Sept. 6, 1938. A. WILLIAMS ET AL 2,129,515

INJECTOR

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Fig. 1.

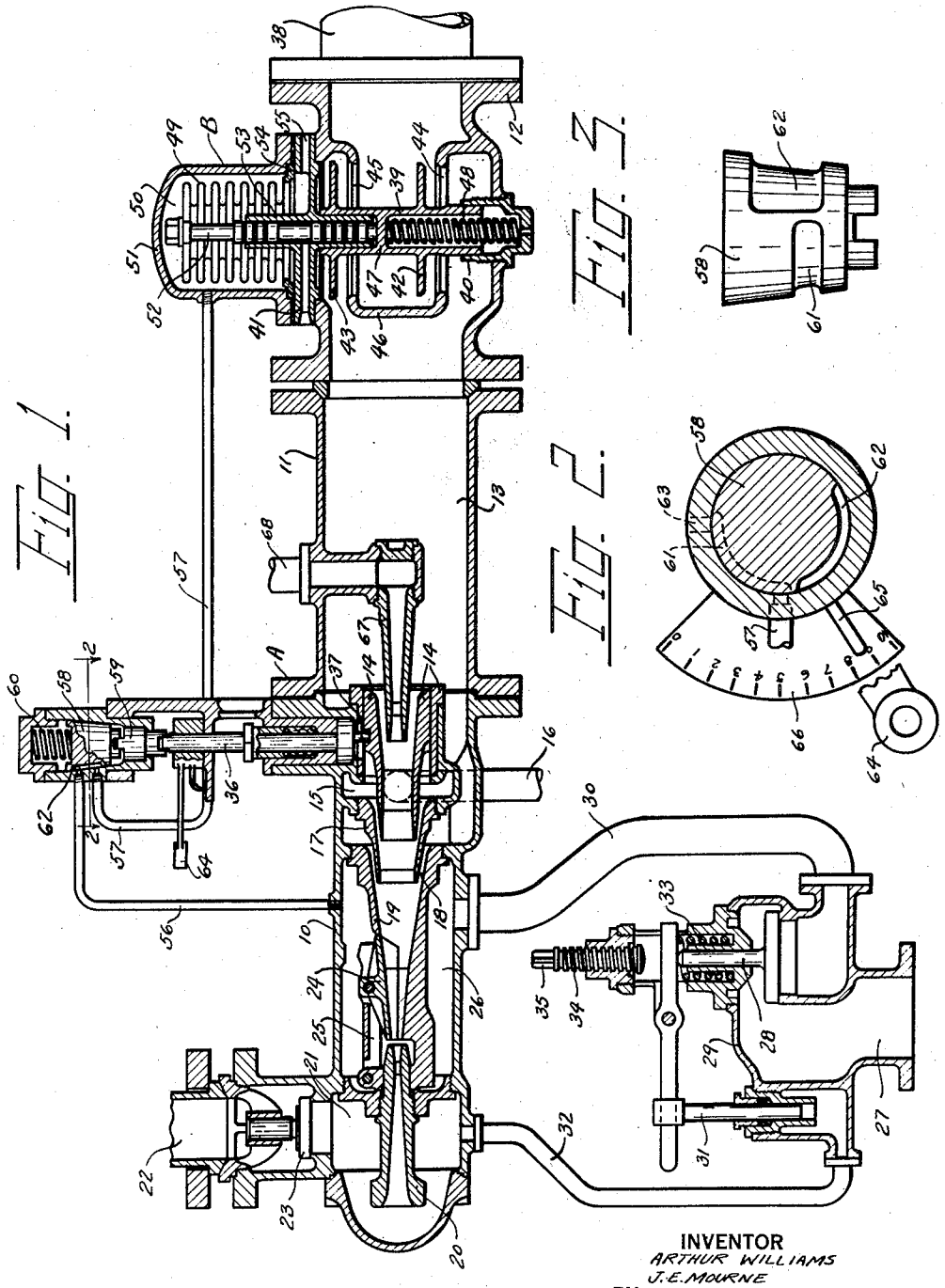


Fig. 3.

Fig. 2.

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INJECTOR

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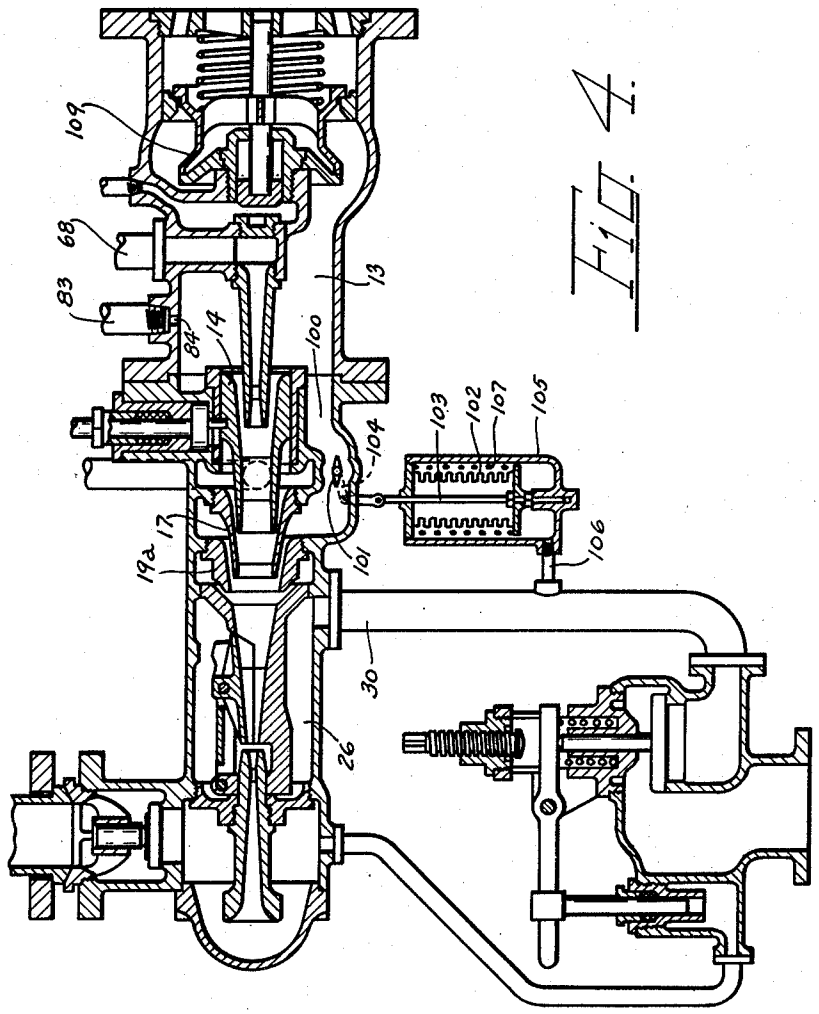


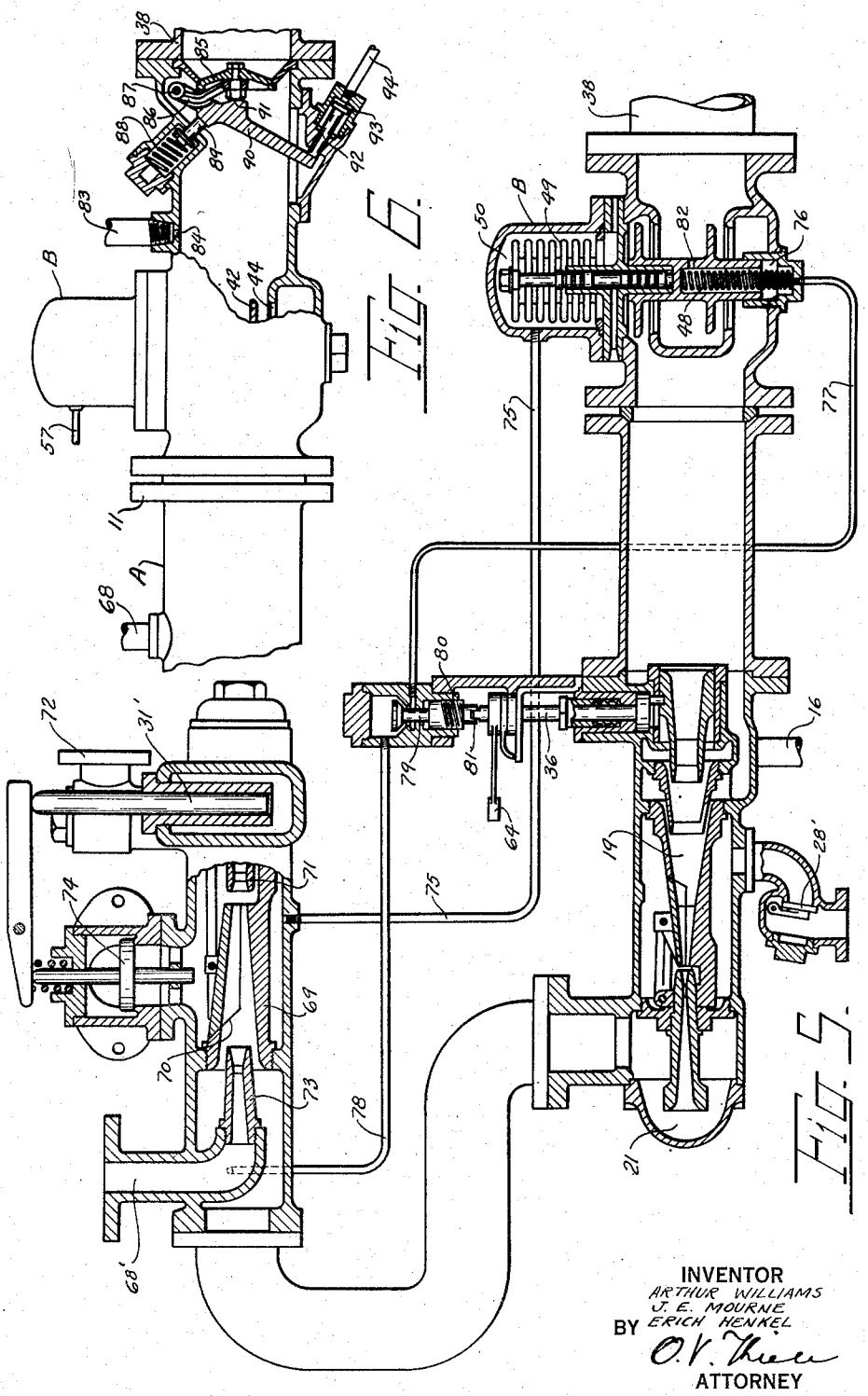
FIG. 4.

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INJECTOR

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UNITED STATES PATENT OFFICE

2,129,515

INJECTOR

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Application January 18, 1938, Serial No. 185,548
In Canada June 9, 1936

16 Claims. (Cl. 103—265)

This application relates back to our applications Serial No. 571,544, filed October 28, 1931, and 671,438, filed May 17, 1933, both now abandoned.

The present invention relates to injectors. More particularly the invention relates to injectors utilizing steam at relatively low pressure and still more particularly the invention relates to exhaust steam injectors of the type adapted to be used to feed locomotive boilers and adapted to be operated wholly by live steam when exhaust steam from the locomotive engine is not available.

When injectors operated by low pressure steam are employed, the low pressure steam utilized is usually exhaust steam and one of the primary objects of using a low pressure exhaust steam injector is conservation of heat by the return to the boiler of the heat content of the exhaust steam condensed in the injector. From this it follows as highly desirable that the maximum quantity of exhaust steam be condensed in the injector under any given set of operating conditions.

It is also highly desirable, particularly in injectors applied to locomotive boilers, to have the range of the capacity of the injector, in terms of pounds of feed water delivered per unit time, as great as possible, in order to take care of the varying boiler feeding requirements for locomotive boilers.

In the prior development of injectors of the character in question very definite limitations upon the capacity of a given injector to condense low pressure steam and upon the range of its delivery capacity have been imposed because of variations in temperature of the water supplied to the injector and because of the character of the exhaust steam supplied to the injector, the latter supply being usually of a pulsating character and also varying between wide limits with respect to its average pressure.

In order to overcome the difficulties with respect to capacity range of injectors of the character in question, when such injectors have been applied under conditions requiring the utilization of low pressure steam of varying pressure, it has been suggested to employ a pressure regulating valve in the low pressure steam supply conduit for the purpose of causing a regulated supply of steam, at substantially uniform pressure, to be supplied to the low pressure steam nozzle of the injector, regardless of pressure variations at the source of low pressure steam. Such valves have been actuated in response to variations in pressure of the low pressure steam supply.

While pressure regulating valves of the above type may operate in some instances to increase to some extent the operating range of the injector under given conditions, they defeat one of the primary objects of an exhaust steam injector because, due to the character of the low pressure steam regulation, the amount of such steam supplied to the injector and condensed thereby under given conditions, may be materially less than the maximum amount which the injector could condense under the given conditions, thus reducing the amount of heat recovery to a value materially below the maximum possible value.

The primary object of the present invention is to improve the performance of injectors with respect to their range of operation and also to improve their performance with respect to the quantity of low pressure steam condensed by the injector under given operating conditions.

The primary object of the invention and other and more detailed objects thereof, which will appear more fully from the description to follow, are attained by utilizing over-flow pressure of the injector to actuate means for controlling the supply of low pressure steam to the injector, in a manner to be hereinafter more fully pointed out.

For a better understanding of the nature and objects of the invention and the advantages to be derived from its use, reference may best be had to the accompanying drawings forming a part of this specification, which drawings illustrate in more or less diagrammatic form different embodiments of apparatus incorporating the invention, and the ensuing description thereof.

In the drawings:

Fig. 1 is a more or less diagrammatic longitudinal section of an exhaust steam injector embodying the invention;

Fig. 2 is a section on enlarged scale taken on the line 2—2 of Fig. 1;

Fig. 3 is a side elevation of the valve shown in Fig. 2;

Fig. 4 is a view similar to Fig. 1 showing a variation of the inventive idea applied to an injector of the same type;

Fig. 5 is a more or less diagrammatic view similar to Fig. 1 and showing the application of the invention to a different type of injector; and

Fig. 6 is a view partly in section and partly in elevation of a portion of the general type of injector shown in Fig. 1 but modified to permit operation thereof as a live steam injector.

Referring now more particularly to Fig. 1, the injector body designated generally at A, is conveniently divided into three flanged portions, 10, 11 and 12. Obviously, the injector body may, if desired, be integral. Within the body portion 11 is the main steam chamber 13 of the injector which communicates with the main low pressure steam nozzle 14. Nozzle 14 projects through an annular water chamber 15 to which water is supplied through the connection 16, and also projects into the water cone 17. Steam from chamber 13 may also advantageously be admitted through the annular space 18 between the water cone 17 and the combining nozzle 19.

The injector jet is established in the usual way by condensation of steam delivered through nozzle 14 which mingles with the water supplied through cone 17. The mingled steam and water, to which may be added the additional steam through the opening 18, enters the combining tube 19 and upon establishment of the jet, passes from the combining tube 19 through the delivery tube 20 to the delivery chamber 21 of the injector, from which it passes to the delivery conduit 22 through the check valve 23.

The combining tube 19 is provided with the usual over-flow opening, which, in the present construction, is substantially closed during normal operation of the injector by the flap valve 24 carried on the hinged arm 25.

Surrounding the combining tube 19 is the overflow chamber 26 of the injector. Flow from this chamber to the outlet 27 is controlled by the overflow valve 28 which in the present diagrammatic showing has been shown as being housed in a separate casing 29 connected to the overflow chamber by means of the conduit 30. In actual construction the valve casing 29 ordinarily forms an integral part of the injector body and the conduit 30 is provided by a suitable cored passage in the injector body.

The over-flow valve shown is of a known type in which, when the injector is operating, the over-flow valve is held in seated position by pressure derived from the delivery chamber 21 and transmitted to piston 31 through the connection 32. Connection 32 as well as the conduit 30 is ordinarily cored in the injector body when the over-flow valve casing forms a part thereof. Piston 31 is advantageously retracted, in the absence of over-flow pressure, by means of spring 33, thus leaving the over-flow valve free to open. Valve 28 may be held in positively closed position by the threaded stud 34 having head 35 adapted to receive any suitable connection (not shown) for enabling stud 34 to be manually adjusted.

Regulation of the amount of water supplied to the injector is, in the illustrated embodiment, effected by moving the nozzle 14 longitudinally within the body of the injector by rotating the control member 36. The lower end of member 36 is provided with the eccentrically disposed pin 37 engaging a suitable recess in nozzle 14.

Steam admitted to chamber 13 is supplied through the conduit 38 and through the control valve indicated generally at B. This valve, which has been shown as incorporated in the portion 12 of the injector body, is preferably of the balanced type and comprises a hollow valve stem 39 guided by members 40 and 41 secured to the member 12 and provided with spaced valve plates 42 and 43 adapted to close ports 44 and 45 respectively in the web 46 which sub-divides the interior of member 12. Stem 39 has a transverse wall 47 therein forming an abutment against which spring 48, located within the stem and reacting against the support 40, acts to normally lift the valve member to open position.

The means for controlling the position of the valve comprises a pressure responsive device consisting of a resilient diaphragm member 49, in the form of a bellows, housed in a chamber 50 provided by the cap 51 mounted on the member 41. The upper end of the bellows 49 has connected thereto the upper end of a stem 52 slidably mounted in the annular central portion 53 of member 41, which forms a guide for the stem as well as a guide for the valve stem 39. The lower end of stem 52 abuts against the wall 47 and from the drawings it will be evident that upon compression of the bellows 49, the valve will be closed against the action of spring 48.

The lower open end of bellows 49 preferably terminates in a ring 54 clamped between members 41 and 51 and the interior of the bellows is placed in communication with the atmosphere by means of the vent passage 55.

Chamber 50 around the bellows 49 is placed in controlled communication with the over-flow chamber 26 of the injector by means of a conduit which in the present embodiment comprises pipes 56 and 57, the connection between which is controlled by means of valve 58. Valve 58 is of the plug type and is connected by means of part 59 to the control member 36 so as to rotate therewith. The valve is conveniently maintained seated by means of spring 60.

Referring now more particularly to Figs. 2 and 3, it will be observed that the body of valve 58 is provided with two recesses or ports 61 and 62, the latter having substantially more vertical extent than the former. The housing for the valve member 58 is provided with a vent port 63 adapted to place the valve port 61 in communication with the atmosphere when the valve is in the position shown in Fig. 2. As will be seen from Figs. 1 and 2, the ends of pipes 56 and 57 are connected to the valve above one another and at substantially right angles with respect to the location of the vent port 63. When the valve is in the position shown in Fig. 1, the ends of pipes 56 and 57 are placed in communication by way of port 62 and when the valve is moved to the position indicated in Fig. 2, the end of pipe 57 is placed in communication with the atmosphere by way of ports 61 and 63 and the end of pipe 56 is closed by the body of the plug.

For rotating the control member 36 any suitable device such as lever 64 may be provided and the position of the nozzle 14 is conveniently indicated by means of a pointer 65 cooperating with a stationary indicator plate 66 which, in the present instance, has been shown as indicating ten different nozzle positions.

When the injector is intended to deliver against a relatively high pressure, such, for example, as the pressure of a locomotive or other power boiler, a small quantity of high pressure steam, hereinafter termed supplementary steam, is required and this steam is, in the form of injector herein illustrated, supplied through the supplementary steam nozzle 67 mounted in the member 11 and projecting into the bore of the main steam nozzle 14. Nozzle 67 is supplied with supplementary steam from any suitable source through conduit 68.

The general operation of the injector is known and need not be described herein in detail. When the injector is started the over-flow valve 28 is free to open and upon the admission of steam and water through nozzles 14 and 17, the steam and water mixture enters combining tube 19 and overflows therefrom through the over-flow valve until the jet is established, whereupon over-flow ceases and delivery of water under pressure commences. As soon as delivery pressure is built up in the injector, this pressure is transmitted to piston 31 and acts to keep the over-flow valve 28 closed until such time as the delivery pressure fails because of operating conditions which cause the jet which has been established to fail or break. Failure of the delivery pressure to keep the over-flow valve 28 closed permits the injector to spill immediately through the over-flow outlet and this, in some

instances, will be sufficient to cause substantially immediate re-establishment of the jet and operation of the injector. If the manually operable means for closing the over-flow valve has been employed, this means must be released before the injector can be restarted.

In an injector of the character under discussion, in which the over-flow is closed by a pressure loaded valve and in which high temperature water is delivered at high pressure by the injector, the over-flow pressure during stable operation of the injector may exceed atmospheric pressure. Under the most stable operating conditions the over-flow pressure is at a minimum value and rises as conditions of operation become increasingly unstable. Thus, for example, when the amount of water supplied to the injector is diminished so as to decrease the delivery from the injector, a point can be reached at which under the existing conditions of steam supply the amount of water fed to the injector will be insufficient to condense the steam and, as a result, the injector will "break" or "fly off". When this occurs, the injector loses its suction and steam blows through the injector and out of the over-flow. On the other hand, regulation of the injector to increase the water supply toward the maximum capacity range of the injector will cause increasing instability of operation and increasing over-flow pressure, and a condition may finally be reached which will cause over-flow or spilling of the injector due to the inability of the steam supplied to properly handle all of the water which is supplied.

In the operation of the apparatus according to the present invention, the control valve B for the low pressure or exhaust steam supply remains fully open under conditions of stable operation with minimum over-flow pressure, thus enabling the maximum amount of steam to be utilized. If, now, it be assumed that the amount of water fed to the injector is decreased with consequent rising over-flow pressure, the pressure control valve B should operate to throttle the steam supply so as to reduce the amount of steam reaching the injector. This action of the control valve will operate to increase the range of the injector by permitting the amount of water supplied to the injector to be reduced to a value lower than would be the case if an unrestricted supply of steam were supplied to the injector regardless of the quantity of water supplied. From the drawings it will be observed that when the water control member **36** is in a position of rotation such that the amount of water is decreased down to the minimum, the valve **58** is in a position such that pipes **56** and **57** are in communication and the chamber **50** is in communication with the over-flow chamber **26**. Thus a rise in the over-flow pressure caused by regulation of the water supply to diminish the quantity of water fed causes the control valve B to throttle the supply of steam to the chamber **13** of the injector, and, as a result, the minimum capacity adjustment of the water can be attained without danger of the injector breaking due to the presence of an excess of exhaust steam supply at relatively high pressure.

Considering now the other condition which is productive of rising over-flow pressure, that is, adjustment of the water supply to maximum capacity, it will be evident that under this condition it is not desirable for the control valve B to reduce the amount of steam supplied to the injector, since the rise in over-flow pressure under the assumed condition is due to a deficiency of steam. Therefore, in accordance with one phase of the present invention, we arrange the valve in the connection between the over-flow chamber and the pressure chamber of the control valve so that as the water regulator is moved to a position approaching maximum capacity of the injector, the control valve B is automatically rendered inoperative. By reference to the figures, it will be evident that when the water control mechanism is moved to a position such as shown in Fig. 2, the port **62** in valve **58** is out of communication with pipes **56** and **57**, the outlet of pipe **56** is closed so as to prevent leakage of water from the over-flow chamber and pipe **57** is vented to atmosphere by way of port **61**. With the parts in this position of adjustment, pressure in chamber **50** is vented and the control valve B is maintained in fully open position by spring **48**. We prefer to locate ports **61** and **62** with respect to the location of the ends of pipes **56** and **57**, so that if the range of capacity of the injector is indicated, as shown in Fig. 2, by a scale having 10 subdivisions, the control valve B is subject to over-flow pressure in all positions of the water control mechanism in the capacity range between minimum and approximately 8, and is rendered inoperative in the positions of the water control mechanism corresponding to injector capacities of from approximately 8 to maximum.

With the apparatus arranged in this manner, the control valve operates to permit the maximum quantity of steam to be condensed in the injector, when the operating conditions are such that this quantity of steam can be condensed without resulting in unstable operation, and also serves to control the flow of steam to the injector so as to prevent breaking of the injector due to the supply thereto of an excess quantity of steam. At the same time, reduction in the quantity of steam supplied to the injector due to the action of the control valve under conditions which require that the maximum amount of steam be supplied to the injector is avoided.

It will be clear from the above, that in some cases the complication involved in making provision for rendering the control inactive at high water rates is not warranted, and in such cases the pipe **56** is connected directly to pipe **57** without interposing any such valve as **58**. Fig. 4 illustrates an embodiment of the invention where no valve such as **58** is used. This form also illustrates the control of the exhaust steam at a different point from that of Fig. 1.

In injectors of this type, the exhaust steam is introduced at two points. The first of these is at the inlet to the main exhaust steam nozzle **14**, and the other is through the annular space surrounding the front end of water nozzle **17**. This annular space is, in Fig. 1, defined by the outer surface of the nozzle **17** and the inner surface of the combining tube **19**. In Fig. 4 a separate secondary exhaust steam nozzle **19a** is shown, this nozzle corresponding to the flared entrance of the combining tube **19** of Fig. 1. The two constructions are interchangeable as far as the present invention is concerned.

In either case the steam to this secondary steam inlet is supplied through a duct **100**, receiving such steam from chamber **13**. This duct **100** is the point at which the exhaust steam supply is controlled in Fig. 4. Instead of adjusting the entire exhaust steam supply, as in Fig. 1, only that part flowing through duct **100** to the secondary steam inlet is regulated.

The regulation is effected by means such as

butterfly valve 101 arranged to shut off more or less the passage 100. The valve is actuated by bellows 102 through rod 103 and link 104. The bellows is housed in casing 105, the interior of which communicates by means of pipe 106 with over-flow pipe 30 and over-flow chamber 26. Pressure on the outside of bellows 102 tends to collapse it, causing upward movement of rod 103 and closing movement of valve 101. A spring 107 extends the bellows 102 resiliently.

A rise in the over-flow chamber pressure will, by this mechanism, result in a proportional closing of valve 101 and cutting down of the exhaust steam to the secondary steam inlet, with the beneficial results elaborated on above in connection with the description of Fig. 1.

As mentioned above, no cut-off valve 58 is provided in pipe 106, in order to simplify the construction. Obviously such a cut-off valve 58 can, if desired, be introduced into this form also, actuated as in Fig. 1.

The main exhaust steam valve is in Fig. 4 shown at 109. It is here not used to adjust the exhaust steam flow in response to overflow chamber pressure, and is of a standard well-known form, different from that of Fig. 1.

Turning now to Fig. 5, another form of injector adapted to deliver against relatively high pressures is illustrated. This injector is of the two-stage type having a low pressure stage adapted to be operated by exhaust steam and a high pressure or forcing stage to which water is delivered from the low pressure stage and which is operated by high pressure live steam.

The general construction of the low pressure stage of this injector is similar to the form already described with respect to the admission of water and of low pressure steam for establishment of the low pressure jet. The over-flow valve construction is, however, different in that instead of a pressure loaded over-flow valve a simple gravity loaded valve 28' is employed. A gravity loaded over-flow valve for this stage is sufficient since this stage normally operates throughout its range of operation with an over-flow pressure which is less than atmospheric. If the design of the injector is such that during normal operation of the low pressure stage an over-flow pressure greater than atmospheric may be attained, it will be evident that an over-flow valve arrangement loaded by delivery pressure and similar to the arrangement illustrated in Fig. 1 may be employed with this stage.

The high pressure or forcing stage comprises a combining tube 69 having a flap covered over-flow opening 70 and a delivery tube 71 discharging by way of the usual delivery chamber to the delivery pipe 72.

High pressure live steam for the forcing stage is supplied from conduit 68' through the high pressure nozzle 73.

The over-flow valve 74 for the forcing stage is loaded, in the manner previously described in connection with the apparatus shown in Fig. 1, by delivery pressure from the delivery chamber of the forcing stage, which pressure acts on the plunger 31'.

The control valve B is similar in construction to the valve shown in Fig. 1 and is responsive to overflow pressure in the over-flow chamber of the forcing stage of the injector.

In the present embodiment, however, another form of apparatus is employed to render the control valve inoperative to reduce the steam supply when the water regulating mechanism is adjusted for maximum or substantially maximum capacity of operation of the injector. In the present instance the pressure chamber 50 of the control valve B is directly connected with the over-flow chamber of the forcing stage by means of pipe 75 so that diphragm 49 is subject at all times to the pressure existing in this chamber. The valve is rendered inoperative by live steam pressure acting counter to the pressure in chamber 50 and this is conveniently accomplished by connecting the space 76, in which spring 48 is located, with the live steam supply conduit 68' by means of pipes 77 and 78. Between pipes 77 and 78 there is interposed a valve 79 adapted to close under the influence of the pressure of steam in pipe 78 and to be lifted from its seat by rotation of the threaded block 80 screwed into the valve housing and connected at 81 to the water control member 36 so as to be rotatable therewith.

The operation of this injector is in general similar to the operation of the injector illustrated in Fig. 1. Low pressure steam is admitted through conduit 38 and water is admitted through the connection 16 to provide for the establishment of a primary or low pressure jet in the combining tube 19. Water from the delivery chamber 21 is delivered to the combining tube 69 of the forcing stage and the forcing jet is established by live steam admitted through nozzle 73.

In a two-stage injector of the type under discussion, in which low pressure steam only is supplied to the low pressure stage, the high pressure or forcing stage is likely to be the more unstable in operation of the two stages and for this reason we prefer to make the control valve B responsive to the over-flow pressure from the high pressure or forcing stage of the injector. The manner in which the delivery pressure of the forcing stage varies with variations in relative stability of the jet is in general similar to what has already been described in connection with the injector shown in Fig. 1, and the valve 79 is accordingly arranged to function in substantially the same way as the valve 58 in the form of apparatus shown in Fig. 1. The threaded block 80 is adjusted so that it will lift valve 79 from its seat only when the water regulating handle 64 is moved to a position corresponding to maximum or nearly maximum capacity of operation of the injector, and it will be evident from the drawings that when valve 79 is lifted from its seat to admit high pressure live steam to chamber 76, the control valve B will be forced to wide open position regardless of the value of the overflow pressure transmitted to the diaphragm through the pipe 75. In this connection it is to be noted that the maximum overflow pressure which can be reached before the injector spills is only a small fraction of the pressure of the high pressure steam employed to operate the forcing stage, so that the admission of high pressure steam to the comparatively small chamber 76 is sufficient to open the control valve in spite of the comparatively large area of the bellows which is exposed to overflow pressure.

It is desirable to provide, in the construction shown, a small vent 82 for relieving pressure from chamber 76 when high pressure steam is not being admitted thereto. The area of this vent is so small that it has substantially no effect upon the apparatus during periods when valve 79 is opened.

In the form of apparatus shown in Fig. 6, the construction of the injector may be either of the type shown in Figs. 1 and 4 or of the type shown in Fig. 5. The type shown in Figs. 1 and 4, in

which supplementary high pressure steam is admitted through conduit 68 to a nozzle in the main body of the injector, has been chosen by way of illustration.

The difference between the present form of apparatus and those previously described, is the provision of means whereby the injector may be operated wholly as a live steam injector when exhaust steam is not available. To this end a conduit 83 is provided for supplying live steam at low pressure to the inlet side of the control valve B. The reduction in the pressure of the live steam admitted through conduit 83, which steam will hereinafter be termed auxiliary steam, may advantageously be effected by means of a choke port through which this steam is caused to flow before reaching the steam chamber of the injector. Such a choke is indicated at 84. Between the place of admission of the low pressure live steam and the source of exhaust steam admitted through conduit 38, there is interposed a check valve 85 for preventing reverse flow of steam through conduit 38. This valve may advantageously be in the form of a flap valve pivoted on arm 86 around pin 87 and opening toward the injector.

This valve is advantageously controlled automatically. It is closed by the action of spring 88 acting on pin 89 which in turn acts on the pivoted lever 90. The latter is relatively turnable with respect to the arm 86 and is provided with a boss 91 adapted to engage the pivoted valve member 85. Lever 90 is retracted, so as to permit valve 85 to swing open under the pressure of steam in conduit 38, by means of the piston 92 operating in cylinder 93 to which steam is admitted through conduit 94.

Conduits 83 and 94 are advantageously component parts of a control system adapted automatically, upon failure of the steam supply in conduit 38, to admit live steam at low pressure to the injector from conduit 83 and to prevent back flow thereof through conduit 38 by simultaneously releasing steam pressure from conduit 94, thus permitting the check valve 85 to be closed by spring 88. Upon establishment or re-establishment of a supply of steam in conduit 38, such a control system automatically operates to cut off the supply of auxiliary steam supplied through conduit 83 and to simultaneously admit actuating steam to the conduit 94 in order to cause the lever 90 to be lifted, thereby permitting check valve 85 to be opened by the pressure of steam supplied through conduit 38.

Automatic control systems for supplying auxiliary live steam when exhaust steam is not available are known per se and form no part of the present invention. An example of a control system of this character, which is adapted to be used in conjunction with the structure shown in Fig. 6, is fully disclosed in United States Patent No. 1,757,566 granted May 6, 1930, to J. F. Griffin et al., and reference may be had to this patent for a more detailed description of the operation of such control systems.

We prefer, in an injector utilizing auxiliary steam, to employ an arrangement such as is shown in Fig. 6, since with this arrangement both the exhaust steam and the auxiliary live steam, when supplied to the injector, are subject to the action of the control valve B. This arrangement is of value in locomotive installations where the boiler pressure may vary considerably and likewise the pressure of the auxiliary live steam may vary considerably. The arrangement shown is, however, not essential to the exercise of the present invention and in instances where the auxiliary steam supplied to the injector is at substantially constant pressure, any one of a number of known forms of control system may be employed in which the conduit for admitting auxiliary steam to the injector may open directly into the main steam chamber of the injector.

It will be clear that the feature first described has application both to the form of the invention of Fig. 1, where the flow of the steam for the main nozzle as well as for the secondary nozzle is controlled, and to the form of Fig. 4, where only the steam flow to the secondary nozzle is controlled.

From the foregoing description of the several embodiments herein illustrated, it will be evident that the present invention may be applied to many different types of injectors, including injectors in which there is but one source of steam which is admitted to the main steam chamber of the injector; injectors in which the steam supplied to the main chamber of the injector is supplied thereto at low pressure and is supplemented by high pressure supplementary steam admitted through a suitable nozzle adjacent to the main steam nozzle; injectors of the multiple-stage type in which the high pressure steam is admitted through a nozzle forming a part of a separate forcing stage of the injector; and injectors of any of the preceding types with which are combined means for supplying auxiliary live steam to the main steam chamber of the injector when the injector is intended to be run primarily on exhaust steam and exhaust steam is not available.

In all of the above mentioned types of injectors, the capacity of the injector and the range of operation thereof, as determined by the range of operation in which the jet or jets is or are relatively stable, are affected by different variable factors among which the most important are the temperature and amount of water supplied to the injector, and the pressure and character of the steam supplied to the main steam chamber of the injector.

The stability of the jet or jets is greatest when the operating conditions are such as to produce a vacuum in the over-flow chamber and is relatively less as pressure is built up therein. We have found, for example, that the pressure in the over-flow chamber of an injector of the type illustrated in Fig. 1, operating against a delivery pressure of 220 pounds per square inch, with supplementary steam supplied at 220 pounds per square inch, low pressure steam supplied at one pound per square inch and suction water supplied at 50 degrees F., varies between a pressure of approximately 13 pounds per square inch gauge at minimum injector capacity of 35,000 pounds per hour, and a vacuum of 8 inches of mercury at maximum injector capacity of 55,000 pounds per hour. We have also found that the same injector operating under the same delivery and steam conditions but with suction water at a temperature of 80 degrees F. has a delivery chamber pressure varying between 10 pounds per square inch gauge at minimum capacity of about 41,000 pounds per hour and five pounds per square inch gauge at maximum capacity of about 47,000 pounds per hour. Under the latter condition the minimum over-flow chamber pressure, occurring at approximately 45,000 pounds per hour capacity, is about four pounds per square inch gauge.

From the above it will be evident that under different operating conditions for the injector,

the pressure in the over-flow chamber varies between relatively wide limits and provides ample opportunity to effect regulation due to such pressure variation. It also is evident from the above that variation in the temperature of the suction water materially affects both the operating range of the injector, other factors being equal, and the stability of the jet.

By the use of the present invention the stability of the jet may be insured to a greater degree than has heretofore been possible since the regulating means for controlling the main steam supply to the jet is responsive to an operating factor that is in turn directly indicative of the relative stability of the jet which, therefore, automatically is responsive to a condition which is produced as a result of the combined action of all of the variable factors constituting the operating conditions for the injector.

For example, let it be assumed that an injector is operating under the first set of conditions above enumerated and is delivering 45,000 pounds of water per hour, this capacity rate resulting in an over-flow chamber vacuum of about three inches of mercury. Let it further be assumed that exhaust steam is available at a higher pressure than the assumed operating pressure of one pound per square inch. If the present invention is utilized, exhaust steam at higher pressure can be admitted to the injector and a greater quantity of such steam condensed in the injector, thereby increasing the delivery temperature, without endangering the continued operation of the injector, since as soon as the amount of exhaust steam introduced at higher pressure tends to render the jet unstable, the unstable condition will be reflected in a rise in the over-flow chamber pressure which will in turn cause actuation of the control valve to throttle the exhaust steam supply to a degree insuring stable operation of the injector.

It will also be evident that if the injector is working near the limit of its capacity so that the jet is in a relatively unstable range, breaking of the jet due to an increase in the temperature of the suction water or of the pressure of the exhaust steam, or even of the pressure or temperature of supplementary high pressure steam, will be prevented by additional throttling of the exhaust or low pressure steam supply due to an increase in the over-flow chamber pressure resulting from the increased instability of the jet due to any one of the aforementioned variations in temperature or pressure of one or more of the fluids supplied to the injector.

The effect of the regulation in accordance with the present invention is, in general, the same in an injector of the type disclosed in Fig. 4, as in the type disclosed in Fig. 1.

As previously stated, we prefer, in a two-stage injector, to regulate the pressure of the low pressure steam in accordance with over-flow pressure conditions in the high pressure stage, but this arrangement is not essential to practice of the invention with a two-stage injector. If desired, the control valve B may be made responsive to the over-flow pressure of the low pressure stage which, in most instances, will be of sub-atmospheric pressure within the normal operating range of the injector. This being the case, the suction on the bellows for controlling the position of the valve would tend to maintain the valve open at all times and the spring 48 should, instead of being a compression spring, be a tension spring tending to close the valve. Further, a suitable stop should be employed to prevent the valve from closing completely under the action of the spring since if such stop were not provided, the valve would be closed by the spring under starting conditions, when no vacuum exists in the over-flow chamber of the injector.

In connection with the foregoing description, it is to be understood that by the term "pressure", with reference to over-flow chamber pressure, we refer to absolute pressure and unless otherwise specifically designated, the term "pressure" may be considered as referring to pressures both above and below atmospheric.

Also, where reference has been made to low pressure steam supplies, this term is to be understood as purely relative and that in injectors where steam is supplied from a single source to a main steam nozzle and without the supplementary action of a secondary steam supply of higher pressure, the term "low pressure steam" is to be construed as meaning such single steam supply, regardless of its actual pressure.

While, in accordance with the patent statutes, we have illustrated the best embodiments of the invention known to us, it is to be understood that these embodiments are by way of example only and that many variations and changes may be made without departing from the scope of the invention as defined in the appended claims and it is further to be understood that certain features of construction may be used, within the scope of the invention, to the exclusion of others.

What we claim is:

1. In an injector, a steam nozzle, means for admitting water to the injector, means providing an overflow chamber, means for supplying steam to said nozzle, and means responsive to pressure variation in said overflow chamber for governing the steam supply to said nozzle.

2. In an injector, a steam nozzle, means for admitting water to the injector, means providing an overflow chamber, means for supplying steam to said nozzle, and means responsive to a rise in pressure in the overflow chamber automatically to reduce the rate of steam flow to said nozzle.

3. In an exhaust steam injector, a main low pressure steam chamber, a main low pressure steam nozzle, a high pressure supplementary live steam nozzle, a water delivery nozzle, a combining tube, all of said nozzles delivering to said combining tube, an overflow chamber with which said combining tube is in communication, conduits for supplying high pressure steam and water to the supplementary nozzle and to the water nozzle respectively, a conduit for supplying exhaust steam to said main low pressure steam chamber, a regulating valve for governing flow of exhaust steam to said low pressure steam chamber, pressure responsive means for moving said valve toward closed position, and means for applying pressure from said overflow chamber to said pressure responsive means.

4. A multiple-stage injector comprising a low pressure steam nozzle, a high pressure steam nozzle, separate combining tubes each cooperating with one of said nozzles, an overflow chamber in communication with one of said combining nozzles, means for supplying low pressure steam to the first mentioned nozzle, means for supplying high pressure steam to the second mentioned nozzle, means for governing the low pressure steam supply, and means responsive to variations in pressure in said overflow chamber for actuating said governing means.

5. In an exhaust steam injector of the type adapted to be operated by auxiliary live steam in the absence of an exhaust steam supply, a conduit for supplying low pressure steam to the injector, a regulating valve in said conduit, said regulating valve being responsive to variations in the overflow pressure within the injector, and a conduit for supplying auxiliary live steam to said low pressure conduit on the inlet side of said regulating valve.

6. In an injector, a steam nozzle, means for admitting water to the injector, control means for governing the amount of water admitted to the injector, means providing an overflow chamber, means for supplying steam to said nozzle, means responsive to a rise in pressure in the overflow chamber to reduce the rate of steam flow to said nozzle, and means for rendering the pressure responsive means inoperative when the control means is adjusted for operation of the injector at a rate approaching its maximum capacity.

7. In an injector, a steam nozzle, manually controllable means for admitting a regulated supply of water to the injector, means providing an overflow chamber, a conduit for supplying steam to said nozzle, a valve for controlling flow of steam through said conduit, pressure responsive means for controlling the position of said valve, a conduit connecting said pressure responsive means with said overflow chamber, and means operatively associated with said manually controllable means for rendering said pressure responsive means inoperative to close said valve when said manually controllable means is adjusted for operation of the injector at a rate approaching maximum capacity.

8. In a multiple-stage injector, a low pressure stage adapted to be operated by low pressure steam and a forcing stage adapted to be operated by high pressure steam, each of said stages having an overflow chamber, a conduit for supplying low pressure steam to said low pressure stage, a valve for controlling flow of steam through said conduit, pressure responsive means for controlling said valve, a conduit for connecting said pressure responsive means with the overflow chamber of the least stable of said stages, and means for rendering said pressure responsive means inoperative when the injector is adjusted for operation at a rate approaching maximum capacity.

9. In the operation of an injector of the type having an overflow chamber, that improvement which consists in varying the rate of admission of a steam supply to the injector in response to variations in pressure in said overflow chamber while the injector is operating in the major portion of its range of operation and admitting the steam from said supply to the injector at an uncontrolled rate while the injector is operating at a rate approaching maximum capacity.

10. In the operation of an injector of the type having an overflow chamber and adapted to be operated by steam at different pressures, that improvement which consists in varying the rate of admission to the injector of a steam supply of lower pressure in response to variations in pressure in said overflow chamber while the injector is operating in the major portion of its range of operation and admitting the steam from said supply of lower pressure at an uncontrolled rate while the injector is operating at a rate approaching maximum capacity.

11. In the operation of an injector of the type having a plurality of stages, each having an overflow chamber and adapted to be operated by steam at different pressures, that improvement which consists in varying the rate of admission to the injector of the steam supply of lower pressure under the influence of variations in pressure in one of said overflow chambers while the injector is operating in the major portion of its range of operating and admitting the steam from said supply of lower pressure at an uncontrolled rate while the injector is operating at a rate approaching maximum capacity.

12. In the operation of a steam injector having an overflow chamber, the improved method which consists in admitting high pressure steam to the injector, admitting exhaust steam to the injector and governing the rate of admission of exhaust steam to the injector in response to variations in pressure in said overflow chamber.

13. In the operation of a steam injector having an overflow chamber, the improved method which consists in supplying exhaust steam to the injector and governing the rate of flow of exhaust steam to the injector in response to variations in pressure in said overflow chamber by throttling the supply of exhaust steam due to increase in pressure in said overflow chamber.

14. In an injector, a main low pressure steam nozzle, a water nozzle, and further nozzle means comprising secondary low pressure steam receiving means and a combining tube, overflow means in communication with the combining tube, means to supply low pressure steam to the main exhaust nozzle, means to supply said secondary low pressure steam, and means to control said secondary low pressure steam supply in response to pressure conditions in the overflow means.

15. In an injector, a main low pressure steam chamber, a main low pressure steam nozzle, a water nozzle, a secondary low pressure steam nozzle, a combining tube, said nozzles and tube being axially alined in the order named, an overflow chamber with which said combining tube is in communication, a conduit for supplying low pressure steam to said main low pressure steam chamber, said main low pressure steam nozzle being arranged to receive steam directly from said main low pressure steam chamber, a conduit from the main low pressure steam chamber to the inlet of the secondary low pressure steam nozzle, a regulating valve in said last-named conduit for governing the flow of low pressure steam to said secondary low pressure steam nozzle, pressure responsive means for moving said valve toward closed position, and means for applying pressure from said overflow chamber to said pressure responsive means.

16. In the operation of an injector of the type having an overflow chamber and two nozzles each having means for supplying it with low pressure steam and arranged for flow successively through them, the improvement which consists in varying the rate of admission of steam supply to the second of said nozzles in the order of flow in response to variations in pressure in said overflow chamber.

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