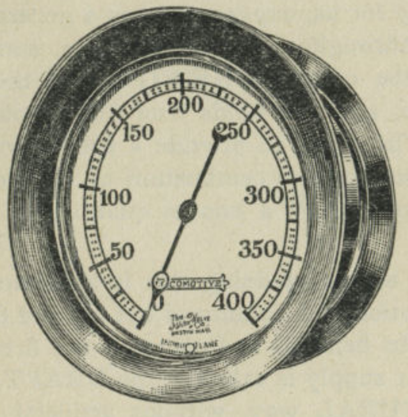
Especially the GASEOUS part of the coal requires TIME for burning IN the fire box, or it will escape unburned as SMOKE—uselessly wasted.

TIME is also needed for the supply of sufficient AIR to the SOLID part of the coal left to burn on the grates as coals —so as to avoid the great loss of heat through its burning to make carbonic OXIDE instead of carbonic ACID gas.

Economy of fuel as well as ease in firing, require that the rate of combustion shall always be kept as SLOW as possible —but yet supply enough heat to keep up the regular steam pressure in the boiler.

A fireman who intelligently looks out for his own and his Company's welfare will always be guided by this knowledge, and will invariably supply NO MORE COAL to his fire than it actually REQUIRES to keep up steam.

(Subject 24 is omitted)



A STEAM GAUGE.

A Steam Gauge is placed on top of the boiler in the cab, and within the easy view of the engineer and fireman. It is the fireman's constant guide in his work.

By an interior mechanism the pointer is caused to move and indicate the varying steam pressure in the boiler, by pointing to the figures on the face of the gauge. These figures show the POUNDS of steam pressure per SQUARE INCH inside the boiler.

LESSON 7.

THE DRAFT THROUGH THE FIRE.

A locomotive's POWER depends upon—and the fireman's WHOLE WORK is regulated by the OPERATIONS OF THE DRAFT. Correctly understanding these enables a fireman to avoid committing faults and omitting duties which injure the fire, waste fuel and damage the boiler.

Natural Draft. Stimulated Draft. How the Draft is Stimulated. Draft From Full Stroke Exhausts. Draft From Short Cut-Off Exhausts. The Blower—How It Works. Use and Misuse of the Blower.

25—Natural Draft.

About 150 cubic feet of air is known to be the exact amount needed to supply the oxygen gas for the perfect combustion of each pound of coal. But in practice it is found necessary to supply double this quantity, or 300 cubic feet, in order to insure the presence in the fire of sufficient oxygen.

Fortunately for us, oxygen gas has a general and invariable distribution throughout our atmosphere, somewhat like salt throughout the ocean. ONE-FIFTH of the volume of the air is oxygen, and this holds true throughout the surface of the earth. Therefore, to provide a fire—anywhere—with the needed oxygen for the combustion of its fuel we have only to arrange to DRAW a known quantity of air through the furnace.

The usual means of doing this is a chimney, wherein the ascending motion of a column of hot air and fire gases is used to draw air in beneath and through the fire. Because thus drawn, the air supply is called—"the DRAFT." When drawn in this NATURAL way, without artificial assistance, it is called—NATURAL draft.

GRAVITY is the cause of the natural draft through a chimney. This force pulls everything toward the center of the Earth, even the air. This pull is manifested in what we call

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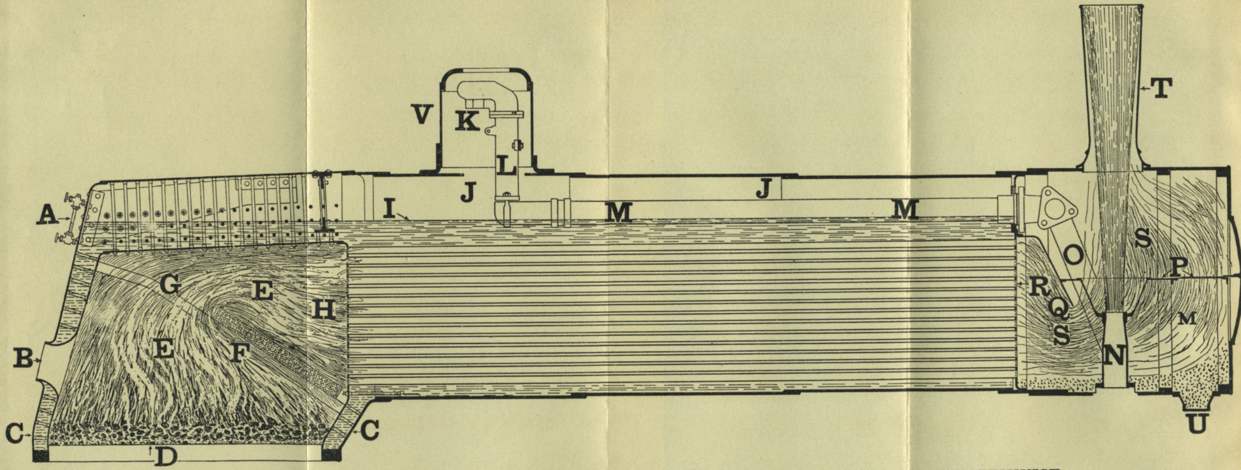


PLATE TWO—DRAWING TO SHOW A LOCOMOTIVE BOILER—CUT IN HALF—LENGTHWISE.

INDEX

A—Water-gauge glass.
B—Fire door way.
CC—Front and back water-legs.
EE—Fire box.
F—Arch.
G—Arch tube.
H—Back tube sheet.
I—Water-level.
JJ—Steam space.
K—Throttle valve.
L—Stand pipe.
MM—Dry pipe.
N—Exhaust pipe.
O—Steam pipe.
P—Netting.
Q—Deflector plate.
R—Front tube sheet.
SS—Smoke box.
T—Smoke stack.
U—Cinder hopper.
V—Steam dome.

the WEIGHT of any object. Air has weight—at the level of the sea it weighs about 15 pounds per square inch—accurately, fourteen and seven-tenths (14.7) pounds.

If two liquids or gases are mixed together—gravity pulls DOWN the heavier of the two, thus causing the lighter one to RISE through the mass. Oil, if mixed with water—RISES rapidly through the heavier water to the top. Bubbles of air, steam or gas do the same.

When air is heated it EXPANDS and occupies more space. It is then LIGHTER than it was before the expansion. If surrounded by cold air, the hot and lighter air will RISE through the cold and heavier air—as we often see it do in hot-air balloons.

In just the same way the mixed hot air and fire gases in a chimney RISE through its interior, leaving a partial VACUUM or empty space behind—to fill which the cooler air below rushes in through the fire and follows the ascending column of heated air and gases in the chimney. Thus the NATURAL DRAFT through a fire and a chimney is kept up.

26—Stimulated Draft.

Natural draft acts on the fire in a locomotive when the engine is at rest—the smoke stack being the chimney. But to provide the intense heat needed to produce the great amount of steam required by a running locomotive—A MUCH STRONGER draft must pass through the fire to force its burning to the intensity necessary to RAPIDLY boil the water in the boiler.

The necessary rapidity of this boiling is shown by the fact that locomotives use about half a barrel of water turned to steam every minute while running along ordinarily—and this rate is often increased to a barrel a minute in hard pulling or fast running.

To provide the great heat necessary for this rapid production of steam—the used or "exhausted" steam, in escaping from the cylinders after its work there is finished, is utilized to produce A BLAST that will induce a draft through the fire so powerful that it often keeps lumps of coal as large as walnuts dancing up and down, like drops of water on a red hot stove—until they are burned, or reduced to the size of peas—and drawn through the tubes and shot from the stack like rockets.

27—How the Draft Is Stimulated.

When the engineer pulls the throttle lever in the cab, this opens the throttle valve located at—K—in the top of the STANDPIPE—L—which may be seen extending up into the steam dome—V—in the interior view of a boiler shown on Plate Two herewith.

The dome is provided, and steam is taken from its highest point, so the DRIEST steam—unmixed with spray from the boiling water beneath—may be sent to the cylinders to drive the engine.

When the throttle valve is open, steam flows through it from the STEAM SPACE—J—(the space above the water in the boiler) into the stand pipe—L—thence down into the DRY PIPE—M and M—which conducts it to the front end or SMOKE BOX—S S. Here it enters the steam pipes—one shown at O—and flows in these down into the steam passages in the cylinder castings—to the steam chests on top of the cylinders. From here the steam is finally admitted to the cylinders on each side of the engine by the automatic actions of the steam valves.

Let us carefully study the actions of the steam in entering, working in and leaving the cylinders, and thereafter stimulating the DRAFT to nicely suit the varying needs of the engine—as our own breathing changes with our varying exertions, and for a similar purpose—thus making the locomotive the most lifelike of all Man's creations.

Figure 1 on the next page shows the inside arrangement of a steam chest and a cylinder. They are shown as cut in half—lengthwise. In this drawing—A and A—is the space inside the steam chest which is filled with "live" steam which has just arrived from the boiler in the way described, and is waiting to be admitted to the cylinder—to there perform its work of pushing the piston.

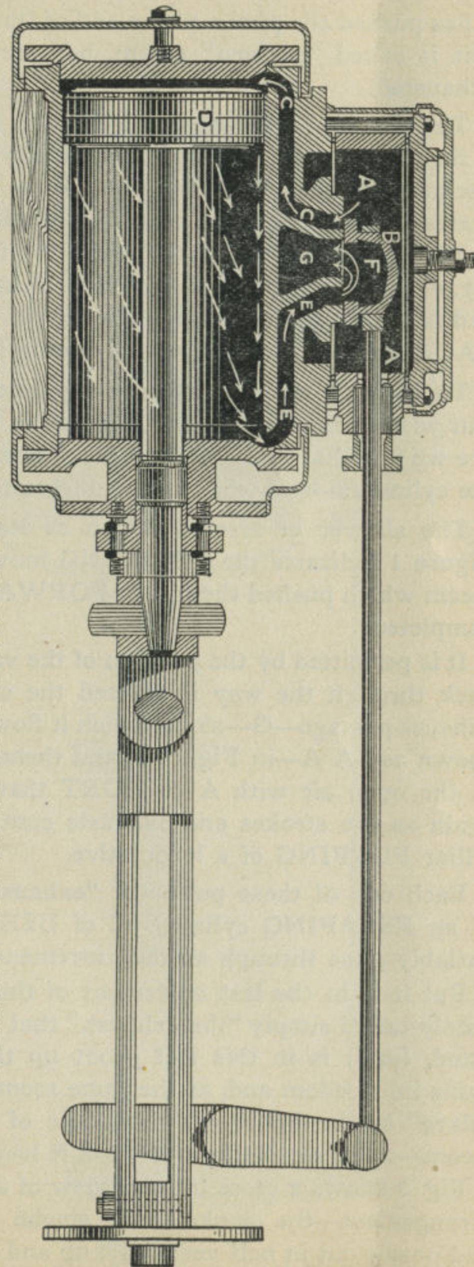


FIG. 1. SECTIONAL VIEW THROUGH STEAM CHEST AND CYLINDER.

Showing the piston, D, as having just completed a forward stroke, and ready to begin a backward stroke.

NOTICE that the valve, B, is moving backward, and is allowing EXHAUSTED steam to ESCAPE from the cylinder through the back steamport, E E, to the exhaust-cavity in the valve, F, thence into the exhaust-passage, G, and thence to the exhaust-pipe in the smoke-box.

NOTICE also that the valve, B, is BEGINNING to ADMIT new live steam from the steam chest, A, to enter the cylinder IN FRONT of the piston through the front steam-port, C C; thus commencing the backward stroke.

Steam fresh from the boiler is called "live" steam. After it has pushed the piston to the end of its stroke in the cylinder—it is called "exhaust" steam, because its pushing effort is exhausted.

The piston—D—is shown in Fig. 1 as having just completed a forward stroke, and as being ready to begin the return backward stroke. The mechanism of the valve gear operates so that at this moment the steam valve—B—is pulled backward so that its front edge UNCOVERS the front steam-port opening, allowing "live" steam to enter the steam-port—C and C—and flow into the cylinder where it will push the piston—D—BACKWARD, as it is shown as doing in Figure 2.

This is how steam reaches the cylinders and works therein. But as we are studying the creation of the draft through the fire we now have greater interest in how the steam LEAVES the cylinders—and what it does thereafter.

The shower of arrows shown as leaving the cylinder in Figure 1 indicates the ESCAPING movement of the exhaust steam which pushed the piston FORWARD in the stroke just completed.

It is permitted by the position of the valve—B—to ESCAPE back through the way it entered the cylinder—E E—to the exhaust-passage—G—along which it flows to the exhaust-pipe, shown as—A A—in Figure 3, and thence up the smoke stack to the open air with A REPORT that—repeated again and again as the strokes and exhausts continue—produce the familiar PUFFING of a locomotive.

Each one of these puffs—or "exhausts"—is the REPORT of an ESCAPING cylinder-ful of USED steam that has invariably gone through all the movements just described.

But it is in the last movement of the exhaust steam, commonly called simply "the exhaust," that we are specially interested, for it is in this last shoot up the stack that it both gains its freedom and, at the same moment, produces another "slave" in the boiler—in the shape of an equal quantity of steam—to repeat the useful work it has performed.

Fig. 3 shows a cross interior view of a locomotive front end arrangement—the smoke stack, smoke box and exhaust pipe and nozzle cut in half vertically, up and down. B and B show

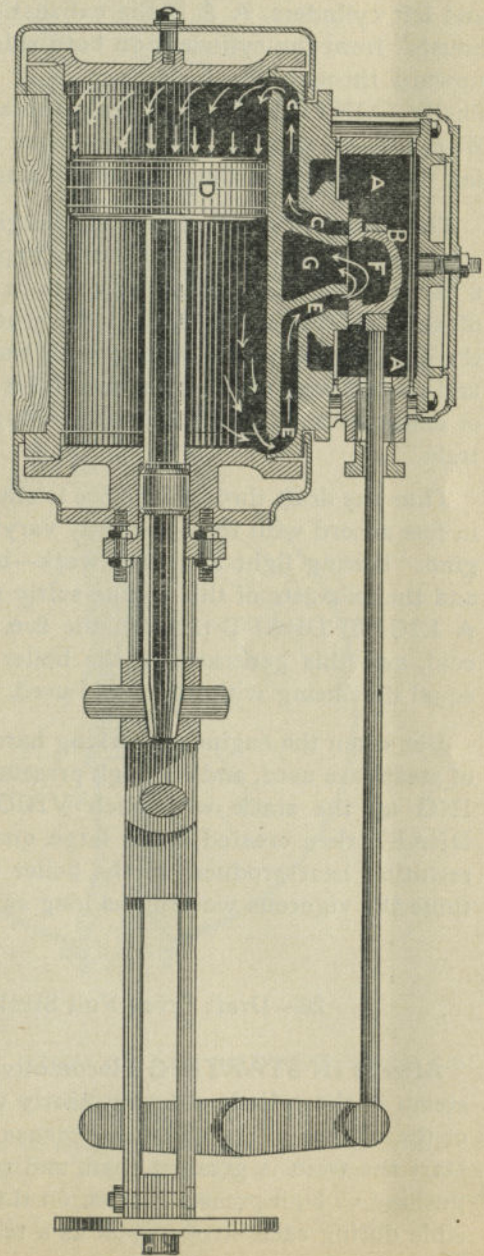


FIG. 2. SECTIONAL VIEW THROUGH STEAM-CHEST AND CYLINDER.

Showing the piston, D, as having begun and traveled SIX INCHES, or one-fourth of a backward stroke.

NOTICE that the valve by this time has moved forward and CLOSED the front steam-port, C C, thus CUTTING OFF the flow of steam to the cylinder. The steam that is so far admitted and is thus imprisoned in the cylinder, pushes the piston the remainder of the stroke by its EXPANSION.

An engine using steam in this way is said to be:—"working at SIX INCHES" or "working at a SIX INCH CUT-OFF."

the terminations of the exhaust passages leading from the right and left cylinders, A A is the exhaust pipe in which the "exhausts" from the cylinders on both sides enter to be directed upward through the inside centre of the smoke stack, and finally CONTRACTED in their passage through the NOZZLE—N—so they may be given extra force and velocity during their last act in shooting up the stack.

The stream of steam shown as emerging from the nozzle and ascending the stack, in a constantly expanding volume, creates a partial VACUUM or empty space in the smoke-box; and to fill this—AIR is drawn through the grates and fire and tubes to the smoke box, where—along with the fire gases and smoke and cinders with which it has mixed—it is caught by the stream of exhausts and HURLED UP through the stack above the train.

Thus the draft through the fire is stimulated and maintained in fine accord with the constantly varying workings of the engine. During light and easy work—but little steam is used, and the exhausts of this escape softly up the stack, producing A LIGHT DRAFT through the fire, which burns but little coal, and this generates in the boiler only enough steam to equal that being withdrawn and used.

But when the engine is working hard—then great quantities of steam are used, and the high pressure exhausts go SNORTING up the stack with such VIGOR that the STRONG DRAFT then created burns large quantities of coal, and the resulting heat produces in the boiler sufficient steam to continue the vigorous working as long as necessary.

28—Draft From Full Stroke Exhausts.

Always IN STARTING a locomotive it is necessary to admit steam to the cylinders during nearly the WHOLE LENGTH of the strokes of the pistons—because the strain of the pull to start the train is greatest then, and requires the hard, steady pushing of high pressure steam on the pistons as long as possible during each stroke—just as a team of horses, in starting

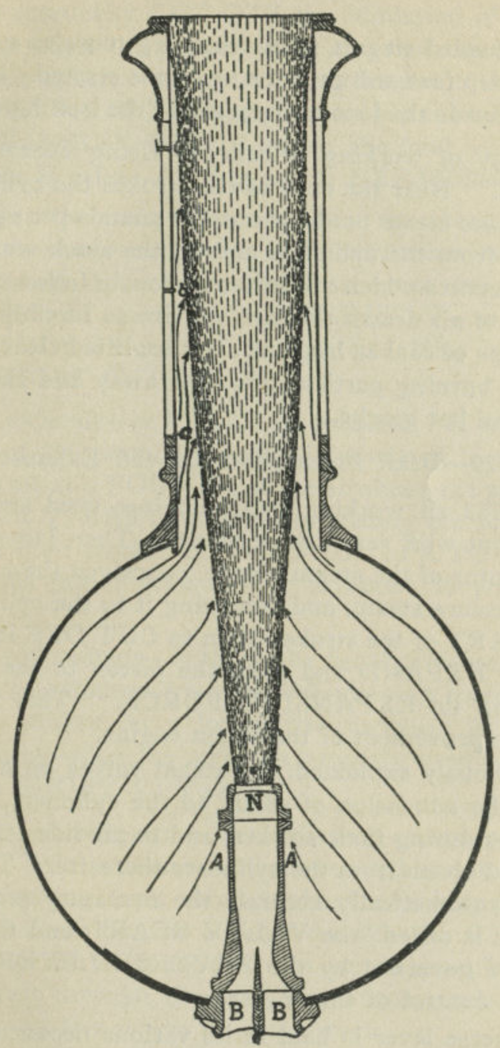


FIG. 3. SECTIONAL VIEW OF LOCOMOTIVE SMOKE-BOX AND STACK.

Showing the smoke-box, or front end, and the stack cut in half vertically—up and down—and the action of exhaust steam in escaping up the smoke-stack. Determined by tests conducted by a committee of the American Railway Master Mechanics' Association.

a heavily loaded wagon, strain their leg muscles strongly during each step forward until the wagon is started. Not without good reasons is the locomotive called "the iron horse."

This way of working is called—"Using Steam at FULL STROKE." Near the ends of the strokes the cylinder-fuls of high pressure steam used—about 150 pounds per square inch—ESCAPE from the cylinders and up the stack with LOUD—SHARP reports which are instantaneously followed by strong BLASTS of air drawn through the fire so forcibly that sometimes lumps of coal as large as eggs are lifted clear off the fire, and small burning particles are torn away and shot from the stack as red hot sparks.

29—Draft From Short Cut-Off Exhausts.

Until 1782 all working steam engines used steam "at full stroke"—but with very low pressures. Then James Watt, the chief inventor of the steam engine, conceived the idea of using higher pressure steam, and admitting it to the cylinder during only A PART of the stroke—then to CUT OFF its admission and let it EXPAND and push the piston to the end of the stroke with its EXPANSIVE FORCE. This was Watt's greatest improvement of the steam engine.

As previously explained, the steam valves on a locomotive regulate the admission of steam to the cylinders, to push on the pistons during their strokes, and to provide for the escape of the used steam from the cylinders thereafter. The mechanism that automatically controls the necessary movements of the valves is called "the VALVE GEAR"; and the workings of this are governed by the REVERSE LEVER in the cab under the control of the engineer.

The reverse lever is held in its various necessary positions by a latch that engages in closely spaced notches in an iron QUADRANT—along which the reverse lever moves as its position is changed.

To cause the engine to work at full stroke ahead, as in starting, the reverse lever is placed FULL FORWARD. After the train is fairly started—the reverse lever is pulled backward several notches and latched in position. This causes the valve gear to alter the movements of the steam valves so

they will automatically CUT OFF the admission of steam to the cylinders when the pistons have traveled over the first HALF of their strokes—thus permitting the steam then in the cylinders to EXPAND and push on the pistons—PURELY with its EXPANSIVE FORCE during the final half of their strokes. This is called—"Using steam EXPANSIVELY."

Gradually as the train attains speed from about 10 to 15 miles an hour—the reverse lever is pulled further back along the quadrant and latched in position to cause the valves to CUT OFF the admission of steam SHORTLY—or at about A FOURTH of the length of each stroke. This is—"Using steam at a SHORT CUT-OFF."

As steam expands—it FALLS in pressure. If while running, steam of 200 pounds pressure is admitted to the cylinders and cut off at a FOURTH of the strokes—the steam will expand FOUR TIMES in volume in pushing the pistons the remainder of their strokes and will FALL to A FOURTH of its 200 pounds initial pressure—or to about 50 pounds per square inch.

This then—50 pounds—is about the usual pressure of steam that escapes as exhausts from the cylinders on completion of the pistons' strokes on a locomotive carrying 200 pounds steam pressure—when the steam is properly used while running with a SHORT CUT-OFF.

In working at full stroke the exhausts escape practically UNREDUCED in pressure—at between 100 and 150 pounds—and the resulting draft through the fire is very hard and STRONG. In working at a short cut-off—the REDUCED PRESSURE of the escaping exhausts causes a much milder—SOFTER draft through the fire—that burns much less coal and throws very few sparks from the stack.

30—The Blower—How It Works.

As the exhausts are used to stimulate the draft through the fire while the engine is running and "using steam"—so a very simple arrangement called "the BLOWER" is used to stimulate the draft as may be needed while the engine is standing, or while it is running with steam shut off. The natural draft acting on the fire at such times is not always sufficient, and must frequently be stimulated with the blower.

The blower consists simply of a cock on the boiler-head in the cab, which when opened admits steam to a one-inch pipe that runs along the outside of the boiler to the smoke-box—which it enters and reaches to the exhaust-pipe. The blower-pipe ascends the outside of the exhaust-pipe—A A Fig. 3—to nearly the tip of the exhaust-nozzle—N—so it will point upward to the centre of the stack.

Thus when the blower-cock in the cab is opened, a small stream of steam flows through the blower-pipe and escapes up the stack—causing a steady draft through the fire like the natural draft—only strongly stimulated.

31—Use and Misuse of the Blower.

The blower is used mostly by the fireman—and he should use it properly and judiciously, because its careless use wastes coal and damages the boiler.

In raising steam—do not use the blower unless it is necessary to obtain increased pressure within a short time. Even then—use it as LIGHTLY as the available time will allow, or it will cause waste of fuel and possible damage to the boiler. The FULL TIME allowed should always be used to GRADUALLY raise the steam pressure, either before starting or while on the road.

The passage or TRANSMISSION of HEAT from the fire into the water through the metal surfaces of a boiler—takes TIME. So the lighter the draft, and the slower the motion of the hot fire gases in passing the heating surfaces and through the tubes of a boiler—the MORE HEAT we capture for USE from the burning of each pound of coal. Therefore it is wasteful to make the fire burn any faster than necessary.

Another and more important reason for always increasing the steam pressure GRADUALLY is because with increasing steam pressure there is an increase of TEMPERATURE of the boiler and its steam and water.

In increasing the steam pressure from 50 pounds to 100 pounds the temperature of the boiler is increased FORTY DEGREES, or nearly one degree per pound. Likewise an increase from 100 pounds to 200 pounds pressure increases the temperature FIFTY DEGREES.

The boiler EXPANDS when heated, and when the steam pressure is raised rapidly—the RAPID RISE of temperature causes SUDDEN EXPANSION of the boiler—which is DAMAGING to its plates and stay bolts—often cracking the plates and breaking the bolts.

Naturally, if the steam pressure is permitted to FALL, there is a fall of temperature—or COOLING of the boiler and CONTRACTION of its parts. These movements of expansion and contraction, or stretching and shrinking, following changing steam pressures, are very DESTRUCTIVE in their influence on locomotive boilers, and teach the importance of ALWAYS keeping the PRESSURE as STEADY as possible——and of guarding against rapid changes of pressure either way.

The blower usually gets in its worst work on the boiler while being used in working at the fire when it is at a low heat, or in cleaning the fire. In these operations the SOLE USE of the blower is to create enough draft to keep the fire gases from coming out of the open doorway into the cab.

A very LIGHT application of the blower is enough for this purpose—but careless firemen often put it on its full force—causing a draft so strong that a large volume of cold air is drawn into the fire box through the open doorway—and HURLED against the tube sheet and tubes, the surfaces of which are over three hundred degrees HOTTER than the blast of chilling air that then sweeps in upon them. Many leaking—"weeping"—tube sheets in locomotive fire boxes show the ABUSE they suffer from such MISUSE of the blower.

LESSON 8.

OBSTRUCTIONS TO THE DRAFT.

The subjects in this Lesson deal with conditions of very great importance in firing every locomotive.

Ashes and Clinkers on the Grates. Purpose of Movable Grates. The Ash Pan. Clinker on the Tubes. Tubes Stopped up.

32—Ashes and Clinkers on the Grates.

As we have seen, the work of the draft—whether natural or stimulated—is to make the fire burn with the intensity necessary to generate steam as fast as the engine needs it. This is usually easily done when the fire is fresh and "clean," as at the beginning of trips.

But all coal contains impurities which do not burn—soil, slate, stone, etc. Ordinarily these impurities, called ASH, or "ashes," amount to about 10 per cent. of the weight of coal—or about 200 pounds of ashes in a ton of coal.

As the coal in burning disappears—this incombustible matter remains on the grates—covers the air spaces in them, and OBSTRUCTS the inflow of air to the fire.

Clinkers are formed in the fire by the ashes MELTING and running together into solid chunks, varying in size from a man's fist to masses as large as the trunk of his body. Air can no more pass through them than through a stone.

When a bed of ashes or clinkers three or four inches thick forms over the whole grate surface—it seriously obstructs the draft, and causes waste of fuel in imperfect combustion.

Sometimes with poor coal, or careless management of the fire when on a trip where much coal is burned—a mass of ashes or large and thick clinkers will cover the grates to a depth of 8 to 12 inches. Then only a FRACTION of the air the fire needs can reach it, and the coal burns so poorly that not enough heat is produced to make sufficient steam. Then

with reduced steam pressure the engine loses time with its train—or stalls on some ascending grade. It is very discreditable to a fireman to allow his fire to get into such a bad condition.

33—Purpose of Movable Grates.

Movable grates are placed on locomotives to enable firemen to remove the ashes that accumulate on them—when they begin to obstruct the draft—and before they melt and form large clinkers.

The grates are made in sections, some with fingers which interlace. They have spaces between them for the admission of air, and they are so connected that they can be rocked or shaken—so the ashes will fall through their openings into the ash pan. Lightly interlace your fingers and move them up and down, so you can see the action of the grates when they are shaken.

34—The Ash Pan.

The "ash pan" is a sheet iron pan that fits and is attached to the bottom of the fire box. It extends beneath the grates, to catch and hold the hot ashes and burning coals which fall through them—so these cannot fall on and set fire to inflammable objects on the road-bed, such as ties, the timbers in cattle-guards, culverts, bridges and station platforms.

Nearly all the air for the fire must pass into the ash pan before it can reach the grates, through which it must be drawn by the draft. As the ashes accumulate in the ash pan and partly fill it, the area or space for the ENTRANCE of air is reduced—and another obstruction to the draft begins its evil work to cause imperfect combustion, waste of fuel, and decrease the heat of the fire.

Ashes and clinkers in the bed of fire and in the ash pan—are usually the worst obstructions to a locomotive's draft, and it is very important that the fire and the ash pan shall be clear of these impediments at the beginning of a trip, and KEPT SO as nearly as possible during the run over the road.

35—Clinker on the Tube Sheet.

Clinker on the tube sheet is another common obstruction to the draft. It is caused by some of the impurities in the coal being lifted from the fire by the draft, and hurled as small melted particles against the tube sheet—to which they cling like mud plastered on a wall. This is often called "honey-comb," because the particles accumulate on the tube sheet until some or most of the tube openings are covered and CLOSED—just as the cells in real honey-comb are sealed over with bees' wax.

Of course the draft cannot act through sealed tubes, so when clinker covers many tube openings the heat of the fire is reduced and coal is wasted in imperfect combustion—and the work of the engine suffers for want of steam.

This "honey-comb" is usually only about a quarter of an inch thick, and can be easily scraped off the tube sheet with the ash hoe. See the illustration of an ash hoe on page 46. REMOVE as soon as you can any clinker that forms on your tube sheet. Do not jab the iron ash hoe roughly against the tube sheet. This would nick the sheet and might cause some of the tubes to leak. All nicks or indentations on the tube sheet, or around the tube openings—provide clinging places for the particles of clinker to stick to and continue their bad work.

Clinker around the tube openings, and on the heads of stay bolts has a tendency to cause them to leak—so it must be removed for this reason also.

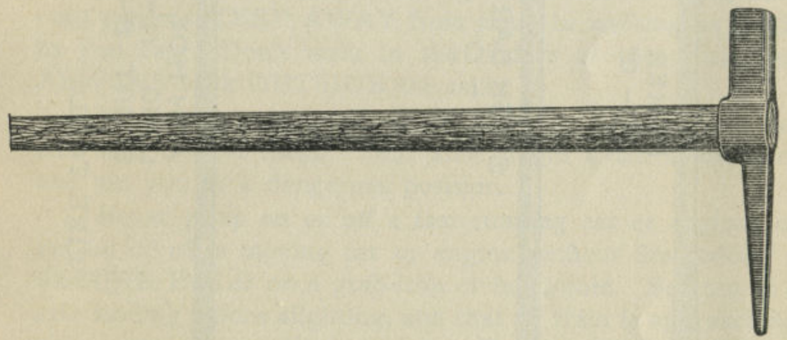
36—Tubes Stopped Up.

Another usual obstruction to the draft is in tubes partly filled or entirely closed by accumulations of soot and fine ashes, which are deposited in them by the draft.

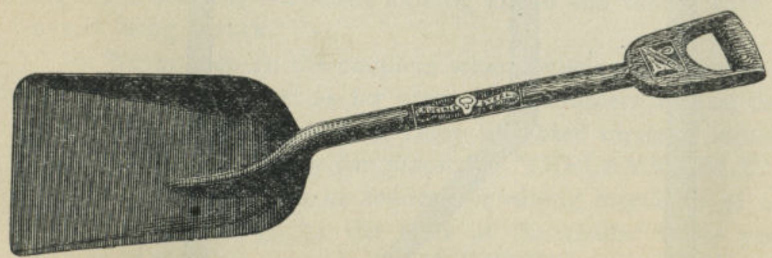
A large amount of useful heat is lost by even the partial filling of ONE tube with this material—because it is a NON-CONDUCTOR of heat, and prevents much of the heat of the fire gases in passing through the tube from entering the water in the boiler.

A tube clogged with this stuff is in a worse condition than if its opening were covered with clinker—which is easily removed. Tubes internally clogged must usually be bored out with a long auger—or an air-blast—used for this purpose by workmen at terminals while there is no fire in the engine, when this work is reported as necessary by the engineer.

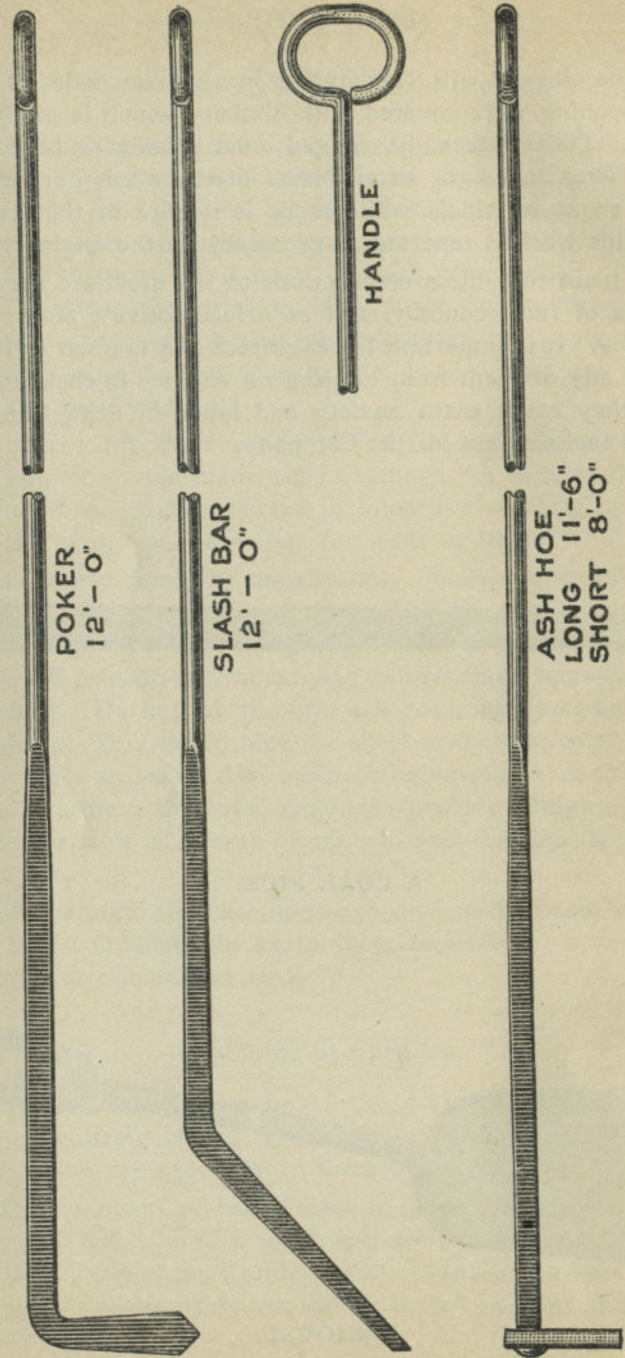
It is plain that these obstructions to the draft are the arch enemies of fuel economy, and of a locomotive's power and efficiency. It is important for engineers and firemen to PREVENT any of them from existing on engines in their charge—for they cause extra anxiety and labor in firing, and increased fuel expense for the Company.



A COAL PICK.



A SHOVEL.



FIRE TOOLS

TWELVE SAFETY COMMANDMENTS

1. Always ring the bell—as a warning—before the engine moves forward or backward.

2. Always keep your mind on your duty. Be deliberate, and make sure in your movements that you do not put yourself into danger.

3. Always look in BOTH directions before you step upon a railroad track. In crossing tracks—beware of standing cars and engines. Give them a wide berth.

4. Never step from one track to another to let a train pass —GET OFF ALL the tracks.

5. Watch your steps in walking on, across or along railroad tracks. KEEP AWAY from them in walking as much as you can. Don't walk in the middle of the track, but ALWAYS walk OUTSIDE the rails.

6. Never step on the rails or on "frogs." RAISE your feet and step OVER them. Your shoe might catch somewhere and pin you in a dangerous position.

7. Never jump on or off a fast running car or engine; or get on or off a moving car or engine without first taking a SECURE HOLD on a grab-iron or hand-hold. Be sure of a safe landing before alighting, and that no train is approaching either way on an adjacent track. Always—LOOK AHEAD —in getting on or off.

8. Never go beneath an engine until you KNOW the engineer knows what you are going to do.

9. Never lean out beyond the side of the cab while the engine is running—without looking ahead and taking care to avoid being struck.

10. Never step on the couplers when crossing over between cars. Keep your feet as far away from couplers as you can.

11. Never light a match or carry a lighted torch or lantern near a loaded or empty car placarded "INFLAMMABLE"— or near any car, tank or tender containing any kind of oil.

12. When you go to the back of the tender while your engine is running—keep in the MIDDLE of the coal pile, and guard against any jolt or sway that might throw you off.

INSTRUCTIONS FOR FIREMEN

LESSON 9.

STARTING ON THE RUN.

Much of the success of every trip depends on the proper preparation of an engine and its fire and fuel for a RIGHT START.

Preparing an Engine for the Run. Inspection Before Starting. Wetting the Coal. Raising Steam. Starting on the Run. Evils of an Open Fire Door.

37—Preparing an Engine for the Run.

You should always arrive at your engine fully thirty minutes before leaving time. There is always enough to do before starting to keep you busy half an hour.

As sufficient WATER in the boiler is the FIRST SAFETY NECESSITY you must MAKE SURE that the water-level is at A SAFE height as soon as you arrive on the engine, and before you replenish the fire or stimulate its burning.

Look at the fire as soon as you can and note its condition. This may save delay and trouble. Do not delay in seeing that the grates are COMPLETELY COVERED with live fire, and if any fresh coal is needed on the fire—put it on.

The men who "fire-up" the engines are sometimes careless about the condition of the bed of fire they leave on the grates, especially about spreading the fire EVENLY over the entire grate surface. They sometimes leave the grates in the CORNERS of the fire box uncovered with fire—and often the FORWARD part of the grates, next to the tube sheet. It is most important that these parts should be kept WELL COVERED with LIVE FIRE to prevent cold air being drawn into the tubes to chill them and cause them to leak.

When air is permitted to pass through the fire box of a locomotive without being brought close to burning fuel—it reaches the tubes 200 or 300 degrees COLDER than they are, and immediately chills, contracts and DAMAGES them. This injury

is intensified by every increase of draft under such circumstances. Therefore—DON'T use the blower any stronger than is NECESSARY—until the grates are COVERED ALL OVER WITH LIVE FIRE.

38—Inspection Before Starting.

After making sure that your fire is in good condition, you should next make sure that the tube-sheet is clear of adhering clinker or "honeycomb."

Also see that the ash pan is clear of ashes, and that the grates are ALL LEVEL and connected. This must be done by getting down off the engine and looking carefully into the ash pan.

Notice if EACH BOLT in the grate connections is in place. Sometimes these get displaced through rough usage by roundhouse men; and it is very important that such a defect should be discovered and reported before starting out, otherwise the disconnected grate may be partly melted or "burned," and cause a serious train delay.

Examine the ash pan at this time also, and see that it is in good condition to prevent hot coals dropping along the road —which might start a destructive fire.

The proper condition and operation of the grates is so important that—in addition to this inspection—they should also be TESTED to make sure they are in good working order by operating the shaker rigging. The damper rigging (where provided) should also be operated to make sure of its condition.

If the engine is equipped with a mechanically operated fire-door and grate-shaker—see that they are in good working order.

Before starting, you must also make sure that the tender is FULL of water, and the sand box FULL of sand; also that you have upon the engine the necessary tools for handling the coal and attending to the fire—a shovel and an extra shovel—a coal pick, ash hoe and slash bar. Anything found in bad order, or any necessary tool found missing must be reported to the engineer.

THOROUGH INSPECTION of all these matters before starting is of FIRST IMPORTANCE—to avoid engine failures on the road, and resulting delays to trains.

After you complete these inspections—put everything inside the cab in order. Wet and sweep the deck and wipe the dust from the cab seats, boiler head, gauges, etc. Take PRIDE in this work and do it well. A GOOD fireman is always neat and clean.

Always before leaving—make sure that the top of the coal pile on the tender is leveled or "TRIMMED" so no coal will fall off while running—which is both WASTEFUL and DANGEROUS.

Every needed preparation should be made before leaving, including the breaking of large lumps of coal, so that after starting you can give full attention to the work of properly FIRING the engine.

39—Wetting the Coal.

Cleanliness requires that in warm and moderate weather the coal on the tender must be dampened to keep down the dust. Attend to this before starting out on trips.

Fine coal needs to be well dampened so it will fall and burn ON the fire—instead of being whirled by the draft unburned through the tubes. Also, moist fine coal cokes better on the fire and is not burned up so quickly.

In moderate weather frequently use the sprinkling hose, usually attached to the left injector—to wet the coal on the tender and the deck in the cab. Don't do this if the weather is so cold that ice will form on the deck, gang-way or coal.

This sprinkling should be done frequently and lightly to secure a uniform effect. Don't throw large quantities of water on the coal pile.

In using the hose be careful to avoid burning yourself or others with its stream of VERY HOT water. DON'T lay the hose down or let loose of it while the water is passing through it. FIRST—shut off the water.

An uncontrolled hose, having even a small bend in it may be straightened out by the water passing through it—and send its burning stream in unexpected directions.

40—Raising Steam.

Until leaving time is near—do not build a big, hot fire. Keep the fire in good condition, but at a moderately low heat—to avoid making too much steam and having it blow away through the safety valve.

It is necessary that at leaving time the steam pressure shall be nearly as high as is desired—usually between 175 and 200 pounds. If the steam pressure is low it should be raised GRADUALLY.

In building up the fire before starting on the trip, or to start after any long wait along the road—NEVER put fresh coal on a DEAD SPOT or hole in the fire. First spread burning coals over such places, and then cover these with fresh coal—not too heavily. The burning coals must KINDLE the fresh coal. Give such places your special attention until they get to burning brightly.

Carefully watch the coal you are using and put aside any stone, slate or other incombustible substance that would tend to make the fire "dirty."

In firing, grasp the handle of your shovel firmly with your right hand—and DON'T let it slip out of your grasp and into the fire—to be destroyed.

41—Starting on the Run.

Our engine having now been properly prepared for the run, the train being ready and the time "up," it is necessary that a good bed of fire, burning well, shall cover the entire grate surface. You must exercise your best judgment as to the QUANTITY of coal you should place on the fire just before starting—but these requirements are important:—

The steam pressure in the boiler at starting should be usually within 10 or 20 pounds of the maximum pressure carried, and the water level in the boiler should be as high as it properly may be, usually showing within two or three inches of the top of the "water-glass."

The fire must be prepared with these conditions in mind. If either the steam pressure or water-level is LOWER than as stated, then MORE coal will be needed on the fire; but if the conditions are as stated, then only enough fresh coal will be needed to "hold" the fire and prevent the strong draft caused by the escaping strong FULL STROKE exhausts from "pulling" it—or BLOWING IT OUT.

The exhausts will continue strong while the engine is working hard in starting the train, and the fire must have BODY enough to stand the "pulling" effects of the strong draft. No heavier charge of coal than is necessary for this should be put on the fire before starting, as any more will cause a surplus of steam to form, which in blowing from the safety-valve will HOWL about the fireman's—POOR JUDGMENT!

42—Evils of an Open Fire Door.

The fire being prepared, the fire box door should be CLOSED or "on the latch" before the FIRST exhaust escapes from the cylinders—to avoid the chilling effect on the boiler that would be caused by the inrush of cold air through a wide open doorway, drawn in by the escaping exhausts. This is important for fuel economy and to avoid damage to the boiler.

When the door is "on the latch" the small opening permits a thin sheet of air to be drawn into the fire box ABOVE the fire, which reduces the force of the strong draft THROUGH the fire from beneath. This is good practice.

Not only at the beginning of trips should this work receive your careful attention, but during all runs over the road you should ALWAYS put ANY NEEDED coal on the fire BEFORE starting up from stops.

On passenger engines, if the train is light and easily started, it may not be necessary to put on more coal just before starting. But usually, especially on freight engines, the coal put on the fire BEFORE STARTING should be sufficient to last until the train has been forced into speed and the engine is working at a short cut-off. Then, if necessary, more coal can be put on under the favorable conditions of a softer draft.

Some careless firemen pursue the opposite course and—WAIT until the engine begins to start the train before they make a move toward putting needed coal on the fire. The first exhaust is the signal they wait for. When it resounds up the stack the fire box door is pulled open—then blast after blast of cold air, drawn in by the escaping full stroke exhausts, sweep through the open doorway, through the low temperature of the fire box, and spend their force and cooling effect upon the tube sheet and tubes.

Coupled with a charge of cold, COOLING fuel—the fire and the boiler are often so chilled in this way that the steam pressure is reduced ten or twenty pounds.

The proper way in such a case is to put in a good "fire" of 4 or 5 shovelfuls of coal just before starting, and if necessary, a slight application of the blower for half a minute before the engine starts will heat up the coal and start the fire burning well. Then, when the engine starts, the fire will be in good condition and the door can be left closed or "on the latch" until the train is well in motion and the engine is working easier.

The results of this way will be—less work for the fireman, less fuel burned, and no loss of steam pressure or chilling of the boiler—ALL good results which will save considerable labor and fuel, and avoid much abuse of the boiler.

LESSON 10.

FIRING ON THE ROAD.

{Lessons 10 and 11 teach the proper methods of firing locomotives continuously on the road.}

Where Coal Should Be Put. System of "Cross Firing." Spreading the Coal. Frequency of Firing. Evils of a Bank in the Fire. Wide Fire Boxes. Anticipate Changing Conditions.

43—Where Coal Should Be Put.

On a running and working locomotive, its fire's proper condition is that it shall not be over four or five inches thick—and heaviest in the CORNERS and along the SIDES. The surface of the central portion should be LEVEL, and the whole fire BRIGHT and WHITE all over.

This is the perfect and beautiful condition that you should strive to keep your fire in. Such a fire, covered with LIGHT charges of coal—only WHERE and WHEN needed—will produce the most perfect combustion, and the greatest heat with the least coal and labor.

When you open the fire door to put fresh coal on the fire, look first to see where some is needed—and where it is not needed. Only the places NEEDING coal should be supplied. This need is shown by the condition of the fire. Any places in the fire that show BRIGHT and WHITE are ready for more coal, and should be covered lightly. Put no coal on any bank or heap in the fire until it burns down to the general level. Always see WHERE coal is needed before it leaves the shovel.

If you want to look at your fire's surface, and too much smoke is in the fire box—put the blower on moderately strong if the engine is not working—INVERT your shovel, or turn it upside down, and move it around just inside the fire door so as to DEFLECT the current of air drawn in through the doorway DOWN upon the fire. This will clear away the smoke from the parts of the fire you deflect the air upon. If the engine is working you will not need the blower.

Practice to become skillful in this. Tilt the inverted shovel sideways to deflect the air DOWN along each side of the fire. Rest the shovel, inverted, on the inside of the doorway and tilt it downward to see the fire just beneath the door. Then turn it to the right and left and tilt it so you can see the whole side and central portions of the fire.

Engines usually require very little coal placed on the middle of the fire. "Fire" carefully to cover the bed close in the corners and along the sides. The draft will usually work enough coal toward the center of the fire.

Also some engines—pull their fire forward, especially those having fire boxes sloping forward. On such engines avoid putting much coal on the front, and put more on the back of the fire. Aim to keep your fire of uniform depth all over, and place your coal accordingly.

While on duty—LIVE WITH YOUR FIRE—and keep your mind on it. REMEMBER where you placed the last and previous shovelfuls of coal, and avoid putting too much on any part.

44—System of "Cross Firing."

A SYSTEM always helps in any work. The system of "CROSS FIRING" shown on the following page insures a proper distribution of coal—ALTERNATELY over the TWO SIDES of the fire's surface, and prevents putting too much coal on either side at one time.

This aids in the proper burning of the GASES in the coal, because it is always necessary that they shall NOT be produced in great quantities simultaneously in one place, or on one side of the fire.

So firing first on one side, and then on the other, as this plan requires—systematically DISTRIBUTES the coal and keeps down the quantities of gas produced on each side of the fire. This gives the gas the BEST CHANCE to meet with enough air and oxygen—and BURN IN THE FIRE BOX before it passes into the tubes—where it would be turned into SMOKE and WASTED in the outside air.

CAREFULLY STUDY the plan of "cross firing" shown in Fig. 4, and form and follow the habit of placing coal on the fire accordingly—except when banks or clinkers cause you to do otherwise to keep the fire in good condition.

To easily describe "cross firing"—the bed of fire shown in Fig. 4 is divided into SECTIONS and numbered.

SECTION 1. Spread the first shovelful of coal over the left front corner of the fire—thickest in the CORNER, and along the SIDE for a couple of feet.

SECTION 2. Next cover this section in the same way.

SECTION 3. Spread the next shovelful along the CENTRAL SIDE of the fire—thickest as shown in the illustration.

SECTION 4. Next cover this section in the same way.

SECTIONS 5 and 6. Finally, in their proper order, cover these two corner sections in the same way as stated for sections 1 and 2. Be sure to put the coal thickest IN the corners and ALONG the sides.

45—Spreading the Coal.

It is important in firing to make EACH square foot of fire surface do its share of the work of generating steam. Only in this way can the heat required for keeping up steam be generated with the least coal, labor and smoke.

To accomplish this—SPREAD each shovelful of coal you place upon the fire—EVENLY over the LARGEST surface you can. PRACTICE the spreading of coal in this way until you become EXPERT in doing it.

The draft usually acts strongest in the corners and along the sides of the fire box. KEEP these places well supplied with coal—but in doing so be zealous to spread the coal over them as you throw it in. NOTHING shows up a poor fireman quicker than carelessness in SPREADING his coal.

46—Frequency of Firing.

How soon one charge of coal should be followed by another depends upon the kind of coal, the condition of the fire, and

FIG 4. DIAGRAM SHOWING PLAN OF CROSS FIRING.

ing. It usually results from the fireman carelessly dumping several shovelfuls of coal on the spot where the bank forms.

The coal he should have SPREAD over 6 or 8 square feet of fire surface—he DUMPED on 2 or 3 square feet, either through carelessness or unwillingness to spread the coal as he threw it on the fire. Such firing may be tolerated in a beginner until he learns how to handle his shovel, but, happening often, it is inexcusable in an experienced fireman.

A bank of coal that cannot burn acts as a blanket, and practically puts out of action all the fire surface it covers, so far as steam making is concerned, until it is broken up, or after some minutes of interior burning the air finally struggles through its crusty top.

Plainly, a bank in a fire is an enemy of quick steam making. It is also an enemy of economy, for during the time the fire's surface it covers is SMOTHERED by it—the other portions of the fire have to do more than their share of work.

Also a bank often injures the fire by starting the formation of a clinker. When a bank is formed, it should be allowed to burn down level, or be broken up and spread out with the slash bar so its coal may burn. No more coal should be put on that part of the fire until it reaches a bright white heat.

Half of a fireman's SUCCESS depends on knowing WHAT NOT TO DO. No more coal should ordinarily be put on any part of a fire that has not burned to a white heat, but is still giving off flame or smoke. This condition shows that part of the fire has already as much coal as can burn there. No coal but MORE TIME must be given such places.

48—Wide Fire Boxes.

Locomotives built to burn "fine" or small sizes of coal are provided with wide fire boxes to give each a large grate surface.

Experience has taught that the smaller the coal, the larger must be the grate surface on which it is burned, the thinner must be the bed of fire, and the softer must be the draft.

A softer draft is required for burning fine than for burning coarse coal—to prevent the small coal from being lifted from the fire by the draft and thrown out the stack.

To burn small coal requires that it shall be spread in thin layers over the surface of the fire. If dumped in heaps on the fire, or put on heavily, it forms banks through which the air required for burning can not pass.

The softer draft, the smaller coal and the larger fire surface of wide fire boxes all require that, in firing them, more than ordinary care must be exercised in SPREADING the coal evenly over the surface of the fire.

The softer draft used with wide fire boxes is not weaker than the draft used with smaller fire boxes. The draft may be stronger in the wide fire box, but being distributed over a greater fire surface it acts more softly on every part of the fire —just as when a shovelful of fine coal is spread over a large portion of the fire, the layer thus added is thinner at every part than if spread over a smaller portion.

49—Anticipate Changing Conditions.

A good fireman will, before putting in each "fire" anticipate or THINK AHEAD of the work the engine is going to do while that charge of coal is burning, and he will regulate the amount of coal he puts upon the fire accordingly.

Always measure the coal to your fire—not only for its present needs—but look beyond its present conditions of heat and draft to what these will be before the "fire" you put in will be burned up, and regulate the amount of coal to secure the best results and AVOID LOSS.

While it is the mark of a good engineer to be always just on time with his train, it is the mark of a good fireman to be always a little AHEAD of time in his work—always preparing ahead for coming conditions, thus keeping himself their Master, instead of being their slave.

Coal should not be put on the fire shortly before steam is to be shut off. Nearly all coal put on then is WASTED. Neither should the fire be allowed to burn so low that the steam pressure will fall much—because steam is to be shut off. Aim at a happy medium between these extremes, and try to have the fire in such condition when steam is shut off that there will be neither much reduction of pressure nor much surplus steam generated.

Try to do all your firing on a straight track, or on curves toward the RIGHT—the engineer's side—so when the engine is rounding curves to the left—your side—you can look ahead. This is for SAFETY.

Keep a sharp lookout for signals while passing through towns and yards—and at all places where it is difficult for the engineer to see clearly ahead.

Before coming to a heavy pull—get the fire in good shape. Don't wait to do this until the engine is put to the heavy work of starting for or climbing the hill. THINK AND PLAN AHEAD!

LESSON 11.
FIRING ON THE ROAD.

Importance of Sufficient Air. Access of Too Much Air. The Grates. Shaking the Grates. Light Firing. Perfect Firing.

50—Importance of Sufficient Air.

If a fire is not forced, and is supplied with sufficient air—the combustion will be "perfect," and a pound of good coal so burned will make enough heat to turn about TWELVE pounds of cold water into steam.

If the fire is not supplied with sufficient air—then "imperfect" combustion will result. A pound of coal so burned will make TWO-THIRDS LESS HEAT than if sufficient air were supplied, or only enough heat to turn about FOUR pounds of cold water into steam.

Thus the heat of a fire is greatly reduced if its supply of AIR is restricted in any way.

This is the CHIEF LESSON in firing. You can do nothing that will so effectually make steam, save coal and lighten your labor as to ALWAYS keep your bed of fire in such condition that the air has an easy passage through it to the coal burning on its surface.

About 300 cubic feet of air must pass through our fire to give the best results from the burning of each pound of coal put upon it. Shovels, such as locomotives are generally provided with, hold when ordinarily full—about 16 pounds of coal. When the fire needs more coal, sometimes four shovelfuls or 64 pounds will be spread over its surface, and this quantity will last three or four minutes—20,000 cubic feet of air—EIGHT BOX-CARS-FUL—must pass through the fire in this short time to burn the charge of coal in the way that will produce its greatest heat.

51—Access of Too Much Air.

While it is important that a free admission of air through the grates is necessary to secure the best results—it must not be supposed that the more air admitted the better—for all in excess of the quantity needed for perfect combustion only absorbs the heat of the fire and carries it away.

Therefore be careful to keep the fire thick enough, and of uniform depth, to prevent access of too much air. The time to guard against this most carefully is in shaking the grates, which, while running, should usually be done only after fresh coal has been put on. Even then—be careful to not shake the grates so hard as to injure or make a HOLE in the fire.

No air holes, dead spots or bare spaces on the grates must be permitted; but the FULL GRATE SURFACE must be kept covered with FIRE.

52—The Grates.

The grates of any furnace constitute the FOUNDATION on which its fire rests. They support the fire, and through the openings between their bars, projections or "fingers," they provide passages for the admission of air to the fire above.

As its FIRE is the LIFE of any steam engine, and the source of all its power, so the grates are a vital part of its construction.

Therefore the proper inspection and treatment of his grates is one of a fireman's most important duties. It is important for the preservation of the grates from being "burned" that they shall always rest perfectly LEVEL. Any part of a tilted grate section that projects into the fire may be melted.

Great care must be taken to place the grates level after each time they are shaken; otherwise lumps of clinker may get wedged between their sections and allow much fire to fall into the ash pan, where it may melt or "burn" the grates. The arrangement provided for locking the grates in a level position must always be used by firemen every time they move them.

53—Shaking the Grates.

PART THREE

The grates and their connections are very plainly shown on the colored chart opposite page 8. The projections shown as extending upward at the back of the boiler-head receive an adjustable lever with which the fireman can shake the grates as the condition of his fire demands.

The grates should be shaken lightly and occasionally while running so as to keep a thick bed of ashes or clinkers from forming over them. Usually the grates should be shaken about every FIFTEEN miles on freight engines, and about every THIRTY miles on passenger engines.

Care should be taken while shaking the grates to remove only the dead ashes and cinders from the bottom of the fire, and avoid shaking live fire into the ash pan. This can be accomplished best by moving the grates with SHORT, QUICK movements. Avoid slow, long movements which tilt the grates extremely.

When the glow of the fire can be seen in the ash pan—this indicates the absence of dead ashes on the grates, and that they do not need shaking.

The best time to shake the grates is when steam is shut off, or when the draft through the fire is lightest. If the grates

Plate 1. PERFECT CONDITION of Fire Bed—CROSSWISE. Level throughout the MIDDLE—but thicker along the SIDES—because the Draft acts stronger and requires more fuel there than in the central part. See subject 43.

Plate 2. WRONG CONDITION of Fire Bed. Too deep in the MIDDLE—where the Draft is weakest—and too shallow at the Sides where the Draft is strongest. Compare Plates 1 and 2.

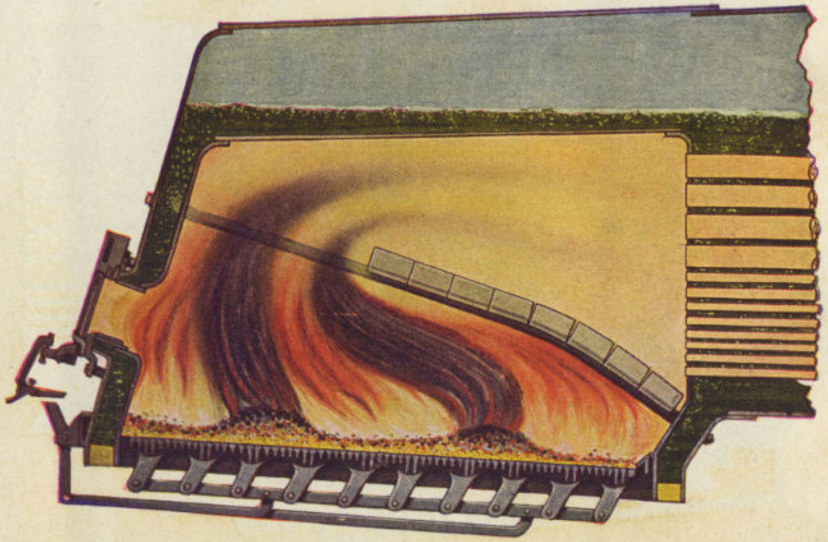


Plate 7. TWO BANKS in the fire. Either the fireman carelessly put TOO MUCH coal on the parts of the fire where the banks form—or CLINKERS prevent access of sufficient air through those parts to burn the coal placed there. REMEDY—SPREAD each bank so its coal can burn—or REMOVE the clinkers. See subject 47.

These BEST pictures of locomotive fires ever created were originally produced by the University of Illinois—then revised and perfected by the Joint Committee on Fuel Conservation of the American Railway Association in 1921. It is by the courtesy of this Committee, and the University, that these Plates are presented here.

are shaken when the exhausts are strong—a cloud of smoke and a hail of sparks are belched from the stack. This is wasteful and dangerous—as the hot sparks sometimes start destructive fires along the road—for which the Company pays thousands of dollars annually.

54—Light Firing.

The most important thing in firing, aside from keeping up steam, is to keep as LIGHT a fire as is consistent with the nature of the work the engine is doing. The best way to do this is to fire lightly and frequently, avoid heavy firing, and to loosen the bed of fire occasionally by shaking the grates as stated.

While placing the first shovelful of a charge—notice the condition of the fire and form your plan for placing the one or more shovelfuls the fire may need. Then follow out your plan—conforming with the system of "cross firing" as nearly as practicable. The number of shovelfuls per charge should always be KEPT DOWN to the FEWEST actually needed.

55—Perfect Firing.

PERFECT FIRING of bituminous coal is to feed the fire with but ONE shovelful of coal at a time, placed alternately on the different portions of the fire as needed—the fire door to be closed "on the latch," and remain closed 10 to 20 or 30 seconds between each shovelful, according to the work the engine is doing.

This method requires almost constant attention, especially when the engine is working hard. But there is ample time for breaking the coal and leisurely placing it properly on the fire. Much less coal is then burned, less smoke is produced, and a steady steam pressure is more easily kept up than when the fire is fed with larger charges.

The lessened coal consumption saves money for the Company and LABOR for the fireman, less smoke makes the journey of the passengers or the work of the trainmen more pleasant, a more steady steam pressure avoids expansion and contraction of the boiler—and this means greater safety and reduced expense for boiler repairs.

LESSON 12.

FIRING ON THE ROAD.

Lesson 12 deals with WASTEFUL firing practices—and the waste of fuel and water in "popping."

Heavy Firing—Its Evil Results. Avoid Rapid Firing. Avoid "Pulling" the Fire. Waste of Coal and Water in "Popping." Prevention of "Popping." Preservation of Surplus Steam.

56—Heavy Firing—Its Evil Results.

Careless firemen sometimes feed the fire with heavy charges of coal—five to ten shovelfuls per "fire." This is heavy firing. Its disadvantages are numerous, and they react disastrously on the engine, the fireman, and the railroad's earnings.

A heavy charge of coal put on a hot fire produces a large quantity of GAS that can not meet enough AIR to burn as FLAME in its flight through the fire-box into the tubes—and so escapes unburned through the stack as SMOKE.

Much of the fire's heat is absorbed to expel and vaporize the gas in the heavy charge of coal—so it becomes A ROBBER if we let it escape without burning and giving up the heat it can produce.

Heavy firing thickens the fire and helps the formation of large clinkers which shut off the air supply—making it necessary for the fireman to either clean the fire or shovel much more coal.

Heavy firing injures the boiler. Large charges of coal COOL the fire and lower the steam pressure and the TEMPERATURE of the boiler, causing CONTRACTION of its parts. Then later, the steam pressure and the temperature of the boiler are increased, causing EXPANSION of its parts.

These SHRINKING and STRETCHING movements often break staybolts, crack firebox sheets, open up seams and cause the tubes to leak. This means spending money to repair damages, and—WOE for the fireman. Usually it is hard to keep up steam on a leaking boiler.

57—Avoid Rapid Firing.

RAPID firing is wrong for the same reasons that heavy firing is wrong. Some firemen exert themselves to HASTILY throw several shovelfuls of coal on the fire in rapid succession. A much easier and more economical way is to commence in time, and put the "fire" in LEISURELY, closing the door for a while between each shovelful.

Never hurry in your work unless in some emergency. The best results can always be obtained by leisurely movements in firing. The coal being properly prepared and on the shovel, the fire box door should be opened. The first shovelful should be spread over the part of the fire where it is most needed. Then the door should be CLOSED immediately, and left closed while the next shovelful is being prepared for placement.

Even when the fire needs a charge of several shovelfuls of coal, each one should not be rapidly followed by another, except in extreme cases—as when a fire is being "pulled."

58—Avoid "Pulling" the Fire.

One of the worst accidents that can happen to a fire is for it to be "pulled" by the strong exhausts at starting. If the fire is allowed to burn too low during a long wait, and the engine is started and worked HARD before the fire is properly prepared—the strong full stroke exhausts draw heavy blasts of air through the poorly burning fire, dislodging live coals from their places and turning some of them over—hot side up.

They cannot continue burning that way—in opposition to the draft—and unless good fire is beneath to REKINDLE them they are EXTINGUISHED by the next few blasts of cold air. Sometimes a large part of the fire is so turned over and extinguished—crippling the engine until the fire can be REKINDLED.

Such a mishap may cause a serious train delay. When it occurs—both the engineer and fireman are to blame. The fireman must not allow the fire to burn so low that its LIFE may be endangered; and in starting, the engineer should know enough about the condition of the fire to avoid "pulling" it.

PREVENTION—by keeping the fire in good condition ALL THE TIME is the only precaution against this mishap. When the draft is so severe that it endangers the fire—close the dampers and open the fire door to reduce the draft THROUGH the fire. Warn the engineer so he may ease off steam and reduce the draft. QUICKLY put on more coal and partly close the fire door. Put the blower on STRONG to rekindle the fire.

If a considerable part of the fire is extinguished, and the work ahead for the engine is heavy and important—then the throttle must be closed, or used very lightly, until the fire can be rekindled with the blower and more coal.

59—Waste of Coal and Water in "Popping."

It should be a fireman's constant aim to keep an EVEN STEAM PRESSURE while running—close to that usually desired. But—NO SURPLUS steam should be made to uselessly blow away through the safety-valve.

With the usual high steam pressure carried on locomotives —about 200 pounds per square inch—it is known that when an engine "pops" or blows off surplus steam—coal and water are wasted in large quantities.

At this pressure, steam escapes from an ordinary safety-valve at the rate of 147 pounds a minute—which means a waste of 147 pounds or 18 gallons of WATER per minute.

In ordinary locomotive work about six pounds of water are turned into steam per pound of coal burned. So it takes about 25 pounds of coal to make the 147 pounds of steam that the safety-valve lets loose a minute.

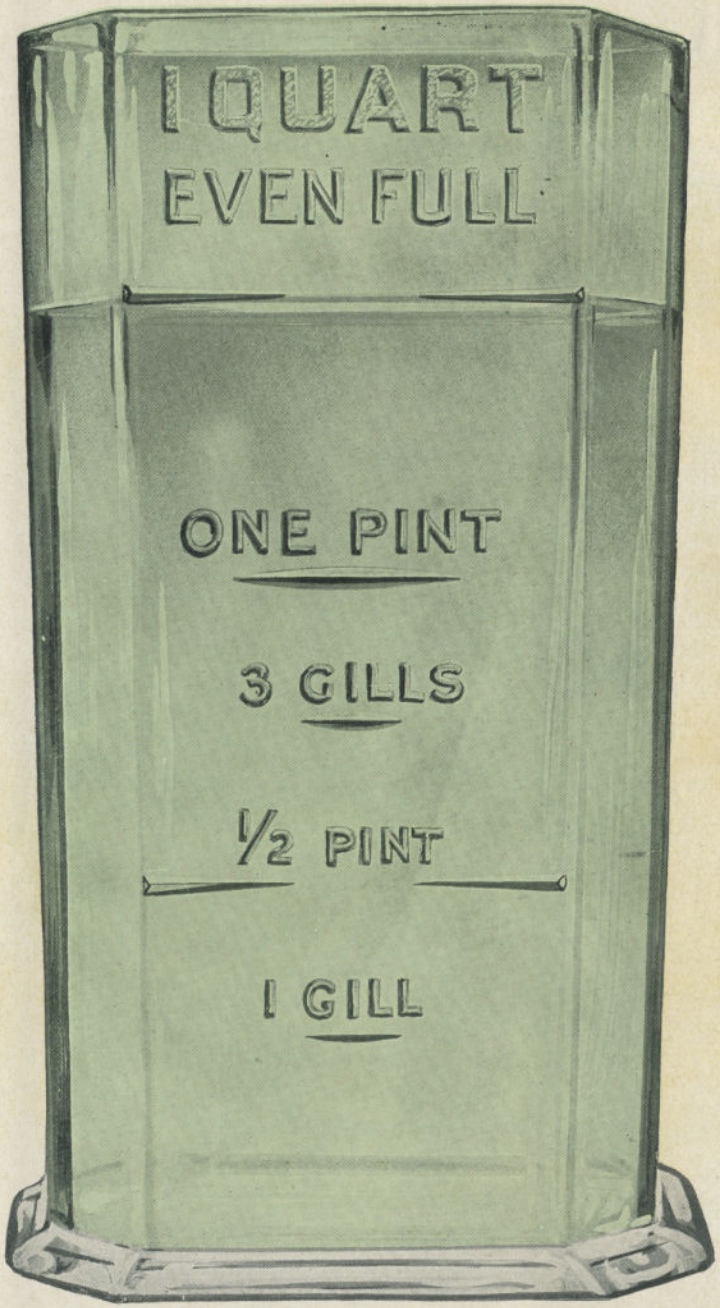
Wasting coal at the rate of 25 pounds a minute, is throwing away A THIRD of a pound A SECOND!

Wasting water at the rate of 147 pounds a minute, is throwing away 2½ pints—over A QUART A SECOND!

Fig. 12 is an illustration of a lump of coal weighing a third of a pound, and the engraving on the opposite page shows a quart of water. Imagine lumps of coal as large as apples—and QUARTS of water flying out the safety-valve EVERY

FIG. 12. A THIRD OF A POUND OF COAL.

Amount usually WASTED EACH SECOND an Engine is "popping."



A QUART OF WATER.

Quantity usually WASTED EACH SECOND an Engine is "popping."

SECOND that steam blows off—and this will picture the INVISIBLE WASTE of coal and water going on in "popping."

Regardless of cost, these wastes are objectionable because they deprive the engine of the materials most necessary for its operation. An engine out of coal or water IS HELPLESS——and many a locomotive has been put in this condition by carelessly permitted and excessive "popping."

But coal and water cost the Company immense sums of money, and every pound and quart that is wasted—is just so much money thrown away. A safety-valve when opened by excessive pressure usually blows off steam for half a minute before it closes—and wastes over 12 pounds of coal—a level shovelful—and nine gallons of water.

With coal on the tender costing $3 a ton—12 pounds cost nearly two cents; and ten gallons of water cost about a cent—making an average loss of about THREE CENTS every time an engine "pops."

While this is a small loss, considered singly, yet when an engine "pops" 50 times in a day's work—it amounts to about $2.00; and when this waste is extended over 100 locomotives it aggregates about $200 a day!

A fireman who carelessly lets his engine "pop" fifty times during a day or a trip—actually THROWS AWAY about 600 pounds of coal and TWO TONS of water through the safety-valve.

Such carelessness continued will waste EIGHT or TEN TONS of COAL monthly on a single engine, and if it should extend to many engines the waste on them would of course be in proportion—aggregating on 100 engines a loss to the Company of between FIVE and SIX THOUSAND DOLLARS a month for COAL alone—and several hundred dollars more for WATER.

60—Prevention of "Popping."

When the blower is used in raising steam—it should usually be shut off before the steam pressure rises to within 10 pounds of the blowing off point.

The exercise of correct judgment will regulate the feeding of the fire to keep up an even steam pressure without making surplus steam to be blown away, or surplus HEAT to be counteracted by opening the fire-door to admit cold air to the fire-box.

The open door, or the howling "pop"—DECLARES the carelessness or poor judgment of the fireman. When putting in the "fire" that made the surplus steam he was careless, or he put in TOO MUCH. The result in either case is a waste of fuel.

When too much coal has been put on the fire, rather than open the fire-door and admit cold air to COUNTERACT the undesired heat which the burning coal is producing, it is more economical and less injurious to the boiler to CLOSE THE DAMPERS (on engines which have them) and thus SUSPEND COMBUSTION until greater heat is needed.

Understanding how necessary air is to combustion, we know why the burning of the fire is checked by closing the dampers. The supply of air—the OTHER PART of the FUEL—is thus cut off, and combustion is partly suspended, or temporarily SMOTHERED.

When steam stops blowing off (when dampers are closed)—open the dampers before putting on more coal.

If the fire door must be opened to prevent steam blowing off, or to cause it to cease doing so while the engine is working—do not pull the door wide open and leave it so until the boiler cools. The inrush of cold air would cause rapid COOLING and CONTRACTION of the fire box sheets, and be especially hard upon the tubes and tube sheet. The door held JUST AJAR, or swung to and fro, obtains the best results. It is not an evidence of good firing to even do this very often.

61—Preservation of Surplus Steam.

Surplus steam, when formed, may usually be PRESERVED —and "popping" prevented—by starting an injector for one or two minutes, or, if one is working—by increasing its flow. This will USE the surplus steam to put 40 or 50 gallons of water into the boiler and HEAT it over 300 degrees. This

is the best way to USE and STORE surplus heat if there is proper room in the boiler for more water. The injector should be put on BEFORE the safety-valve opens.

Should the boiler be too full to allow putting more water in it—the surplus steam may be blown back into the water in the tender through an injector. Open the tank valve, then the injector steam valve—GRADUALLY at first until the water is blown back out of the tank hose—then open the steam valve FULL to relieve the boiler of the surplus steam. This will be CONDENSED by the cool water in the tank—and both the water and the HEAT in the steam will be PRESERVED. Water warmed in the tank—REQUIRES JUST SO MUCH LESS HEAT IMPARTED TO IT IN THE BOILER TO TURN IT INTO STEAM.

Always do one or the other of these two things rather than let your engine "pop" and throw away a lot of coal and water. FIRST—put on an injector if there is proper room in the boiler for more water. Second—blow the surplus steam into the tank, unless the water there is LOW or WARM.

If the water in the tank is made too hot—the injectors can not work properly. But they will usually work well with water blood-warm. So don't let surplus steam be wasted while your tank water is cooler than blood-warm.

FIRING ON THE ROAD—CONCLUDED.

Cleaning the Fire. Banking the Fire. Cleaning the Ash Pan. Taking on Coal. Save Small Quantities of Coal. Smoke Prevention. Avoid "Drumming." Approaching Terminals. Care of Engines at Terminals.

62—Cleaning the Fire.

When a bed of clinkers forms over the grates thick enough to prevent access of sufficient air to the fire—the earliest opportunity must be improved to clean them out. Such an opportunity exists whenever the train has to wait somewhere about fifteen or twenty minutes for orders, or for another train.

Before starting to clean a fire—always, if there is time, fill the boiler with water to the highest proper level, so no more water need be put in the boiler until the new fire is burning well.

Also prepare about ten shovelfuls of well broken coal that you can use without delay to put on the fire when you finish cleaning it.

Supposing the train is STANDING and the fire needs cleaning—you should proceed as follows:

FIRST. Get the ash hoe and the "slash-bar" ready at the fire box door. Put on the blower SLIGHTLY—only enough to carry all the gas from the fire out of the stack. Open the fire door, and with the ash hoe pull all the LIVE FIRE back close beneath the fire door. This will lay bare the whole bed of clinkers lying on the forward part of the grates.

SECOND. Lower the "drop-grate"—the forward section of the grates, which is made so it will tilt downward and give an opening of six or eight inches across the front of the fire box. Take the slash bar and punch the clinkers out through this opening.

Punch out all the clinkers that lie forward of your bank of live fire. Avoid pushing out live fire along with the clinkers.

SAVE all the good burning coals you can, but knock out all the clinkers and ashes at the front of the fire box.

THIRD. When the job has progressed so far, the back half of the grates will still be covered with a deep bank of fire, including that raked back at the beginning. Beneath this bank lie some large clinkers which must also be removed. Jab the slash bar down through the fire and pry them up—push them forward to the drop-grate opening and punch them out. Keep this up if you have time until you rid your fire of all large clinkers.

FOURTH. Then lift and fasten the drop-grate in its CLOSED position. With the ash hoe QUICKLY spread all the remaining live coals around evenly ALL OVER the whole grate surface. Be careful to push live fire into the CORNERS and over the FORWARD part of the grates. Then as quickly as possible spread five or six shovelfuls of well broken lump coal all over the fire, being careful to cover the corners and the sides as well as the central portion.

Now close the fire box door "on the latch" and put the blower on moderately strong. Glance at the fire after a minute—to see if the fresh coal has caught fire and is burning well all over. Spread a few more shovelfuls of broken coal over the places that are burning best. Close the door and keep the blower on moderately until the fire is burning brightly all over.

If your work has been well done, your fire should now be in as good condition for steam making as it was at the beginning of the trip.

But a newly cleaned fire is usually so thin that strong exhausts may pull holes in it, or turn some portions of it over. So be careful to avoid this mishap by watching the fire closely and keeping it well supplied with good coal until it is evenly thick enough all over—about three or four inches deep—to be safe from being "pulled."

Cleaning the fire must never be done when the engine is working—because the exhausts would pull such volumes of cold air into the fire box—through the open doorway and bare grates—that damage would result to the tubes, probably causing them to leak.

If clinkers are pulled from the fire—SPECIAL CARE must be taken to MAKE SURE that none are thrown off the engine while running, where—by ANY POSSIBILITY—they may strike any person. Also to avoid setting fire to the grass or trash along the road—always cool off hot clinkers with water before you throw them off.

When crossing a bridge or trestle—DON'T disturb the fire so hot coals may fall out along the track. Do not shake the fire or pull out clinkers then.

Fires or ash pans must not be cleaned near any bridge or culvert, depot or building. Hot ashes and clinkers are always dangerous if left lying on the track, as some may be dragged by a low-hanging part of a passing engine or car to a spot where it can start a fire that might destroy life and property.

Therefore always QUENCH with water the hot coals and clinkers you remove from the fire and the ash pan—before you leave them.

63—Banking the Fire.

Sometimes in construction work, or during long delays on the road, an engine must stand some hours or all night. In moderate weather the fire can then best be kept alive by making a BANK of smouldering coals which when desired can be spread out to kindle a new fire.

The first move to prepare an engine for a long stand must be to fill the boiler with water to the proper height—so no further injection will be necessary while the fire is banked.

If there is an arch in the fire box—pull all the live burning coals to the BACK of the grates, and cover this fire THICKLY with six or eight shovelfuls of broken or fine coal. Close the fire door and dampers so as to shut off all the draft.

If there is no arch in the fire box, then the BANK should be made on the FRONT of the grates—next to the tube sheet, to protect the tubes from being chilled and damaged by drafts of cold air. With an arch in the fire box—its hot bricks protect the tubes, and the bank can be made at the back, which is more convenient.

In either case the bank needs attention and probably two

or three shovelfuls of fine or small coal every hour or so to keep it in good condition. Keep down the draft through the grates and the bank so no more coal will be burned than is necessary.

Fully an hour before the engine should be ready for service—the fire must be cleaned and the bank spread over the whole grate surface, as described in subject 62.

64—Cleaning the Ash Pan.

After the fire has been cleaned it is always necessary to clean the ash pan, as much ashes and coals generally fall through the grates in cleaning the fire.

Before beginning to clean the ash pan MAKE SURE that the engineer knows you are going to do this, so he may keep the engine standing STILL until you finish. Open both front and back dampers wide, and with your ash hoe clear out all the ashes in the pan. A clean ash pan gives a clear passage for the AIR to reach the grates—so ABSOLUTELY necessary for a good burning fire.

Do not wait to clean the ash pan until you have to clean the fire. With good coal you may seldom have to clean the fire, but the ash pan usually needs to be cleaned once or twice every 100-mile trip on freight engines.

Always clean the ash pan before it gets full of hot ashes and coals. When the grates are heated red hot by fire both above and beneath them—they are so greatly WEAKENED that they break down beneath the fire's weight upon them. This is called "burning the grates."

Such a serious damage would disable an engine, and as it could result only from the fireman's NEGLECT—he would be held responsible and disciplined.

Continually WATCH the condition of your ash pan. Inspect it before starting on every trip, and while on the road assure yourself by inspections during stops that it is safely clear. When it becomes HALF full it should be cleaned, for both safety and fuel economy. If the stops of the train offer no good chance to clean it when needed—tell your engineer you want an opportunity to do so.

65—Taking On Coal.

In taking coal when necessary on the road—never stand between the cab of an engine and the "apron" or chute of a coal dock. A sudden backward movement of the engine might catch you between the cab and chute, and injure you.

Also do not take on so much coal that some will spill off over the sides of the tender. Take only what the tender will hold SECURELY. All coal spilled overboard while running is WASTED.

After taking coal "TRIM" or level the top and sides of the coal pile to insure that no coal shall be lost overboard while running—and to avoid danger to trackmen and others. The coal should be kept within the limits provided for it on the tender, and not allowed to accumulate around the water-hole.

Bituminous coal deteriorates or loses value rapidly when exposed to the air and weather. Therefore long standing accumulations of coal must not be permitted on any part of the tender. The coal should be shoveled ahead at least once a month, and replaced by fresh coal which, if needed in an emergency will be in good condition to make steam.

66—Save Small Quantities of Coal.

The "gangway" of a locomotive is the passage-way—across—between the engine and tender. It is partly covered by an iron "apron" that extends from the back of the engine to cover the crevice between the engine and tender. The "deck" of an engine is the floor of either the cab or the tender on which the fireman stands while at work.

As coal is passed from the tender into the fire box, some is spilled in the process. Careless firemen often sweep this spilt coal OUT of the gangway onto the ground. This is an INEXCUSABLE WASTE of fuel. All coal that falls on the deck, or the apron, or in the gangway, should be swept back into the coal pit of the tender with the broom provided for the purpose.

Watch against the waste of coal in SMALL quantities—the handfuls, the pounds and the shovelfuls make up TONS

on your engine—and HUNDREDS OF TONS on all the engines on the road. Therefore be zealous to save the SMALL QUANTITIES.

67—Smoke Prevention.

Air admitted ABOVE the fire helps the burning of the gases coming from the coal, and is effective in preventing smoke. Smoke disappears from the stack when the fire box door is opened and a current of fresh air is drawn into the fire box ABOVE the fire by the blower or the exhausts.

Engines must not be permitted to emit smoke while about stations and depots, and should be prevented from doing so by closing the dampers or opening the fire door and using the blower slightly; or, if the engine is working, by light and careful firing—whichever plan best suits the circumstances.

Special care should be exercised on passenger engines in preparing the fire to START from large stations. If the fire is at a low heat it can be best built up by easy stages—by spreading one or two shovelfuls of well broken and WET coal over the surface, then, with the fire-door ajar and the blower on slightly if necessary, give TIME for the GAS in the coal put on to escape and burn before more coal is added.

Aim to have your fire BURNED DOWN so on approaching stopping places and the tops of hills where steam is shut off—that the least possible smoke will be produced when the throttle is closed. If much smoke is made then—OPEN the fire door, and if necessary put on the blower slightly to clear it away.

Smoke trailing back from an engine running shut off on either freight or passenger trains is most objectionable. On freight trains it obscures the vision of the trainmen, and on passenger trains it enters the coaches and annoys the passengers. Smoke from a working locomotive is not so objectionable in these ways because the exhausts throw it up above the train—but smoke is always an evidence of WASTE.

68—Avoid "Drumming."

Frequently a drumming noise is made by the fire, when it is light and clean. It is caused by the hydrogen gas expelled from the coal combining in the fire with the oxygen in the air and causing innumerable small explosions.

The explosions occur in rapid succession, and cause a deep rumbling or drumming noise. It is undesirable on locomotives on or near passenger trains—or at stations—and should be prevented by closing one or both dampers, or opening the fire door slightly, whichever is most effectual.

69—Approaching Terminals.

Always in aproaching the terminal station of the run, the fire should be allowed to burn down moderately—without decreasing the steam pressure more than 20 pounds—so there will not be much fuel left on the fire to produce smoke—or be wasted through the "pop" before the fire is cleaned.

70—Care of Engines at Terminals.

Round-house employees and engine watchmen must see that the tube sheet is cleaned of adhering clinker before an engine is "fired up"—and that the fire is evenly spread over the entire grate surface as soon as possible. They must be particularly careful to see that LIVE FIRE is placed over the FORWARD part of the grates, and next to the tube sheet before the blower is used.

At the end of trips, the remaining heat of the fire must be utilized to STORE as much hot water in the boiler as is practicable, to assist in economical firing up.

After the fire has been removed from the fire box, at the end of trips, the dampers and the fire door must be KEPT CLOSED—to prevent cold air chilling and damaging the tubes and fire box sheets—and injectors MUST NOT BE USED WHEN THERE IS NO FIRE ON THE GRATES.

When an engine is held under steam at a terminal—after its fire has been cleaned—then that portion of the grates not covered by the bank should be covered with a thin layer of "green" coal to exclude cold air from the fire box, and prevent chilling and damage to the fire box and tubes. In this case, on an engine with no arch in the fire box, a bank should be made at the back and another at the FRONT of the grates to protect the tubes from damage.

24—How a Locomotive Works.

A locomotive consists of a BOILER having an internal furnace or "fire box" for generating steam, and A PAIR of steam engines—one on each side. The whole arrangement is supported and held in place by heavy steel side frames, suitably mounted on the axles of the driving wheels.

Plate One herewith shows the general outline of the RIGHT SIDE of an 8-wheel or "American" locomotive. The various important parts of the engine are numbered on the drawing, and named in the Index.

To make the locomotive move and "work," a slight pull on the throttle lever in the cab opens the throttle valve in the steam DOME—21—and permits steam to flow forward through the "dry pipe" inside the boiler to the STEAM CHEST—2—at the forard end of the boiler. The automatic movements of the STEAM VALVE inside the steam chest govern the admission and release of steam to and from the CYLINDER—1.

A closely fitting steam-tight PISTON is driven by the steam forward and backward inside the cylinder. It is attached to the PISTON ROD—3—which is connected to the CROSS HEAD—4—which moves forward and backward between its top and bottom GUIDES—12 and 12—as it is pushed and pulled by the piston.

To the cross head is also attached the forward end of the MAIN ROD—5—which at its back end is attached to the CRANK PIN—A—on the front or MAIN DRIVING WHEEL—7. The SIDE ROD—6—connects the crank pins—A and B—on the front and back driving wheels, or "drivers," so they must turn together.

This is the train of mechanism through which the force of the steam admitted to the right cylinder is exerted to make the drivers revolve and propel the locomotive.

The steam valve in the steam chest, actuated by its mechanism, moves automatically to admit steam alternately to the front and back ends of the cylinder to PUSH THE PISTON on its forward and backward "STROKES." The steam valve also provides for the ESCAPE of the used or "EXHAUSTED" steam at the end of each stroke.

On Plate One, the position of the driving wheels shows that the BACKWARD stroke of the piston—only half finished —has acted on the cross head—4—and main rod—5—to PUSH the crank pins on the drivers—A and B—BACKWARD.

In completing its stroke the piston's push will force the crank pins further backward until they reach their back CENTERS—D and F—or straight back.

Then the piston will stop—begin its FORWARD stroke and PULL the crank pins forward until they reach their front CENTERS—C and E—or straight ahead. Then another backward stroke will begin.

Thus the continuous strokes of the piston in the cylinder PUSH and PULL the cranks of the drivers around and around —and urge the locomotive forward with its train.

For the sake of simplicity, only the actions of the steam engine and its parts on the RIGHT side of the locomotive are here described. Similar parts on the LEFT side act similarly and simultaneously.

The cranks on the right and left drivers are set at right angles to each other—so they can not reach their CENTERS together, because just then the pistons' pushes and pulls CEASE as they complete their strokes—STOP, and begin their return strokes. For this and other reasons these centers are also called "DEAD CENTERS."

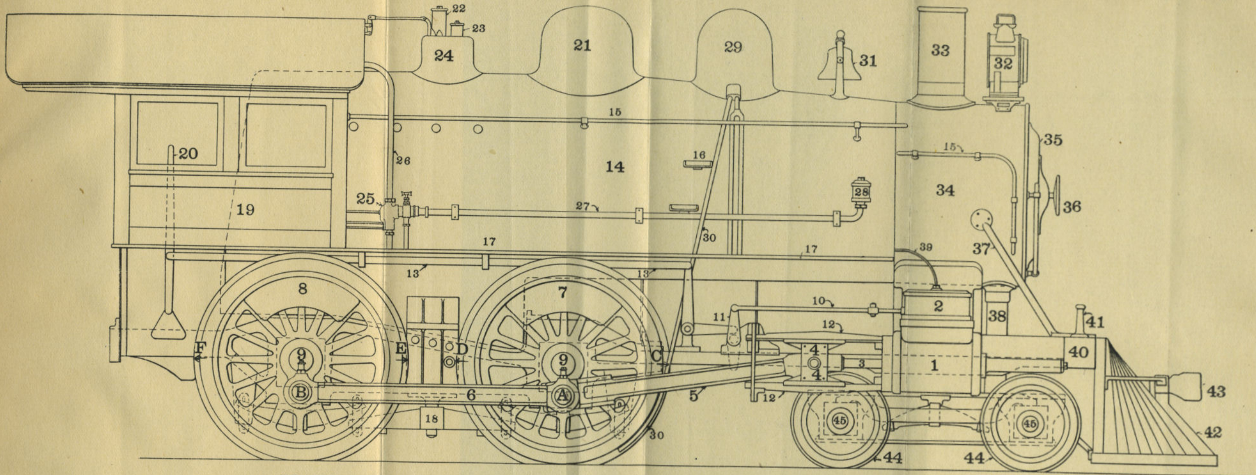


PLATE ONE—DRAWING TO SHOW THE VARIOUS PARTS OF A LOCOMOTIVE.

INDEX.

A—Main or forward crank pin. B—Rear crank pin. C and E—front centers of the cranks. D and F—Back centers of the cranks.

1. Cylinder.
2. Steam chest.
3. Piston-rod.
4. Cross-head.
5. Main rod.
6. Side rod.
7. Main driving wheel.
8. Rear driving wheel.
9. Main and rear driving axles.
10. Valve-stem.
11. Rocker-arm.
12. Guides.
13. Reach-rod.
14. Boiler.
15. Hand-rail.
16. Sand-box steps.
17. Running-board.
18. Driving-spring equalizer.
19. Cab.
20. Reverse-lever.
21. Steam dome.
22. Whistle.
23. Safety-valve.
24. Auxiliary-dome.
25. Injector.
26. Injector steam pipe.
27. Injector delivery pipe.
28. Check valve.
29. Sand box.
30. Sand pipe.
31. Bell.
32. Headlight.
33. Smoke stack.
34. Smoke box.
35. Smoke-box front.
36. Number-plate.
37. Smoke box brace.
38. Cinder-hopper.
39. Oil pipe.
40. Bumper-beam.
41. Flag staff.
42. Pilot.
43. Coupler.
44. Engine-truck wheels.