Sept. 20, 1971 G. G. CURRY ET AL 3,605,777

CLOSURE MECHANISM

Filed May 11, 1970

FIG. 1

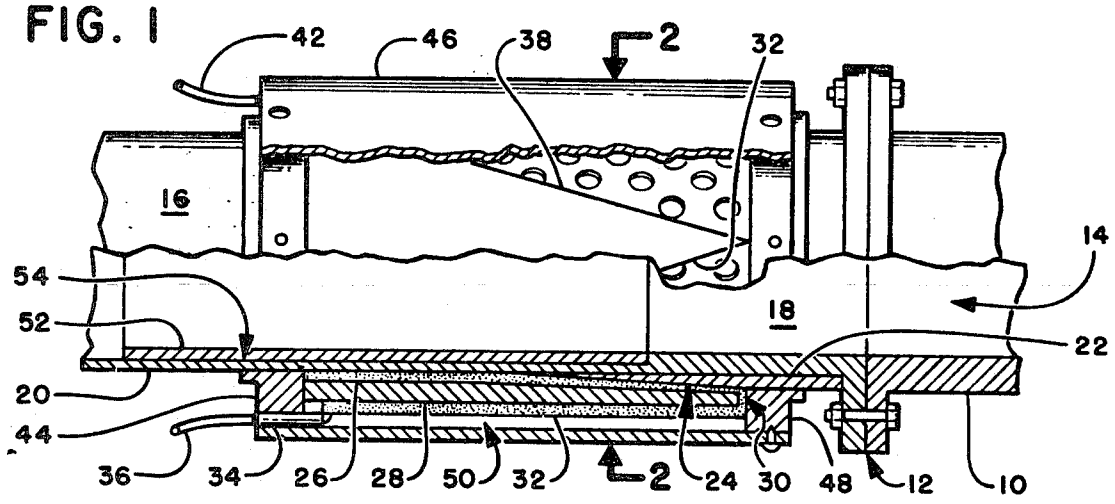


FIG. 3

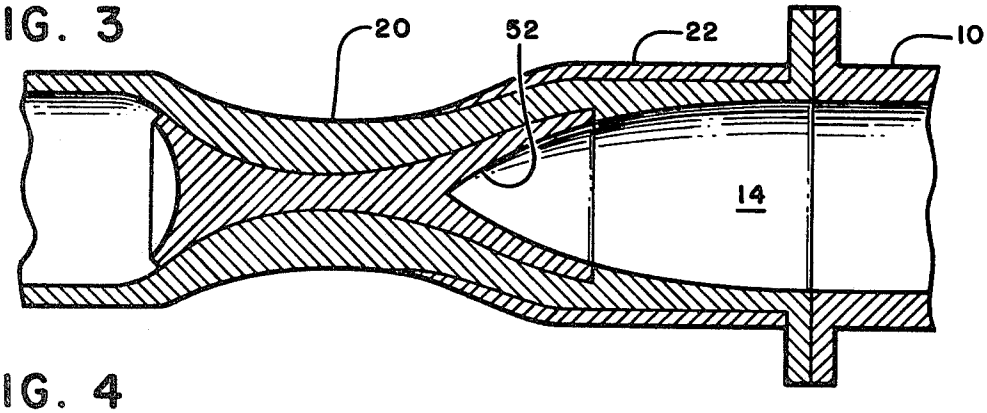
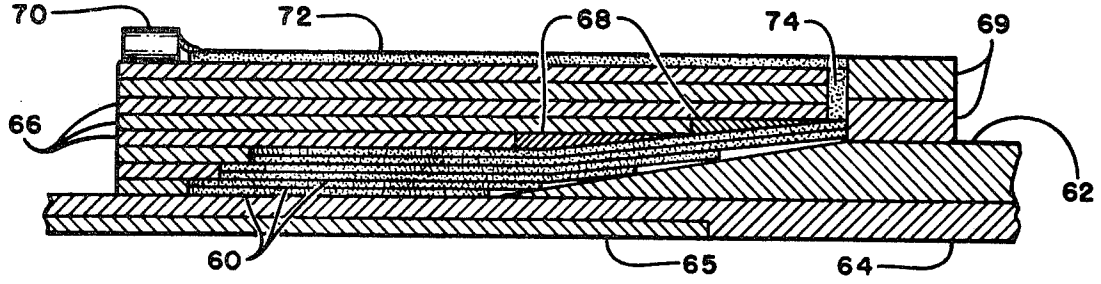


FIG. 4



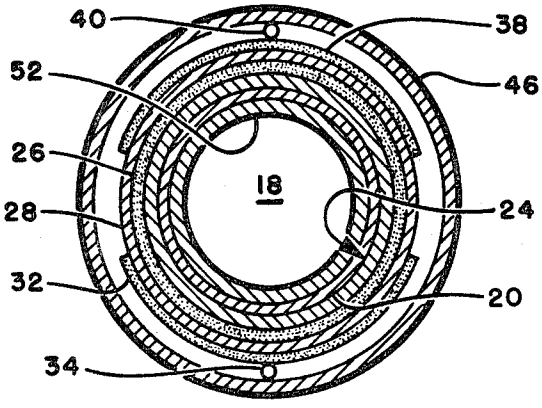


FIG. 2

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CLOSURE MECHANISM

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U.S. Cl. 137—67 10 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for rapidly closing a conduit by pinching off with an explosive utilizing a tapered explosive collar about a tapering wall with a tamper for directing explosive energy against the tapering wall, and simultaneously igniting the explosive collar about its circumference.

BACKGROUND OF INVENTION

There are applications where it is desirable to rapidly close or pinch-off a pipe or other conduit to stop the flow of some material through the pipe or prevent the passage or conductance of material or effects through or along the pipe. One such application may be in certain tests or operations, such as in explosive tests, where it is desired to monitor certains effects of an explosive event with instruments or the like being directly subjected to the initial effects of the event, the light, heat or other radiation emitted at detonation or soon thereafter. After the instruments have been subjected to these effects or have completed their measurements it is desirable in many applications, because of the type of measurements being made or the cost of the experimental equipment, to protect the instruments from the shock wave and other destructive forces produced by the explosive event. Because of the speed at which these forces travel and the proximity of the instruments to the explosive event, the instruments may have to be protected within milliseconds or even microseconds after the measurements have been completed. In many instances, the instruments may be mounted in a pipe or conduit which is aligned with the location of the explosive event so that the desired effects may be measured without any obstructions between the explosive event and the instruments. However, the shock wave and other forces may travel along and through the same pipe and destroy the instruments soon after the measurements are completed, unless some form of protection is provided such as the rapid closing of the pipe.

Another application may be in certain fluid or other material conduits or pipes where it is desired to close off the flow of fluid or material because of some unexpected event or some economic reason. A typical application may be in oil well work where it is desirable to close off a well which either suddenly becomes a gusher or when oil is first struck in a gusher type well, or which acts out of control, in addition to those instances where the well is on fire and it is hence desired to close off the flow of oil. These applications and others like oil or gas pipelines may be particularly critical in off shore oil wells and other areas where the continued flow of oil is not only an economic waste but also a source of extensive pollution of the surrounding area. The more rapidly the pipe can be closed, the lower the economic loss and the lower the potential pollution.

Generally, as the diameter of the pipe or conduit is increased, it becomes more difficult to close a pipe requiring more complex and extensive arrangements to provide good closure seal as well as higher energy power sources to effect pipe closure. Conventional mechanical

valve closures typically require relatively long closure times, particularly as the size of the pipe or strength requirements increase.

High speed closures may often be achieved with explosive valve or pipe closures, but such closures have been lacking in achievement of both high strength and high speed closures. Also, with explosive type closures it is desirable to minimize the amount of explosive material, and consequently the explosive force, needed to effect a complete closure so as not to unduly damage any surrounding equipment or submit any personnel in the area to any unnecessarily high potential chance of injury. Further, explosive pipe closures may produce spallation and jets of high temperature material within the pipe passageway which may constitute a hazard to adjoining equipment or material. Because of the factors involved, it is generally desirable that mechanical or explosive-type closures be relatively inexpensive and capable of reliable operation.

SUMMARY OF INVENTION

In view of the above, it is an object of this invention to provide a novel, rapidly closing explosive pipe closure apparatus.

It is a further object of this invention to provide an explosive pipe closure which utilizes a minimal amount of explosive material for any given pipe diameter and strength.

It is a still further object of this invention to provide an explosive pipe closure of minimized overall size and dimensions.

It is a still further object of this invention to provide a compact, simple and reliable explosive closure mechanism which does not generate internal shrapnel or other high velocity materials or jets.

Various other objects and advantages will appear from the following description of the invention, and the most novel features will be particularly pointed out hereinafter in connection with the appended claims. It will be understood that various changes in the details, materials and arrangements of the parts, which are herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art.

The invention comprises an annular explosive collar disposed about and in contiguity with a tapering wall, tamper means for restraining the explosive collar and for directing explosive energy produced thereby inwardly and means for simultaneously igniting the explosive collar about the collar circumference.

DESCRIPTION OF DRAWING

Embodiments of an explosive closure incorporating features of this invention and its operation are shown in the accompanying drawing wherein:

FIG. 1 is partially cutaway elevation view of a section of a pipe to be closed and the closure apparatus;

FIG. 2 is a cross-sectional view of a portion of a pipe and pipe closure apparatus taken along lines 2—2 of FIG. 1;

FIG. 3 is a cross-sectional view of a pipe after initiation of the explosive closure; and

FIG. 4 is a fragmentary cross-sectional view of another embodiment of an explosive closure mechanism.

DETAILED DESCRIPTION

The explosive closure mechanism of this invention may be attached directly to and form a part of the pipe or conduit which is to be closed or it may be mounted as a separate unit at the end or at an intermediate location along the pipe, in either case as an extension or portion of the pipe or conduit. In the embodiment shown in

FIGS. 1 and 2, the explosive pipe closure apparatus or mechanism is mounted as a separate unit to a pipe **10**, which is to be closed, by means of a flange attachment arrangement **12**. Pipe **10** may have an internal passageway **14** and tubular wall thickness, composition and strength dependent upon its intended use.

The explosive pipe closure mechanism may include a tubular extension **16** having an internal passageway **18** communicating and aligned with passageway **14** of pipe **10**. It will be desirable in many applications that the internal passageway **18** have an internal cross section corresponding to that of passageway **14** so as not to impede or otherwise hinder the use of pipe **10** during normal operation. Tubular extension **16** may be made from a single tubing which is machined in the desired configuration or more conveniently from one or more interior tubing **20** having the central passageway **18** with one or more outer tubing or annular wall **22** shrunk or otherwise fitted concentrically about tubing **20**. The number of concentric tubing or piping used and the materials of each may be determined by convenience of manufacture or by strength and operating characteristics. The combined wall thicknesses of tubing **20** and tubing **22** at the end adjacent to and fastened to pipe **10** and the materials thereof generally should be such as to provide sufficient strength to match or exceed the strength of the wall of pipe **10** after a closure is effected. The wall thickness of tubing **20** should be selected to provide sufficient strength to perform prior to pipe closure under the same conditions as pipe **10**.

Outer tubing or wall **22** is provided with a tapered portion **24** having a decreasing wall thickness from a position adjacent to pipe **10** with a distal end terminating at a position at tubing **20** and directed away from pipe **10**, as shown or with a portion of the wall of tubing **22** remaining about tubing **20**. The wall thickness of tubing extension **16** thus varies from a first combined wall thickness of tubings **20** and **22** with an intermediate, tapered and decreasing wall thickness to the wall thickness of tubing **20** alone or a portion of tubing **22** with tubing **20**.

In order to insure a clean and complete closure, particularly where it is desirable to use very high strength materials for tubings **20** and **22** which may be somewhat brittle, a liner **52** made of a material having a greater malleability than the material forming tubing **20** may be disposed within an appropriate groove **54** in the interior surface of tubing **20** so that the liner **52** defines an internal passageway the same as or similar to passageways **18** and **14**. Liner **52** may limit or prevent spallation and other production of shrapnel in the interior of the pipe extension as the closure is effected and then form a solid closure section in the center of the closed pipe. As the tubing and liner are driven and fuzed together, they are work hardened by the explosive energy to provide even greater strength.

If it is desired to completely separate pipe **10** from any other piping attached to tubular extension **16**, tubing **20** may be notched (not shown) about the outer circumference thereof or a flange (not shown) fitted over tubing **20** at a position on the other side of the explosive closure apparatus from pipe **10**. Such arrangements may provide a planned separation point.

The tubular extension **16** may be made of any appropriate material or combinations of materials which have the desired strength and wall thicknesses, such as steel and other metal alloys. Liner **52** may be made of a malleable material such as an annealed mild steel or some lower strength material like copper, aluminum or brass, depending upon the strength requirements of the closure.

A suitable annular explosive collar **26** may be disposed about the tapered wall portion **24** of tubing **22** and a portion of tubing **20**, as shown. Explosive collar **26** is preferably provided with a tapered or varying wall thickness beginning at the outermost extremity of tapered portion **24** and increasing along tapered portion **24** to a point adjacent tubing **20** at the distal end of wall **22** and then continuing with a uniform or an increasing or decreasing wall thickness to the end thereof. An appropriate high density annular member **28** is then disposed about explosive collar **26** and may have a tapered cross section corresponding with explosive **26** to provide tamping for the explosive by restraining the explosive collar against the tubular extension **16** and directing the explosive energy produced by the explosive collar inwardly against tubular extension **16**. Explosive **26** may be bent or carried around the narrow end of tamper **28** by an annular explosive portion **30** to provide a circumferential explosive ignition path to explosive **26**. Annular explosive **30** may be ignited uniformly and simultaneously about its circumference by an appropriate line wave generator **32** or other conventional powder train. Line wave generator **32** may be ignited by an appropriate blasting cap or detonator **34** with an appropriate power supply (not shown) through lead **36**. One or more additional line wave generators, such as line wave generator **38** and its corresponding detonator **40** and lead **42**, are utilized to insure the simultaneous uniform ignition of explosive **30** about the entire circumference thereof. As the diameter of the explosive closure apparatus is increased, additional line wave generators and detonators may be needed. The detonators may be mounted in a suitable flange **44** or other support. Flange **44** may also be used to support a cover or enclosure **46**, if desired, along with an additional flange support **48**. The space **50** about tamper **28** and the line wave generators **32** and **38** within cover **46** may be filled with additional tamping material or left empty, depending upon the desired use of the closure and size and weight restrictions.

Any appropriate explosive may be used for explosive collar **26** which will provide a burning rate and shock force to effect complete closure. The explosive may be cast or pressed into the desired shape shown or it may be provided by winding layers of explosive sheet material about the respective tubings **20** and **22** in the tapered configuration shown including about 4 to about 12 grams of explosive per square inch per inch of wall thickness of said annular tube. The explosive should be formed so as to provide a detonation front of uniform intensity about the circumference of the tubular extension **16**. Typical explosives may include granular trinitrotoluene, nitroguanidine, pentaerythritol tetranitrate (PETN), cyclotrimethylenetrinitramine and mixtures thereof and/or with mixtures of various plasticizers and/or plastic, felt or the like fillers. A particularly appropriate explosive may be explosive sheets of 63% PETN and a flexible material which are laminated to the desired dimensions. Tamper **28** may be cast or made of laminated sheets of dense metallic material, such as lead, with a minimal thickness of about $\frac{3}{16}$ inch. If tamper **28** is formed from laminated sheets, it is desirable that the sheet material be staggered to avoid preignition from the line wave generators placed outside the tamper material.

When the annular explosive **30** and explosive collar **26** are properly ignited by detonators **34** and **40** and line wave generators **32** and **38**, the explosive collar **26** will burn evenly through its tapered, increasing wall thickness section and drive tapered portion **24** of tubing **22** and tubing **20**, in that order, with increasing force to implode, constrict and fuze the driven wall portions together to form a solid wall closure across passageway **18**, as shown in FIG. 3. A complete closure may be achieved with minimal or no spallation or other breakage of the interior surfaces of the tubing **20** or **22**.

In the embodiment shown in FIG. 4, the explosive is formed from laminating flexible explosive sheets **60** (shown with exaggerated thickness) about and against the tapered portion of outer tubing **62** and the inner tubing **64**, adjacent liner **65**, to provide the desired overall form of the explosive shown. Explosive sheets **60** may be restrained by layered tamper members **66**, tamper fillers **68** and tamper end members **69** ignited by one or more

detonators **70**, one or more line wave generators **72** and annular coupling or transition explosive **74**. The explosive form, taper of tubing **62** and tampers **66**, **68** and **69** permit the minimization of explosive material needed to achieve complete closure.

In a typical application using a pipe **10** having a 4 inch inside diameter and a 6-inch outside diameter, a tubular extension was used having a tube **20** wall thickness of about ½ inch and a tube **22** wall thickness of about ½ inch, each being annealed seamless alloy steel tubing having about 80 to 90,000 p.s.i. tensile ultimate strength. Tapered portion **24** had a uniformly changing circumference with a length of about 6 inches. Explosive **26** included sheets, each typically about 1/32 inch thick, of explosive extending for a length of about 10 inches and including about 63% PETN with a total explosive sheet weight of about 2 pounds. The tamper **28** varied from about ⅛ inch thick to about ½ inch thick. The total length of the tapered portion **24**, explosive collar **26**, tamper **28**, line wave generator and the enclosing cover was about 12 inches. Upon ignition of the line wave generators, the explosive pipe closure provided complete pipe closure in about 150–200 microseconds. A proportionately dimensioned 8-inch inside diameter pipe using about 8 pounds of explosive and a taper about 12 inches long through two or three concentric tubings 1–1.5-inch wall thickness (all comprising tubing **22**) to a central tubing **20** of 0.5 to 1-inch wall thickness provided a pipe closure in about 300–400 microseconds. These closures provided equivalent to about 20,000 p.s.i. external hydrostatic pressure strength.

It has been found using these configurations a complete closure without internal spallation and fracture of closure materials may be best achieved by using a tapered portion **24** in tubing or wall **22** of at least about 1.5 times the internal diameter (D) of passageways **14** and **18** with the explosive collar **26** extending beyond the taper an additional distance of about 1 (one) D. Also, liner **52** may extend towards pipe **10** a distance of about 0.5 to 0.75 the length of the taper from the taper end and extend in the other direction any desired distance. The overall length of the explosive closure may therefore be about 2.5–3.0 times D or more. It has also been found that the outside diameter of the tubular extension **16** at the end adjacent to pipe **10** may be about 1.5 times D depending upon the desired strength of the closure. With such an outside diameter, the overall diameter of the explosive pipe closure may be about 2.2 times D with tubing **20** having an outside diameter of about 1.25 times D.

What is claimed is:

1. Means for closing the passageway of a conduit, comprising an annular explosive collar, an annular tapering wall encircled by said explosive collar, an annular tube having a wall portion encircled by both said tapering wall and collar, a generally tubular tamper surrounding at least a portion of said explosive collar to direct explosive energy radially inward, and means for igniting a portion of said explosive collar substantially entirely about the circumference thereof to inwardly constrict said tapering wall and tube and close said conduit.

2. The means of claim **1** wherein said explosive collar has increasing wall thickness about said tapering wall.

3. The means of claim **2** wherein said tamper comprises an annular high density member disposed about said length with a thickness varying proportionally with said explosive collar thickness.

4. The means of claim **1** wherein said igniting means includes a plurality of line wave generators coupled to said explosive collar portion about the circumference thereof at a location disposed away from the distal end of the taper of said tapering wall.

5. The apparatus of claim **4** wherein said line wave generators are laid over said tamper with each of said line wave generators decreasing in width away from said coupling terminating at explosive detonators.

6. The mean sof claim **1** wherein said explosive collar has a length of about 2.5 to 3 times the diameter of said conduit passageway.

7. The means of claim **1** wherein said tapering wall has a length of about 1.5 times the diameter of said conduit passageway.

8. The means of claim **1** wherein said annular tube includes an annular metal liner having greater malleability than said annular tube and wall.

9. The means of claim **1** wherein said annular tube and said conduit have internal passageways of uniform diameter.

10. The means of claim **1** wherein said explosive collar includes from about 4 to about 12 grams of explosive per square inch per inch of wall thickness of said annular tube along said explosive collar.

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29—421; 102—24; 251—4