June 27, 1967 F. J. LOPREST ETAL 3,327,628

METHOD OF AND APPARATUS FOR QUENCHING DETONATIONS

Filed Oct. 22, 1965

FIG. 1

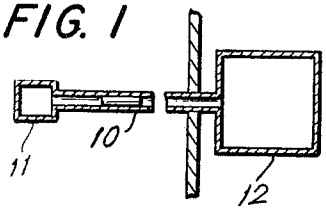


FIG. 2

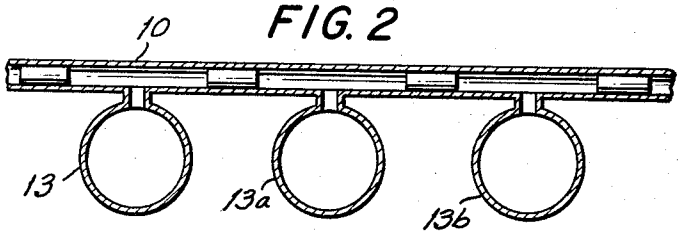
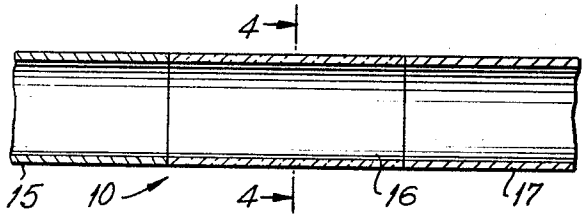


FIG. 3



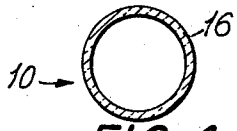
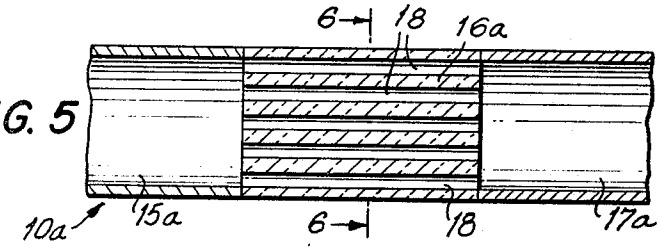


FIG. 4

FIG. 5



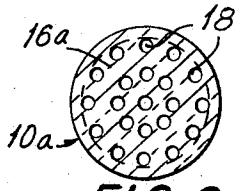
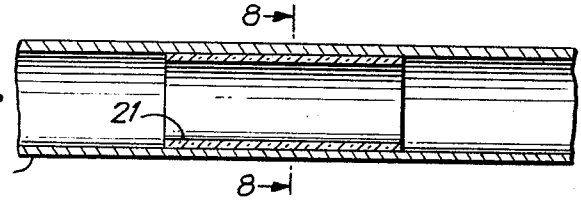


FIG. 6

FIG. 7



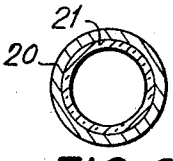
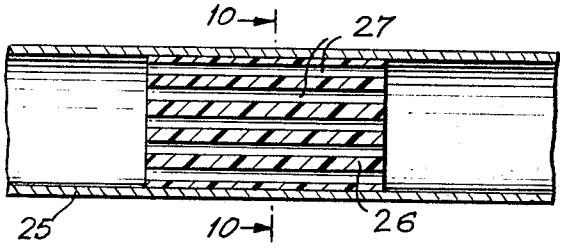


FIG. 8

FIG. 9



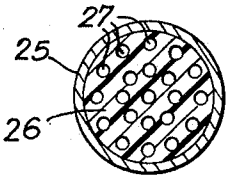


FIG. 10

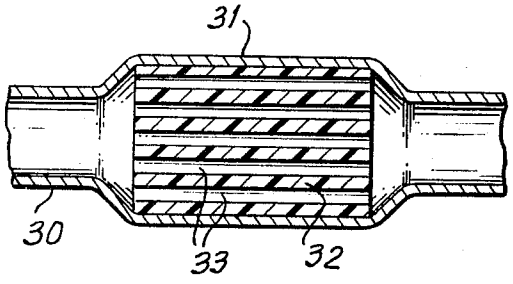


FIG. 11

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METHOD OF AND APPARATUS FOR QUENCHING DETONATIONS

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15 Claims. (Cl. 102—1)

The present invention relates to a method of and trap for quenching the propagation of a detonation in containers or conduits containing an explosive fluid.

The manufacture and use of explosive or rapid burning fluids presents a serious hazard of explosions resulting from deflagrations or detonations transmitted through conduits of a fluid flow system. For example, the explosive fluid may be a fuel supplied from a tank through a conduit to a rocket engine for experimental testing, or may be a product used in or resulting from a commercial installation for reacting chemicals, or the like. A detonation in such equipment, if not checked, can cause an explosion of enormous proportions. For instance, if a detonation is initiated in the combustion chamber of a rocket enigne, or a relatively small chamber of a chemical reactor, it may be propagated back through a connecting conduit to a fuel tank, or to another chamber in the reactor, and explode the entire engine or apparatus.

The ability of a liquid explosive or propellant to propagate a detonation or explosion is dependent upon a variety of intrinsic thermodynamic properties. A knowledge of these properties can be used to predict important characteristics of the detonation or explosion, such as the velocity of propagation and the temperature and pressure in the reaction zone. Furthermore, it is known that if the diameter of a cylindrical conduit in the fluid flow system is progressively decreased, a diameter will be reached below which a detonation or explosion will fail to propagate. This diameter at which the detonation is quenched is known as the "critical diameter" for the particular material and explosive fluid. When the conduit is of some other shape than cylindrical it will have a critical transverse dimension corresponding to the diameter of a tube. Each material has such a critical dimension for a particular explosive liquid, but the critical detonation quenching dimension for most materials used for structural parts, such as iron, aluminum, stainless steel, copper, etc. have in many cases such a low critical diameter as to be of little valve in designing connecting parts which will automatically quench detonations.

One of the objects of the present invention is to provide an improved method of automatically quenching the propagation of a detonation in a flow channel having a transverse dimension several times larger than its critical dimension for the particular explosive fluid.

Another object is to provide a safety device for quenching the propagation of a detonation through conduits connecting parts of commercial manufacturing apparatus, rocket engines and the like.

Still another object is to provide a detonation trap of the type indicated which is of simple and compact construction, economical to manufacture and one which is reliable in operation to quench the propagation of a detonation.

These and other objects will become more apparent from the following description and drawing in which like reference characters denote like parts throughout the several views. It is to be expressly understood, however, that the drawing is for the purpose of illustration only and is not a definition of the limitations of the invention, reference being had for this purpose to the appended claims.

In the drawing:

FIGURE 1 is a diagrammatic sectional view indicating a rocket engine and fuel tank connected by a conduit and in which the detonation trap of the present invention may be incorporated to quench the propagation of a detonation from one location, such as the engine, to another location, such as a fuel storage tank;

FIGURE 2 is a diagrammatic view showing the trap of the present invention applied to conduits connecting the plurality of chambers of a reactor to quench detonations originating in one of the chambers;

FIGURE 3 is an enlarged view of a detonation quenching trap in a connecting conduit illustrated in FIGURES 1 and 2 and having successive sections of different materials to provide a surface in the conduit of higher critical diameter than the remainder of the conduit;

FIGURE 4 is a sectional view taken on line 4—4 of FIGURE 3 showing the circular form of the conduit;

FIGURE 5 is a sectional view of a detonation quenching trap of modified construction which is in the form of a plug of solid material having longitudinally extending holes therein;

FIGURE 6 is a transverse sectional view taken on line 6—6 of FIGURE 5 and showing the arrangement of the holes in the plug of materials;

FIGURE 7 is a sectional view of a detonation quenching trap of further modified construction having a different material applied to the interior of a tube as a lining or coating;

FIGURE 8 is a transverse sectional view taken on line 8—8 of FIGURE 7 to show the tube wall and detonation quenching lining at the interior of the tube;

FIGURE 9 is a sectional view of a detonation quenching trap of another modified construction in which a perforated plug of a material having a high critical diameter is enclosed in the tube;

FIGURE 10 is a transverse sectional view taken on line 10—10 of FIGURE 9 to show the arrangement of the holes in the plug; and

FIGURE 11 is a sectional view of a detonation quenching trap of a still further modified construction in which the plug is located in an enlarged portion of the tube to increase the face area of the holes through which liquid may flow relative to that of the tube.

In accordance with the method of the present invention a surface is applied at the interior of a vessel or conduit containing an explosive fluid which has a critical dimension greater than the material of the conduit for the particular explosive fluid to quench the propagation of a deflagation or detonation therein. It has been found that a detonation propagating into the trap section acts along said limited surface in the same way that it would if the entire conduit were made of the material having the higher critical dimension.

When the vessel or conduit is of cylindrical shape the critical detonation quenching dimension is a diameter, and when it is of any other shape it will be measured as the greatest distance across the passage. Therefore, the term critical dimension and critical diameter are intended to be generic and specific, respectively, as hereinafter used in the specification and claims. The method of quenching detonations is applicable to any system for fast burning and explosive fluids where a detonation is apt to be propagated from one place to another, such as, for example, commercial manufacturing plants where several reactors are connected to a manifold, or in propellant lines connecting a fuel storage tank to an engine. The method is also applicable to quenching the propagation of rapid burning fluids as well as detonations of an explosive and the term explosive fluid is intended to include fast burning combustible mixtures in liquid and gas phase as well as for self-oxidizing explosives.

As stated above, every material has a critical dimension for a particular explosive fluid at which a detonation will be dissipated and ultimately quenched. Most conduits suitable for the flow of explosive fluids are in many cases made of materials having low critical dimensions, such as metals, while other non-conductive materials such as glass, Teflon, epoxy resins and other plastics have normally a much higher critical dimension. The reason for this phenomenon is not understood. The following Table I shows the critical diameters of various materials for particular explosive fluids.

TABLE I.—CRITICAL DIAMETER (mm.) OF VARIOUS MATERIALS FOR PARTICULAR EXPLOSIVE FLUIDS

Material	Nitromethane	Tetranitromethane/Acetonitrile (2:1 Mole Ratio)	Cavea B
Al	<4.5	<4.5	4.5–9.0
SS	<4.5	<4.5	4.5–9.6
Cu	<4.5		
Glass	16–17	4.5–9.0	23–47
Polyethylene	>12		
Lucite	23–50	3.3–9.0	23–52
Alumina	10–25	<11	10.8–25
Zircon-Mullite	10–25	<9.6	21.1–25

SS—Stainless Steel.

The surface of other material having a higher critical dimension may comprise a separate short section of said material, or a perforated plug of the material, or may be applied as a lining or coating on the interior of the conduit wall of a material having a lower critical dimension. Whatever the form of the surface having a high critical dimension, it should be continuous to surround and confine the detonation but need only extend a short distance along the conduit. When a section of conduit of a different material is used, the section must be connected and bonded to the ends of adjacent sections of other tubing materials. When a plug is used it may be made in the form of a solid block with holes therein and either inserted in the conduit as a separate section or located wholly within the conduit. With such an arrangement the total cross sectional area of the conduit may be much larger than the individual holes in the plug which, in turn, need only be made of a size slightly smaller than the critical dimension for the particular material and particular explosive fluid. When the surface area of the other material is applied as a lining or coating on the inside of the conduit wall it may extend throughout the length of the tubing or may extend only a short distance along the length of the tubing.

For example, it has been found that an aluminum tube has a critical diameter of 4 mm. with respect to nitromethane while glass, on the other hand, has a critical diameter of 16 mm. for the same explosive fluid. Thus, in accordance with the present invention an aluminum tube having an inside diameter of 16 mm. with a lining of glass around its entire periphery for a length of 22 mm., only, will quench the propagation of a detonation therethrough when the tube is filled with nitromethane. Other combinations of materials and explosive fluids which will quench detonations as determined by tests is shown in the following tables.

TABLE II.—SECTIONAL CONSTRUCTION CONTAINER OF COPPER-GLASS-COPPER SECTIONS JOINED IN SERIES, FIGS. 3 AND 4

Material	Nitromethane		
	I.D. (mm.)	Length (mm.)	Result
Cu Sections	7	50	Quenched.
Glass Section	7	100	Do.

TABLE III.—LINING OR COATING CONTAINER HAVING OUTSIDE WALL AND INSIDE LINER OR COATING, FIGS. 7 AND 8

Material	I.D. (mm.)	Lining		Results
		Material	Thickness (mm.)	
	Nitromethane			
Al	16	Glass	1.3	Quenched.
Al	16	Polyethylene	2	Do.
	Cavea B			
Al	16	Glass	1.3	Quenched.

TABLE IV.—CONTAINER HAVING OUTSIDE WALL AND INTERNAL PLUG, FIGS. 9 AND 10

Material	I.D. (mm.)	Plug				Results
		Mat.	Length (mm.)	Hole Size (mm.)	No. of Holes	
	Nitromethane					
Al	17	PE	20–50	2.6–4.7	7–19	Quenched.
Al	17	SS	25	1.4	13	Do.
	Cavea					
Al	17	PE	25–39	2.6–4.7	7–19	Quenched.
Al	17	SS	7	2.7	19	Do.

PE—Polyethylene.
SS—Stainless steel.

Referring now to the drawings, FIGURE 1 illustrates the present invention applied to a conduit **10** connecting one vessel **11** to another vessel **12** and containing a fast burning or explosive fluid. For example, the vessel **11** may be the combustion chamber of a rocket engine and the vessel **12** may be a storage vessel for a fast burning or explosive fluid, or the connecting conduit **10** and vessels **11** and **12** may be considered as illustrative of any commercial apparatus in which the fluid is transferred from one place to another. FIGURE 2 illustrates another apparatus in which the conduit **10** connects a plurality of reactors **13** for preparing a potentially detonatable material and through which reactants are introduced into the reactors, or through which the detonatable material is discharged. The conduits **10** as illustrated in FIGURES 1 and 2 are of cylindrical form but may have any other shape in cross-section and, in any case, have a critical detonation quenching dimension. Thus, each of the conduits **10** may be made small enough so that it will have a dimension less than its critical detonation quenching dimension for the particular explosive fluid, but such conduits would then be so small as to interfere with the free flow of the fluid. It is desirable, therefore, to make the conduits **10** of larger dimensions to increase the flow

rate with a minimum of material in each conduit while at the same time preventing the propagation of a detonation therethrough.

In accordance with the present invention a surface is provided at the interior of the conduit of a material having a critical detonation quenching dimension greater than that of the conduit wall and then making the conduit of a dimension only slightly less than the critical detonation quenching dimension of the surface material. FIGURES 3 to 11 illustrate several different forms of construction which incorporate the trap of the present invention.

In the form of construction illustrated in FIGURES 3 and 4, each tube **10** is made up of a series of sections joined in end to end relationship. For example, the section **16** may be made of glass, polyethylene, Lucite, epoxy resin, Teflon, or the like, joined to sections **15** and **17** of a material such as copper, aluminum or stainless steel. Thus, when the sections **15** and **17** are made of, for example, copper and the section **16** is made of glass, the tube **10** may be made from 3 to 4 times the diameter of a continuous copper tube and at the same time quench the propagation of any detonation therethrough when filled with nitromethane. The bonding of glass to copper is possible by known techniques. Any detonation propagated through the tube **10** as shown in FIGURES 3 and 4 then acts as if the entire trap section were constructed of glass and is quenched even though the section of glass **16** extends for a distance of less than 50 mm.

FIGURES 5 and 6 illustrate a modified construction in which the glass or other material having a high critical detonation quenching dimension is in the form of a solid cylinder inserted between tube sections **15***a* and **17***a* and the ends of the sections attached to each other in the same way as in FIGURES 3 and 4. The plug **16***a*, however, has a series of holes **18** therein through which the explosive fluid, for example, nitromethane flows. With this construction the tube **10***a* may have any dimension so long as each hole **18** is less than the critical detonation quenching dimension for the particular material For example, if the tube **10***a* were made of copper sections **15***a* and **17***a* the tube could have a diameter of, for example, 50 mm. so long as the diameter of each hole **18** in the glass section **16***a* is less than 16 mm. Any detonation propagated in the tube **10***a* when containing nitromethane would be quenched by the section **16***a*.

FIGURES 7 and 8 show a further modified construction in which a continuous tube **20** has a lining or coating **21** of a material with a critical detonation quenching diameter greater than the material of the tube. For example, the tube **20** may be fabricated from a material such as aluminum, stainless steel, copper, or the like, and the lining **21** may be formed of glass, polyethylene; Lucite and the like. The diameter of the conduit **20**, therefore, may have a diameter greater than its critical detonation quenching diameter for the particular explosive fluid but yet quench a detonation, due to the fact that the lining **21** has a higher critical detonation quenching diameter. Of course, with this construction the inside diameter of the lining **20** must be less than the critical detonation quenching diameter of the material of the lining such as glass. The lining **21** may coat the interior surface of the tube **20** throughout its length or may extend for only a portion of its length such as 50 mm. or less. If the tube **20** is made of aluminum, stainless steel or copper having a critical detonation quenching diameter less than 4.5 mm. and the lining is made of Lucite having a minimum critical detonation quenching diameter of 23 mm. for the particular explosive fluid, the inside diameter of the lining of the tube **20** may be made, for example, 20 mm. in diameter and have a length of 50 mm. only. Such a construction provides a conduit having a diameter four times larger than an aluminum, stainless steel or copper tube that would quench the propagation of a detonation therethrough and still produce the quenching result. The lining **20** may be applied as a sleeve bonded to the interior of the tube, or may be deposited on the surface of the tube, or may be applied on the surface of the tubing as a coating.

FIGURES 9 and 10 show a still further modified form of detonation trap incorporating the novel features of the present invention. In this form of construction a tube **25** of a structural material such as aluminum, stainless steel or copper of any diameter contains a plug **26** of a material having a higher critical detonation quenching diameter than the tube **25** such as, for example, glass, polyethylene, Lucite and the like. The plug **26** has a series of holes **27** with each hole having a diameter less than the critical detonation quenching diameter of the particular material for the particular explosive fluid. Thus, the tube **25** may have a diameter of any desired size so long as each hole **27** in the plug **26** is below the critical detonation quenching material for the particular explosive fluid, the same as in the form of construction illustrated in FIGURES 5 and 6.

FIGURE 11 shows a still further modified form of construction in which the tube **30** is provided with an enlargement **31** for receiving a perforated plug **32** having holes **33** therein. With this construction the holes **33** may have a cross sectional face area equal to or closely approaching the cross sectional face area of the remainder of tube **30**. The form of construction illustrated in FIGURE 11 operates in substantially the same way as the form of construction illustrated in FIGURES 9 and 10.

It will now be observed that the present invention provides a method of and detonation trap for quenching detonations propagated into a conduit or other container for an explosive fluid. It will also be observed that the present invention provides a safety device in a system for transporting and handling explosive fluids to prevent the propagation of detonation from an outlet end back to a supply tank. It will still further be observed that the present invention provides a detonation trap which is of simple and compact construction, economical to manufacture and one which is reliable in operation to quench the propagation of a detonation.

While a single method and several modified forms of detonation traps are shown and described herein it will be understood that changes may be made in the steps of the method and in the form of construction of the detonation trap without departing from the spirit or scope of the invention. Therefore, without limitation in this respect the invention is defined in the following claims.

We claim:

1. A method of quenching the propagation of a detonation through a container of explosive fluid which comprises, providing a surface at the interior of said container of a different material than the material of the container and having a critical detonation quenching dimension which is greater than the critical detonation quenching dimension of the material of the container for the particular explosive fluid, and arranging said surface of different material at the interior of said container so as to produce a peripheral dimension less than its critical detonation quenching dimension.

2. A method of quenching the propagation of a detonation through a conduit containing an explosive fluid comprising the steps of, providing a surface of another material at the interior of said conduit, selecting a material for said surface having a high critical detonation quenching diameter for the particular explosive, and limiting the inside diameter of said conduit to less than the critical detonation quenching diameter of said surface material whereby quench detonations in a conduit which would otherwise propogate such detonations therethrough.

3. A method of quenching the propogation of a detonation through a conduit containing an explosive fluid comprising the steps of selecting a conduit of a diameter to produce a predetermined flow rate, said conduit being composed of a material and having a diameter greater than the critical diameter for the particular explosive

fluid which will permit the propagation of a detonation therethrough, and preventing the propagation of such a detonation by providing a surface of another material in said conduit having a critical detonation quenching diameter greater than the critical diameter of the material of the conduit but less than the critical detonation quenching diameter for the particular explosive fluid.

4. A method of quenching the propagation of a detonation in accordance with claim 3 in which the conduit is a cylindrical tube and the surface of another material comprises a section of said tube.

5. A method of quenching the propagation of a detonation in accordance with claim 3 by applying the surface on the interior wall of said conduit as a lining.

6. A method of quenching the propagation of a detonation in accordance with claim 3 in which the surface is applied by inserting a body of the surface material into the conduit as a plug having perforations to provide a peripheral dimension in the conduit less than its critical diameter.

7. A method of quenching the propagation of a detonation in accordance with claim 3 in which the surface material is applied to the conduit as a coating.

8. A method of quenching the propagation of a detonation in accordance with claim 3 in which the surface extends around the entire periphery of the conduit and for only a short section of its length.

9. A detonation trap for quenching the propagation of a detonation comprising, a conduit containing an explosive fluid, said conduit having an enclosing surface of another material along its length, said material forming said enclosing surface having a critical detonation quenching dimension greater than the critical detonation quenching diameter of said conduit material for the particular explosive fluid, and said conduit having a peripheral dimension which would otherwise permit the propagation

of a detonation therethrough and less than the critical detonation quenching dimension of said surface material for the particular explosive fluid to quench such detonation.

10. A detonation trap in accordance with claim 9 in which the surface of other material is a lining bonded to the interior of the conduit wall.

11. A detonation trap in accordance with claim 9 in which the surface of another material is a porous plug in said conduit.

12. A detonation trap in accordance with claim 9 in which the plug has a plurality of holes with each hole having a dimension less than the critical detonation quenching dimension of the material for the particular explosive fluid.

13. A detonation trap in accordance with claim 12 in which the conduit is cylindrical, the plug is located in an enlarged section of the conduit, said holes in the plug providing a total cross sectional area substantially equal to the diameter of the conduit so as to eliminate any appreciable resistance to flow, and each hole being of a diameter less than the critical detonation quenching diameter of the material.

14. A detonation trap in accordance with claim 11 in which the surface is formed by a short section of said conduit.

15. A detonation trap in accordance with claim 11 in which the surface comprises a coating on the inner wall of said conduit.

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SAMUEL W. ENGLE, *Primary Examiner.*