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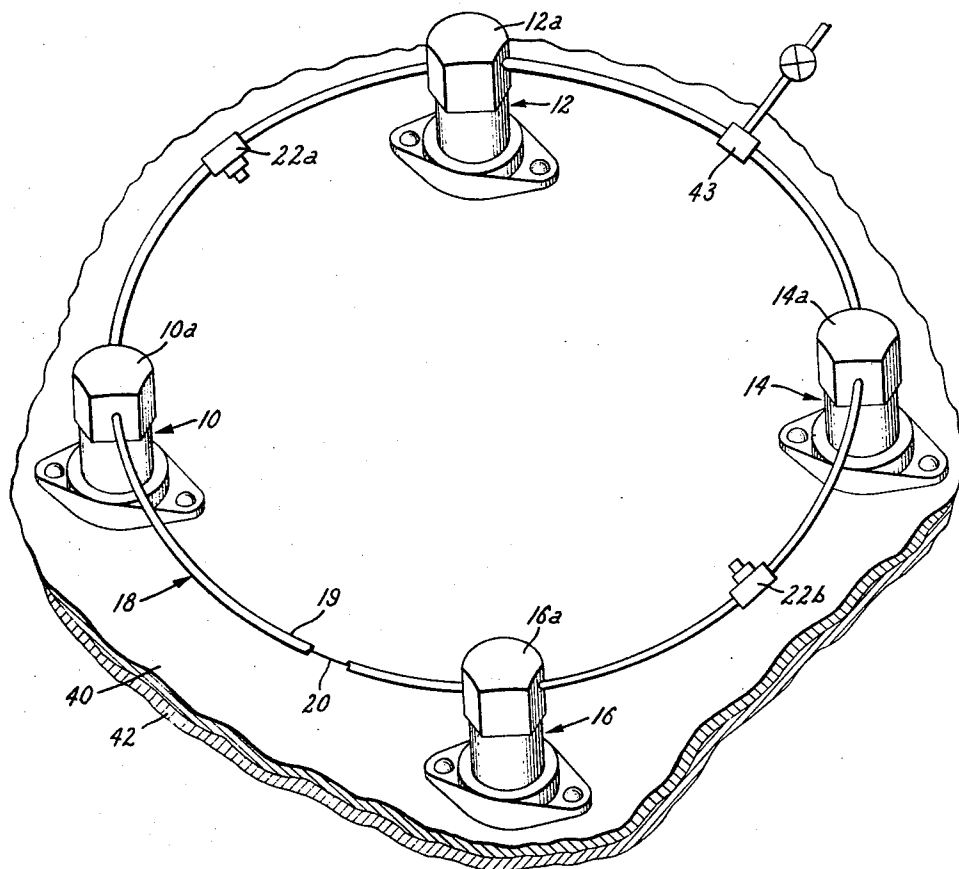
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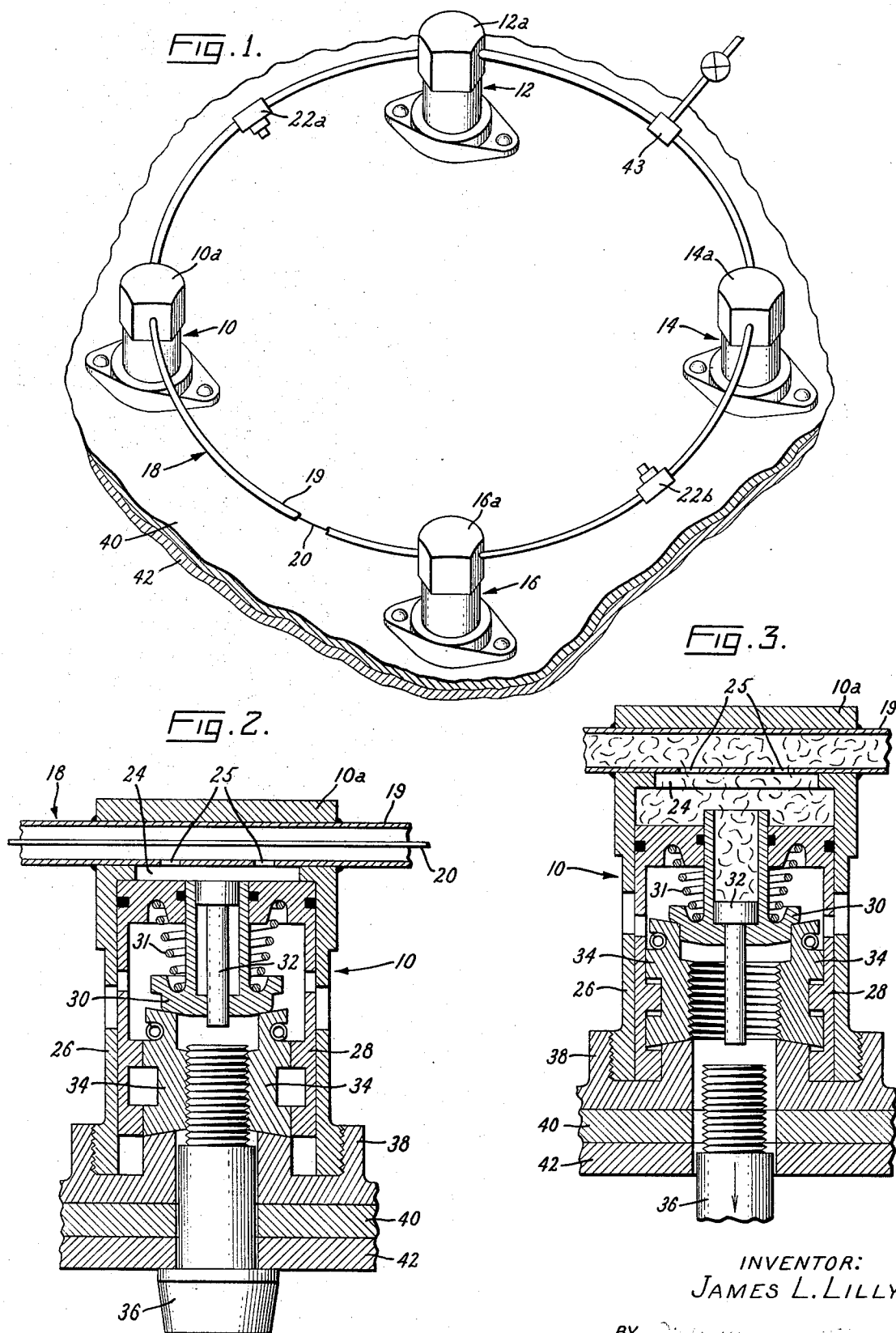
[54] **LINEAR GAS GENERATOR ACTUATED LATCHING AND THRUSTING DEVICE**
10 Claims, 5 Drawing Figs.

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 102/27, 102/49
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 F01b 31/00, F01b 9/00
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ABSTRACT: Apparatus for providing fluid actuation of a plurality of devices by the use of a combustible cord continuously extending through fluid actuation chambers for each of the devices. One or more ignition means are provided for the combustible cord. After the cord is ignited, combustion of the cord propagates down its length. When combustion of the cord within a fluid actuation chamber occurs, the gases formed thereby effect actuation of the device.





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Fig. 4.

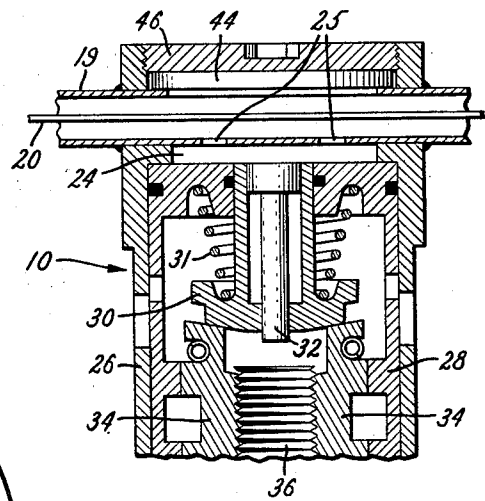
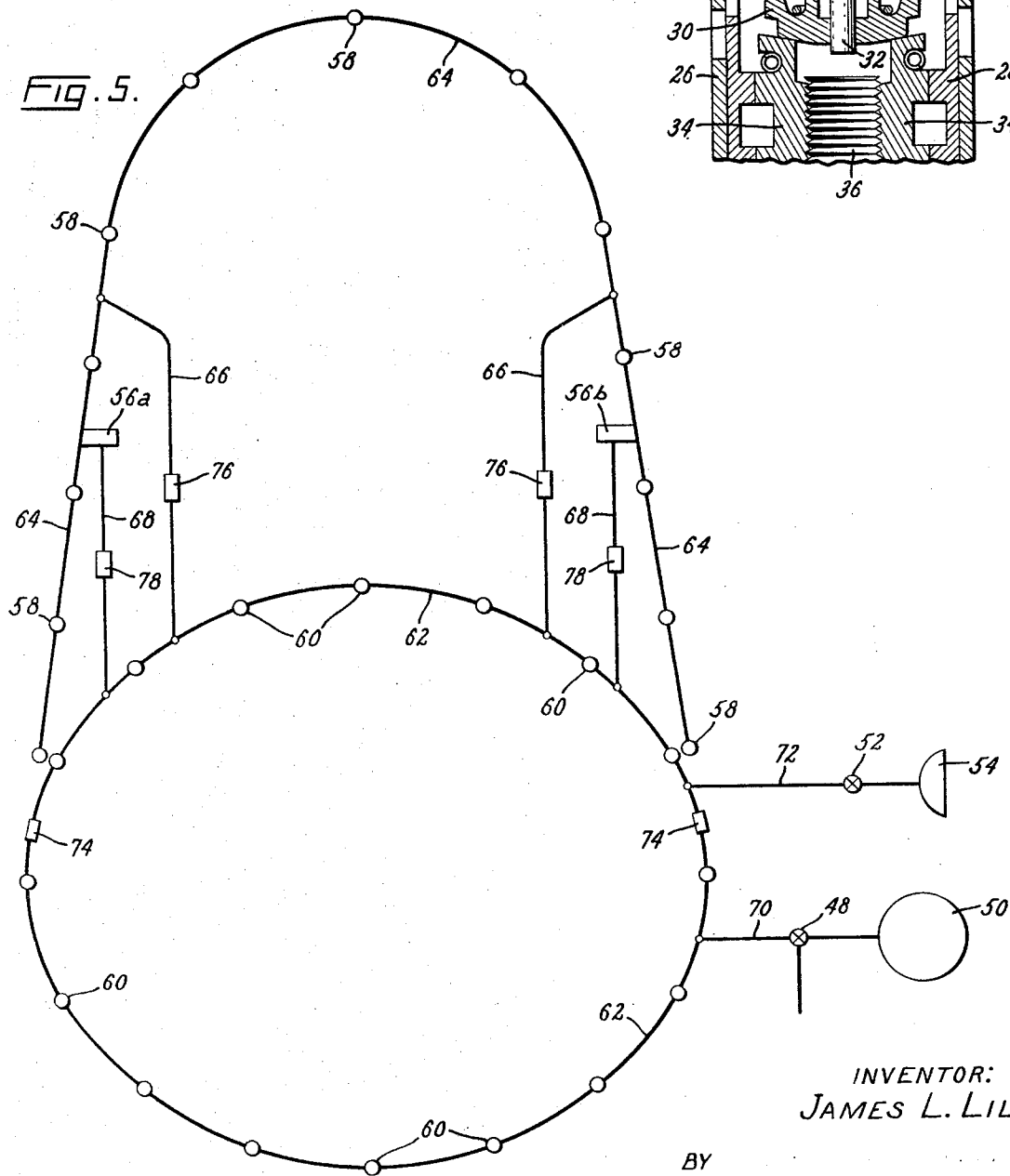


Fig. 5.



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LINEAR GAS GENERATOR ACTUATED LATCHING AND THRUSTING DEVICE

BACKGROUND OF THE INVENTION

The subject invention generally relates to the field of fluid actuation and, in particular, to apparatus for providing fluid actuation of a plurality of devices.

Due in large part to the increasing amount of interest in space and undersea operations, a need has developed for providing reliable separation apparatus and fluid actuating mechanisms which preferably generate little if any debris. Separation devices have been developed for use with apparatus such as an emergency escape hatch or for providing separation of components of a space vehicle. One type of separation apparatus uses a plurality of explosive bolts, each bolt being actuated by ignition of an explosive charge located therein by means of one or more ignitors connected to each explosive bolt. This configuration requires for each bolt, one or more ignitors (depending on the reliability desired) with a suitable energization means connected to each ignitor. If there is to be delayed actuation of any one or more of the explosive bolts, additional control of the energizing means must be used. Due to the large number of elements involved, such a system is generally very complex and expensive and may represent a sizeable weight penalty. A second type of separation apparatus that has been used involves a linear charge such as an explosive cord generally located adjacent a weakened connecting section so that ignition of the explosive cord causes a breaking of the connecting portion. The apparatus used in such a technique is expensive to fabricate, frequently results in the formation of debris and generally cannot be tested except to destruction.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the subject invention to provide a simple apparatus for actuating by fluid pressure a plurality of devices.

A further object is to provide a highly reliable separation device which generates no debris.

Another object of the subject invention is to provide apparatus for fluid actuation of a plurality of devices in a given time sequence.

Still another object of the subject invention is to provide apparatus for fluid actuation of a plurality of devices which can be tested and reused.

The subject invention fulfills the above-stated objects by providing in combination with a plurality of devices each having a fluid actuation chamber, a gas generator of a linear shape which includes a combustible member, such as an explosive cord extending through and between said fluid actuation chambers and means for igniting the combustible member. In operation, the combustible member is ignited and the combustion zone of the member propagates along the length thereof. When combustion of the portion of the member within a fluid actuation chamber occurs, the gases generated actuate the device and the combustion zone continues to propagate along the member actuating the other devices. The rate of propagation of the combustion zone along the member and length of the member between devices determines the time delay between actuation of consecutive devices. Alternatively, by use of a series connected time delay device, the time delay between actuation of the devices can be preselected. Also, if desired, a secondary combustible charge can be located within a device to provide additional fluid actuation pressure. Devices that can be fluid actuated by means of an explosive charge or fluid pressure pulse within a fluid actuation chamber can be used as one of the plurality of devices included in the subject invention.

The subject invention is particularly pointed out and distinctly claimed in the concluding portion of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject invention, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a perspective view of one embodiment of a fluid actuation system utilizing the subject invention;

FIG. 2 is a cross-sectional view of one of the bolts shown in FIG. 1, before actuation thereof;

FIG. 3 is a cross-sectional view of the bolt shown in FIG. 2, after actuation;

FIG. 4 is a cross-sectional view of an explosive bolt with an additional combustible charge therein for use with the apparatus of the subject invention; and,

FIG. 5 is a schematic representation of another embodiment of a fluid actuation system utilizing the subject invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 an example of a preferred embodiment of the subject invention is shown. Four explosive, resettable bolts 10, 12, 14 and 16 are provided, each of the bolts having an upper portion 10a, 12a, 14a, 16a containing therein a fluid actuation chamber. A linear gas generator 18 including a continuous loop of thin-walled tubing 19 and a linear combustible member 20 within tubing 19 extends between and through the fluid actuation chambers of each of the bolts. Tubing 19 acts as a manifold for gases generated by the combustion of the linear combustible member. Linear combustible member 20 is preferably of an elongated shape and is hereinafter referred to as explosive cord 20. Ignition means 22a, 22b for initiating the generation of gases by igniting cord 20 are located along the length thereof at two positions, as shown in FIG. 1. While only one ignition means 22a is necessary for proper operation of the subject invention, two (as shown) or more may be used to provide added reliability.

FIG. 2 is a cross-sectional view showing the internal mechanism of one of the bolts 10 of FIG. 1. Tubing 18 with explosive cord 20 located therein passes through an upper portion 10a of bolt 10 and extends through a fluid actuation chamber 24 thereof. A plurality of apertures 25 are located in the wall of tubing 18 to allow fluid communication between the interior of tubing 18 and fluid actuation chamber 24.

Bolt 10 is comprised of a hollow cylindrical casing 26, an outer, cylindrical piston 28 adjacent to the interior surface of casing 26, a coaxial camming member 30, a spring 31 between piston 28 and member 30, a small inner piston 32 located within camming member 30, a plurality of annularly spaced collet segments 34, a bolt member 36 and a base member 38. Bolt 10 holds together two parallel plates 40, 42.

The operation of linear gas generator 18 and explosive bolt 10 is explained below. When actuation of the explosive bolts is desired, explosive cord 20 is ignited by igniter means 22a, 22b. Combustion of cord 20 propagates from igniter means 22a, 22b along the length of cord 20 and through each of the bolts. When the combustion zone of cord 20 reaches fluid actuation chamber 24, the gases produced thereby flow from tubing 19 into fluid actuation chamber 24 through apertures 25. The gases within the fluid actuation chamber 24 act on the upper surface of outer piston 28 causing it to move vertically downward and unlock collet segments 34. The gases also act on camming member 30 and inner piston 32, pushing camming member 30 downward with the help of spring 31 so as to push collet segments 34 radially outward to disengage the bolt while inner piston 32 moves downward to engage and push bolt member 36 downward thereby allowing separation of the two plates 40, 42.

As the combustion zone of cord 20 passes through the fluid actuation chamber of each of the bolts, each of the bolts is actuated and release occurs. Time delay between actuation of successive bolts is determined by the propagation rate of the explosive cord, the length of the cord between successive explosive bolts and the location of the igniter means.

Substantially simultaneous actuation can be effected by using an explosive cord having a very high propagation rate, minimizing the length of cord between successive explosive bolts or by placing the igniter means and the successive cords such that there is an equal length of explosive cord from each igniter means to each explosive bolt.

The apparatus described above can be reused merely by recocking each of the explosive bolts and installing a new piece of explosive cord and ignitor means.

If desired, a tap 43, as shown in FIG. 1, may be connected to the linear gas generator manifold 19 to provide a second fluid actuation system. The tap is connected to an external fluid pressure source, not shown, and includes a valve for controlling fluid flow between the external pressure source and the interior of the manifold. One example of external fluid pressure source that may be used is a gas cartridge filled with a gas at a high pressure. In operation, the valve is opened and high-pressure fluid is ducted through tap 43 to the interior of the manifold to cause actuation of the devices connected to the manifold. This may be used to test the fluid actuation system without the necessity of igniting the explosive cord, as an emergency or backup system in the event the explosive cord cannot be used or malfunctions, or as a primary actuation system with the explosive cord as part of a backup system.

In FIG. 4, a slightly modified embodiment of the subject invention is shown wherein an explosive charge 44, acting as a supplemental gas generator, is located in fluid actuation chamber 24, of bolt 10 adjacent a portion of linear gas generator 18. When the combustion zone of explosive cord 20 reaches the interior of fluid actuation chamber 24, explosive charge 44 becomes ignited; thereby producing additional gases which collectively act with the gases formed by the combustion of cord 20 to produce an increased gas pressure acting within fluid actuation chamber 24. The above embodiment is desirable where the gas pressure necessary to provide actuation of a device is greater than the pressure that can be conveniently produced by the linear gas generator itself. If desired, a removable closure member, such as a screw-threaded member 46 adjacent fluid actuation chamber 24 may be provided to allow easy replacement of the supplemental gas generator.

While the embodiments of subject invention has been disclosed above for use with explosive bolts, the subject invention may be used with any device which can be actuated by a fluid pressure pulse that can be obtained from a linear gas generator with or without an adjacent secondary gas generator. Such devices, including explosive bolts, will be hereinafter generally referred to as fluid-actuated devices.

In FIG. 5, a schematic representation of a multiple actuation system of the subject invention using a variety of different types of fluid-actuated devices is shown. Specifically, the fluid actuated devices utilized are a fluid-actuated valve 48 for "enabling" a fluid propulsion system 50, a fluid actuated release member 52 for deploying an antenna 54, two thruster mechanisms 56a, 56b for deploying shrouds and a plurality of fluid-actuated bolts 58, 60, not shown. The purpose of the system shown in FIG. 5 is to release and deploy a shroud of a rocket stage and simultaneously actuate apparatus of the rocket stage itself.

The system is comprised of two primary linear gas generators 62, 64, two pairs of transfer linear gas generators 66, 68 and two connecting linear gas generators 70, 72. Each linear gas generator is considered to include manifold tubing and a linear combustible member, such as an explosive cord, enclosed therein.

Linear gas generator 62 which is circular in shape extends between and through a plurality of fluid actuated bolts 60 which fasten a shroud (not shown) to a rocket stage (not shown). Means 74 for initiating combustion of the linear gas generators, hereinafter referred to as ignitor means, are located along the length of linear gas generator 62.

Transfer linear gas generators 66 extend from linear gas generator 62 to linear gas generator 64 to allow propagation of combustion therebetween. Means 76 for delaying the

propagation of combustion of a linear gas generator, hereinafter referred to as a time delay, is located along the length of each of linear gas generators 66 to assure that all of the fluid-actuated bolts 60 connecting the shroud to the rocket stage are actuated before actuation of any of the devices along linear gas generator 64. As is well known in the art, a time delay may be comprised of a length of combustible material having a slower rate of propagation than the other combustible material used. Linear gas generator 64 extends between and through a plurality of fluid-actuated bolts 58 which serve to hold together two halves of the shroud member.

Transfer linear gas generators 68 extend between linear gas generator 62 and thrusters 56a, 56b to allow propagation of combustion therebetween. Thrusters 56a, 56b are used to propel the shroud away from the rocket stage and separate the two halves of the shroud. Time delays 78 are located along the length of each linear gas generator 68 to assure that all bolts 60 are actuated before actuation of thrusters 56a, 56b. Thrusters 56a, 56b, when actuated, operate for a time period sufficient to disconnect the two halves of the shroud and properly deploy the shroud.

Connecting linear gas generators 70, 72 extend between linear gas generator 62 and enabling valve 48 and antenna deploying means 52, respectively, to allow propagation of combustion therebetween.

In operation, ignitor means 74 are actuated by suitable control means (not shown) causing combustion to propagate along the length of linear gas generator 62. The combustion propagation causes actuation of fluid-actuated bolts 60, releasing the shroud from the rocket stage. Substantially simultaneously therewith, combustion propagates through connecting fluid gas generators 70, 72 thereby actuating devices 48 and 52. Actuation enabling valve 48 allows fluid flow to propulsion unit 50 for subsequent propulsion maneuvers after shroud unit has been deployed. Actuation of antenna-deploying device 52 causes antenna 54, which is connected to the rocket stage, to be deployed, thereby allowing signals to be transmitted from or received by apparatus within the rocket stage. Combustion of transfer linear gas generators 66, 68 is initiated by the combustion of linear gas generator 62. Due to time delays 76, 78, the combustion of linear gas generators 66, 68 is not transmitted to the thrusters 56a, 56b and linear gas generator 64 until all of fluid actuator bolts 60 have been actuated. After the time delay, fluid actuator bolts 58 are actuated so as to release the shroud halves from each other and thrusters 56a, 56b are actuated. Thrusters 56a, 56b cause the two shroud halves to be propelled away from the rocket stage.

In linear gas generators of the subject invention linear combustible members need not be enclosed by manifold tubing. However, use of the tubing is preferable as it protects the combustible member enclosed therein, obviates problems due to contamination from combustion products, prevents damage to adjacent members by the combustion activity and acts as a manifold for the generated gas thereby increasing the pressure acting within the fluid actuation chambers above what would be obtained by using a similar combustible member without the tubing.

The linear combustible member for most uses must include its own oxygen for combustion and may be in any form desirable; i.e., solid, amorphous, liquid or gas. While a solid explosive is generally preferable, a linear charge of plastic explosives or a tube containing liquid or gas explosives may be used.

It should be noted that whatever type of linear combustible member is used, if it is to be enclosed within manifold tubing, the interior cross-sectional area of the manifold tubing should be much larger than the cross-sectional area of the combustible member so that combustion of the member does not rupture the tubing. It is obvious to one skilled in the art that many other modifications may be made to the subject invention without departing from the scope thereof.

Thus, the subject invention provides apparatus for actuating a plurality of fluid actuated devices either simultaneously or in any desired sequence with a minimum number of initiating devices.

What I desire to secure by Letters Patent of the United States:

1. Means for providing fluid actuation of a plurality of devices, each having a fluid actuation chamber, comprising:

- a. a linear gas generator extending through each of said fluid actuation chambers of said devices, said gas generator including means for confining gas generated therein and for controlling the flow of gas generated to said devices; and,
- b. means connected to said linear gas generator for initiating the generation of gases therein.

2. Means as in claim 1 wherein said linear gas generator is comprised of a manifold and a linear combustible charge located therein.

3. Means as in claim 2 further including means for connecting a pressurized fluid source to said manifold.

4. Means as in claim 2 wherein each portion of manifold ex-

tending through a fluid actuation chamber has at least one aperture therein.

5. Means as in claim 4 wherein the cross-sectional area of the interior of said manifold is much greater than the cross-sectional area of said linear combustible charge.

6. Means as in claim 1 wherein said linear gas generator includes an explosive cord.

7. Means as in claim 1 further including a supplemental gas generator located within at least one of said devices adjacent a portion of said linear gas generator.

8. Means as in claim 1 further including means for delaying the propagation of combustion along said linear gas generator.

9. Means as in claim 1 wherein said linear gas generator is shaped to include at least one closed loop and at least one connected linear gas generator extending therefrom.

10. Means as in claim 9 including means for delaying the propagation of combustion along said linear gas generator which is located along the length of said connected linear gas generator.

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