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Chairman —Mr. A. H. Nash.

" INJECTORS AND FEED PUMPS FOR LOCOMOTIVES, "

BY

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(With Discussion.)

When Giffard, a French Engineer, invented the injector in 1858, the idea was treated with derision by the great majority of engineers, as the principles involved seemed to be an apparent contradiction of known principles. Giffard' s injector remains, however, almost identical in the proportions of the body and tubes as it was originally designed, showing how complete was his knowledge of the principles of the injector and how careful were his experiments.

There are two theories as to how an injector works, the generally accepted theory being that the velocity of the steam being so much greater than the velocity of water when they are the same pressure, is sufficient to force the induced supply of water against the pressure of water in the boiler, or the issuing velocity of the water under pressure in the boiler.

We know, for example, that if a glass tube with a closed end is filled with mercury, and then inverted in a bath of mercury, the atmospheric pressure on the bath of mercury is sufficient to support a column of mercury about 30 inches high ; but if water is used instead of mercury, the column will be about 34 feet high, owing to the greater density of the mercury, showing that the greater the density of the liquid or gas the shorter will be the column supported by atmospheric pressure ; and, conversely, the lighter the liquid or gas the longer the column supported. There will, then, be a considerable difference between water and steam.

To illustrate this : Suppose a **U** tube with a bib cock at the bottom of the **U**, and a similar cock to each arm of the **U** is taken, one arm to be about 30ins. long and the other about 34ft. (Fig 1), and in the short arm is poured 30″ of mercury, and in the other 34 feet of water, then the pressure will be the same on each side of the centre cock ; but if the cock for the long arm is opened the water will be found to issue at (four times) a greater velocity than the mercury will issue at the other cock, because the water will fall from a height of about 34 feet, whereas the mercury only falls 30 inches ; as $V^2 = 2gs$, or the square of the velocity varies as the height of a falling body).

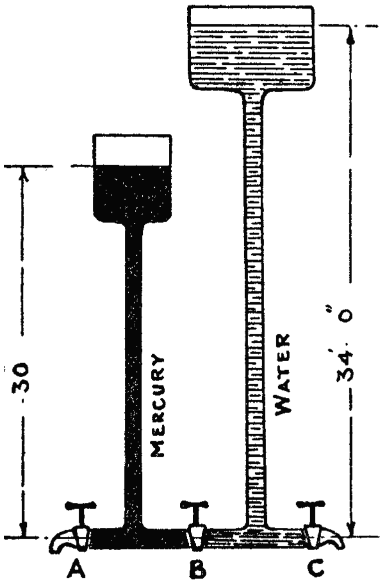

FIG. 1.

It will therefore be readily seen that the velocity with which a fluid or gas issues from a vessel is greater for a given pressure the lighter the fluid or gas. The velocities with which water and steam are discharged from the water and steam spaces respectively of a boiler are about in the ratio 1 : 25.

TABLE 1.

Press, lbs. per sq. in.	Velocities in ft. per sec. Steam.	Water.	Ratio of V Water to Steam.
15	1400	46	1 : 30
30	1950	66	1 : 29
60	2400	94	1 : 25
90	2650	115	1 : 23
120	2850	133	1 : 21

The velocity of steam at even low pressures is very great, and even when combined with the feed water the reduced velocity of the jet issuing from the combining tube is much greater than the velocity of a jet of water from the boiler would be; moreover, the velocities quoted

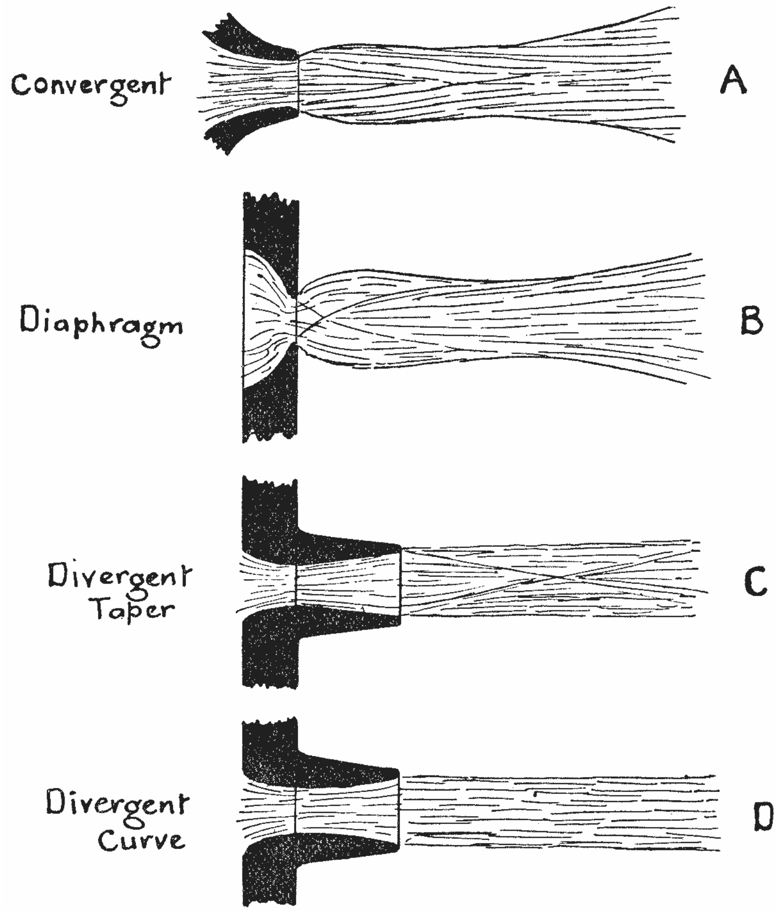

Fig. 2.

are for jets discharging into the atmosphere, and in an injector the velocity of the steam jet would be higher because of the vacuum formed between the steam cone and combining tube.

The second theory, and one which is accepted by several of the principal injector makers, is that the action of an injector can be likened to the action of a steam pump, the forcing of water being dependent on the excess of total pressure in the steam tube, due to the greater area of the steam nozzle opposing the flow of water from the delivery nozzle ; and they point out that if the velocity theory is correct injectors could be made with the diameters of the steam and delivery nozzles the same, whereas an injector requires the area of steam nozzle to be in excess of the area of the delivery nozzle to work properly.

A simple injector consists of a steam cone, combining tube and delivery nozzle.

The steam nozzle was originally a gradually tapering convergent tube, but in its final development it is a divergent tube of the form shewn in Fig. 2 (D). The advantage of this latter form of nozzle was discovered by Schau, an early injector maker of Vienna, and with this form of nozzle the velocity attained by the jet is much greater than the original form of nozzle for the same weight of steam. The jet from the first nozzle spreads laterally as shewn in Fig. 2 (A), and part of its energy is thus diffused, but the velocity of the jet shewn in Fig. 2 (D) is concentrated in parallel lines of direction.

The combining tube is a gradually convergent taper nozzle, and between it and the steam cone is a gap communicating with the water supply. The steam issuing from the steam cone strikes the water, and is condensed, and at the same time imparts a large proportion of its velocity to the water, and the mixed condensed steam and water issues from the combining tube as a solid rod of water.

The steam is not condensed immediately on meeting the water, so the wall of the combining tube decreases as the volume decreases. It is the design of this tube which largely affects the efficiency of the injector, and this tube varies for the different types of injectors.

The delivery nozzle is a divergent taper tube, and its function is to gradually reduce the velocity of the jet and convert it to pressure. The diverging walls of the tube allow the jet to increase in area at the expense of its velocity. There is no loss of energy (except the slight amount expended in friction), the nature only of the energy is altered.

This action on the part of the delivery nozzle can be likened to the conversion of the energy of momentum of a hammer driving in a nail, the momentum of the hammer being converted into pressure on the nail immediately it strikes the nail head.

There are numerous types of injectors, and they can be roughly divided into the following classes : –Single set of tubes, Double ditto, Adjustable and self-adjusting tubes, Fixed tubes, Open overflow, Closed overflow ; and these can be again sub-divided into : Re-starting, Automatic, Non-lifting and Lifting.

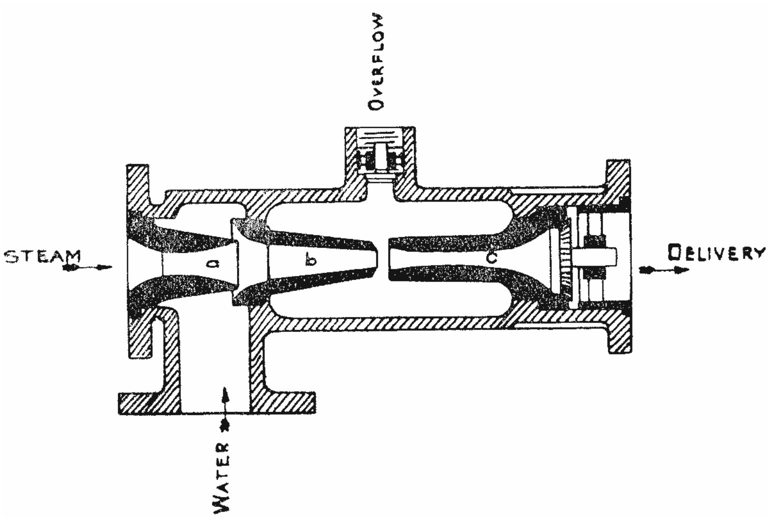

FIG. 3.

For locomotive purposes it is essential that the injectors should give the minimum amount of trouble to the men working the engine; that is, they must supply water to the boiler regularly, and not be seriously affected by variations in pressure, or " fly off, " at every little unevenness of the road.

The Giffard injector was used for many years on locomotives, and is still used on many stationary boilers, and is of the open overflow, adjustable type, but as it had to be adjusted for variations of steam pressure, and was apt to fly off when the locomotive lurched or jolted ; and, in addition, the adjustable portion was found difficult to keep packed properly, it was superseded by a fixed tube injector of the type which is fitted to many of the G.W.R. engines of the older class even to-day ; but they are both being replaced by an injector that will automatically re-start when the working has been checked.

Several methods are adopted to attain this desirable feature, but they all amount to the same thing, and that is, the provision somewhere in the combining tube of a free discharge of the steam and air, the area of such discharge being greater than that of the steam nozzle.

Different makers have adopted different ways of doing this. Messrs. Davies and Metcalfe split the cone of the combining tube, and hinge

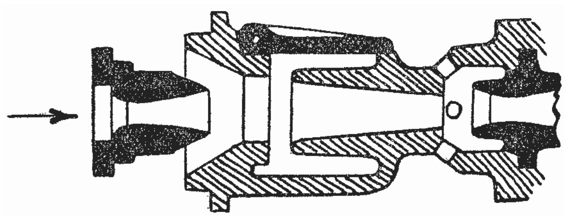

FIG. 4.

the one part to the other. This method is used on the injectors made by the Great Western Railway. When steam is admitted to one of these injectors, the flap is moved outwards or upwards, depending whether the injector is fixed vertically or horizontally, and the area of the combining tube is thus considerably increased. As soon as the water is lifted, and the steam condensed, and the jet formed, the flap falls on its seating, and the injector forces the water into the boiler.

A variation of the flap nozzle is the divided combining cone with a flap valve controlling the overflow from the " spill. " (Fig. 4.)

Messrs. Gresham and Craven have another arrangement in which the combining cone is divided, with one part made moveable in a vertical direction. When the steam is turned on, the steam and air pass the gap in the two parts of the combining cone, and when the steam is condensed the vacuum formed draws the lower portion of the cone up to the other portion.

The same result is attained in the majority of American and Continental injectors by dividing the combining cone by a number of transverse slots or spill ways, the area of which is greater than the area of the steam cones.

Practically all modern injectors are provided with non-return valves at the overflow, and in the case of re-starting injectors at the supplementary overflows or spill way passages, which assist in the starting action, and in the maintenance of an unbroken jet, and it also to some extent increases the delivery, as it prevents the induction of air, with the accompanying noise.

In both the Simplex and Monitor Injectors there is a supplementary nozzle for lifting the water. If the injector is to lift its feed water it must exhaust the water pipe and chamber at the beginning of the combining cone of air. To do this the steam nozzle must be capable of being adjusted, or a supplementary nozzle must be provided to act as an ejector. A reference to Fig. 5 will illustrate this.)

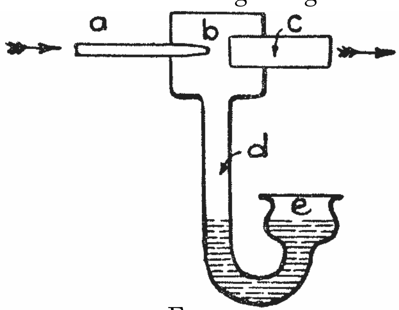

Fig. 5.

By blowing through the pipe marked (*a*) the liquid from the vessel (*e*) will rise in the pipe (*d*), shewing that a partial vacuum is created in (*b*). If (*c*) is blown through instead of (*a*) the water level in (*d*) falls, shewing that there is a pressure in (*d*).

In the first instance, the small jet of air discharged from (a) mixes ; with the air in (*b*) and ejects it through (*c*) and creates a partial vacuum in (*d)*, and the atmospheric pressure acting on the liquid in (*e*) forces it up the pipe (*d)*. In the second case, the larger tube (*c*) passes more air into (*b*) than (*d*) can discharge, and pressure is set up in (*b*).

In an injector the minimum diameter of the combining tube is less than the diameter of the steam cone, so that unless the area of the steam cone is reduced pressure is formed in the water chamber instead of a vacuum.

Giffard reduced the area of the steam cone by inserting a spindle, which was only slightly withdrawn until water came from the overflow of the injector, but it was then fully withdrawn from the cone. This was improved upon by other makers by drilling a small hole up the spindle and another across the spindle, which made the end of the spindle a small steam jet to act as an injector to lift the water.

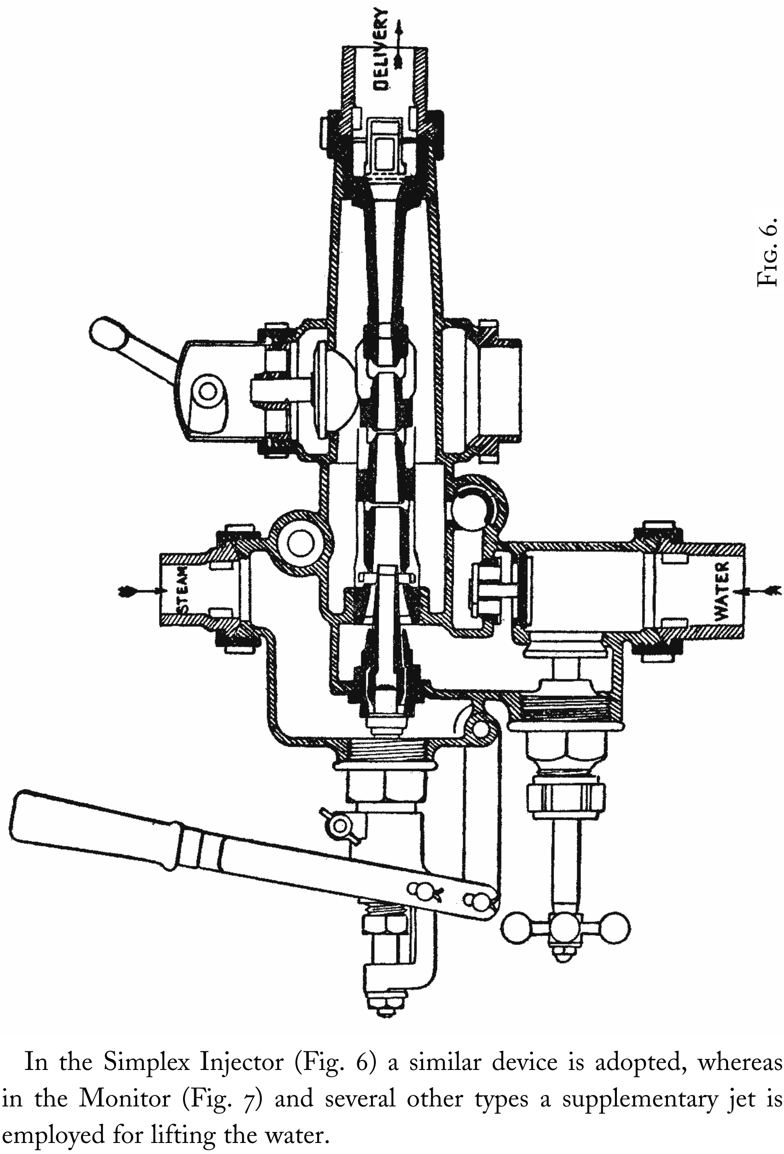

Fig. 6.

In the Simplex Injector (Fig. 6) a similar device is adopted, whereas in the Monitor (Fig. 7) and several other types a supplementary jet is employed for lifting the water.

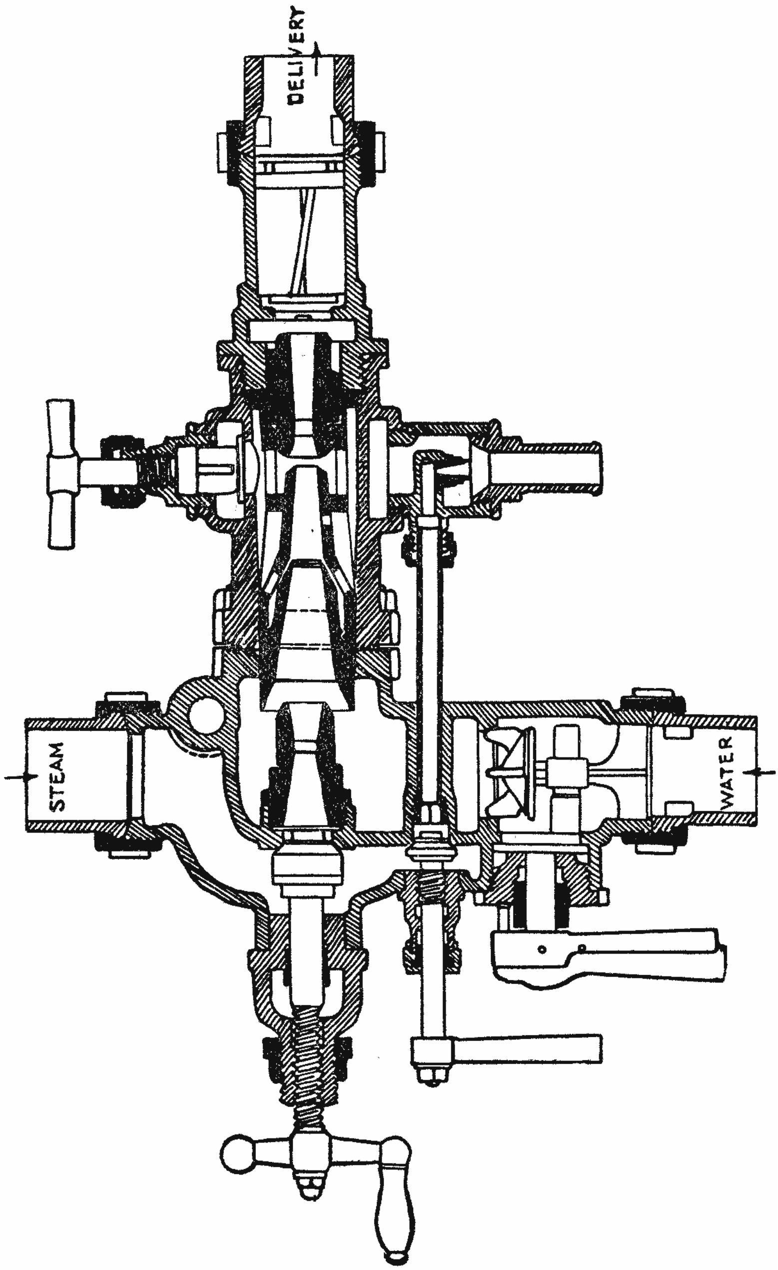

FIG. 7.

The spill combining tube and the divided combining cone of the Davies and Metcalfe with the valve for the passage increases the area of the combining cone, so that these injectors also act as lifting injectors to a certain extent without any mechanical adjustment.

Hot Water Injectors. – On locomotives it is a great convenience sometimes to be able to turn steam back into the tank to save it from being wasted at the safety valve, particularly when the engine is standing waiting for a return train, but if steam is turned into the tank the feed water will get so hot that difficulty will be experienced with the usual type of injectors. If, however, hot water injectors are fitted to the engine, they will feed the water at a much higher temperature than the ordinary type of injector. An injector will not lift the water properly if it is hot, because the action of lifting creates a partial vacuum above the water; that is, it reduces the pressure, and steam would be given off and the vacuum destroyed. The injector should, therefore, be fixed below the bottom of the tank to get the best results when supplied with hot water. With a boiler pressure of 100 lbs. it has been found by experiment that with the feed water at 80° F there is a diminution of delivery for 5ft lift of 8 per cent. and for 10ft, of 14 per cent. ; and it has also been found that with a boiler pressure of 15 lbs. per sq. in. the quantity of water delivered per lb. of steam is 30 lbs., but at 200 lbs. pressure the quantity is only 10 lbs. The temperature of the feed water can therefore be higher the lower the steam pressure, as the weight or water for effecting condensation in the combining tube will be greater. The critical temperature being about 150° F at 35 lbs. per sq. in., 120° F at 100 lbs., and 80° F at 250 lbs. pressure.

If the injector has to lift the water a certain height, the atmospheric pressure has to balance the column of water, and the effective pressure for forcing the water into the injector is the difference between the absolute pressure in the combining cone and the atmospheric pressure, minus the weight of the column of water to be lifted. This fall in the effective pressure could be compensated for by increasing the inlet area of the combining tube, but the area would require adjusting for every variation in the steam pressure, and an injector so constructed would be less affected by high temperatures of the feed water, and its lifting capacity would not fall off to anything like the extent it does with the fixed type of injector.

The fixed tube type of injector if designed with the inlet area sufficiently large to take enough water at the higher pressures will work without regulation for increasing pressures up to a certain point, but it will only deliver the maximum amount of water per lb. of steam at one particular pressure.

An injector therefore to work with hot feed water must be designed so that the feed is supplied to the injector under pressure if possible, and the area of the water space must be of sufficient size to take enough water at the higher pressures to condense the weight of steam passing through the steam cone, and as this varies as the steam pressure varies the injector should be adjustable.

Messrs Holden and Brooke have designed an injector which ingeniously meets most of these requirements.

Means are provided by which the inlet area to the combining tube and the area of the steam nozzle are simultaneously varied.

The minimum area of the delivery nozzle is constant, so that a rise in the steam pressure should be met by a diminution of the steam cone orifice.

As the steam pressure increases a greater weight of steam is passed, with the result that the vacuum in the combining tube falls and less water enters the annular space per lb. of steam discharged, so that this injector can be adjusted by turning the handle which for high pressures reduces the area of the steam cone and increases the area of the water passage and reverses the action for lower pressures.

But it is an exceedingly good single tube injector which will take feed water at 125° F, with the steam pressure 100 lbs. per sq. in. or 96° F at 200 lbs. per sq. in. Compound injectors will however deal with much higher temperatures. The detrimental effect of high temperature feed water on an injector can be counterbalanced to some extent if the feed water is supplied under pressure. This pressure may be obtained by means of an auxiliary injector, but the two injectors are usually combined in the one casing.

The general arrangement of most types of compound injectors is shown diagramatically in Fig. 8.

If the lower or lifting injector delivers the water to the upper cones at about 30 lbs. per sq. in. we know that the proportion of water to steam is high, and that a good vacuum will be produced in the first combining tube, and the higher limit of temperature of feed water can be raised.

During its passage through the second or upper set of tubes the temperature may be higher than 212° F, but as it is at a pressure of 30 lbs. per sq. in., at which pressure the boiling point is 274° F, the second steam jet is completely condensed. The final temperature of the jet necessitates a closed overflow, otherwise part of the jet would burst into steam and discharge into the atmosphere.

These injectors are usually operated by a single movement, the over-

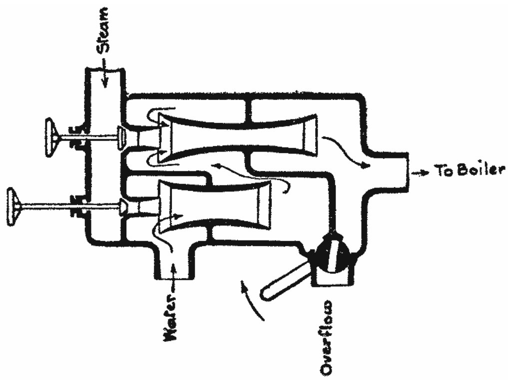

Fig. 8.

flow cock being coupled to the steam valves in such a way that there is no adjustment required, the movements syncronising.

An apparatus of this kind is self regulating under varying steam pressures. If the steam pressure rises the capacity of the lifting jet increases and vice versa.

The permissible temperature of the feed water is at least 45° F higher than the single tube injectors will take. That is, at 200 lbs. pressure per sq. in. they will take feed water at about 140° F instead of 90° F.

Some of the American injectors are arranged with the lifting steam jet cone surrounding the forcing jet cone, and although not so efficient as the double tube type, they are more economical in steam consumption. At 100 lbs. pressure they will take feed water at 126° F with automatic overflow, and at 140° F with locked overflow.

It will be remembered that the velocity of steam at even low pressures is very high. At 15 lbs. per sq. in. it is about 1,400 ft. per sec., which is considerably higher than water at say 90 lbs per sq. in. ; and advantage has been taken of this fact by one or two makers, who have made a compound injector for using part of the exhaust steam from the engine by using an injector with large passages and tubes to heat the water and supply it to the supplementary injector under pressure, and at a higher temperature than it could otherwise take, and the supplementary injector is arranged to have a locked overflow when the jet is formed to prevent the jet from having communication with the atmosphere.

The advantages of injectors that can supply the water to the boilers at high temperatures are obvious, but the advantages are even greater for locomotive purposes, as they work under such varying conditions of load and forced draught that the hotter the feed the less the disturbance, not only to the engine steam supply but to the tubes and stays and other parts of the boiler itself.

Professor Perry remarks in his book on the " Steam Engine " that he anticipates that by making the steam nozzle telescopic, so that more and more steam enters as the water quickens in speed, the injector will be greatly increased in efficiency. And although the steam nozzle has not been made telescopic, Messrs. Davies and Metcalfe produced an exhaust injector with an auxiliary steam passage, which is giving exceptional results, working with about 3 lbs. of steam pressure into a boiler with 160 lbs. pressure.

The G.W.R, have practically dispensed with pumps for feeding locomotive boilers, but the type that was used in the Metropolitan class engines, and the 7′ 8″ single wheel engines consisted of a barrel with suction and delivery valves (large ball clacks), and a ram which was connected to the crosshead.

In operating it was necessary to be careful in opening the water valve, which was usually opened with a screw, otherwise there was a tendency to get a water hammer in the delivery pipe, and these pipes fairly frequently broke off under the flange.

When the motion blocks became worn a bending action was set up at the end of the ram, which eventually caused the end to break off.

An injector was usually fitted as well to feed the boiler when the engine was standing, otherwise it was necessary to run the engine up and down a siding to put water in the boiler, or if a single wheel engine the rail was greased the tender brake screwed on, and the wheels made to slip.

The Metropolitan class was fitted with pumps, as the steam was condensed in the tanks when the engine worked in the tunnel, and this heated the water considerably ; but there was a considerable amount of slip, due to the head of water from the tanks being none too great, and the pump not flooding sufficiently rapidly to avoid the partial vacuum formed by the pump on the suction stroke, and steam being liberated from the water. With a tender engine this defect was greater if the steam was turned into the tank because there was even less head of water. The best results were obtained with pumps of this class when the pumps were of good size, and with as short a lift as possible to the delivery clack, about $\frac{3}{16}''$ being ample.

On the L. & S.W.Rly. Mr. Drummond has fitted to his 4-6-0 four cylinder engines a set of duplex pumps something like Worthington or Tangye pumps, and he has a feed water heater in the tender tank. These pumps are fixed vertically to the expansion stay between the frames in front of the firebox, with the pumps at the bottom. The water supply is heated with steam from the exhaust of the engine, Mr. Drummond having designed a pipe arrangement in the tender to act as a feed water heater. This combination is the latest attempt to arrange a feed pump to give the same service as an exhaust injector.

In " The Practice and Theory of the Injector," a book by an American Engineer, Strickland L, Kneass, is given a comparison in the efficiency of an injector and a direct-acting steam pump, and he shows the saving of coal when the boiler is fed by an injector is 1·3 per cent, over the steam pump, and states that this corresponds to the heat wasted by the exhaust steam from the pump, which is returned to the boiler by the injector. It is very necessary, however, to see that the injector is working efficiently. Heating the feed water is beneficial, but it should not be with live steam from the boiler if it can be avoided.

The work that locomotives are called upon to do at the present time demands every ounce of steam that the boiler will generate, and it frequently happens that the cold water injector can only be put on when running down hill, or when stopped by signals, or at a station.

The actual amount of steam required by an injector when feeding a boiler is considerable. An evaporation of 2,500 gallons of water per hour requires for some injectors 2,300lbs of steam, which, at 35lbs. per H.P., amounts to 65 H P. If the injector were used more efficiently this could be reduced to probably 45 H.P., and the temperature of the water entering the boiler would be 25 per cent lower. It is therefore necessary that the smallest weight of steam that can possibly be used to perform the work should be used to attain the most economical results. A larger steam jet means that a proportion of the steam is being used as a feed water heater. That is why the exhaust steam injector is so efficient. The advantage of hot feed water is obtained, which will not of course reduce the boiler pressure so rapidly, without using the live steam to do it, and it is possible to keep the injector on continuously, and maintain a constant water level in the boiler, without materially affecting the steaming of the engine.

In conclusion, then, the engineer has to carefully consider the advantages and disadvantages of injectors and feed pumps when deciding the type to use.

Injectors occupy less space. They can be obtained quite as efficient. The cost of maintenance should be less, as there is no oiling, and practically no packing required. It is cheaper for renewals, because a set of cones can be changed, making the injector as good as new, or in emergencies the injector can be changed in a very short time ; but the repairs to a pump, or the changing, would be much more expensive.

If the water supply is hard the pump would, no doubt, give less trouble if the feed water is not heated, but the boiler would give proportionately more trouble owing to the greater difference in temperature of the feed water and the boiler temperature ; and if a feed water heater is used with hard water the lime deposits in the feed water heater will give much more trouble than the lime deposits in an injector would, owing to the ease with which the cones can be changed.

The most efficient arrangement is undoubtedly an exhaust steam injector with an auxiliary injector that will take feed water at a comparatively high temperature, or, as an alternative, two compound injectors, although the Author believes the compound injectors are not so economical of steam as the first arrangement.

DISCUSSION.

The Chairman said they would all agree that the paper had been a very interesting one. With regard to the exhaust injector and the split nozzles, it was the practice at Swindon to carefully bed down the portions of the flat joint—he referred to the horizontal joint. Was this really necessary ? He had heard of some experiments being made wherein a series of holes were bored at right angles to the cone, and these did not affect the working of the injector at all. Was this borne out in practice ?

There were certainly some strong points in favour of the one movement injector. It appeared to him necessary to arrange some sort of independent adjustment between the water and steam openings, as the one handle performed every operation. He thought some means should be provided for varying the relative positions of the steam and water cones.

With regard to pumps, he thought it was rather necessary to have some fine regulating device to ensure a regular quantity of water being pumped into the boiler, owing to the irregular falling in the gauge glass.

Mr. Drummond claimed to reduce, the coal consumption from 32lbs. to 25·7, effecting a saving of 6·3lbs. of coal per mile over the injector. The figures seemed hardly credible. He also pointed out that in that particular design, with the use of a feed water heater in the smokebox as well as one in the tender, it was possible to get water into the boiler at 350 degrees F. This figure appeared to be rather high.

The Author, replying to Mr. Nash *re* bedding down of the split cone, said he had seen the internal cones of injectors with $\frac{1}{32}''$ of lime deposit on the joint, yet the injectors had worked. It seemed to him that to get an efficient, working injector, it was necessary to keep the cone absolutely in line, and a hole drilled at right angles to the face of the cone would have a much better effect than if the cone were drilled out of centre, as only spill ways would be formed.

The Americans used the one movement injector. They claimed by having a projection on the steam valve it was possible to regulate the valve to a nicety, and the water regulated itself by means of the supplementary valve communicating with the opening in the top chamber.

He thought the saving of coal on the South Western engines fitted with feed pumps was largely due to light loads. It is doubtful if the Salisbury engines could work as low as that.

It was obvious that the exhaust steam of the steam pump was wasted, so that there was a certain amount of steam being wasted from the boiler. This steam in an exhaust steam injector was saved, because live steam was used for driving the pump, and the live steam used for the injector was being put back in the boiler.

Mr. R. H. Smith asked, if the velocity was the principal cause of the injector working, why would the injector not work unless it had an overflow pipe ? If such were the case, the overflow could be dispensed with and the water saved. He took it that atmospheric pressure was acting as well. The velocity would create a vacuum, and the atmospheric pressure would help to carry the water into the boiler. The Gresham and Craven injector gave very little trouble, and both the water regulator and steam valve were very easily worked. He was afraid insufficient attention was paid to exhaust injectors. With proper attention there was nothing to equal them for loco. purposes.

The Author, replying to Mr. Smith, said that until the steam had condensed and imparted its velocity to the water, something had to be done with the water, condensed steam, and air, so that the overflow pipe was necessary. Of course after a jet had been formed the overflow pipe could be closed. The Gresham and Craven injector was well made, and was placed conveniently for examining and adjusting. The G.W.R. injectors were not easily accessible, as the axles and brake gear were in the way. The maintenance of injectors by the Running Department was better now than it had ever been. At many of the principal engine sheds 10% Muriatic Acid was kept, by means of which the scale was removed without damaging the cones. Before that rimers were employed, and the round end of a file was frequently used to take the lime off.

Mr. J. W. D. Clinch mentioned that in the factory two Davies and Metcalf's exhaust steam injectors of an improved pattern had of late been installed at the Central Power Station. It was possible to work these injectors under the conditions existing there, without the aid of any live steam. The pressure of the boilers fed by these injectors was 165lbs. Feed water was obtained from a tank some distance away, using softened water, and giving a head of from 20 to 30 feet, while the exhaust steam came from two air-compressing engines close to Central Power Station. No undue back pressure was put on these engines, as the pressure of exhaust steam entering injectors was insufficient to move a gauge, and its temperature was just about 212°. These injectors were fitted with a bye pass, which enabled a portion of the exhaust steam which did not go into combining cone, to travel round and enter a second cone, and thereby impart increased velocity to water entering boiler. In ordinary conditions without a head of water, these injectors used a very small quantity of live steam.

Mr. C. C. Champeney referred to the Chairman' s remark that the South Western Railway had, by using a feed pump and feed water heated, effected a saving of 6·3lbs. of coal per mile. From observations he had made when taking trips on engines, the exhaust injector was superior to the restarting injector, the use of the former resulting in a large saving of fuel and water. He doubted whether such good results could be obtained by the use of the steam pump. He thought that the pump had an advantage over the injector in the matter of sediment produced in the boiler. When feeding the boiler with the injector, the water, on just entering, had a very high velocity, and on being stopped, heat was generated, and this favoured the production of deposit. He believed Herr Golsdorf had put a chamber just over the clack, which would be cleaned out. The greatest deposit took place near the clack, hence the chamber. Since the introduction of this device, boilers which were previously washed out every eight days, only required washing out about every fourteen days.

The Author, in reply, said that of course it was a fact that where the injector delivered its water, there was the greatest lime deposit. In the case of some motor boilers he had watched working on the Brentford Branch, there was about 3″ deposit on the top of the crown plate in about seven weeks, and they found that the deposit was usually just inside the clacks with most classes of engines, but it had been decreased enormously by the use of softened water obtained from the troughs. Those of the members present who heard Mr. Crebbin' s paper read last session, would probably remember that he referred to the chamber Mr. Champeney had mentioned, which was inside the boiler on each side of the tubes. Herr Golsdorf found that if these chambers were blown out every trip, the deposit left in the chamber as mud could be very readily disposed of. There was no hardening of the scale, because it was blown off before the boiler had cooled at all, and exceedingly good results were obtained.

Mr. H. Holcroft remarked that the G.W.R. practice was to put the injectors underneath the footplate, whereas the standard British practice was to put them on the back plate of the firebox. What advantage did the G.W.R. claim in their system ? By having them on the back plate of the firebox, there was an internal feed pipe, and although Mr. Stanier pointed out that this would be liable to scale, it could be made of larger internal diameter, and the advantage of the internal feed would be that there would be a higher temperature than with the outside delivery pipe. There would be less strain on the boiler plates, and it would be in a better position for working, as the men would not have to reach up to the steam valve. The water and steam valves could be examined even while running. With regard to obtaining the water supply from the tender, the usual thing was to put a strainer over the suction pipe. The result was that the water velocity through the holes was fairly high, and any foreign bodies in the tender got carried forward, became stuck, and very quickly caused failure. Would it not be well to make the transverse wash plate an inverted plate instead ? With larger holes the velocity would be lower, and the water would be swilling about and so washing off foreign matters.

The Author remarked, with reference to the question as to the position in which water should be supplied to the boiler, this depended very largely upon the engineer. Some preferred to put it in at the firebox end, others at the smokebox end. If the injector is fixed on the firebox, the water is heated when passing through the internal tube. In the Great Western practice the water delivered into the boiler was more nearly the temperature of the water it had to meet, and there was not so much contraction and expansion of the plates. No doubt the injectors on the footplate were more accessible, and the American practice was to put an injector of the Sellars Simplex type on each side of the firebox, the handles being in the cab and the front part projecting in front of the cab plate. It was hardly British practice to put the injectors on the back of the firebox. The Midland Railway had the injector up by the hand rail, and the North Western Railway had them attached to a clack box on the back plate of the boiler. Davies and Metcalf made their supplementary portion in this form, very similar to the Gresham and Craven combination injector, and it is being used by the Great Central Railway. Mr. Holcroft had suggested that, instead of having the ordinary strums over the feed pipes in the tender, which of course get blocked, the front swash plate should be perforated. In either case it was necessary for a man to get inside the tank to clean it. On the Great Bear tender they were now trying a hopper arrangement from which the delivery pipes were taken. Inside the hopper was a strainer. The water had to pass through the strainer to the delivery pipe. At the bottom was a valve which could be flushed out ; this valve was locked with a bolt, and could be swung out of the way, and the valve of the tender tank closed. When the hopper was being flushed, the water could be retained in the tank. Personally, he thought that it would be a first-class arrangement when it had been developed. With the tender tanks it was impossible to adequately keep the tanks cleaned out, especially at that time of the year. On every trip, leaves and cinders were picked up, and if this hopper arrangement, when developed, could be applied to all tenders, it would save a good many injector failures and be of great assistance to the shed staff. With the type of injector used on the Great Western, they could pass fairly large articles into the boiler, but with the Friedman injector the annular space between the tip of the steam cone and the combining tube was quite small, and articles such as smokebox ashes had lodged there and interfered with the working.

Mr. Champeney remarked that with the exhaust injector as applied to G.W.R. engines, it was necessary to have a head of water, and to get this head of water it was necessary that the injector should be placed below the tender. An exhaust injector would not work if it were placed above the level of the water in the tender, and then again, with the restarting injector, there was the advantage of the head of water which accrued by placing it as low down as possible.

Mr. R. H. Smith said he would rather have other means of taking the dirt from the tender. The driver should be given the means of cleaning out the dirt at every trip. It was absolutely necessary with the strums and perforated baffle plate for some one to clean them out. By having the strum suspended, the tendency would be for the leaves, etc., to wash to the bottom.

Mr. Champeney pointed out that it was said that the steam nozzle must be larger than the delivery nozzle in order to get the injector to work. He supposed the jet pump did not work under the same theory, as the jet pump delivery nozzle was always larger than the steam nozzle.

The Author : –Some American injector makers worked to that theory, but it was not essentially an American theory.

Mr. Holcroft asked, with regard to the failure of injectors being caused by stopping up strum, whether it was not possible to blow steam back to clear the strum, or could they not have a system of scrapers on the strum similar to that on the economiser tubes ?

Mr. Smith said it was possible to turn the water back into the tank, and heat it with the Gifford injector, and these injectors worked with very hot water. A stop-cock was operated, and the steam turned back into the tank.

The Author also said it was possible to turn the steam back into the tank. Of course the Gifford injector worked at a very low pressure, and the lower the pressure the hotter the water could be taken.

Mr. Smith pointed out that turning back the steam did not cure the trouble.

Mr. E. T. J. Evans said that by using the exhaust steam a considerable amount of the oil and grease used for lubrication was brought over with the steam, and asked whether the strainer was efficient. If not, this would probably be the cause of the boilers priming.

The Author thought the strainer fitted to the standard Great Western exhaust injector was quite efficient, provided the Turkish towelling was changed frequently. If it was properly looked after, no trouble was experienced. A more efficient strainer would probably mean a much more complicated strainer.