Fire Protection Surge Suppressor
for
Automatic Sprinkler Systems

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Fire Protection Surge Suppressor for Automatic Sprinkler systems

1. Definition

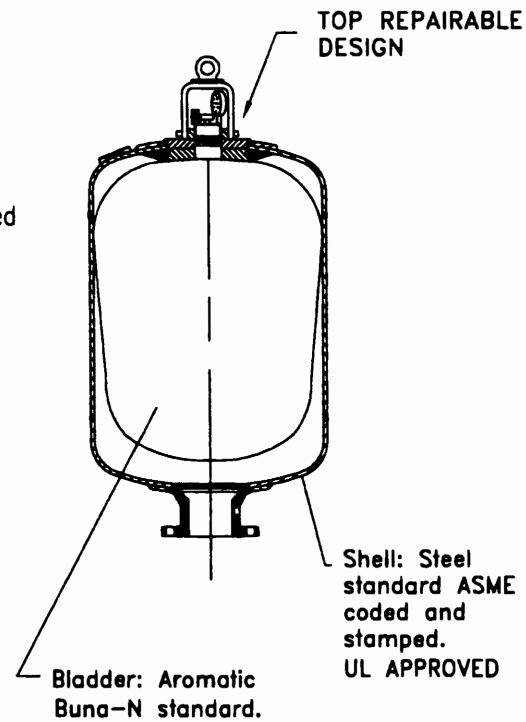
The Young Engineering Surge Suppressor is a hydropneumatic accumulator designed to control pressure surges in fire protection sprinkler systems created by hydraulic transients resulting from fire pump start-up and shut-down.

2. Description

The Surge Suppressor is a carbon steel constructed pressure vessel containing a rubber bladder separating the gas precharge from the water. The vessel is designed and constructed in accordance with A.S.M.E. Section VIII Pressure Vessel Code. The design is also listed by Underwriters Laboratories, Inc.

The steel vessel is rated up to 500 psig by the A.S.M.E. Code and U.L. The fluid connection is a 4" ANSI RF flange. Within the fluid connection is an orifice screen which prevents the bladder from extrusion during precharging.

The rubber bladder is molded from synthetic nitrile rubber (Buna-N). The gas precharge in the bladder should be dry nitrogen gas for optimum performance and life.



SURGE SUPPRESSOR

The mechanical analogy of the pump start-up can be represented by a long stationary rod being impacted by a hammer with a spring between the rod and hammer. (fig 3.)

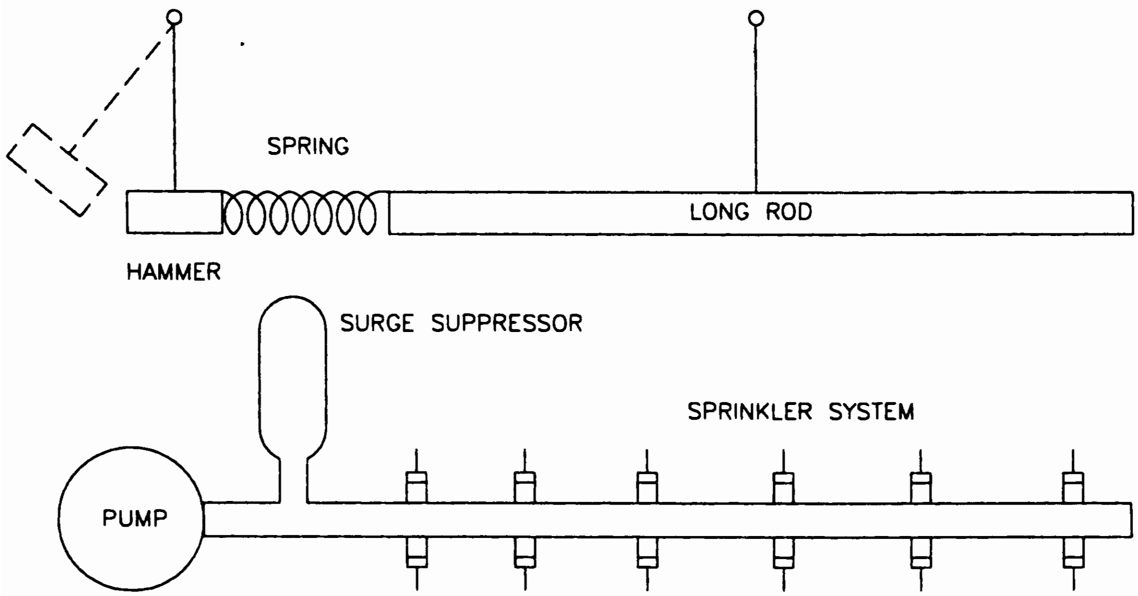


FIG. 3

The hammer is equivalent to the rapid starting pump. The spring is the surge suppressor and the rod is equivalent to the long fluid column. Without the spring the hammer would impact the rod with a large transient force. With the spring added, the hammer impact is softened and allows the rod to accelerate before the hammer comes to a rest.

The gas volume or size of the Surge Suppressor dictates the amount of cushioning effect during the pump start-up. An increase in volume decreases the maximum pressure incurred as a result of the pump starting.

3. Operation

The Surge Suppressor protects fire protection piping systems against excessive pressure transients by balancing the energy in the pipeline during a start-up and shut-down condition.

During the start up of a fire pump, the column of fluid in the pipeline must be accelerated from zero to the steady state of velocity. The resistance to the acceleration creates a high transient pressure at the pump discharge until the steady state flowrate has been achieved. (fig. 1)

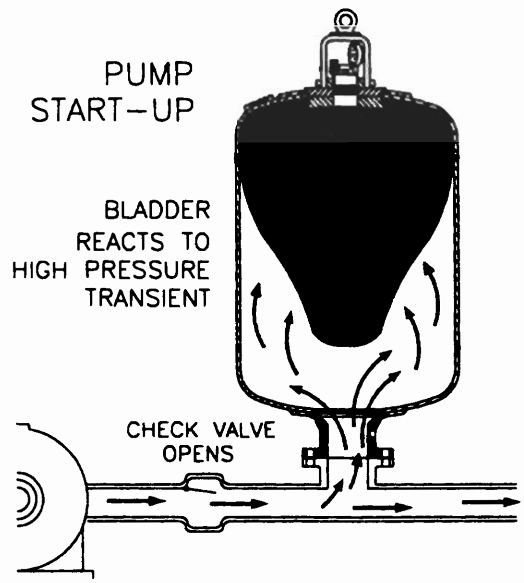


FIG. 1

By installing a Surge Suppressor at the pump discharge, the pump is decoupled hydraulically from the sprinkler system piping. When the pump starts up the Surge Suppressor absorbs fluid from the pump until the fluid column achieves steady state velocity. The Surge Suppressor then discharges fluid in the system to balance the pressure. (fig 2.)

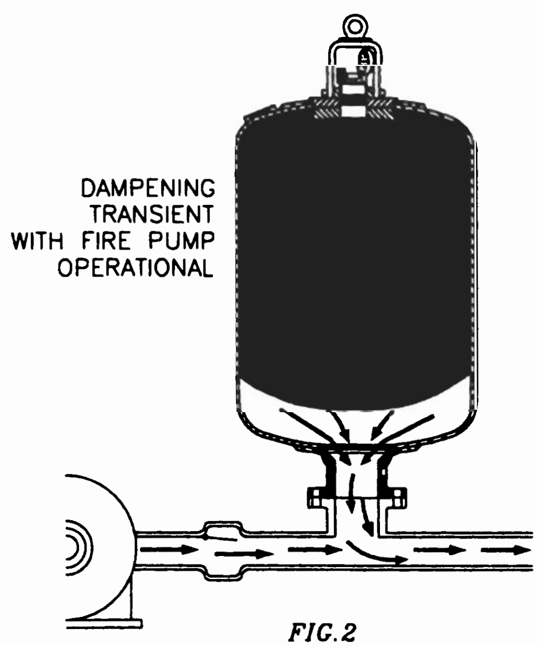


FIG. 2

The pump shutdown condition becomes a problem when the fluid system is flowing at a steady state velocity and suddenly the power to the pump is cut off. This creates an instantaneous low pressure region at the pump discharge. The fluid column with its momentum continues to move away from the pump discharge. If the pressure drops below the vapor pressure the fluid column will separate creating a large gas vapor pocket at the pump discharge. (fig 4.)

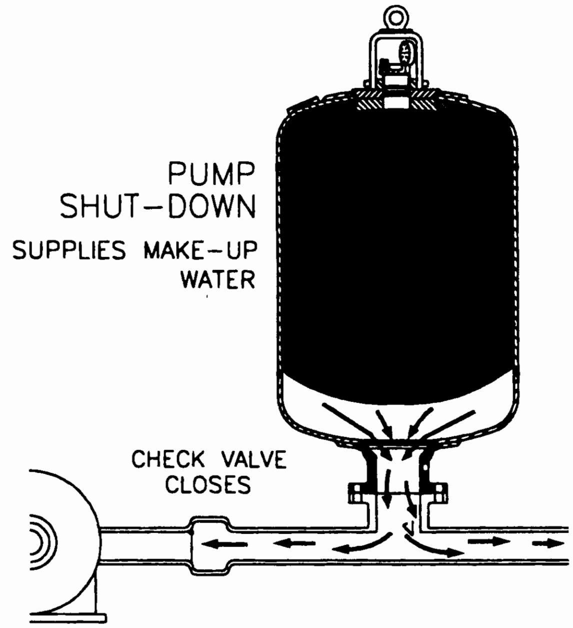


FIG.4

After the fluid column decelerates to zero velocity, the column will reverse in direction because of the differential pressure created by the fluid momentum. The reverse flow collapses the gas vapor pocket generating extremely high transient pressures as a result of the rejoining energy. The reverse flow also generates a water hammer surge when the pump check valve is slammed closed. The column will continue to oscillate until its energy has dissipated through the fluid losses.

With a surge suppressor installed at the pump discharge column, separation can eliminated. When the surge suppressor is precharged to 50% of the operating pressure approximatly half of the shell volume is available to the pipeline during the shutdown. This stored fluid is discharged into the pipeline when the pump is shut off. This continues until the fluid column comes to a rest. The discharge pressure is maintained above the vapor pressure thereby preventing column separation.

Upon reverse flow, the surge suppressor absorbs the fluid after the check valve has closed thereby eliminating the waterhammer. (fig 5). The energy of the reverse flow velocity is dissipated in the compression of the nitrogen precharge of the bladder.

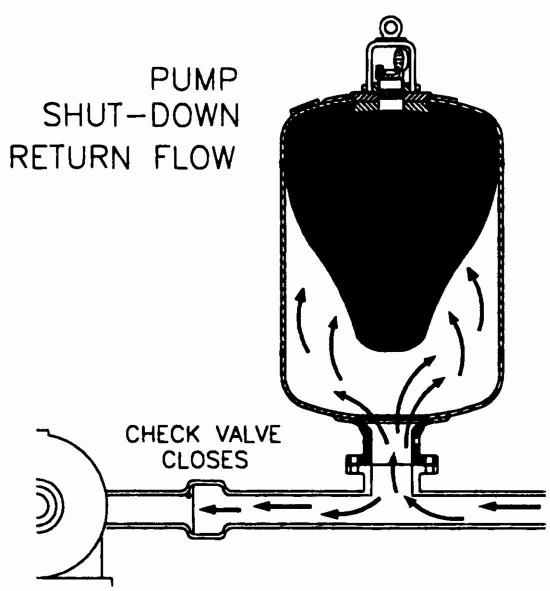


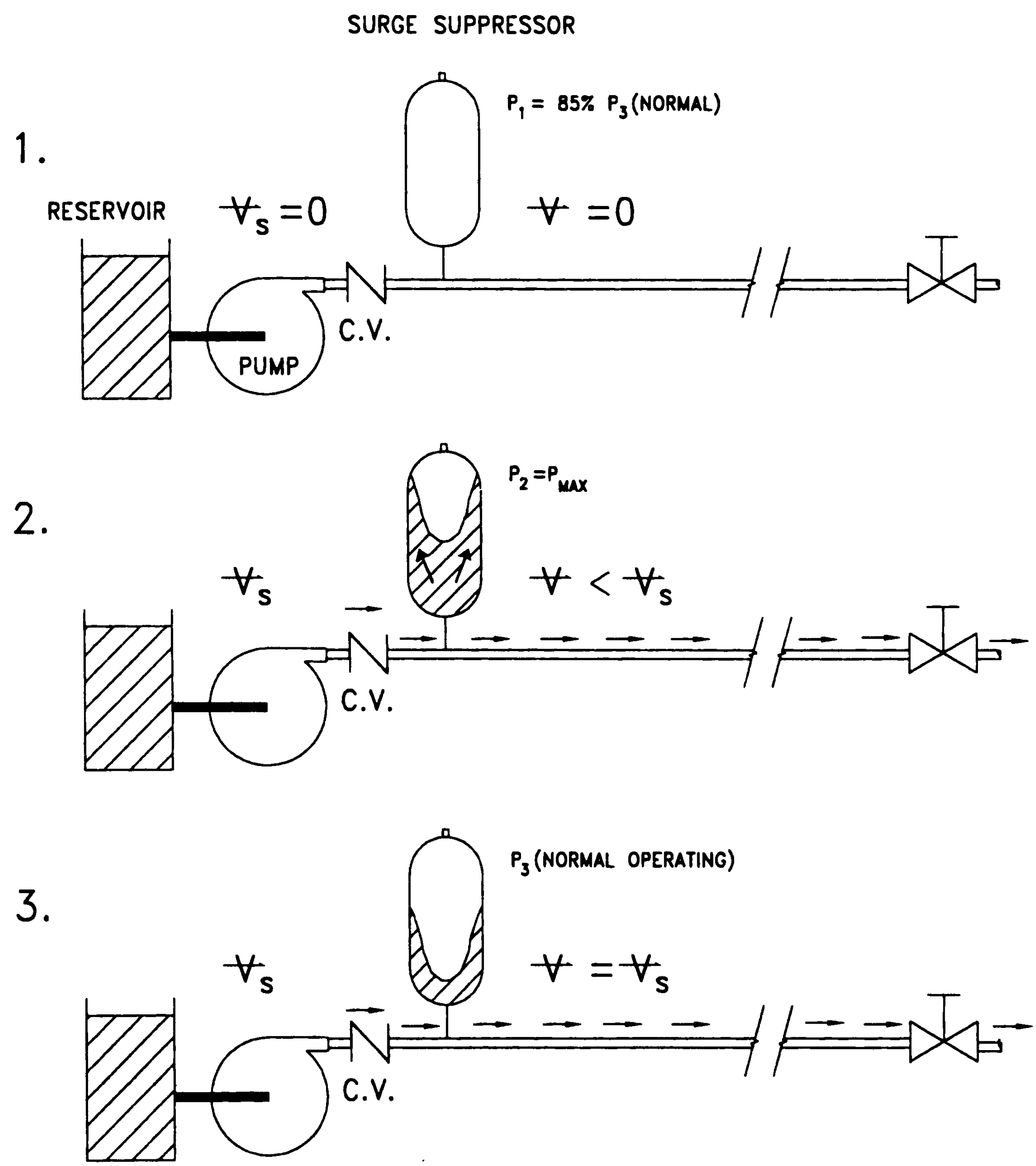
FIG.5

Pump Start-up Condition

1. Surge Suppressor is precharged to 85% of normal system pressure (Water system is at rest, no flow exists.)

2. Pump starts against the static system. Pump flow enters the Surge Suppressor and compresses the precharge pressure to p_2 or p_{max}

3. Pipeline flow steady state.



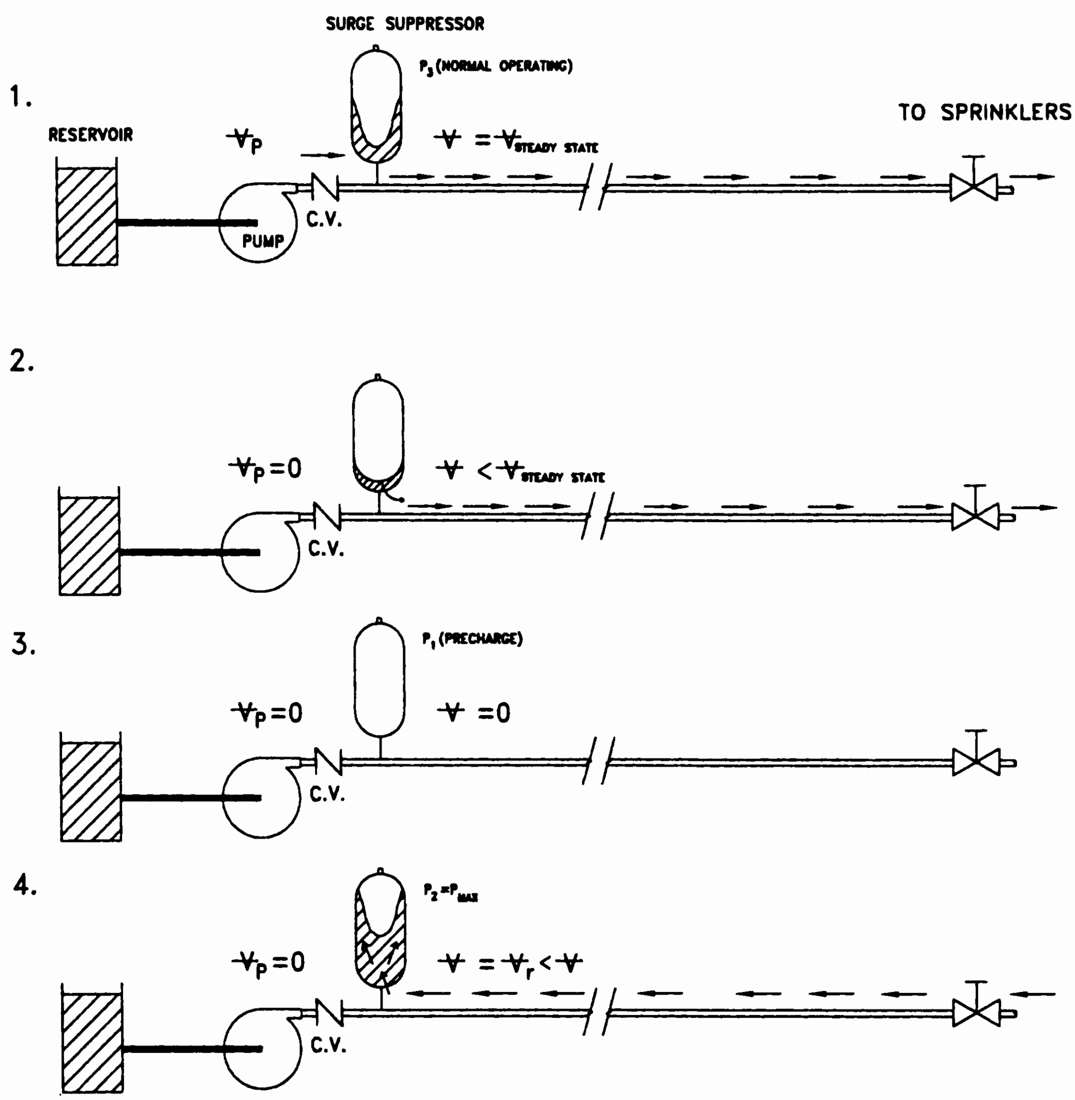
Pump Shut-down Condition

1. System flowing at steady state flowrate. Gas volume in Surge Suppressor is approximately 50% of the precharge volume.

2. Pump is shut-off. Pipe flow continues and Surge Suppressor discharges fluid to system preventing column separation.

3. All of the fluid in the Surge Suppressor is depleted. The fluid column has reached zero velocity.

4. Pressure differential exists between pump discharge and downstream of the pipeline. This creates a reverse flow back towards the pump slamming the check valves closed. The Surge Suppressor absorbs the return fluid and dampens the reverse flow waterhammer.



IV. Start-up Sizing Formula Derivation

$$WE_p = WE_c$$

WE_p = Energy exerted by Pump on Fluid in System

WE_c = Energy dissipated from Gas Compression

$$WE_p = P_s \ (Q_s \cdot T_c)$$

where: P_s = 1.4 P_1

Q_s = Pump start flowrate

T_c = Time Constant = $\frac{2L}{a}$

$$WE_c = -\int_{V_1}^{V_2} PdV$$

where: V_1 = Accumulator Volume

V_2 = Compressed gas volume

P = Gas pressure

$$1.4 \ P_1 \ (Q_s \cdot T_c) = -\int_{V_1}^{V_2} PdV$$

$$1.4 \ P_1 \ (Q_s \cdot \frac{2L}{a}) = \frac{P_1 V_1 \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]}{n - 1}$$

$$V_1 = \frac{\left[\frac{Q_2 \ 2L}{449a} \right] \left(\frac{P_2}{P_1} \right)^{\frac{1}{n}}}{\left(\frac{P_2}{P_1} \right)^{\frac{1}{n}} - 1}$$

V. Sample Calculation:

Pump Start-up Sizing Example:

A fire protection system consisting of 500 feet of 6 inches steel pipe requires a Surge Suppressor to prevent a pump start-up surge. A jockey pump, operating discharge head of 250 feet, keeps a static pressure on the system. The normal required operating pressure when the main fire pump is engaged is 128 psig. The maximum allowable pressure at the start-up can be no more than 150 psig. The main fire pump is capable of flowing 1500 GPM of water (SG = 1.00).

Q_s = Fire pump flow rate = 1500 GPM

SG = Specific gravity of liquid = 1.00

a = Speed of pressure wave = 4000 ft/sec.

L = Line length (ft)

d = Pipe diameter = 6.0 inches

P_1 = Precharged gas pressure 108 psig = 125 psia

P_2 = Maximum allowable pressure = 165 psia

n = Nitrogen gas constant (1.4)

$$V_{static} = \frac{\left[\frac{2\,Q_s L}{449a}\right]\left[\frac{P_2}{P_1}\right]^{\frac{1}{n}}}{\left[\left(\frac{P_2}{P_1}\right)^{\frac{1}{n}} - 1\right]}$$

$$V_{static} = \frac{\frac{(2)\,(1500)\,(500)}{(449)\,(4000)}\left(\frac{165}{123}\right)^{\frac{1}{1.4}}}{\left[\left(\frac{165}{123}\right)^{\frac{1}{1.4}} - 1\right]}$$

$$= 4.41\ Ft^3 = 33\ \text{Gallons}$$

Recommend a 40 Gallon 275 psi Surge Suppressor.

V_1 = Accumulator Volume (cu. ft.)

P_1 = Precharge Pressure (psia)

P_2 = Maximum allowable pressure (psia)

Q_s = Start-up flowrate (GPM)

L = Line length (ft)

a = Pressure Wavespeed (fps)

n = Nitrogen gas constant (1.4)