Feb. 20, 1945. W. H. TINKER 2,369,692

STEAM JET PUMP

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Fig. 1a

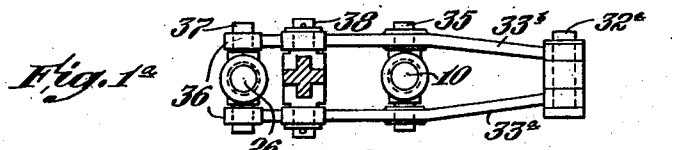


Fig. 6

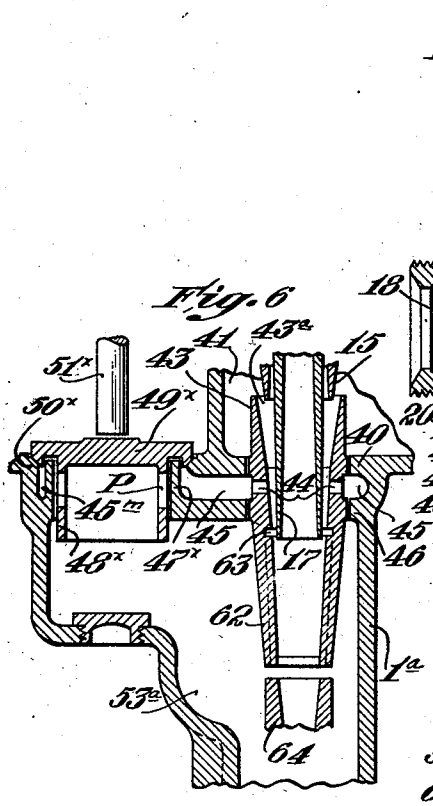
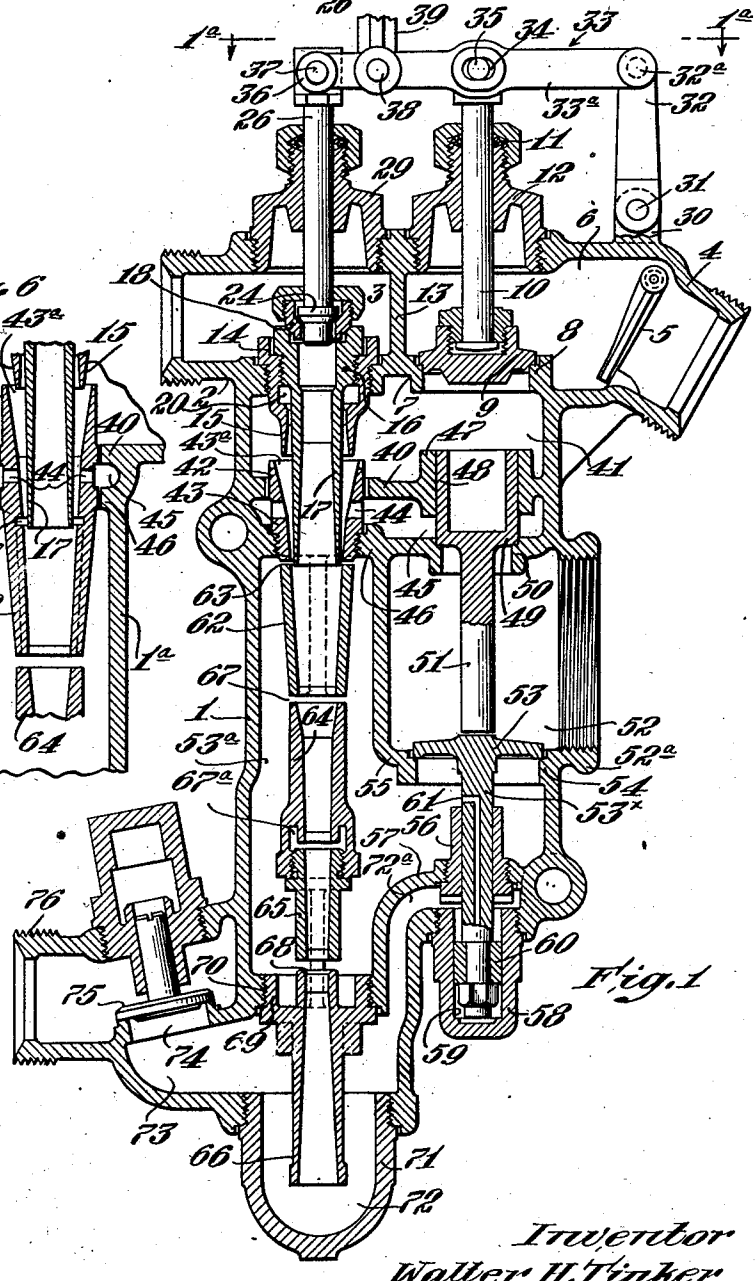


Fig. 1



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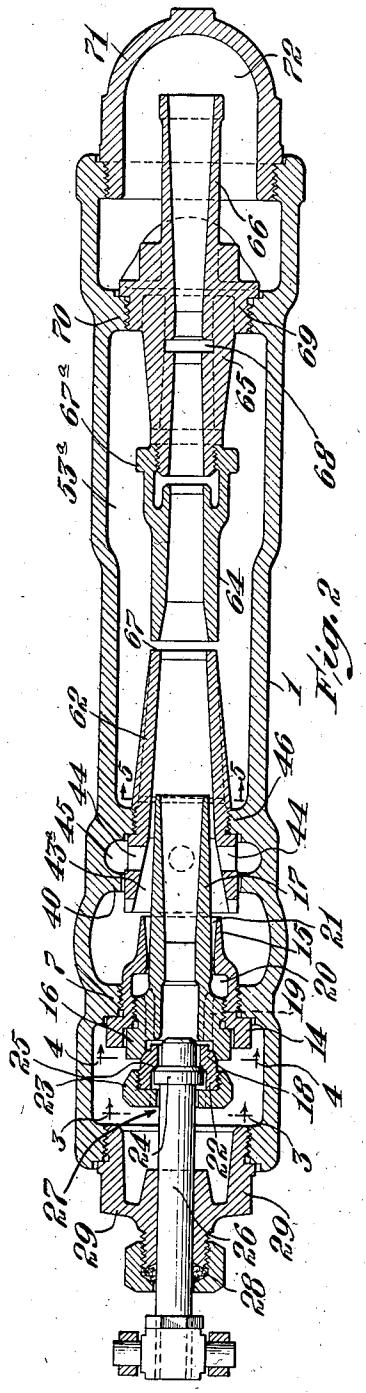


Fig. 2

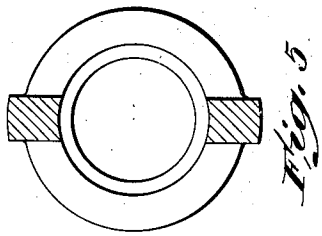


Fig. 5

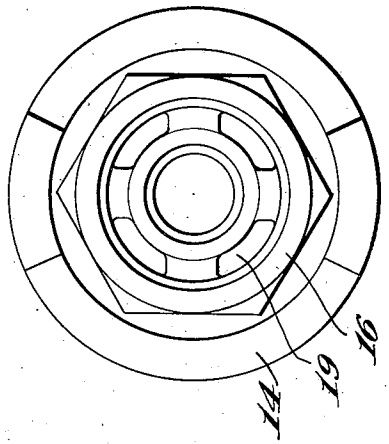


Fig. 4

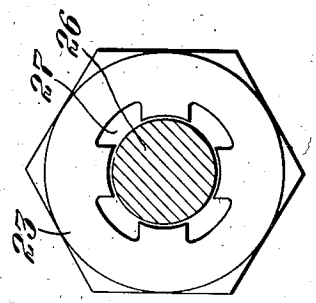


Fig. 3

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Fig. 7

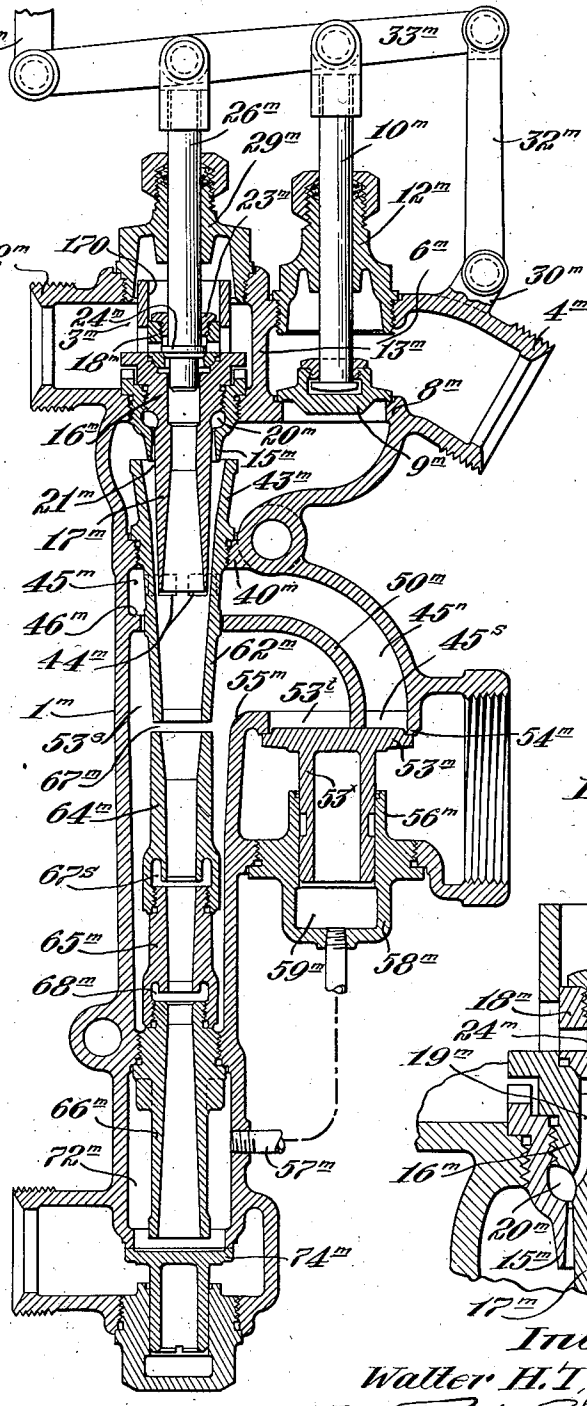
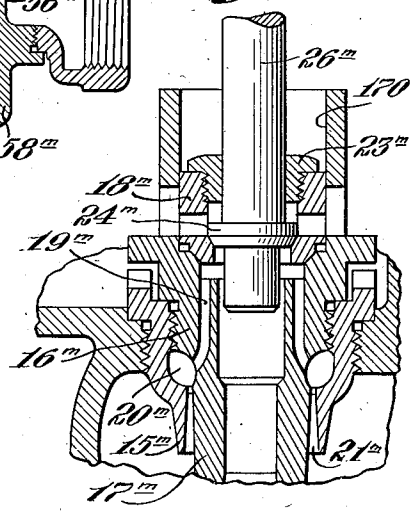


Fig. 8



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UNITED STATES PATENT OFFICE

2,369,692

STEAM JET PUMP

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Application August 21, 1942, Serial No. 455,563

17 Claims. (Cl. 103—270)

This invention pertains to steam jet pumps of the type commonly known as injectors and wherein a portion of the heat energy of steam is directly converted into mechanical energy for the purpose, for example, of forcing feed water into a boiler against a pressure which may be as great or greater than that of the steam supplying the jet and the residue of such heat is returned directly to the boiler.

While of broader utility and application, the invention is herein described and illustrated by way of example with reference to its embodiments in an injector of the axial-flow type. Preferably, although not necessarily, it is intended to be arranged in accordance with usual locomotive practice at a level below the level of the feed water supply so that under normal conditions water under some head is present in the injector inlet.

A primary object of the invention is to provide an injector of automatic restarting type which is also satisfactory in respect to its ability to deliver hot feed water against pressures encountered in practice.

In the operation of an injector of this type there must be a free communication with the water supply when the injector is started, and after the injector has come into full operation and is delivering water to the boiler against the boiler pressure, it is desirable to control the rate at which the water is so delivered. For practical reasons, it is difficult to control this rate of delivery merely by varying the amount of steam supplied, and it is generally desirable and common practice to continue the steam supply at maximum flow through the operation of the instrument, after starting, and to vary the rate of delivery of water to the boiler by governing the amount of water which enters the injector. Heretofore, this has commonly been done by providing the water supply pipe with a valve independent of that which controls the admission of steam, thus permitting the water valve to be opened more or less without necessarily disturbing the setting of the steam-admission valve.

In its more general aspects a further object of the invention is to provide an injector capable of delivering against a boiler pressure of the order of 300 pounds per square inch for example; which has a single control handle for starting, regulating and stopping it; which will automatically restart if it breaks during operation due to lack of or excessively hot feed water; which starts without excessive waste of water; which may be depended upon to start and operate effectively with feed water as hot as 135° F; and which is of simple, durable and inexpensive construction.

It is a known fact that an injector will start more rapidly when the steam is first admitted and caused to entrain the water from the supply rather than when the steam is admitted to flooded injector chambers. When the steam leads the water, the first water which enters the combining tube combines quickly with the steam, condensing the latter and starting the effective injector action, such action often taking place under such circumstances so quickly that there is no waste of water at all through the overflow. This relation of events prevents premature development of liquid pressure in the delivery chamber which might close the overflow valve too soon, that is prior to establishment of the delivery jet.

Accordingly, it is a more specific object of the present invention to provide practical and simple means whereby, in an injector of this type, the steam leads the water when the apparatus is started and wherein the admission of water may readily and accurately be controlled without decreasing the amount of steam below that required to deliver the water admitted through the water-admission valve, and in which the movement of both the water and steam-admission valves from full-closed to full-opened position, as well as the regulating movement of the water-admission valve, may be accomplished by manipulation of a single handle.

The initial establishment of flow and the maintenance of such flow under adverse conditions, such for example as abnormally warm feed water, are among the most difficult problems confronting the designer of injectors. To facilitate the establishment of flow it is common, at least in the axial-flow type of injector, to provide an overflow passage or passages so devised that when the steam is first admitted, the free flow of steam, condensate and feed water will not be greatly impeded, thus permitting progressive building up of velocity until energy sufficient has been developed to force the feed water past the check valve into the boiler. While the continued operation of the apparatus, after the jet is once established, is not dependent upon the closing of this usual overflow, it has been found that if this overflow remain open during operation, there is a tendency for the jet to draw in air, dust and cinders, which are delivered with the water into the boiler. For these reasons, among others, it has been common to provide the overflow with a valve designed to be closed after the jet has been

established and also to be closed while the injector is idle. However, if this be a manually operated valve, skill and careful attention on the part of the operator are necessary for its proper actuation and furthermore, if the injector "breaks" during operation, the flow will not be reestablished until the operator has manually opened this overflow valve.

Commonly the tube assembly is furnished with a plurality of spaced spillway passages all leading into an overflow chamber of limited capacity. During establishment of the delivery jet, the several spillways successively come into action so as to vent the advancing stream of fluid and thereby prevent undue decrease in velocity. After the jet has been established, these spillways continue to have functional value, the later spillways of the series, in particular, permitting a sort of "breathing" action during which fluid may move outwardly through some and inwardly through others. However, the entrance end of the tube assembly is where the greatest difficulty is encountered in establishing the jet and it is here that the stream of mixture is at all times most sensitive to variations in pressure conditions. Thus, at this entrance end, sufficient spillway area must be provided during starting to insure free escape of the steam delivered by the entraining nozzle, together with some at least of the entrained water, thereby to insure the requisite high velocity for the proper entrainment of the water. On the other hand, too large an area of spillway at this early stage is not conducive to good continued operation, particularly if this early spillway be subject to the variable pressure conditions which subsist during operation in the overflow chamber into which the later spillways deliver.

As just above pointed out, it is common practice in injectors of the open overflow type, just referred to, to make the combining tube in several sections with a lateral outlet or spillway adjacent to the delivery end of each section, all of such spillways being constantly open into the main overflow chamber of the injector. However, so far as I am aware, it has not previously been recognized that greatly improved results with respect to initial establishment of flow and particularly automatic restarting after "breaking" may be obtained by making the first spillway of large capacity and providing a conduit leading from said first spillway directly to the outer atmosphere or other space wherein pressure conditions are substantially constant, said first spillway being of such capacity as to discharge substantially all of the steam delivered by the regulating nozzle together with the water entrained thereby, but with the proviso that said auxiliary spillway be closed (preferably automatically) when the injector is idle and when it is in full operation but be open directly to the atmosphere (not into the main overflow chamber) during the establishment of operative flow. Accordingly, a further object of the invention is to provide an injector having adequate spillway area at an early point in the tube assembly, for example at a point not far removed from the delivery end of the forcer nozzle, but with provision for protecting this initial spillway of large area from the variable pressure conditions existing in the main overflow chamber into which the other spillways deliver, and with further provision for automatically closing this initial spillway as soon as the jet has been established.

A further object of the invention is to devise an injector of this general type having provision whereby the quick starting of the injector is assured and its continued operation made certain even under adverse conditions, but without requiring the provision of auxiliary manually operated valves or other devices for controlling the overflow.

A further object is to provide an injector of this type which will start and automatically restart more easily and certainly than previous injectors; which will deliver against a high pressure head; which is of simple and durable construction; and which embodies an automatic overflow valve which functions not only to close the usual overflow conduit of the injector when the latter is idle or in full operation, but which also controls an auxiliary overflow conduit leading from the first spillway located at a point near the entrance throat of the combining tube and which does not communicate with the usual overflow chamber.

Other and further objects and advantages of the invention will be pointed out hereinafter and by reference to the accompanying drawings, wherein

Fig. 1 is a vertical section illustrating one embodiment of the present invention;

Fig. 1[a] is a fragmentary horizontal section substantially on the line 1[a]—1[a] of Fig. 1;

Fig. 2 is a longitudinal section (to larger scale and horizontally disposed) in a plane at right angles to that of Fig. 1, illustrating the nozzle assembly and omitting other parts;

Fig. 3 is a section, to larger scale, on the line 3—3 of Fig. 2;

Fig. 4 is a section, to larger scale, on the line 4—4 of Fig. 2;

Fig. 5 is a section, to larger scale, on the line 5—5 of Fig. 2;

Fig. 6 is a fragmentary section similar to Fig. 1, but illustrating a modification;

Fig. 7 is a section similar to Fig. 1 but illustrating another and preferred embodiment of the invention; and

Fig. 8 is a fragmentary section, to larger scale than Fig. 8, showing details of the steam-admission valve and adjacent parts.

Referring to Figs. 1 to 5 of the drawings, the numeral 1 indicates the casing of the injector. This casing as here shown (Fig. 1) is a unitary casting so devised and with the operative parts so relatively arranged and located as to permit all necessary machine work to be done easily and inexpensively. This casing has a projecting screw-threaded nipple 2 to which the steam supply pipe may be connected, the steam which is supplied through the pipe entering an inlet chamber 3 within the casing. The casing also has a projecting screw-threaded nipple 4 to which the feed water hose is connected, a feed water check valve 5 being arranged at the entrance to the water inlet chamber 6.

The casing has a transverse septum 7 provided with an aperture defined by an annular valve seat 8 with which cooperates the water-admission valve 9. This valve 9 has an actuating stem 10 which passes out through a stuffing box 11 carried by a removable cap 12 coaxial with the valve stem 10 and which is screw threaded into an aperture in the casing wall. Preferably, the stem 10 is so connected to the valve 9 as to permit the valve to seat without cramping and also to allow a slight axial movement (for ex-

ample of the order of ⅛ of an inch) between the valve and stem.

A partition 13 separates the steam inlet chamber 3 from the water inlet chamber 6. That portion of the septum 7 which forms the lower wall (Fig. 1) of the steam inlet chamber 3 is provided with a screw-threaded opening which receives the externally threaded annular body portion 14 (Figs. 1 and 2) of the regulating or lifting or entraining nozzle 15. This body portion of the regulating or entraining nozzle is also internally screw threaded and receives the externally screw-threaded body portion 16 of the forcer nozzle 17, said forcer nozzle 17 being coaxial with and extending through the regulating nozzle 15. The upper end (Fig. 1) of the body portion 16 of the forcer nozzle 17 is shaped to constitute an annular valve seat with which cooperates the main steam-admission valve 18 (Fig. 2). Passages 19 lead from a point just below said seat through the body portion 16 of the forcer nozzle to an annular chamber 20 (Fig. 2) within the body portion 14 of the regulating nozzle. The annular flaring passage 21 of the regulating nozzle leads from the chamber 20.

The main steam-admission valve comprises a hollow skirt portion 22 (Fig. 2) provided with a removable cap 23 thereby providing a chamber for the reception of a pilot valve 24 which normally seats against an annular valve seat 25 within the skirt portion of the main valve. A stem 26 fixed to the pilot valve 24 extends with clearance through an aperture 27 in the cap 23 and through a stuffing box 28 carried by a plug 29 threaded into an aperture in the casing wall, said valve stem 26 being coaxial with the regulating and forcer nozzles, the chamber in part 22 being of such axial depth as to permit unseating the pilot valve before the latter engages the cap 23.

A boss 30 (Fig. 1), projecting upwardly from the casing, receives a pivot pin 31 which passes through one end of a fulcrum lever 32 whose upper end is pivotally secured by a fulcrum pin 32^a to one end of the valve-actuating lever 33. This lever is arranged to swing in the plane of the axes of the two valve stems 10 and 26 and at an intermediate point in its length is provided with spaced elongate bearings 34 for the opposite ends of a pin 35 extending from a cap or collar fixed to the valve stem 10, the lever 33 comprising substantially parallel bars 33^a and 33^b (Fig. 1^a) spaced to receive the valve stem 10 between them.

The free end of the lever 33 is provided with bearings 36 for the ends of a pivot pin 37 extending from a collar fixed to the valve stem 26. Intermediate these pins 35 and 37, the lever 33 has bearings for a third pivot pin 38 which is carried by a link 39 forming one element of suitable connections leading to an actuating handle (not shown) located conveniently in the locomotive cab.

As illustrated, the relative location of the pivot pins 32^a, 35 and 37 is such that when the actuating handle is manipulated so as to swing the lever 33 about its fulcrum pin 32^a, the arc of movement of the pin 37 is greater than that of the pin 35 and thus the rate of opening of the steam valve is greater than that of the water valve. When the actuating handle is first moved, the pilot valve is separated from its seat, thus substantially balancing the pressure upon the main steam valve and making it easy to raise the latter from its seat. The ratio of distances between the pins 37 and 35 and the fulcrum pin 32^a will be determined with reference to the relative sizes of the steam and water valves. This ratio is so calculated that the steam supply valve may be opened to maximum capacity well before the water valve has been opened to full capacity, and thus, further movement of the actuating handle in the same direction, although not affecting the quantity of steam delivered, varies the amount of water which may enter the injector. In other words, when the steam valve is at full opening, the water supply may be regulated by manipulating the same handle and without reducing the steam supplied. Obviously, by using valves of other, but well-known types, it would be possible to obtain the desired regulation by the use of a single handle, even though the ratio of distance between the fulcrum pin 32^a and the stems 10 and 26 were quite different from that herein specifically suggested.

A second transverse septum 40 extends across the casing and forms the bottom wall of the water supply chamber 41. This septum 40 has an aperture, coaxial with the forcer nozzle, which receives the annular body portion 42 of the water-regulating cone 43, said cone constituting, in effect, the first or throat section of the multi-section combining tube, said cone having a converging annular throat 43^a through which passes the free end portion of the forcer nozzle, the annular space between the wall of this annular throat and the forcer nozzle determining the quantity of water fed to the forcer nozzle. In accordance with the present invention, auxiliary or emergency spillway passages 44 lead laterally from the converging throat 43^a of the cone 43. These passages have no communication with the usual overflow chamber and open into a chamber 45 between the aforesaid septum 40 and a substantially parallel septum 46 which constitutes the upper end of the usual overflow chamber, said septum having a screw-threaded aperture which receives external screw threads upon cone 42, the cone making leak-tight contact with the septum.

The auxiliary spillway passages 44 have a combined area sufficient to pass substantially all of the steam delivered by the regulating nozzle 15 together with any water entrained thereby, and in the event of abnormally high pressures in the combining tube and overflow chamber, such as may occur when the injector "breaks," these auxiliary spillways 44 prevent steam from backing up into the water chamber 41 by affording a free exit to the atmosphere for steam from the regulating nozzle.

The second section 62 of the combining tube is supported by and as here shown is integral with the cone 43, there being a constantly open spillway passage 63 between the delivery end of cone 43 and the receiving end of the tube section 62. The delivery end of the forcer nozzle 17 is here shown as just within the larger end of section 62.

The septum 40 (Fig. 1) is provided with an open ended elongate guide bearing 47, coaxial with the water valve 9, in which slides the cylindrical skirt portion 48 of an automatic overflow valve 49 designed at times to engage an annular seat 50 defining the upper edge of an aperture in the septum. This valve has a stem 51 extending downwardly across a large outlet chamber 52 always freely open to the atmosphere, the casing having an internally threaded

nipple portion 52ª defining a port leading from the chamber 52 and to which a waste water connection may be secured. When the valve 49 is seated, the outlet from chamber 45 is closed, but when the valve is unseated chamber 45 is vented directly and very freely to the atmosphere through chamber 52 and in that event pressures in chamber 45 are wholly unaffected by conditions in the main overflow chamber of the injector.

The end of valve stem 51 is normally disposed closely adjacent to (but slightly spaced from) the head 53 of the main overflow valve (of larger diameter than the valve 49) designed at times to engage an annular seat 54 defining the upper edge of a passage in a web 55 extending transversely of the casing, said passage providing communication (when the valve head 53 is unseated) between the outlet chamber 52 and the main overflow chamber 53ª of the injector.

The stem 53ˣ of valve 53 extends through a vertically elongate guide sleeve 56 (Fig. 1) having threaded engagement with an aperture in a web 57 and into a removable cap 58 having threaded engagement with the casing wall, said cap 58 being internally shaped to provide a cylindrical guideway 59 in which fits a piston 60 secured to the end of the valve stem 51. A port 72ª leads from the delivery chamber 72 to the space within the cap 58 at the upper side (Fig. 1) of the piston 60, so that the upper side of the piston is always exposed to delivery chamber pressure. The valve stem 53ˣ has a small axial passage 61 leading from the overflow chamber 53ª into the closed end of this cap 58 (or alternatively the cap may have a small aperture in its closed end) thereby preventing the trapping of air in the closed end of the cap, insuring free movement of the piston and affording escape for leakage, thereby preserving the desired unbalanced condition of the valve.

The third section 64 (Fig. 2) of the combining tube is removably supported by and in axial alignment with the fourth setcion 65 of the combining tube which in turn is supported by the delivery tube 66, it being noted that lateral spillways are provided at the points 67, 67ª and 68. The delivery tube 66 has an externally threaded body portion 69 which engages a threaded opening in the web 70. A removable cap 71, having a screw-threaded engagement with the casing 1, provides a chamber 72 into which the jet is discharged by the delivery tube 66, said chamber 72 communicating freely with the delivery chamber 73 from which leads a delivery opening 74 with which cooperates the line check valve 75. A nipple 76, integral with the casing, provides for connection of the boiler feed pipe.

Since the caps 29 and 71 are in alignment with the nozzles 15 and 17 and the tube sections, and since the caps 12 and 58 are in axial alignment with the water and overflow valves 9 and 49, it is possible to machine the valve seats and threaded apertures without difficulty and to install or withdraw the various operative parts at will, even though the casing be of unitary one-piece construction.

In Fig. 6 a modified construction is suggested, wherein the essential elements of the injector are in general similar to those above described, the injector comprising the casing 1ª provided with the water supply chamber 41, the regulating and forcer nozzles 15 and 17, respectively, the regulating cone 43, the combining tube sections 62, 64, etc. and the main overflow chamber 53ª, together with the steam-admission valve and other parts not shown. However, if desired the manually actuated water control valve is omitted, the water inlet then being provided with a check valve, not shown, generally similar to valve 5 above described, but having connections to the actuating handle whereby it may be used for throttling the water.

In the arrangement of Fig. 6, the automatic overflow valve 49 of Figs. 1 and 2, is replaced by a valve 49ˣ which cooperates with a seat 50ˣ so as normally to close an annular port 45ᵐ leading from the chamber 45 directly to the atmosphere. The valve 49ˣ has an elongate cylindrical guiding skirt 48ˣ which slides in a guide sleeve 47ˣ, the skirt having ports P which provide communication between the main overflow chamber 53ª and the atmosphere when the valve 49ˣ is fully open. A control rod 51ˣ, suitably guided for axial movement, has one end normally disposed closely adjacent to the outer surface of the valve 49ˣ, the opposite end of this rod being pivotally secured to an actuating lever (not shown) corresponding to the lever 33 above described, by means of which the steam-admission valve is manipulated. When the steam-admission valve is closed, the end of the rod 51ˣ is so located that the valve 49ˣ cannot leave its seat and thus when the injector is idle the valve is closed. When the steam valve is open, the valve 49ˣ is then free to move away from its seat. One of the first effects of opening the steam valve is to build up pressure in the main overflow chamber 53ª and in response thereto the valve 49ˣ moves away from its seat. At an early stage in such movement it uncovers the port leading from chamber 45, thus freely venting the auxiliary spillway passages 44 to the atmosphere. Soon thereafter the ports P are uncovered to permit water to overflow from the chamber 53ª. However, when the delivery jet has been actually established, pressure in the chamber 53ª normally drops to subatmospheric and the valve 49ˣ is thereby automatically closed, thus closing the ports P and also closing the outlet from the chamber 45. Obviously, if the injector should "break" while the steam-admission valve is open, the resultant back pressure in chamber 53ª will instantly open valve 49ˣ thus automatically restoring the parts to starting position.

Assuming that the injector is idle and that its several parts occupy the relative positions substantially as illustrated in Figs. 1 and 2, the operator may start the device into action by so moving the link 39, by means of the control handle, as to swing the lever 33 in a clockwise direction, as viewed in Fig. 1. This movement of the lever 33 results in a simultaneous axial movement of the valve stems 10 and 26, respectively, but since the pivot pins 35 and 37 are located at different distances from the fulcrum pin 32ª, the valve stems will move at different speeds. Thus as illustrated, the lever arm 32ª—37 is twice as long as the lever 32ª—35 and thus the steam valve stem will move twice as fast as the water valve stem. At this point it may again be noted that the diameter of the water inlet valve 9 is substantially greater than that of the steam-admission valve 18. If, for specific example, it be assumed that for full opening the water valve 9 must move a distance of $^{10}/_{16}$ of an inch and that maximum opening of the steam valve 18 requires a movement of $^{7}/_{8}$ of an inch, it may readily be seen that when the water valve is fully open the steam valve will have moved twice $^{10}/_{16}$ of an inch.

or 2/16 of an inch, and that when, on the reverse movement, the water valve has been half closed, or is 1/8 of an inch open, the steam valve is still 1/16 of an inch open, that is to say, well beyond its maximum effective opening. It therefore follows that in starting the injector, the steam valve reaches full open position when the water valve is less than half open, and that continued movement of the single actuating handle in the opening direction after the steam valve is fully open results in a further, idle movement of the steam valve but in an effective increase in opening of the water valve. Thus a substantial regulation of the amount of water admitted to the chamber 41 is possible by moving the actuating handle back and forth after it has been swung far enough to open the steam valve to maximum effective opening.

During the initial actuation of the operating handle the steam valve leads the water valve, thus always assuring an adequate supply of steam, and permitting independent control of the water supply when the steam is entering in full volume, but without necessitating the employment of a separate handle for varying the water supply.

The first effect of moving the steam valve stem 26 is to unseat the pilot valve 24, thus admitting steam in sufficient quantity to the under side of the main valve partially to balance the latter, and thus to make it easy to unseat the main valve by continued movement of the stem 26. As the steam passes from the chamber 3 and through the open main valve, some of it flows through the passages 19 into the chamber 20, from whence it passes through the throat of the regulating or entraining nozzle 15 into the large or entrance end of the converging throat 43a of the regulating cone 43. This steam delivered from the nozzle 15 entrains water from the chamber 41 and delivers it into the throat 43a wherein the steam is partially condensed. A much larger volume of steam passes directly through the forcer nozzle 17 and entering the main overflow chamber 53a establishes therein a superatmospheric pressure. This pressure, acting upon the valve 53, unseats the latter, thus providing free communication between the main overflow chamber 53a and the atmosphere. As the valve 53 unseats it engages the end of the stem 51 and thus unseats the valve 49, thus connecting the auxiliary spillway passages 44 in the cone 43 directly with the atmosphere. Resistance to the forward travel of the steam and water within the entrance to the throat 43a is thus immediately reduced and this reduction in pressure at this point has been found to be highly effective in the rapid establishment of high velocity flow through the cone 43 and into the first combining tube section 62. Since the passages 44 are vented directly to the atmosphere, the pressure within the throat 43a is in no way affected by pressure variations within the overflow chamber 53a. The steam which is delivered by the nozzle 15 into the throat 43a is condensed and loses pressure and some of the entrained water and condensate pass on through the narrower part of the throat 43a to the spillway 63 where the water meets steam delivered through the forcer nozzle and condenses some of this steam, thus further adding to the velocity of the jet, the several spillways, 63, 67, 67a and 68, functioning in the usual manner until the jet through the delivery tube 66 has been fully established. Upon establishment of the jet the pressure in the overflow chamber 53a tends to drop and the valves 53 and 49 thereupon close and remain seated during the operation of the apparatus. However, if during operation the injector "break," due for instance to lack of feed water the resultant back pressure in chamber 53a immediately unseats the valves 53 and 49, thus restoring the parts to starting position, with the result that the injector will restart without attention from the operator and without substantial loss of feed water. It may be noted that the valve 49 is substantially balanced as respects pressure variations in the spillway passages 44, and that the valve 53 is normally held closed during operation of the apparatus by pressure from the delivery chamber 73 acting (through the port 72a) upon the upper side (Fig. 1) of the piston 60. After the injector has thus been placed in operation, manipulation of the actuating handle within a range above that effective fully to open the steam valve, will move the water valve so as to regulate the amount of water supply. To shut down the injector it is merely necessary to actuate the handle so as to swing the lever 33 in a counterclockwise direction until both the steam and water valves are closed.

Referring to Fig. 7 of the drawings, which illustrates another and preferred embodiment of the invention, the numeral 1m indicates the casing of the injector, said casing corresponding in general to the casing 1 above described, having the screw-threaded nipple 2m to which the steam supply pipe may be connected and having the steam inlet chamber 3m, and also having the screw-threaded nipple 4m to which the feed water hose is connected and which gives access to the water inlet chamber 6m.

The casing has a transverse septum provided with an aperture defined by an annular valve seat 8m with which cooperates the water-admission valve 9m. This valve has an actuating stem 10m which passes out through a stuffing box in a removable cap 12m.

A partition 13m separates the steam inlet chamber 3m from the water inlet chamber 6m, and that portion of this septum which forms the lower wall of the steam inlet chamber 3m is provided with a screw-threaded opening which receives the externally screw-threaded body portion of the regulating or lifting nozzle 15m (Fig. 8). The body portion of the regulating nozzle is internally screw threaded to receive the externally screw-threaded body portion 16m of the forcer nozzle 17m, the latter having the upwardly extending cylindrical portion 170 (Fig. 8) constituting a guide for the main steam valve 18m which controls the delivery of steam to the regulating and forcer nozzle. The valve 18m is annular and provides a seat for the pilot valve 24m, the latter having limited movement relatively to the main valve as determined by the removable bushing or cap 23m secured to the skirt of the main valve. The pilot valve 24m is integral with the lower end of the actuating stem 26m which passes out through a stuffing box in the cap 29m.

A boss 30m, integral with the casing 1m, provides a bearing for a pin forming a pivot for the lower end of the fulcrum lever 32m. This lever swings in the plane of the axes of the two valve stems 10m and 26m, and its upper end forms a fulcrum for the valve-actuating lever 33m which is pivotally connected to the upper ends of the valve stems 10m and 26m, respectively, and whose free end is pivotally secured to an actuating link 39m forming one element of suitable connections leading to an actuating handle (not shown). The

relative location of the pivot pins which connect the valve stems to the lever 33m may be as above described with respect to the structure shown in Fig. 1. While this relative arrangement of the pivot pins is desirable when valves such as here illustrated are employed, it is to be understood and is obvious that if the water-admission and steam-admission valves be of different types or different relative dimensions, the ratio of distances between the fulcrum point of lever 33m and the pins which connect it to the respective valve stems may be different from that here shown without affecting the proper sequence of operation of the valves.

In the arrangement shown in Fig. 7, two parallel partitions or septums 46m and 40m extend transversely across the casing, being spaced apart to provide between them the upper portion 45m of a spillway conduit. In this instance the septum 40m is screw threaded for the reception of external screw threads upon the exterior of the water-regulating 43m, said cone constituting the upper or first member of the combining tube.

The body portion 16m of the forcer nozzle is furnished with passage 19m (Fig. 8) which lead from a point immediately beneath the main valve 18m into an annular chamber 20m from which leads the flaring annular passage 21m of the regulating nozzle 15m, said annular passage 21m being here shown as terminating substantially at the entrance end of the regulating cone 43m. The forcer nozzle 17m extends down into the water-regulating cone 43m, terminating substantially at the level of the spillway chamber 45m, the combining tube being provided with the auxiliary spillway openings 44m leading from its interior into the conduit 45m. The combined area of these spillway openings 44m is preferably sufficient to accommodate the maximum volume of steam which may be delivered by the regulating nozzle 15m together with the water which is entrained by said steam.

The casing is provided with an internal septum 55m having an aperture defined by the annular valve seat 54m with which cooperates the automatic overflow valve 53m. This valve is provided with a stem 53x which slides in a cylindrical guideway 56m provided in a cap 58m which is screw threaded into the casing wall. This cap is shaped to provide a chamber 59m which communicates by means of a pipe 57m with the delivery chamber 72m.

The septum 46m, above referred to, is extended across the casing to provide the dividing wall 50m which defines the lower part 45n of the conduit 45m, separating said conduit from the usual overflow chamber 53s. The overflow valve 53m constitutes a closure for the outlet end 45s of the conduit 45m—45n and also for the outlet port 53t leading from the overflow chamber 53s, the valve 53m being arranged to seat upon the seat 54m and also (preferably with a slight clearance) against the lower edge of the wall 50m. During the operation of the injector, the valve 53m is held seated by fluid pressure acting beneath the valve head, the pressure thus acting on the valve head being that which subsists in the delivery chamber 72m.

The combining tube comprises a second section 62m and a third section 64m having their ends spaced to provide the spillway passage 67m opening into the usual overflow chamber 53s. The combining tube also comprises the fourth section 65m which is spaced from the delivery end of the section 64m to provide the spillway passage 67s leading into the overflow chamber 53s. Between the delivery end of the combining tube section 65m and the receiving end of the delivery tube 67m is another spillway passage 68m, also leading into the overflow chamber 53s. It is to be understood that the spillway passages 67m, 67s and 68m and tapers of the tube sections 62m, 64m, etc. are proportioned to accommodate the flow of steam from forcer nozzle 17m upon starting and the flow of mixture during operation, said spillways and tube proportions being in general of conventional size and arrangement such as commonly used in in injectors of the open overflow type, the spillways being of properly limited capacity to avoid substantial interference with the uninterrupted delivery of the water against a high boiler pressure when once the delivery jet has been established.

A line check valve 74m is arranged coaxially with the delivery tube 66m and is operative to close the end of said tube when the injector is not in operation, assisted by the spring D and any pressure within the delivery chamber. This check valve 74m has a tubular guiding stem and may be held to its seat, when the injector is idle, by a spring (not shown). When the delivery jet is established, a pressure is built up in the chamber 59m sufficient to close the overflow valve 53m and to hold it closed during the operation of the injector. When this valve is seated, it closes the conduit 45m and thus makes virtually ineffective the primary or auxiliary spillway 44m, the latter being operative to deliver steam and water only during the starting of the apparatus.

The injector is started into operation in the same way as that above described, by so actuating the handle as to swing the lever 33m, thus unseating the water and steam valves, the steam valve leading the water valve. When the main steam valve is unseated, steam flows in large volume through the forcer nozzle 17m and also, but in very considerably smaller volume, through passages 19m into the chamber 20m and thence through the entraining nozzle 15m into the entrance end of the combining tube section 43m. By reason of the great volume of steam delivered by the forcer nozzle there is a tendency to establish a substantial pressure within the combining tube sections in spite of the presence of the spillways 67m, 67s, such pressure, acting upon that portion of overflow valve 53m which is exposed to the pressures in the overflow chamber, acting positively to unseat the valve, even though it may not previously have opened in response to gravity. However, if cold water is available for entrainment by the steam from nozzle 15m, the delivery of this water into the combining tube throat quickly condenses steam delivered by the nozzle 17m, reduces the pressure in the converging passages of the combining tube, and although in the initial stages of the operation steam and water may pass out of the lateral spillways, some into the conduit 45m and the rest into the overflow chamber 53s, the result of the rapid condensation is that an extremely high velocity is quickly established in the combining and delivery tubes and a sufficient pressure set up in the chamber 72m to open the check valve and deliver the entrained water into the boiler, the high pressure fluid in chamber 72m acting through pipe 57m on piston 53x to reseat the valve 53m.

However, if for any reason, either at the outset of the operation or during the operation of the injector, the supply of water should be cut off, as for example by an abnormally low water level in the tank, the breakage of the supply hose or other-

wise, or if the feed water be too hot, condensation will not take place with sufficient rapidity in the combining tube, and the volume of high pressure steam delivered by the forcer nozzle 17m tends to establish high pressure in the combining tube and also in the overflow chamber 53a. If it were not for the primary or auxiliary spillway passage 44m, the back pressure thus developed might be sufficient to cause the steam to back up through the entrance end of the combining tube, overcoming the entraining action of the small volume of steam delivered by the nozzle 15m, and thus blow back through the open water inlet valve 9m and into the supply hose, burning the latter and overheating such water as may be in the hose or tank.

However, by the provision of the primary or auxiliary spillway 44m, which is of large capacity, any backing up of hot steam into the water inlet chamber 41m is substantially prevented, since this passage 44m provides a direct outlet through the chamber 45m to the atmosphere, it being noted that the overflow valve 53m is normally unseated either by gravity or positively by overflow chamber pressure when the injector is not forcing water into the boiler. Thus, if the injector break during operation, the valve 53 immediately opens, providing a direct escape for such steam as is delivered by the nozzle 15m, together with any water which may be entrained by said steam and also affording an outlet for steam which may back up in the second section of the combining tube, and thus when cool feed water again becomes available, the entraining nozzle 15m is able to start this water with substantial velocity into the cone 53m and in sufficient volume to condense the steam emerging from the end of the forcer nozzle 17m, thus very quickly and automatically reestablishing the delivery jet. On the other hand, when once the jet has been established, the spillways 67m, 67s, 68m, etc., function in the usual manner of such spillways, all of these latter spillways being constantly open into the usual overflow chamber 53s which is of limited capacity and in which subnormal pressure usually but not always subsists when the delivery jet has been established.

The apparatus of Fig. 7 thus functions in substantially the same way as that previously described, although the apparatus is considerably simpler and easier and cheaper to construct and to maintain in operative condition.

In each of its illustrated embodiments, the improved injector is of automatic type and has but a single manually actuable element for starting it into operation, for regulating the water supply, and for stopping it at the end of the operation; the overflow valve or valves is or are automatic in action and closed while the injector is in full operation and when idle, but open during starting; and these valves open automatically if the injector should break during use.

While certain desirable embodiments of the invention have herein been illustrated by way of example, it is to be understood that the invention is not limited to these precise embodiments but is to be regarded as broadly inclusive of any and all modifications falling within the scope of the appended claims.

I claim:

1. A steam jet pump of the kind having a casing which houses a tube assembly including a converging combining tube and a delivery tube, steam nozzles arranged to deliver water-entraining and forcing jets into the entrance end of the combining tube, steam and water-admission valves, and means for actuating said valves, the tube assembly being provided with a plurality of longitudinally spaced spillways, one of said spillways being so located and of such capacity as to clear the steam from the entraining nozzle thereby to permit the latter to draw water, and the others being arranged to clear the steam from the forcer nozzle thereby to prevent excessive back prssure within the combining tube while the steam and water valves are moving to full open position, means providing a conduit leading directly from the first spillway to the atmosphere, the other spillways opening into an overflow chamber within the casing, and a single automatically actuated overflow valve for closing said conduit and also the outlet from the overflow chamber and to keep them closed during the normal operation of the injector and subsequent regulating movements of the steam and water valves, and pressure motor means, responsive to delivery jet pressure, for moving said single overflow valve to closed position.

2. A steam jet pump of the class described comprising a casing which houses a steam-admission valve and a water-regulating valve, seats with which said valves cooperate, a single actuating handle for the valves, and connections from said handle to the valves, the diameters of the valves being such and the actuating connections being so constructed and arranged that movement of the handle in one direction causes the steam valve to reach full effective opening before the water valve is fully open so that continued movement of the handle in the same direction thereafter moves the steam valve idly while progressively increasing the opening of the water valve.

3. A steam jet pump of the class described comprising a casing which houses a steam-admission valve and a water-regulating valve, seats with which said valves cooperate, said valves having actuating stems, an actuating lever, means including pivot elements uniting each stem to the lever, fulcrum means for the lever, and manually actuable means for swinging the lever, the ratio of distances between the respective pivot elements and the fulcrum means being such that the steam valve moves away from its seat substantially faster than does the water valve when the lever is swung.

4. A steam jet pump of the class described comprising a casing which houses a steam-admission valve and a water-regulating valve, seats with which said valves cooperate, said valves having actuating stems, a lever, means including pivot elements uniting each stem to the lever, fulcrum means for the lever, manually actuable means for swing the lever, the ratio of distances between the respective pivot elements and the fulcrum means being such that the steam valve will reach full effective opening when the water valve has been opened only approximately one-half way.

5. A steam jet pump of the kind having a tube assembly provided with a series of spaced spillways, means providing a conduit leading from the first of said spillways to the atmosphere, means providing a space of limited capacity with which later spillways of the series always communicate, means providing a conduit leading from said space to the atmosphere, and valve means for closing both of said conduits, and pressure motor means, responsive to delivery jet pressure, when the delivery jet is established, for

moving said latter valve means to conduit closing position.

6. A steam jet pump of the kind having a casing which houses a multi-section combining delivery tube having lateral spillways between its several sections, a steam-admission valve, a delivery tube, regulating and forcer nozzles arranged to deliver steam jets into the entrance end of the combining tube, the first of said spillways being of sufficient capacity to pass substantially all of the steam delivered by the regulating nozzle, together with the water entrained thereby, means providing an auxiliary overflow conduit leading directly from said first spillway to the outside of the casing, the other spillways discharging into a main overflow chamber within the casing, a main overflow valve controlling the delivery of fluid from said overflow chamber, automatic means for closing said auxiliary overflow conduit, and means operative concomitantly and positively to close the main and auxiliary overflow valves when the delivery jet is established.

7. A steam jet pump of the kind having a tube assembly provided with a series of spaced spillways, the first of said spillways being of substantially greater capacity than any of the others, means providing a conduit leading from the first of said spillways to the atmosphere, means providing a chamber which always affords communication between the outlets of the later spillways of the series, means providing a conduit leading from said chamber to the atmosphere, and a single valve operative automatically to close both of said conduits when the delivery jet has been established.

8. A steam jet pump of the kind having a casing which houses a combining tube having a plurality of spillways leading into an overflow chamber within the casing, an overflow valve operative to control the escape of fluid from the overflow chamber, a steam-admission valve, a delivery tube, regulating and forcer nozzles arranged to deliver steam jets into the entrance end of the combining tube, a regulating cone arranged to provide an annular convergent throat coaxial with the forcer nozzle and terminating adjacent to the delivery end of the latter, characterized in having means providing a spillway leading directly to the outer atmosphere from a point intermediate the ends of said convergent throat, and a valve for closing said latter spillway, the spillway valve being coaxial with the overflow valve, and pressure motor means arranged to close the overflow valve upon the establishment of delivery jet pressure, and means for transmitting motion from the overflow valve to the spillway valve thereby to close the latter when the overflow valve closes.

9. A steam jet pump of the kind which includes a combining tube having a plurality of spillways leading to an overflow chamber, an overflow valve operative to control the escape of fluid from the overflow chamber a delivery tube, a steam-admission valve, a forcer nozzle arranged to deliver a steam jet into the entrance end of the combining tube, an entraining nozzle coaxial with the forcer nozzle, and means providing a convergent annular passage into which the entraining nozzle delivers combined steam and water, characterized in having an auxiliary spillway leading directly to the outer atmosphere from said annular passage at a point rearward, in the direction of flow, of the delivery end of the forcer nozzle, and a valve for closing said lateral spillway, said spillway valve opening automatically in response to superatmospheric pressure in the overflow chamber, and pressure motor means operative to close said spillway valve when the delivery jet is established.

10. A steam jet pump of the kind which includes a combining tube having a spillway leading to an overflow chamber, an overflow valve operative to control the escape of fluid from the overflow chamber, a delivery tube, a steam-admission valve, a forcer nozzle arranged to deliver a steam jet into the entrance end of the combining tube, an entraining nozzle coaxial with the forcer nozzle, and means providing a convergent annular passage into which the entraining nozzle delivers combined steam and water, characterized in having an auxiliary spillway leading directly to the outer atmosphere from said annular passage at a point rearward, in the direction of flow, of the delivery end of the forcer nozzle, a valve normally closing the auxiliary spillway, said overflow and spillway valves being arranged to open in response to the initial admission of steam to the nozzles, and motor means responsive to the pressure of the delivery jet when established to close the overflow and spillway valves.

11. A steam jet pump of the kind which includes a combining tube having a spillway leading to an overflow chamber, a delivery tube, a steam-admission valve, a forcer nozzle arranged to deliver a steam jet into the entrance end of the combining tube, means providing an entraining nozzle coaxial with the forcer nozzle, and means providing a convergent annular passage into which the entraining nozzle delivers combined steam and water, characterized in having an auxiliary spillway leading directly to the outer atmosphere from said annular passage at a point rearward, in the direction of flow, of the delivery end of the forcer nozzle, a valve for closing said lateral spillway, and pressure motor means responsive to superatmospheric pressure in the overflow chamber for opening said valve, and pressure motor means responsive to delivery jet pressure when the delivery jet has been establishd to close the spillway valve.

12. A steam jet pump of the kind having a casing which houses a combining tube having a lateral spillway leading into an overflow chamber within the casing, a steam-admission valve, a delivery tube, regulating and forcer nozzles arranged to deliver steam jets into the entrance end of the combining tube, a septum defining the upper end of the overflow chamber, means providing a spillway leading laterally from the combining tube at a point between said septum and the entrance end of the combining tube, said latter spillway extending directly to the outer atmosphere and being of such capacity as to pass substantially all of the steam delivered by the regulating nozzle and the water which is entrained by said steam, a valve for closing said latter spillway when the delivery jet has been established and motor means responsive to the pressure of the delivery jet for closing the spillway valve.

13. A steam jet pump of the kind having a casing which houses a combining tube having a lateral spillway leading into an overflow chamber within the casing, a steam-admission valve, a delivery tube, regulating and forcer nozzles arranged to deliver steam jets into the entrance end of the combining tube, a septum defining the upper end of the overflow chamber, said sep-

tum having therein an aperture in which the combining tube fits substantially leak-tight, the septum constituting the upper end wall of the overflow chamber, means providing a lateral spillway in the wall of the combining tube at a point between said septum and the entrance end of the combining tube, means providing a conduit leading from said latter spillway directly to the atmosphere, and a pressure controlled automatic valve operative to close the delivery end of said conduit when the delivery jet has been established.

14. A steam jet pump of the kind having a casing which houses a multi-section combining-delivery tube having lateral spillways between its several sections, a steam-admission valve, a delivery tube, regulating and forcer nozzles arranged to deliver steam jets into the entrance end of the combining tube, the first of said spillways being of sufficient capacity to pass substantially all of the steam delivered by the regulating nozzle, together with the water entrained thereby, said first spillway being so located that it does not directly receive steam forming the jet from the forcer nozzle, means providing a conduit leading from said first spillway to the outside of the casing, the other spillways discharging into an overflow chamber within the casing, and a single automatically actuated valve arranged to close the delivery end of said conduit and also to close the discharge port from the overflow chamber when the delivery jet has been established.

15. A steam jet pump of the kind having a casing which houses a combining tube having a plurality of spaced lateral spillways leading into an overflow chamber within the casing, a steam-admission valve, a delivery tube, regulating and forcer nozzles arranged to deliver steam jets into the entrance end of the combining tube, a partition defining the upper end of the overflow chamber and means providing a spillway leading from a point above said partition and below the delivery end of the regulating nozzle, said spillway extending to the outer atmosphere, and a single automatic pressure-actuated valve operative to close the delivery end of said spillway and also to close a port leading from the overflow chamber when the delivery jet is established.

16. A steam jet pump of the kind which includes a combining tube having a spillway leading to an overflow chamber, a delivery tube, a steam-admission valve, a forcer nozzle arranged to deliver a steam jet into the entrance end of the combining tube, an entraining nozzle, and means providing a convergent annular passage into which the entraining nozzle delivers combined steam and water, characterized in having an auxiliary spillway leading directly to the outer atmosphere from said convergent annular passage at a point intermediate the ends of said passage, an auxiliary overflow valve having a cylindrical skirt portion normally closing the outlet from said auxiliary spillway, said valve, when open, providing free and direct communication between the auxiliary spillway and the outer atmosphere, a main overflow valve normally closing a port leading from the main overflow chamber, said main overflow valve being arranged to open in response to superatmospheric pressure within the main overflow chamber, and means for transmitting motion from the main overflow valve to the auxiliary overflow valve for opening the latter.

17. A steam jet pump of the kind which includes a combining tube having a spillway leading to an overflow chamber, a delivery tube, a steam-admission valve, a forcer nozzle arranged to deliver a steam jet into the entrance end of the combining tube, an entraining nozzle, and means providing a convergent annular passage into which the entraining nozzle delivers combined steam and water, characterized in having an auxiliary spillway leading directly to the outer atmosphere from a point intermediate the ends of said annular passage, an auxiliary overflow valve normally closing said auxiliary spillway, said valve being so arranged as, when open, to provide free and direct communication between the auxiliary spillway and the outer atmosphere, a main overflow valve normally closing a port leading from the main overflow chamber, the main overflow valve being arranged to open in response to superatmospheric pressure in the main overflow chamber, and a rigid member operative to transmit motion from the main overflow to the auxiliary overflow valve for opening the latter.

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