DETONATION TRAP STUDIES

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ABSTRACT

Methods were evaluated to stop detonation propagation in liquid and slurry energetic materials in process. Numerous concepts were evaluated and tested to prevent propagation of detonation. Numerous methods were found to stop detonation but growth-to-detonation down stream could still be possible. Criteria was also established to prevent growth to detonation.

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INTRODUCTION

In numerous processes dealing with manufacturing chemical processing and transportation of liquids or slurries, the fluids may be capable of propagating detonation. The fluid ability to detonate depends on how energetic it is when initiated, size of piping or processing equipment, temperature, pressure and velocity of flow. From the safety standpoint, prevention of detonation is the first line of defense. The second consideration is that of minimizing the potential explosion damage. This normally is done by utilizing continuous process (versus batch) methods. It becomes very critical that a detonation once initiated will not propagate throughout the process. In this paper, methods to prevent detonation propagation (normally called detonation traps) are reviewed.

METHODS

Numerous methods can be utilized to stop detonation propagation should an initiation occur in a liquid/slurry flow process. Typically, they can be divided into the following categories:

- Dilution
- Reduction of Dimensions
- Disruption of Flow Pattern
- Energy Absorption
- Flow Disruption
- Stoppage of Flow

In the following paragraphs, these will be described in more detail. They will be evaluated regarding functionability, performance, safety and reliability later.

DILUTION

By diluting the detonable fluid with other media, detonation can no longer occur. This can be done by the following means:

DILUTANT	METHOD TO REMOVE DILUTANT
Solvent	• Wiped film evaporators • Distillation
Water	Same as above
Other Liquids Immiscible in Detonable Fluid	• Centrifuge • Dropout Pots
Solid Particles	• Centrifuge • Dropout Pots • Screens • Filter Media •

Solvent dilutent will be effective for process fluids which will not be altered by them. A typical example is the use of solvents for gun propellant manufacturing. Centrifugal separation and drying of formed grains removes the solvents. Solvent extrusion processes are also used on nitramine propellant manufacturing.

Water dilution has been used for years to ship highly sensitive detonable fluids. For materials such as lead styphnate, the water barrier mostly prevents initiation of detonation, but may do nothing to prevent shock initiation and propagation. This is also true for fine grain RDX and HMX. Water separation is normally facilitated by adding water soluble solvents (e.g., acetone, etc.) which aid separations.

An example of dilution detonation trap is show in Figure 1.

Other liquid immiscibles can be introduced and mixed with detonable fluid. The effectiveness to stop detonation will be a function of uniformity of mix (no settling out). Once reaching its destination, the mixture is passed through a centrifuge or dropout tank for separation of immiscible liquid.

Solids can be introduced into the fluid line to prevent propagation. The solids effectiveness will depend on the concentrations in fluid, size of solids, mixture of solids, solids mixing and solid material type. The solids can be separated in the following ways:

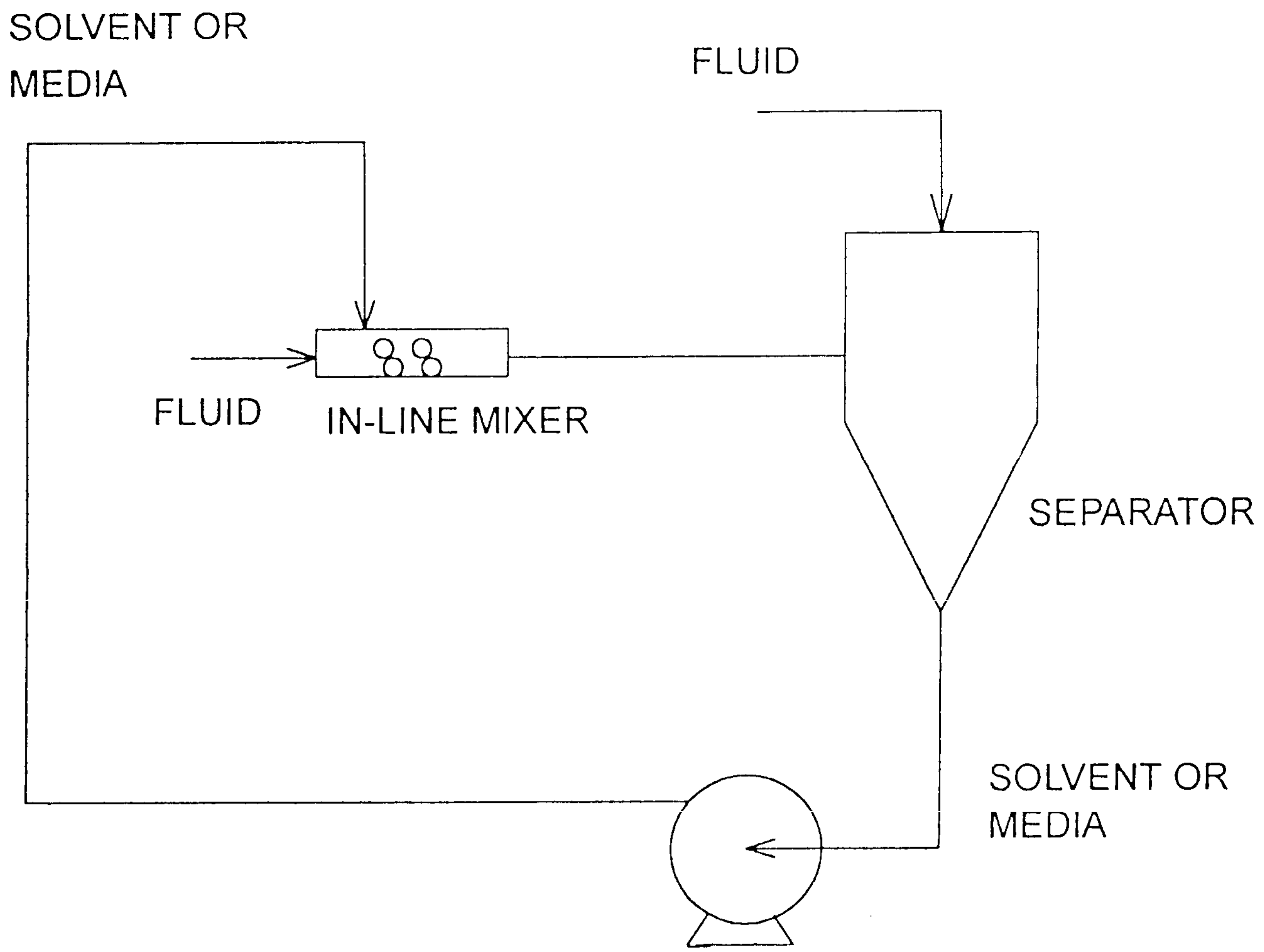


Figure 1. Dilution detonation traps.

- Centrifuge
- Screen/Filter
- Rota Clove
- Settling Tank

The solids would then be reintroduced upstream in the detonable fluid.

REDUCTION OF DIMENSIONS

In previous technology, detonation traps consisted of flow manifolding through a series of sample tubes. The tube's inside diameter was so small that detonation would die out because they were smaller than critical diameter (dimension). See Figure 2 for an example. The length of tube bundles, wall thickness of tubes, tube material type are variables effecting the ability to stop detonation. If deflagration to detonation (DDT) transition is very short, it is possible, that growth-to-detonation can occur downstream of detonation trap.

DISRUPTION OF FLOW PATTERN

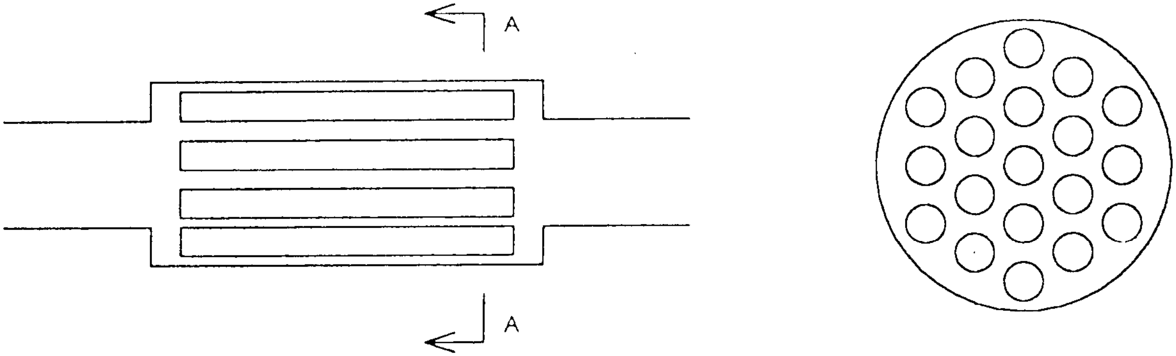
One way to stop detonation is that of providing ways to disrupt the detonation wave and reaction front. A few methods which will knock down a detonation front are as follows:

- Fine Mesh Screens
- Filter Media
- Packed Columns
- In-Line Mixers

See Figure 3 for examples of disruptors.

Fine mesh screens will break up the detonation wave if screen openings are way below propagation dimensions. If the screens occupy a short travel distance in flow (~ 1 length = 1 critical diameter), the deflagration-to-detonation transfer can occur and defeat the method.

Filter media sized for the detonable flow rates can act as very effective detonation stoppers depending on the media and porosity. They may be prohibitive if process flow pressures are very low (i.e., pressure drop too great to maintain flow).



Section A-A

Figure 2. Reduction of dimensions detonation trap.

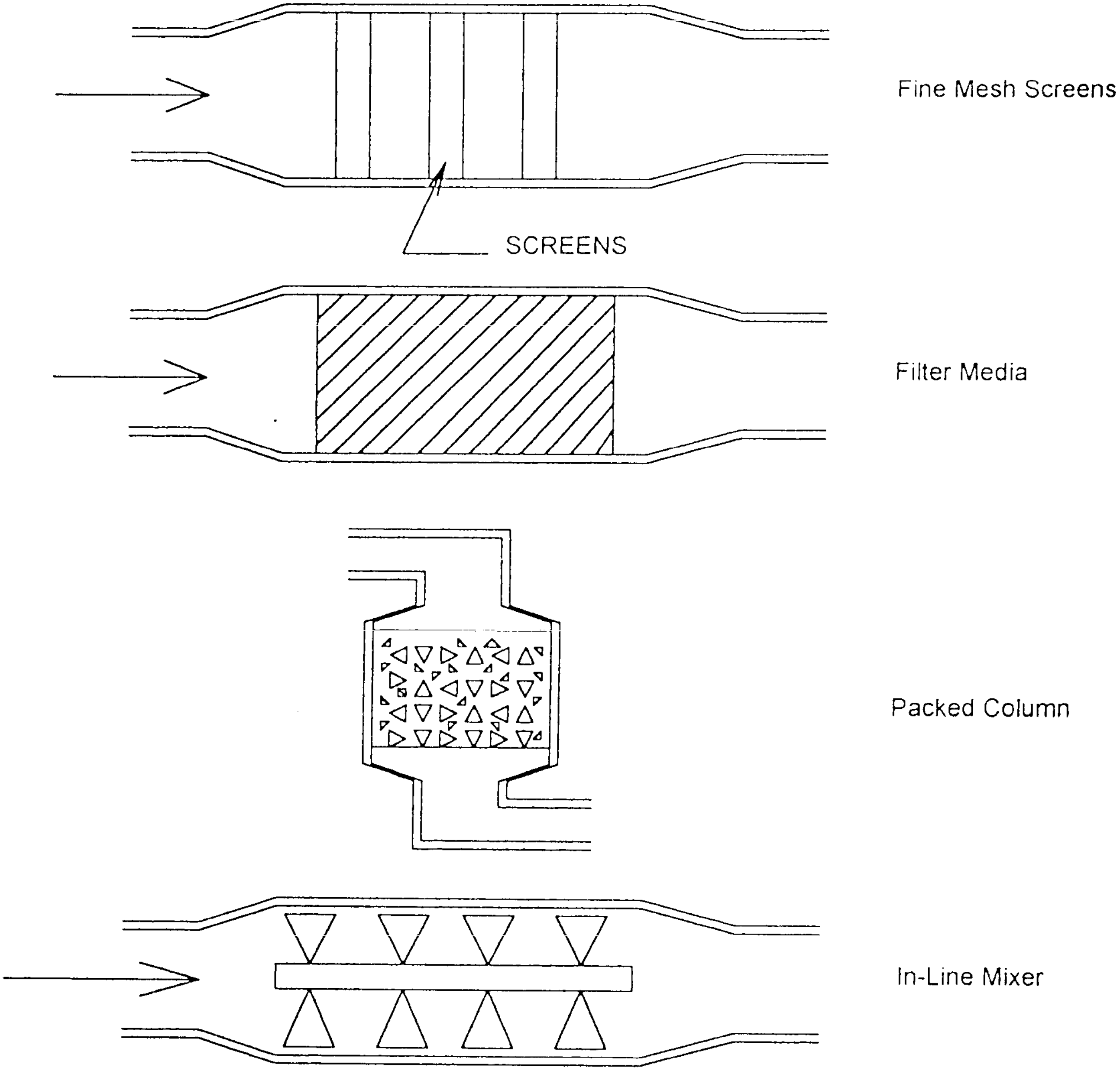


Figure 3. Flow disruption detonation tubes.

Packed columns can be used to stop detonation also. The size, type, shape and material of packing will govern detonation, stoppage effectiveness. Changes in flow directions into the packed column will also aid in stopping detonation. Total liquid flooding is required in the packed column to prevent adiabatic compression initiation of fluid in the column.

In-Line Static Mixers can be used to break up detonation waves due to groove changes in fin directions (to mix flow).

ENERGY ABSORPTION

Several methods can be incorporated to absorb detonation and reaction energy to stop reactions. The following ways to absorb energy can be used:

- Fins to Transfer Heat Away
- Meltable Media
- Encapsulated Liquid Pouches

See Figure 4 for examples.

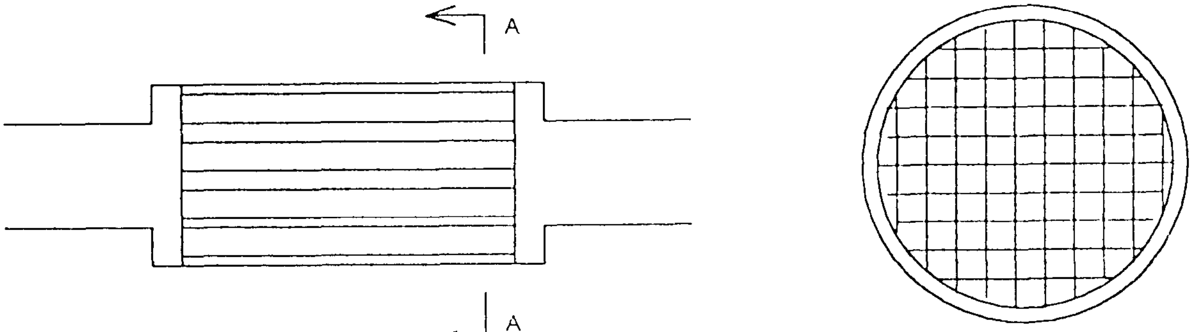
Finned sections in flow such as used to stop vapor detonations can be utilized to absorb detonation and reaction energy. The length, gap distance and material of fins will govern their effectiveness.

Meltable media can be used in trap sections, in filters or in packed columns so that when detonation hits the media, energy will be absorbed due to media heat-of-fusion loss. The meltable media could also be used for flow dilution.

Encapsulated liquid pouches could be used in-line so that when a detonation encounters the media, the liquid breaks free to stop reaction propagation. Usually, encapsulated liquid particle diameters are very small, thus, containment of the media may be very difficult.

FLOW DISRUPTION

If the detonating fluid flow is not continuos but pulsed, a detonation wave will be stopped from propagating. Typical examples are as follows:



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Metal Fins (or Channels)

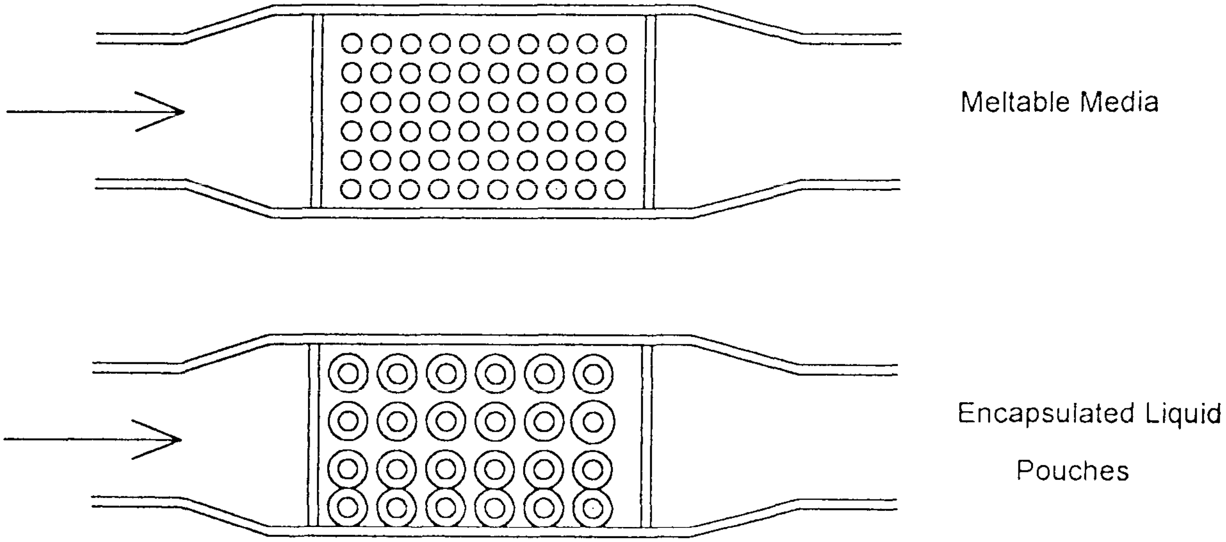

Figure 4. Energy absorption detonation traps.

- Pulse Feeder
- Star Valve Feeding
- Peristaltic Pump Feed
- Diaphragm Feed

See Figure 5 for examples.

All of the above methods utilize flow stoppage and separation. Certainly, potential for DDT downstream of the devices is possible. The effectiveness will be a function of pulse length and diameters.

FLOW STOPPAGE

In the past, an extensive study was conducted to develop detonation trap valves that once a detonation was sensed on a melted castible liquid explosive, an upstream detonation valve has activated stopping flow completely. See Figure 6 for illustration.

Detonation loops in pipe were evaluated for some liquid explosives which are designed to cause rupture of upstream piping prior to arrival of the detonation front. Refer to Figure 7.

SELECTION CRITERIA

Methods to prevent detonation propagation will depend on the following detonable fluid parameters:

- Fluid Critical Dimensions for Propagation
- Fluid Detonation Reaction Zone Thickness
- Heat-of-Detonation and Reaction
- Fluid and Materials of Construction
- Sound Propagation Velocity and Density
- Fluid Vapor Pressure, Specific Heat and Thermal Conductivity
- Fluid DDT Characteristics
- Chemical Reactivity of Fluid (Acid/Base)

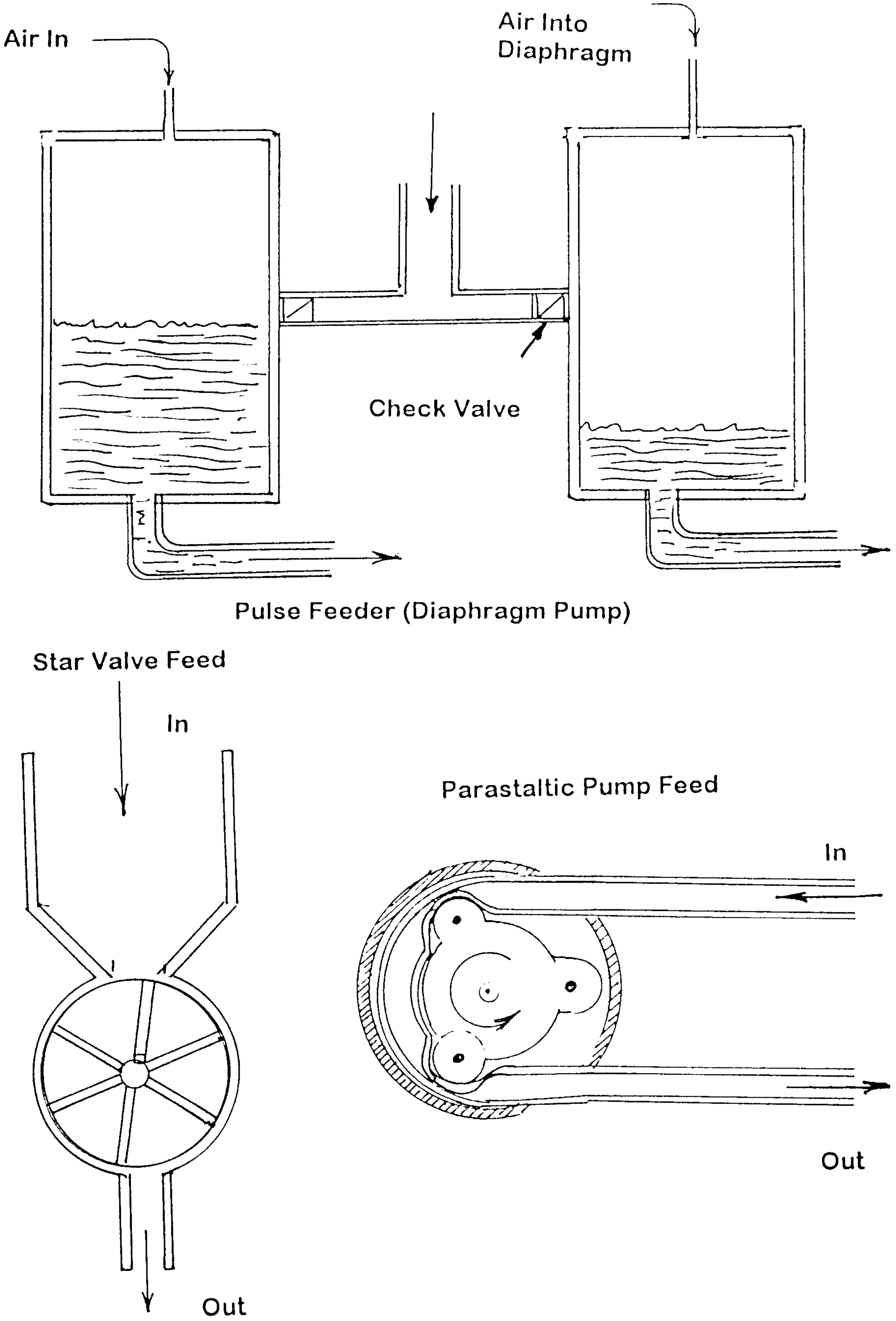

Figure 5. Flow disruption detonation traps.

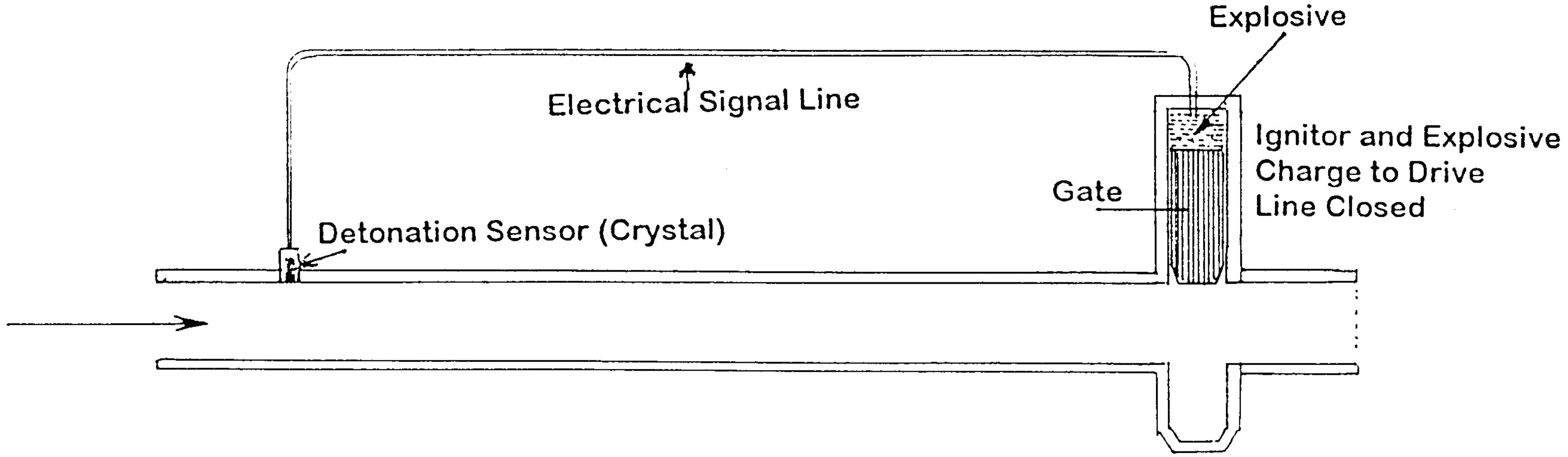

Figure 6. Flow stoppage trap.

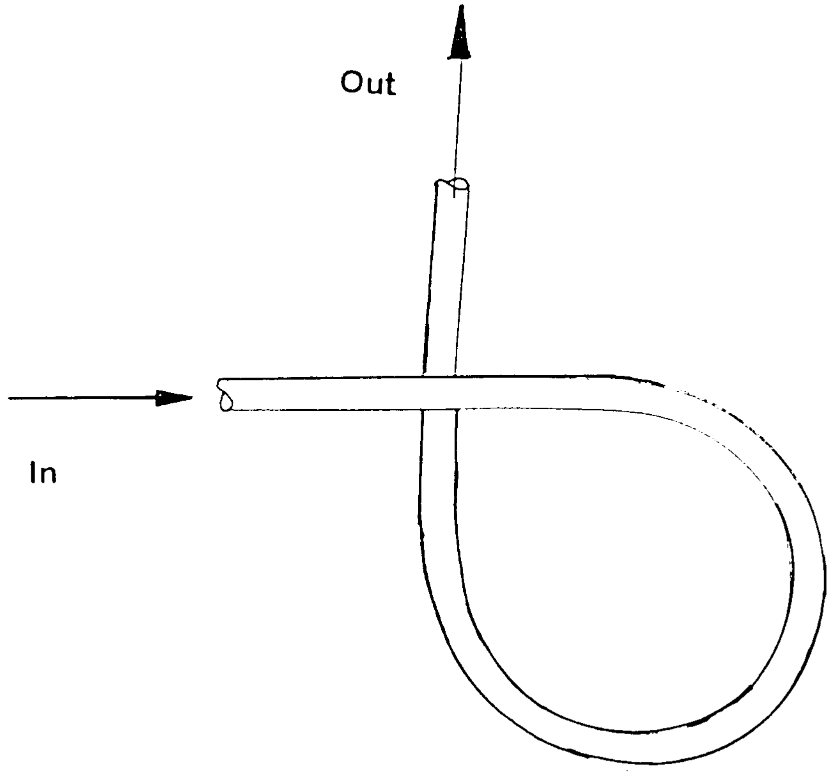

Figure 7. Detonation loop.

To optimize method selection, the following items must be evaluated and traded off:

- Simplicity
- Compatibility with Fluids
- Reliability
- Maintainability
- Safety
- Costs
- Structural Integrity
- Performance/Effectiveness

For detonable fluids that are very chemically reactive (strong acids or strong bases), materials of construction, energy absorbers and dilutants must be selected which will not react or adversely effect fluid quality.

The DDT characteristics of the fluid really depend on reaction zone thickness, heat-of-detonation/reaction, sound velocity, and thermal characteristics (e.g., specific heat, thermal conductivity).

The cost, reliability and maintainability are all greatly effected by the simplicity of the design.

Detonation trap performance (i.e., stop detonation) may be satisfactory if the reaction can build back up again. Transition to detonation will occur downstream of the trap.

The fluid property characteristics will greatly influence selection of the optimum detonation trap method. Applicability of the trap method based on fluid properties is shown in Table 1.

METHOD OPTIMIZATION

Each method is then evaluated relative to the system parameters mentioned above. Ranking levels are made for each method so that the overall ranking can be made. Ranking values from 1 to 6 (1 being the best) were assigned as shown in Table 2. For one example, an overall rank was made by adding up all the ranking values for each method and finding the lowest value. For

TABLE 1

POTENTIAL DETONATION TRAP METHODS

FLUID PROPERTY	DILUTION	DIMENSION REDUCTION	FLOW PATTERN DISRUPTION	ENERGY ABSORPTION	FLOW DISRUPTION	FLOW STOPPAGE
I. Critical Dimension						
- Small (< 5 mm)	X		X	X	X	X
- Large (> 20 mm)		X	X			
- Average (=5-20 mm)	X		X	X	X	X
II. HEAT-OF-DETONATION						
HIGH	X				X	X
LOW		X	X	X		
MEDIUM	X	X	X	X	X	
III. HEAT-OF-REACTION						
HIGH	X					X
LOW	X			X		
MEDIUM	X			X		
IV. DDT CHARACTERISTIC						
SHORT	X				X	X
LONG		X	X	X	X	
MEDIUM		X	X	X		X

TABLE 2

DETONATION TRAP OPTIMIZATION EXAMPLE FOR A LIQUID DETONABLE MATERIAL

FLUID PROPERTY

- Critical Dimension = 2.5 mm
- Acid Based Fluid
- Heat-of-Detonation - High
- Heat-of-Reaction - High
- Heat Transfer Ability - Low
- DDT Characteristics - Short

Ranking from 1 to 6
One being best

Optimization Item	Dilution	Dimension Reduction	Flow Pattern Disruption	Energy Absorption	Flow Disruption	Flow Stoppage
Simplicity	5	1	2	3	4	6
Compatibility with Fluids	6	1	2	4	3	5
Reliability	2	6	5	4	3	1
Maintainability	5	1	2	3	4	6
Safety	2	6	3	5	4	1
Cost	5	1	2	3	4	6
Structural Integrity	1	4	2	3	5	6
Detonation Trap Performance/ Effectiveness	1	6	2	3	4	5
Reaction Stoppage Effectiveness	2	6	4	5	3	1
TOTALS	32	32	24	33	34	37

example, flow pattern disruption was found to be the best. The flow pattern disrupter also will stop reaction.

CONCLUSIONS AND RECOMMENDATIONS

Various detonation trap methods were reviewed. Criteria for selection was identified based on detonable fluid properties and system considerations. An example of method optimization was also presented. Numerous methods to stop detonation were identified. Potential for growth-to-detonation downstream exists for many of them. Thus, extreme care must be utilized to select traps that will stop both detonation and reactions. Fluids with very low critical dimensions for propagation are especially difficult to stop reaction growth (DDT) to detonation.