

March 10, 1970

F. RERECICH ET AL

3,499,456

FLUID FLOW CONTROL SYSTEM

Filed June 5, 1967

2 Sheets-Sheet 1

FIG. 1.

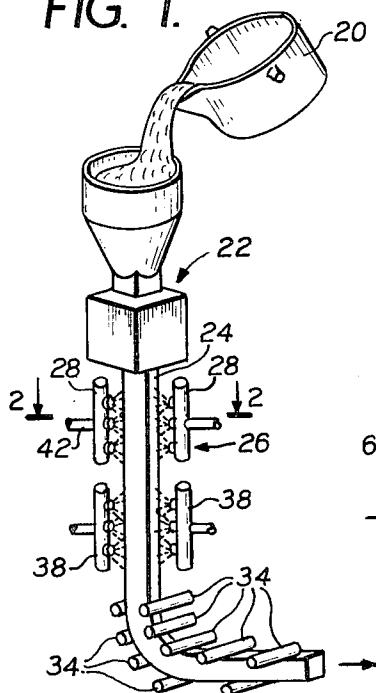


FIG. 2.

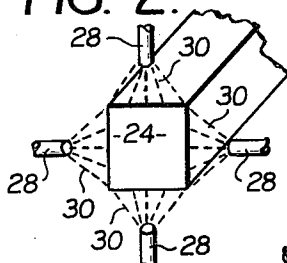


FIG. 3.

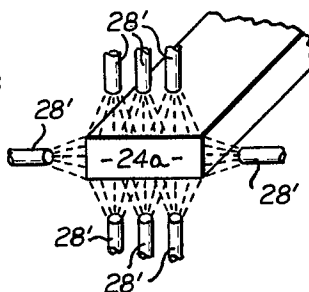
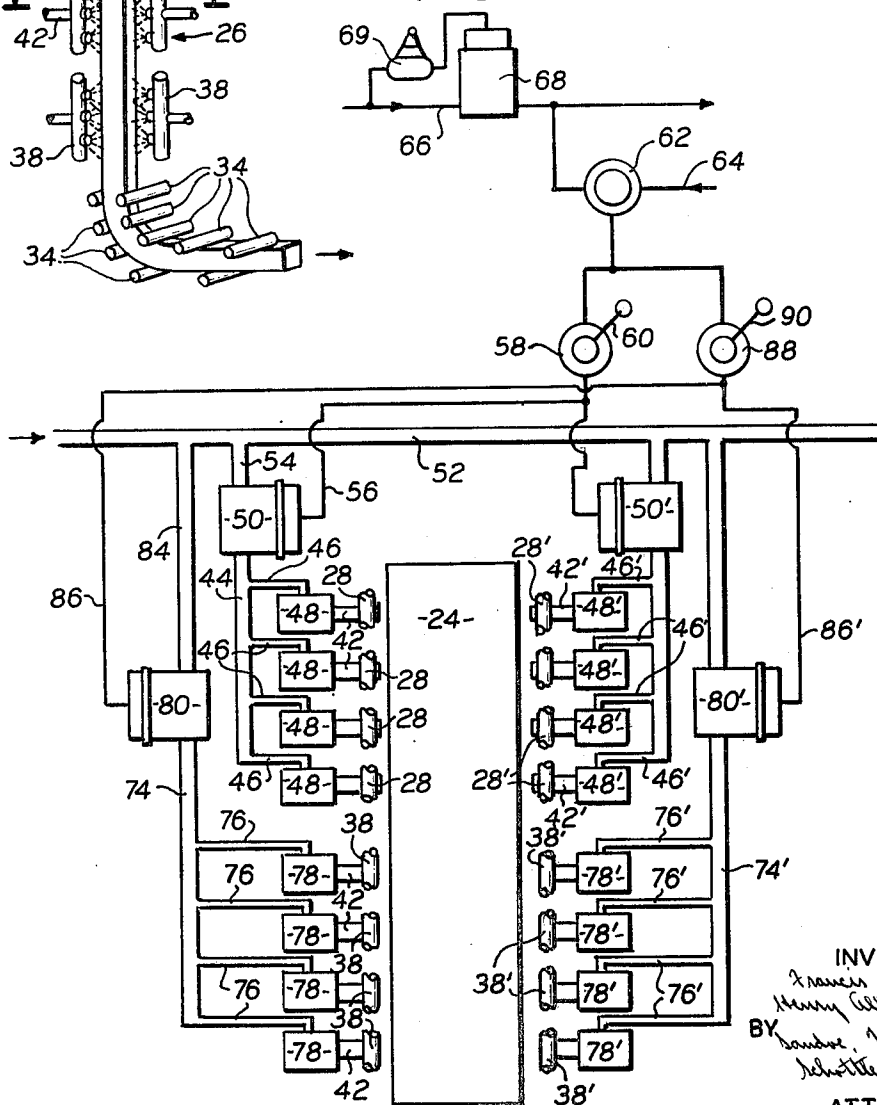


FIG. 4.



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FIG. 5.

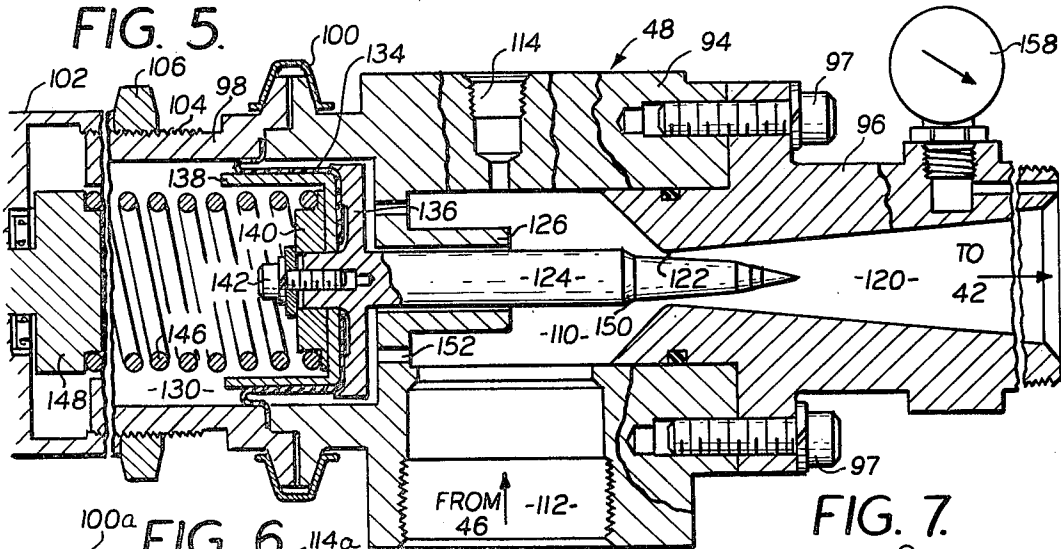


FIG. 6.

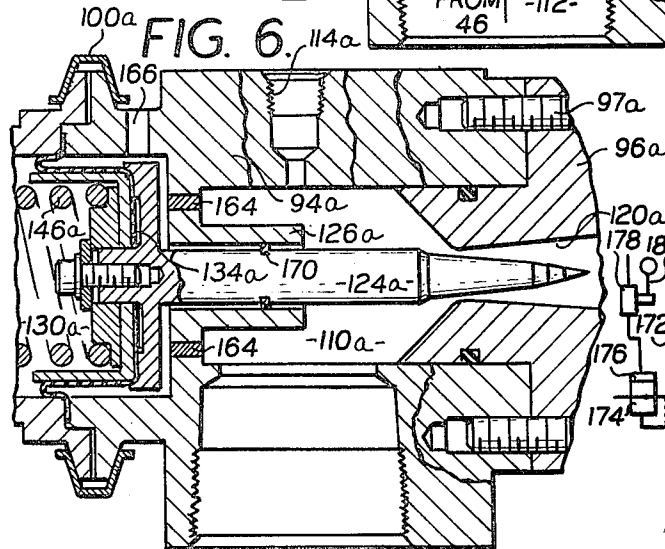


FIG. 7.

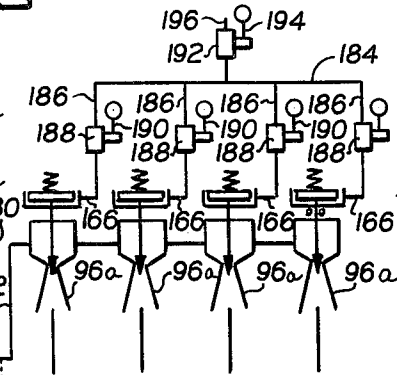
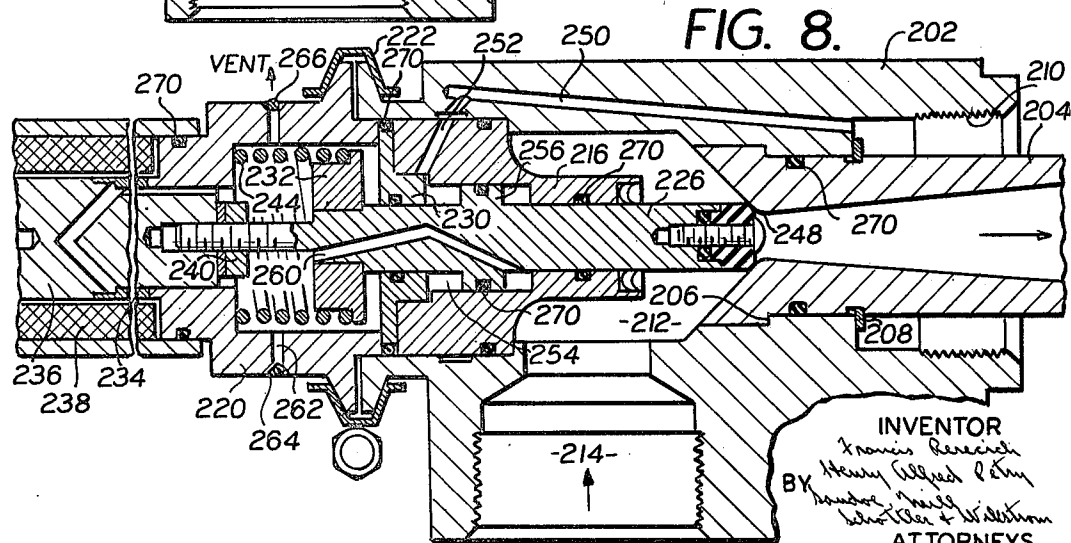


FIG. 8.



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FLUID FLOW CONTROL SYSTEM

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5 Claims

ABSTRACT OF THE DISCLOSURE

A fluid flow control system delivers constant volume of fluid in spite of variations in the back pressure over a substantial range. A constant inlet pressure is used for the fluid, and a cavitating venturi is placed in the delivery line so that flow is independent of back pressure as long as the back pressure does not reach a critical value which is substantially 85% of the upstream pressure on the venturi. The system is suitable for various uses requiring somewhat different combinations, but one of the principal use is to supply fluid for cooling the metal in continuous casting processes where it is essential that the amount of coolant sprayed on all sides of the casting be uniform to prevent warping or stressing, and cracking or rupturing of the casting.

BRIEF DESCRIPTION OF INVENTION

In its broader aspects, this invention is an improved system for controlling the flow of fluid in such a way as to obtain uniform delivery of fluid regardless of variations, within a substantial range, of the back pressure against which the fluid is delivered. The invention obtains this result by using cavitating venturis in the system that convert the pressure head upstream from the venturis to velocity head at the throat of the venturis.

A specific embodiment of the invention is a combination of a coolant control system with continuous casting apparatus having cooling on all sides of the casting proportioned with respect to the shape of the casting, and preferably with two or more stages of independent control of the pressure, but with "ganging" of the control for the different sides of the casting in each stage.

In the preferred embodiment of the invention, the flow of the fluid is adjusted by changing the cross-sectional flow area at the throat of the venturi, and this system provides means for changing the cross-section of a number of venturis similarly and simultaneously. Some modifications of the invention vary the cross-section in proportion to changes in the upstream pressure of the fluid that is supplied to the venturis. In such a case the flow control is self-adjusting. Other modifications have the cross-section responsive to the pressure of some other control fluid, the pressure of which is independent of the fluid that is controlled. In any case, a gang of spray nozzles can have their fluid supplies adjusted by the same amount by making them responsive to the same pressure.

Changes in back pressure may result from a variety of causes. For example, with spray nozzles, particularly where the spray is against hot metal and there is violent splashing and steaming, particles may be blown against nozzles and stick so that some of the nozzle outlets are clogged or partially clogged. Where coolant is supplied to a stack, back pressure varies depending upon whether the stack damper is open or partially closed.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

BRIEF DESCRIPTION OF DRAWING

FIGURE 1 is a diagrammatic view showing a continuous casting apparatus with cooling means for cooling the surface of the casting;

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FIGURE 2 is a diagrammatic, enlarged, sectional view taken on the line 2—2 of FIGURE 1;

FIGURE 3 is a view similar to FIGURE 2 but showing the coolant applied to a casting of different cross-sectional shape from that of FIGURE 2;

FIGURE 4 is a piping diagram for a coolant system such as used in the other views;

FIGURE 5 is a greatly enlarged sectional view showing one of the cavitating venturis used for controlling the spray in FIGURES 1—4;

FIGURE 6 is a sectional view, similar to FIGURE 5, but showing the cavitating venturi controlled by fluid other than that which is supplied to the venturi;

FIGURE 7 is a diagrammatic view showing the controls for venturis of the type shown in FIGURE 6; and

FIGURE 8 is a sectional view of a modified form of venturi that can be used for the invention.

DETAILED DESCRIPTION OF INVENTION

FIGURE 1 shows continuous metal casting apparatus. The apparatus shown is a vertical or high head machine. Molten metal is poured from a ladle 20 into the top of a water jacketed mold 22 from which the cast metal, with the surface hardened, emerges as a continuous ingot or work piece 24. Just below the mold 22, the work piece passes through a secondary cooling station 26 where jets of coolant, preferably water, are sprayed against the surface of the work piece by spray head 28. FIGURE 1 shows different spray heads 28 directing sprays of coolant against different sides of the work piece 24. There are sprays directed against a plurality of sides of the work piece 24 in FIGURE 1, but actually some of the spray heads are omitted for clearer illustration; and in practice there are spray heads on all sides of the work piece 24. For a work piece of square cross section, such as shown in FIGURE 1, there are spray heads 28 of equal size on all four sides as illustrated in FIGURE 2. The sprays of coolant are indicated in dotted lines and designated by the reference characters 30. These sprays distribute the coolant substantially uniformly over the surfaces of the work piece 24.

The additional cooling supplied at the secondary cooling station 26 solidifies the work piece to a greater depth below its surfaces and the work piece passes on to turning and straightening rolls 34, preferably with additional cooling from spray head 38 in the region of the rolls 34.

If the work piece is square as in the case of the work piece 24 shown in FIGURE 2, the amount of coolant required for all surfaces is equal; but with a work piece 24a as shown in FIGURE 3 it is necessary to have more spray heads 28' directed against the wide sides of the work piece than are directed against the narrow sides of the work piece.

FIGURE 4 is a piping diagram showing the control of coolant to the spray heads 28 and 38. Each of these spray heads receives its coolant through a fluid supply line 42. All of the spray heads 28, on the left side of the work piece 24 in FIGURE 4, receive their coolant from a common header 44 through branch pipes 46. There is a control unit 48 associated with each of the spray heads 28 for controlling the amount of coolant that reaches the spray head 28 from the branch pipe 46. The construction of these control units will be explained in connection with FIGURES 5—8. The coolant for the header 44 comes from the delivery side of a pressure regulator 50 which receives its coolant from a supply line 52 through an inlet pipe 54. The pressure regulator 50 is adjustable and its loading is controlled by fluid pressure supplied through tubing 56 which leads to the sensing or loading chamber of the regulator 50. Such regulators are well understood and no further description of the

regulator 50 is necessary for a complete understanding of this invention.

The fluid supply for the tubing 56 comes from a differential pressure regulator 58 which, in the illustrated construction, is adjustable manually by a handle 60 to change the pressure of fluid supplied to the tubing 56, and to thereby regulate the adjustment of the pressure regulator 50 which controls the coolant. There is a selector valve 62 which permits the use of fluid from a source of fluid under pressure that delivers the fluid through a supply line 64, or fluid from a pressure regulator 68 having a loading dome that is supplied with pressure through an adjustable pressure regulator 69. The pressure regulation effected by the pressure regulator 68 affects the pressure supplied to all of the downstream fluid lines and thus provides for simultaneous and equal pressure changes to different venturis and groups of venturis.

The spray heads 38 receive their coolant from a header 74 which has branch pipes 76 leading to the respective spray heads 38 and with a controller 78 associated with each of the spray heads 38 in the same manner as the controllers 48 are associated with the spray heads 38. There is a pressure regulator 80 for regulating the pressure of the coolant in the header 74. Coolant is supplied to the regulator 80 through an inlet pipe 84 from the supply line 52. This pressure regulator 80 is loaded by fluid pressure supplied to tubing 86 from a regulator 88 which can be adjusted by a manual control handle 90.

On the other side of the work piece 24 the spray heads 28' and 38' are supplied with coolant in the same way as on the left hand side in FIGURE 1 and the corresponding parts are indicated by the same reference characters with a prime appended. The regulator 50' is supplied with coolant from the same supply line 52 as is the regulator 50, and so is the regulator 80'. The regulators 50 and 50' are both loaded by fluid from the same regulator 58 so that any adjustments made by the handle 60 have equal effects on the regulators 50 and 50'. Similarly, the regulators 80 and 80' are loaded from the same regulator 88 so that both of them are adjusted equally by movement of the manual control handle 90 on the pressure regulator 88. In practice, all of the spray heads at the secondary cooling station 26 on all sides of the work piece 28 are similar to the samples shown for the left and right hand sides of the work piece 24 in FIGURE 4. That is, all of them are controlled from the same controller 58 and from the same valve 62. In similar fashion all of the spray heads 38 adjacent the rolls are controlled from the same pressure regulator 88.

FIGURE 5 shows the construction of one of the control units 48. This control unit includes a housing having a center housing portion 94. A venturi 96 which forms the discharge end of the housing 48 is connected with the center housing portion 94 by a circle of screws 97. There is a cylindrical portion 98 of the housing fastened to the center portion 94 by a clamping ring 100. An end cap 102 screws over threads 104 on the cylindrical portion 98, and the end cap 102 is secured in position by a lock nut 106.

The center housing portion 94 encloses a chamber 110 which is the upstream chamber of the venturi. There is an inlet port 112 through which coolant is supplied to the control unit 48 from the branch pipe 46. There is another port 114 which can be used for an upstream pressure gauge which can be calibrated in flow units because of the independence of flow and downstream pressure obtained by this invention.

The venturi 96 has a center opening 120 with a throat 122 where the cross-section of the venturi opening is a minimum. The venturi tapers in both directions from the throat 122. A movable needle valve element 124 extends through the throat 122. This needle valve element 124 can close the throat completely if moved far enough to the right in FIGURE 5. The movable element 124 is tapered so that as it moves toward the left, the open cross-section of the venturi throat increases progressively. Thus

the movable valve element 124 is a means for changing the cross-sectional flow area at the venturi throat.

In the chamber 110 there is a bearing element 126 projecting from an end wall of the chamber 110 opposite the throat 122 but in alignment with the throat. The movable valve element 124 slides back and forth in the bearing element 126, and left hand end of the movable valve element 124 extends into a cylindrical chamber 130 which is located partly in the cylindrical portion 98 of the housing and partly in an aligned section of the central housing portion 94. A movable wall extends across this chamber 130. In the construction illustrated this movable wall includes a flexible diaphragm 134 which has its peripheral edge clamped between the cylindrical portion 104 and the center portion 94 of the housing. The movable wall also includes a flange 136 which extends from the valve element 124 on one side of the diaphragm 134, and a cup 138 having a flat bottom which bears against the other side of the flexible diaphragm 134. A collar 140 is clamped against the bottom of the cup 138 and clamps the cup 138 against the diaphragm 134 and the diaphragm against the flange 136. This collar 140 is held in position by a screw 142 threaded into an opening in the end of the valve element 124.

There is a spring 146 in the chamber 130; and this spring 146 is compressed between a flange on the collar 140 and a flange on a disk 148 located in the cap 102.

The movement of the movable wall in the chamber 130 determines how far the valve element 124 moves in the venturi throat 122 and the movable wall assembly is held centered in the diaphragm 130 by the portion of the valve element 124 which slides in the bearing element 126. In the construction shown, the movable wall is close to its right hand limit of travel and the cavitating venturi is almost as fully restricted as it can become. If it is desirable to have the cross-section of the venturi further restricted, the venturi 96 can be removed by unscrewing the retaining screws 96 and a venturi which extends further into the chamber 110 can be used. If the venturi extends all the way to a sloping face 150 of the valve element 124, then the venturi throat is completely closed.

The movable wall consisting of the diaphragm 134 and the elements which clamp it, as previously explained, is moved toward the left in FIGURE 5 against the tension of the spring 146 by fluid pressure in the chamber 110 passing through openings 152 in the end wall of the chamber 110. This pressure enters the chamber 130 on the right hand side of the diaphragm 134 and when the pressure is sufficient to overcome the spring 146, it moves the valve element 124 toward the left and causes the open section of the venturi 122 to increase in area. Toward the downstream end of the venturi 96, there is a gauge 158 for indicating the downstream pressure in the venturi passage 120.

As long as the back pressure on the venturi 96 is less than the "critical venturi back pressure," the flow of fluid through the venturi can be determined by the formula

$$\text{Flow} = K A_t \sqrt{\frac{P_a - P_v}{\text{S.G.}}}$$

Where

A_t is the throat area of the venturi

P_a is the pressure upstream of the throat

P_v is the vapor pressure of the coolant

S.G.=specific gravity

Since P_v is low it can be ignored in practical computations. Since S.G. does not change significantly, its effect can be ignored in computations. The critical back pressure, above which this equation is no longer true, is about 85% of the inlet pressure if there is no obstruction in the venturi. With an obstruction such as results from the tapered valve element 124, making the open throat.

area annular, the critical back pressure is somewhat less than 85% of the upstream pressure.

The back pressure can be determined from the gauge 158 and as long as this back pressure is below the critical pressure, the flow of coolant through the venturi can be considered as depending only upon the upstream pressure and the area. In the construction shown in FIGURE 5 an increase in the pressure of coolant supplied to the chamber 110 increases the flow in two ways after the pressure has become high enough to influence the spring 146. For example, the increase in pressure raises the upstream pressure and also increases the area by pushing the diaphragm 134 back so as to draw the tapered movable element 124 further to the left thus increasing the area of the annular opening at the throat 122.

FIGURE 6 shows a modified construction which is the same as that shown in FIGURE 5 except that the movement of the valve element is responsive to an independent pressure instead of the pressure in the venturi itself. The parts in FIGURE 6 which correspond to those in FIGURE 5 are indicated by the same reference characters with a letter *a* appended. The ports through the end wall of the chamber 110*a* are closed by plugs 164 so that there is no communication between the valve chamber 110*a* and the cylindrical chamber 130*a* which contains the flexible diaphragm 134*a*. In order to provide a control fluid pressure on the side of the diaphragm 134*a* opposed to the spring 146*a*, there is an extra port 166 provided in the center housing portion 94*a* and the control fluid supplied through this port 166 operates the diaphragm 134*a* to move the valve element 124*a*. In order to prevent leakage of fluid from the valve chamber 110*a* to the diaphragm chamber through the bearing element 126*a*, a sealing ring 170 is provided in the bearing element 126*a*.

FIGURE 7 shows the way in which a group of venturis 96*a* are operated by pressure independent of the coolant fluid pressure. Coolant is supplied to all of the venturis 96*a* through a supply line 172 in which the pressure is regulated by a pressure regulator 174 having a sensing pressure chamber 176 loaded by fluid from a pressure regulator 178 which can be adjusted by the manual control handle 180.

Control fluid is supplied to the ports 166 of all of the venturis 96*a* from a header 184 having a separate branch 186 leading to each of the venturis 96*a*. The pressure of the control fluid supplied to the ports 166 of each of the venturis is individually adjustable by a differential pressure regulator 188 in the branch 186 leading to that venturi. Each of these pressure regulators 188 is adjustable to changes in delivery pressure by moving a manual adjustment handle 190. The pressure supplied to the header 184 is controlled by another pressure regulator 192 which has an adjustable control handle 194.

With the piping diagram of FIGURE 7 it will be apparent that the pressures for the individual venturis 96*a* can be regulated at the differential pressure regulators 188. The pressure regulator 192 which is common to all of the venturis 96*a* provides means for simultaneously changing the upstream pressures on all of the differential pressure regulators 188. The fluid supply to the pressure regulator 192 comes from a supply line 196.

FIGURE 8 shows another modification of the invention. In this modification there is a housing 202 which contains a venturi 204. This venturi fits against a shoulder 206 and is held in place by a snap ring 208. The fitting to which the venturi supplies coolant screws into threads 210 in an opening in the end of the housing.

The housing 202 encloses a valve chamber 212 to which coolant is supplied through an inlet passage 214. There is a bearing fixture 216 located in the left hand end of the housing 202 and this bearing fitting 216 is held in place by an end portion 220 of the housing at-

tached to the main housing 202 by a circumferential clamping ring 222.

The housing 202 also contains a valve element 226 which seats against the tapered wall on the upstream side of the venturi 204. This valve element 226 slides in a bearing in the bearing fitting 216 and in another bearing in a collar 230 which is assembled in alignment with the bearing fitting 216 and which in effect forms a part of the bearing fitting 216. On the portion of the valve element 226 which projects beyond the left hand end of the bearing fitting 216 there is a collar 232 attached to the valve element 226 by a press fit; and the bearing element 226 beyond the collar 232 is threaded for connection with a plunger 234 of a solenoid comprising a core 236 and a coil 238. There is a lock nut 240 for locking the plunger 234 in any desired adjusted position to which it may be moved along the threads on the valve element 226. A compression spring 244 is compressed between a flange of the collar 232 and a shoulder of the chamber in which the spring 244 is located.

When the coil 238 is energized, the plunger 234 is pulled to the left in FIGURE 8 to move the valve element 226 away from the tapered surface of the venturi 204 and this opens an annular space between the valve element 226 and the surface of the venturi 204 so that coolant in the chamber 212 can flow through the throat 248 of the venturi. Unlike the constructions shown in FIGURES 5 and 6, the modification shown in FIGURE 8 is a two-position control unit which either shuts off the flow of coolant or provides maximum cross-section for flow of coolant through the venturi. The supply of coolant can still be controlled, however, by regulating the upstream pressure at which the coolant is supplied through the inlet port 214. The construction can be made without the valve in the venturi, and the fluid flow can be controlled by external means.

The valve element 226 is balanced by a passage 250 which leads from a location exposed to the pressure in the supply line from the venturi back to a port 252 which opens into a chamber 254 containing a piston 256 of an annular area which balances the area of the valve element 226 that is exposed to downstream pressure when the valve element 226 is in the closed position shown in the drawing.

The other parts of the housing including the space on the right hand side of the piston 256 and the space in which the collar 232 and spring 244 are located are connected together by a communicating passage 260 and pressure can vent from the spring chamber through radial ports 262 that open into a circumferential groove 264 containing a flexible and elastic ring 266 that serves as a vent valve. Sealing rings 270 are provided at various locations to prevent the leakage of fluid under pressure from one portion of the assembly into another.

The preferred embodiments of the invention have been illustrated and described, but changes and modifications can be made and some features can be used in different combinations without departing from the invention as defined in the claims.

What is claimed is:

1. A fluid control system for supplying uniform cooling to different locations independently of back pressure at the different locations including a fluid supply line, a cavitating venturi in series with the supply line, means for changing the pressure in the supply line to a level substantially higher than the critical back pressure of the cavitating venturi, a fluid delivery line to which the fluid flows downstream of the venturi, there being a plurality of spray nozzles directed against different areas to be cooled, a different cavitating venturi through which cooling fluid is supplied to different spray nozzles, and a common controller for changing the inlet pressure to the different venturis equally and simultaneously.

2. A fluid flow control system including a fluid supply line a plurality of cavitating venturis connected with the

supply line, means for changing the cross sectional flow area of the throat of each venturi to adjust the rate of flow through the venturi, means for supplying the fluid through the supply line to the upstream side of the venturis at a pressure substantially higher than the critical back pressure of the cavitating venturi, a fluid delivery line to which the fluid flows downstream of each venturi, the means for supplying cooling fluid to the supply line supplying said fluid at a delivery pressure substantially higher than the back pressure produced by the spray nozzle, and a common controller for changing the cross sectional flow area at the throats of all of the venturis equally and simultaneously.

3. A fluid flow control system including a fluid supply line, a cavitating venturi in series with the supply line, means for changing the cross sectional flow area at the throat of the venturi to adjust the rate of flow through the venturi, means for supplying the fluid through the supply line to the upstream side of the venturi at a pressure substantially higher than the critical back pressure of the cavitating venturi, and a fluid delivery line to which the fluid flows downstream of the venturi, a first chamber at the upstream end of the venturi through which fluid from the supply line flows into the venturi, and a second chamber in the housing sealed off from the first chamber, the means for changing the cross sectional flow area at the throat of the venturi including a movable element at the throat of the venturi, a wall of the second chamber that is movable in response to the fluid pressure in the second chamber, a motion-transmitting connection between the movable wall and the movable element at the throat of the venturi, characterized by the motion-transmitting connection having a cylindrical portion between the movable wall and the movable element, a bearing in the housing substantially in axial alignment with the venturi and in which the cylindrical portion of the motion-transmitting connection slides, the movable element being a tapered valve element connected with said cylindrical portion and extending through the throat of the venturi and restricting the cross section at the throat to an annular cross section, the radial width of which varies with axial movement of

the tapered valve element, the movable wall being a flexible diaphragm, and the bearing for the cylindrical portion being of sufficient length to center the diaphragm in the chamber of the tapered element in the venturi throat.

4. A fluid flow control system for supplying uniform cooling to different locations independently of back pressure at the different locations, including a fluid supply line, a plurality of cavitating venturis, means for supplying fluid at equal pressure to all of the cavitating venturis, means for changing the pressure of the fluid supply equally and simultaneously for all of the cavitating venturis, and a plurality of different nozzles supplied with cooling fluid from different venturis, the nozzles being directed against different locations on areas to be cooled.

5. The fluid flow control system described in claim 4 characterized by conveyor means along which a workpiece moves, the nozzles being located along the course of a workpiece on the conveyor for cooling the workpiece as it moves past said nozzles, some of the nozzles being on one side of the course and some being on the other side of the course, the nozzles on both sides receiving equal flow output of cooling fluid from the cavitating venturis and being disposed in position to effect substantially equal cooling of the different sides of the workpiece to avoid warping or stressing of the workpiece as the result of unequal cooling.

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