

Dec. 25, 1934.

J. Y. DAHLSTRAND

1,985,404

MEANS FOR REGULATING A STEAM TURBINE

Filed Jan. 23, 1933

4 Sheets-Sheet 1

Fig. 1.

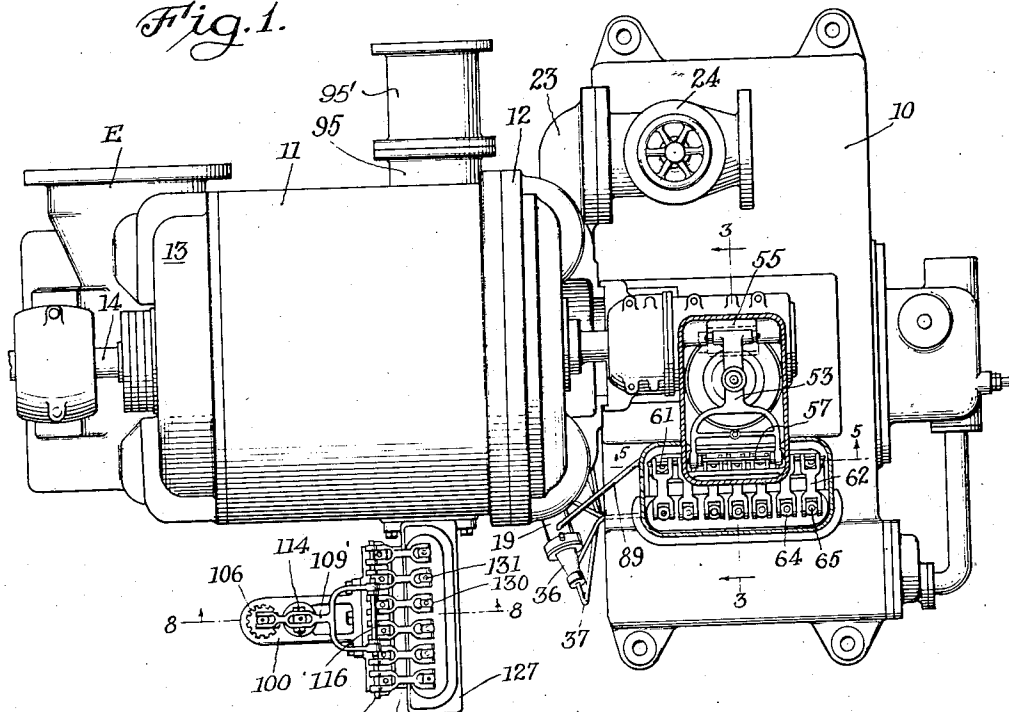
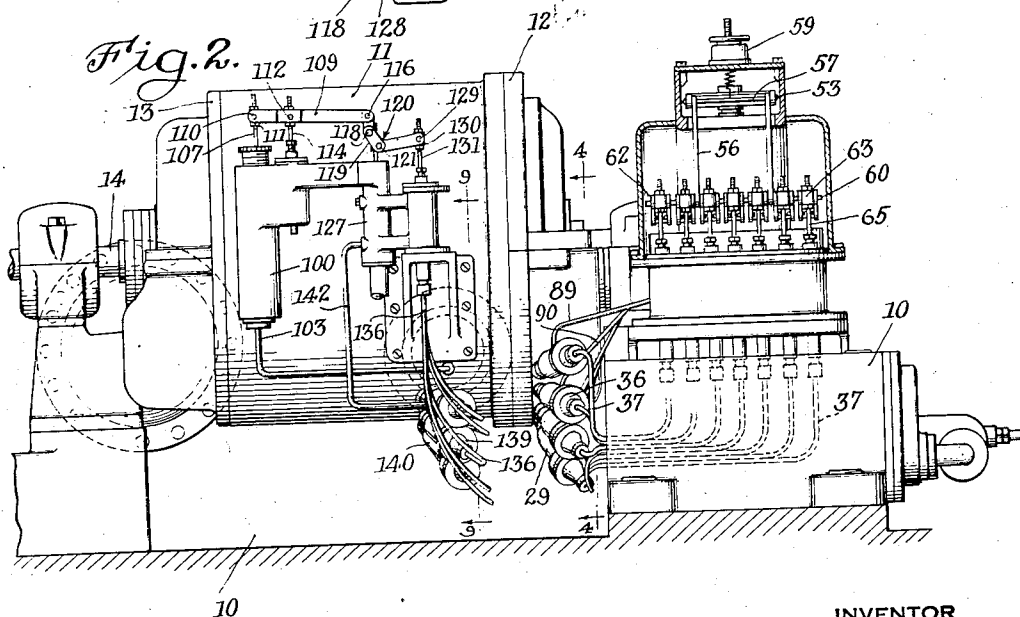


Fig. 2.



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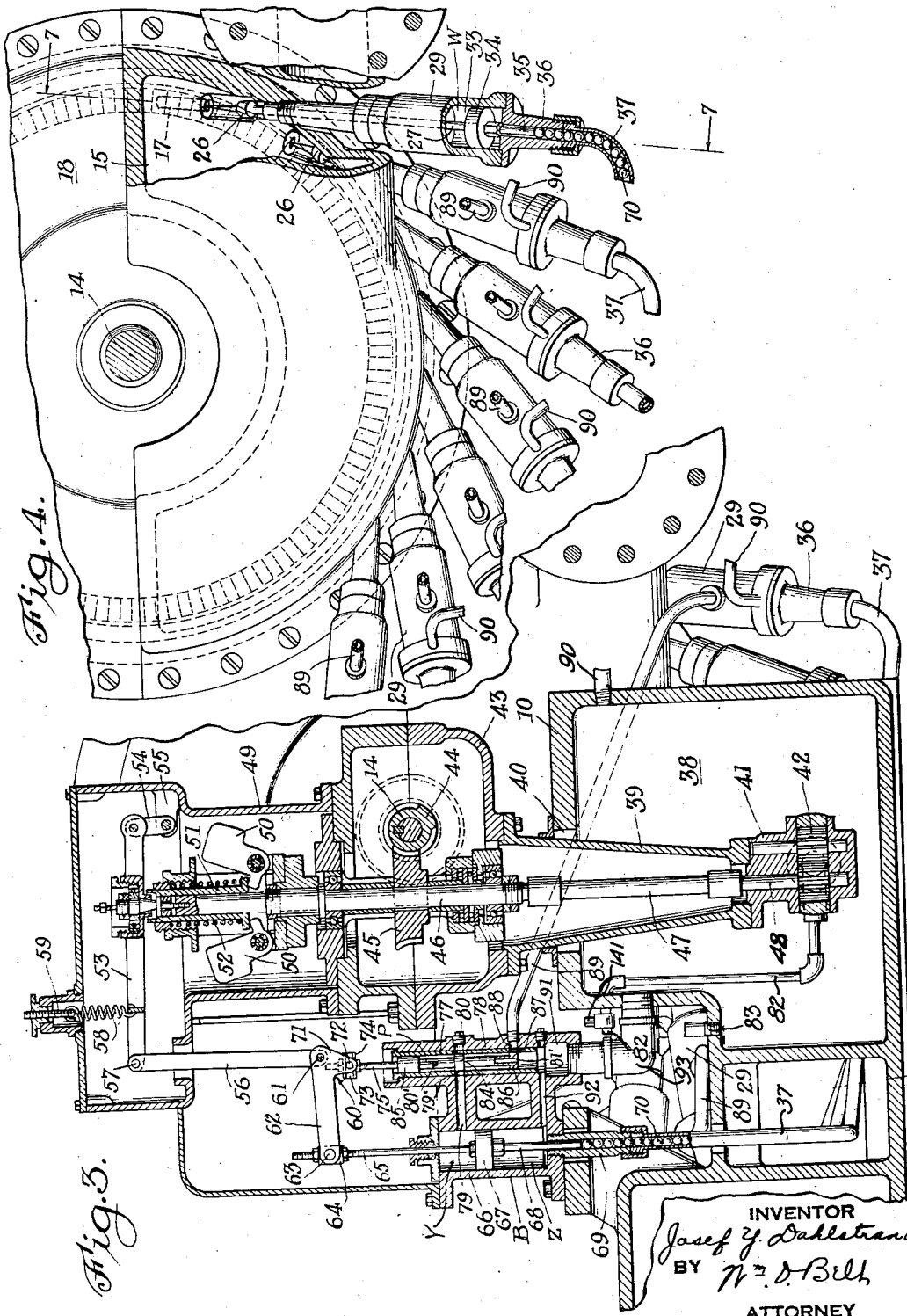
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Fig. 5.

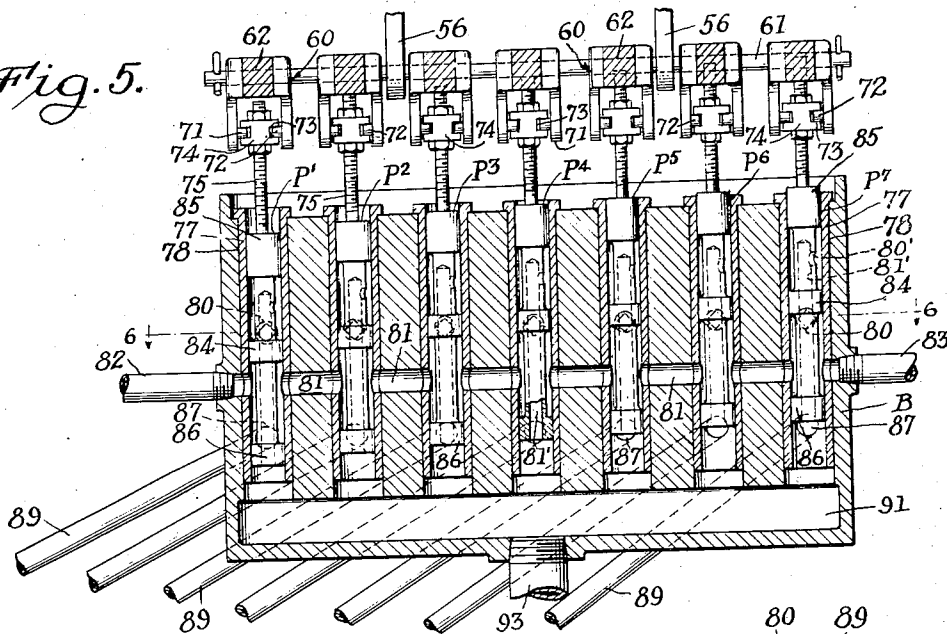


Fig. 6.

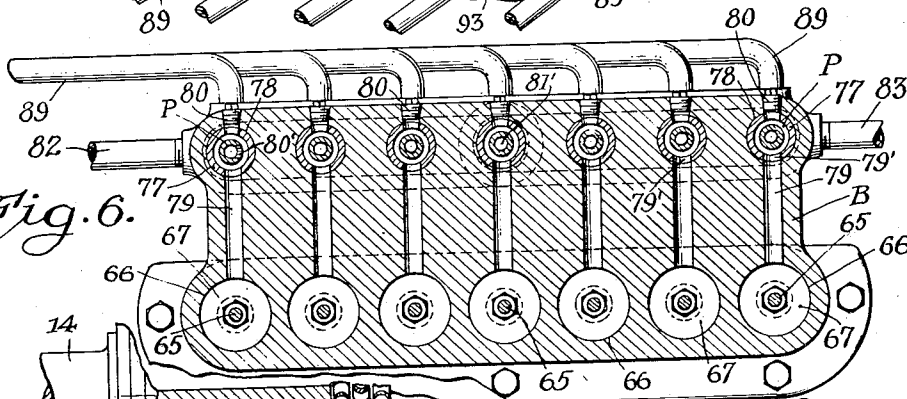
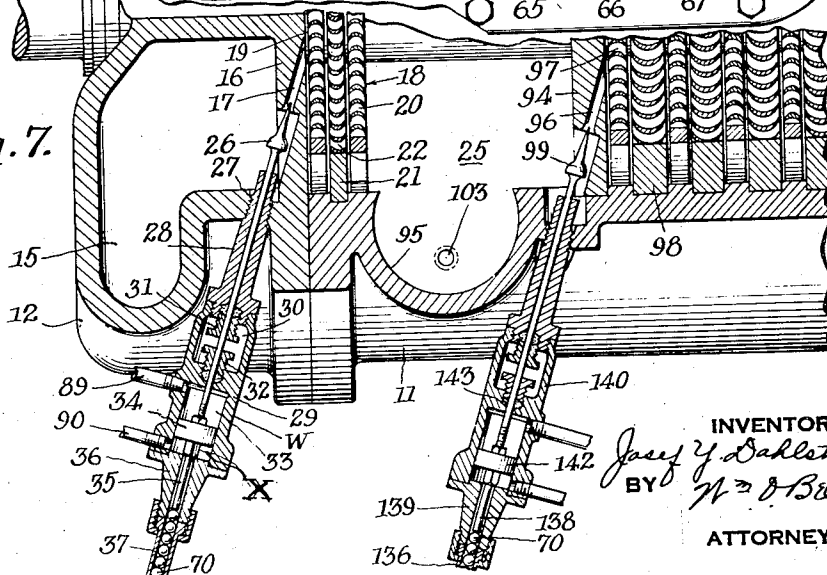


Fig. 7.



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1,985,404

MEANS FOR REGULATING A STEAM
TURBINEJosef Y. Dahlstrand, Burlington, Iowa, assignor
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Application January 23, 1933, Serial No. 653,047

10 Claims. (Cl. 253—59)

This invention relates to means for regulating a steam turbine of the impulse type.

In steam turbines of the impulse type the kinetic energy of steam jets impinging on curved blades or buckets fixed to a turbine wheel is converted into mechanical work. The steam jets are produced by expanding steam in nozzles which extend at an angle to the plane of rotation of the wheel and these nozzles have restricted throats communicating with the steam ring or bowl of the turbine and relatively enlarged mouths opening in juxtaposition to the path of the blades on the wheel.

Turbines are often operated under varying load conditions and require regulation to compensate for the variations in the load. This has been done in the past by interposing a governing valve between the supply line and the ring of the turbine to regulate the steam flow. Such a valve creates a pressure differential between the steam in the supply line and that in the ring and the valve throttles the steam with a resultant waste of British thermal units. Poppet valves have also been employed to regulate turbines but these valves also throttle the steam.

The salient object of my invention is to regulate the operation of a turbine without creating a pressure differential between the steam in the supply line and that in the ring of the turbine to thereby avoid throttling the steam and the resultant waste of British thermal units.

Turbines are usually rated to be operated at a given speed under a determined ring pressure and under these conditions the highest efficiency is attained. If a throttling governing valve is employed and there is a material reduction of the load on the turbine, the governing valve so operates that the ring pressure in the turbine is materially reduced. The nozzles are divergent, this being essential to expand the steam below fifty-eight percent of the initial pressure. To provide a divergent nozzle, the area of the throat is made less than the area of the mouth and the divergence or taper of the nozzle, known as the expansion ratio, is a function of the ratio between the ring pressure and the stage back pressure in the turbine. Hence, when the ring pressure is materially reduced, the steam consumption greatly increases and the efficiency of the turbine is reduced. Moreover, the calculation of the expansion ratio of a particular set of nozzles is partially based on the stage back pressure. As the load on the turbines lightens, the stage back pressure lessens and it is beneficial to vary the expansion ratio to

compensate for a reduction in back pressure. However, nozzles may be under-expanded in an appreciable amount without affecting their efficiency but over-expansion of the nozzles materially affects the efficiency thereof.

Therefore, still another object of my invention is to provide a turbine wherein the expansion ratio of the nozzles may be adjusted to afford efficient operation under various operating conditions including a material reduction in stage back pressure.

The power developed by a turbine is proportionate to the quantity of steam admitted and hence, when the load on the turbine is materially reduced, it is advantageous to reduce the steam admission and this may be done by reducing the aggregate nozzle area.

Another object is to regulate the operation of a turbine by controlling the steam flow through the nozzles without reducing the ring pressure so that maximum efficiency may be maintained and an ancillary object is to vary the aggregate nozzle area of the turbine proportionately to the load.

A turbine is often arranged so that steam may be withdrawn therefrom at one or more stages in order that steam at different temperatures and pressures may be supplied to appliances such as cooking vats and the like, and a turbine so equipped is known as a bleeder turbine. Heretofore, a throttling valve has been provided to regulate the bleed from a turbine but the use of such a valve is subject to many disadvantages. Hence, a further object of this invention is to provide a novel bleeder turbine in which the steam withdrawal is controlled by varying the area of the outlet nozzles from the bleeder chamber.

Still further objects of the invention are to provide a turbine having novel reamed nozzles into which tapered adjustable needle valves are extended to afford variation of the nozzle area and expansion ratio; to automatically actuate the needle valves proportionately to variations in operating conditions; to control a plurality of nozzles so that wide variations in operating conditions may be accommodated; to provide an expeditious adjustment so that the same turbine may be used under different operating conditions such as variations in initial steam pressure, load, and speed; and to provide a novel turbine control of simple and economical construction and efficient and positive operation.

Selected embodiments of the invention are illustrated in the accompanying drawings wherein Fig. 1 is a plan view;

Fig. 2 is a side elevation;

Fig. 3 is a vertical sectional view taken substantially on the line 3—3 on Fig. 1;

Fig. 4 is a vertical sectional view taken substantially on the line 4—4 on Fig. 2;

Fig. 5 is a vertical sectional view taken substantially on the line 5—5 on Fig. 1;

Fig. 6 is a horizontal sectional view taken substantially on the line 6—6 on Fig. 5;

Fig. 7 is a vertical sectional view taken substantially on the line 7—7 on Fig. 4;

Fig. 8 is a vertical sectional view taken substantially on the line 8—8 on Fig. 1; and

Fig. 9 is a fragmentary vertical sectional view taken substantially on the line 9—9 on Fig. 2.

In the accompanying drawings, 10 indicates a base supporting a turbine casing 11 having end plates 12 and 13 providing bearings in which a turbine shaft 14 is journaled. A ring or bowl 15 is provided in the end plate 12 and this end plate includes a wall 16 in which the nozzles 17 are provided. The first stage wheel 18 of the turbine is fast on the shaft 14 adjacent the wall 16 and the buckets or blades on the periphery of this wheel are arranged in two rows 19 and 20. A diaphragm 21 is carried by the casing 11 and is interposed between the rows of buckets 19 and 20 and has a row of buckets 22 thereon. An inlet 23 has a valve 24 therein and leads to the ring 15. Steam flows through the inlet into the ring and through the nozzles 17 which extend at an angle to the plane of rotation of the wheel 18 and the jets of steam emitted from these nozzles first impinge on the buckets in the row 19, then on the buckets in the row 22, and then on the buckets in the row 20 from whence the steam flows into the bleeder chamber 25 when the turbine is equipped with such a chamber behind the first stage therein. If no bleeder chamber is provided at this position, the steam flows into the second stage or to the exhaust as the case may be.

The nozzles 17 are of the kind described and claimed in my Patent No. 1,561,835, patented November 17, 1925 and are straight reamed holes. In order to provide for efficient expansion of steam in the nozzles, which is usually accomplished by tapering the nozzles, tapered needle valves 26 are extended into the throats of the nozzles and these tapered needle valves may be used to vary the aggregate nozzle area as will be explained. In the illustrated embodiment of the invention, I show seven nozzles but a greater or less number might be provided depending upon the size of the turbine, the horse power to be developed, the speed of operation, and the like.

The valve 24 is preferably of the type affording unobstructed steam passage and hence it does not have any throttling effect and since the inlet 23 leads directly to the ring or bowl and as the intakes of the nozzles communicate with the ring, it is clear that the pressure at the intakes of the nozzles is line pressure.

The seven nozzles provided in the illustrated turbine are arranged side by side and so far as constructional features are concerned, they are identical. The needle valve for each nozzle includes a stem 27 that is extended through a bore in the body 28 mounted in a tapped opening in the plate 12. A housing 29 is screw threaded onto the end of each body 28 and each has a chamber 30 therein in which packing nuts 31 and 32 are provided. The stem 27 of each needle valve extends into the housing 29 through the packing nuts 31 and 32 and suitable packing engaged by

these nuts so that when the nuts are tightened the packing is tightly clamped about the stems 27 to prevent leakage thereby. A cylinder 33 is provided in each housing and a piston 34 is reciprocally mounted in each cylinder. The outer ends of the stems 27 are respectively connected to the pistons. Chambers W are thus defined between the faces of the pistons to which the stems are connected and the adjacent ends of the cylinders. Pins 35 extend axially from each piston 34 opposite to but in alinement with the stem 27 connected to the piston and these pins project into bores in the caps 36 secured to the outer ends of the housings 29. Other chambers X are thus defined between the faces of the pistons to which the pins are connected and the adjacent ends of the cylinders. Tubes 37 are connected at the outer ends of each of the caps 36 and the bores in the tubes communicate with the bores in the caps. A chamber 38, Fig. 3, is provided in the base 10 at the forward end thereof. A tubular housing 39 projects through an opening 40 in the upper wall of the chamber and has a body 41 at the lower end thereof in which a gear pump 42 is provided. A housing 43 is secured to the upper end of the housing 39 and the shaft 14 extends thereto. A gear 44 is fast on the shaft 14 in the housing 43 and meshes with a gear 45 fast on the vertical shaft 46 journaled in suitable bearings provided in the housing 43. A coupling 47 interconnects the shaft 46 with the shaft 48 of the gear pump 42 so that when the shaft 46 is rotated with the shaft 14 the gear pump is operated. The chamber 38 serves as an oil reservoir and the gear pump withdraws oil from this reservoir and forces the oil under pressure through an outlet to operate certain devices as will be explained hereinafter.

Another housing 49 is mounted on the upper end of the housing 43 and encloses a weight-actuated governor 50 of the usual construction and which includes a sleeve 51 disposed about the shaft 46. A spring 52 is disposed about the sleeve 51 and acts thereon to urge the weights of the governor 50 toward the shaft 46. A lever 53 has a link 54 connected to one end thereof and this link is pivotally connected to a lug 55 in the housing 49. The sleeve 51 is connected to the lever 53 adjacent the end thereof connected to the link 54. Links 56 are pivotally mounted on a rod 57 carried by the forked end of the lever 53 opposite the end thereof connected to the link 54. One end of a spring 58 is connected to the lever 53 intermediate the rod 57 and the connection thereof to the sleeve 51. The other end of the spring 58 is connected to an adjusting device mounted in the top plate of the housing 49 and by means of which the tension on the lever 53 may be varied.

The needle valves are controlled by the governor 50 and preferably these valves are so arranged that each can be operated independently. This may be accomplished in a variety of ways and in the illustrated embodiment of the invention I have shown pressure-actuated means for this purpose. The pressure-actuated means provided for each of the needle valves includes a cylinder having a piston therein and a pilot valve for controlling movement of the piston in the cylinder. The pilot valves are actuated by the governor 50 and to this end the free ends of the links 56 are connected to a rod 61. Seven bell cranks 60 are mounted at spaced intervals on the rod 61. The arms 62 of each of the bell cranks are pivotally connected at 63 to sleeves 64 adjustably mounted on rods 65 extended through packing nuts and

suitable packing into the cylinders 66 whereat they are respectively connected to the pistons 67. The cylinders 66 are arranged in side-by-side relation and in the illustrated embodiment are formed in a block B, Fig. 6. A chamber Y is defined in each cylinder 66 intermediate the face of the piston 67 to which the rod 65 is connected and the adjacent end of the cylinder. Pins 68 extend from the pistons 67 opposite to and in alignment with the rods 65 connected to the pistons and these pins project into sleeves 69 leading from the cylinders 66. A chamber Z is defined in each cylinder 66 intermediate the face of the piston 67 to which the pin 68 is connected and the adjacent end of the cylinder. The tubes 37 which are respectively connected to the caps 36 are respectively connected to the sleeves 69 and the tube leading from the first of the needle valves is connected to the first of the sleeves 69 while the tube leading from the second of the needle valves is connected to the second of the sleeves 69 and so on in succession. The respective tubes 37 are entirely filled with balls 70 so that the space between each set of pins 35 and 68 is entirely filled and preferably these balls operate in a light lubricating oil to insure free movement.

Seven pilot valves are provided in the block B and these valves are respectively aligned with the cylinders 66. Each pilot valve includes a plunger P and these plungers are respectively connected to the arms 71 of the bell cranks 60 by pins 72 (Figs. 3 and 5) disposed in slots 73 in the blocks 74 adjustably mounted on the rods 75 respectively connected to the upper ends of the plungers P. Each of the plungers is reciprocal in a sleeve 77 and these sleeves are fitted in vertical bores 78 in the block B. Passages 79 in the block B interconnect the respective pilot valves and the chambers Y in the cylinders 66 respectively aligned with the valves. The ends of these passages outwardly of the pilot valves are closed by plugs 80. Ports 79' are provided in the sleeves 77 in alignment with the passages 79. A passage 81 is drilled through the block B and the sleeves 77 and interconnects the various sleeves. An intake pipe 82 is connected at one end of the passage 81 and this pipe is likewise connected to the outlet of the pump 42. An outlet pipe 83 is connected to the other end of the passage 81 and leads to the chamber 38. The ports 79' are disposed in the sleeves 77 above the passage 81. Collars 84 are provided on the plungers P which slide on the sleeves 77 to open and close the ports 79'. Enlarged portions 85 are provided at the upper ends of the plungers P which also slide on the sleeves 77 and guide the plungers in their reciprocation. The portions of the plungers P intermediate the collars 84 and the enlarged portions 85 are relieved. When the collars 84 are positioned in the sleeves to be disposed below the passage 81, this passage and the ports 79' are in communication due to the relief of the plungers. The collars 84 may be moved into such a position that communication between the passage 81 and the ports 79' is shut off.

Collars 86 are provided at the lower ends of the plungers P and the portions of the plungers intermediate the collars 84 and 86 are relieved so that when the collars 84 are positioned in the sleeves to be disposed above the passage 81, oil flowing through said passage may flow past the relieved portions of the plungers P. Ports 87 are provided adjacent the lower ends of the sleeves 77 and respectively communicate with passages 88

in the block B. Conduits 89 are connected to the respective passages 88 and lead to the housings 29 to communicate with the chambers W therein. The collars 86 control flow of oil through the ports 87 and when the plungers P are so disposed that the collars 86 open the ports 87 for communication with the relieved portions of the plungers P intermediate the collars 84 and 86, oil flows to the conduits 89 into the chambers W. The plungers P may be so positioned that the collars 86 close off the ports 87 from communication with the passage 81. Likewise the plungers may be so disposed that the collars 86 open communication between the ports 87 and the open lower ends of the sleeves 77.

A chamber 91 is provided at the bottom of the block B and the bores 78 and sleeves 77 open into this chamber. A transverse passage 92 in the block B establishes communication between the chambers Z of the cylinders 66 and the chamber 91 so that any oil leaking past the pistons 67 flows into said chamber. Each plunger P includes a bore 81' which extends axially there-through from the lower end thereof to a port 80' located in the relieved portion of the plunger P intermediate the collar 84 thereon and the enlarged portion 85 thereof. The collars 84 control communication between the ports 79' and the ports 80' and, when communication is opened between the ports 79' and the ports 80', oil may flow through the bore 81' into the chamber 91. An outlet pipe 93 leads from the chamber 91 to the reservoir 38. A drain pipe 90 leads from each of the chambers X in the housings 29 to the reservoir 38 so that any oil seeping past the pistons 34 may be returned to the reservoir.

The nozzles are so calculated that when all are open sufficient steam flows therethrough to efficiently operate the turbine under a load greater than its rated capacity. In this turbine, wherein seven needle valves are provided, and when it is operated under a load of seventy-five percent of its rated capacity, which obviously requires less steam than when the turbine is operated under a load of its rated capacity or more than its rated capacity, some of the nozzles may be closed off. By way of example, when the turbine is operating under a seventy-five percent load, two of the needle valves are tightly seated on the intakes of their nozzles so that no steam flows through these nozzles. When the load is decreased, say for example to twenty-five percent of the rated capacity of the turbine, four of the needle valves are tightly seated on the intakes of their nozzles to close off steam flow therethrough. Thus, by seating or unseating the needle valves from their nozzles, the aggregate nozzle area may be varied and I vary this aggregate nozzle area proportionately to the load on the turbine. The speed of the turbine is determined by the load thereon for it operates at slightly different speeds at different loads and hence changes in load affect the governor 50 and since the pilot valves are controlled by the governor 50 and as these pilot valves, in turn, control the means regulating the needle valves, I am enabled to control the steam flow from the ring or bowl into the first stage proportionately to the load on the turbine.

As stated, when the turbine is operating under a load of seventy-five percent of its rated capacity, two of the needle valves are seated on the intakes of their nozzles. Under this condition, four of the nozzles are opened fully and one is used for regulating purposes, as will be explained. This is accomplished by setting the

plungers P at different positions in the sleeves 77. Thus, the plunger P¹, which regulates the movement of the piston 67 in the cylinder 66 connected through a tube 37 to the first of the needle valves, is so positioned that when the turbine is operating in the manner just described, the collar 86 thereon is disposed below its cooperating port 87 and therefore oil flows from the passage 81 through the port 87, passage 81 and conduit 89 into the chamber W of the housing 29 of the first needle valve and the pressure of this oil acts on the piston 34 to force it against the outer end of the cylinder 33 as illustrated in Fig. 7. At this same time the collar 84 is so positioned that communication is opened between the port 79' and the port 80' and therefore oil pressure in the chamber Y may be relieved for oil may flow from the chamber Y through passage 79, port 79', port 80', bore 81' into the chamber 91 to be returned to the reservoir 38. The plunger P² is positioned somewhat similarly to the plunger P¹ so that oil may flow into the chamber W in the housing 29 of the needle valve for the second nozzle. However, the plunger P² is so positioned that upon conjoint movement of the plungers P¹ and P² (the plungers all being connected to the rod 61 for such movement with the rod), the collars 86 and 84 on the plunger P² will close off oil flow in the above described manner before the collars 84 and 86 on the plunger P¹ so act. Inasmuch as four nozzles are to be wide open when the turbine is operating at seventy-five percent of its rated capacity, the plungers P³ and P⁴ are also so positioned that oil will flow to the chambers W in the housings 29 for the needle valves of the third and fourth nozzles. However, the plungers P³ and P⁴ are respectively so positioned relative to the plungers P² and P¹ that the collars 84 and 86 on the plunger P⁴ will close off the foregoing communication upon conjoint movement of the plungers prior to the time the collars 84 and 86 on the plunger P³ close off communication, and likewise the collars 84 and 86 on the plunger P³ are positioned to close off communication before the collars 84 and 86 on the plunger P² so close off communication. The plunger P⁵ is also set relative to the plunger P⁴ so that the collars 84 and 86 thereon will close off the foregoing communication prior to the time the collars 84 and 86 on the plunger P⁴ so operate. However, when the machine is operating at seventy-five percent of its rated capacity, the collar 84 on the plunger P⁵ is arranged in the manner shown in Fig. 3, that is to say, it is disposed directly over the port 79' so that communication through this port is shut off. Likewise, the collar 86 on the plunger P⁵ is disposed over the port 87 so that communication through this port is shut off. The plunger P⁶ is so set that the collars 84 and 86 thereon are advanced beyond the position of the collars 84 and 86 on the plunger P⁵. Hence, since the collars 84 and 86 are disposed directly over the outlet of the passage 79 and the port 87, it is clear that the collars 84 and 86 on the plunger P⁶ are arranged in an opposite manner to the collars 84 and 86 on the plunger P⁴. Hence, the collar 84 on the plunger P⁶ is so disposed that communication is opened between the passage 81 and the port 79' and hence oil flows from the passage 81, past the relieved portion of the plunger, through port 79', and through the passage 79 into the chamber Y of the cylinder alined with the pilot valve including the plunger P⁶ and the pressure of the oil acts on the piston 67 to force the same toward the chamber Z. At this same time the collar 86 is so disposed that communication is opened between the port 87 and the chamber 91. The oil pressure on the piston 67 tends to force the pin 68 through the sleeve 69 and this movement is transmitted through the balls 70 to the pin 35 connected to the piston 34 in the cylinder 33 of the housing 29 for the valve of the sixth nozzle and this urges the piston 34 toward the chamber W. At this time oil is free to flow from the chamber W through the conduit 89, passage 81, port 87 into chamber 91 and therefore the oil pressure on the piston 67 so acts that the needle valve 26 for the sixth nozzle is urged into seating engagement with the intake of the nozzles and closes off this nozzle. The collars 84 and 86 on the plunger P⁷ are positioned similarly to the collars 84 and 86 on the plunger P⁶ but these collars are so arranged that communication to the chamber Y of the seventh cylinder will be established prior to the time communication is established to the chamber Y of the sixth cylinder and likewise communication will be opened from the chamber W of the seventh needle valve prior to the time communication is opened from the chamber W of the sixth needle valve. Hence, when the machine is operating at seventy-five percent of its rated capacity, four needle valves are held in wide open position and two are closed. The other needle valve is so arranged that it can fluctuate to compensate for slight variations in the speed of the turbine. When the turbine is loaded to seventy-five percent of its rated capacity, it operates at a predetermined speed and the weights of the governor assume a determined position. When, however, the load on the turbine is decreased, and the steam flow from the ring or bowl is to be decreased, the turbine speeds up which causes the weights of the governor 50 to move outwardly and therefore the sleeve 51 is moved upwardly. Upward movement of the sleeve 51 moves the lever 53 and the links 56 upwardly and consequently raises the rod 61. All of the plungers P are connected to the rod 61 and hence when this rod 61 moves upwardly all of the plungers move similarly, the bell cranks 60 fulcruming about the pivotal connections 63. However, when the movement is slight, none of the plungers are moved sufficiently to affect the needle valves controlled thereby except the plunger P⁵. Since the collars on this plunger are positioned directly over the ports 79' and 87, slight movement of the plunger P⁵ opens these ports. Hence, when, as described, the rod 61 moves upwardly, indicating an increase in speed of the turbine, which is indicative of a decrease in the load, it is essential that the steam supply be slightly reduced in order to bring the turbine back to its normal speed for a seventy-five percent load. Therefore, when the plunger P⁵ moves upwardly, the collar 84 thereon moves into such a position that communication is established between the passage 81 and the port 79' and passage 79 leading to the fifth cylinder and therefore additional oil flows into the chamber Y which moves the piston 67 to move the pin 68 through the sleeve 69 and this movement is transmitted through the balls 70 to the pin 35 to move the piston 34 of the fifth needle valve toward the chamber W and, since at this time communication is established between the port 87 and the chamber 91, movement of the piston 34 toward the chamber W forces oil from the chamber W into the chamber 91. At the time the piston 67 moves in the manner just described, the pin 65

is, of course, moved. This changes the position of the pivotal connection 63 and the fifth bell crank pivots about the rod 61 which moves the arm 71 of the fifth bell crank and causes the pin 72 thereon to move through the slot 73 and this forces the plunger P⁵ downwardly so that the collars 84 and 86 move back into position to close off the passage 79 and the port 87. Thus, the fifth needle valve is returned in the position into which it has been moved. However, since the fifth needle valve has been moved inwardly in a slight amount, the steam flow through the fifth needle valve is reduced which may be sufficient to cause a decrease in the speed of the turbine. Therefore, the weights of the governor 50 are moved inwardly and the spring 52 acts to move the sleeve 51 downwardly. This moves the lever 53 and the links 56 downwardly and consequently the rod 61 also moves downwardly and pivots the bell cranks 60 about the connection 63. However, this movement will be slight and none of the plungers P will be moved sufficiently to affect the seating of the needle valves controlled thereby except the plunger P⁵. This plunger will so move under these conditions that the collar 84 thereon will move from position over the port 79' and open communication between the chamber Y and the port 80'. At this same time the collar 86 opens communication between the port 87 and the passage 81. Hence oil flows through the port 87, passage 83 and conduit 89 into the chamber W of the fifth needle valve and the pressure of this oil acts on the piston 34 to move this piston toward the chamber X and this movement is transmitted through the balls 70 so that the piston 67 is urged toward the chamber Y, and oil is forced from the chamber Y through the passage 79, port 79', port 80' and bore 81' into the chamber 91. However, when the piston 67 moves upwardly, the pin 65 is also moved upwardly and the fifth bell crank fulcrums on the rod 61 and the pin 72 moves through the slot 73 to move the plunger P⁵ back into position whereat the collar 84 shuts off the port 79' and the collar 86 closes the port 87.

The fifth needle valve continues to fluctuate in this manner so long as there are slight variations in the turbine operating speed and the turbine continues to operate under a seventy-five percent load. However, when there is a material reduction in the load on the turbine, say for example, when the load is reduced to twenty-five percent of the rated capacity of the turbine, there is a noticeable increase in speed of the turbine. This causes the weights of the governor 50 to move outwardly which causes the sleeve 51, links 56 lever 53 and rod 61 to move upwardly and in this instance the movement of the rod 61 is sufficiently to move the plungers P⁵ and P⁴ into positions similar to that in which the plungers P⁶ and P⁷ have been disposed; that is to say, so that communication is established between the chambers W of the fourth and fifth needle valves and the chamber 91 and so that communication is opened between the chambers Y of the fourth and fifth cylinders and the passage 81. Therefore, oil flows into these chambers Y and acts in the above described manner to seat the needle valves on the intakes of the fourth and fifth nozzles to thereby close off these nozzles. The foregoing movement moves the plunger P³ into a position similar to that shown in Fig. 3 so that this plunger P³ then begins to operate in the manner in which the plunger P⁵ operates when the turbine is operating under seventy-five percent load con-

ditions. The normal turbine speed for a twenty-five percent load is different from that for a seventy-five percent load and therefore notwithstanding the fact that two nozzles have been shut off entirely, the turbine will not slow down to the speed at which it was operating before the foregoing change occurred. Hence, the rod 61 is disposed in a slightly different position and the various plungers are so disposed that the fourth, fifth, sixth and seventh needle valves remain closed whereas the first and second remain open and the third needle valve fluctuates to care for slight variations in speed.

If the machine is operating under twenty-five percent load as just described and the load is increased to one hundred percent load, the turbine slows down, the weights of the governor 50 move inwardly, and the spring 52 acts to move the sleeve 51 downwardly and therefore the lever 53, links 56 and rod 61 move downwardly, and this movement of the rod 61 is sufficient to so position the plungers that the first, second, third, fourth and fifth needle valves are open wide while the seventh needle valve remains closed and at this time the sixth needle valve is fluctuated in the manner in which the fifth needle valve fluctuates when the machine is operating under a seventy-five percent load, as described above. If the machine is overloaded, the rod 61 moves downwardly still more and the sixth needle valve is opened wide and the seventh needle valve then fluctuates in the manner described to care for slight variations in turbine speed.

From the foregoing it will be apparent that I have provided an arrangement which regulates the operation of a turbine without throttling the steam. The device so operates that the steam input to the first stage is controlled proportionately to the load on the turbine and furthermore the device so operates that the steam input is varied proportionately to slight variations in the load or speed of the turbine and this regulation for slight variations in speed operates under a great variety of load conditions; that is to say, it is effective either in fractional loads, normal load or overload.

In the illustrated turbine, a bleeder chamber 25 is provided between the first and second stages. This chamber includes a bleeder outlet 95 to which a steam line 95' is connected so that steam bled from the turbine may be directed to appliances in which the steam is used for heating purposes and the like. As these appliances are turned on and off the steam consumption varies which varies the pressure in the bleeder line and consequently in the bleeder chamber 25.

One of the objects of this invention is to maintain a constant pressure in the bleeder line and bleeder chamber without throttling the steam and to this end nozzles 96 are provided in the wall 94 at the inner end of the bleeder chamber 25. The nozzles 96, which are similar to the nozzles 17, extend at an angle to the plane of rotation of the second stage wheel 97 fast on the shaft 14 adjacent the wall 94. The steam jets emitted from these nozzles impinge on the blades or buckets on the wheel 97 and the steam then impinges on the blades or buckets on the diaphragm 98 juxtaposed to the wheel 97. In the illustrated embodiment of the invention, the steam next flows to the buckets on the wheel for the third stage and so on through the turbine to the exhaust E. It is to be understood, however, that it is within the purview of my invention to provide another bleed-

er chamber after the second stage or the steam may pass directly to the exhaust, any of these arrangements being in accordance with the well-understood practice.

5 In order to regulate the pressure in the chamber 95 without throttling the steam, needle valves 99, substantially similar to the needle valves 26, are provided for the nozzles 96.

10 As the pressure in the chamber 25 falls, means are provided for closing off one or more of the nozzles 96, six nozzles being provided in the illustrated turbine. As the pressure in the chamber 25 rises, additional nozzles are rendered operative so as to increase the steam flow to the second stage which will reduce the pressure in the chamber 25.

15 Inasmuch as the steam flow through the nozzles 96 is determined in accordance with the pressure in the chamber 25 or the bleeder line, pressure responsive means are provided for controlling the operation of the needle valves 99. This pressure responsive means, illustrated in detail in Fig. 8, includes a body 100 secured to the turbine casing 11. A cylinder 101 is provided in the body 100 and a piston 102 is reciprocal therein. A conduit 103 leads from the pressure chamber 25 to one end of the cylinder 101 and pressure variations in the chamber 25 are transmitted through this conduit to the cylinder 101 whereby the position of the piston 102 is varied. The piston includes a shouldered end 103' and extends into a chamber 104 in the body 100 above and about the cylinder 101. A spring 105 in the chamber 104 bears on the shouldered end 103' of the piston and against an adjusting nut 106. By varying the position of the adjusting nut 106, the tension of the spring 105 may be varied which affords an adjustment for regulating the operation of the device. A rod 107 is connected to the shouldered end 103' of the piston 102 and extends out through an opening 108 in the nut 106. One end of a lever 109 is pivotally connected at 110 to a sleeve 111 adjustably mounted on the rod 107. The lever 109 is connected intermediate its ends at 112 to a sleeve 113 adjustably mounted in the rod 114 which extends through a packing gland into the cylinder 115 provided in the body 100 and this end of the rod is connected to a piston reciprocal in the cylinder 115. The forked end of the lever 109 opposite to that connected to the sleeve 111 is pivotally connected at 116 to links 117. The links 117 are pivotally connected to a rod 118. In the present instance, where six nozzles and needle valves are provided, six bell cranks 120 are provided and the arms 119 of these bell cranks are pivotally connected to the rod 118. Pins 121 in the bell cranks extend into slots 122 in blocks 123 adjustably mounted on rods 124. The rods 124 are connected to the upper end portions 125 of the plungers V of the pilot valves 126. A block 127, similar to the block B, is provided and the valves 126 are formed in this block as are six cylinders 127 in which pistons 133 are reciprocal. Rods 131 are connected to the pistons 133 and extend from the cylinders through suitable packing glands and have sleeves 130 adjustably mounted thereon. The arms 128 of the bell cranks 120 are pivotally connected at 129 to the sleeves 130. Pins 134 project from the pistons 133 opposite to and in alignment with the rods 131 and these pins extend into sleeves 135 mounted at the lower ends of the cylinders 132. Tubes 136 are respectively connected to the sleeves 135 and these tubes are respectively connected to caps 139 provided at the outer end of the bodies 140 of the needle

valves cooperating with the six nozzles. The tubes 136 are filled with balls 137 which are arranged similarly to the balls 70.

10 In operation, certain of the needle valves are arranged to be wide open and others are seated against the intakes of their nozzles and this arrangement is such that, so long as a predetermined pressure is maintained in the bleeder chamber 25, the needle valves remain in this position. One needle valve is arranged to fluctuate in the manner previously described so as to care for slight variations in pressure, slight variations in pressure imparting small movement to the piston 102 which moves the rod 107 which, in turn, pivots the lever 109 about its fulcrum 112. This movement is transmitted through the links 117 to the rod 118 to lower the rod 118 when the pressure in the chamber 25 rises and to raise the rod 118 as the pressure falls. The plungers V are arranged in staggered relation in the same manner as the plungers P and hence, when the rod 118 moves downwardly, communication is established between the oil intake line 141 and the conduits 142 which lead to chambers in the bodies 140 substantially similar to the chambers W, the number of conduits 142 connected to the intake line 141 being dependent upon the pressure, it being apparent that when oil flows through the conduits 142 the needle valves 99 are moved into open position. The oil intake line 141 is connected to the oil supply line 82, Fig. 3. Likewise, when the pressure drops and the rod 118 moves upwardly, the plungers V also move upwardly and said plungers close off communication to one or more of the conduits 142 and open communication into one or more of the cylinders 132 to act on the pistons 133 therein to move the pins 134 through the sleeves 135 to thereby force the needle valves to which the various tubes 136 lead inwardly to seat on the intakes of the nozzles. As stated, one of the nozzles, which is always the nozzle adjacent the last wide open nozzle, fluctuates to care for slight variations in pressure.

15 The provision of a plurality of nozzles leading from the bleeder chamber and the provision of means for controlling steam flow through these nozzles enables me to care for variations in pressure in the bleeder chamber without throttling the steam and, by providing a plurality of nozzles, I am enabled to care for wide variations in pressure. At the same time, the arrangement is such that compensation is made for slight variations in pressure and therefore it is possible to maintain within relatively narrow limits a desired pressure in the bleeder chamber.

20 It will be apparent from the foregoing description that I have provided a method and means for regulating a turbine so that the steam input may be kept proportionate to the load on the turbine and furthermore I am enabled to maintain the turbine speed within definite narrow limits. Moreover, the arrangement is susceptible for use in connection with a bleeder chamber so that desired pressure may be maintained in the bleeder chamber and bleeder line. Since the arrangement is such that it directly controls the steam flow through the nozzles, it is possible to regulate the operation of the turbine or the pressure in the bleeder chamber without throttling the steam which obviously increases the efficiency of the apparatus.

25 In the foregoing description I have described my invention in connection with a steam turbine but it is to be understood that steam is used in

a generic sense for my invention is adaptable for use with any turbine employing an elastic fluid.

While I have illustrated and described selected embodiments of my invention, it is to be understood that these are capable of variation and modification and I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. In a steam turbine, a wheel having buckets thereon, a plurality of nozzles for emitting jets of steam to the buckets on said wheel, a needle valve for each of said nozzles and shaped to determine the expansion ratio of the nozzle with which it cooperates when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, the position of said needle valves relative to the inlets of said nozzles regulating steam emission from the nozzles, fluid operated means for independently effecting movement of the needle valves into closed and wide open positions and positions intermediate the closed and wide open positions, means for controlling operation of the turbine proportionately to operating conditions thereof and operable to selectively actuate said fluid operated means to selectively position said needle valves in closed or wide open positions or in positions intermediate closed and wide open positions to regulate steam emission to said buckets, and second fluid operated means cooperating with the first fluid operated means to hold said needle valves in the positions into which they are moved upon operation of the means controlling operation of the turbine, said means controlling operation of the turbine including pilot valves for regulating flow of fluid to the first and second fluid operated means.

2. In a steam turbine, a wheel having buckets thereon, a plurality of nozzles for emitting jets of steam to the buckets on said wheel, a needle valve for each of said nozzles and shaped to determine the expansion ratio of the nozzle with which it cooperates when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, the positions of said needle valves relative to the inlets of said nozzles regulating steam emission from the nozzles, fluid operated means for independently effecting movement of the needle valves into closed and wide open positions and positions intermediate the closed and wide open positions, means for controlling operation of the turbine proportionately to operating conditions thereof and operable to selectively actuate said fluid operated means to selectively position said needle valves in closed or wide open positions or in positions intermediate closed and wide open positions to regulate steam emission to said buckets, and second fluid operated means cooperating with the first fluid operated means to hold said needle valves in the positions into which they are moved upon operation of the means controlling operation of the turbine, said means controlling operation of the turbine including pilot valves for regulating flow of fluid to the first and second fluid operated means, and means common to said pilot valves and operable upon operation of said means controlling operation of the turbine to selectively control the flow of fluid to said first and second fluid operated means.

3. In a steam turbine, a wheel having buckets thereon, a plurality of nozzles for emitting jets of steam to the buckets on said wheel, a needle valve for each of said nozzles and shaped to determine the expansion ratio of the nozzle with which it cooperates when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, the positions of said needle valves relative to the inlets of said nozzles regulating steam emission from the nozzles, fluid operated means for independently effecting movement of the needle valves into closed and wide open positions and positions intermediate the closed and wide open positions, means for controlling operation of the turbine proportionately to operating conditions thereof and operable to selectively actuate said fluid operated means to selectively position said needle valves in closed or wide open positions or in positions intermediate closed and wide open positions to regulate steam emission to said buckets, and second fluid operated means cooperating with the first fluid operated means to hold said needle valves in the positions into which they are moved upon operation of the means controlling operation of the turbine, said means controlling operation of the turbine including pilot valves for regulating flow of fluid to the first and second fluid operated means, and means to which all of said pilot valves are connected whereby all of said pilot valves are moved upon operation of said means controlling the operation of the turbine.

4. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, and means cooperating with said piston on the side thereof opposite to that whereat said stem is connected and adapted to retain said piston in positions into which it is moved by fluid admitted into said cylinder on the side of said piston whereat said stem is connected.

5. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, a second cylinder, a piston in said second cylinder, a device extended between said cylinders and having means for transmitting the movement of one of said pistons to the other of said pistons, and means

for admitting a fluid under pressure to the second cylinder to hold the piston therein against movement in one direction whereby the piston to which said stem is connected may be retained in positions into which it is moved by fluid admitted into the first cylinder on the side of the piston therein whereat said stem is connected.

6. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, a second cylinder, a piston in said second cylinder, a device extended between said cylinders and having means for transmitting the movement of one of said pistons to the other of said pistons, means for admitting a fluid under pressure to the second cylinder to hold the piston therein against movement in one direction whereby the piston to which said stem is connected may be retained in positions into which it is moved by fluid admitted into the first cylinder on the side of the piston therein whereat said stem is connected, and means including a pilot valve controlling fluid flow to both of said cylinders and regulating movement of said pistons.

7. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, a second cylinder, a piston in said second cylinder, a device extended between said cylinders and having means for transmitting the movement of one of said pistons to the other of said pistons, means for admitting a fluid under pressure to the second cylinder to hold the piston therein against movement in one direction whereby the piston to which said stem is connected may be retained in positions into which it is moved by fluid admitted into the first cylinder on the side of the piston therein whereat said stem is connected, means including a pilot valve controlling fluid flow to both of said cylinders and regulating movement of said pistons, and means responsive to operating conditions of the turbine for controlling the operation of said pilot valve to regulate fluid flow to said cylinders.

8. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet

and into positions intermediate the closed and wide open positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, means cooperating with said piston on the side thereof opposite to that whereat said stem is connected and adapted to retain said piston in positions into which it is moved by fluid admitted into said cylinder on the side of said piston whereat said stem is connected, and means responsive to operating conditions of the turbine and controlling fluid admission to said cylinder to regulate the position of the piston therein and the position of said needle valve relative to said inlet.

9. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, a second cylinder, a piston in said second cylinder, a device extended between said cylinders and having means for transmitting the movement of one of said pistons to the other of said pistons, means for admitting a fluid under pressure to the second cylinder to hold the piston therein against movement in one direction whereby the piston to which said stem is connected may be retained in positions into which it is moved by fluid admitted into the first cylinder on the side of the piston therein whereat said stem is connected, means including a pilot valve controlling fluid flow to both of said cylinders and regulating movement of said pistons, and means responsive to operating conditions of the turbine for controlling the operation of said pilot valve to regulate fluid flow to said cylinders, said means responsive to the operating conditions of the turbine including a movable member connected to the piston in the second cylinder, a member connected to said pilot valve and having a slot therein, means on said movable member disposed in said slot to be movable therealong, and means connecting the movable member to a device actuated by operating conditions of the turbine whereby actuation of said device moves said pilot valve whereupon movement of the piston in the second cylinder is effected and the movable member is moved with said piston to move the means thereon in said slot along said slot to move the pilot valve back into the position in which it was disposed prior to movement thereof upon actuation of the device responsive to operating conditions of the turbine.

10. In a steam turbine, a wheel having buckets thereon, a nozzle for emitting a jet of steam to the buckets on said wheel, a needle valve for said nozzle and shaped to determine the expansion ratio of the nozzle when extended into the inlet of said nozzle and movable between closed and wide open positions relative to said inlet and into positions intermediate the closed and wide open

positions, a cylinder, a piston in said cylinder, said needle valve including a stem extended into said cylinder and connected to said piston whereby said needle valve is movable with said piston, means for admitting fluid to said cylinder on both sides of said piston to effect movement of said piston and said needle valve, a second cylinder, a piston in said second cylinder, a device extended between said cylinders and having means for transmitting the movement of one of said pistons to the other of said pistons, means for admitting a fluid under pressure to the second cylinder to hold the piston therein against movement in one direction whereby the piston to which said stem is connected may be retained in positions into which it is moved by fluid admitted into the first cylinder on the side of the piston therein whereat said stem is connected, means including a pilot valve controlling fluid flow to both of said cylinders and regulating movement of said pistons, and means responsive to operating conditions of

the turbine for controlling the operation of said pilot valve to regulate fluid flow to said cylinders, said means responsive to the operating conditions of the turbine including a device actuated by changes in the operating conditions, a link connected to said device to be movable thereby, a bell crank lever, means connecting the bell crank lever to the piston in the second cylinder, means connecting the bell crank lever to said link, said pilot valve including a part having a slot therein, means on the bell crank lever movable along said slot, movement of said link moving said bell crank lever to move the pilot valve to admit fluid at least to the second cylinder to move the piston therein and movement of the piston in the second cylinder moving said bell crank to move the means thereon in said slot along said slot to thereby move the pilot valve back into the position in which it was disposed prior to movement of said link.

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