Grand Scales
QUARTERLY

HAND FIRING OF LOCOMOTIVES

FIRING COALS OF THE EASTERN STATES

Purpose of the Instruction.-Before a man can be an efficient locomotive fireman, there are many things that he must learn. Some men acquire this knowledge during years of firing service, learning from the hard knocks of experience. Others learn through the quicker and easier method of studying the experience of others as set forth in written instructions. The purpose of this instruction is to furnish practical information to locomotive firemen on all necessary subjects pertaining to the firing of the coals of the Eastern States.

Importance of a Knowledge of Coal: One of the first essentials of an efficient fireman is a knowledge of the different kinds of coal. There are more than fifty varieties of coal in the country and every variety is burned in locomotives. Some of these coals are good steam coals, others are only fairly good, and still others are burned in a locomotive firebox only with the greatest difficulty.

As there are so many grades and varieties of coals, it is easy to understand that the methods of firing employed must be suitable to the grade and variety of the coal used, and the fireman must know what method to employ in each case. Furthermore, the ash-pan, grates, firebox, and draft adjustment must be suitable to the coal being burned, and the fireman should know whether the conditions are right. If an engine is designed to bum a certain type and grade of coal, better results will be obtained with that grade than with either a better or a poorer grade. For that reason, where conditions will permit, each coaling station should be continuously supplied with the same grade and type of coal, and the locomotives should be properly equipped and drafted to burn it. Under conditions where many grades of coal are supplied and must be burned in the same firebox, the fireman must learn to fire the different grades so as to obtain the best results with each.

COALS AND THEIR COMBUSTION

A study of the coals of the Eastern States shows that they consist of high-rank bituminous, semibituminous, semianthracite, and anthracite. Bituminous coal may be either a coking coal or a free-burning coal.

Coals that coke vary widely in coking properties. Those with the greatest tendency to coke swell up in burning, become pasty, and fuse into a mass of porous coke. This forms a protective covering over the surface of the fire, restricts the draft through the fire, and so cuts down the steaming capacity of the boiler. To offset this, the coke covering must be broken up from time to time with a slash bar, so that air can pass through the fire readily.

Tar Distilled From the Coal.-The tar distilled from the coal consists of about 50 per cent of pitch and 50 per cent of hydrocarbon oils and liquid paraffins. A coal rich in tarry vapors is a most persistent smoke maker, as the tar constitutes the worst smoke-producing constituent of the coal. The power of tarry vapors to make a dense black smoke will be readily understood if a small piece of tar is thrown on a fire and the quantity and color of the vapor that arises from it are noted. If the firebox temperature is high enough, any tar that escapes burning is decomposed into soot and fixed gases. The soot makes dense clouds of smoke, while the gases that escape unburned are a source of fuel waste.

Tendency of Coal to Produce Smoke.- The tendency of a coal to produce smoke depends on both the relative total quantity of volatile matter and on the temperature at which the smoke-producing part of the volatile matter is driven off. For example, Illinois and West Virginia Pocahontas coal contain practically the same amount of smoke-producing volatile matter. The Illinois coal gives off the major portion of its smoke-producing volatile at a low temperture (between 900°F. and 1,lOO°F.), and for that reason is a very hard coal to burn without smoke; the Pocahontas coal gives off the major portion of its smoke-producing volatile between 1,200°F. and 1,500°F., a temperature at which it is burned smokelessly with but little effort. Connellsville, Pennsylvania, coal gives off its major portion of smoke-producing volatile between 1,1O0°F. and 1,500°F., but as it contains a much greater proportion of smoke-forming volatile it must be burned with great care to prevent dense black smoke.

Rate of Distillation of Volatile.- Experiments have shown that the quantity and quality of the volatile distilled from a coal depends on the rate at which the coal is heated and the volatile driven off. With a slow rate of heating, the volatile is smaller in quantity and has a higher percentage of gas and a smaller amount of tarry matter. With a rapid rate of heating, a larger amount of volatile is obtained and a much larger proportion of this is in the form of tarry vapors and of hydrocarbon gases, which are hard to burn without smoke. For that reason, it is much harder to burn a coal without smoke at high rates of combustion than at low rates of combustion if the coal contains heavy smoke-producing volatile matter. Such a coal must have ample draft and ample air spaces in ash-pan and grates, the fire must be clean and as light as can be carried for the work the engine is doing, and there must be no leaks in the firebox or at the front end. At high rates of burning, smokeless combustion will be helped greatly by swinging the fire-door or leaving it on the latch for a short time after each fire. The fire-door must be swung shut after each scoop, so as to maintain a sufficiently high firebox temperature to insure smokeless combustion.

Smokeless Coals.-Coals, such as the semianthracite and semibituminous coals, that have not more than 20 per cent of volatile matter are usually known as smokeless coals, because they can be burned at a much higher rate than the bituminous coals without producing black smoke. The reason for this is twofold: first, they have a smaller amount of volatile matter, and second, most of the tarry matter. has been driven off through the longer period of pressure to which they were subjected. On the other hand, they are more friable and are not so well suited for transportation and repeated handling as the bituminous coals, especially the central bituminous coals of Illinois, etc., so they carry a higher percentage of slack coal, which must be taken care of by the fireman in order to avoid a large fuel loss.

Slack Coal. -Probably the worst fuel loss that a locomotive fireman has to contend with is that which occurs through the escape of unburned fine coal. Where the percentage of fine slack coal is very high, this loss may amount to one-quarter or even one-third of the coal fired. As a scoop of coal is being fired, the draft picks up the fine coal and shoots it through the tubes and out of the stack, in many cases even before it has
been heated sufficiently to drive off the volatile gases. The harder the engine is working the stronger will be the exhaust and draft and the greater will be the fine-coal loss. That is one reason why the fuel record *of* a man in heavy freight service suffers when compared with the record of a man in light freight service of moderate schedule speed. Not only is the fine coal wasted, but the sparks and live cinders thrown out along the right of way are responsible for many fires during dry seasons of the year.

Reducing Slack-Coal Loss.: The best method of reducing the loss through unburned fine coal is to wet the coal until the fine particles stick together while being fired. This can be done only by thoroughly drenching the coal at least a half hour before leaving time, so that the surplus water will have time to drain off. A *light* wetting will not prevent the loss of the fine coal and will add to the fuel loss, because the water must be evaporated and heated to the stack temperature at the expense of the heat of the firebox. In case the coal is sprinkled to keep down the dust in the cab, only just enough water to serve the purpose should be used, to reduce the loss through evaporation of the water.

Ash From Coal.- The analyses of coals of the Eastern States show that the ash may vary from 2 to 15 per cent of the weight of coal. A fireman firing a coal with 15 per cent of ash would fire 300 pounds of ash and 1,700 pounds of coal for each ton of coal used; with a coal having only 2 per cent of ash he would fire only 40 pounds of ash and 1,960 pounds of coal. Furthermore, the extra 260 pounds of ash in the high-ash coal would clog the fire and probably clinker, and would interfere greatly with the proper burning of the coal. It certainly would cut down both the efficiency and the capacity of the firebox, and would tend greatly to produce smoke.

Foreign Impurities.-From the fireman's viewpoint the ash of a coal includes not only the inherent ash which is a definite part of the composition of the coal but also the impurities that become mixed with the coal during the process of mining and in transportation and after handling. The impurities foreign to the coal are the real trouble-makers. The inherent ash of a coal will not cause trouble from clinker if the fire is properly manipulated and the ash is not raised up into the hot zone of the fire. The foreign impurities, on the other hand, are sure to cause trouble. The foreign impurities may consist of: iron pyrite, which occurs in some beds of coal in balls, bands, and lenses and in other beds in veinlets or as small particles and usually is a trouble-maker on account of the tendency of its iron to form clinker; slate, shale, and sandstone from the roof of the mine; slate, shale, and sulphur balls sandwiched in between the coal strata; clay from the floor of the mine; and pieces of iron, rock, and earth that are picked up en route orin the subsequent handling of the coal.

The foreign impurities are very apt to give trouble through clinkering. If they do not fuse they settle down onto the grate and as the run proceeds gradually form a screen on top of the grate that shuts off a large part of the grate air space and so restricts combustion. If the fireman does not know the cause of the trouble he will probably fire more heavily than usual, with the result that the thickness of the fire bed will be increased and the steam production decreased.

A great deal of worry and hard labor will be avoided ifth_ fireman will watch every shovel of coal fired for pieces of rock, slate, and other impurities. These should be picked out of the coal and placed in a pile at one side near the gangway where they can be thrown off at some point where there is no danger of hurting persons who might possibly be along the right of way.

Hard Clinker.- The formation of hard clinker in a locomotive firebox is one of the chief causes of a fireman's troubles. Where clinker does not form, it is a comparatively easy matter to carry a light, level, clean fire that is easy on the coal pile and makes steam freely. When clinkers form, the fire becomes dirty, grows thick, burns unevenly, smokes, and steam pressure is maintained with the greatest of difficulty. Since the hard clinker, which is the form ordinarily met with, is formed generally by the melting of some foreign impurity in the coal, the way to avoid the clinker is to watch the coal for impurities and pick them out before firing the coal. The work required to do this is as nothing compared to the work and worry caused by throwing the impurities on the fire with the coal.

Hard clinker is sometimes formed by inserting the slash bar too deeply in the fire and raising some of the ash into the hot zone of the fire, where it melts and in cooling cements a lot of coal and ash together into a big clinker. The way to avoid this is to use the slash bar as little as possible, and then with care.

The appearance of the fire indicates when a clinker is forming. When a spot in the fire begins to grow darker in color than the rest of the fire and it is not due to a bank, it indicates that the air is restricted through that spot, probably due to the formation of a clinker. As soon as this is noticed the clinker should be broken up by a careful operation of the grates. The time to do this is when the clinker first forms. Ifit cannot be broken up by shaking the grates, it should be raised to the surface of the fire and removed at the first opportunity.

Soft Clinker.-Soft clinker is a slag formed by the chemical combination of the constituents of the ash at firebox temperature. To bring about this chemical combination, sufficient heat must be supplied to cause fusion. When a soft clinker first forms the appearance of the fire is the same as if a hard clinker had formed, but the soft clinker grows steadily in size until finally it spreads over the whole grate area. Inspection will show that the clinker is in a fluid condition underneath the crust. The fluid portion penetrates through the lower ash and often hangs like icicles from the grate bars.

Fortunately all ash does not contain the right constituents for combining chemically to form a slag at firebox temperatures. Also, the temperature of fusion usually is higher than the temperature to which the ash is subjected. It should always be borne in mind, however, that the temperature may be near slagging temperature and anything that may increase it only slightly may cause the ash to start slagging, and once this is started, it is practically impossible to stop it. The only way to remedy the trouble is to pull the fire, clean the firebox *and the grate,* and start a new fire.

Anything that increases the ash-pan temperature has a tendency to cause the formation of soft clinker, and anything that tends to reduce that temperature tends to prevent the formation of clinker. Therefore, as a precautionary measure against the formation of clinker, the ash-pan, which should have ample air openings, should be kept clean and after the grates are shaken, when weather conditions will permit, the hot ashes should be cooled by spray piped from the injector overflow pipes. The grates should not be shaken hard enough to shake burning coal into the ash-pan.

Mixing Coals.-Many coals may be mixed and burned without causing trouble from clinker. On the other hand, two coals, neither of which clinkers in burning, may cause considerable trouble from clinker if mixed and burned together, or if burned in the wrong order. For example, if anthracite or semianthracite is fired on a fire bed of bituminous coal, the result is almost sure to be disastrous, whereas bituminous coal can be fired on a fire bed of anthracite without the least trouble. It is well, therefore, for a fireman to know whether the coals at the two ends of a division can be burned together without causing trouble.

CONDITIONS FOR ECONOMICAL COMBUSTION

Draft of Locomotives.- It is important that an engine have the proper draft for burning coal economically at the rate necessary to supply the maximum amount of steam. If the draft is not sufficient, the engine will not steam, especially when working hard. If the draft is not distributed evenly, the fire will not burn evenly. When the action of the draft on the fire is not what it should be, the fireman should report it, being careful to tell exactly what is wrong. It should be borne in mind that while the action of the draft on the fire is not right, the trouble may not be due to wrong adjustment of the draft appliances, so no readjustment should be made until the actual cause of the trouble is located. If the fire indicates too little draft the draft appliances may be properly adjusted to produce the necessary draft, but steam or air leaks Into the front end, or an obstruction in the ash-pan, grates, tubes, front end, or the netting may be reducing the amount of air flowing through the fire. Of course, the draft can be increased by reducing the size of the nozzle or by bridging the nozzle, but that will simply increase the waste of fuel through increasing the back pressure in the cylinders. The proper procedure is to find the cause and remedy that without touching the draft appliances unless they are found to be at fault. The ash-pan openings may be partly closed or the pan may be too full of ashes. A large number of air openings in the grate may be filled up. Often 60 per cent of the openings have been found entirely closed. A large number of the tubes may be plugged up or the netting may be choked. The fireman should determine wherein the trouble lies so that he can turn in a correct report.

Draft Restrictions.-If a number of the air spaces in the grate are stopped up the fire will burn both poorly and unevenly on account of a lack of air. If the ash-pan opening on one side becomes partly closed up and the total amount of ash-pan air opening is small, the fire will burn poorly on the side on which the ash-pan opening is partly closed.

A fireman should insist that the real cause of any trouble be located *before any change is made in the draft appliances.* Of course, the draft can be regulated to offset the effect of leaks or other defects, but this means burning more coal to keep up the steam supply and additional work for the fireman. On the other hand, if the real cause of the trouble is located and remedied, the extra coal and work can be saved.

Failure of Engine to Steam.-Failure of an engine to steam, after being fired in accordance with the best practice, can generally be laid to a condition or set of conditions that decrease the draft or flow of air through the fire. This may be due to conditions over which the fireman mayor may not have control. The dampers or ash-pan netting may not be open, or the ash-pan may be full of ashes. Conditions over which he has no control are leaky steam pipes or superheater units, washout plug leaking in front end, blocked flues or netting, air leaks into smokebox, exhaust nozzle loose and leaking, and exhaust-nozzle tip of the wrong size or out of line with the stack. There may not be sufficient opening through the grates, or bricks may have fallen out of the brick arch.

The symptom of a reduced draft through the fire is difficulty experienced in getting the fire to burn white, as it will have a more or less dull color. Leaking tubes apparently reduce the draft out of all proportion to the extent of the leak. This is due to the fact that when water is heated to form steam, it increases in volume about eighteen hundred times. The steam generated from a small leak in the tube-sheet then has an appreciable effect in decreasing the draft through the fire.

Scale and Soot.-The effect of scale and soot on the steaming qualities of an engine is very marked. The loss in heat transmission due to ordinary scale varying in thickness up to % inch may amount to 10 or 12 per cent. This means that out of every ton of coal fired from 200 to 250 pounds is practically wasted. In other words, in doing work that ordinarily would require the fireman to fire nine tons of coal with tubes clean of scale, the scale would make him fire ten tons, and he would have a much harder struggle to maintain steam pressure. On some roads today it is the practice when a locomotive has been out of the shop for six or eight months to either reduce the nozzle tip or to bridge it in order to offset the bad effects of scale and leaks. A much better practice is to treat the water and so avoid the formation of scale. Soot is formed whenever coal is burned, but the better the combustion, the less soot will be formed. When the condition of the fire or careless firing causes smoke, clouds of soot are formed that coats the heating surfaces and seriously retards the transfer of heat to the water. Soot is said to be five times as good a non-conductor of heat as asbestos. Of course, the scouring action of slack coal passing through the tubes tends in a measure to clean them of soot, but even at the best there is a , considerable fuel loss through soot. The fireman should watch for soot and should see that the tubes are bored out and cleaned frequently, thereby saving himself much unnecessary labor.

Waste at Pop Valve.- With a free-steaming engine, it is often difficult to prevent a large waste of steam at the pop valve. For every minute that the pop is blowing, 30 pounds of coal is wasted. If a scoop of coal is assumed to weigh 15 pounds then two scoops of coal are wasted for each minute the pop is open. If during a run the aggregate time of blowing equals 30 minutes the coal wasted will amount to 30 x 30 =900 pounds. With the two pops blowing occasionally, which sometimes happens, the quantity of coal wasted will be increased. Much labor and expense can then be saved by using care to prevent the pop from blowing.

If the fireman knows the run, it should be a comparatively easy thing for him to plan each fire far enough ahead so that when a regular stop occurs the pop can readily be prevented from opening. In local passenger service, when stops are many and short and stations close together, there is added difficulty in preventing pop waste. Just before closing the throttle the engineer should put on the injector and the fireman should crack the blower. This should prevent the pop from opening; but if indications are that it will not, the fire-door should be put on the latch or swung open and shut just enough times to prevent the pop from opening. While the engine is using steam, the fire-door should never be left wide open to prevent the pop from blowing or to cause the pop to cease blowing, as the large volume of cold air that would flow in a continuous stream through the firebox and tubes would cause tube leakage.

Cooperation of Engineer and Fireman.- The engineer and fireman must work in harmony with each other if good results are to be obtained. When pulling out of stations, the injector should not be started until the fireman has the fire in good condition, and the steam pressure is increasing. Otherwise the fire will have to be crowded to hold up the steam pressure. When approaching shutting-off points, the fire can be allowed to burn down somewhat, and the water level at this time should not be so high as to prevent the injector from being used to keep the engine from popping. The engine should not be run first with a light throttle and then with a heavy throttle, nor should the cut-off be changed frequently, as working the throttle and reverse lever in this way makes it impossible for a fireman to carry a steady fire and an even steam pressure. The position of the throttle and lever should, as far as possible, be changed only when a change in grade makes it necessary.

DETAILS OF FIRING

Preparing Fire for Start.-It is of the greatest importance to have a good fire with which to start the trip. If the fire is not put in shape before starting, it will give the fireman all kinds of trouble. For that reason he should get around in sufficient time to have his fire in perfect shape before leaving time, as he thereby will save himself much worry and hard labor during the run.

On arriving at his engine he should see whether the fire has been well cleaned. If it has not, he should knock out any clinker or ash that remains. Next, he should close the fire-door and put on the blower long enough to start the fire burning brightly so that he can detect any dead spots in it. Sometimes the fire cleaners in spreading the live coals after cleaning the fire do not entirely cover the grates and fire green coal on the bare spots. With a coal that ignites freely this will not matter so much, as the green coal will gradually ignite and the fire will spread over the dead spot. However, if there is a dead spot with the low-volatile, harder-to ignite coals like the semi-anthracite, it will cause so much trouble that it should be done away with before starting. The green coal should be pulled away from the dead spot, the grate covered with good live coals, the green coal spread over the live coals, and the blower applied just long enough to ignite the green coal thoroughly.

Building Up the Fire.-After the fire has been put in good condition all over the grate surface, fresh coal should be lightly spread over it, and, if necessary, the blower put on very lightly. If there is sufficient time in which to build up the fire without the blower, it should not be used. It has been found by experience that when the blower is used freely in building up a fire, more clinker is formed and the fire is not in as good condition as when it is built up under natural draft. After the fresh coal that was spread over the fire is at a cherry-red heat, begin to build up the fire by spreading fresh coal thinly, first over one half of the firebox, lengthwise, and then over the other half. The idea is to always have one half of the fire at a red heat or better, when fresh coal is put on the other half, so that sufficient heat will be assured to burn the gases as they are driven off from the fresh coal. This method of firing will very materially reduce the amount of smoke produced in building up the fire.

The fire should be built up to the required thickness for the service as gradually as time will permit. Each fire should consist of only one, two, or three shovelfulls at a time, each being spread lightly and evenly over half of the firebox surface. A charge of coal that has been put on the fire must not be covered with more fresh coal before it has attained a red heat. Below a fairly bright red heat the first charge has not had its volatile matter driven off, and the second fire will simply retard the distillation and will cause the fire to build up too rapidly with green coal. Then, when the fixed carbon of the coal begins to burn, the hot zone of the fire will be so thick and so hot that clinker will result.

It is of the greatest importance to have a good fire covering the entire grate surface before leaving time for the trip. The depth of the fire will depend on the size of the coal, the weight of the train, and whether the start will be on an up grade, a level, or a curve. In other words, if the engine will have to work hard to start the train the depth of the fire at starting time must be greater than if the train is easily started. The coal necessary to keep up the steam pressure and to keep the fire in shape while the train is being started should be thoroughly ignited, and burning brightly before starting.

Depth of Fire.-It is important to know the best depth of fire to carry under various conditions. Many firemen do not understand this, and are in the habit of carrying one depth of fire at all times unless the thickness of the fire builds up during the run. This is a mistake that causes the fireman much extra work and worry, besides lowering his standing in the fuel records. For light loads, a light fire should be carried, while a thicker fire should be carried for heavier loads. It should not be thicker, however, than is necessary to withstand the effects of the exhaust, as that thickness will give the greatest fuel efficiency and the least trouble in burning.

Fuel Loss Through Thick Fires.-The effect of the thickness of the fire on the efficiency of a certain boiler and firebox is shown in Table I. These results hold good only for the boiler from which the results were obtained. If a test for another locomotive were to be made, the best depths of fire would very probably be different from those given, *but whatever they were found to be, they would vary in a manner similar to these figures.* The results found in. the tests are presented merely to emphasize the fact that a lighter fire will give better results at light loads, whereas a heavier fire must be carried for heavy loads.

From the table it will be seen that in this test a 6-inch fire gave the best results for half and three-quarter loads, but that the efficiency was greatest at half load and dropped away rapidly as the load was Increased. The 7-inch fire was not as efficient as the 6-inch fire for half load, but gave best results from three-quarters to full load. The 8-inch fire gave best results between full load and one and one-quarter load. The 9-inch fire did not give as good results as the 8-inch fire, while the l0-inch fire was considerably less efficient.

Suppose that the man firing for the test had the habit of always carrying a l0-inch fire. How much extra coal would he have had to fire on that account? For half load he would be wasting 11.5 per cent, or 230 pounds, out of every ton fired. For three-quarters load, he would waste 10.5 per cent, or 210 pounds per ton. At full load he would waste 5.5 per cent, or 110 pounds per ton. At one-quarter overload he would waste 5 per cent, or 100 pounds per ton fired. Burning this extra coal means more work in feeding the fire, and more work in keeping the fire at its best, because the more coal that is burned the more dirty the fire becomes. This extra labor and trouble can be avoided by carrying a depth of fire best suited to the load.

TABLE I
EFFICIENCY OF BOILER AND FIREBOX

Depth of Fire Inches	Amount of Load Carried			
	Half Load Per Cent. Efficiency	Three-Quarters Load Per Cent. Efficiency	Full Load Per Cent. Efficiency	One-Quarter Overload Per Cent. Efficiency
6	73.5	67.5	64.0	60.5
7	68.5	67.0	68.5	62.0
8	65.0	64.0	68.0	63.0
9	63.0	60.5	66.5	62.0
10	62.0	57.0	63.0	58.0

Preparation of Coal.-Most of the coal furnished for locomotive service is run of mine. Due to differences in the nature of the coal, in mining methods, methods of preparation, etc., there is a big difference in the make-up of the run of mine from different mines. Run of mine from a district where the coal is soft and friable has a high percentage of slack and a correspondingly low percentage of lump coal. Furthermore, the lumps crumble when exposed to the high temperature of the firebox, so they need not be broken so small as the lumps of the harder varieties. With a soft, friable coal, therefore, the loss of unburned _lack must be prevented by thoroughly drenching the coal.

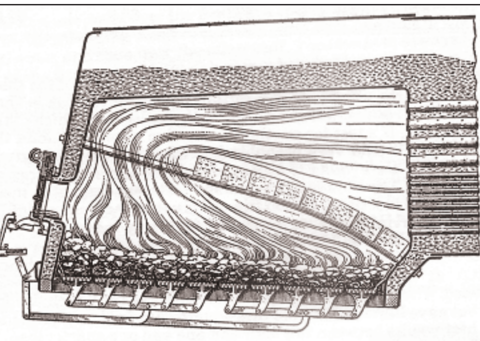

Fig. 1

Most of the coal from the Eastern States is of the harder varieties, so that it has a lower percentage of slack and a higher percentage of lumps, many of which are too large to go through the firedoor. Now, fine coal and large lumps cannot be burned together, because the lumps burn slowly and tend to cause banks and clinkers; also, holes form around the lumps. A fireman will save worry and labor by breaking up large lumps to the size of medium-sized apples before shoveling them into the firebox.

Method of Firing. The thickness of fire carried should be as light as conditions will permit. A good portion of the fire should be at a white heat, the fire should be free from holes and banks, and the flame should be clear and non-smoky and short enough so as not to reach the tubes. The thickness of the fire will increase if the ash continues to accumulate on the grate or if coal is fired faster than it is being burned. The fire should not be allowed to become thicker through the accumulation of ash, because that will surely lead to the troubles that go with a dirty fire. If the grate does not clear itself, it should be shaken very carefully as often as is necessary to prevent an accumulation of ash.

The coal put in at one fire should always be allowed to burn down before another fire is put in that part of the firebox. This is a cardinal principle of firing. If this is done, the fire will not build up in thickness. When the fire is to be built up in anticipation of heavy work, such as climbing a heavy grade, the coal is fired faster than it burns, by shortening the intervals between fires. However, the intervals should not be so short that the coal of one fire does not have time to come to a bright red heat before it is covered with the next charge of coal.

Firebox Temperature.-From the standpoint of both firebox efficiency and smokeless combustion, the temperature of the firebox must be kept high and as nearly constant as possible. If the entire surface of the firebox is covered with green coal at a fire, allowed to burn down and then covered with green coal, the firebox temperature will vary greatly and the steam pressure will vary correspondingly. Such variations mean smoke, leaky tubes, and waste of fuel. The best plan, where the firebox is not too large, is to fire the lengthwise halves of the firebox alternately. In this way, half of the fire can be at a bright-red heat all the time, which will maintain the high constant temperature necessary for good combustion. When the firebox is too large for firing halves, divide it into quarters and fire alternate quarters.

Placing the Coal on the Fire.- It is important that the fireman know where and how to place coal on the fire. With engines having sloping fireboxes, care must be taken not to put too much coal under the arch. Both the slope ofthe-firebox and the force of the draft tend to pull the coal ahead, and unless care is taken the fire will be banked up next to the tubesheet, causing the forward section of the grates to become clinkered over and stuck. Most of the coal should be fired at the back end of the firebox and in the corners and along the sides. Fire only enough in the front end and in the middle of the firebox to prevent holes from forming.

The coal should be fired with only two or three scoops to the fire. It should be placed on the bright spots and never on the dark spots, as that has a tendency to form banks. The bright spots indicate the places where the fire has most nearly burned through. The intervals between fires should be lengthened or shortened according to the requirements. This procedure will make the fireman's work much lighter, as he will handle less coal and a steady steam pressure will be easily maintained. Also, the coal will be burned with much less smoke than it otherwise would be, as
less gas will be liberated to a fire and more time will be allowed for the gas to burn before a new fire is put in.

The rate of firing will be in direct proportion to the draft, because the rate at which the fire burns depends on the rate at which the air is passing through the fire bed. Increasing the amount of air passing through the fire makes the coal burn faster; decreasing the amount slows down the rate of combustion. The amount of coal burning at any time must be sufficient to supply the steam necessary to operate the engine properly under the conditions prevailing.

Swinging the Fire-Door.-If the engine is not equipped with an automatic fire-door, the fireman should swing the door shut after every shovel of coal, which should be fired in a leisurely manner, so that the door will remain shut for a few seconds after each charge. This method requires a little work but saves the fireman a great deal of labor in the end. For, if he leaves the fire-door open, the cooling effect produced wastes much coal and so increases the amount that must be supplied by the fireman. Furthermore, if this extra coal did not have to be burned, a much cleaner fire would result.

Starting the Train.-By leaving time at the terminal station, there should be a good fire burning brightly all over the grates and of a suitable thickness for the work the engine will have to do in starting the train. Under some conditions it may be an advantage to put on the blower for a time just before starting, so as to have a good hot fire. If the train is a heavy one, the new fire may be torn up by the heavy exhausts; so the firedoor should be placed on the latch to reduce the draft above the fire and lessen the tearing effect. When the reverse lever is notched back, a fire should be put in to repair any damage done in starting, and the fire after that should be maintained to suit the work of the engine.

When to Put in a Fire.-The student fireman generally experiences difficulty in reading his fire— that is, he is not sure just when a new fire should be put in-the result being that he generally errs on the side of too much coal and crowds his fire, or adds fresh coal before the coal already in the firebox has been sufficiently burned. When this is done, the fire becomes too thick, the passage of air through it is obstructed, the steam pressure falls and there is, depending on the coal used, a tendency for clinkers to form. The time elapsing between firings will depend on the coal, draft, cut-off at which engine is working, etc., and can be determined either by the appearance of the fire or by the time interval between fires. The experienced fireman does not generally regulate his firing so much by the appearance of the fire as by the intervals of time his experience has taught him must elapse between fires under various conditions. In other words, he expects his fire to be in the proper condition for a fresh supply of coal after a certain time. The judgment necessary for a fireman to determine correctly the time between fires can only be acquired by experience, and in the meantime he must be guided to a great extent by the appearance of his fire. When the coal he has fired before his last fire has burned down to a dazzling white heat, this section of the grates is ready for another charge of coal. For example, if his last fire consisted of three scoops of coal on the right side of the firebox, when the left side has burned to a white heat, his next fire should be along that side. When putting in a fire the fireman should practice making a quick survey of the whole firebox and thus ascertain the kind of fire that is being carried.

Heavy Firing.-Heavy firing with bituminous coal makes both labor and trouble for the fireman. Some firemen habitually fire from eight to fifteen scoops to a fire when the engine is working hard. That is just the time the most skillful firing should be done; yet by heavy firing the fireman not only wastes a great deal of coal but also reduces his chances of maintaining the necessary steam pressure. A heavy charge lowers the firebox temperature and allows the gases to escape unburned. Cooling the firebox reduces the rate at which steam is generated, thereby reducing the maximum hauling capacity of the engine. On a long grade with a heavy freight, this might mean doubling the hill, whereas a properly fired locomotive would make the grade without doubling.

If a coal composed of one-third volatile matter were to be fired in charges of fifteen scoops, each holding 15 pounds of coal, each scoop would have 5 pounds of gas. The 15 scoops would contain 5x15 = 75 pounds of gas, and 75x300 = 22,500 cubic feet of air, or the contents of ten box cars, would be required to burn the gases without counting the air necessary for the burning of the fixed carbon. The draft appliances are not adjusted to admit such a supply of air, and so most of the gases escape unburned. The consequence is that the fireman gets no useful results from half the coal he is firing, and just at a time when he should be getting all the heat the coal is capable of giving. Firing two or three scoops to a fire at frequent intervals would cut his labor in half, maintain a better steam pressure, and greatly reduce the trouble from dirty fires. Furthermore, it would prevent the big fluctuations of temperature that occur with heavy firing, thereby preventing trouble from tube leakage.

Firing Poor-Steaming Engines.-Under favorable conditions-that is, when the coal is of fair average quality and the engine is properly drafted-it is a comparatively easy matter to carry a good head of steam if the fireman keeps in mind the correct principles of firing. However, when the conditions are not favorable, due either to the fuel or to the engine, it is only by exercising good judgment that it is possible to have a successful trip. The fireman should not assume that conditions unfavorable to the free steaming of an engine should cause him to deviate from principles that his experience has taught him produce the best results, as it is only by the application of these principles that the greatest degree of heat can be obtained under any conditions, favorable or otherwise. He should, bn the contrary, apply the principles of correct firing to the conditions under which he is working, and, even if the engine is not kept hot, be satisfied that the results derived from their application will be the best obtainable.' For example, if steam leaks reduce the vacuum in the smoke box and therefore decrease the draft through the fire, special effort should be made to keep the fire clean and light, so as to facilitate as far as possible the passage of the reduced volume of air entering through the grates to the fire, and thus compensate for the reduction in the draft due to leaks. Care should also be taken under these conditions to fire more lightly than usual, as it is very easy to overcrowd the fire under any conditions that cut down the draft. The tendency, however, when an engine is not steaming freely, is to fire too much coal, which in a great number of cases merely aggravates the trouble. In the case of poor-steaming engines there should be closer cooperation between the engineer and fireman than is usually necessary when conditions are more favorable.

Filling Up of Firebox.-Trouble is sometimes experienced by the fire increasing in thickness rapidly even when the grates are shaken frequently. As it is practically impossible in certain classes of service to keep shaking the grates continually, steam failure and detention of the train result. There are two principal causes of filling up the firebox: an excess of ash or foreign matter in the coal, and incomplete burning of the coke. In the first case nothing can be done except to keep the fire as thin as possible by frequent shaking of the grates; but in the latter case the trouble can be avoided by changing the manner in which the coal is being fired.

Some classes of coal burn more slowly than others, and require more time for the gases to distill out, and less smoke is emitted at the stack. Fresh coal is frequently added before the coal already in the firebox has completely burned, causing the fire to become too heavy. Coal of this nature should be fired as light as possible, erring, if necessary, on the side of too little coal rather than too much, until the correct method of firing is found. An examination of the contents of the ash-pan will show whether the trouble is due to impurities in the coal or too heavy firing, as in the latter case a large amount of un burned coke will be found in the ashes.

Shaking the Grates.-How frequently the grates should be shaken depends .on the style of grate, the amount of ash in the coal, and the amount of clinker-forming material in the ash. If the grate has the proper air openings for the coal being burned, and the air openings are not plugged up, and if the ash from the coal is fine and does not clinker, it is possible to go from terminal to terminal without shaking the grates. On the other hand, if the air openings are not right, or are filled up, or if the coal is high in ash and clinkers and contains rock and slate that are not picked out before firing, it will be impossible to get along without shaking the grates. The fireman, therefore, must judge as to whether or not it is necessary to shake the grate; however, he should bear in mind that it should never be shaken except when necessary, as fire trouble is apt to result.

If the appearance of the fire indicates that there is a restriction of the air passing through, the grates should be carefully shaken and the shaking should be repeated every time the appearance of the fire indicates the necessity. The time to shake the grates is when the throttle is closed or when the exhaust is very light. The object of shaking is to remove the dead ashes and clinker from the bottom of the fire, and the shaking should stop at the first indication of live fire dropping into the ash-pan, not only to save fuel but to prevent burning out the grates by live fire in the pan.

Care must be taken always to lock the grates in their level position; otherwise, the fingers on one side of the grate bars will project up into the fire and will probably be burned off, or clinker may get wedged between the fingers of adjacent grate bars and hold them open so that live fire can fall into the ash-pan.

Use and Abuse of Blower. -When the blower must be used, turn it on just as lightly as will do the work. If the blower is used too strongly and at the wrong time it will cause damage to the boiler. The most frequent abuse of the blower and the one that does the most damage to the boiler is using it too strongly with the firedoor wide open or when raking or cleaning the fire. In doing this work, the blower should be put on only just strong enough to prevent the gases from coming out the firedoor into the fireman's face. Turning the blower on harder than is necessary is pretty sure to cause leaky tubes.

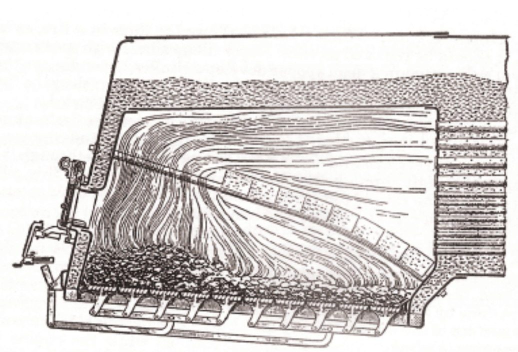

Fig. 2

Banks in the Fire.- The condition of the fire known as a bank is indicated in Fig. 2, and is brought about by the building up of the fire bed considerably above the level of the fire at one point, due to slow burning at that point. Anything that restricts the draft through the fire at any point in the firebox will cause the thickness of the fire at that point to build up and a bank to form. A clinker on the grates, or firing one scoop of coal upon another before the coal from the first scoop has had time to get red hot will form a bank. If the draft at one point in the firebox is very light and coal is fired at that point at the same rate as for the rest ofthe fire where the draft is normal, a bank will build up at the point of weak draft. A bank cuts down the amount of active grate area and makes the distribution of the draft uneven; therefore, it should be removed, if possible, or else coal should be fired around it so as to cause it to burnout. If it is not gotten rid of, it will start a bad clinker.

Holes in Fire.- When a hole is allowed to form in a fire, as in Fig. 3, it should be repaired at once. Never fill up a hole with green coal, as it will either remain a dead spot or develop a clinker, depending on the kind of coal being burned. Fill the hole with live coals by leveling the fire at that point, and then sprinkle fresh coal over the part leveled.

When a hole develops, a large volume of cold air enters the firebox and passes to the tubes in a solid stream that cools the firebox and contracts the tubes and sheets, causing leaks. Also, so much air passes through the hole that the draft through the fire bed is greatly reduced. This still further lowers the rate of combustion and the firebox temperature, and results finally in cracked sheets and leaky tubes.

Clinkers in Fire.-Clinkers cause the worst troubles for the fireman; therefore, he should take all precautions to avoid them. In case they form, the first opportunity must be taken to get rid of them, which may be done by hooking them out, knocking them out, or by raising them to the surface of the fire where they may burn out and crumble. The work of removing a clinker must never be attempted while the engine is working, because in removing it there will be an inrush of cold air, which will cause injury to the firebox sheets and the tubes.

Honeycomb.-The cause of honeycomb, or flue-sheet clinker, is not known, although different theories have been advanced. However, it has been found that quite generally a leak in the tubes or the firebox sheets accompanies honeycomb, and that when the leaks are repaired the trouble from honeycomb ceases; also, wetting the coal seems to aid in preventing it. Honeycomb in many cases will be prevented, or at least retarded, by carrying a light, level fire and providing an excess of air in the firebox. When it starts to form it should be knocked off the flue-sheet; otherwise it soon will entirely block the tubes and so cause an engine failure.

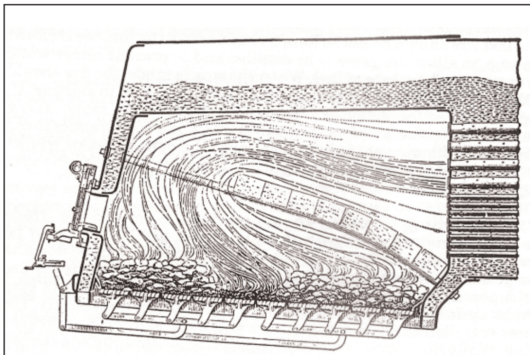

Fig. 3

Station Stops.- When approaching a station, the fireman should have sufficient coal in the firebox to take care of the fire until the start has been made after the stop and the reverse lever has been hooked up. The last fire should be put in long enough before the throttle is closed for the stop, to allow the gases to be distilled and so prevent smoke while at the station and a waste of fuel. When the stop is made, the fire should be sufficient to carry steam pressure until speed is attained in starting. If, through unlooked-for delay or otherwise the fire needs replenishing before this, put the fire in before the train starts. It is a poor practice to put in a fire while the exhaust is heavy, because the open fire-door will let such a large stream of cold air through the firebox and tubes as will cause leakage of the tubes and sheets.

Descending Grades.-In approaching a long down grade where the engine will drift with throttle closed, precautions must be observed to keep the pop from blowing. The fire should be burned down as low as possible without dropping the steam pressure. If there is danger that the pop may open after the throttle has been closed, enough coal should be sprinkled over the fire to prevent this. Also, if necessary, the fire-door may be left on the latch or swung back and forth to prevent popping. While the engine is on the descent is a good time to clean the fire if this is necessary.I

Waiting on Sidings.- When approaching a siding where a long wait is expected, the fire should be burned down as much as possible without lowering the steam pressure. If the fire needs cleaning, this should be done at once so that there will be time in which to build the fire up into shape again before the train has to start. If the fire does not need cleaning, but the injector is working, it should be kept bright until the water level is obtained. Then the fire should be sprinkled over with green coal and if the engine has dampers they should be closed to keep the pop from blowing. If the engine has no dampers, the fire-door should be placed on the latch. The object should be to avoid popping by keeping the fire only high enough to prevent a drop in steam pressure. The fire should never be allowed to get so low as to lose steam pressure, as leaks are apt to develop.

The fireman should begin to prepare his fire in plenty of time before. leaving the siding, so that he will have it built up and in condition to withstand the heavy exhausts of starting the train.

Cleaning the Fire.-If the fire is always carried as light as is consistent for the work the engine is doing, the fireman will have the least amount of coal to shovel, and the chances are that he will not have to clean the fire while on the road. If he does have to clean it, the work of cleaning it will be very much less than if a thick, heavy fire were carried. Heavy firing, either before or after leaving, increases the formation of clinkers and so reduces the time that a fire can go without cleaning. By carrying a light fire, therefore, and taking precautions against the formation of clinker, a fireman can save himself the hard, hot work of cleaning the fire during the run.

Where a train is a long time on the road and the fire becomes dirty and clinkered, it should be cleaned at the first opportunity. The fireman will be well repaid for this labor, as he will get better results with less work and coal, and will avoid leaky, tubes.

If an opportunity is not presented during the run for thoroughly cleaning the fire, a small amount at a time should be cleaned as conditions permit. In this way it will often be possible to complete the trip, whereas without doing so a stop would have to be made to enable the fire to be cleaned.

Cleaning the Ash-Pan.-It is very important that the ashes be not allowed to accumulate in the ash-pan, and that no live fire be shaken into the pan and allowed to burn there. The temperature in the ash-pan rises rapidly as the pan fills with ashes, thereby greatly increasing the tendency of the ash to melt and form a clinker. If fire is allowed to burn in the ash-pan, not only will clinker form on the grates, but also the grates are very apt to be burned out. Some roads pipe the overflow pipes from the injectors into the ash-pans, so that after the grates have been shaken the injector primer can be started and water sent through the overflow pipe to put out any fire that may have been shaken into the pan.

Some roads equip the ash-pan with steam blowers for the purpose of cleaning. In some cases, one pipe in the center is used, while in other gases two pipes are used, one on each side of the center. The steam blower IS not only useful in cleaning out the ashes, but also serves to clean the snow and ice from the pan in winter, thereby avoiding delays necessary to melt the snow and ice by means of a fire. ‘

Terminal Stop.-On approaching a terminal station, engineer should see that there is plenty of water in the boiler and that full steam pressure is carried. The fireman should have enough coal burning on the grates so the hostler will not be required to put in a fresh fire while the engine is in his charge. There should be a good bed of fire left for the fire cleaners, so that the fire can be cleaned properly.

The last fire put in by the fireman should be fired at a distance from the terminal sufficient to enable the gases to be distilled from the coal before the throttle is closed. The fire should be allowed to burn down so that there will be just the right amount of brightly burning coal for the purposes of the hostler when the train arrives at the station.

Summary of Firing Instructions.-The following is a brief summary of the instructions on the hand-firing of locomotives as given in the preceding pages; to obtain the results indicated in the following paragraphs it is assumed that the coal used is off air average quality and does not require any special method of handling when being fired.

The fireman should be at the roundhouse in ample time to prepare his fire properly for the trip. He should ascertain that he has all the necessary tools used in firing on the engine before leaving the roundhouse and should examine the firebox to see if there are any leaks that would be a detriment to the fire or draft and cause engine to fail to steam. The smokebox door should be examined to see that it does not leak and that the nuts holding it closed are screwed up tight. He should ascertain if the grates can be worked, if the fire is free from clinkers, that the ash-pans are clean, and if the slides can be worked. He should also perform any other additional duties prescribed by the rules of the company.

The fire should be built up to the required thickness by adding two or three scoops of coal at a time, and putting the blower on lightly. In order to make a solid bed of fire and avoid the formation of clinkers, additional coal should not be added until the coal already in the firebox has been well burned. The final thickness of the fire’ will depend on conditions, such as the service the engine is in, the intensity of the draft, quality of the coal, etc., but should be sufficient to insure that the starting and pulling out of the train will not injure the fire when the engine is being worked at long cut-off. When building up the fire, the injector can be put on, if necessary, to prevent the engine from popping.

After the train has been started, the coal should be fired at regular intervals, closing the door between scoopfuls. Two or three scoopfuls of coal well scattered should be about the amount necessary to fire at one time. The fireman should aim to keep a level fire by scattering the coal, a bright fire, and a fire of uniform depth by frequent and light shaking of the grates. The fire carried should be as thin as conditions will permit. Banks, holes, and dead places in the fire, especially next to the flue sheet, must be avoided. As a general rule, the tendency is for the fire to burn the heaviest in the four corners of the firebox, along the sides, and next to the flue sheet. In this event the fire, instead of being level, should be thicker at these points.

Fresh coal should not be added until the fire has burned down to a white heat, if the conditions under which the engine is working permit. The steam gauge should be watched closely for indications of improper conditions in the firebox. When the steam pressure begins to fall under apparently favorable conditions, the fireman should examine his fire for banks, holes, or clinkers. The fireman should make a practice of noticing the condition of the fire during the time the door is open when putting in a fire, and should. endeavor to carry a mental picture of his fire at all times. Shake the grates as lightly as possible and often enough to keep the fire clear of ashes and of the correct depth to secure the best results for the conditions under which engine is working. The frequency with which the grates should be shaken will depend on the amount of waste material in the fuel, but ashes should not be allowed to accumulate to such an extent as to render a heavy shaking of the grates necessary. The grates should not be opened up too wide at first, but should be partly opened and closed with short quick jerks. This tends to break up clinkers and avoid the possibility of their being caught in the grates and holding them open. With power grate shakers, if the grates are frequently moved with the limiting lock in position, it will be unnecessary to throw this lock out and open the grates fully.

Endeavor to carry as even a steam pressure as possible when the engine is working. This implies a more or less constant firebox temperature and reduces the tendency of the flues to leak. A high temperature can be maintained by keeping the fire bright, clean, and as thin as conditions will permit, the coal being fired light and often, and well scattered, the door being closed after each scoop.

Except when cleaning the fire, use the rake or hook only when necessary to break up the coke. If the coal is broken up small and fired lightly, very little coke will form and excessive use of the rake can be avoided.

To avoid smoke when shutting off for stations, put in the last fire far enough back so that it is burned down. Crack the blower when putting in a fire at stations, and avoid smoke by firing lightly and putting the fire door on the smoke notch.

The fireman should learn the road over which he is firing and fire according to the grades. He should let the fire burn down for a meeting or passing point if they have to take the siding, and should know where to prepare for the bottom or summit of a hill, and also know how the engineer is going to work the engine at these places.

The deck and gangways of the engine should be kept clean and free from coal not only to prevent loss by falling off, but also to prevent accidents due to stepping on loose coal.