LOCOMOTIVE CORRESPONDENCE COURSE - FIREMEN and ENGINEDRIVERS.

LESSON No. 3.

THE ENGINEDRIVER:

Everything that has been said in previous lessons regarding the qualifications and responsibilities of the fireman apply equally to the enginedriver. It is true that a fireman occupies a responsible position; that a spirit of enquiry is essential to success; that he must devote time, energy and enthusiasm to the effort of mastering the details of his work, but the enginedriver must excel in all these virtues if he wishes to acquire the necessary knowledge to become proficient in the handling and running of the modern locomotive. Just as the best locomotive is the one that performs the greatest amount of work with the least consumption of coal, water and oil, so the best enginedriver is the one who can work up his locomotive to its fullest capacity at the least possible cost. The enginedriver who will not concern himself about finding out how far back he can notch up his reversing lever in order to economise on steam and water, because he has always managed to get along without giving its expansive energy full scope; and who never troubles himself about saving oil, because by his system of over-feeding cups and oil-holes, he has comparatively few hot bearings, has much to learn and may sooner or later realise to his regret that he knows so little.

INSTRUCTION BOOKS:

The Instruction Book for the guidance of Enginedrivers, Firemen and Cleaners clearly defines the main guiding principles to be observed by the enginedriver in the course of his duties during preparation, putting away and the running of his locomotive on the road, whilst the Rules and Regulations contain full instructions affecting train running operations. The main purpose of this lesson is to emphasis some of the more important of these instructions, but the student is urged to make a close study of the books referred to above so that he will leave nothing to chance when booked on duty to run a train.

INSPECTION OF THE LOCOMOTIVE:

An enginedriver's confidence in his locomotive largely depends on how much he knows about it. This necessitates an exhaustive daily inspection of it, with a thorough search for defects. Special attention must be given to split-pins, keys, bolts, check-nuts, set-screws, big and little ends, side-rod brasses, motion pins, axle box wedges, spring hangars, springs, tyres, glands, rods, ash-pan, smoke-box and appliances, guide bars and injectors, while a thorough examination and testing of the Westinghouse brake gear and equipment must be carried out.

PROMPTLY REPORT DEFECTS:

Some enginedrivers omit to report defects unless they become serious. This is a big mistake for in locomotive running a small defect to-day may mean a serious breakdown tomorrow. As a regular precaution the repair journal should be examined before taking charge of the locomotive to see that any defects booked by the previous enginedriver have received attention. Noting defects in this way enables the enginedriver to pay particular attention to the parts repaired that may become overheated, etc., on the road.

It is good practice for the enginedriver to train himself to look over his locomotive when he is oiling or greasing; in this way, he will detect any defects or flaws that might have developed since his initial inspection.

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KNOWLEDGE OF SIGNALS:

It is necessary that the enginedriver should have a thorough knowledge of all the various types of signalling in use over the road on which he runs his train, and the greatest vigilance is needed, especially at night, to correctly interpret the different signal indications.

KNOWLEDGE OF THE ROAD:

Next to having a complete knowledge of signals, a knowledge of the road is important. An enginedriver is required to certify that he has a knowledge of the road, before he is allowed to take charge of a train on any section of line.

Unless the enginedriver has this knowledge of the gradients, curves, and general topography of the country he will not have the confidence to handle his train, with the result that at places where he ought to be gathering speed to help him up a steep bank, probably he would be trying nervously to steady his train by making heavy brake applications. On the other hand, he might have his train travelling at an excessive speed on a down gradient with many sharp curves to negotiate with the result that signals might be missed or overrun.

PRESENCE OF MIND:

Railway service demands constant vigilance, and with the increase in the weight and speed of our locomotives and trains, it is essential that the enginedriver be ready at all times to act with judgment and decision to avert possible accidents. An obstruction may suddenly present itself to the enginedriver's view; the locomotive may break or seize up some portion of the running gear; or some other unexpected development may occur without warning; all demanding prompt action on the part of the enginedriver to avoid possible disaster. It is necessary therefore to keep alert and vigilant at all times to meet any emergency that may arise, especially where familiarity with the road and train crossings may otherwise cause slackening of attention. It is in such circumstances that the worst accidents frequently occur.

PREPARATION FOR THE ROAD:

After the enginedriver has read and signed for his train advices, examined the notice case for special announcements regarding the running of his train, signed the attendance sheet and checked the repair journal (Loco-54) to ascertain that needed repairs to his locomotive have received attention, he will supplement the work of his fireman by testing the water level in the boiler, the make up of the fire, the filling of the W.H. Pump and the mechanical or hydrostatic lubricator and check the performance of the various other duties that devolve upon the fireman. The enginedriver will then attend to the lubrication and other work connected with the preparation of his locomotive for its run.

The detailed work involved has been covered in lesson No. 2 and it is fully set out in the Handbook of Instructions, so no good purpose will be served in making further reference to this phase of the enginedriver's job at this stage.

STARTING TRAIN:

After completion of the brake test, and the other necessary preliminaries prior to the journey. The reverse lever should be in full gear and the regulator opened off the face to permit the locomotive to move slowly until the slack in the train has been taken up and thus permit of a smooth start. Cylinders relief cocks should be left open to thoroughly drain any water from the cylinders and sand used sparingly, if necessary, to avoid slipping of the driving wheels.

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Once the train is well under way, the reversing lever should be notched up to its most economical position. This will be governed by the weight and the class of the train and the necessity for maintaining timetable speed.

ECONOMICAL USE OF STEAM:

To use steam economically, it must be used expansively and in the locomotive this is accomplished by notching up the reverse lever thereby cutting off the steam before the piston completes its stroke. The point at which the steam may be expanded to obtain the greatest economy will vary on different class of locomotives, and, as indicated in the previous chapter, it will depend on the speed, weight of train, and the characteristics of the country being traversed.

The following points should give the enginedriver some indication of the best methods to adopt to secure the most satisfactory results:-

(1) Once the train is well under way, open the regulator wide and control the speed of the train with the reverse lever, by notching up to the most economical position.

If the train is comparatively light, and the track conditions are easy, the speed of the train may tend to become too high, in which case, it will be necessary to ease the regulator down until a satisfactory adjustment is made. To put it another way - after opening the regulator to its maximum, control the train by the reverse lever as long as it is below the notch which secures the greatest economy for the speed and load, but as soon as it reaches that notch, control should be maintained by means of the regulator.

(2) When the locomotive is running with a full regulator and more power is required, drop the reverse lever and a notch or two as may be necessary, until the extra power needed is developed.

(3) The expansive power of steam is lesser or greater according to the boiler pressure and steam has more elasticity as the pressure increases. This is the case in superheated locomotives where the steam, because of its increased temperature, has still greater expansive properties than saturated steam.
The best results can be obtained by keeping the pressure in the boiler as near to blowing off point as possible.

Working with a low boiler pressure is unsatisfactory for the following reason:-

(1) It takes almost as much fuel to evaporate water for low pressure as for high pressure, therefore the difference between the high pressure and low pressure steam is gained by a small extra expenditure of fuel.

TOOLS AND ENGINE EQUIPMENT:

Enginedrivers are issued with a tool box containing the following tools etc., which remains in the personal custody of the member. Any shortages or replacements required should be promptly reported to the locomotive foreman, and the deficiencies made up by the Trust Store. This equipment should be carried on the locomotive at all times.

TOOL BOX EQUIPMENT:

1 No.	Chisel, cross cut.	1 No.	Spanner, $\frac{5}{8}$" x $\frac{3}{4}$"
1 No.	Chisel, flat.	1 No.	Spanner, $\frac{7}{8}$" x 1"
1 No.	Chisel, round nose.	1 No.	Spanner, crocodile jaw.
1 No.	Cylinder Cock Blind.	1 No.	Spanner, shifting, 15".
1 No.	Hammer, hand.	1 No.	Spanner, shifting, 8".
3 No.	Pin Punches, assorted.	1 No.	Gauge Glass 10".
1 No.	Spanner, $\frac{3}{8}$" x $\frac{1}{2}$"	6 No.	Washers, I.R. $\frac{3}{4}$".

Tool boxes and equipment are examined by the locomotive foreman, usually in the month of September in each year, when Working Timetables and Rule Books are checked.

The following is a list of tools and equipment carried on an Ab locomotive. Slight variations and additions occur for other classes of locomotives, but the list is practically the same for all classes.

4 No.	Engine axlebox chocks.	2 No.	Piston chocks and clips.
2 No.	Leading bogie axlebox chocks.	1 No.	Plugging iron.
		3 No.	Firebox tube plugs.
2 No.	Big end brass clips.	3 No.	Smokebox tube plugs.
12 No.	Assorted bolts nuts.	1 No.	Pricker.
1 set	spare assorted cotters.	2 No.	Sets wood quadrant blocks.
2 No.	Coupling hooks, pins, & securing chains.	1 No.	Rake.
		1 No.	Set assorted set screws.
12 No.	Detonating signala.	1 No.	Valve centring set screws.
2 No.	Electric light globes.	1 No.	Coal shovel.
1 No.	12" hand file.	1 No.	Snifting valve stop.
1 No.	Set hand signal flags.	1 No.	Set service spanners.
1 No.	Grease container.	1 No.	Set breakdown spanners.
1 No.	Coal hammer.	1 No.	Set split and taper pins.
1 No.	Heavy coal hammer 18" handle.	1 No.	Steam heat hose.
		1 No.	Tommy bar.
1 No.	Set hardwood packing.	1 No.	Tablet fork and sling.
1 No.	Bottle jack	1 No.	1" W.H.B. coupling hose 22" long.
2 No.	Traversing jacks.		
2 No.	Jack bars.	1 No.	W.H.B. engine tender coupling hose 30" long.
2 No.	Jack traversing ratchets.		
1 No.	Hand signal lamp.	1 No.	W.H.B. Main reservoir hose 30" x 1$\frac{5}{8}$"
1 No.	Extra red tail lamp.		
20 No.	Marline.	1 No.	Wheel lifting wedge.
1 No.	1 gallon oil can.	1 No.	Wheel gauge.
1 No.	$\frac{1}{2}$ gallon oil can.	12 No.	18 I.S.W. Copper wire.
1 No.	set oil feeders.		10 yards worsted.
1 No.	set packing drawers & tongs.	1 No.	Drop grate lever extension.
1 No.	Pinch bar.	1 No.	Transition coupler head.

HOW AN INJECTOR WORKS:

How can an injector lift and force large volumes of water into the boiler against the same or even higher pressure than that of the steam ?

It is proposed to answer the above question in some detail because its mode of action is nothing less than a paradox to many of those whose business it is to use it.

Before going into details it may be advisable to state very simply how it works and why it is capable of producing the apparantly paradoxical result of taking steam from a boiler and forcing many times its weight of feed water back into the same boiler or even into a boiler at a higher pressure.

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HOW AN INJECTOR WORKS:

Briefly, the principle of the injector's action is as follows:- A jet of steam issuing from a contracted nozzle under a given pressure possesses more velocity than a corresponding jet of water would have at the same pressure. If a jet of steam is suddenly brought into contact with a flow of water, a portion of the steam is condensed and its resultant velocity becomes imparted to the water to a sufficifnt extent to enable the combined steam and water to lift the boiler clack valve and enter the boiler against its own pressure.

WHY SHOULD AN INJECTOR WORK?

Let us assume that the boiler pressure is 180 pounds - that is to say, every square inch of the sheets, top and bottom, receives an internal pressure of 180 pounds. If a thermometer is placed inside, it is found that both the water and the steam are at the same temperature, 379 degrees.

But the steam contains more heat than the water, because after water is heated, more coal must be burned to break up the drops of water to change them into steam. This heat is stored in the steam and represents work done by the burning of the coal. Steam not only exerts a pressure of 180 pounds per square inch, but also can expand eight to twenty-six times its original volume, depending upon whether it exhausts into the air or into a partial vacuum. Water under the same pressure would be discharged in a solid jet and without expansion.

Either steam or water can be used in the cylinder of an engine or to drive the vanes of a steam or water turbine, but one pound of steam is capable of much more work than one pound weight of water, on account of the heat which has been used to change it into steam. This is easily seen by comparing the velocities of discharge from a steam nozzle and a water nozzle under 180 pounds pressure; steam would expand while issuing, reaching at the end of the nozzle a velocity of about 3600 feet per second, while the water, having no expansion, would have a velocity of only 164 feet per second, about 1/22 of that of the steam. The same weight of steam discharged per second would therefore have vastly more power than the water jet.

If a steam or water jet comes in contact with a body in front of it, the tendency is to drive the body forward. The amount of motion which a body has is called "momentum" and is equal to the weight of water or steam discharged by the jet in one second, multiplied by its velocity per second. If 1 pound of both the steam and water are discharged per second, the "momentum" of the steam jet is 3600, because 1 multiplied by 3600 = 3600; the momentum of the water jet is 164. If the water jet discharged about twenty-two pounds per second, its momentum would be the same as that of the steam, because 22 multiplied by 164 is nearly 3600. The two jets are discharged under the same pressure, but the steam has twenty-two times as much "momentum" as the water jet; it could, therefore, easily enter a boiler at 180 pounds pressure if we could reduce it to the size of the hole of the water nozzle.

HOW OUGHT AN INJECTOR TO WORK?

Here a practical difficulty is reached. A steam jet 6" from the nozzle is much larger than at the opening, and it would appear almost impossible to make it enter a smaller tube. Even at the narrowest part of the nozzle it is more than sixteen times larger in diameter than a water jet discharging the same weight per second therefore, if the steam is changed to water without reducing its velocity, it would pass through a hole one-sixteenth the diameter of the "steam nozzle" at a velocity of 3600 feet per second. The simplest and best way to reduce its size is to condense it, and to use water for this purpose, especially as water is needed in the boiler. To condense the steam and utilize its velocity, the water must be brought into close contact with it, without interfering with the direct line of discharge; a funnel or "Combining Tube" suitably placed will compel water to enter evenly all around the steam jet. The mouth of this funnel must not be too large, or too much water will enter and swamp the jet; if too small, insufficient water will enter to condense the steam. The effect of condensing the steam is to reduce the diameter of the jet; therefore the funnel or combining tube must be a smooth, converging taper, to lead the combined jet of water and condensed steam into the smaller hole of the delivery tube. The effect of the impact of the steam is to give to the water its momentum, so that a solid stream shall issue from the lower end of the tube. Each little drop of entering water is driven ahead faster and faster by the steam moving hundreds of times as rapidly, until the steam and water thoroughly combine into one swiftly moving jet of water and condensed steam, which contracts sufficiently in diameter to enter the smaller delivery tube.

WHY DOES THE JET ENTER THE BOILER?

The combined jet now passes from the end of the combining tube into the delivery tube. Why does it enter the boiler?

If a pipe shaped like a fire-hose nozzle or a "delivery tube" is connected to a tank or boiler carrying 180 pounds, the water will issue in a solid jet with a velocity of about 164 feet per second (see page 1); or, if we could force water into the tube at a speed of 164 feet per second at the same part of the tube, this water would enter and fill up the boiler or tank against 180 pounds pressure. Therefore to enter the boiler the combined jet of water and steam issuing from the combining tube must have a velocity of at least 164 feet per second.

Now what is the vebcity of the combined jet at the lower end of the combining tube? If the steam nozzle discharges one pound per second at 3600 feet velocity, the momentum of the steam is 1 multiplied by 3600, or 3600. If the vacuum caused by the condensation of the steam lifts and draws into the combiningtube ten pounds of water per second at a velocity of forty feet, its momentum is 400; and that of the combined jet is 3600 added to 400, or 4000. The weight of the combined jet is eleven pounds, and at the time of entering the delivery tube itsvelocity ought to be equal to 4000 divided by 11, or 366 feet per second; but as the water and the steam do not meet in precisely the line of discharge there is a loss of momentum, and the velocity in the delivery tube is only 198 feet per second. But the jet only needs a velocity of 164 feet to enter the boiler or tank carrying 180 pounds pressure; therefore the acutal jet in the delivery tube is able to overcome a pressure of 206 pounds per square inch, or twenty-six pounds above that of the steam, because the velocity of a jet of water under a head pressure of 206 pounds would be 198 feet per second. This excess is more than sufficient to overcome the friction of the delivery piping and the resistance of the main check valve. Therefore,

"The action of the Injector is due to the high velocity with which a jet of steam strikes the water entering the combining tube, imparting to it its momentum and forming with it during condensation a continuous jet of smaller diameter, having sufficient velocity to overcome the pressure of the boiler.

HOW TO USE AN INJECTOR TO SAVE FUEL.

Owing to the simplicity of the modern injector it is possible for any one with ordinary common sense to prime it and to force water into a steam boiler, but to operate a locomotive injector according to the most approved methods for economy of fuel and efficient running of the engine requires a knowledge of underlying principles and the exercise of judgment as to the operating conditions.

The importance of the judicious use of the injector is being realized strongly by railway men. A report of the committee of the Travelling Engineer's Association states that "It would hardly cut any figure how careful an enginedriver might be in the handling of his train, with the skill he uses in regulating speed or in the adjustment of the regulator and the reverse lever, if the water was not put into the boiler at the right time and the right place. In our experience we have known almost remarkable results to be brought about in an engine fuel performance by explaining this matter to enginedrivers who perhaps had not given it the thought that the subject deserves." It was not possible for this committee to give detailed instructions, nor will this now be attempted, but it may be helpful to state the reasons why judgment is required and to outline some general suggestions.

When an injector is working, the steam is taken directly from the boiler itself, causing a temporary fall of the steam gauge, which varies with the volume of the steam space in the boiler and other conditions. This is because each gallon of water fed takes out of the boiler about two cubic feet of steam, while, owing to condensation, only one-sixth of a cubic foot is returned. The heat of the steam is not lost; it is now stored in the feed water, but there has been taken away from it the power to exert pressure on the pistons for pulling the train. Therefore, in order to maintain the same quantity of steam in the boiler and at the same pressure, it is necessary to strengthen the fire and burn enough coal to change sufficient water into steam to make about two cubic feet of steam for each gallon of water fed. This shows that to run the injector it takes a large amount of available power away from the cylinders, and this loss is most severely felt when the boiler is pressed to its full capacity. A No. 9 injector delivers about 3000 gallons per hour, and the steam required to run it may vary from 65 to 120 horse-power, or from 8 to 15 per cent. of the power of the engine, depending upon the pattern of the injector in use; yet it must be clearly understood that although that steam goes back into the boiler as heat in the feed water, the effect produced is a temporary reduction of the pressure and of the pull on the draw-bar, unless the cut-off is lengthened; but this in turn takes more steam from the boiler and further lowers the gauge pressure. It therefore can be easily seen that when and how to use the injector has, an important bearing upon both the fuel comsumption and the running schedule.

As all the heat from the coal, and that stored in the steam, is returned to the boiler, it becomes important to analyse the question a little further. The loss must be due to the varying demands for heat upon the fire -- to the necessity for a heavy fire at one time, with the consequent heavy pall of smoke and the losses due to it, and the thin fire and light draught at other times. To save fuel the fire should be kept as even as possible, and the drain upon the steam supply held as constant as changes of grade will allow, using the injector to check the tendency of the boiler at times to make steam too fast.

It is easy to keep the fire even when feeding with some styles of injectors, while others are noted for pulling down the pressure and making it hard for the fireman. If an injector has a wide range of capacities -- that is, if the feed can be throttled very low without causing the jet to "fly off" it can be used continuously, if the road is reasonably straight and level, with the feed regulated to suit the evaporation of the boiler. But when a hill is in sight, shutting off the injector adds at least ten per cent. to the power available for the pull up the grade. When the summit is reached, starting the injector at full capacity prevents the pop valve rising on the down grade because the boiler is filling with comparatively cold water, which temporarily checks the rapidity with which steam is made; the steam-making power of the boiler may then be used by the injector alone, and an opportunity is given to prepare for the next heavy pull without too strongly checking the fire. If a considerable amount of steam is still needed for the cylinders the injector may be used at half its capacity, when the temperature of the delivery will be nearer that of the steam and the steam making power of the boiler will be less affected. At the minimum capacity the temperature of the feed should be anywhere from 250 to 280 degrees, filling the boiler with water much closer to the steam temperature, so that by careful handling at proper parts of the run and with judicious regulation of the amount of feed and the temperature of the delivery the injector can be utilized not only to keep the boiler full -- which is the primary use of the injector -- but to maintain the full gauge pressure and to keep the pop valve from blowing off, giving a constant temperature to the boiler sheets.

The old prejudice against feeding when the engine is not using steam is now almost entirely overcome, although still partially retained from the time when the cold delivery from the pumps was apt to chill the boiler, due to the water not circulating freely; with the hot feed from the injector there is no danger of this happening. When approaching a stop it is the practice of careful firemen to allow the water to run low, utilizing the heat stored in the water in the boiler to save fuel; when the station is reached both the water level and the fire will need replenishing, and the injector can be started either at full or half capacity, depending upon the length of time the train waits at the station. The train can then be drawn out of the station and full speed reached and the fire adjusted to the new conditions before water is needed, so that both steam and coal are saved. The secret of economy in almost all operations consists in maintaining all conditions constant. With boiler firing it is the frequent change from light to heavy firing caused by extreme variations in the amount of steam used, that is responsible for much of the fuel loss. To obtain the greatest economy and to give the least work to the firemen, keep the feed as cool and the fire as uniform as conditions will permit; when changes must be made, make them as gradual as possible. Also, keep the steam pressure constant, as this reduces the wear and tear on the boiler and lessens the cost of repair.

On long non stop runs the aim of the fireman should, however, be directed to feeding the boiler at such a rate which will ensure that the water level will be kept fairly constant. It should also be carefully noted that the provisions of the last paragraph are not to be confused with the operation of the Exhaust Steam Injector. With this type of injector in use on the locomotive, the method of feeding the boiler is reversed to the extent that in order to secure the maximum of economy, this injector should as far as is possible, only be used when the locomotive is working so that the fullest advantage and use can be made of the exhaust steam to replenish the boiler feed water.

HOT WATER INJECTOR:

This portion of the lesson will be devoted to a description of the construction, operation and some information on the general maintenance of the Davies & Metcalfe type of Hot Water Injectors which are installed on our "K", "Ka", "Kb", "G" and "Ja" class locomotives.

It was explained in Lesson No. 1 that the above class of locomotives were fitted with two injectors, the one on the left hand side being an exhaust injector, whilst on the right hand side the injector was a live steam injector of the non-lifting type. Both injectors being operated from the fireman's side of the locomotive cab.

Apart from the fact that the Davies & Metcalfe Hot Water Injectors have long been universally recognised as the simplest and one of the most efficient methods of boiler feeding, the increasing size of the modern locomotive boilers with their resultant greater water capacity, necessitated the provision of an injector of a much wider capacity range than was possible by the otherwise very reliable Sellers injector. Consequently our larger class of locomotive are now amply provided for in regard to the boiler feeding capacity by the two types of injectors now installed.

The Metcalfe Hot Water Injector has been specially designed to operate successfully under the severest conditions of hot feed water and high boiler pressures, it being guaranteed to work with the feed water as high as 140 degrees Fah. and with boiler pressure up to 250 lbs. per square inch, and under these conditions it is entirely automatic and re-starting in action so that no special attention is necessary, beyond the inital opening of the steam and water valves.

POWER:

This type of injector is much more powerful than the ordinary live steam injector, giving a greater excess of delivery pressure over the steam pressure, It can, therefore, be relied upon for all working conditions. In addition the injector will continue working without waste at the overflow even when the cones are considerably worn.

CONSTRUCTION OF THE HOT WATER INJECTOR:

The working parts consist of the usual cones, viz., the steam cone, the draft tube, combining cone and delivery cone.

THE STEAM CONE is of the solid jet type screwed into the injector body. THE COMBINING CHAMBER of the injector, is divided into two separate portions, known as the first and second overflow chambers, each fitted with a separate overflow valve (auxiliary overflow valve No.22 Fig. 2). The first overflow chamber contains the draft tube, and between this tube and the upper end of the combining cone there is a gap or slot. This overflow chamber is fitted with a valve of the ordinary drop non-return type, which opens freely to allow any steam or water to escape to the overflow pipe, but which when closed, seals the overflow chamber, so preventing any admission of air.

THE SECOND OR MAIN OVERFLOW CHAMBER; contains the combining cone and is fitted with a patent pressure controlled overflow valve. The combining cone is constructed on the flap nozzle system, in which the combining cone is split longitudinally at its middle section for a portion of its length and hinged so as to swing open freely and so afford a free exit for the water and steam. The opening of this flap ensures the prompt starting and automatic working of the injector.

WHEN STEAM AND WATER are turned on into the injector, the flap opens and the mixture of steam and water passes freely into the overflow. When condensation takes place and the jet is established, a vacuum is created in the combining cone; the flap falls and closing the escape to the overflow chamber, forms a solid wall cone, supporting throughout its length a continuous and steady jet. If the jet is at any time broken, then the pressure of steam opens the flap, steam and water escape freely until a vacuum is again formed and the continuity of the jet re-established. By this method the prompt starting and perfect automatic action of the injector is ensured.

THE TEMPERATURE OF THE DELIVERY WATER in an injector varies with the initial temperature of feed water, so that in a "hot water" injector using hot feed water, the delivery temperature may be considerably higher than boiling point, (212 deg. Fah.) e.g., with feed water at 140 deg. Fah., the delivery temperature may be 260 deg. Fah. With these high temperatures a corresponding pressure is found in the main overflow chamber, so that a closed overflow is imperative, otherwise the jet would expand and waste into the overflow.

Any system of hand-locking the overflow is too dangerous, as the injector would then require constant attention and very careful handling and if the jet should break from any cause, the steam would be unable to escape to the overflow and would blow back into the water tank and if not noticed, the feed water would become too hot for the injector. An automatic self-acting overflow valve is therefore a necessity.

This is illustrated in fig. 3 and consists of the overflow valve "V" which seals the main overflow chamber, and the small piston "P" which is fitted into the delivery chamber of the injector. The piston is coupled to a lever "L" pivoted to a fulcrum on the injector casing, the other end of the lever bearing against the upper stem of the overflow valve "V".

WHEN THE INJECTOR IS WORKING the delivery pressure under the piston "P" acting through the lever "L", holds the overflow valve on its seat, thus sealing the overflow chamber.

If the injector breaks off from any cause, the delivery pressure under piston "P", is reduced and the valve "V" opens. It thus allows the steam and water to escape into the overflow until the injector re-starts; the delivery pressure then increases and acting under piston "P", again closes the overflow valve. This is a safe and positive method; no steam is blown back into the feed tank and the action being perfectly automatic, the injector requires no attention.

A further feature of the injector is the supplementary water passage connecting the water supply inlet pipe with the first overflow chamber.

It is found that at the gap in the part of the combining nozzle in the first overflow chamber a high vacuum is formed, and this is utilised to draw in an additional supply of water, so increasing the capacity of the injector. A non-return valve (Supplementary valve No 13) is fitted into the passage to prevent any steam blowing back into the water pipe when starting.

The injector is construced of gun-metal throughout and is of the self-contained type, being fitted with water cock delivery check valve, fixing brackets and flanged pipe connections. All cones are fitted with screwed bearings and can be removed for cleaning or renewal without breaking any pipe joints or taking down the injector.

WORKING OF THE INJECTOR:

When the water and steam are turned on into the injector the steam flows through the steam cone into the combining cone. Part of the steam escapes through the gap between the draft tube and the combining cone and so into the first overflow chamber, thence through the auxiliary overflow valve into the overflow pipe and so to the atmosphere. The flow of steam from the steam nozzle into the combining cone entrains with it a supply of water from the water chamber. Intermediate mixing of steam and water takes place, the steam being condensed and the mixture of steam and water enters the combining cone. As condensation takes place the jet becomes established and passes down the cone and as the bore decreases so the density of the jet and its velocity increase until it reaches the end of the combining cone. The jet then passes across the overflow gap into the delivery cone, attaining its maximum velocity at the entrance or throat of this cone. Passing along the delivery cone the velocity decreases as the bore of the cone increases, so the kinetic energy of the jet is changed into pressure energy, which increases and travels along the cone until at the end its pressure is higher than the boiler pressure.

AT THE INLET END of the combining cone, as soon as the jet is established a vacuum is formed, due to the condensation of the steam, and this vacuum is effective in the primary overflow chamber, through the gap or slot in the combining cone. The auxiliary air valve on this chamber is consequently kept closed by the external atmospheric pressure.

During working the overflow valve of the main or second overflow chamber is kept on its seating, being, as previously explained, controlled by the delivery pressure of the injector.

The injector will therefore work without wasting at the overflow even if there is considerablg pressure in the overflow chamber, which occurs when the temperature of the jet exceeds 212 deg. Fah.

ADVANTAGES:

The following are some of the advantages of the Hot Water Injector :-

(1) It will work with the feed water at any temperature up to 14o deg. Fah., and delivers the water into the boiler at a temperature of 260 deg. Fah.

(2) It is perfectly automatic and re-starting.

(3) Requires no regulation of steam and water once the water valve is set for the usual working pressure.

(4) It will work from as low as 30 lb per square inch boiler pressure.

(5) It will start promptly on opening the steam valve.

As indicated previously, the hot water injector is a non-lifting injector as is consequently fitted below the level of the water tank supply to permit of gravity flow.

GENERAL INSTRUCTIONS:

TO WORK THE INJECTOR:

(1) Open the water cock.

(2) Open the steam valve.

The injector shoudl immediately start to work and the only regulation necessary is the regulation of the feed water to suit the demands of the boiler.

MAINTENANCE:

The most frequent causes of injector failure are:-

(1) Dirt or scale deposit in the cones or valves.

(2) Leaky joints.

The injectors should be examined at regular intervals, when the cones should be taken out and cleaned and the valves examined, and if necessary, booked for re-grinding.

When replacing the cones, care should be taken that all joints faces are clean and that the cones are screwed firmly into the seatings so as to secure a tight joint.

JOINTS:

All joints and connections should be examined for leakages, especially on the suction side, so as to prevent air leakage into the injector. Special attention should be given to the feed water pipe from injector to tender.

THE STRAINER:

The feed water strainer in the tender should be examined and cleaned at frequent intervals depending on the condition of the supply water.

The attached sectional view of the injector will enable students to trace the names of the various parts referred to in the lesson.

EXHAUST STEAM INJECTORS: CLASS "J"

The latest New Zealand built locomotives, the "Ja" class are now coming into regular service in the South Island and amongst other features, they have been fitted with an improved type of exhaust steam injector, known as the Davies and Metcalf class "J". The earlier model of the exhaust steam injector fitted to mainly the "K", "J" "Wab", "G" and many of the "Ab" class locomotives is designated by the symbol "H".

In the North Island, the "Ka" class locomotives which were fitted with the A.C.F.I. Feed Water Heater in addition to a live steam injector, are now having the former type of injector removed as they pass through the Workshops, and in some instances the newer type of "J" class exhaust steam injector is being installed as a replacement.

The purpose of this lesson is to give students an outline of the principal differences in construction and operation of the "J" type of exhaust injector as against the older "H" class.

The class "J" Exhaust Steam Injector represents a considerable improvement on the "H" type in that the automatic control system has been much simplified and the injector is now operated in a similar manner to an ordinary non-lifting live steam injector.

Two operations are necessary to start the injector, namely, the opening of the combined water regulator valve and the injector steam valve. The only other manipulation necessary is the adjustment, when required, to running conditions of the water regulator to vary the quantity of feed water supplied to the boiler. Compared with the previous type of exhaust steam injector, the main feature of the latest development is a far reaching simplification in design without eliminating any of the advantages of the "H" type and the addition of the automatic choke which improves the feeding at very low boiler pressures, an important feature when lighting up in the running shed. It should be noted that unlike its predecessor, the class "H" injector, which has an automatic water valve controlled by live steam from the boiler, the Class "J" injector has a manually operated water valve of the disc pattern combined in the water regulator.

The main features of the "J" class exhaust injector may be summarised as follows:-

(1) The flap valves as used on the exhaust side of the model "H" type injector are replaced on the "J" type injector by a double beat balanced valve and a simplified operating valve.

(2) The moving parts of the model "H" type injector in the automatic water valve are replaced in the model "J" by a manual disc valve which is on the same spindle as the adjustable cone. (exhaust steam cone)

(3) On the model "H" type of injector, the fixed size of choke for auxiliary steam (replacing exhaust steam) when working with locomotive standing, has been replaced on the model "J" by an automatic variable choke, which increases the auxiliary steam

supply if boiler pressure is low, thus improving the injector performance at low pressure.

ECONOMY IN USE OF INJECTORS

A considerable fuel saving can be effected through the judicious use of the injector while on the road. On level tracks the injector should be adjusted in such a way that it can be kept on continuously, but in undulating country it should be used as much as possible while drifting on a down grade and the working while ascending grades restricted to the limit necessary for the maintenance of a safe water-level. The injector should not be used when starting a train, and firing should also be avoided until the train is well under way. In all cases firemen should endeavour to keep the demands made on the boiler as uniform as possible.

Several modifications in boiler-feeding have been introduced since the Sellars injectors were adopted, and changes have also been made to the installations to suit the convenience of locomotive crews. Exhaust-steam injectors and feed-water heaters using exhaust steam for heating have been brought into operation extensively, and on some classes fitted with such equipment the live-steam injectors have been moved across to the Fireman's side of the cab to provide additional flexibility.

It is the duty of the staff concerned when operating locomotives fitted with exhaust-steam injectors or feed-water heaters to use this equipment fr the purpose for which it is intended, and to resort to the use of the live-steam injector only in circumstances that render the use of the former devices uneconomical or when such equipment is defective.

Generally speaking, it should be necessary to use the live-steam injector only when the locomotive is drifting or standing, and even though both types may be located on the same side of the cab, Firemen should make every effort to become proficient in the handling of the exhaust-steam-operated units, so that all running may be carried out in the most economical manner possible.