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Carsten

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[54] **HYDROPNEUMATIC CAPACITOR**

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[52] **U.S. Cl.**..... **137/211.5,** 137/491, 137/492.5; 138/30, 239/99, 251/38, 251/65

[51] **Int. Cl.**..... **B67d 5/54,** F16k 31/12

[58] **Field of Search**..... 61/12, 13; 137/489, 211.5, 137/491, 492.5; 138/26, 30; 169/9, 13; 239/99; 251/29, 33, 35, 38, 45, 65; 141/46, 47, 49, 52, 54, 192, 285

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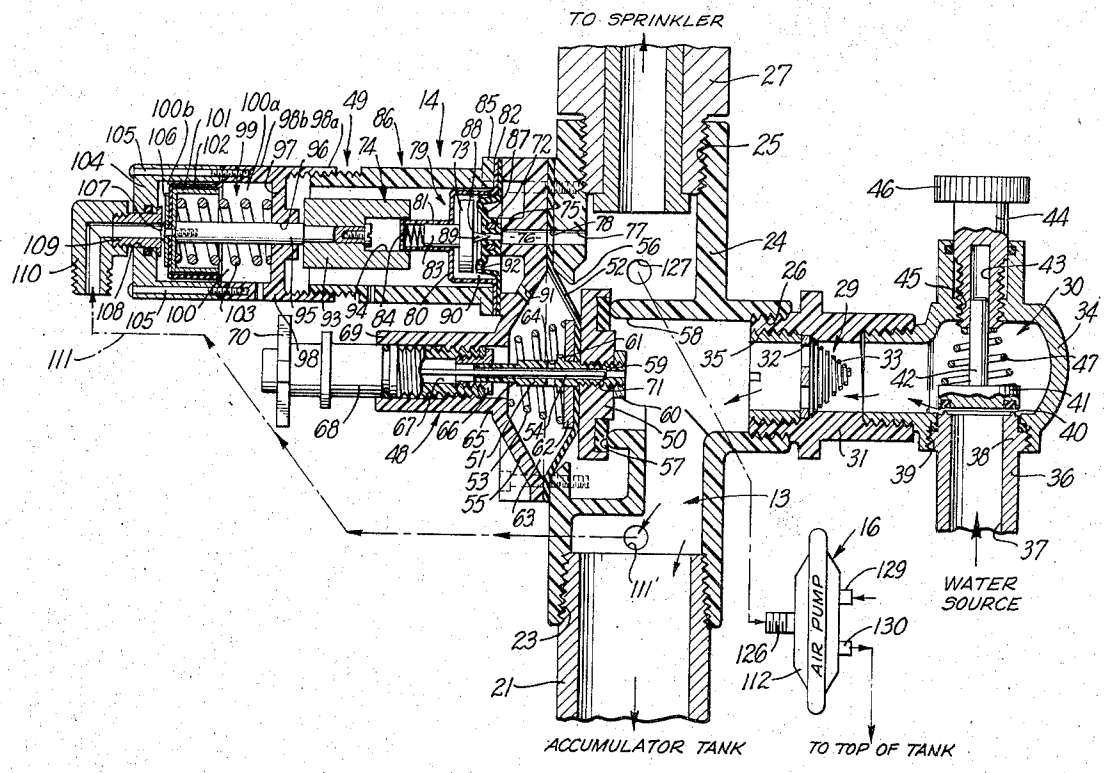
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[57] **ABSTRACT**

A hydropneumatic capacitor particularly useful in sprinkler systems and comprising an air-water accumulator tank connected by conduit means to a low gallonage water source and by a normally closed valve means to a sprinkler head. The valve means possesses a predetermined pressure threshold of operation for rapidly opening to discharge water from the tank through the sprinkler head. Upon each discharge from the tank, air is pumped into the tank by operatively associated pump means to charge the tank with compressed air.

8 Claims, 8 Drawing Figures



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FIG. 3.

FIG. 1.

FIG. 2.

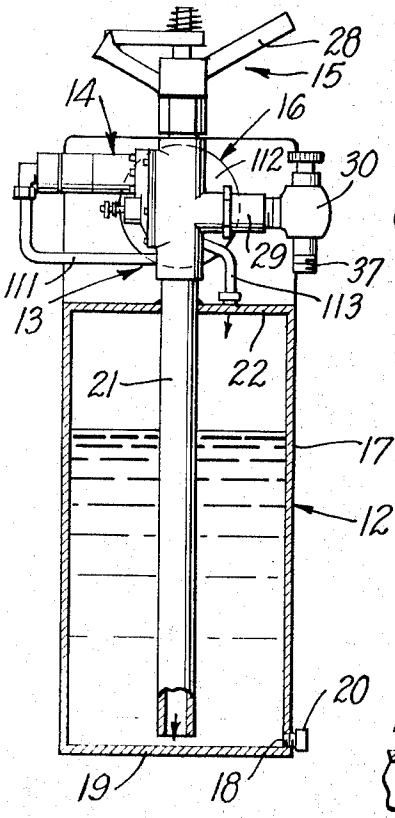


FIG. 4.

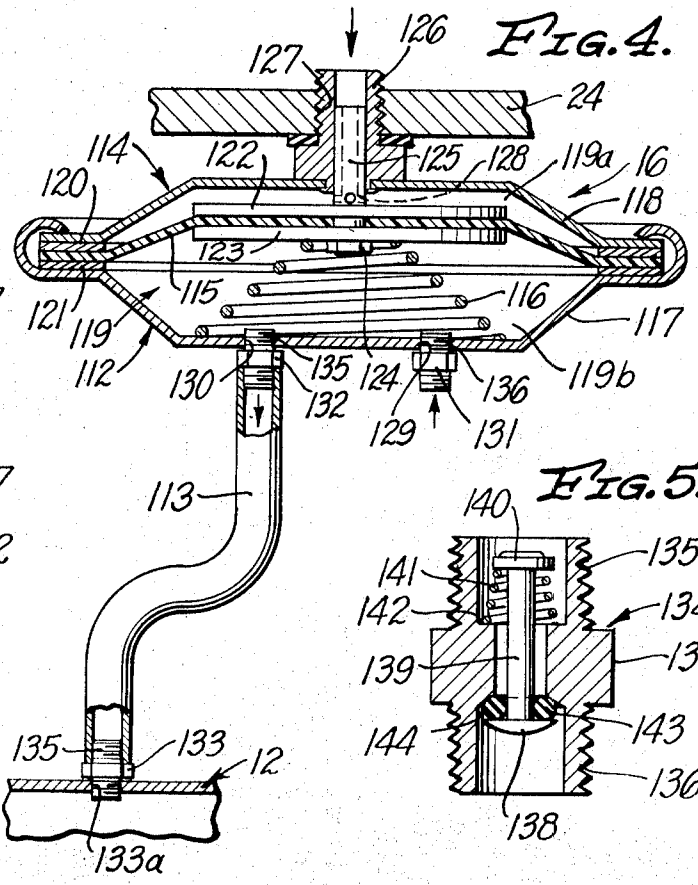
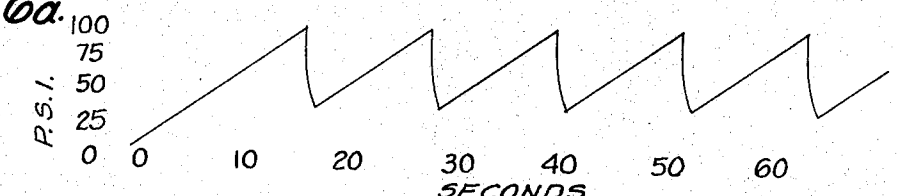


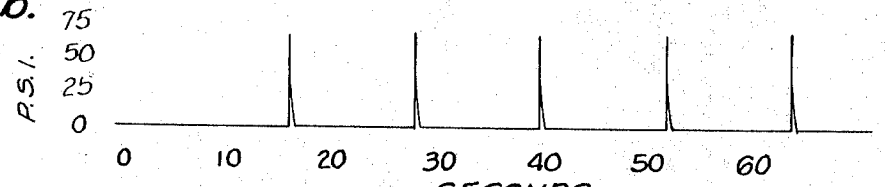
FIG. 5.

FIG. 6a.



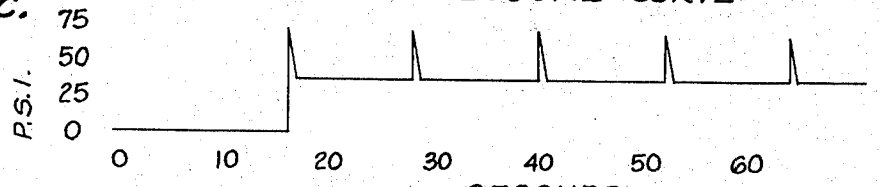
ACCUMULATOR TANK PRESSURE CURVE

FIG. 6b.



AIR PUMP PRESSURE CURVE

FIG. 6c.



COMPRESSION CHAMBER PRESSURE

HYDROPNEUMATIC CAPACITOR

The present invention relates to hydropneumatic capacitors and more particularly to such a capacitor which is ideally suited for use in sprinkler systems for agricultural and turf irrigation as well as for environmental dust control.

Geneally speaking, there are two basic forms of sprinkler irrigation systems. The first includes an array of closely spaced sprinkler heads connected by piping, valves, and controls to a relatively low gallonage water source. Such systems are usually employed as residential lawn irrigation systems. Because of the extensive piping and controls required in such systems, as well as the high cost of the component parts and the installation thereof, such systems are not generally employed in the irrigation of larger areas such as golf courses, farm fields, and the like. The second form of sprinkler irrigation system is usually employed in such situations.

The second form of sprinkler irrigation system includes a fewer number of widely separated sprinkler heads connected by piping to a water source. The water source is a high gallonage source. This allows the sprinkler heads to apply water over relatively long distances and permits a fewer number of sprinkler heads to apply water to a large area.

While the use of a high gallonage source permits discharge water over long distances, it also results in a rather steady application of large quantities of water to the soil being irrigated. Usually, the water is applied to the soil faster than it can be absorbed. Under such conditions, quantities of water accumulate in puddles and ponds on top of the soil while other quantities of water run off and produce undesired soil erosion. To avoid such occurrences requires the addition of manual or electrical valves and controls to produce a timed and successive operation of the sprinkler heads in the second form of the sprinkler system. This material increases the purchase price as well as the cost of installation and maintenance of such systems.

The present invention is directed to a hydropneumatic capacitor including in combination an air-water accumulator tank, quick-opening normally closed valve, and an air pump, for use in sprinkler systems of the second form. The capacitor is designed to enable such systems to utilize low gallonage water sources and to intermittently discharge water from the sprinkler heads thereof over long distances. The rate of discharge is controllable to insure that the soil will absorb all water dispensed by the sprinkler heads, thereby preventing undesired puddling, water run-off, and soil erosion.

Accordingly, it is a general object of the present invention to provide the second form of sprinkler irrigation system with simple and economical means for automatically dispensing measured quantities of water without use of extensive electrical or electromechanical controls or the like.

Another object of the present invention is to provide a hydropneumatic capacitor suited for use in sprinkler systems and which will enable sprinkler heads to intermittently discharge water from a low gallonage source over long distances.

A further object of the present invention is to provide a hydropneumatic capacitor of the foregoing character comprising a fluid accumulator tank connected by conduit means to a low gallonage water source and by a normally closed valve to a sprinkler head, the valve possessing a predetermined pressure threshold of operation for rapidly opening to discharge water from the tank through the sprinkler head.

Still another object of the present invention is to provide a capacitor of the foregoing character including air pump means for pumping air into the tank to charge the tank with compressed air upon each discharge of water therefrom.

A still further object of the present invention is to provide a hydropneumatic capacitor of the foregoing character wherein the valve means comprises a magnetically actuated valve for rapidly and momentarily opening to discharge desired quantities of water through the associated sprinkler head at predetermined and controllable time intervals.

Another object of the present invention is to provide a hydropneumatic capacitor of the foregoing character which is substantially insensitive to pressure changes in the line supplying water thereto and which may be regulated to discharge like quantities of water independent of its placement at different altitudes in a sprinkler irrigation system.

The foregoing as well as other objects and advantages of the present invention may be more clearly understood by reference to the following detailed description when considered with the drawings which, by way of example only, depict one form of hydropneumatic capcitor connected to a sprinkler head and embodying the features of the present invention.

In the drawings:

FIG. 1 is the side view of the hydropneumatic capacitor and sprinkler head combination supported on the ground and ready for connection to a water source for dispensing quantities of water at a predetermined rate;

FIG. 2 is the side view of the combination illustrated in FIG. 1 partially in section and showing the interior of an air-water accumulator tank of the capacitor;

FIG. 3 is a sectional side view of a portion of the capacitor including conduit means for supplying water to the accumulator tank and to valve means for regulating operation of the capacitor;

FIG. 4 is a sectional side view of air pump means for the capacitor;

FIG. 5 is a sectional side view of one of the check valves included in the air pump means; and

FIGS. 6*a*, 6*b*, and 6*c* are curves schematically representing changes in pessure at various points in the capacitor during operation thereof.

In the drawings, the hydropneumatic capacitor is denoted by the numer **8**, and as shown in FIG. 1 may be supported on the ground by a tripod **9** including a support ring **10** and three legs **11***a*, *b*, and *c*. Basically, the capacitor **8** comprises a fluid or air-water accumulator tank **12** connected by conduit means **13** to a low gallonage water source (not shown) and by normally closed valve means **14** to a discharge means **15.** The conduit means **13** supplies water to a lower portion of the tank **12** to rise within the tank and compress air in an upper portion thereof. The valve means **14** possesses a predetermined pressure threshold of operation. When the fluid pressure in the tank reaches the predetermined threshold value, the valve rapidly and momentarily opens to discharge liquid from the tank through the discharge means **15.** As fluid pressure in

the tank drops, air is pumped by air pump means 16 into the upper portion of the tank to charge the tank with compressed air.

More particularly, the tank 12 comprises a closed vertically extending cylinder 17 having a drain port 18 immediately adjacent a bottom 19 of the tank. The drain port 18 is normally closed by a plug 20. With the plug in place, water supplied by the conduit means 13 will rise in the lower portion of the tank and compress air in the upper portion thereof.

To accomplish this, the illustrated conduit means 13 comprises a tube 21 extending vertically through a closed top 22 of the tank to a point immediately adjacent the tank bottom 19. The tube 21 is open at its lower end to dispense water from the source to the lower portion of the tank. The upper end of the tube 21 is also open and is secured in an internally threaded bottom port 23 of a main housing 24.

In addition to the bottom port, the main housing 24 includes internally threaded top and side ports 25 and 26. The top port 25 is adapted to receive the connecting pipe 27 of the discharge means 15, here a conventional sprinkler 28 head of the "rain-bird" type. The side port 26 is adapted to receive a flow control valve 29 having its input connected to a manually adjustable spring-loaded pressure regulating check valve 30.

The flow control valve 29 is designed to automatically regulate the rate of flow of water into the tank 12 from the source independent of pressure changes upstream of the flow control valve. Preferably, the flow control valve is of the type described in copending patent application Ser. No. 168,316, filed Aug. 2, 1971, entitled AUTOMATIC RATE OF FLOW CONTROL VALVE, now U.S. Pat. No. 3,703,913. As illustrated most clearly in FIG. 3 and as described in the copending application, the flow control valve includes a tubular housing 31, an orifice plate 32, and a coinically shaped helical spring 33. One end of the housing 31 is externally threaded for attachment to the internally threaded side port 26. An opposite end of the housing is internally threaded for receiving an externally threaded portion of the check valve housing 34. The orifice plate 32 is seated within the housing 31 transverse to the direction of fluid flow therethrough and is secured in place by a threaded sleeve 35 with a base coil of the spring 33 seated on an upstream face of the orifice plate. Thus arranged, the coils of the spring 33 are adapted to move axially toward and away from the orifice plate with changes in the pressure differential thereacross to automatically regulate water flow through the orifice plate to a predetermined rate independent of pressure changes upstream of the flow control valve.

In addition to the housing 34, the check valve 30 includes a tubular coupling 36 having externally threaded lower and upper ends 37 and 38. The lower end is adapted for connection by suitable piping to the water source. The upper end is secured in an internally threaded lower port 39 of the check valve housing. Within the check valve housing, the upper end of the coupling 36 is shaped to define an annular seat 40 for a valve disc 41 connected to a valve stem 42. The valve stem rides vertically in a cylindrical cavity 43 in the lower end of an externally threaded rod 44. The rod extends into the housing 34 through a threaded top port 45 and carries a knob 46 external to the housing. Handturning of the knob 46 adjusts the vertical location of the lower end of the rod 44 within the housing and controls the compression of a coil spring 47 bearing on a top of the valve disc 41.

Thus arranged, the valve disc 41 is normally urged by a spring 47 onto the valve seat 40. As water flows upwardly from the source to the capacitor 8, it engages the valve disc 41. The pressure of the water, being the highest pressure in the sprinkler system, is sufficient to overcome the force of the spring 47 causing the valve disc 41 to rise from the seat 40 and permit water flow through the check valve.

In flowing through the check valve 30, the water suffers a pressure loss determined by the precompression of the spring 47 as hand-adjusted by the rod 44. By selective adjustment of the check valve for each capacitor in a sprinkler system, the water pressure losses may be selectively controlled to insure that water at a common pressure is applied to each capacitor independent of the relative altitudes or elevations of the capacitors within the system.

Further, the check valve 30 as constructed, functions to prevent the back flow of water from the capacitor upon a los of pressure upstream thereof or a turn-off of the sprinkler system. This insures that the capacitor will be charged and ready for operation upon a subsequent turnon of the system.

Thus, with the conduit means 13 connected to a low gallonage water source, the water flows at a predetermined and controlled rate through the check valve 30 and flow control valve 29 and into the tube 21. From the tube, the water is dispensed at the lower portion of the tank 12 to rise therein. As the water rises within the tank, it compresses the air in the upper portion thereof. The increase in fluid pressure is transmitted through the water to the normally closed valve means 14 until the pressure threshold of operation is reached. At that time, the valve rapidly and momentarily opens to discharge water at the threshold pressure from the tank through the sprinkler head 28.

With regard to the foregoing, it is important that the valve means 14 be characterized by the rapid substantially frictionless operation at the predetermined threshold value, which should be adjustable. To accomplish this, the illustrated form of the valve means 14 comprises a normally closed main valve 48 and a magnetically actuated pilot valve 49 for regulating operation of the main valve.

As illustrated most clearly in FIG. 3, the main valve 48 comprises a valve disc 50, a tubular valve stem 51, a diaphragm 52, a spring 53, and a needle valve 54. These are all enclosed in a cover member 55 secured by bolts to a side of the main housing 24. The valve disc 50 is adapted to fit through a side opening 56 in the main housing and is continuously urged by the spring 53 to rest on a valve seat 58. The valve seat is defined by an inner annular shoulder 57 around the side port 26 and is open to the conduit means 13. The valve stem 51 is externally threaded at one end and is adapted to screw into an internally threaded central hole 59 in the valve disc 50. A nut 60 locks the valve stem to the valve disc with an annular shoulder 61 on the valve stem bearing tightly against a washer 62 to secure the diaphragm 52 against a downstream face of the valve disc. The annular marginal edge of the diaphragm is secured between marginal edges of the cover member 55 and an outside wall of the main housing 24 around the opening 56. The diaphragm thus acts as a frictionless

seal between the valve disc 50 and the inner side wall of the cover member 55 and with the cover member defines a chamber 63 for receiving water flowing through the valve stem and small openings 64 in the stem behind the disc 50. The pressure of the water in the chamber 63 assists the spring 53 in normally seating the disc 50 on the seat 57.

To guide the valve disc 50 in its movement onto and away from the seat 57 with operation of the main valve 48, the end of the valve stem 51 remote from the valve disc is of a reduced diameter to define a shoulder 65 and is adapted to ride in a sleeve bearing 66. The bearing is secured in a cavity 67 in the end of an externally threaded rod 68. The rod extends into an internally threaded cylindrical projection 69 from the cover member 55 for hand-turning by a knob 70 to regulate the travel of the valve disc 50 from the valve seat 57 and hence to a degree, the rate of water flow from the capacitor upon actuation of the valve means 14. In addition, the rod 68 carries the needle valve 54 for metering the flow of water into the chamber 63. As illustrated, the needle valve 54 extends from the base of the cavity 67 and into the tubular valve stem 51 to seat against an interior shoulder 71 defined by a reduction in the diameter of the opening in the valve stem at an upstream end thereof. Thus, in addition to controlling the travel of the valve disc 50, a turning of the rod 68 also regulates the bleeding of water through the valve stem and into the chamber 63.

As previously indicated, the fluid pressure exerted on the downstream side of diaphragm 52 combines with the force of the spring 53 to maintain the valve disc 50 tightly on the valve seat 57 to prevent fluid flow through the valve means 14 until the fluid pressure in the tank 12 reaches the threshold pressure value, as detected by the pilot valve 49. In this regard, the pilot valve basically includes a valve seat 72, a magnetically attractable valve disc 73 and magnet means 74. The valve disc 73 is normally seated on the valve seat 72 to block fluid flow to the sprinkler head while the magnet means 74 is normally separated from and movable toward the valve disc as fluid pressure increases in the tank 10 to rapidly and momentarily draw the valve disc from the valve seat when the fluid pressure reaches the threshold value. This, in turn, rapidly and momentarily actuates the main valve 48 to permit water in the tank to be discharged through the sprinkler head.

More specifically, the valve seat 72 is formed by an annular flange 75 surrounding an orifice 76 in the cover member 55. The orifice 76 communicates with an orifice 77 in a side of the main housing 24 through a hole 78 in the diaphragm 52. The valve disc 73 is formed of a magnetic material and is housed within a case 79 of non-magnetic material.

The case 79 includes a main cylindrical portion 80 for receiving the valve disc, a closed cylindrical projection 81 coaxial with the cylindrical portion, and an annular flange 82 extending from a base of the main cylindrical portion. The projection 81 is adapted to slidably receive a valve stem 83 of nonmagnetic material extending from the valve disc and a coil spring 84 for normally urging the valve disc toward the valve seat 72. The annular flange 82 is captured and secured between an outer face of the cover member 55 and an annular flange 85 projecting outwardly from the open end of a cylindrical housing 86. The housing is adapted to receive the case 79 and the magnet means 74.

Also captured between the flange 85 and the cover member 55 is a diaphragm 87 having a central port 88 communicating with the orifice 76 and adapted to receive a needle valve 89 carried by the valve disc 73. Thus arranged, the diaphragm 87 combines with the case 79 to define a fluid chamber 90 for receiving water from the chamber 63 through a port 91 in the cover member and a small hole 92 in the diaphragm 87. The pressure of the fluid in the chamber 90 combines with the force of the spring 84 to maintain the needle valve 89 seated in the central port 88 and the valve disc 73, in effect, seated on the valve seat 72 to normally prevent water flow through the orifices 76 and 77 to the sprinkler head.

As previously indicated, the magnet means 74 is mounted in an end of the housing 86 adjacent the case 79 for movement toward and away from the valve disc 73. In this regard, the illustrated form of the magnet means includes a magnet 93 having a cavity 94 therein for receiving the cylindrical projection of the case. The magnet is secured on one end of a rod 95 slidably supported for axial movement through a hole 96 in the base 97 of a double ended coupling member 98. One end 98*a* of the coupling member 98 is secured to and closes the end of the housing 86 remote from the valve seat 72 while an opposite end 98*b* of the coupling member is adapted to receive a control means 99 for moving the magnet means toward and away from the valve disc in response to fluid pressure changes in the tank 12.

In the drawings, and as most clearly shown in FIG. 3, the illustrated control means 99 includes a cylinder 100, a piston 101, a diaphragm 102 and a coil spring 103. The cylinder 100 is defined by the end 98*b* of the coupling member and a cylindrical cap 104 secured to the end 98*b* by a plurality of bolts 105. The piston 101 is secured to an end of the rod 95 while the spring 103 coils around the rod and bears on the base 97 of the coupling member and a base of the piston to urge the piston and hence the magnet away from the valve disc 73.

The diaphragm 102 is bell-shaped with a central portion secured by a washer 106 and screw 107 to a top of the piston 101 and a marginal edge portion captured and sealed between abutting ends of the cap 104 and end 98*b* of the coupling member. Thus arranged, the diaphragm 102 acts as a frictionless seal between the piston 101 and the cylinder 101 and divides the cylinder into two isolated compartments 100*a* and 100*b*. The compartment 100*a* includes the rod 95 and coil spring 103 while the compartment 100*b* includes an end port 108 connected to a fluid line from the tank 12. In this regard, a sleeve fitting 109 is secured in the port and receives an elbow 110 for connection to a tube 111 (see FIG. 2) extending from a port 111′ (see FIG. 3) in the main housing 24 immediately above the tube 21. The tube 111 defines a fluid passageway from the tank to transmit fluid pressure from the tank to the compartment 100*b*.

As the fluid pressure in the tank slowly increases, (as illustrated by the curve of FIG. 6), the fluid pressure is transmitted to the compartment 100*b* to exert a force on the piston 101 moving it slowly against the force of the spring 103 to the right within the cylinder 100. As the piston moves slowly to the right, it drives the rod 95 and hence the magnet 93 to the right over the end of the case 79. At a predetermined point in the travel of the magnet, the magnetic attraction between the mag-

net and the valve disc **73** is sufficient to overcome the force of the spring **84** and the fluid pressure acting on the valve disc. At this point in the travel of the magnet **93**, the valve disc **73** rapidly snaps to the end of the case **79**. This occurs at the threshold pressure value.

When the valve disc snaps against the end of the case, the needle valve **89** moves from the central port **88** in the diaphragm **87**. Liquid then rushes through the port and through the orifices **76** and **77** creating a pressure differential across the diaphragm **87** which causes the diaphragm to move from the valve seat **72**. This allows water to rapidly surge from the chamber **63** through the port **91** and, in turn, instantaneously creates a pressure differential across the diaphragm **52** and valve disc **50** sufficient to rapidly move the valve disc from the valve seat **57**. This opens the main valve and allows fluid in the tank **12** to rapidly surge upward through the tube **21** and to the sprinkler head.

In FIG. **6***a*, the threshold value is represented by the maximum pressure at which time water surges from the tank to the sprinkler head resulting in a rapid reduction in the fluid pressure within the tank **12**. Because of the rapid flow of high pressure fluid from the tank to the sprinkler head, the sprinkler head is able to discharge the water over a long distance to provide the desired coverage by the sprinkler head of a relatively large area adjacent thereto. Thus, from a low-gallonage water supply, the capacitor **8** is able to periodically generate a high pressure charge of water for dispensing over long distances by the sprinkler head.

Of course, as the pressure drops in the tank **12**, a like pressure reduction occurs in the compartment **100***b* of the cylinder **100** allowing the spring **103** to drive the magnet **93** away from the valve disc **73** and the spring **84** to again seal the needle valve in the central port **88** of the diaphragm **87**. As this occurs, fluid pressure rapidly builds in the chamber **90** and combines with the spring **84** to seal the diaphragm **84** on the seat to close the pilot valve **49**. As the pilot valve closes fluid pressure builds in the chamber **63** to combine with the spring **53** to close the main valve **48** readying the capacitor for another cycle of operation.

In practicing the present invention, it has been found that uniform cyclic operation is most easily maintained if upon each discharge of the capacitor **8**, the tank **12** is charged with a quantity of compressed air prior to water recharge of the tank. In the preferred form of the present invention, this is accomplished by the pump means **16**. Generally speaking, the pump means **16** is responsive to fluid pressure immediately downstream of the valve means **14** for pumping compressed air into the upper portion of the tank **12**. The form of the pump means illustrated in FIG. **3** and FIG. **5** includes a hydropneumatic pump **112** and a compression chamber **113**. The pump **112** is adapted to respond to pressure of the fluid rapidly surging through the valve means **14** to compress a quantity of air and store it in the compression chamber **113** until the pressure in the tank **12** drops below the pressure in the compression chamber, at which time the high pressure air is allowed to slowly bleed into the tank.

More particularly, the hydropneumatic pump **112** includes a closed housing **114**, a diaphragm **115**, and a coil spring **116**. The housing is formed of two similar cup-shaped members **117** and **118**. The member **117** includes an outwardly projecting marginal edge which is bent outwardly and over an outer marginal edge of the member **118** to form a closed air tight chamber **119** which is divided by the diaphragm **115** into two isolated compartments **119***a* and **119***b*. In this regard, the marginal edge of the diaphragm is clamped between a pair of washers **120** and **121** and mating portions of the marginal edges of the cup-shaped members. A central portion of the diaphragm is clamped between a pair of plates **122** and **123** secured by a nut **124** on one end of a rod **125**. An opposite end of the rod **125** is hollow and extends into the compartment **119***a* and into a sleeve bearing and coupler **126** securing the housing **114** to the main housing **24**. As shown in FIG. **4** and as diagrammatically represented in FIG. **3**, the coupler extends into a port **127** in the main housing **24** immediately downstream of the valve means **14** to define a fluid inlet port for the compartment **119***a* through the hollow end of the rod and side ports **128** therefrom.

The coil spring **116** is seated in the compartment **119***b* and normally urges the diaphragm **115** away therefrom and from an air inlet port **129** and compressed air outlet port **130**, having check valves **131** and **132** seated therein. Generally speaking the check valve **131** is designed to open and allow air at atmospheric pressure to be drawn into the compartment **119***b* as the diaphragm **115** moves toward the fluid inlet port in response to a drop in fluid pressure and in response to the force of the spring **116**. The check valve **132** is designed to open when the air pressure in the compartment **119***b* exceeds the pressure in the compression chamber **113** to which the check valve is connected.

Thus in operation, and as graphically depicted in FIG. **6***b*, as the valve means **14** opens and water at the threshold pressure surges to the sprinkler head, the increase in fluid pressure is transmitted through the fluid inlet port into the compartment **119***a*. This produces a force on the diaphragm **115** sufficient to drive the diaphragm away from the fluid inlet port to compress air in the compartment **119***b*. As the air in the compartment **119***b* is compressed, the check valve **132** opens to allow the compression chamber to rapidly fill with compressed air. As the valve means **14** closes, the fluid pressure at the air inlet port and in the compartment **119***a* rapidly drops allowing the spring **116** to drive the diaphragm **115** to its orginal position. As this occurs the check valve **132** rapidly closes and the check valve **131** opens to draw air into the compartment **119***b* readying the pump for another cycle of operation.

As illustrated, the compression chamber **113** comprises a tube connected to the check valve **132** and to a similar check valve **133** secured in a port **133***a* in the top of the tank **12**. The check valve **133** is designed to open when the fluid pressure in the compression chamber **113** exceeds the fluid pressure in the tank **12** thereby permitting compressed air to bleed into the upper portion of the tank. This operation is depicted by the curve of FIG. **6***c* and occurs shortly after the valve means **14** opens — the fluid pressure in the tank exceeding the air pressure in the compression chamber **113** for a short period of time.

By way of example only, the check valves **131, 132** and **133** may be of the type shown in FIG. **5** comprising a tubular housing **134** having externally threaded opposite ends **135** and **136** and a hexagon-shaped central portion **137**. Within the housing, the check valve includes a valve disc **138** carried by a valve stem **139** having an enlarged end **140**. A coil spring **141** bears on the

end 140 and an annular shoulder 142 to normally urge an O-ring 143 on the valve disc against an annular valve seat 144 to close the valve. Thus arranged, when the fluid pressure acting on the enlarged end 140 and O-ring 143 develops a force greater than the force of the spring 141 the valve opens. In the air pump means 16, the valve disc of the check 131 faces the compartment 119*b* while the valve discs of the check valves 132 and 133 face the compression chamber 113 and tank 12 respectively to function as previously described.

The curves of FIGS. 6*a*, 6*b* and 6*c* depict the cyclic nature of the capacitor operation. As previously indicated the frequency of operation as well as the rate of water discharge are controllable. The frequency of operation may be controlled by regulation of the flow control valve 29 to change the rate of water flow into the tank 12. The frequency of operation may also be controlled by changing the value of the pressure threshold of operation of the valve means as by changing the springs or magnet means therein. Regulation of the needle valve 54 will also vary the rate of closure of the valve means 14 and hence alter the frequency of operation of the capacitor. The rate of discharge of water from the tank 12 may be controlled by the adjustment of the rod 68 to limit the travel of the main valve as previously described.

In view of the foregoing, it is appreciated that the present invention provides a hydropneumatic capacitor ideally suited for use in sprinkler systems and which enables a sprinkler head to intermittently discharge water from a low gallonage source over long distances and at a controllable frequency and rate.

While a particular form of hydropneumatic capacitor has been described in some detail herein, changes and modifications may be made in the illustrated form without departing from the spirit of the invention. Therefore, it is intended that the invention be limited in scope only by the terms of the following claims.

I claim:

1. A hydropneumatic capacitor comprising:
a closed fluid accumulator tank;
conduit means connected to a source for supplying liquid to a lower portion of said tank to rise within said tank and compress air in an upper portion thereof;
liquid discharge means;
normally closed upstream pressure sensitive valve means having a predetermined pressure threshold of opening connected to said discharge means and to said tank for rapidly opening to discharge liquid from said tank through said discharge means when fluid pressure in said tank reaches said predetermined threshold value and for automatically closing when fluid pressure in said tank drops below said predetermined threshold value; and
air pump means responsive to fluid pressure downstream of said valve means for pumping compressed air into said upper portion of said tank after the fluid pressure in said tank has dropped below said predetermined threshold value and said valve means has closed and including
hydropneumatic pump means having a liquid inlet connected to said capacitor downstream of said valve means, an air inlet and a compressed air outlet, for pumping compressed air through said compressed air outlet as liquid discharges from said tank, and
compression chamber means having an inlet connected to said compressed air outlet and an outlet connected to said upper portion of said tank for storing compressed air from said hydropneumatic pump and feeding it to said tank as the fluid pressure therein drops below the air pressure in said compression chamber means.

2. The capacitor of claim 1 wherein said conduit means includes automatic rate of flow control valve means for automatically regulating the rate of flow of liquid to said tank from said source independent of pressure changes upstream of said flow control valve.

3. The capacitor of claim 2 wherein said conduit means further includes a valve seat upstream of said flow control valve and a manually adjustable spring-loaded pressure regulating check valve for seating on said seat to prevent liquid back flow in said conduit means to said source.

4. The capacitor of claim 1 wherein said valve means includes:
a valve seat;
a magnetically attractable valve disc;
first spring means for urging said valve disc to seat on said valve seat and block liquid flow from said tank to said discharge means;
magnet means normally separated from and movable towards and away from said valve disc in response to fluid pressure increases and decreases respectively in said tank for rapidly and momentarily drawing said valve disc from said seat in opposition to said first spring means when said fluid pressure in said tank reaches said threshold value; and
second spring means for urging said magnet means away from said disc and for rapidly returning said magnet means to said normally separated condition when said pressure in said tank drops below said threshold value upon an opening of said valve means and a discharge from said tank.

5. The capacitor of claim 4 wherein said valve means further includes:
a case of nonmagnetic material covering said valve disc, said case housing said first spring means between said case and said disc to normally urge said disc against said valve seat;
a cylinder;
piston means in said cylinder;
a rod extending from one side of said piston means and carrying said magnet means for movement toward and away from said case, said second spring means being located in said cylinder and bearing on said piston means to normally urge said rod and said magnet means away from said case; and
a passageway from said tank and to an end of said cylinder remote from said rod for supplying fluid to said cylinder at the pressure in said tank to drive said piston means, rod and magnet means toward said case as said fluid pressure approaches said threshold value, whereby said valve disc is rapidly attracted and moved towards said magnet means when said threshold value is reached to rapidly and momentarily open said valve.

6. The capacitor of claim 1 wherein said valve means includes:
a normally closed main valve and a magnetically actuated pilot valve for regulating operation of said main valve;

said main valve comprising

a first relatively large valve seat open to said conduit means,

a first valve disc having a port therethrough for passing liquid to a downstream side of said first valve disc,

first spring means normally urging said first valve disc onto said first valve seat, and said pilot valve comprising

a second relatively small valve seat open to said downstream side of said first valve disc and to said discharge means,

a second valve disc of magnetic material,

second spring means normally urging said second valve disc onto said second valve seat, and

magnet means normally separated from and movable toward said second valve disc as fluid pressure increases in said tank to rapidly and momentarily draw said second valve disc from said second valve seat when said fluid pressure reaches said threshold value.

7. The capacitor of claim **6** wherein said main valve further includes manually adjustable stop means downstream of said first valve disc for limiting travel of said first valve disc away from said first valve seat.

8. The capacitor of claim **1** wherein said air pump means further included:

diaphragm means in said hydropneumatic pump means dividing said hydropneumatic pump means into two isolated compartments, a first compartment including said liquid inlet and a second compartment including said air inlet and said compressed air outlet;

one-way check valve means at said air inlet and compressed air outlet of said hydropneumatic pump means and at said outlet of said compression chamber for only passing air into said second compartment through said air inlet as said diaphragm moves away from said air inlet, for only passing compressed air from said second compartment through said compressed air outlet when air pressure in said second compartment exceeds air pressure in said compression chamber and for only passing compressed air into said tank when air pressure in said compression chamber exceeds fluid pressure in said upper portion of said tank.

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