

[54] **RAPID FIRE SUPPRESSANT DISCHARGE**

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[73] Assignee: The United States of America as represented by the Secretary of the Army, Washington, D.C.

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[51] Int. Cl.² A62C 35/08

[58] Field of Search 169/62, 26, 28, 71, 74, 169/89

[56] **References Cited**

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Assistant Examiner—Michael Mar

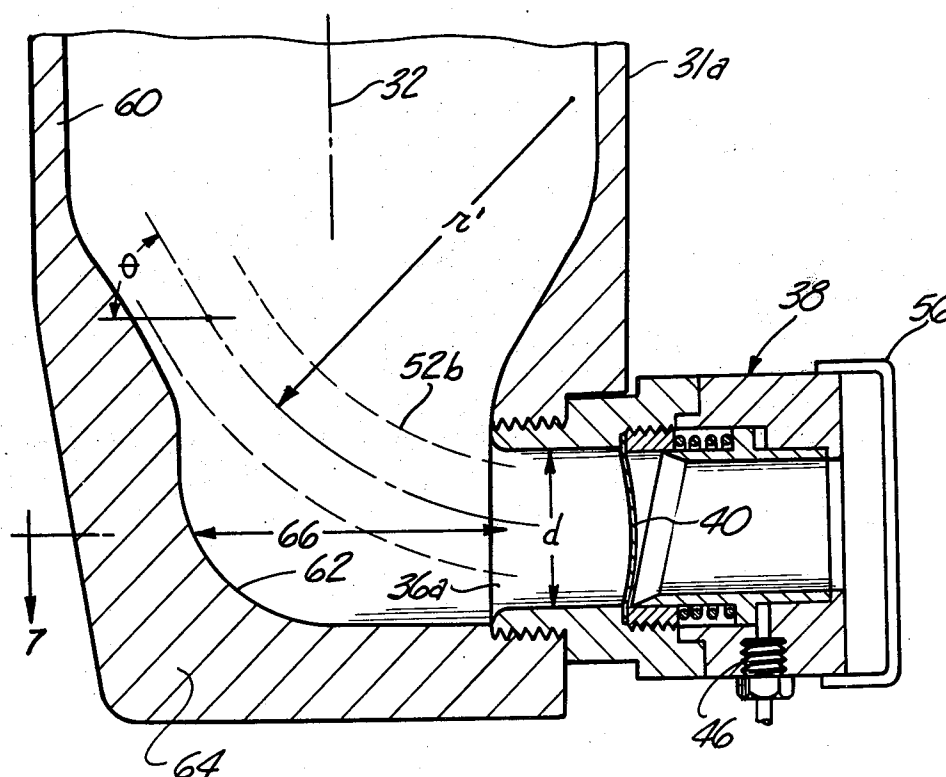
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[57]

ABSTRACT

Disclosed is a fire-suppressant bottle having a discharge port and control valve arranged to discharge the bottle contents in a linear trajectory, i.e., without any abrupt directional changes. The arrangement facilitates discharge of the pressurized suppressant within a short time period, e.g., five pounds of Halon 1301 within 50 milliseconds. In one arrangement the bottle is positioned upright within a military vehicle, with the discharge port and control valve at the lower zone of the bottle side wall, such that suppressant is sprayed horizontally to suppress explosive fires generated when a projectile pierces the vehicle fuel tank. The invention is also useful in preventing the growth of deflagration fires such as may be generated in bilges, hydraulic systems, or flammable cargo.

2 Claims, 8 Drawing Figures



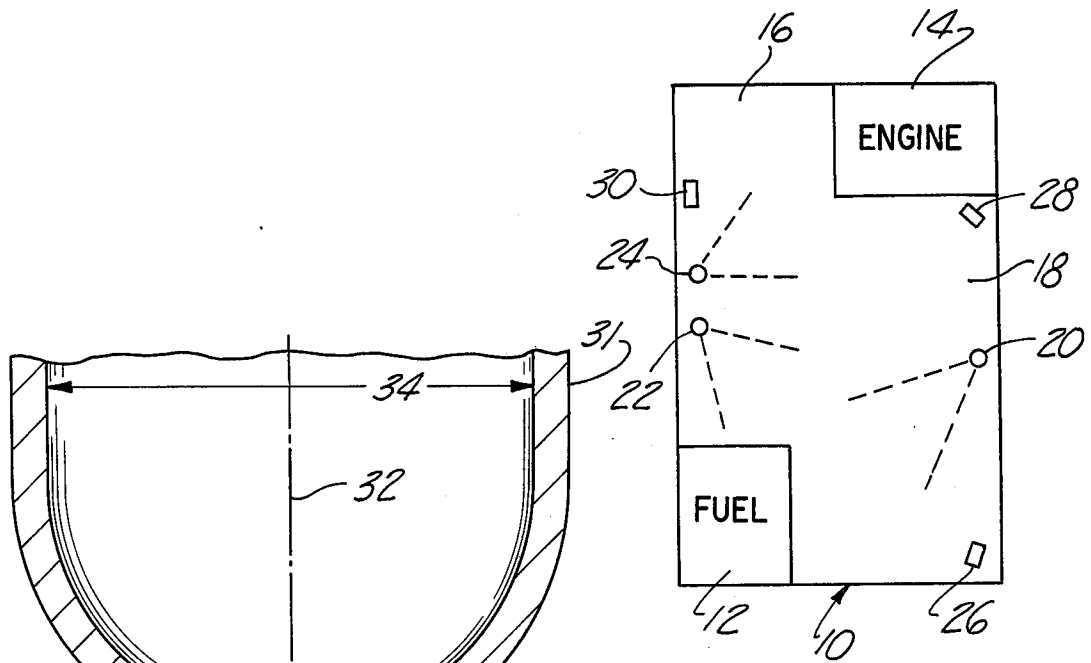


Fig-1

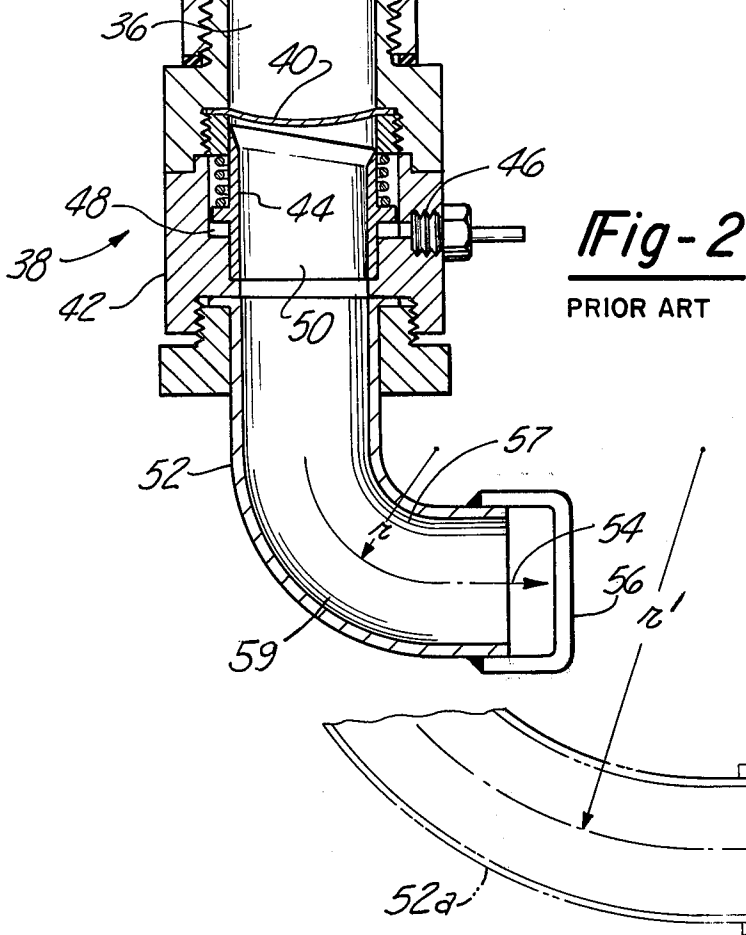


Fig-2

PRIOR ART

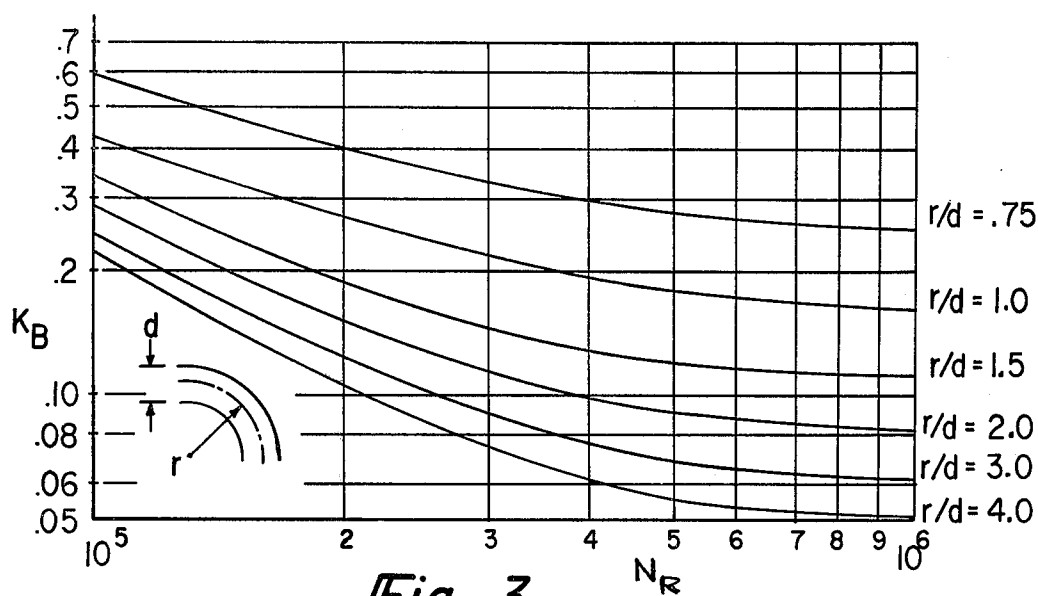


Fig-3

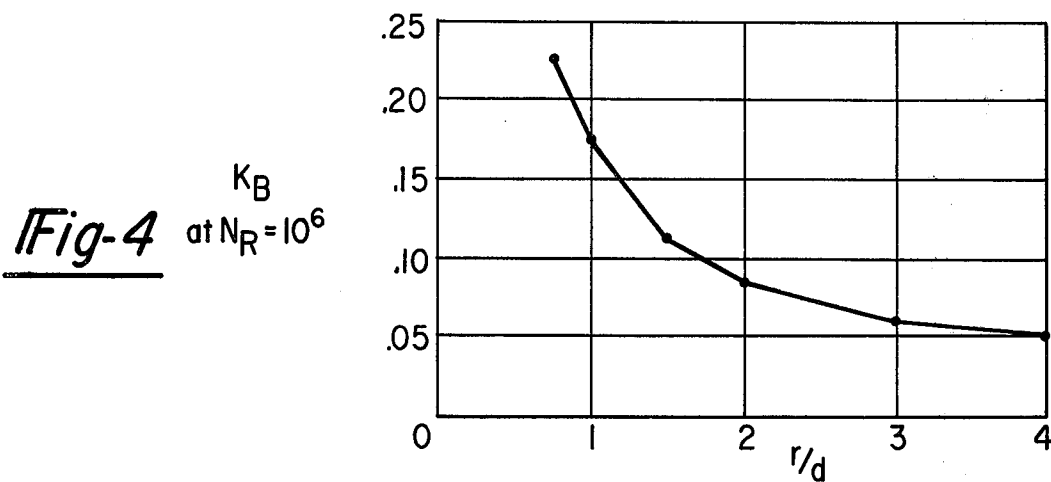


Fig-4

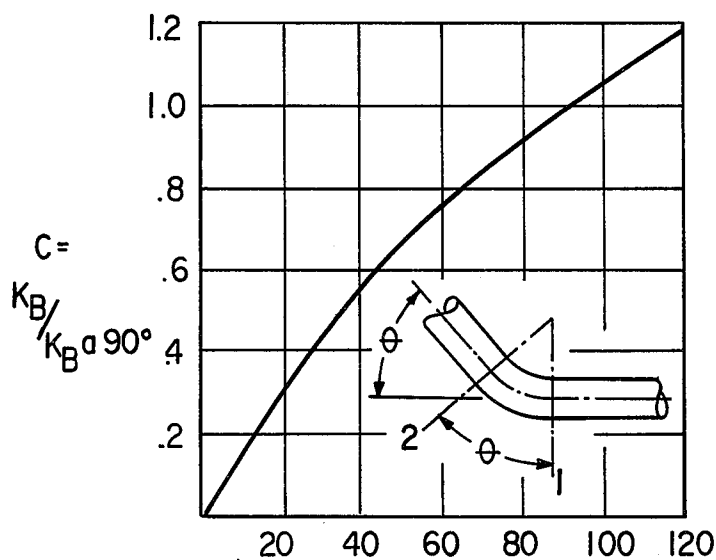
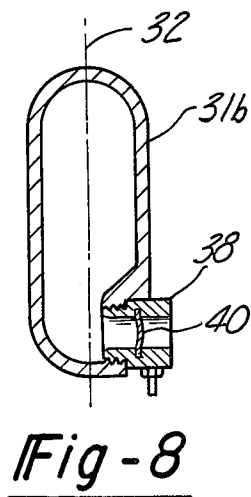
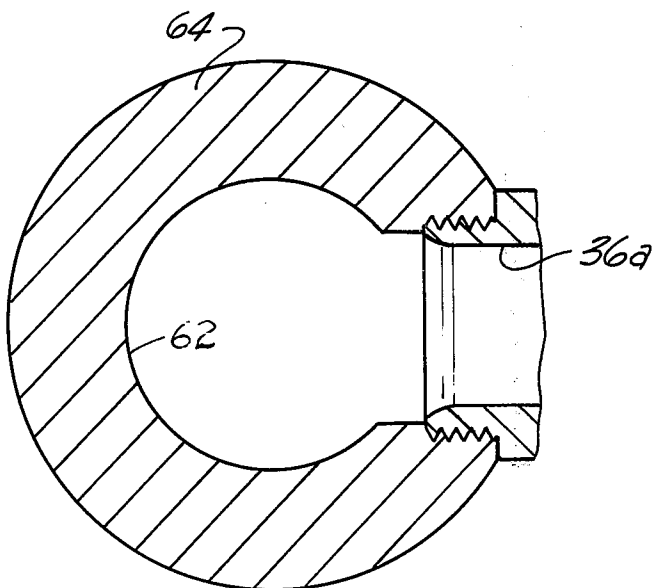
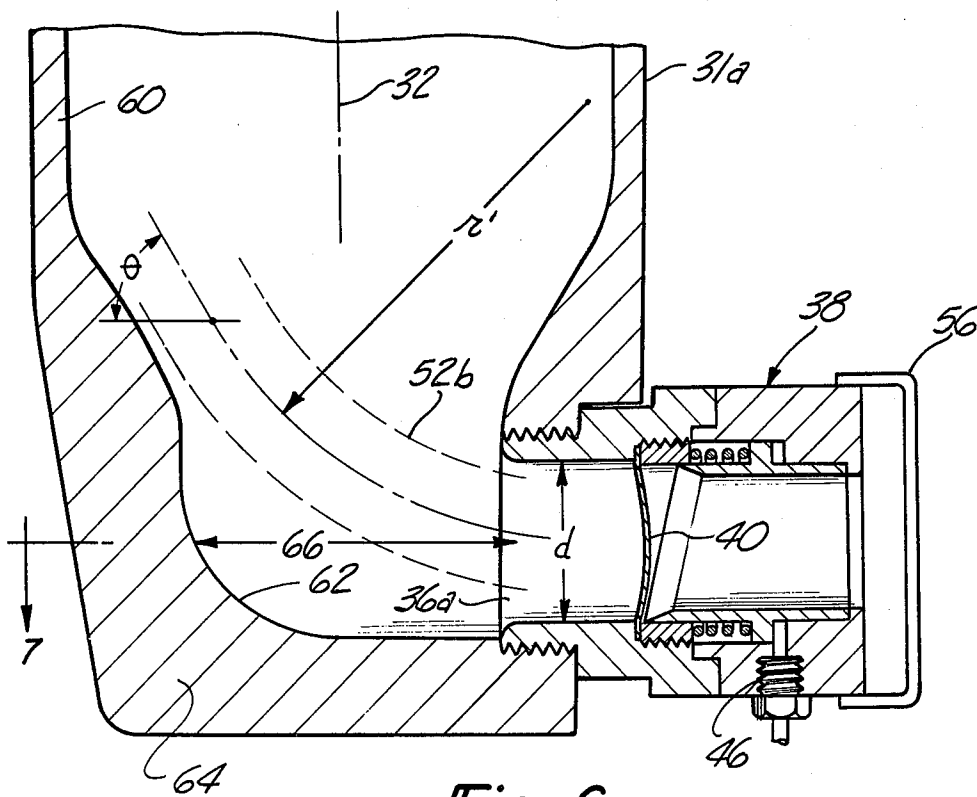


Fig-5



RAPID FIRE SUPPRESSANT DISCHARGE

SUMMARY OF THE INVENTION

The present invention relates to a unique discharge passage configuration for a fire-suppressant bottle. In a known bottle arrangement the pressurized suppressant is discharged downwardly from the bottle and thence laterally through a control valve to the fireball zone; the discharge path is in the nature of a right angle bend. Flow through a right angle bend produces a pressure drop and high velocity heads which can result in vaporizing the suppressing agent prematurely and detracting from the effective mass flow rate. In the proposed bottle design the pressurized suppressant is discharged from the bottle in a horizontal trajectory, thereby eliminating the detractive pressure drop and high velocity heads that accompany a right angle bend type of discharge.

THE DRAWINGS

FIG. 1 is a schematic plan view of a military vehicle interior space equipped with three fire extinguisher bottles.

FIG. 2 fragmentarily illustrates a prior art bottle design.

FIGS. 3 through 5 are charts illustrating the effect that passage configuration has on flow rate.

FIGS. 6 and 7 fragmentarily illustrate a bottle design under the invention.

FIG. 8 illustrates a variation of the bottle design shown in FIGS. 6 and 7.

GENERAL ARRANGEMENT (FIG. 1)

FIG. 1 schematically shows in top plan a military vehicle interior space 10 comprising a fuel tank zone 12, engine compartment 14, driver's area 16, and personnel space 18; the arrangement corresponds in a general fashion to that of the U.S. Army personnel carrier known as M-113.

Three upright fire extinguisher bottles 20, 22 and 24 are arranged within space 10 to direct pressurized fire suppressant into selected areas of the space in response to electrical signals transmitted from optical sensors 26, 28 and 30; the sensor signals actuate electrically triggered valves located on the bottles. Each optical sensor may be of the type that responds to infra-red, or ultra-violet radiation or dual wavelengths generated by explosive type fires, e.g., hydrocarbon fuel fires; response time for such sensors is on the order of microseconds, (five milliseconds maximum).

In the extinguishment of explosive fires it is important that the pressurized fire suppressant be delivered to the fireball very rapidly. It has been estimated by the U.S. Bureau of Mines that a fireball for a given hydrocarbon fuel spreads several feet within the first one-half second after ignition. A fireball generates toxic pyrolysis by-products that can cause death due to excessive lethal concentrations or asphyxiation. Therefore, it is desirable that the fire suppressant be delivered to the fireball area as quickly as possible.

Suppressant delivery time may be considered as the response time for the optical sensor, plus the time required for actuation of the control valve on the bottle, plus the time required for the suppressant to travel from the bottle to the target zone (potential propagation space of the fireball), plus the time required for reaction of the suppressant with the fuel and/or oxidizer

to inert the atmosphere. The present invention is concerned with reducing or minimizing the travel time from bottle to target. This is accomplished by designing the bottle to minimize directional changes of the suppressant as it moves from the bottle interior to the bottle exit opening; such directional changes produce pressure drops that limit or reduce the velocity head at the exit opening.

The military vehicles for which the system is particularly suited pose unavoidable constraints on the bottle design and dimension. Thus, each bottle is preferably oriented in an upright position closely adjacent a side wall of the vehicle to avoid undue projection into the personnel space. Also, for proper coverage of the personnel space, the suppressant trajectory should be horizontal, not vertical.

FIG. 2 fragmentarily illustrates a fire extinguisher bottle considered to be representative of the prior art. The cylindrical bottle 31 is located in an upright position with its central longitudinal axis 32 vertical and its transverse diametrical dimension 34 horizontal. A bottle constructed to deliver 5 pounds of suppressant, e.g., Halon 1301 (CF_3Br), might have an internal length along axis 32 of approximately 12 inches and an internal diameter of approximately 5 inches. The suppressant is ordinarily pressurized to approximately 750 p.s.i. at 70° F with an inert pressurizing gas such as nitrogen; if the bottle were charged only with pure Halon 1301 the driving pressure head would be effectively limited to the vapor pressure of the Halon which is approximately 200 p.s.i. at 70° F. In a bottle system charged with nitrogen and Halon 1301 the liquid Halon, with some dissolved nitrogen, occupies the lower portion of the bottle; the pressurizing agent, with some Halon vapors, occupies the space above the liquid Halon. The bottle is ordinarily charged to a pressure in the vicinity of 700-800 p.s.i.

During the operating period pressurized suppressant (Halon 1301) flows from the bottle through a discharge port 36 that communicates with a squib-operated valve 38. Valve 38 may be similar to the valve shown in U.S. Pat. No. 3,491,783 issued on Jan. 27, 1970 to O. L. Linsalato. As shown in attached FIG. 2, the valve comprises a rupturable disk or diaphragm 40 suitably secured within a valve body 42 that slidably mounts an annular cutter element 44. An electrically triggered explosive squib 46 generates high gaseous pressures on the order of 2500-4500 p.s.i. in annular space 48 to drive cutting annulus 44 through disk 40, thereby permitting pressurized suppressant to flow from port 36 through valve passage 50 and into a curved tube or nozzle 52. The nozzle sprays the fluid suppressant toward the target in a horizontal direction, as denoted by numeral 54. A spreader rod 56 extends across the diameter of tube 52 at its exit end to promote lateral divergence of the spray pattern and reduced impact forces on personnel in the line of discharge. The overpressure in bottle 31 necessary to achieve a given mass flow rate may be determined in accordance with such factors as:

1. minimum velocity head at the outlet end of tube 52,
2. maximum pressure drop experienced between port 36 and the tube 52 outlet,
3. need to prevent flash vaporization within tube 52,
4. loss of pressure head within the bottle due to withdrawal of Halon from the bottle (i.e., expansion of the nitrogen pressurizing agent), and

5. changes in system pressure due to ambient temperature variations.

The velocity head at the outlet end of tube 52 determines the linear velocity through the tube. Therefore, working back from the desired mass flow rate, we can ascertain the necessary velocity head to achieve such a rate. Assuming a desired suppressant flow rate of 5 pounds in 50 milliseconds through a tube 52 having a diameter of 1 inch, the corresponding linear velocity is approximately 2200 inch per second. The pressure required at the exit end of the tube for such a flow may be calculated from the formula:

$$P = \frac{\omega V^2}{2g}$$

where P is pressure in lbs/in², ω is weight of the suppressant per unit volume in lbs/in³, V is linear velocity in inches per second and g is acceleration due to gravity (386 inch/sec²).

$$P = \frac{.058 \times (2200)^2}{2 \times 386} = 362 \text{ p.s.i.}$$

If this velocity pressure head is to exist at the exit end of tube 52 then an estimation of the frictional pressure drop in tube 52 is desirable to gage the overpressure requirements in bottle 31.

The pressure drop in a curved tube can be visualized as the pressure drop that would occur in an equivalent length of a straight tube, plus a correction based on the tube curvature. In HYDRAULIC SYSTEM ANALYSIS by George R. Keller, at page 51 thereof, the pressure drop is said to follow an equation essentially as follows:

$$\Delta P = \left[f \frac{l}{d} + C \times K_B \right] \frac{\omega V^2}{2g}$$

where

f is a dimensionless friction factor,

d is the tube diameter in inches,

l is the tube length in inches,

K_B is an experimental correction factor for a 90° tube bend, and

C is a correction adjustment of K_B for bend angles different than ninety degrees.

Friction factor f is dependent on the Reynolds Number N_R . However at high Reynolds Numbers in the turbulent zone the friction factor f is approximately 0.01 for a wide range of flows.

Tube bend correction factor K_B relates the effect of bend radius and the tube diameter on friction. Attached FIG. 3, taken from the aforementioned HYDRAULIC SYSTEM ANALYSIS, plots K_B versus Reynolds Number N_R for six different "bend radius - tube diameter" ratios. At low Reynolds Numbers the value of K_B for any given r/d ratio varies substantially with variation in Reynolds Number. However as N_R goes beyond 10⁶ the value of K_B for any given r/d ratio remains relatively constant. For purposes of analyzing the FIG. 2 flow system we can use K_B values for $N_R = 10^6$. FIG. 4 illustrates how K_B varies at different r/d ratios when N_R is 10⁶.

FIG. 5, taken from HYDRAULIC SYSTEM ANALYSIS plots correction factor C against an angle θ repre-

senting change in flow-direction as the fluid traverses the bend between the starting and ending planes 1 and 2. In the FIG. 2 system the starting direction would be vertically downward and the leaving direction would be horizontal; angle θ would be ninety degrees, giving C a value of 1.0.

The FIG. 2 bottle is here assumed to have a tube 52 diameter of 1 inch, a tube bend radius r of one inch, and a tube length l of 1½ inches. Using these figures on the above equation:

$$\Delta P = \left[.01 \times \frac{1.5}{1.0} + 1 \times .17 \right] 362$$

$$\Delta P = 67 \text{ p.s.i.}$$

As previously noted, the system pressure should be such as to preclude flash vaporization of Halon 1301, particularly while it is flowing through tube 52. The vapor pressure of Halon 1301 at 70°F is approximately 200 p.s.i. Considering bottle 31 and tube 52 as a "system," the system pressure must at all times be maintained above 200 p.s.i. to preclude flash vaporization. The curved nature of tube 52 is detrimental in this respect in that it tends to produce localized low pressure at the inner radius zone 57. Thus, inertial effects tend to produce a concentration of the fluid near the outer radius zone 59, leaving inner radius zone 57 relatively vacant. The resultant low pressure head in zone 57 tends to permit flash vaporization in that zone even though the average pressure head may be above the lower limiting value of 200 p.s.i. Flash vaporization produces gaseous bubbles of lessened density than the liquid phase; such bubbles detract from the mass flow rate, and hence from the fire-suppressant action.

As previously mentioned, the mass flow rate is also affected by expansion of the pressurizing agent during the course of the discharge period. As the Halon 1301 level in the bottle is lowered the volume of the pressurizing agent is increased or expanded, thereby resulting in a reduction in suppressant pressure within the bottle. Such a pressure reduction constitutes a lowering of the driving force and a consequent lowering of the suppressant flow rate. The initial nitrogen overpressure should be set high enough to avoid a low "dribble" flow rate during the latter stages of the discharge operation. However the initial overpressure should not be set so high that excessive amounts of nitrogen go into solution with the Halon. At high partial pressures of the nitrogen the nitrogen solubility in liquid Halon 1301 is increased. Therefore, if a bottle of a given capacity were charged to an abnormally high pressure with liquid Halon 1301 and gaseous nitrogen, then the liquid phase might contain a significant quantity of dissolved nitrogen. During the operating period dissolved nitrogen would be carried along with the Halon 1301; the nitrogen would tend to come out of solution in the form of bubbles. Such bubbles would detract from the effective mass flow rate of Halon 1301. Therefore a useful high mass flow is not necessarily achieved by merely pressurizing the bottle to a high value with nitrogen. The "nitrogen solubility" problem could be overcome by separating the nitrogen and Halon from each other, as by the use of a piston or diaphragm. However such an expedient adds to system complexity and cost.

In general, the physical arrangement of FIG. 2 poses some problems in selection of bottle overpressure. Thus, the curved nature of tube 52 requires an increase

in bottle pressure to take care of the frictional pressure loss and flash vaporization capability near the inner surface of the tube curvature. The higher overpressure requirement tends to accent the adverse effects due to the nitrogen solubility problem.

Some of the disadvantageous characteristics of the FIG. 2 structure are overcome with the structure fragmentarily shown in phantom lines in FIG. 2. In the phantom line structure a tube 52a, having a relatively large bend radius r^1 , replaces the tube 52. The larger bend radius provides a higher r/d ratio, a lower K_b factor and a lesser pressure drop. Tube 52a has a more uniform velocity across the tube diameter, hence lessened likelihood of localized flash vaporization near the inside radius of the tube. As before noted, vaporization would contribute to low mass flow rates.

Tube 52a suffers operationally in that it offers a longer passage length, hence higher boundary layer friction and longer travel time prior to entry into the atmosphere. A practical difficulty with tube 52a is that it projects a considerable distance from the bottle, both vertically and horizontally; it thus constitutes an attractive nuisance to personnel who would be apt to use the tube for a handhold and/or foothold.

FIG. 6 illustrates a bottle design of the present invention arranged for improved flow capability and compactness. The structure comprises a control valve 38 connected to an opening 36a in the bottle side wall; liquid suppressant is discharged in a horizontal trajectory.

Dashed lines 52b illustrate an imaginary curved duct defining an idealized flow path around an imaginary radius of curvature r^1 having substantially the same magnitude as radius r^1 in FIG. 2. Angle θ in FIG. 6 is substantially less than 90° . The values for radius r^1 and angle θ provide relatively low values for K_b and C (FIGS. 4 and 5), hence low pressure losses.

Angle θ is shown in FIG. 6 to have a constant value. In actuality its value varies as the liquid level moves down in the bottle. The flow force lines are generated at the free surface of the liquid; in the idealized case the force lines would be generated near wall 60 to produce the flow path 52b. Initially the free liquid surface is elevated appreciably above opening 36a so that angle θ then has a value approaching ninety degrees; as the liquid level is lowered angle θ becomes less because the force lines are directed more predominately in the horizontal direction. The illustrated angle θ represents what might be termed the average angle.

FIG. 6 represents the flow in one plane. Actual flow is three dimensional and convergent in the zone near opening 36a; such convergent three dimensional flow implies a lower value for θ , hence lower losses. The losses upstream from opening 36a are probably not much greater than the losses upstream from opening 36 in FIG. 2. FIG. 6 avoids the use of a curved tube 52 or 52a, and the accompanying losses. At the same time the FIG. 6 structure is considerably more compact than the structure of FIG. 2. Additionally the FIG. 6 structure has a shorter passage length, hence a slightly shorter time before entry to the atmosphere.

The FIG. 6 structure includes a spherical lower cavity surface 62 that has the effect of minimizing the liquid quantity in horizontal alignment with opening 36a. When the free surface of the liquid drops to the level of opening 36a the driving force is dissipated so that liquid then remaining in cavity 62 is discharged by a relatively slow boiling-off process. Minimizing the

quantity of boil-off liquid is beneficial when the liquid is expensive, as in the case of Halon 1301.

The spherical cavity 62 allows wall areas 64 to be thickened without forming protrusions on the bottle; the thickened wall areas can accommodate a recessed gage and/or blow-out disk. However cavity 62 should be sufficiently large to provide a flow space 66 at least approximately twice the diameter of d of opening 36a to insure a gradual convergence to the opening.

FIG. 8 illustrates a slight variant of FIG. 6 structure designed to provide a slightly greater recessing of control valve 38 within the bottle, hence a lesser projection of the valve into the personnel space. Operationally the FIG. 8 structure will probably not perform quite as well as the FIG. 6 structure, due to a slightly lower effective radius r^1 and a slightly higher approach angle θ .

The present invention is concerned with the arrangement of FIGS. 6 and 8, wherein discharge port 36a is located in the bottle side wall for directing pressurized suppressant in a generally horizontal direction; the control valve is arranged to provide a linear flow path that constitutes a continuation of the horizontal path provided by port 36a. The bottle preferably has an internal transverse dimension (horizontal direction) that is at least twice the diameter d of the discharge port 36a for attainment of the desired large curvature radius r^1 . For example, the bottle can have a transverse diameter in the range of 3 to 5 inches, and a port 36a diameter in the range of 1 to $1\frac{1}{2}$ inches. The discharge port is located as close as possible to the lower end of the bottle to minimize boil-off liquid. The arrangement also conserves bottle materials.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to a person skilled in the art.

We claim:

1. In a military vehicle, a stationary fire extinguisher comprising an upright pressure-resistant bottle containing pressurized fire suppressant of the flashable vapor type; said bottle being located within the personnel space of the vehicle in close proximity to a vehicle side wall for discharge of suppressant into the personnel space; said bottle having an internal length dimension extending essentially vertically, and an internal transverse dimension extending essentially horizontally; said bottle having a discharge port in its side wall for directing pressurized suppressant from the bottle interior in a generally horizontal direction, said port being located in a portion of the bottle side wall immediately adjacent its lower end; and a control valve connected directly to the discharge port, said valve having a linear flow passage therethrough constituting a horizontal continuation of the bottle discharge port; the control valve flow passage constituting a nozzle for discharging the pressurized suppressant directly to the personnel space in a horizontal trajectory; the internal transverse dimension of the bottle taken along the axis of the discharge port being at least approximately twice the diameter of the discharge port; said bottle defining a single chamber in open communication with the discharge port, the fire suppressant being pressurized by means of an inert gas in physical contact with the suppressant.

2. The combination of claim 1: said bottle having an internal transverse diameter in the range of approximately five inches, and the discharge port having a diameter in the range of approximately 1 inch to $1\frac{1}{2}$ inch.

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