METCALFE'S

PATENT
TYPE "D"

LOCOMOTIVE

:: EXHAUST STEAM ::

INJECTOR

DAVIES & METCALFE
LIMITED.

Injector Works, ROMILEY,

near MANCHESTER.

ENGLAND.

METCALFE'S PATENT

TYPE "D."

Locomotive Exhaust Steam Injector.

The most economical method of Boiler Feeding.

Economy—15% in Coal and Water.

DAVIES & METCALFE Ltd.,

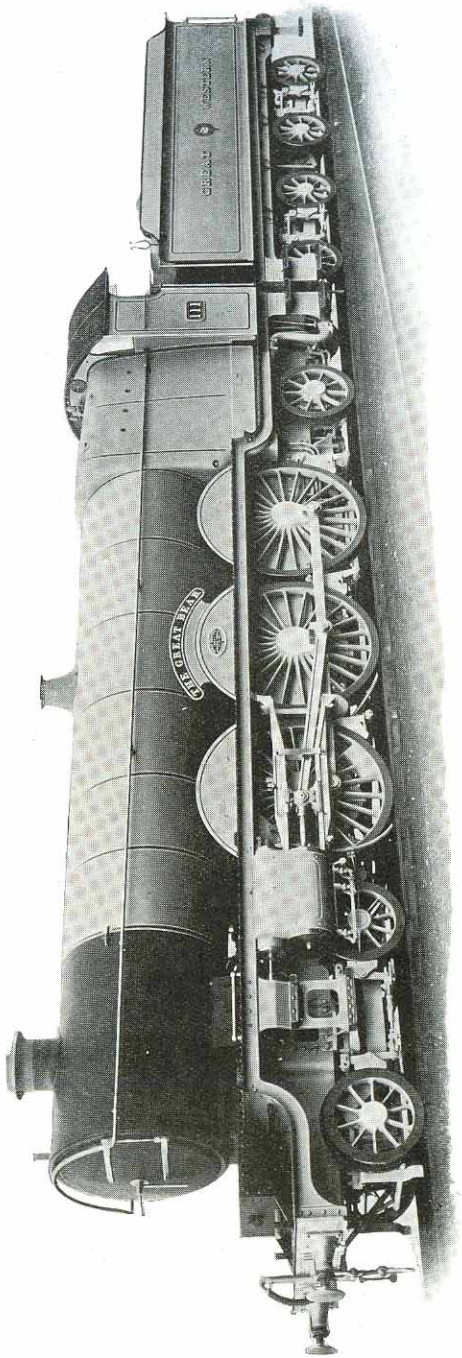
INJECTOR WORKS,

Manufacturers of all classes of INJECTORS and VACUUM BRAKE FITTINGS. - - -

ROMILEY,

near MANCHESTER.

ENGLAND.



By kind permission of "Great Western Railway Magazine."

Fitted with Davies & Metcalfe's Patent Exhaust Steam Injector.

IN MODERN locomotive practice the problem of reducing working expenses is of the first importance, and one of the chief directions in which saving can be effected is by utilizing waste heat and so economising fuel.

A great amount of energy is lost with the exhaust steam from locomotives. This has long been recognised by Engineers, and many attempts have been made to make practical use of this.

The early efforts had for their object the utilization of the exhaust steam as a feed water heating medium by using a combination of feed heater and pump, but the complications of this system, and the drawbacks experienced, due to the increase in cylinder back pressure and choking of the feed heater tubes, led to its abandonment in general practice.

The simplest and most efficient means of turning such waste energy to useful account, is to be found in the Locomotive Exhaust Steam Injector, which has stood the test of practical operation on locomotives for a number of years.

The great superiority of this type of Injector over the ordinary Live Steam Injector or Feed Pump is now universally admitted, and it is only necessary to study the working results, to recognize its great advantages in efficiency and economy.

With the introduction of the Injector and its general adoption for boiler feeding, came the recognition of the fact that in an Injector the energy of the boiler steam

is utilized both as a feed water heating medium and as a propulsive force, and it was soon realised that considerable economy would be obtained if exhaust steam could be used for working the Injector in place of live steam from the boiler. Many experiments were carried out with this object in view, and in 1876 Messrs. E. Davies and J. Metcalfe invented the first Injector worked by exhaust steam.

This original Exhaust Injector, working with steam at atmospheric pressure, was capable of feeding against pressures up to 70 lbs. per sq. inch; and at its introduction considerable attention was given to the discovery that such high delivery pressures could be obtained, when using low pressure steam.

A further important feature of this Injector was the introduction of the principle of "automatic re-starting." Previous to this all Injectors were of the non-automatic type, but by the invention of the "Flap Nozzle" employed in this Injector, it was shewn that the appliance could be made to automatically re-start without attention. This feature has now been universally adopted for all types of Injectors.

The Exhaust Injector was fitted upon locomotives soon after its introduction and it is now well known to all Locomotive Engineers, having been adopted by many of the leading railways and fitted to the largest express passenger locomotives.

To obtain the highest efficiency and economy in boiler feeding, it is necessary that the feed water should be heated

to the highest possible degree, before its admission to the boiler, and recent tests have shewn that considerable economy can be obtained even when utilising live steam from the boiler for feed water heating purposes.

The great value of the Exhaust Injector is at once apparent, when it is recognised that the feed water is heated, and forced into the boiler, by the utilisation of the exhaust steam which would otherwise go to waste.

On a locomotive, from tests made under ordinary service conditions, the actual **economy** shewn is from **seven to ten lbs. of coal,** and about **40 lbs. of water** per mile. These results have been demonstrated by a series of carefully conducted trials made on locomotives, with and without, these Injectors, and the large number of locomotives now fitted with Exhaust Injectors shows that such results are maintained in service.

The Exhaust Injector is equally suitable for use on Simple or Compound Locomotives working with either Saturated or Superheated Steam.

In the arrangement of the Exhaust Injector on a locomotive, no alteration whatever is necessary in the blast pipe arrangements, a pipe connection between the blast pipe and the Injector being alone required.

Advantages.

The advantages to be derived from the use of the Exhaust Injector may be briefly stated as follows:—

1st.—It utilises the Exhaust Steam both for feed water heating and boiler feeding purposes, thus saving both steam and water, the average **economy** being from **seven to ten lbs. of coal and 40 lbs. of water** per mile.

2nd.—The application of the Injector **reduces the cylinder back pressure considerably,** thus increasing the power of the engine.

3rd.—Hot Water only is delivered to the boiler, so improving the circulation and reducing the stresses in the plates due to unequal contraction set up by the admission of a low temperature feed.

4th.—The steaming of the boiler is greatly improved and the Injector can be kept constantly feeding on gradients, and in bad weather, without causing a drop in steam pressure.

5th.—It can be worked as an ordinary Live Steam Injector when the engine is standing.

Theory of the Working of the Exhaust Injector.

THE Exhaust Injector is still a mystery to many who handle it, or read about it, as it seems to be contrary to all accepted principles that the waste steam from the cylinders issuing at atmospheric pressure, should be able to force about ten times its own weight of water into a boiler under a pressure of 120 lbs. per sq. inch.

This seeming paradox, however, is easily explained when the action of the exhaust steam on the water is considered.

An Injector may be defined as an apparatus in which a jet of steam moving at a high velocity is condensed by a body of water moving at a low velocity, the momentum of the steam jet being transferred to the water, producing a combined jet moving with a resultant velocity sufficient to overcome the boiler pressure.

Exhaust steam at atmospheric pressure has no velocity relative to the atmosphere, but if such steam be allowed to issue into a vacuum, it has a very high velocity (e.g., the velocity of exhaust steam at atmospheric pressure flowing into a perfect vacuum would be over 2000 feet per second).

It is known that when steam is condensed, a vacuum is created the degree of which is dependent upon the temperature of the water of condensation.

In the Exhaust Injector a very high degree of vacuum is obtained by the condensation of the exhaust steam by

the feed water, in the combining nozzle of the Injector. The highest vacuum is at the point of the steam nozzle, where the steam and water meet. A vacuum of 24 to 26 inches is obtained, so that the exhaust steam flows in at an exceedingly high velocity. It there meets the feed water, and being condensed by it gives up its momentum to the combined jet which then flows along the combining nozzle where complete condensation takes place. The jet leaves the end of the combining nozzle at a velocity which is sufficiently high to carry it forward through the delivery nozzle and into the boiler.

The Exhaust Steam Injector differs from the Live Steam Injector in having the steam inlet nozzle of a much larger cross sectional area than that of a Live Steam Injector of similar size. This is necessary to provide for the large volume of exhaust steam which must be passed; for it will be understood, that though the velocity of the particles of exhaust steam on leaving the steam nozzle and entering the vacuum formed in the combining nozzle may be approximately as great as if boiler steam of considerable pressure were used, yet the weight of steam passed through a given area will be less in proportion to the inferior density of the exhaust steam.

It will also be seen that the working of the Injector is not dependent on the steam being supplied under pressure as is so often supposed, the sole determining factor being the steam velocity.

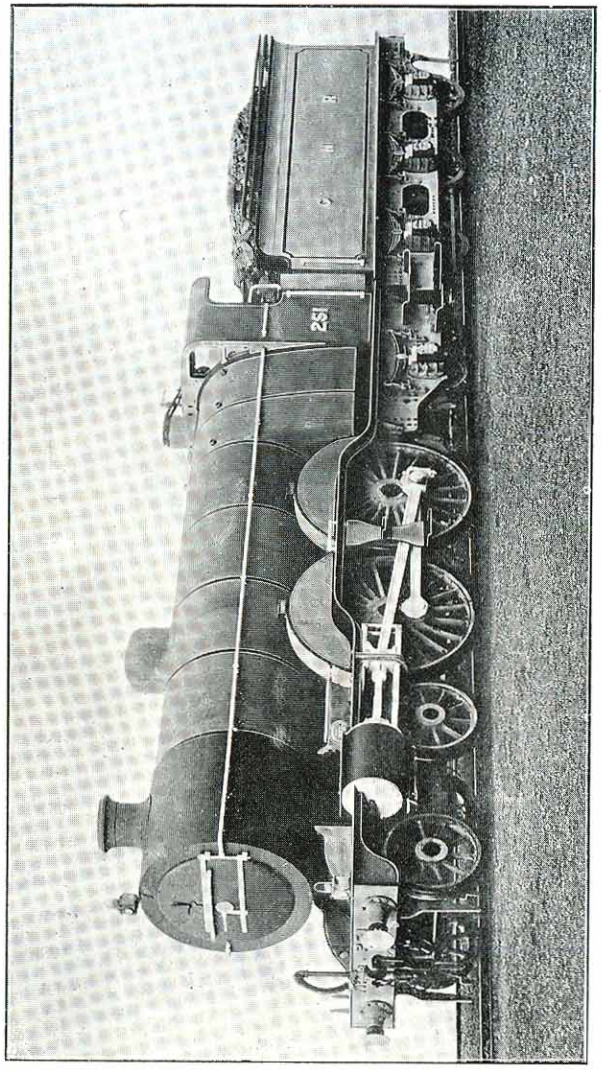
In practice it is found that there is an immediate reduction of back pressure in the engine cylinder when the Injector is put to work, the Injector acting as a condenser,

working at a vacuum of 24 to 26 inches, into which the steam is drawn.

In the new patent Type "D" Exhaust Injector, a greatly increased duty is obtained from the exhaust steam by a special arrangement of nozzles. This Injector, working with exhaust steam alone, is capable of delivering against the pressures shewn in the following table:—

EXHAUST STEAM PRESSURE Pounds per square inch.	DELIVERY PRESSURE Pounds per square inch.
1	120
5	150
10	180
15	210

In the double jet system employed in the type "D" Injector, the exhaust steam entering the Injector passes into the main central exhaust steam nozzle, at the mouth of which it meets the feed water (fig. 3). Condensation immediately takes place—a very high degree of vacuum being formed—and the combined jet flows forward at a high velocity through the draft tube into the combining nozzle. The region of high vacuum extends to the entrance of the combining nozzle, and at this point a second supply of exhaust steam is admitted, which flowing in at a very high velocity, impinges on and is condensed by the combined jet, imparting to it a further supply of energy, so increasing its velocity. The combined jet now enters the combining nozzle, where complete condensation takes place, giving a jet of hot water. After passing through the combining nozzle, the jet enters the delivery nozzle, where its velocity is reduced, the kinetic energy being changed into pressure energy, and leaving the Injector passes into the boiler.



Great Northern Railway.

Atlantic Express Locomotive.

Fitted with Davies & Metcalfe's Exhaust Steam Injector.

The complete apparatus, as now supplied for locomotive purposes, consists of—

Grease Separator.
Automatic Exhaust Valve.
Exhaust Injector.

The Exhaust Injector is fixed beneath the driver's footplate, in any convenient position, being fastened to either the engine frame or footstep. Rods are coupled to the Exhaust Valve and Water Regulator Spindles, leading up to the footplate for convenient handling by the fireman.

The Exhaust Steam Pipe connecting the Injector to the Blast Pipe, should be coupled to the latter as close as possible to the cylinders. No other alteration to the blast pipe arrangement is required.

GREASE SEPARATOR, *etc.* The exhaust steam on its way to the Injector is passed through the Patent Grease Separator, which is fixed in any convenient position in the exhaust steam pipe, preferably at its lowest point.

The function of the Grease Separator is to remove from the exhaust steam all particles of grease,

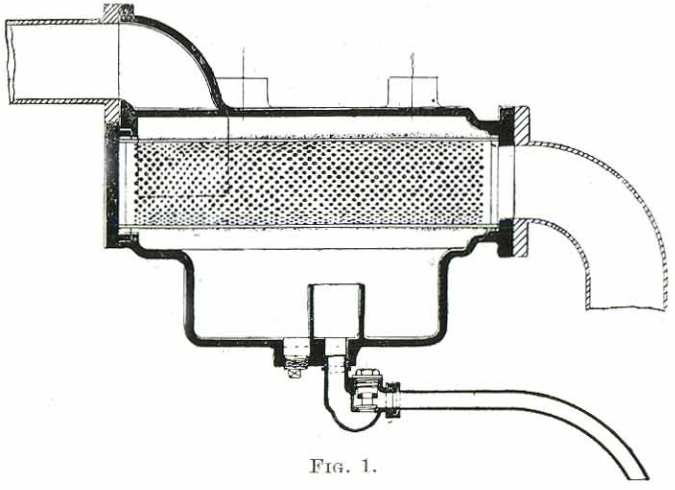


Fig. 1.

dirt, or condensed steam which may have been carried along from the blast pipe. The steam entering the casing strikes against the baffle plates, which deflect the suspended matter into the well below, whence it is discharged through the automatic drip valve into a drain pipe. The steam then passes through a perforated metal cylinder, which is covered by a sleeve made of absorbent towelling. The latter further dries the steam and removes any impurities remaining in it.

AUTOMATIC EXHAUST VALVE.

This Valve governs the supply of exhaust steam to the Injector, and also provides means for the admission of a supply of live steam, for working the Injector when the engine is standing, or when running with steam shut off and no exhaust steam available. It consists of a casing coupled to the Exhaust Injector. the exhaust steam passing through this on its way to the Injector. Within this casing is fixed the Exhaust Steam

Automatic Exhaust Valve.

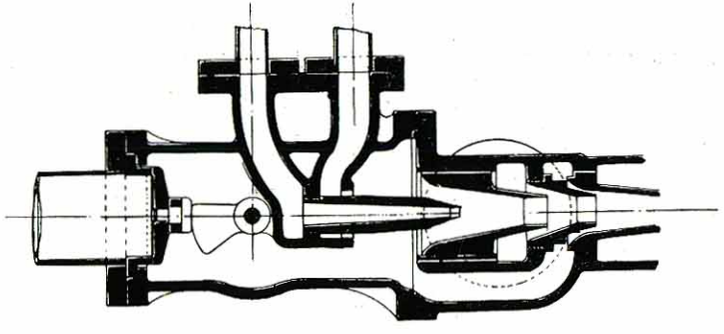


Fig. 2.

Valve set to hang freely and offer no resistance to the passage of the exhaust steam.

This Valve can be closed by a cam to shut off communication between the exhaust pipe and the Injector, thus preventing any passage of steam when the latter is not in use. The cam is fixed on a spindle to which is coupled a rod carried up to the footplate, so that it can be easily operated by the driver or fireman.

On the body of the valve casing are two live steam inlets. The first, or supplementary inlet, admits a supply of live steam to the supplementary nozzle. The purpose of this is explained later.

The second, or auxiliary inlet, supplies live steam to work the Injector when the engine is standing, or when no exhaust steam is available, the supply of live steam being admitted to replace the exhaust steam.

EXHAUST INJECTOR.

This new type of Exhaust Injector presents several new and important features, and represents a very great advance over all previous types. When working with exhaust steam at atmospheric pressure it is capable of delivering against a pressure of 120 lbs. per square inch (as compared with 75 lbs. per square inch in all previous types), and with the addition of a small supplementary live steam jet it can feed against pressures up to 300 lbs.

per square inch. This result is obtained by the better utilisation of the exhaust steam.

The Injector consists of a casing containing the various nozzles and also branches for the delivery, overflow, and water pipes.

The nozzles consist of the Exhaust Steam Nozzle, Draft Tube, Combining or Flap Nozzle and Delivery Nozzle, while in the Exhaust Valve Casing is fixed the Supplementary Steam Nozzle which projects into the Exhaust Steam Nozzle.

From the section, fig. 3 it will be seen that the exhaust steam from the blast pipe passes through the Exhaust Valve Casing, and flows into the Central Exhaust Steam Nozzle, at the mouth of which it meets the feed water. The steam is condensed by, and imparts its velocity to the jet of water and as previously explained (page 8) the combined jet flows forward through the Draft Tube into the Combining Nozzle. A high degree of vacuum is maintained along the Draft Tube and at its mouth the second jet of exhaust steam is admitted (fig. 2) in the form of an annular jet, which, impinging on the outside of the moving jet imparts a further supply of energy to it, so increasing its velocity as it enters the Combining Nozzle.

This nozzle is constructed on Davies & Metcalfe's well-known Patent Hinged "Flap Nozzle" system, in which (fig. 3) the Combining Nozzle is split longitudinally at its middle section, up to a point near the Draft Nozzle, where

Exhaust Injector and Valve.

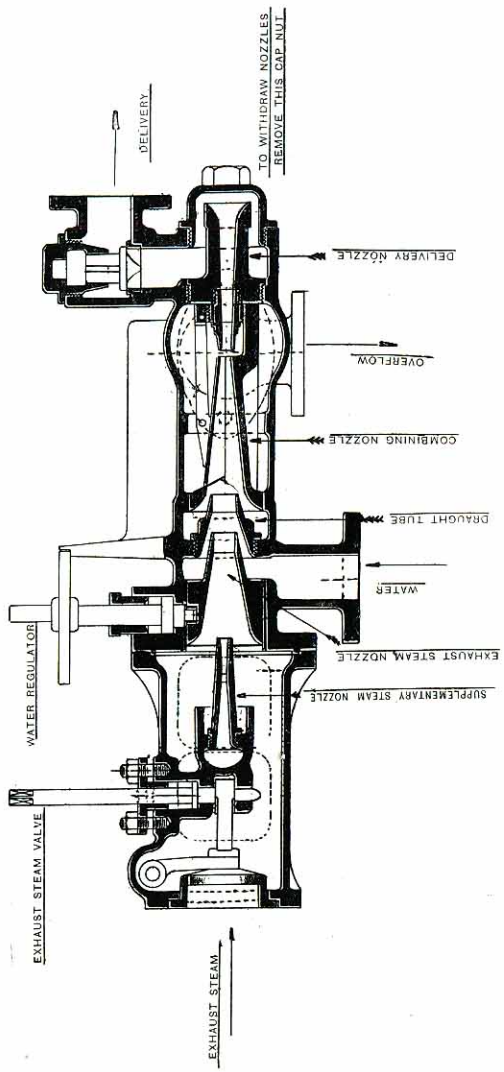


Fig. 3.

the cross section of the cone is sufficiently large to permit an easy exit for the water and steam. This ensures the prompt starting and automatic working of the Injector.

The force of the steam striking against the hinged flap opens it, exposing a large area of discharge, and enabling the steam to pass freely into the overflow pipe. As soon as the water is admitted and meets the steam, condensation takes place and a partial vacuum is formed, causing the closing of the flap, which is held in that position as long as the jet is continuous. The jet is thus completely supported along the combining nozzle, there being no gaps, etc. to weaken it.

If the jet is in any way broken, then the pressure of the steam pushes open the hinged flap, and a free discharge is offered until a vacuum is again formed and the continuity of the jet re-established.

Leaving the combining nozzle the jet passes into the delivery nozzle, where its velocity energy is transformed into pressure energy, and leaving the Injector it passes into the boiler.

As before stated, the exhaust steam alone develops a pressure of 120 lbs., and for higher pressures a small jet of live steam is introduced through the supplementary nozzle, which gives the additional pressure required.

SUPPLEMENTARY NOZZLE. This is a live steam nozzle of small bore, which is carried by a branch in the exhaust valve casing at the entrance to the main exhaust nozzle. It obtains its steam supply through the passage shewn in the Exhaust Valve Casing from a pipe connected to the Supplementary Steam Valve on the boiler. The small jet of steam introduced through this nozzle gives the additional force required to feed the boiler.

WATER REGULATOR. The water regulation of the Injector is effected by varying the area for the entrance of water into the nozzles. This is done by moving the Exhaust Steam Nozzle to and fro, so that the surrounding area between the end of the Exhaust Nozzle and the Draft Tube (fig. 3) is varied, and consequently the quantity of water entering is regulated according to the amount required.

This movement of the steam nozzle is imparted by an eccentric pin fitting into a slot on the outside of the nozzle, and worked by a rod from the footplate. By this means a very large range of delivery can be obtained and the Injector set so as to give a constant feed under all conditions of working.

OVERFLOW VALVE. The Injector is fitted with an Automatic Overflow Valve, which, when the Injector is working, seals the overflow chamber, and prevents the admission of air. In starting or re-starting, the valve opens freely, so that the steam and water escape readily, causing the Injector to be very prompt in starting.

The Injector is very massive in construction and designed specially for hard wear.

All nozzles are constructed of the best gun-metal, and can be easily removed for examination, or cleaning, by unscrewing the body cap nut.

COMBINED STEAM and DELIVERY VALVE. This is a very convenient type of valve, which we supply for use in conjunction with the Exhaust Injector. It consists of a casing bolted by a flange to the fire-box back, in a position convenient for easy handling, and contains self-contained boiler check valve, supplementary steam valve, and auxiliary steam valve, with pipe connections for leading to the Injector.

WORKING WITH LIVE STEAM.

It is sometimes necessary to work the Injector as a live steam Injector (as when the engine is standing, etc.). For this purpose a supply of live steam is introduced into the automatic exhaust valve casing through the auxiliary steam branch, and it then enters the Injector at the annular nozzle surrounding the supplementary nozzle. This supply flows into the exhaust steam nozzles, replacing the exhaust steam, and the Injector works exactly as when exhaust steam is used.

When thus working with live steam, the pressure of the steam in the Automatic Valve casing closes the Exhaust Steam Valve, so preventing the entrance of any air which would have a tendency to destroy the vacuum and so impair the working of the Injector.

It will thus be seen that to change over from exhaust steam to live steam working, it is only necessary to open the steam supply to the auxiliary steam pipe, when the Injector will work as efficiently as before.

In fact, this Injector working with live steam makes as reliable and simple an instrument as any live steam Injector, and is equally prompt in starting and certain in action.

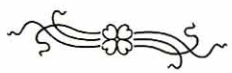
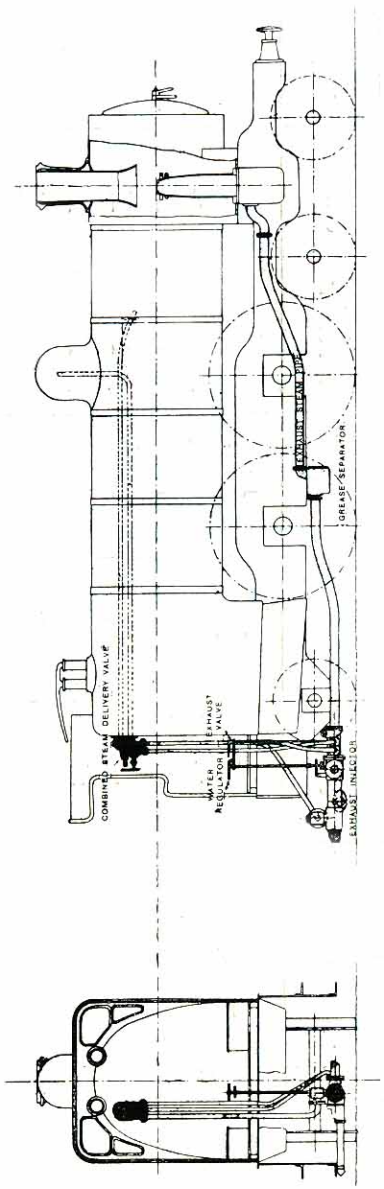


TABLE OF PIPE SIZES AND DELIVERIES OF EXHAUST INJECTORS.

Metcalfe's Patent. Type "D."

Size of Injector.	Delivery in Gallons per hour.	INTERNAL DIAMETER OF PIPES IN INCHES.					
		Exhaust Steam.	Live Steam to work Injector when engine is standing.	Water from Tank	Supplementary Live Steam	Overflow	Delivery to Boiler.
6	850	$2\frac{1}{2}$	1	$1\frac{1}{4}$	$\frac{7}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$
7	1150	$2\frac{3}{4}$	1	$1\frac{1}{4}$	$\frac{7}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$
8	1500	3	$1\frac{1}{8}$	$1\frac{1}{2}$	1	2	$1\frac{1}{2}$
9	1900	3	$1\frac{1}{8}$	$1\frac{3}{4}$	1	$2\frac{1}{4}$	$1\frac{1}{2}$
10	2300	$3\frac{1}{2}$	$1\frac{1}{4}$	2	$1\frac{1}{8}$	$2\frac{1}{4}$	$1\frac{3}{4}$
11	2800	4	$1\frac{3}{8}$	2	$1\frac{1}{4}$	$2\frac{1}{2}$	2
12	3300	$4\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{3}{4}$	2
13	3800	$4\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{3}{4}$	$2\frac{1}{4}$



Fixing arrangement of Exhaust Injector (Type "D") on Locomotive.

Instructions for Fixing.

The Exhaust Injector is fixed under the footplate on the fireman's side below the bottom water level. Controlling Rods must be coupled to the Exhaust Steam Valve and Water Regulator Spindles, and carried up into the cab, the handles being fixed in a position where they can be easily operated.

PIPE CONNECTIONS.—The branch exhaust pipe from blast pipe to Injector should have no dips where water can lodge. All joints in the Exhaust Steam Pipe should be made with flanged connections (not union coupling nuts).

GREASE SEPARATOR.—This may be fixed at any convenient point in the exhaust steam pipe, preferably at its lowest position, so as to drain all water out of the pipe.

Special care should be taken that all joints in the Exhaust Steam Pipe and Injector Feed Pipe are perfectly tight, so that there can be no leakage of air.

The inlet to the Feed Pipe in the tender must be protected against dirt, etc., by a large but fine mesh sieve or strainer.

Working Instructions.

Open Tender Feed Cock. Open Exhaust Steam Valve, and then turn on Supplementary Steam. If there is any overflow, regulate by means of water regulator handle, and *not* by tender feed cock.

NOTE.—The Supplementary Steam Valve should be only opened sufficiently to make Injector work without overflow.

To Work Injector when Engine is standing:—

Open Tender Feed Cock. Open Supplementary Steam Valve. Turn on sufficient auxiliary steam until Injector starts working. Regulate by water regulator handle.

Injector Troubles.

In dealing with Exhaust Injector troubles, it should be noted that the principal causes of Injector failures are:—

1st. Air leakages.

2nd. Dirt or scale in nozzles or pipes.

1st. AIR LEAKAGES.—It has already been explained that the satisfactory working of the Injector is dependent upon a vacuum being formed, due to the condensation of the exhaust steam by the feed water. Any leakage in either the exhaust steam or feed water supply pipes results in small quantities of air being drawn in, which reduce the vacuum and cause unreliable working.

Special care should be taken that all joints on the exhaust steam pipe and feed water pipe are perfectly tight.

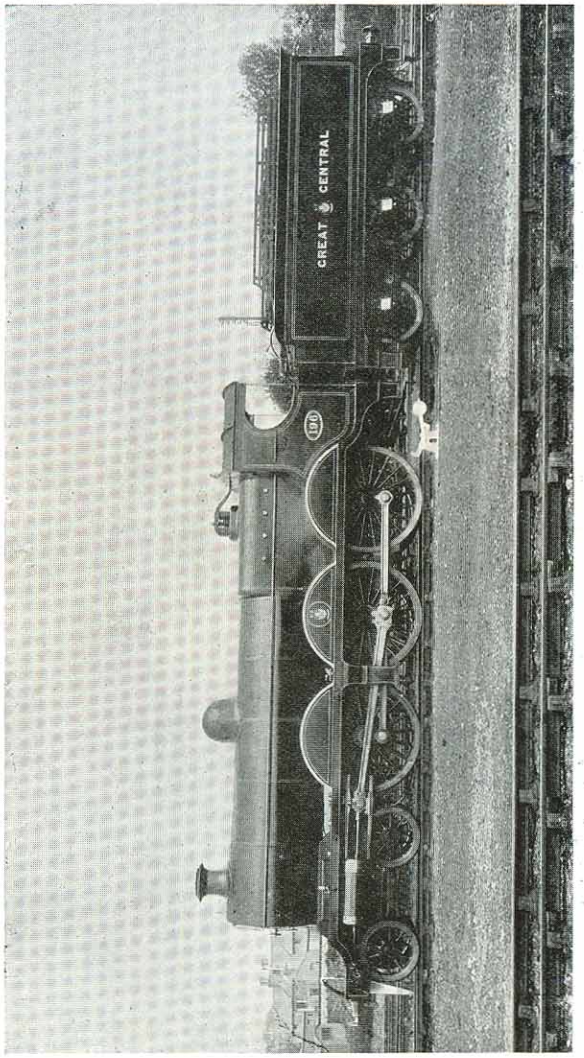
2nd. DIRT OR SCALE.—This is a frequent cause of trouble, especially in districts where the water contains a large amount of lime in solution, this being deposited as scale in the nozzles, delivery valves and pipes.

Nozzles and Valves should be removed occasionally and cleaned, also delivery pipe from Injector to boiler should be cleaned.

NOTE.—All scale and deposit on nozzles can be removed by soaking in a solution of:—

Spirits of Salts	...	1 part.
Water	... ...	10 parts.

A defective strainer in the tender sometimes causes a failure, dirt, leaves, etc., passing into the feed pipe and nozzles and causing a stoppage.



Six-Coupled Bogie Express Locomotive. Great Central Railway.

Fitted with Davies & Metcalfe's Exhaust Steam Injector.

OUR OTHER LOCOMOTIVE
SPECIALITIES INCLUDE :—

1. Automatic Re-starting "Hot Water" Injectors (METCALFE'S PATENT).

Works with feed water at 140° F.
Made in all patterns, both lifting & non-lifting.
The only reliable Injector for warm climates.

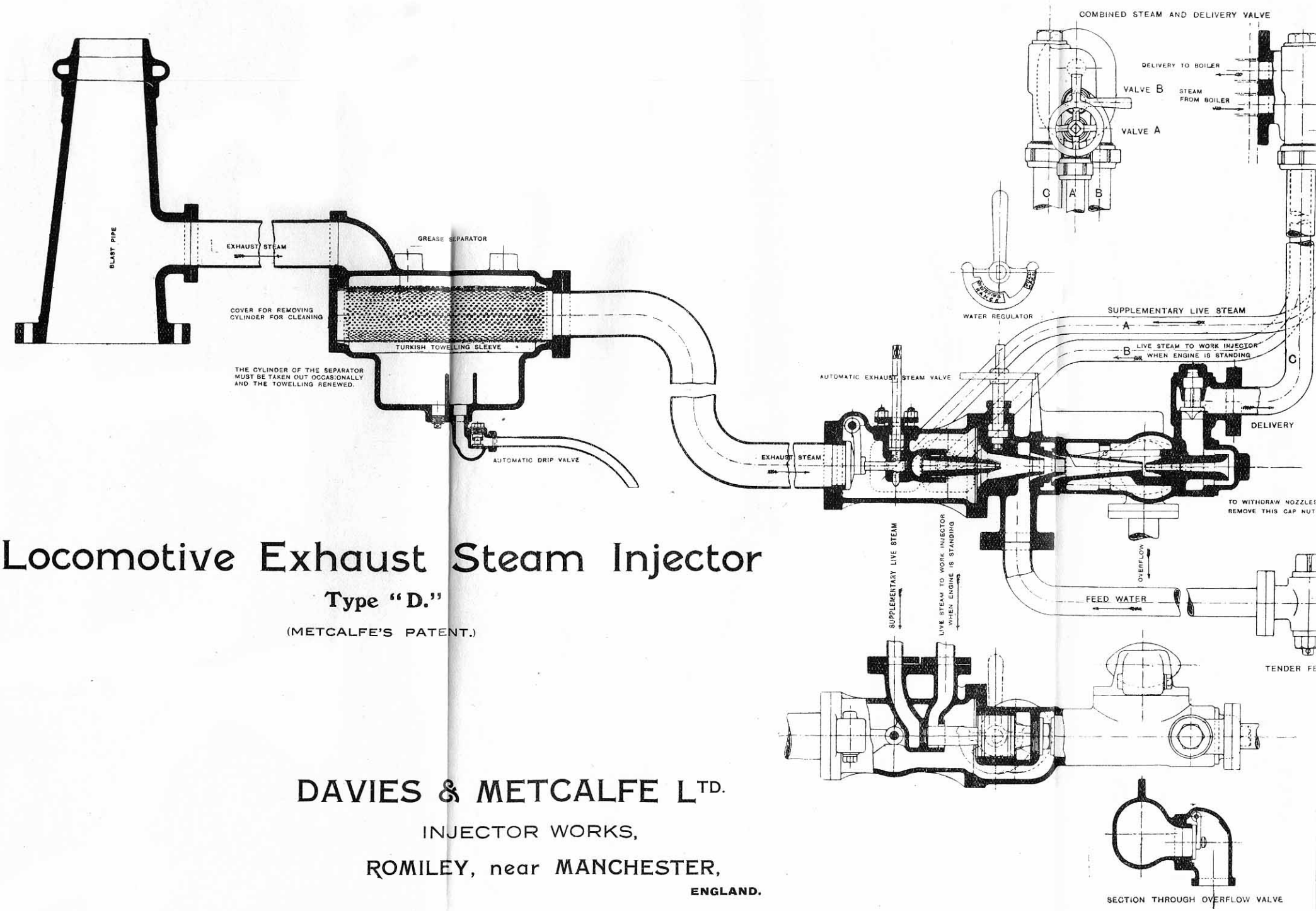
2. Standard Live Steam Injectors

In "Combination" and all other patterns.
Perfectly Automatic and Re-starting.
Designs to interchange with any existing type.

3. Vacuum Brake Ejectors
(METCALFE'S PATENT).

High Vacuum with low steam consumption.
No rotating air or steam valves.
No annular steam nozzles.
The simplest and most reliable Ejector made.
Interchanges with existing types.

DAVIES & METCALFE LTD.,
ROMILEY,
Near MANCHESTER.



Locomotive Exhaust Steam Injector

Type "D."

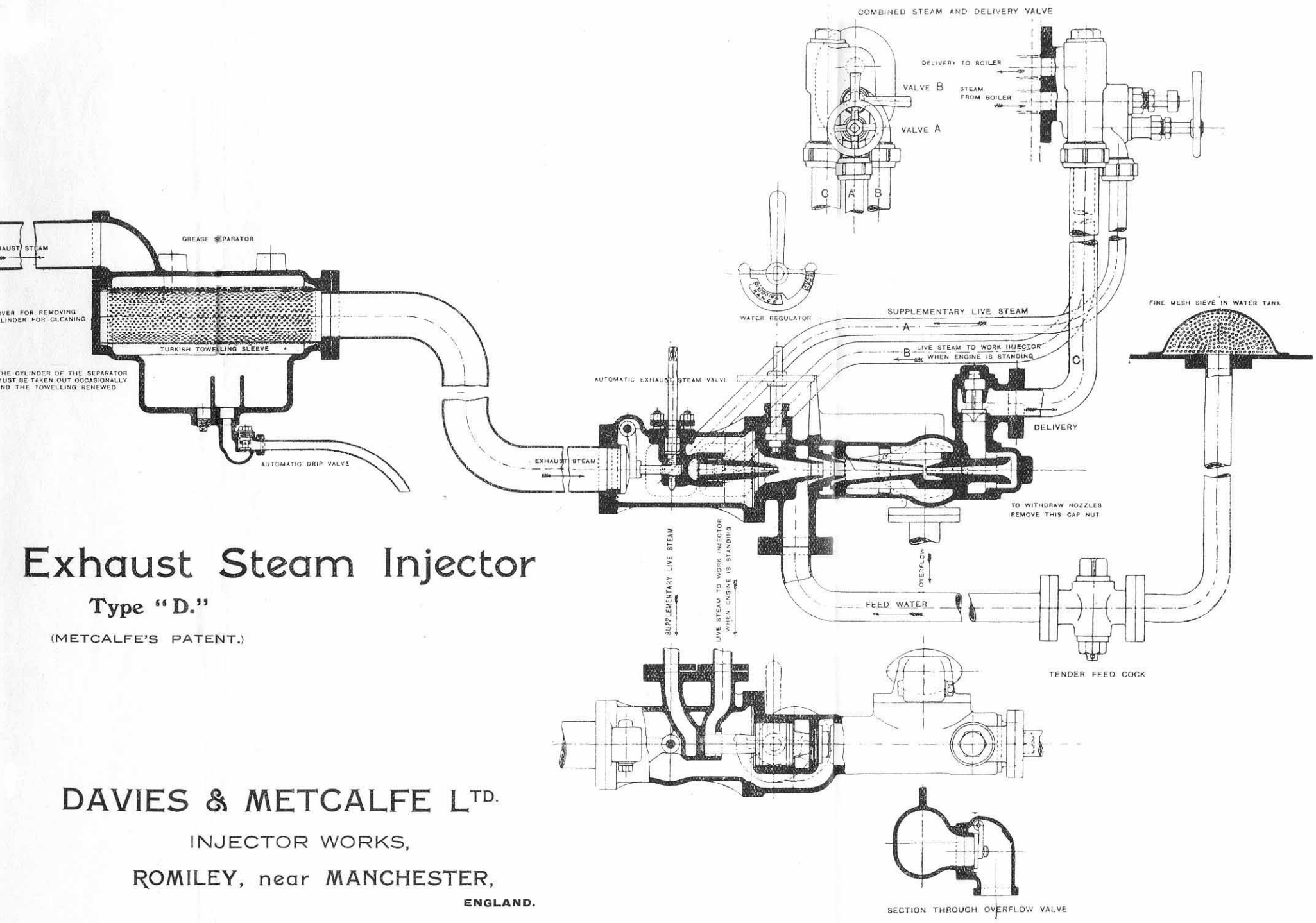
(METCALFE'S PATENT.)

DAVIES & METCALFE LTD.

INJECTOR WORKS,

ROMILEY, near MANCHESTER,

ENGLAND.



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