FIREMAN'S PREPARATORY INSTRUCTION

Part Three

RAILWAY EDUCATIONAL ASSOCIATION

FIREMAN'S
Preparatory Instruction

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PART THREE

ECONOMICAL BOILER-FEEDING
FIRING WITH ANTHRACITE COAL
FIRING WITH OIL FUEL

The Railway Educational Association
New York

TABLE OF CONTENTS

ECONOMICAL BOILER-FEEDING

LESSON 14. THE LOCOMOTIVE BOILER

LESSON 15. INJECTORS—GAUGE COCKS—WATER-GLASS

LESSON 16. HEAT—THE SOURCE OF POWER

LESSON 17. WATER—THE GREAT HEAT ABSORBER

LESSON 18. FORMATION OF STEAM

LESSON 19. ECONOMICAL BOILER-FEEDING

FIRING WITH ANTHRACITE COAL.

LESSON 20. FIRING WITH SMALL ANTHRACITE.

LESSON 21. FIRING WITH SMALL ANTHRACITE—Concluded.

LESSON 22. FIRING WITH COARSE ANTHRACITE.

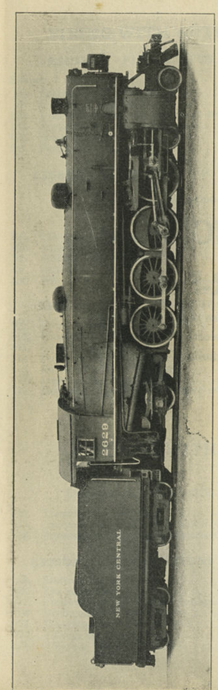
FIRING WITH FUEL OIL

LESSON 23. FUEL OIL ON LOCOMOTIVES.

LESSON 24. INSTRUCTIONS FOR FIRING WITH OIL.

ECONOMICAL BOILER-FEEDING

There is no phase of Locomotive Management more worthy of careful study than proper methods of Boiler-Feeding.

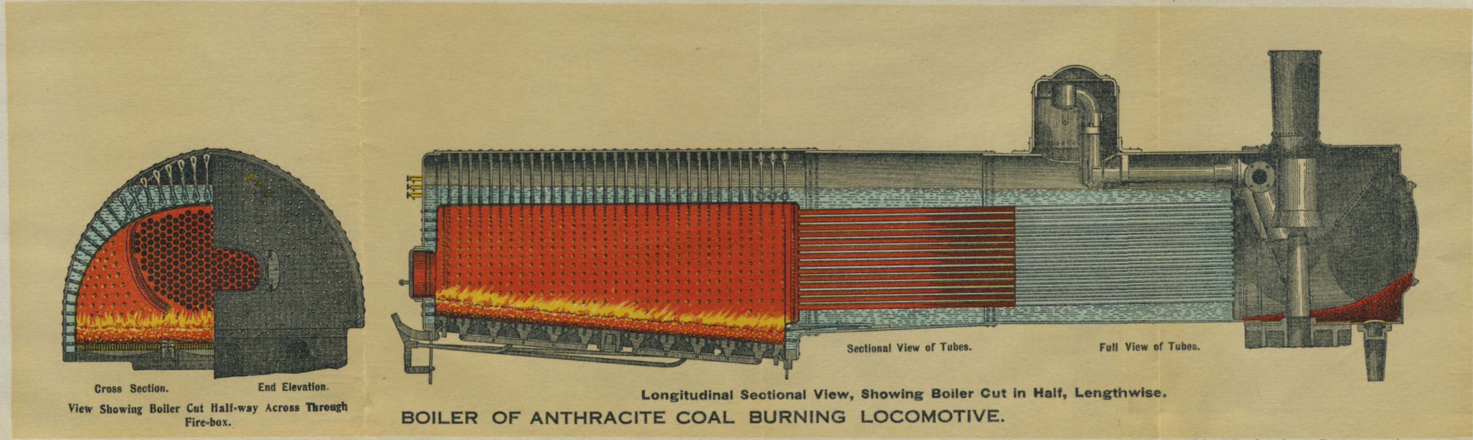


SUPERHEATER, SOFT COAL BURNING LOCOMOTIVE, NEW YORK CENTRAL RAILROAD

Built by the Lima Locomotive Works, 1923

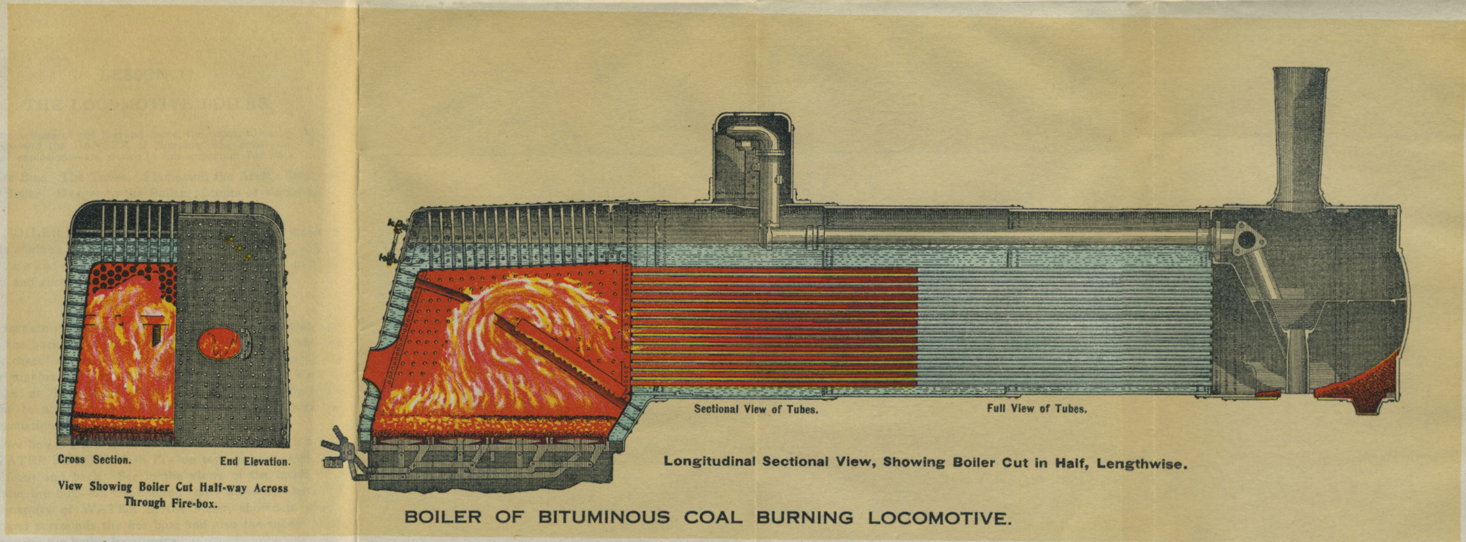
BOILER—80 inches in diameter; steam pressure 190 pounds; fire box 114 inches long, 84 inches wide; grate area 67 square feet; tubes 216—2¼ inches, 21 feet, 6 inches long; superheater tubes 45—5½ inches.

CYLINDERS—28 x 28 inches. DRIVING WHEELS—69 inches. WHEEL BASE, engine and tender—79 feet, 9 inches. TENDER CAPACITY—8,000 gallons of water, 14 tons of coal. TOTAL WEIGHT in working order, engine and tender—509,500 pounds. MAXIMUM TRACTIVE POWER—51,400 pounds.



BOILER OF ANTHRACITE COAL BURNING LOCOMOTIVE.

This Chart shows a fire of small Anthracite coal burning in a wide fire-box. See the short flame. This coal, having but little gaseous matter in its composition (only about 5 per cent.), and being nearly all "fixed" carbon burns with little flame and no smoke.



BOILER OF BITUMINOUS COAL BURNING LOCOMOTIVE.

Bituminous coal is about half gaseous matter. The fire liberates this in large volumes. They burn with a long flame or produce much smoke. The "arch" compels the flame to make a long sweep before reaching the tubes to give the gases more chance and time to burn. The water in the boiler (shown in green) covers the fire-box on top, surrounds it at each end and on each side; and submerges the tubes through which pass the hot fire gases from the furnace to the front end. The red hot cinders lying in the front end have fallen where they are seen after being whirled through the tubes by the draft, but stopped in their flight up the stack by wire netting.

boiler and connect the fire box at the back to the "smoke box" at the front—so the hot gases from the fire may be drawn

LESSON 14.

THE LOCOMOTIVE BOILER.

The actions of the fire and flame, the construction of the boiler—and the DANGER of "burning" the boiler and of boiler explosions—are shown in this important Lesson.

The Fire Box. The Tubes. Flame and the Arch. Safety of the Boiler. Danger to the Boiler. Limits of Variation of Water-Level.

The BOILER is the most important part of a locomotive. It is the engine's generator and reservoir of POWER, and its proper care and management is vitally important for the economical and successful operating of the engine.

71—The Fire Box.

The furnace or "firebox" in the boiler consists of two side sheets, the back sheet, the "tube sheet" at the front, and the "crown sheet" at the top. Several sections of grates at the bottom support the fuel. An opening is made in the back of the boiler, or "boiler-head" for a doorway through which the fire may be attended to and supplied with fuel. Wide fire boxes sometimes have two doorways.

The fire box is built in the back of the boiler in such a way that WATER SURROUNDS IT—on top, on both sides, and at the front and back. See in the views of the inside of a boiler and fire box—on the colored chart herewith—how the great quantity of WATER in the boiler, shown in green, covers and surrounds the fire box, and also the tubes which pass through the boiler lengthwise.

72—The Tubes.

Locomotive boilers usually have from 200 to 300 hollow tubes, each about 2 inches in diameter and 15 to 20 feet long, according to the length of the boiler. They pass through the boiler and connect the fire box at the back to the "smoke box" at the front—so the hot gases from the fire may be drawn by the draft through their hollow interiors from the fire box to the smoke box, and thence hurled up through the smoke stack to the open air.

See in the back END view of the boiler on the colored chart—the dark round openings of the tubes just above the flame. These tube openings occupy the whole upper portion of the tube sheet.

See also in the LONG view of the boiler how the tubes pass through it—beneath and SUBMERGED in the water.

So many small tubes are used in a locomotive boiler to provide sufficient AREA for the draft to act on the fire and draw away its burnt gases; and also to get the benefit of the great HEATING SURFACE obtained with many small tubes.

When the fire is burning actively, its temperature is about 2,500 to 3,000 degrees, and the flame and fire gases are about so hot when they leave the fire-box.

But the temperature of the steam and water in the boiler is usually LESS than 400 degrees—or about 2,000 degrees COLDER than the temperature of the stimulated fire and its flaming gases passing into and through the tubes. This vast difference in temperature compels the swiftly moving hot gases to quickly give up their heat to the 2,000 degrees COLDER water surrounding the tubes—and the gases escape into the smoke box COOLED to less than 1,000 degrees.

73—Flame and the Arch.

Bituminous or "soft" coal softens when it is put on a fire, and nearly half of its substance melts into gases—which escape from the coal and burn above the fire as FLAME. Flame is always BURNING GAS.

Before this gaseous part of the coal can burn—it must "catch fire" or be IGNITED—and this requires a certain HIGH TEMPERATURE called the "igniting temperature" or "temperature of ignition."

If you try to set fire to gas escaping from coal on a smouldering fire with an iron poker only DULL red-hot—you will fail because the iron is only about 1,200 degrees hot. You must heat it to at least BRIGHT red-hot—or to 1,800 degrees

—before you can ignite the gas.

This then—1,800 degrees—is the IGNITING TEMPERATURE of coal gas. When the gas ignites and bursts into flame—the FLAME is about 3,000 degrees hot, or hotter than WHITE-HOT iron. This is why flame so quickly "sets fire" to any combustible thing it touches.

But although flame is so hot—it is quickly extinguished if anything CHILLS it or reduces its temperature below 1,800 degrees. Then the combustion of the gases in the flame—STOPS—and, unburned, they drift away as SMOKE. So orderly are the processes of Nature!

The views through the fire box on the colored chart show the bed of burning coals resting on the grates, and the flame above. A charge of fresh coal, shown by the thin dark layer on the front surface of the fire, is shown as producing the large volume of gas that appears burning in the long flame sweeping around the Arch.

The Arch is built across the FRONT half of the fire box, as shown on the colored chart. It is made up of large "fire bricks," and is supported by several ARCH TUBES which reach from the front to the back of the fire box, as shown. Their ends penetrate the tube-sheet and the back-sheet of the fire box so WATER shall circulate through them, to keep them from being melted by the intense heat of the fire.

The purpose of the arch is to OBSTRUCT the flight of the burning gases into the tubes, and compel them to travel and remain longer in the fire box so as to GIVE MORE TIME for their mixing with the AIR and burning AS FLAME—IN THE FIRE BOX—before they enter the tubes.

Soon after the flames enter the tubes they are EXTINGUISHED by the colder temperature therein, then their remaining unburned gases pass on, and the 2,000 degrees colder water surrounding the tubes continues to absorb their heat until they escape into the smoke box, reduced in temperature to between 700 and 900 degrees. This is why we never see any flame issuing from a locomotive's smoke stack—only smoke and sparks.

74—Safety of the Boiler.

In building locomotive boilers—SPECIAL care is taken to insure their GREAT STRENGTH to withstand the high steam pressure they must contain, and the strains they must bear in service caused by varying steam pressure and temperature.

Generally the fine steel plates of which a locomotive boiler is made must have sufficient "tensil" or tenacious strength to resist tests to tear them apart with pulls exceeding 55,000 pounds per square inch. The plates and other parts must be not only STRONG—but ductile also, or able to bend and stretch considerably without breaking. To insure that boiler plates are obtained in this high degree of excellence—separated "test pieces" of each are subjected to severe pulling and bending tests to prove their quality before they are used.

Again in riveting the plates of a boiler together—great care is taken to fit and drill the corresponding rivet holes in each seam so perfectly that the insides of the holes in each two joined sheets are like ONE HOLE drilled through ONE PIECE of metal. Then the superior iron or steel rivets driven in these smooth holes must fit them exactly and be of great strength.

Every strain that the boiler must stand in service is accurately calculated in advance—before it is made—and abundant provision for STRENGTH and SAFETY is provided by braces, bolts and stays of the most tenacious steel—ALL as taught by over a century of experience and perfected science in making steam boilers.

But even with all this care in building—vigilance is not relaxed regarding the safety of boilers. Each is inspected in service with constant zeal to detect the first sign of any weakening part, or flaw, so it may be repaired or renewed in ample season for safety.

Much also remains to be done by the engineer and fireman to preserve the boiler from damage, and keep it safe while it performs its work of supplying the POWER for the engine to run mile after mile continuously during its trips—for days, months and years.

The colored chart shows a safe height of water—about SIX inches—over the crown sheet of the fire box and the tubes. Usually the "water level" (its top surface) should be kept at this height—or higher. If it gets any LOWER—the first opportunity must be improved to put enough more water in the boiler to raise the level to at least the height shown.

The chart shows the boiler, and the water in it, as when an engine is on a LEVEL track. When an engine is ascending a grade the FRONT of the boiler is highest. When descending, the BACK of the boiler is highest. These variations of grade sometimes make a difference of an inch or more in the depth of water at the front or back of a boiler—as the grade is up or down.

It is MOST IMPORTANT to consider this when an engine is approaching the top of a hill, and is to continue on down the other side with steam shut off. The incline of the down grade may LOWER the water over the crown sheet an inch or more.

75—Danger to the Boiler.

Always when a fire is in an engine it is VITALLY IMPORTANT that a sufficient quantity of water shall be kept in the boiler to ENTIRELY COVER all its heating surfaces—those interior parts which are exposed to the heat of the fire—especially the CROWN SHEET.

DANGER to the engine becomes IMMINENT whenever the water in the boiler fails to ENTIRELY COVER this very important part. The metal plates with which the boiler is constructed—WEAKEN RAPIDLY when heated much over 400 degrees.

It is known that there is no weakening of the strength of the boiler plates up to this temperature. The weakening begins AFTER the sheet is heated considerably OVER 400 degrees. WEAKNESS in steel or iron develops then, and rapidly INCREASES with the temperature until the metal SOFTENS and loses its sustaining power. When 1,000 degrees hot the strength of the metal is reduced 80 per cent., or FOUR-FIFTHS. In other words, a boiler plate heated to

1,000 degrees possesses but—A FIFTH of the strength it had at 400 degrees—and yet the sheet would not be even DULL red-hot at 1,000 degrees.

With water completely covering the heating surface of a boiler there is no danger of overheating. But DISASTER threatens AS SOON as a portion of the heating surface of a boiler under high steam pressure is BARED to the heat of the fire. With a hot fire and a bare crown-sheet—probably in HALF A MINUTE the fire might heat the sheet to a temperature at which its strength would be weakened enough to let it GIVE WAY beneath the heavy pressure upon it—for with 200 pounds pressure per square inch—there is a pressure of over FOURTEEN TONS on each SQUARE FOOT of the crown-sheet!

Then the engine would be "burned"—damaged by low water, and at least disabled for service indefinitely, with expensive repairs required. But also the boiler might EXPLODE—with possible fatal results to every person near it.

Locomotive boilers are so well built, and so carefully inspected and repaired that—of the 70,000 locomotives used on all the railroads in North America—there are usually only about TWO boiler explosions a year which result from OTHER CAUSES than LOW WATER.

From official records gathered from all North American railroads for a period of five years, by a committee of the American Railway Master Mechanics' Association, it was found that the AVERAGE annual locomotive boiler explosions DUE TO LOW WATER were over FIFTY—in which over thirty engineers and firemen were killed, and over thirty more were injured.

There were also over 500 locomotive boilers DAMAGED annually through LOW WATER, by which three more men were killed, and fifty-seven were injured.

During these five years there were 260 explosions, killing 147 men and injuring 144; also 2,499 cases of damaged boilers, "burned" by low water—a yearly average of 517—annually killing 15 men and injuring 57 others.

Nearly all these "burnings" and explosions were due to FAILURES of the MEN in charge of the engines to supply SUFFICIENT WATER to the boilers to keep their heating surfaces COVERED—thus exposing them to quick destruction by the fire, and exposing themselves to injury and death.

This shows how important it is for EVERY MAN engaged on a locomotive to ALWAYS keep in mind the absolute NECESSITY of keeping sufficient WATER in the boiler to SURELY COVER the crown-sheet and the tubes—EVERY MOMENT while there is a hot fire in the fire-box.

It is the engineer's duty to keep sufficient water in the boiler while the engine is in his charge, and to continually supply it with as much water as is being used as steam. This is not a fireman's duty except in the engineer's absence, or unless it is delegated to him by the engineer—and then it is to be done according to the engineer's orders, as he is responsible.

NOTICE the height of water in the boiler as indicated in the water glass AS SOON as you arrive on an engine. Do this BEFORE you do ANYTHING else. Unless water appears IN MOTION in the water glass, or can surely be drawn from the bottom gauge-cock—take action IMMEDIATELY to correct or report this dangerous condition.

76—Limits of Variation of Water-Level.

On the other hand—the boiler must never be filled TOO FULL of water. When this is done the inside top space in the boiler, or STEAM ROOM is lessened. Then when the throttle is opened—the escape of steam from the boiler is accompanied by violent boiling, and this throws water into the steam which carries it to the cylinders, where it washes the lubricating oil from the surfaces of the valves and cylinders.

The place for water is NOT in the cylinders, where its work is altogether evil and dangerous. Water, although a liquid, is yet as solid and incompressible as IRON when confined where it cannot escape—as many shattered cylinder-heads have shown.

To avoid the opposite extreme, the water-level should never be allowed to fall below a good fair margin for safety. The best results will follow a medium between extremes.

Usually within three inches of the top and three inches of the bottom of the gauge-glass will be the proper limits of variation of the water-level.

LESSON 15.

INJECTORS—GAUGE COCKS—WATER-GLASS.

{ A correct understanding of a locomotive's "water-works" —by EVERYONE employed in the care or operation of engines—is important for the SAFETY of the boiler. }

Escape of Steam and Waste of Water. Operation of Injectors. The Gauge Cocks. The Water Glass.

77—Escape of Steam and Waste of Water.

All the steam used in operating a locomotive is permitted to escape into the air after it has done its work of pushing the pistons in the cylinders—and is thus LOST.

In a locomotive's ordinary work every time the driving wheels turn round—from one to two pints of water, and sometimes more, are boiled by the fire and turned into steam—used in the cylinders and WASTED in the air.

This consumption of steam and water continues while the engine is working. As the driving wheels revolve about 300 times in running every mile, between 50 and 100 gallons of water are usually boiled and used per mile run, or between 5,000 and 10,000 gallons in a day's trip of 100 miles.

To always keep the proper quantity of water in the boiler, as much fresh water must be supplied to it as is used from it in steam. This is called "feeding the boiler" or—"boiler-feeding."

78—Operation of Injectors.

The usual method of feeding water to locomotive boilers according to their needs is by the use of an instrument called the INJECTOR. Usually each locomotive is equipped with two injectors—one on each side.

An injector will induce a flow of water from the tender—impart high velocity to the stream, and hurl it HIGHLY HEATED into the boiler.

The injector can be regulated to increase or diminish the stream of water it puts into the boiler. It is independent of the motion of the engine. It works equally well whether the engine is standing or running.

In the injector a jet of steam moving at high velocity mingles with a stream of flowing water drawn from the tender, and, imparting velocity and heat to the water—HURLS the stream of HEATED water through a pipe into the boiler against the interior steam pressure.

The injector's stream of water CONDENSES the steam it uses—ABSORBS all its heat, and is delivered to the boiler at temperatures ranging between 200 and 250 degrees—nearly as hot or HOTTER than ordinary boiling water.

Every man connected with the care or operation of locomotives should understand the operation of injectors, as at any time it may become necessary for him to operate an injector on an engine.

Never start an injector while passing a station platform, or where there is any possibility of scalding anyone with water from the overflow.

There are several kinds of injectors in general use on locomotives, but their principles of operation are nearly alike, as described and illustrated on the two following pages.

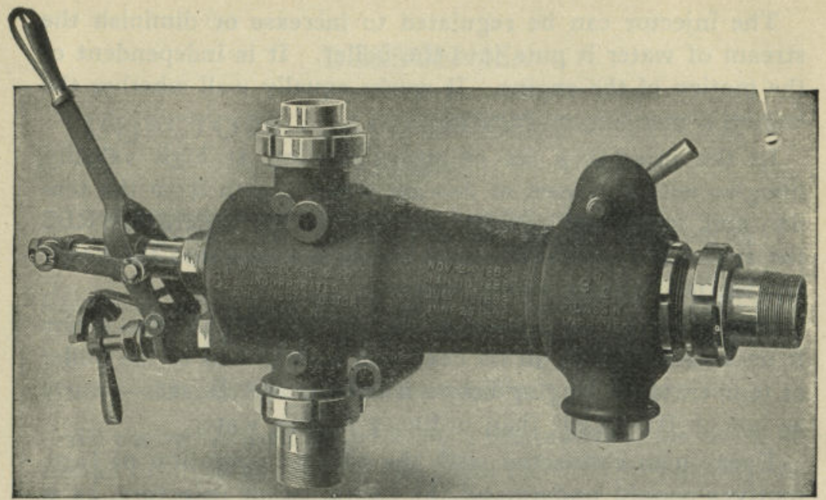


FIG. 13. A SELLERS' LOCOMOTIVE INJECTOR.

The principles of the operation of all injectors are similar to those described in the operation of this injector on the opposite page.

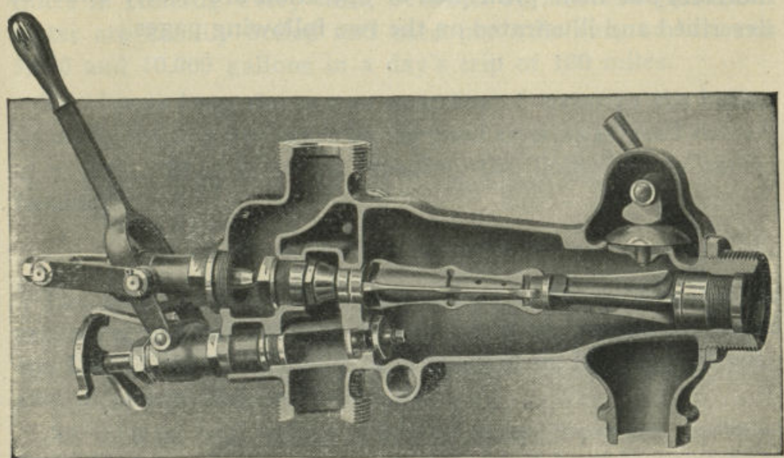


FIG. 14. SECTIONAL VIEW OF INJECTOR.

Showing it cut in half lengthwise, and the arrangement of its interior parts.

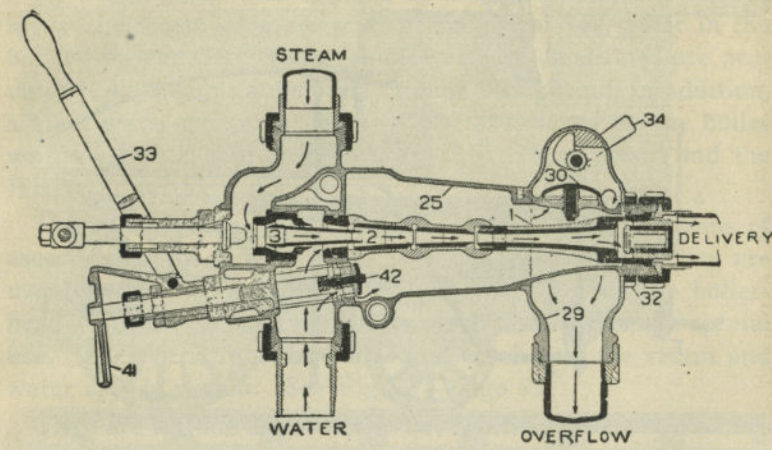


FIG. 15. DIAGRAM SHOWING ACTION OF INJECTOR.

An Injector must be "PRIMED" or prepared for action by causing a FLOW OF WATER through it. To do this, the STARTING LEVER—33—is drawn backward slightly. This permits a little steam to enter the small diagonal holes shown just above and below the STEAM NOZZLE—3. The steam flows AROUND this nozzle and enters the COMBINING TUBE—2—where it meets and mingles with the water there—GIVES MOTION to the water, which moves forward as shown by the arrows in —2.

At first the water does not move with enough force to enter the delivery tube—1—but digresses upward, lifts the OVER-FLOW VALVE—30—and escapes to the ground through the WASTE PIPE—29.

The Injector is now "PRIMED" and ready for effective action. The STARTING LEVER—33—is drawn back its full movement. This withdraws the plug from the mouth of the steam nozzle—3— and permits a full head of steam to leap through it and plunge into the water flowing through the combining tube—2.

The steam imparts some of its high VELOCITY of movement and all its HEAT to the water, is CONDENSED by the water, and the resulting solid stream of heated water is SWIFTLY HURLED through the delivery pipe and into the boiler.

The handle extending downward—41—is used to regulate the flow of water to the injector to suit the needs of the boiler.

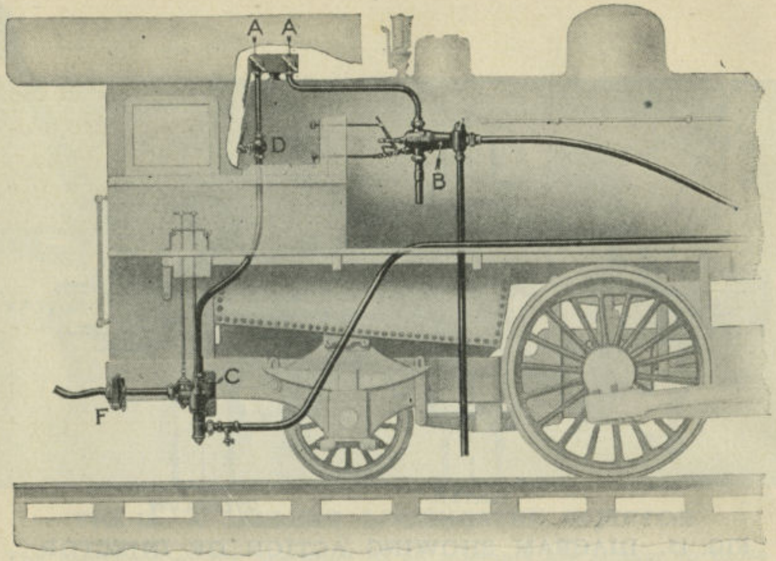


FIG. 16. LOCATION OF INJECTORS ON A LOCOMOTIVE.

The injector shown and described on pages 90 and 91 is called a "LIFTING" injector because it LIFTS its water above the level in the tender. It is always placed on an engine within the convenient reach of the enginemen, either in the cab or about as shown at—B—in the engraving above.

Another type of injector is shown at—C—in the engraving. It is called a "NON-LIFTING" injector because it does not lift its water. It is always placed on an engine lower than the bottom of the tender, so its water will run to and through it by gravity.

Steam is taken to operate either injector from some place at the top of the boiler, about as indicated at—A A.

To prevent cinders and other obstructions from being drawn into the injector—a STRAINER is located at—F—in the hose connection through which water passes from the tender to the engine.

The strainer is the first thing to examine if the injector fails to "go to work" properly. In that case the strainer will usually be found clogged with cinders, waste or other material.

The injector delivers its water into the boiler through a "check valve" at the termination of the delivery pipe. This valve opens only to ADMIT water to the boiler. It closes to CHECK or stop any escape of water from the boiler.

79—The Gauge-Cocks.

As the engineer and fireman of a locomotive must always know the steam pressure and the height of the water in the boiler—proper GAUGES to indicate these conditions are provided. A "steam gauge" and "gauge cocks" and, in addition, a glass water-gauge or "water-glass" are placed on the boiler within easy view to show the PRESSURE of steam and the HEIGHT of the water.

The gauge cocks are the oldest and most reliable means of ascertaining the height of the water in the boiler. They are usually three in number, placed on the right of the boiler-head—within the engineer's easy reach and are for his special use. They penetrate the boiler and reach into the steam and water spaces within. See Fig. 17—page 95.

They are set one above the other, slanting, about two inches apart. When a gauge cock is opened, the escape of steam or water from it will declare by sight and sound whether the water in the boiler is above or below, or just even with it.

If only steam escapes—this shows that the top surface of the water or "water-level" is BELOW that cock. If steam and some water escape together—this shows that the water-level barely reaches the cock. But if a SOLID stream of water escapes—this shows that the water-level is well ABOVE the cock.

80—The Water-Glass.

The "water-glass" is placed on the left of the boiler-head to SHOW the varying water-level. See Fig. 18. It is placed within the unobstructed view of the engineer and fireman, and at night is illuminated by a lamp so that the constantly changing column of water inside the glass may always be seen.

This gauge consists of a thick glass tube that connects with two cocks—one above the other—which penetrate the boiler and reach into the steam and water spaces inside, just as the gauge-cocks do.

The bottom cock enters the boiler at about the LOWEST safe point that the water-level should ever reach; and the top cock enters the boiler in the steam space—ABOVE the level the water should usually reach.

When both cocks are open—water enters the glass tube at the bottom, and steam enters it at the top. Thus the height of the water-level in the boiler APPEARS constantly in the glass, and the changing height of the water in the glass shows plainly and exactly the changing height of the water in the boiler.

DISTRUST the water-glass if its column of water is STILL. When this gauge is in proper working order, its column of water is in INCESSANT MOTION—up and down—when there is steam pressure in the boiler.

STILL water in the glass is a sure sign that this gauge is NOT working. It is either stopped up, or one of its cocks is shut off—so steam and water cannot CIRCULATE through it. In this case, make sure that both top and bottom cocks are open.

Mud from the water often collects in and stops up the lower cock. The "drain cock" shown on the bottom of the lower cock is placed there to be opened occasionally to let this mud be blown out by steam. Open the drain cock and blow this mud out occasionally. Do it AT ONCE if the water in the glass does not move freely up and down.

The water-glass is placed on a locomotive equally for the information of the fireman, so he may always SEE the height of the water. Both the fireman and engineer should watch it closely all the time. It and the steam gauge are a fireman's chief guides in his work.

If the water-glass breaks, which it sometimes does, with a report like a pistol's—first shut off the BOTTOM cock through which the hot water is escaping. In doing so, cover your hand with something to keep off the hot water. A glove of skin, a cap or soft hat is a sufficient shield for the hand. This is not a matter of much danger, as the small stream of water thrown upward from the cock is sprayed in the air and considerably cooled before it falls.

After the bottom cock is closed, shut off the top cock also. The steam that escapes from it is harmless in this operation.

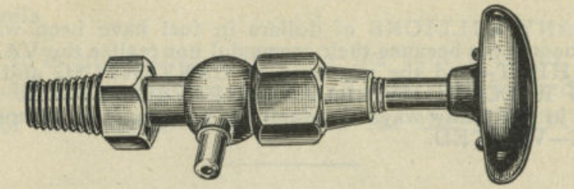


FIG. 17. A GAUGE COCK.

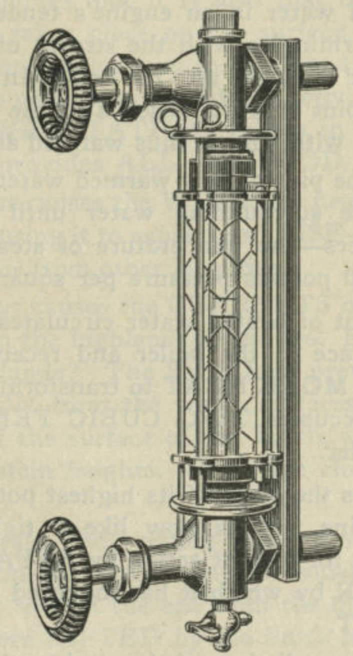


FIG. 18. A WATER-GLASS.

LESSON 16.

HEAT—THE SOURCE OF POWER.

MANY MILLIONS of dollars in fuel have been wasted on locomtives because their crews did not realize the VALUE OF HEAT—and the necessity of GENERATING and USING it ECONOMICALLY—and PRESERVING it from loss in the many ways Carelessness permits it to escape unused—WASTED.

Heat the Source of Power. Work of the Sunshine. The Sun—Its Great Distance and Size. The Heat of the Sun. Measurement of Heat. Value of Heat.

81—Heat the Source of Power.

All enginemen should keep in mind the important fact that HEAT is the SOURCE of an engine's POWER. Heat does the WORK.

A pint of cold water in an engine's tender is drawn into the injector, intermingles with the stream of swiftly moving steam therein and is hurled into the boiler. In passing through the injector the pint of water absorbs all the HEAT from the steam it mingles with, and is thus warmed about 170 degrees.

In the boiler the pint of now warmed water absorbs MORE HEAT from the surrounding water until its temperature equals 388 degrees—the temperature of steam and water in a boiler with 200 pounds pressure per square inch.

Finally the pint of heated water circulates in contact with the heating surface in the boiler and receives—direct from the fire—enough MORE HEAT to transform it into a volume of steam that occupies TWO CUBIC FEET in the steam space of the boiler.

Thus it reaches the stage of its highest potential usefulness in a steam engine, and is now like a tightly compressed SPRING—ready for instant action by EXPANSION. Notice that the POWER by which it has mounted each step in this ascent is—HEAT.

Admitted to the cylinders of the engine, the two cubic feet of high pressure steam will EXPAND like springs—PUSH

on the pistons and force one or more revolutions of the driving wheels.

Thus it is plain that HEAT is the source of an engine's power—IS its power; and that all the coal burned on the grates of the engine is consumed for the CREATION of HEAT.

82—Work of the Sunshine.

The ultimate source of the power that moves every steam engine—is the stored SUNSHINE of millions of years ago, since it was the sunshine then that made the forests grow which were buried in the ground and formed the COAL we burn to-day—in burning which we REPRODUCE, in concentrated form, the heat and light of the ancient sunshine.

The Sun's heat is not only the ultimate source of the motive power of all engines, but it is also that of nearly EVERY MOTION that takes place on the surface of the Earth. It is the power that enables men to move and work, and all living creatures to perform their natural activities—for it causes the growth of VEGETATION—which in various ways and many changes provides ALL with FOOD.

The Sun's heat causes the WINDS by heating the air in one locality, thus causing it to expand and RISE—to be replaced by movements of air from other localities.

The Sun's heat causes the CURRENTS of streams and rivers flowing from the highlands to the sea. How did the water reach the highlands? The Sun's heat previously caused its EVAPORATION from the water surfaces which constitute three-fourths of the surface of the Earth, and RAISED it as clouds to mountain heights. From the clouds it fell as rain or snow.

The falling rain and melting snow produce the peaceful brooks, the mountain torrents and the widely flowing rivers—always moving toward the sea from the high lands to which their waters were LIFTED by the Sun's heat.

Truly Heat is one of Nature's greatest wonders; and, held in bounds and rightly used, it is Man's most mighty friend and useful servant.

HEAT.

The snow-cap on the mountain,
The music of the fountain,
Plunging torrents down the steep,
The majestic river's sweep,
Every flower sweet and fair,
Every bird that sails the air,
Ants that toil and gleanings store,
Waves that roll and beat the shore,
Every leaflet on the tree,
Leap of frog and hum of bee,
Engines rolling o'er the rail,
Engines throbbing under sail,
Brain and muscle work of man—
Name their value, those who can—
Summer showers and winter sleet,
Owe their status first to Heat,
Owe their motion all to HEAT!

83—The Sun—Its Great Distance and Size.

Since the invention of the telescope, about 300 years ago, the Sun has been the object of the most constant and searching study by successive generations of astronomers all over the world, and they have proved the accuracy of their observations and conclusions.

The Sun is so far distant from us that it does not appear very large—indeed not much larger than the full Moon. But the Moon is a near little neighbor compared with the distant, colossal Sun. The distance to the Moon is about 240,000 miles, but the Sun is nearly 400 times farther away—Ninety-Three Million (93,000,000) Miles. No one can imagine such a vast distance, but some mental pictures have been presented by astronomers to give some idea of it.

Suppose a man could walk at the ordinary gait of four miles an hour for ten hours a day regularly—it would take him over 68 years to traverse one million miles, and more than 6,300 years to reach the Sun. If a railroad could be built from the Earth to the Sun, and if we could run a train over it at 60 miles an hour, day and night without stopping—175 years would be required for the journey.

If one is stuck with a pin, or injured in any way, it seems that the pain is felt instantly. Indeed it is felt in about the fiftieth part of a second. Sensation travels through our nerves at about 100 feet a second or 68 miles an hour. Knowing this, it has been estimated that if an infant could have an arm long enough to touch the Sun and burn himself—he would die of old age before the pain could reach him, as it would need 150 years to traverse the distance. If a cannon ball could be shot from the Earth to the Sun, with undiminished speed in the flight——it would take nine years to reach its target.

Evidently an object that is so far away and yet exerts such a mighty influence over us must be very LARGE—much larger than the Earth on which we live; for our Earth is subject to the Sun, and not only receives all its heat and light and life from the Sun (even moonlight being but reflected sunshine), but by the Sun's power the Earth is HARNESSED to an orbit or track along which it is always flying once a year around the Sun.

Even astronomers who spend their lives in studying the heavenly bodies are sometimes overwhelmed with awe when they contemplate the VASTNESS of the Sun, as they know it to be. In size or bulk it is 1,300,000 times greater than the Earth. Professor Charles A. Young, of Princeton University, in his book on "The Sun," suggests a conception to enable us to form some idea of the great size of the Sun, as follows:

Imagine the Sun to be hollowed out, leaving its surface as a shell, and suppose the Earth were placed in the center of the hollow space within the shell thus formed. Then the shell of the Sun—"would be like a SKY to us, and the Moon would have scope for all her motions far within the inclosing surface—indeed * * * there would be room for a second satellite 190,000 miles beyond her."

Room within the Sun's mighty shell for the Earth and TWO moons,—the second nearly as far away as the first!

84—The Heat of the Sun.

But it is with the HEAT of the Sun that we are most concerned. The Sun is known to be a vast ball of FIRE—at least ten times hotter than any earthly fire. Its surface is an OCEAN of molten matter, with waves of liquid fire. There iron, nickel, silver and other metals we know—exist as boiling liquids and glittering vapors!

Storms and clouds and rain are upon the Sun, as here—but the clouds are metallic vapors, the rain is molten metal, and the storms are FLAMES—THOUSANDS OF MILES HIGH—which sweep unceasingly over the surface, sometimes as fast as 100 miles a second, or 6,000 miles a minute!

Such a vast ball of raging hot fire must radiate, or throw off from its surface in all directions—an IMMENSE amount of HEAT. This has been measured, but stated in ordinary terms it is quite beyond our comprehension. So again some mental pictures have been drawn to give us a possible conception of it that our minds can grasp and understand.

Suppose in some way a shell of ice—FIFTY FEET THICK—could be placed close around the whole surface of the Sun. It would be MELTED in a MINUTE!

Professor Young says: "If we could build up a solid column of ice from the Earth to the Sun, nearly TWO MILES and a HALF in diameter, spanning the inconceivable abyss of ninety-three million miles, and if the Sun should concentrate his power (total heat) upon it—it would dissolve and melt, not in an hour, nor a minute, but in a single SECOND. One swing of the pendulum, and it would be water; seven more, and it would be dissipated in VAPOR." Melted in a second—boiled away in seven!

"To produce this amount of heat by combustion would require the hourly burning of a layer of anthracite coal nearly TWENTY FEET THICK over the entire surface of the Sun—nine-tenths of a ton per hour on each square foot of surface—at least nine times as much as the consumption of the most powerful blast furnace known to art."

Only an inconceivably small portion of the Sun's light and heat reaches our Earth. We know that a railroad train in crossing a continent illumined by the sunshine receives, each instant, but a very little bit of the total sunshine covering the whole continent. So in its annual flight around the Sun the Earth occupies, each instant, but a mere SPECK in

FLAMES ON THE SUN.

Solar "Prominences," or Flames on the Sun observed by Astronomer Charles A. Young, of Princeton University. The heights to which they rose above the Sun's surface, as shown by the scale, exceeded 20,000 to over 60,000 miles.

FLAMES ON THE SUN.

Such storms and whirlwinds of Flame, towering many thousand miles high, sometimes sweep over the Sun's surface with inconceivable velocity—thousands of miles A MINUTE!

the vast area of space into which the Sun contantly pours its heat in all directions. This "speck" is known to be but a $\frac{1}{2,200,000,000}$ part of the whole area—and so the Earth receives but a Two Billion, Two Hundred Millionth PART of the HEAT that the Sun is constantly giving off.

Yet this small fraction of the sunshine is enough to give us, all over the world, all our clouds, rains, snows, rivers, winds—all vegetation and activities of living creatures, all artificial lights,—and the manifestations of power we see in all steam engines, electric motors, and machinery in shops and factories.

HEAT is not only the Source of Power of all these things, but IT IS the POWER and the LIFE of our world! Only through its operations is there any action, life or light; and all things without its influence are locked in dead and eternal stillness.

85—Measurement of Heat.

As it is always necessary to measure amounts of anything we use—so we need to measure QUANTITIES of HEAT.

We have dollars to indicate AMOUNTS of money, pounds and bushels to indicate QUANTITIES of produce, and miles to indicate LENGTHS of distance. The dollars, pounds, bushels and miles are UNITS of measurement of money, produce and distance, respectively.

We know that these "units" represent certain amounts of the things we speak of—a dollar being 100 cents, a pound 16 ounces, a bushel four pecks, and a mile 5,280 feet. For the same reason that we have these units, so that we can measure and comprehend quantities—A UNIT or basis of measuring HEAT has been adopted.

The AMOUNT of HEAT that will raise the TEMPERATURE of a POUND of ice cold water—ONE DEGREE is selected as this UNIT and it is called—a "UNIT of HEAT."

This is simply enough heat to WARM a pound (about a pint) of water ONE degree. Two units of heat will warm a pound of water TWO degrees, or two pounds ONE degree. Ten units of heat can warm ten pounds of water one degree—or one pound of water ten degrees; and so on, indefinitely.

86—Value of Heat.

The average cost of fuel for locomotives is now about Ten to Fifteen Thousand Dollars a year and over per engine. This is spent to produce the HEAT required by the engine to do its work from day to day.

Plainly—HEAT so produced is VALUABLE, and since the quantity required by an engine in a year costs a FORTUNE—any portion, however small, costs something. To waste ANY quantity of HEAT—is to waste its value in MONEY.

Understanding this the student will remember that as a locomotive man—HEAT is the principal Agent with which he must always deal. A locomotive is a HEAT engine. So his constant duty is to always PRODUCE and USE heat ECONOMICALLY—and PREVENT as much as possible all LOSSES of heat in its generation, preservation and use.

When the steam engine was first used for practical work over 200 years ago, it was so poorly planned and so EXTRAVAGANT in its consumption of fuel—that for over 100 years it remained in unsuccessful competition with horses. It was cheaper to provide food for the horses required for any work—than the fuel a steam engine consumed. This was because the early steam engine inventors did not know the facts about HEAT and STEAM which were afterward discovered, and which enabled James Watt after 15 years of effort—in the most discouraging poverty—to finally perfect the steam engine so it would work successfully, and with reasonable economy in fuel consumption.

All the great improvements in steam engines in the last 200 years have been accomplished by changes which ECONOMIZED in HEAT and FUEL; and those improvements which may come in the future must follow these lines.

LESSON 17.

WATER—THE GREAT HEAT ABSORBER.

The extraordinary power of water to ABSORB and HOLD HEAT, and thus prevent its frequent escape and loss—is of great FUEL SAVING importance, and should be fully understood by every locomotive man. This would from many a "popping" save us, and waste of steam.

Great Importance of Water. High Specific Heat of Water.

87—Great Importance of Water.

Sunshine, Air and Water are the three great essentials for all forms of life and effort in our World, and their general freedom and abundance are our greatest blessings.

We have learned the importance of Sunshine in the creation of our fuel, and as the source of all motive power and motions; and of the importance of Air in the burning of our fires. Let us now glance at the other great wonder with which we deal in locomotive operating—WATER.

With all our equipment of tracks, cars and engines, fuel and fire—we would yet be unable to make a single effective move without this Great Agent through which the power in our fuel can be exercised to put our engines and cars in motion.

Constant and familiar association with water makes it appear commonplace and uninteresting, but it is one of the most important and wonderful substances in Nature. It is everywhere, and in all we do. From the clouds come the rains which nourish and support all vegetable and animal life.

Water permeates the air we breathe, the food we eat, and nearly everything we need or use. We see it in ice and snow and sleet, in streams and rivers, lakes and oceans. Like FIRE, it is our obedient and useful servant if kept within safe bounds—or our cruel destroyer if loosened from control.

As we direct it, water will either fight and extinguish fire for us—or compel the fire's heat to serve us in the preparation of our food, the warming of our houses, or the operation of our engines and machines. Forming by weight three-fourths of our very bodies, it is—excepting only the breath of life—our chief and most constant necessity. A poet has written:

WATER.

"Traverse the desert, and then you can tell
What treasures exist in the cold deep well.
Sink in despair on the red parched earth,
And then ye may reckon what water is worth."

The plight of the thirsty traveler finds a close parallel in a locomotive without water—for it, too, will "die" on the spot, as thousands have, unless revived with a supply of the indispensable liquid.

Water is so abundant throughout the World that it covers three-fourths of the Earth's surface. The beds of the oceans are as deep below their surfaces as the dry land is high above them; and it has been calculated that the water in them is so great in quantity that if the dry land were moved to fill the ocean depths—making the Earth's surface LEVEL all over—an Ocean about TWO MILES DEEP would cover the World!

88—High Specific Heat of Water.

A most remarkable and useful characteristic of water is—its GREAT POWER to absorb and hold HEAT. It is not known just why—but this ability or "capacity for heat" VARIES greatly with different substances—somewhat like WEIGHT—and is called—"SPECIFIC HEAT."

SPECIFIC HEAT is the QUANTITY OF HEAT required to warm A POUND of any substance ONE DEGREE.

The specific heat, or capacity for heat, of different substances has been measured—and WATER, being the SUPERIOR in this power, was made the Standard for all other substances to be compared with.

Thus a unit of heat, that will warm a pound of water ONE degree—will raise the temperature of a pound of other liquids TWO degrees; or a pound of iron, zinc, copper or brass NINE degrees; or nine pounds of either metal 1 degree; or twenty pounds of silver or tin 1 degree—or THIRTY pounds of mercury, gold or lead 1 degree.

WATER is to HEAT what a SPONGE is to water—it can ABSORB or "soak up" and hold so much more heat than other substances.

It is as if all other substances were small or tiny vessels for holding heat, being so quickly filled with it, as compared with WATER—the HOGSHEAD.

This great power of water to hold heat—affects the climate of CONTINENTS and the lives of MILLIONS of people exposed to its influence. Near the equator the water of the ocean absorbs the heat of the Sunshine, and being then carried in currents to distant and colder parts of the Earth—WARMS the climate of vast stretches of country adjacent to the sea coasts. The mild climate of the British Isles, of the western coast of Europe, and the semi-tropical climate of our own California are manifestations of water's great capacity for STORING HEAT.

And we soon shall see how this great power of water to receive and HOLD HEAT—can be USED to help a locomotive perform its hardest tasks of work successfully, and economically as regards fuel consumption—by STORING QUANTITIES of HEAT in the WATER on the engine during idle times, or when surplus heat is generated, and LATER—USING this STORED HEAT to MODIFY the intensity of the fire necessary to "keep up steam" during the engine's hardest work—and so SAVE much fuel and fireman's labor.

LESSON 18.

FORMATION OF STEAM.

No locomotive man can afford to be ignorant of the information plainly given in this Lesson regarding the formation of steam—and the PRESERVATION of the boiler from the MOST DAMAGING influences it is subjected to in service.

Atmospheric Pressure. Formation of Steam. Latent Heat of Steam. Table of Steam Pressures and Temperatures. Importance of Steady Steam Pressure.

89—Atmospheric Pressure.

Our atmosphere extends to an unknown height above the Earth, and it rests upon the surface with a PRESSURE that varies with the varying HEIGHTS of the surface. The higher we ascend above the uniform level of the oceans—which is called "sea level"—the LIGHTER we find the air pressure—because the higher up we go the LESS AIR there is above us to press downward.

At the level of the sea the air pressure is uniformally 14.7 pounds per square inch—usually called 15 pounds. This is what is meant by the term "atmospheric pressure." When we speak of steam of atmospheric pressure we mean its pressure is just EQUAL to the AIR pressure at sea level. It is the pressure of steam that forms from boiling water in an open vessel—like an uncovered kettle.

The pressure of the air is exerted equally in all directions, and we must contend with it in every movement. In the cylinder of an engine—steam of only atmospheric pressure is incapable of exerting any EFFECTIVE push on the piston—because its push is OPPOSED—by the equal pressure of the air on the opposite side of the piston—AGAINST the piston's movement.

Always therefore the pressure indicated on an engine's steam gauge is pressure in the boiler—in EXCESS of the atmospheric pressure, and is called—EFFECTIVE pressure, because it is effective in making the engine work.

90—Formation of Steam.

In the process of boiling—the PRESSURE on the water is the great GOVERNING FACTOR. In the Table on page 108 we see that steam of only atmospheric pressure is 212 degrees hot—while steam of 200 pounds effective pressure is 388 degrees hot. Why is there this great difference of temperature—176 degrees?

Here is the explanation: Steam forms in BUBBLES from the water in contact with the heating surface of a boiler. Each bubble must form under all the PRESSURE upon it. Its ability to form depends upon the STRENGTH of its interior steam to DISPLACE a volume of water of its own size. It must MAKE A PLACE for itself in the world—and to do so must actually RISE UP under the pressure above it.

The greater the pressure—the more difficult it is for the bubble of steam to form, and the more STRENGTH it must have. As its only source of strength is HEAT, it must therefore have more heat to be able to form under a heavy pressure than under a light pressure. When it has the added heat it is HOTTER.

Therefore—that temperature at which water BOILS, called the "boiling point"—depends altogether on the PRESSURE upon the water. Under NO pressure, as in a vacuum, water will boil at 96 degrees—two degrees below blood heat.

Under the pressure of the air only, at sea level, water boils at 212 degrees, making steam of atmospheric pressure and 212 degrees temperature. Under 200 pounds effective pressure water must be heated 176 degrees hotter—to 388 degrees to make it boil. It will then generate steam of 200 pounds pressure and 388 degrees temperature.

In all cases the steam and the water it comes from are EQUALLY HOT—one is as hot as the other. The steam has about two-thirds more heat IN IT than the water, but this extra heat—having been USED in the WORK of turning the water into steam—lies HIDDEN in the steam, and does not make the steam any hotter than the water. This HIDDEN HEAT is called "Latent Heat."

91—Latent Heat of Steam.

Heat that goes to raise the temperature of water remains SENSIBLE to the thermometer—but heat that goes to CHANGE the water into steam—DISAPPEARS. Practically this hidden or "LATENT" heat has been turned into WORK —the work of TRANSFORMING water into steam.

The LATENT HEAT of steam is that QUANTITY of heat that DISAPPEARS in changing A POUND of boiling water into steam.

The following Table shows the TEMPERATURES of steam and boiling water under various PRESSURES—also the amount of latent heat, and the total heat in a pound of steam at the different pressures.

TABLE OF STEAM PRESSURES AND TEMPERATURES.

Showing the TEMPERATURES, and the LATENT HEAT of Steam of Various PRESSURES. Also the TOTAL HEAT required to Convert A POUND of Water Into Steam At Different Pressures.

EFFECTIVE Pressure per Square Inch.	TEMPERATURE of Steam and Boiling Water.	Units of HEAT in Each POUND of Steam. "Total Heat"—that used to turn into Steam a pound of "Ice Water"—or from 32°	
		LATENT HEAT	TOTAL HEAT
Atmospheric— 0	212 degrees.	966 units.	1,146 units
25	267 "	926 "	1,163 "
75	320 "	888 "	1,179 "
100	338 "	876 "	1,184 "
125	353 "	865 "	1,189 "
150	366 "	856 "	1,193 "
175	377 "	848 "	1,196 "
200	388 "	840 "	1,200 "

Whenever heat performs work it DISAPPEARS as heat, but when the work is UNDONE—it REAPPEARS as heat. When steam condenses to water—all its latent heat reappears.

If we turn a pound of steam into the tank water, its latent heat will reappear and WARM the water.

This is why steam is so effective in warming trains. In passing through the radiating pipes and condensing, it gives up its rich store of latent heat. Also this is why the injector is such an efficient boiler feeder. The steam it uses not only imparts sufficient velocity to the water to force it into the boiler, but all the steam's LATENT HEAT is given to the water—thus heating it usually to over 200 degrees before it enters the boiler.

The MAIN FACT concerning steam formation that every locomotive man should remember is that, roughly speaking—to turn water into steam—requires ONE-THIRD of the necessary heat to WARM the water to the BOILING POINT, and the other TWO-THIRDS to TURN it into STEAM.

This FACT is of GREAT IMPORTANCE in locomotive operating. The steam and water contents of a boiler with 200 pounds pressure being 388 degrees hot, all the water that enters it quickly absorbs sufficient heat to RISE to this temperature, and in doing so becomes STORED with ONE-THIRD of the HEAT needed to turn it into steam.

The importance of these facts in locomotive boiler-feeding, and the opportunities they offer to SAVE FUEL in the daily work of every locomotive, are explained in the following lesson.

92—Importance of Steady Steam Pressure.

The Table showing the TEMPERATURES of steam and boiling water under various pressures—points out a fact of great importance in preserving the boiler from damage.

The most destructive influences which affect locomotive boilers are the actions of EXPANSION and CONTRACTION of their metal sheets and parts. These actions result from VARYING TEMPERATURE. Metal expands when heated and contracts when cooled. One of these actions takes place with EVERY variation of temperature, and the resulting repeated stretching and shrinking movements of the different parts of a boiler subjected to frequent CHANGES of PRESSURE are very DAMAGING to them, and are the cause of nearly all leaking tubes, broken stay-bolts and cracked and damaged fire box sheets.

The Table of Temperatures shows that a variation of pressure is always accompanied by a variation of temperature of the steam and water contents of a boiler; and, of course, of the METAL of the boiler also.

To maintain an even temperature of a boiler, and thus avoid the damaging effects of expansion and contraction—it is NECESSARY to maintain an EVEN STEAM PRESSURE.

It should be the constant aim of every engineer and fireman to see that the boiler is supplied with water in such ways and at such times as will surely preserve an EVEN PRESSURE of steam. If considerable water is injected into the boiler while the engine is standing or running shut off—the blower must be used if necessary to keep up the steam pressure.

THE STEAM PRESSURE should be kept within the limits of ABOUT TEN POUNDS.

LESSON 19.

ECONOMICAL BOILER-FEEDING.

FUEL ECONOMY, in the operation of locomotives, depends upon three MAIN PHASES of management—Firing, Boiler-Feeding, and Use of Steam. Correct BOILER FEEDING stands second to none for safety and fuel economy, but —more than the others—it requires an understanding of the scientific facts explained in the previous four lessons—which never can be learned by EXPERIENCE ONLY on engines.

Value of Reserve Heat. Reserve Heat Stored in the Boiler. Warming the Tank Water. Careless Boiler-Feeding. Firemen Operating Injectors.

93—Value of Reserve Heat.

Economy, safety and success in a locomotive's work require greater attention and skill in boiler-feeding than is necessary with any other steam engine—hence our recent lessons on Heat and Water and Steam Formation. The knowledge they impart constitutes THE SCIENCE of proper locomotive boiler-feeding.

The work of locomotives is very changeable and irregular—standing IDLE—starting and FORCING trains into speed—running EASILY on levels,—or laboriously climbing grades—then descending hills with steam SHUT OFF. Hourly exercising every possible variation of power.

These variations in a locomotive's work require similar varying demands upon its boiler for steam, and upon the FIRE for varying amounts of HEAT. The intensity of a coal fire cannot be varied suddenly. It must be rather gradually increased or subdued.

Plainly something is needed to give STABILITY in these emergencies—to equalize the varying conditions—and we find it present in the WATER on the engine! Fortunately, because of its high SPECIFIC HEAT—water is the one thing that can most perfectly help us to equalize the sudden demands upon our fire for varying amounts of heat to suit the engine's fluctuating work.

We can store in the water in a boiler having 200 pounds steam pressure—A THIRD of the heat necessary to convert it into steam. Then when extra steam is needed for the engine's heaviest work we only need to supply the final two-thirds of the total heat required—the LATENT HEAT—to change this stored hot water into steam of 200 pounds pressure.

With a boiler holding a good reserve of highly heated water, say warmed to 388 degrees (nearly twice as hot as familiar boiling water in an open vessel)—a large amount of steam can be quickly provided to do some heavy task of work without FORCING the fire to furnish——during the emergency—ALL the heat required to produce the needed steam.

The stored THIRD of the required TOTAL heat then comes into play to the GREAT RELIEF of the fire—often saving from 100 to 500 pounds of coal in such emergencies. Then later, when the engine is working easily, or running with steam shut off, or standing IDLE—the reserve store of heated water in the boiler can be replenished, probably with irrepressible surplus heat that would otherwise be WASTED as steam blowing off.

This plan of boiler-feeding requires that the feed-water injection shall be VARIED to suit the engine's work—reduced or suspended temporarily during short—HARD tasks of work, and continued or increased in the engine's subsequent EASY work or inaction, to RESTORE the boiler's WATER RESERVE and utilize the surplus heat always produced in such times.

Soldiers are the power in war. An ancient general vanquished a foe of superior strength by holding in reserve a portion of his soldiers—to be used at the critical time and place most needed. Since then every army has had its reserves. Money is the power in business, and every business needs money in reserve.

HEAT is the motive power of railroads, and every locomotive needs all the HEAT IN RESERVE it can hold in the water in its boiler and tender. Surplus heat should never be wasted—but STORED in the water at hand—so liberally provided, and so fortunately endowed by Nature with just

the special STABILIZING power we so urgently require.

As it is usually difficult to make enough steam to supply the needs of the engine while working hardest, and a surplus of steam is always formed during the times an engine is idle, working easily or running shut off during a day's run—it is plain that George Washington's wise maxim:—

"IN TIME OF PEACE PREPARE FOR WAR"

should wisely be adopted as our Motto for good boiler-feeding.

During all the minutes of inaction in the course of a trip, such as while running into stations and down hills with steam shut off, stopping at stations and on sidetracks, and in switching, great care should be taken to judiciously inject into the boiler all the water it can properly hold without becoming liable to "prime" or pass water to the cylinders with the steam after the engine is started.

By the term "judiciously inject" is meant that this should be done with CARE and JUDGMENT—judgment to dictate HOW MUCH water shall be thus injected, and care to require that whatever injection is made it MUST be done without causing any great variation of STEAM PRESSURE.

When this practice is properly followed, it will be found that IN ALL TASKS OF HARD WORK the injection of water to the boiler may either be made very light or suspended altogether during the emergency, insuring a liberal supply of steam—SAVING MUCH COAL—and lightening the labor of the fireman.

A PRACTICAL EXAMPLE: An engine is ready to start with its train from some stop along the road. If the injection was continued while the train was stopping—probably the water-glass is two-thirds full of water. At starting, the injector may be shut off—and the first half mile or MILE may be run with no feed water entering the boiler.

By this time the water-level has probably decreased to half a gauge-glass full—plenty for safety usually. But the hard task of work is OVER and the engine is working easier —at a short cut-off—so the injector may be started under very favorable conditions, as the fire can now easily supply the heat that the engine needs.

Whenever the steam pressure lags while the engine is running and using steam, the injector should be adjusted to feed LESS water, or shut off entirely when safe and proper, until the desired pressure has been regained—rather than FORCE the fire to regain the lost pressure with the injector working.

94—Reserve Heat Stored in the Boiler.

In the water-space in an ordinary locomotive boiler—within which the water-glass shows the rise and fall of the water-level—there is room for about 600 gallons or 5,000 pounds of water.

A rise or fall of ONE INCH of water in the glass—indicates an increase or decrease of about 60 gallons or 500 pounds of water in the boiler.

Let us measure the HEAT STORING CAPACITY of the 500 pounds of cool fresh water we take from the tender at the temperature of 50 degrees, and inject into the boiler. If our steam pressure is 200 pounds—the steam and water in the boiler is 388 degrees hot—or 338 degrees HOTTER than the cool water we will take to inject into it.

All the steam the injector uses in its work is CONDENSED by the cool water passing through it, and its heat is absorbed by the water—which is thus usually HEATED about 170 degrees, or to 220 degrees.

On entering the boiler—this fresh "boiling hot" water circulates among the still hotter water within, which is 388 degrees hot—or 168 degrees hotter than it. The new water immediately absorbs more heat from the hotter water it mingles with until their temperatures are equalized.

Altogether, each pound of the fresh water put in the boiler absorbs—from steam in the injector and hot water in the boiler—about 338 units of heat to warm it from the temperature it had in the tender, 50 degrees, to the temperature it must rise to in the boiler—388 degrees.

The 500 pounds of fresh water we inject into the boiler to raise the water-level ONE INCH—absorbs 500x338—or 169,000 heat units. This is the RESERVE of HEAT stored in the water in the boiler represented by ONE INCH in the water-glass.

But this is only A PART of the reserve of hot water we can store in the boiler and utilize for fuel economy. A depth of six inches of water maintained over the crown sheet—showing as about three inches in the glass—insures the safety of the boiler.

We may put enough MORE water in the boiler to raise the column in the glass SIX inches. As one inch of water in the glass represents 60 gallons in the boiler—six inches in the glass will represent 360 gallons or 3,000 pounds of water in the boiler.

THIS is the STORE of HOT WATER that we can properly USE in the engine's hardest tasks of work to HELP IT and SAVE FUEL—by reducing or suspending the injection of water into the boiler until each hard task is finished.

As 169,000 heat units are STORED as sensible heat in the 500 pounds of water represented by one inch in the glass—six inches of water in the glass represent the GREAT RESERVE STORE of 6x169,000=1,014,000—over A MILLION units of heat!

With such a good store of HEAT in the boiler an engineer and fireman may feel sure of having an abundance of steam during the performance of any hard work the engine must do —for then the injection may be SUSPENDED a short time whenever it is desired to get more steam or save fuel.

Whether the call is to "bottle up" a few thousand heat units about to escape in steam from the "pop," or to lay in a RESERVE of a million heat units in the boiler before starting—or lay in A DOUBLY LARGE RESERVE of heat in the water on the tender—an engineer will understand that as HEAT is his engine's POWER, and WATER is A STOREHOUSE for that power—his duty is to take advantage of every opportunity to STORE UP as much heat as will provide his engine with the largest practicable measure of RESERVE POWER.

95—Warming the Tank Water.

It is a good practice, that saves much fuel, to warm the tank water to about blood heat before starting out on trips; and also, if time and opportunity permit, to do so before leaving water stations with a tank full of cold water, by blowing steam into the tank through the injector not in use.

The advantage of this is similar to that derived by starting out with a boiler full of hot water. It is an additional STORE OF HEAT.

Take for example a tender holding 5,000 gallons of water of ordinarily about 50 degrees temperature. A gallon of water weighs 8⅓ pounds, and 5,000 gallons weigh 41,650 pounds. We can properly and safely warm this water to 98 degrees—just blood warm—and the injector, if in good order, will handle it properly. In warming the 41,000 pounds of cool water to 98 degrees we will add 48 units of heat to each pound—and STORE TWO MILLION heat units in the tankful of water.

This is exactly the same as if we started out with TWO ADDITIONAL BOILERS FULL of water heated up to 388 degrees temperature.

Such a quantity of warm water on an engine—is a GUARANTEE of sufficient steam for its work for many miles of the trip—to be easily and economically obtained.

96—Careless Boiler-Feeding.

If an injector is carelessly allowed to supply the boiler with MORE water than is being used as steam while the engine is working ordinarily—it causes much waste of fuel. When this is done the fire must be forced to furnish considerable MORE HEAT to keep up steam than would be needed if the injector supplied only as much water as is being used as steam.

The proper way to feed the boiler while the engine is working ordinarily is to adjust the injector so it will supply slightly LESS water than is being used, if the boiler is sufficiently full to allow this, and then REPLENISH the reserve supply of water in the boiler by CONTINUING the injection after the steam is next shut off.

97—Firemen Operating Injectors.

Firing and boiler-feeding should go "hand in hand," and it is well for the fireman to operate the injector, when his experience and judgment justify the engineer in entrusting this important duty to him. He can then regulate his firing to his boiler-feeding with great exactness to secure economical results, and save much fuel and labor.

If the engineer operates the injector—his methods and habits of doing so must be observed by the fireman, and he must be guided by them in the regulation of his fire. If it is the practice to suspend the injection of feed-water during periods of hard work, as in starting trains—then LIGHTER charges of coal should be used to start out with.

If it is the practice to leave the injection suspended during the first mile's run from a station—the fireman should REMEMBER this and not FORCE the starting of the injector sooner by making his fire too hot. Firemen who do this—work against their own interests and waste much fuel.

But it is important, when the injector is to be started after being suspended some time while running, that its coming demand for MORE HEAT shall be met by a good "fire" put in —BEFORE the injector is started.

After the injector is started—then the TOTAL HEAT of all the steam being used must be supplied by the fire—A THIRD more than while the injector was suspended. Hence the hotter fire necessary to supply this additional heat.

Knowing that the injector is to be started, the good fireman will put in his "fire" in time to have it burning well—in ADVANCE.

Do not keep the fire too hot when the water-level in the boiler is HIGH. Fire lighter then, and let the fire cool down so as to give the engineer a chance to reduce or shut off the injector.

Full coöperation between an engineer and fireman in boiler-feeding is one of the "secrets of success" in operating a locomotive economically—and so with the greatest ease in firing.

RULES FOR BOILER-FEEDING

1. Engineers are responsible for the constant maintenance of a safe supply of water in the boiler; also for the observance of proper methods of boiler-feeding, in accordance with these Instructions.

2. The water-level must not be allowed to rise so high in the boiler that water will be carried over in the steam passing to the cylinders or superheater.

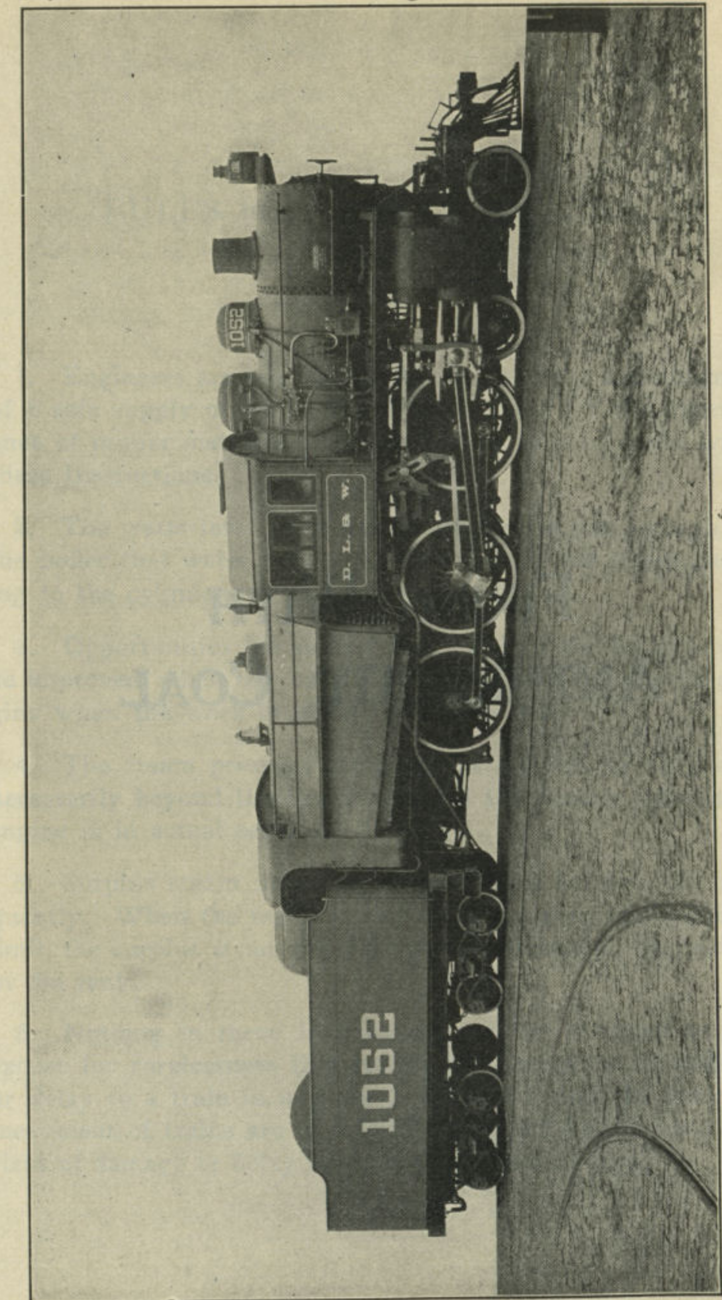
3. Opportunities for storing hot water in the boiler must be improved, when this can be properly done, to help the engine when the work is heavy, and save fuel.

4. The steam pressure must not be allowed to vary unnecessarily beyond the limits of about ten pounds while the engine is in actual service.

5. Surplus steam must not be permitted to blow off frequently. When the water in the boiler is up to the working limit, the surplus steam must be used for warming the water in the tank.

6. Nothing in these Instructions will be accepted as an excuse for carelessness that results in damage to an engine or delay to a train in any way. SAFETY and the prompt movement of trains are of FIRST IMPORTANCE—and no risks of damage or delay must be taken to save fuel.

FIRING WITH ANTHRACITE COAL



ANTHRACITE COAL BURNING LOCOMOTIVE

This engine is built to burn small grades of coal, and is provided with an extra wide fire-box for this purpose, as is shown in the extension of the boiler over the rear driving wheels.

LESSON 20.

FIRING WITH SMALL ANTHRACITE.

Formation of Anthracite Coal. History of Anthracite Coal. Difficulty in Kindling Anthracite. Preparing the Fire for the Start. Starting on the Run. Firing While Running.

Anthracite coal is largely used on railroads running in and near the anthracite regions in the Eastern States. Many hundred locomotives burn anthracite coal for fuel exclusively.

These Lessons on firing with anthracite were originally prepared for the instruction of the engineers and firemen on the Delaware, Lackawanna & Western Railroad, nearly all the locomotives on which burn anthracite. In their preparation the writer consulted over two hundred Lackawanna engineers and firemen, whose combined experience in running and firing anthracite coal-burning engines exceeded two thousand years.

98. Formation of Anthracite Coal.

ANTHRACITE or "hard" coal, differs from bituminous or "soft" coal in the same way that coke does. In fact, anthracite coal is NATURAL COKE. It is commonly known that coke is made by heating coal red hot in a retort from which air is excluded, permitting its gaseous matter to escape, but not permitting the coal to burn.

Also charcoal is made by charring wood in a kiln or retort from which air is excluded—so the wood cannot burn—thus driving off its moisture and gaseous matter which otherwise would burn as flame.

This is what occurred to form anthracite coal. It was originally formed as BITUMINOUS coal, but sometime during the millions of years it lay buried far in the depths of the soil, it was subjected to intense heat from volcanic disturbances which permitted the heat of the internal fires (raging now as our volcanoes show) to reach the imbedded coal and heat it red or white hot, thus causing its gases to escape in the same way as we make coke to-day by heating coal to redness in a retort from which air is excluded.

The coal thus heated gave up its gases, which escaped, and the great pressure of the soil and rocks (averaging 80 pounds of weight per cubic foot) above the hot, soft coke, compressed it into the shiny hard blocks which we know as anthracite coal.

The following table shows the usual composition of anthracite coal:

FIXED CARBON	85 per cent.
GASEOUS matter and moisture	5 per cent.
ASH (incombustible matter)	10 per cent.

As anthracite coal is nearly all solid or "fixed" carbon, and contains very little gaseous matter, it burns like the carbon or solid part of bituminous coal burns, after its gaseous matter is expelled, that is—as red-hot or white-hot coals. It burns with a short, transparent flame, and makes no smoke.

The colored chart opposite page 81 shows the differences in the burning of anthracite and bituminous coal in a locomotive's fire-box.

Anthracite coal must be heated RED HOT before it will ignite while "soft" coal will "catch fire" at a temperature that will ignite its inflammable gases. The burning gases of bituminous coal serve as KINDLING for its carbon, which, like anthracite, requires to be made red hot before it will burn. Therefore anthracite coal—being without these gases—is more DIFFICULT to set on fire, and requires more CARE and attention in kindling than bituminous coal.

99. History of Anthracite Coal.

Anthracite coal was known to the early settlers of Pennsylvania for many years before it came to be generally regarded as of any possible use as a fuel. When its value as such was first announced the people laughed at the idea of anyone trying to burn "those black rocks." Attempts at burning it extended over a number of years, often ending in discouraging failures before finally its value as a fuel and the proper way of burning it began slowly to be understood.

The first recorded use of anthracite coal was in 1776, for the United States Army at Carlisle, Pa. Yet the people generally remained so long in ignorance of its usefulness that 36 years later, in 1812, when Colonel George Shoemaker sent nine wagon loads of anthracite from Pottsville to Philadelphia —he could only sell two loads of it "with difficulty," and had to GIVE AWAY the other seven loads. "He was regarded as an impostor for attempting to sell STONES to the public as coal, and had some difficulty in getting out of the City to avoid arrest!"

Regarding one of the loads sold—"A whole night was spent in the effort to make the coal burn, when the hands in despair quit their work, but left the door of the furnace SHUT. Fortunately, one of the workmen forgot his jacket and returning found everything red hot!"*

Thus they learned how to make the coal burn. The closed fire door intensified the draft from BENEATH and through the fire—and letting it alone for a while gave TIME for the coal to get heated up to the igniting temperature. Then it burned satisfactorily.

For many years anthracite was commonly known as "stone coal"; and it was found difficult not only to start a fire with the coal, but also to replenish the fire so that it would not go out. The coal had to be heated red hot before it would begin to burn. If the fire was permitted to burn low before fresh coal was put on, then it could not heat the fresh coal red hot and thus ignite it, or make it burn.

100. Difficulty of Kindling Anthracite Coal.

This old difficulty is still characteristic of the burning of anthracite coal, and forces stricter attention than is necessary in burning bituminous coal. If through lack of attention, the fire is permitted to die to a dull red heat—fresh coal then put on may not catch fire promptly, or may even find insufficient heat in the COOLING coals beneath it to set it on fire at all.

Burning coals are always at their highest heat when they are WHITE HOT. Every degree of increased BRIGHTNESS in incandescent or glowing coals declares a higher

*"Story of American Coals," by William Jasper Nicolls.

TEMPERATURE. DULL red coals are but 1,200° hot—BRIGHT red, 1,800°—ORANGE, 2,200°—WHITE hot, 2,500°—DAZZLING white, 2,700°.

To promptly "catch fire" anthracite coal requires the temperature of the BRIGHT red or the ORANGE heat. To keep an anthracite coal fire burning intensely—fresh coal should be added in SMALL quantities, spread evenly over the fire's whole surface—while this is yet brightly red hot, and before it burns down to a dull red heat.

101. Preparing the Fire for the Start.

As soon as the fireman of an anthracite coal burning engine arrives on duty ready for work, he should notice if the fire has been well cleaned; also if there are any dark or dead spots in the fire. If the fire has not been thoroughly cleaned, any remaining ashes or clinkers should be knocked out.

Dead spots may be detected, if any exist, by a brief application of the blower with the fire-door closed. Such a spot results from incomplete distribution of live fire over the grates after the fire was cleaned, and from putting fresh coal on places where there was not sufficient fire to ignite it. Such a defect in the fire must be cured before leaving, or its evil results will be felt afterward in more work for the fireman and less steam for the engine.

The dead coals must be shoved or pulled away from the dead spot, and good, live fire put in place of the coal thus removed. It is best to then cover the place with the same coal that was removed from it (now considerably heated) and, if necessary, apply the blower long enough to thoroughly ignite it.

In preparing the fire after it has been cleaned, or from a "bank," great care must be taken to spread the remaining live coals so that they will thoroughly cover the entire grate surface, not only in the center, but well up in the corners, and along the sides, before any fresh coal is put on. It may be necessary to use the blower to bring the newly spread coals up to a bright cherry-red heat or white heat before adding any fresh coal.

After the fire has been spread, and found to be or is put in good condition, it should be completely, but lightly, covered

over with fresh coal. Judgment must be used as to whether an application of the blower is necessary to properly ignite this fresh coal. The blower must be used NO MORE than is necessary. If there is switching to do, or if leaving time is distant, use of the blower may be avoided.

The amount of coal necessary to build up the fire to the proper depth, to raise the steam pressure and to properly fill the boiler with water, must be put on the fire gradually—a few shovelfuls at a time, each spread lightly and evenly over the surface. Each charge must be given time to get to burning well before another equally light and evenly spread charge of coal is added.

Circumstances may require the use of the blower in this work; but if such use can be avoided without delay or fluctuating pressure a better fire will be produced with simply the natural draft acting on the fire with the door closed, stimulated by the air pump exhausts.

It is of the greatest importance to have a good fire to start out with. If the fire is not put in good shape before starting it will be found hard, if not impossible, to put it in good shape afterward.

102. Starting on the Run.

At leaving time it is necessary that there shall be a bed of fire covering the entire grate surface, about three or four inches deep and level in the centre, but from three to five inches deeper along the sides, in the corners, and at the back of the fire-box, as it is at these places that the draft acts strongest.

The exact depth of the fire at starting must conform to the weight of the train and the character of the road, therefore to the way the engine will be worked—hard or easily—in starting the train and forcing it into speed. Whatever coal is needed to keep up steam, and keep the fire in good condition during this hard task of work, must be placed on the fire and thoroughly ignited before starting.

At starting, the fire should be burning brightly all over; and while the use of the blower is to be avoided as much as possible in preparing and building up the fire, yet it can often be used to good advantage a minute or so JUST BE-

FORE starting to create a hot, brightly burning fire for the start.

103. Firing While Running.

In firing a locomotive with anthracite coal the fire must be watched for the development of white spote—places in the fire which reach the white heat. This being the moment of highest temperature, it is also the moment for fresh coal to be added, to insure its rapid ignition and the maintenance of a hot fire.

If through lack of attention, the fire is permitted to burn past the white heat, and die to a red heat, the coal then put on may not "catch fire" at all. Then that place in the fire will "go out," making extra work necessary for the fireman to clean out the dead spot, and possibly crippling the engine through lack of sufficient steam until the evil is corrected, and the fire is put in good condition.

LESSON 21.

FIRING WITH SMALL ANTHRACITE—

Concluded.

Practice Light Firing. Avoid Heavy Firing. Making Station Stops. Descending Grades and Waiting on Sidings.

104. Practice Light Firing.

The small sizes of anthracite coal are necessarily burned in wide fire boxes, which have large grate surfaces. Therefore all that is said in Lesson 10 about the necessities for light firing—and SPREADING COAL—with small sizes of "soft" coal applies also to firing with small sizes of anthracite.

As a soft draft is necessary for burning small coal, it follows that the bed of fire must be kept as light and as free from ashes and clinkers as possible, so that the air required for properly burning the coal may find easy passage through it. To keep the fire in this condition while running, it must be carried nearly LEVEL and fed as lightly as possible consistent with its needs and the way the engine is working.

Each shovelful of coal put on the fire should be spread AS LARGELY over its surface as possible, and never placed thickly on any one part. With an engine working ordinarily on level grades, only one or two shovelfuls of coal should be used per "fire," and these should be thoroughly spread over the surface, or those portions of it that arrive at a white heat.

When an engine is working hard or on up grades the same method of feeding the fire must be adhered to; although during such work feeding may necessarily be more frequent, and the charges of coal per "fire" may then be made three, or even four shovelfuls, with the largest fire-boxes.

105. Avoid Heavy Firing.

Charges of over THREE shovelfuls per "fire" while working ordinarily on level grades, or over FOUR shovelfuls per "fire" on up grades, constitute unnecessarily heavy firing, and should be avoided.

In feeding the fire while running the aim should be to keep it as level as possible, and to feed always and only on those portions of the fire that have reached A BRIGHT heat. Nothing is gained by covering with fresh coal those portions of the fire which are only red-hot, and which have not yet reached a white-heat. Until such portions become WHITE-HOT they have not given off all or the highest heat they are capable of giving, and fresh coal should not be put on them until they do this. In other words, more coal should never be used until we have gotten all the heat we can out of the coal burning on the fire.

Ordinarily, in feeding the fire, the door should be closed between each shovelful of coal. Circumstances may altar this somewhat, as when an engine is about to "pop," and advantage is being taken of this to put in a fresh "fire." Also when coal is being put in just before an engine is to be shut off, and it is desired to reduce the steam pressure slightly to prevent "popping." But generally the fire should not be kept so hot that it will be desirable to cool it at such times with an open fire-door.

If holes are pulled in the fire they should be leveled over with the poker or the hoe—never filled up with fresh coal.

106. Making Station Stops.

In making station stops a "fire" should be put in either just before or right after the throttle valve is closed. The purpose for this is twofold. Usually at such times the fire is so hot that a surplus of steam is made, even if the injector is continued at work. This gives a good chance to put a charge of coal on the fire sufficient to last and keep it in good shape during the coming start from the station. The fresh coal put on at this time ABSORBS the surplus heat being given off by the fire, becomes heated red-hot—IGNITED, and is already for the start.

Thus an even steam pressure is maintained and "popping" avoided while running into the station; and the fire being in perfect condition for the start keeps up the steam pressure without further feeding while the engine is working hard starting the train.

Whether a "fire" should be put in just before or right after the throttle valve is closed will depend upon whether the surplus generation of steam should be checked before shutting off, or afterward. If the engine is a free steamer, or if the fire is very hot—the fresh coal should be put on BEFORE shutting off. But otherwise, unless necessary to prevent "popping," the fresh coal should be put on RIGHT AFTER shutting off.

In either case the supply should be sufficient to last during the next start while the engine is working hard, and until it can be put to working at a short cut-off. Whichever plan is followed, this should be held as a motto of good firing for station stops—Put in the needed fire always on SHUTTING OFF and never on STARTING.

107. Descending Grades.

Special care is necessary in managing the fire while descending long hills with steam shut off. In approaching long down-grades the fire should be cooled off gradually by letting it burn down well, so "popping" will not occur when the throttle is closed for the descent. As the injector will be continued at work to fill the boiler with water after the throttle is closed, the fire should be left as bright as may be necessary to supply the heat required by the injector, and to keep up the steam pressure.

If the fire, in this bright condition, makes more steam than the injector can use up, then its sides and back portion should be covered over with fresh coal, leaving the middle and forward portions of the fire bright. While the injector continues working, the fire-door may be left open, or ajar, if the steam pressure does not fall; but it must be closed if there is any indication of falling pressure.

After the injector is shut off, more of the fire may be covered over, including the centre; but the first 15 or 20 inches of the forward part of the fire should be left bright to protect the tubes from being chilled by currents of cold air. The fire-door should stand on the latch, or wide open if necessary, to prevent "popping." If the engine has dampers, these should be closed with this end in view.

108. Waiting on Sidings.

In approaching a siding where a wait is expected the fire should be allowed to burn down well, especially on engines having wide fire-boxes. While waiting on sidings, practically the same management of the fire is necessary to keep it in good condition and avoid reduced steam pressure or waste of steam, as in descending long grades. If the wait is to be considerable it will give a good chance to clean the fire or put it in good condition; and do whatever other work may help to make firing easier after the start.

If the fire does not need cleaning, then after getting in on the siding it should be kept as bright as necessary to keep up the steam pressure while the injector is working. After the injector is shut off, the fire should then be covered over at the sides and the back, leaving the centre and forward 15 or 20 inches BRIGHT for the protection of the tubes. If the engine has dampers, these should be closed. Otherwise the fire-door should be opened or placed on the latch. If the engine is inclined to "pop" with the fire in this condition, then the centre should be covered over also; but it is necessary that the tube-sheet shall be protected by bright fire near it, and that there shall be no great fall of steam pressure.

Careful efforts should be made during waits in whatever way is best to prevent a draft through the fire that will cause the coal used for a covering to burn up and be wasted.

Should it become necessary during the wait to put more water in the boiler, then the fire-door must be closed and a draft through the fire created to keep up the steam pressure while the injector is working.

LESSON 22.

FIRING WITH COARSE ANTHRACITE

Proper Depth of Fire. Evils of Heavy Firing. Firing While Running. Be the Master of the Fire. Making Station Stops. Descending Grades and Waiting on Sidings.

109. Firing Coarse Anthracite Coal.

The coarse sizes of anthracite coal form a superior and higher-priced fuel than the small sizes. They are burned on engines having usually deeper and much smaller fire-boxes. As much care must be exercised in preparing the fire for the start with coarse coal as with small coal. A heavier fire is carried with coarse coal, and for this reason the fireman must be particularly careful to see that the bed of coals upon which he is to build his fire is in perfect condition—that it is free from clinkers or dead spots, and that it thoroughly covers the whole grate surface, especially close up against the tube-sheet.

The deep fire-boxes used for burning coarse coal have shallow ash-pans, ten or twelve inches deep. The intense heat generated by anthracite coal in burning on a grate, in addition to the heat given off by the coals which fall down through the grates into the ash-pan, makes it necessary to use "water-grates" with shallow ash-pans. These are tubes which traverse the length of the fire-box at the usual grate level, and are connected with the boiler's "water legs" at the front and back of the furnace. Water circulates freely through these tubes, and prevents their being melted.

As the water-bars are immovable, provision is made for removing ashes and clinkers when necessary by having three or four movable solid iron grate-bars placed in between, and alternating or running parellel with the water-bars, lengthwise of the fire-box.

These solid grate-bars pass loosely through tubes provided for them in the back water-leg of the boiler, and their front ends rest on a "bearing-bar" that runs across the fire-box front, at the bottom of the water-leg. The grate-bars may be pulled out backward, leaving open spaces several inches wide between the water-bars, through which ashes and clinkers are knocked out as desired.

After the fire has been properly spread, and found to be in perfect condition, it must be immediately and lightly covered over with coal broken up to about the size of apples. The fire-door should then be closed and the blower lightly used—if necessary—until the fresh coal is thoroughly ignited and is burning well. A heavier covering of broken coal should then be put on, and allowed to get to burning well; then lump coal should be put on to build the fire up to the necessary depth to suit the work the engine has to do after starting, building the corners, sides and back portions higher than the middle and forward parts.

After the necessary charge of coarse coal has been put on the spaces between the lumps must be filled in with finely broken coal, especially along the sides and in the corners, to prevent holes being worked in the fire.

110. Proper Depth of Fire.

A proper depth of fire for coarse coal at starting can not be stated. It must depend on the size of the coal, the size of the fire-box, and the work to be done. It should never exceed six to eight inches deep in the front, or eight to twelve inches deep at the back. The aim must be to keep the bed of fire as light as possible without running any risk of having holes drawn in it; but it should be deep enough so that it will not require further feeding while the engine is working hard starting the train, or until the fire gets to burning well and making steam freely. Much coal is often wasted by building fires too heavy before starting.

111. Evils of Heavy Firing.

What is known as "loading up" before starting, so a long distance can be run before "loading up" again, is a bad and wasteful practice that must not be followed. With such firing, the heavy bed of coal obstructs the easy passage of air through the fire, thus reducing the amount of air admitted below what is needed for perfect combustion. The result is imperfect combustion of a very large portion of the coal put on the fire and

burned, from which only A THIRD as much heat is obtained as would be if it had sufficient air to burn properly.

Too heavy firing either before the start, or during the run, increases the formation of clinkers; and therefore reduces the length of time a fire can be used without being cleaned.

In burning anthracite coal the depth of the fire carried is dependent upon the size of the lumps used. With large lumps a thick fire is required, and even then there is a constant tendency toward the formation of spaces, or "holes," between the large lumps. While large lumps of anthracite coal under a forced draft soon disintegrate or "go to pieces," yet the particles usually stick so closely together that they can not be burned with as much advantage as small lumps distributed more evenly over the fire.

Therefore to obtain the advantages that come from a light fire long kept clean, and the more perfect burning of the coal, all large lumps should be broken to at least the size of a man's fist before being put on the fire. Thus will the life of the fire in good condition be prolonged, the combustion of all the coal burned on it be improved, resulting in more heat and steam from any given quantity of coal, and reduced labor for the firemen.

112. Firing While Running.

After starting, the fire must be closely watched. About the same depth of fire as was had in starting should be maintained by adding one or two shovelfuls of broken coal as needed to the parts of the fire that reach a white heat. Thus the parts inclined to burn to a lower depth will be kept filled up, the sides higher than the middle. Not over two or three shovelfuls at a time should be used in doing this while the engine is working ordinarily.

"Eternal vigilance is the price of safety" in firing all sizes of anthracite coal; and as great care must be exercised with coarse as with small coal to keep the fire light and in good condition, to feed it with light, carefully placed charges while running, closing the door ordinarily between each shovelful, and giving time between each charge for the fire to regain high temperature.

Within proper limitations, the lighter a fireman can keep his fire, the less coal he will have to shovel, the less work he will have to clean his fire, the more steam he will have, and the more gain he will effect for the Company.

113. Be the Master of the Fire.

Feeding coarse coal to a fire has a more chilling effect than feeding small coal, because it takes longer to heat the coarse coal red-hot and start it to burning. Therefore the blacksmith's maxim to—

"Strike while the Iron is Hot"

is of particular significance in firing coarse anthracite.

The fireman must be more alert than with small anthracite to "strike" while the coal is hot—to watch for the moments when the different portions of his fire reach their highest heat, the white heat; then quickly, but carefully, cover these places with coal. Firing postponed until the white heat dies out, or the steam pressure begins to fall, is sure to cause a heavy loss of pressure, and increased consumption of fuel.

114. Making Station Stops.

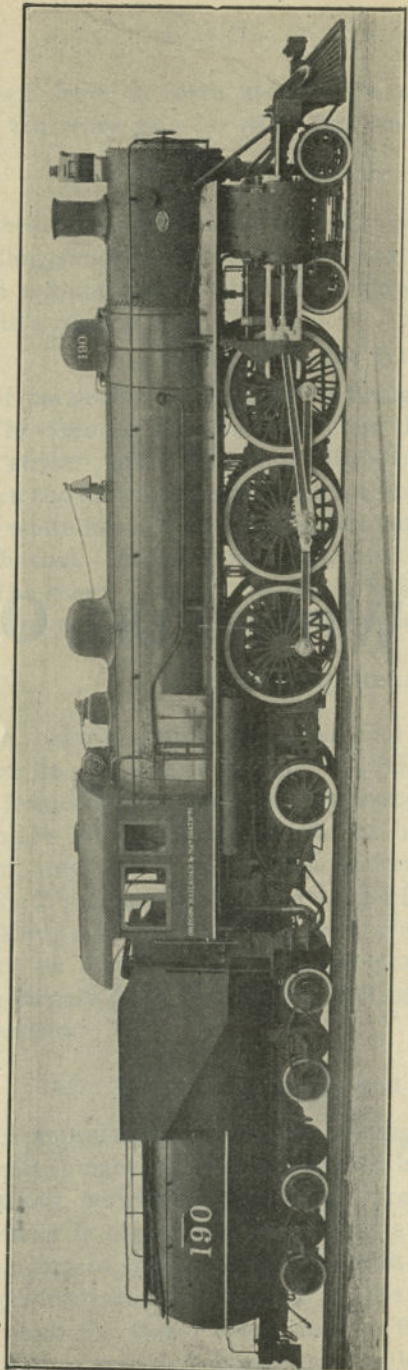
In making station stops, the coal needed for the next start must be put on the fire just BEFORE the throttle is closed, or immediately after, for the same reason as explained in Subject 106. The fire should be in perfect conditon at the start, and this requires that whatever coal it needs shall be ON IT, and thoroughly ignited, BEFORE the start.

Always in starting, the door should be left open on the latch as much as is found advantageous. This relieves the fire largely from the pulling, tearing effects of the full stroke exhausts.

115. Descending Grades and Waiting on Sidings.

In approaching a long descending grade, or a siding where a wait is expected, the fire should be permitted to burn down without permitting the steam pressure to fall. After the throttle is closed for descending a grade, the fire should be managed in the same way as with small coal. It is equally important that steam shall not be wasted by blowing away through the safety-valve, and no fall of steam pressure permitted to chill and damage the boiler.

FIRING WITH FUEL OIL



OIL BURNING LOCOMOTIVE ON A PACIFIC COAST RAILROAD

This engine is built to burn CRUDE PETROLEUM ("liquid coal") as its fuel. Its tender is a round tank built to carry two liquids SEPARATELY—the WATER to generate steam in the boiler, and the OIL to burn as fuel in the furnace. The forward part of the tender is made to carry also a supply of coal, in case coal should sometimes be used as fuel.

LESSON 23.
FUEL OIL ON LOCOMOTIVES

Formation of Petroleum. Carrying Petroleum on Locomotives. Burning Petroleum on Locomotives.

Petroleum is a brown mineral oil, composed of about 85 per cent. CARBON, 13 per cent. hydrogen and two per cent. of oxygen gases. Thus we see that, as in coal—CARBON is the chief element of fuel oil—existing in it in the same proportion as it does in anthracite coal, 85 per cent. So we may almost regard petroleum as—LIQUID COAL.

116. Formation of Petroleum.

Coal was formed by decomposed vegetable matter, and petroleum was probably formed by decomposed animal and vegetable matter. Professor Garrett P. Serviss, writing of this says:

"Petroleum is found in the rocks of the earth's crust, but it was probably not formed from the rocks. The prevailing opinion is that it is derived from decomposition of animal or of vegetable matter, or of both.

"The organisms, whether plant or animal, that were transformed into oil, must have been inhabitants of the ocean in early geologic times. Some geologists contend that the material was supplied entirely by marine animal life, and that vegetation has played no part in the phenomenon.

"If this be true, what a picture arises in the mind when we remember the location of many of the great oil wells, and then recall the facts that A SEA abounding with life once rolled where the mountains now rise and the rivers flow, and that millions of gallons of oil, formed from the bodies of the inhabitants of that vanished sea, and stored for millions of years in the great reservoirs of the earth, are now piped away for the uses of creatures (human beings) whose earliest types were not to come into existence until vast eons of time after the oil-makers, and the sea they swam in, had disappeared.

"As the remains of marine animals were transformed into strata of chalk and limestone, making platforms for continents and frames for mountain ranges, so, too, they filled huge pockets of the earth's crust with petroleum.

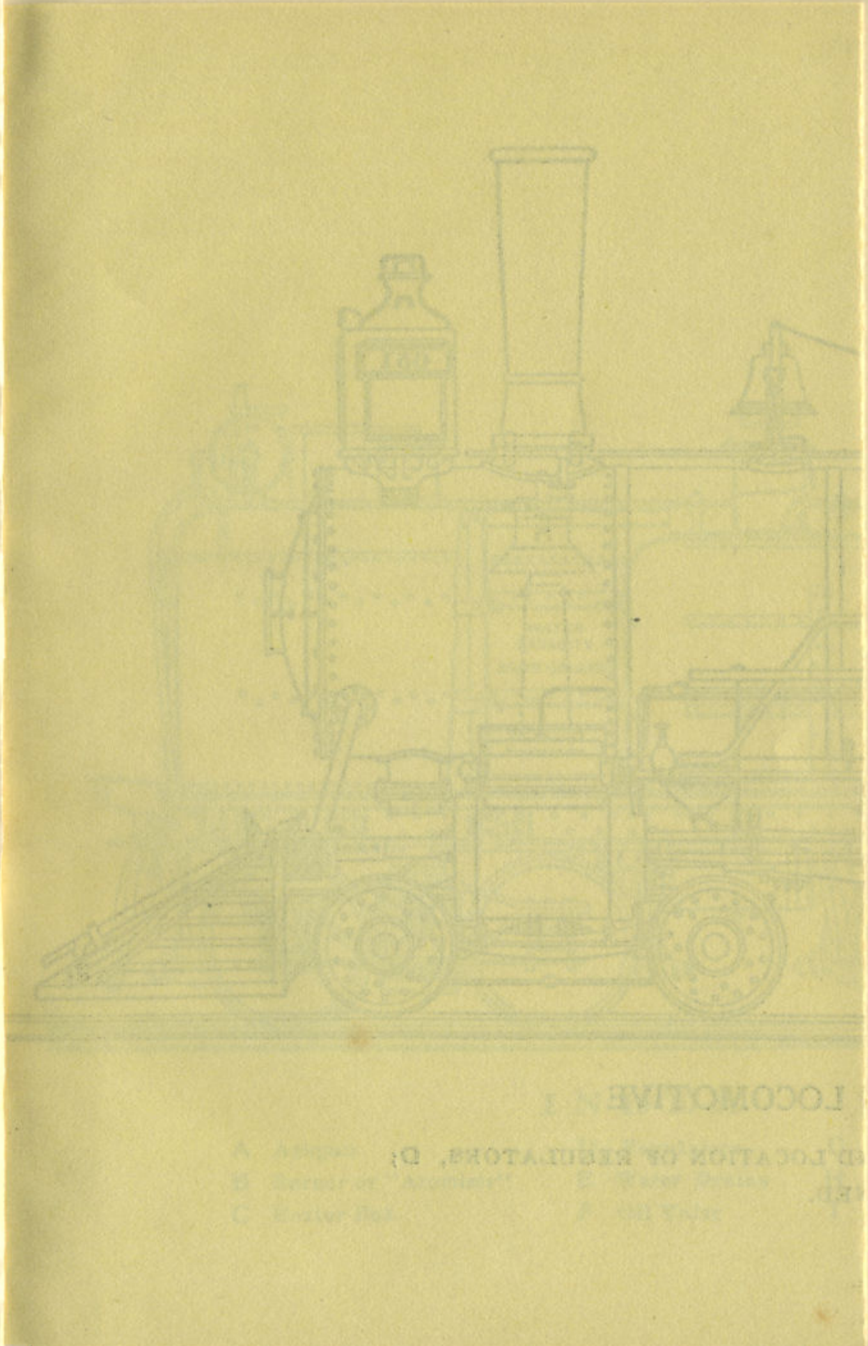
"In ancient seas dwelt shoals of marine creatures, generations following generations. They lived and died, and lived and died, and filled cemeteries of the sea—until strange essences were distilled from their packed bodies, while their sandy coverings changed to rock.

"Then came great earthquakes and upheavals of the soil and rocks—and the oily substance that had taken the place of countless trillions of once living little bodies collected in cavities, and here and there reached the surface of the Earth through some crevice, from which it gave forth fumes that astonished the inhabitants above by catching fire, or else leaked out in the form of 'burning water.'"

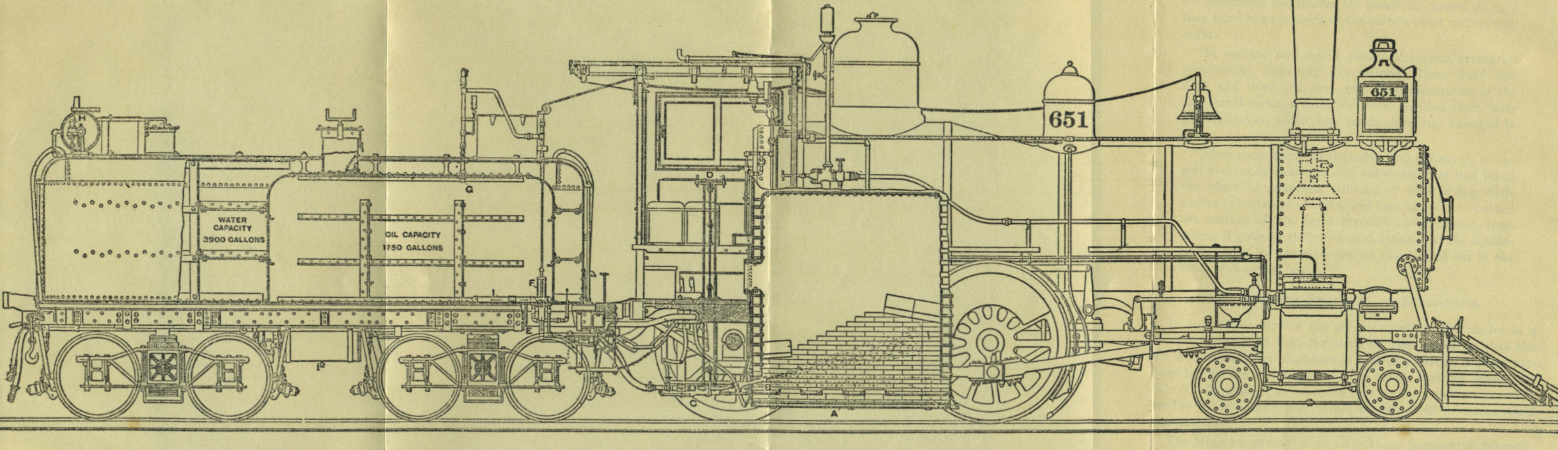
117. Carrying Petroleum on Locomotives.

In locomotive service the oil is carried on the tender in a compartment built into the tank on the tender so that the oil is protected from exposure in case of accident, it being surrounded by the water space of the tender and the water that fills it. In case of an accident that would puncture the tank on the tender—the water would be permitted to escape—and not the oil.

The large engraving of an oil-burning locomotive herewith shows a portion of the side of the tender cut away, and reveals the space reserved for water, 3,900 gallons, and the tank prepared for oil, holding 1,750 gallons. This arrangement is called a "combination tank," the oil being carried in the inner tank, which is surrounded by the water. Under all ordinary circumstances this arrangement would prevent the oil from escaping even if the locomotive were overturned. Automatic valves are also provided which would close so as to prevent the oil from escaping should any of the pipes leading to the furnace become disconnected.



it from the SIDE.



INDEX

A Ashpan
B Burner or "Atomizer"
C Heater Box
D Regulators
E Water Drains
F Oil Valve
G Safety Valve
H Reducing Valve
I Heater

OUTSIDE AND INTERIOR VIEWS OF AN OIL BURNING LOCOMOTIVE

SHOWING INTERIOR OF TENDER WHERE THE OIL IS CARRIED; INTERIOR OF CAB AND LOCATION OF REGULATORS, D; AND INTERIOR OF FIRE BOX WHERE THE OIL IS BURNED.

the oil from escaping should any of the pipes leading to the furnace become disconnected.

118. Burning Petroleum on Locomotives.

This drawing also shows the side of the boiler cut away, revealing the arrangement in the fire-box for burning the oil. The fire-box is built up with fire-brick at both sides and in front to form a combustion chamber. A light fire is built on the grates. Oil from the tank and steam from the boiler reach the atomizer or "BURNER" shown at the bottom and center of the fire-box. The steam heats the oil and throws it

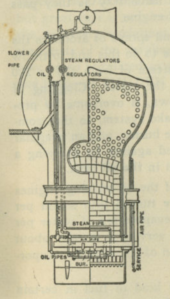


FIG. 1.

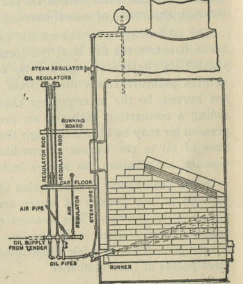


FIG. 2.

Rear and Side Interior Views of the Fire-Box of an Oil Burning Locomotive.

in A FINE SPRAY upon the fire or heated fire-brick, which ignites the oil and causes it to burn.

Other views of the fire-box and the arrangement for feeding the oil are given in Figures 1 and 2. Figure 1 gives a view of the boiler-head and fire-box, looking into it from the REAR. Figure 2 gives a view of the fire-box and burner, looking into it from the SIDE.

It will be seen that the furnace is arched over the top more than half its length. This is for the same purpose that the brick arch is used in the fire-box of a soft coal burning locomotive—so that the oil, turned into gas in the furnace by the great heat to which it is subjected, shall have time to burn AS FLAME in passing around the arch, before it enters the tubes, where the flame is quickly extinguished by the colder surfaces it there comes in contact with.

Of course the hot fire gases and other products of combustion pass through the tubes of the boiler to the smoke-box and out of the smoke-stack in the same way as they pass through the boiler of a coal-burning engine.

The oil burner has a flat mouth, and sprays or atomizes the oil as it enters the fire-box; the force to do this and to throw the oil on the fire is supplied by steam of from 170 to 200 pounds pressure taken direct from the boiler. Clogging of the burner, in the arrangement shown, is overcome by providing a connection with the air brake system, so that compressed air may be blown through the burner, and an irregular flow of oil to the burner is provided against by carrying a 4-pound air pressure per square inch in the oil tank.

It has been found in the service of the oil burning engines that about 9½ pounds of water are turned into steam per pound of oil burned. The average evaporation of water per pound of coal burned in locomotive service is usually about six pounds. This is a fair illustration of the superior evaporative power of the liquid fuel.

The practicability of using either kind of fuel in certain localities must be governed by the relative prices of the same. Where coal is cheap and petroleum is expensive, coal will be the natural and necessary choice, but in localities where coal is very expensive, as on the Pacific coast and in the Southwestern States, where petroleum is easily and cheaply obtained, petroleum affords a means of successful locomotive operation with great economy over coal fuel, besides many other advantages in the nature of cleanliness, cheapness in handling, the ease of firing, and the reduction of possible losses through inefficient firing.

In the Pacific Coast and Southwestern States coal is not so

plentiful as petroleum, which is therefore generally used as "fuel oil" instead of coal on locomotives in those sections.

The care of firemen on oil burning locomotives is necessarily exercised more to prevent damage to the furnace and the fire-box sheets than, as with coal, to getting the greatest possible heat from a minimum quantity of fuel. With proper adjustment the oil-burning apparatus will easily produce the required heat with a minimum supply of oil, and in this way there is less left to the care and judgment of the firemen as regards ECONOMY of fuel than on coal-burning locomotives; but great care is required to manipulate the oil supply so that the necessary variations in the intensity of the fire, to suit the needs of the varying character of the locomotive's work, may be so regulated as to AVOID SUDDEN HEATING at one time—or SUDDEN COOLING at another time.

LESSON 24.

INSTRUCTIONS FOR FIRING WITH OIL.

Starting the Fire. The Sand Blast. Preserve the Boiler from Damage. Drumming and Black Smoke. Warming the Oil in the Tank. Putting Out the Fire. Warning Against Explosion.

119. Starting the Fire.

In starting a fire in an oil-burning locomotive it is very necessary to make sure that there is no obstruction in front of the burner, at the bottom of the fire-box, that would interfere with the free passage of oil from the burner to the front of the fire-box. Sometimes a brick will fall in front of the burner, or sand that is often in the oil will accumulate beneath the burner. It is of FIRST IMPORTANCE to be SURE—before the fire is started—that no such obstruction is in the way of the burner.

To start the fire, open the burner or atomizer valve long enough to blow out of the pipe any water that may be accumulated therein; then close the valve and throw a lighted piece of oily waste into the center of the fire-box. Put on the blower strong enough to create the necessary draft. Then open the oil valve slightly and turn on the atomizer strong enough to carry the oil to the blazing waste. Open the oil valve very slowly until the oil is burning well; and in raising the steam pressure be careful to use only enough oil to do so without making any black smoke.

It is very necessary in firing up a cold engine to watch the fire closely until the engine gets hot, as the fire is liable to go out. In case it should become necessary to fire up an engine with wood, care must be taken to not damage the brick work in the fire-box by throwing in the wood carelessly.

All oil-burning engines are provided with a "sprinkler-pipe" that leads to the ash-pan, its purpose being to flood the ash-pan and carry off any oil drippings that reach the pan when the fire is being started. This sprinkler must be used whenever a new fire is started, to prevent such drippings catching fire and doing damage.

In case an engine is left alone for a short time by its crew or a watchman, the sprinkler must be used to wash away any oil drippings in the ash-pan.

It is necessary for the preservation of the boiler from damage by currents of cold air that a good fire shall be burning BEFORE the engine starts up from any stop. The oil valve should be opened gradually at first, and care must be taken to keep the TEMPERATURE of the fire-box as nearly UNIFORM as possible. As the engine increases its speed, the fireman should gradually increase the supply of oil in accordance with the requirements of the service.

The firing should never be forced—not even to prevent falling pressure. If the steam pressure falls five or ten pounds, it must be restored to that usually carried, by degrees—GRADUALLY. Forced firing will fill the tubes with soot, overheat the fire-box sheets, burn off the rivet heads, and damage the boiler in other ways so that it will leak.

120. The Sand Blast.

With oil fuel, the boiler tubes are kept free of soot by the use of the "sand funnel," a device for carrying sand to the fire-box through a small hole in the furnace door, from whence it is carried by the draft through the tubes, where it acts as a mild sand blast, and cuts the soot loose from the tubes and carries it out the stack.

The sand blast must be used to clear the tubes of soot as the engine is going from the roundhouse to its train, whenever this can be done. It should be used again in pulling out, or starting the train. This is very important, as it is while standing housed at terminals, and being fired up, that an engine is most apt to be "smoked up," or to have its tubes thickly covered with soot. This soot is a non-conductor of heat, and will make an oil burning engine fail in steam quicker than any other cause.

To thoroughly cleanse the tubes and other heating surfaces of soot, "sanding" should be resorted to several times during the first mile or two in starting out on a trip. "Sanding" should be repeated at short intervals as long as quantities of black smoke are produced by this scouring process. In doing this the sand must always be directed up over the arch, instead of beneath it. If the supply of sand runs short, a fireman may take what is needed from the engine's main sandbox, or he may recover some that he has already used from the cinder pot in the front end, and use it over again.

121. Preserve the Boiler from Damage.

Great care must be exercised to prevent the engine from slipping or working hard when the fire is out, or before the fire is lighted. Such abuse of the boiler will cause the tubes to leak immediately.

After an oil fire is started at the beginning of a trip it must not be put out entirely at any time until the engine is put in the roundhouse at the end of its run. Of course the fire should be reduced to a very low heat while waiting at stations if the injector is not working; but while the injector continues to fill the boiler the steam pressure should be kept to within about ten pounds of that usually carried.

Great care must be taken to never leave the fire door unfastened while the fire is being started, for if too much oil is turned on an explosion may occur that would drive the flame out through the door-way into the cab, if the door were loosely closed, and this might injure anyone in the cab.

A fireman must also be careful to never use the blower any stronger than necessary to clear the black smoke away from the stack, as it will cause a waste of oil, make an unnecessary noise, and if the fire is burning lightly it will cause the tubes to leak.

122. Drumming and Black Smoke.

"Drumming" of engines is usually caused by the careless handling of the oil valve by the fireman when the engine is working slowly, or by the atomizer valve being opened too much.

Firemen on passenger trains should use the utmost care in handling the oil valves and atomizers, in order to avoid disturbances of this character.

Firemen should always aim to avoid black smoke, as it is usually a sign of careless firing. It shows that imperfect combustion is going on, for if the oil were all burned as flame in the fire-box there would be no smoke.

An accurate combination of oil and steam in the atomizer, with the proper admission of air, is necessary to thorough combustion. To prevent smoke in starting and stopping, engineers should always notify the fireman when they are going to open or close the throttle.

123. Warming the Oil in the Tank.

It is desirable that the temperature of the oil in the tank shall be warm, but that it should not exceed 100 degrees. If it is necessary to warm the oil in the tank by putting on the heater, care must be exercised so that no more steam is sent back into the oil than is necessary, as the condensed steam, or water, is liable to interrupt the continuous flow of oil to the burner.

Whenever the oil in the tank is to be heated, the heater should be put on STRONG until the oil is sufficiently warm, and then shut off. Opening the heater lightly, and leaving it on continuously is bad practice. Heating the oil in this way should always be done while standing, if possible.

124. Putting Out the Fire.

To put out the fire, at the end of the trip, first shut off the oil valve, and allow all the oil then in the pipe to escape through the burner and burn. Then close the regulators and dampers.

It is very important for the preservation of the boiler from damage that the dampers shall be closed as soon as the fire is extinguished, so as to prevent the passage of cold air through the hot fire-box and tubes.

125. Warning Against Explosion.

Petroleum contains a great amount of explosive gases, which are given off at low temperatures—therefore under no circumstances should lighted torches, lamps or lanterns be taken near the openings or into tanks that have contained crude oil, until they have been thoroughly washed out.

Do not approach nearer than ten feet to a manhole or vent hole in the tank with a lighted torch or lantern. To ascertain the amount of oil in the tank, use the stick or rod made for that purpose—and carry it to the light to see what it registers.