United States Patent [19]

McCullough et al.

[11] **3,852,526**

[45] **Dec. 3, 1974**

[54] **INSPECTION INSTRUMENT**

[75] Inventors: **Edward E. McCullough,** Brigham City; **Kerry G. Zundel,** Tremonton; **La Ron D. Binggeli,** Logan, all of Utah

[73] Assignee: **Thiokol Corporation,** Bristol, Pa.

[22] Filed: **Oct. 9, 1973**

[21] Appl. No.: **404,522**

[52] **U.S. Cl.**..... **178/7.1,** 178/DIG. 1, 178/DIG. 30, 354/63, 356/241

[51] **Int. Cl.** **H04n 7/18**

[58] **Field of Search**..... 178/DIG. 1, DIG. 30, 7.81, 178/7.2; 350/11; 356/237, 241; 354/63; 73/167

[56] **References Cited**

UNITED STATES PATENTS

3,329,059	7/1967	McCormac	356/241
3,399,614	9/1968	Fischer	178/7.81
3,609,236	9/1971	Hellman	178/DIG. 1
3,689,695	9/1972	Rosenfield	178/7.81
3,764,736	10/1973	Kosky	178/DIG. 1

Primary Examiner—Howard W. Britton
Assistant Examiner—Michael A. Masinick
Attorney, Agent, or Firm—Edward E. McCullough

[57] **ABSTRACT**

An observation device for inspecting elongated cavities is attached to the outer end of a cable made of pneumatic tubes and electrical conductors encased in a flexible sheath. The cable passes through a sleeve attached in an inflatable support that curves through an arc of approximately 90°, so that it enters the base of the inflatable support and emerges through the top thereof. The cable is attached to a control box containing connectors to a pressurized source of gas, a source of electrical power, and control means therefor. A series of inflatable braces concentrically surrounds the cable for supporting it in the center of the cavity to be inspected, each brace being inflatable through a pneumatic tube leading from the source of gas. The protective sheath of the cable is inflatable to impart rigidity when in use, and also to surround the pneumatic tubes with the same pressure as their interiors, so that wall thicknesses thereof may be minimized for compactness when stored.

10 Claims, 7 Drawing Figures

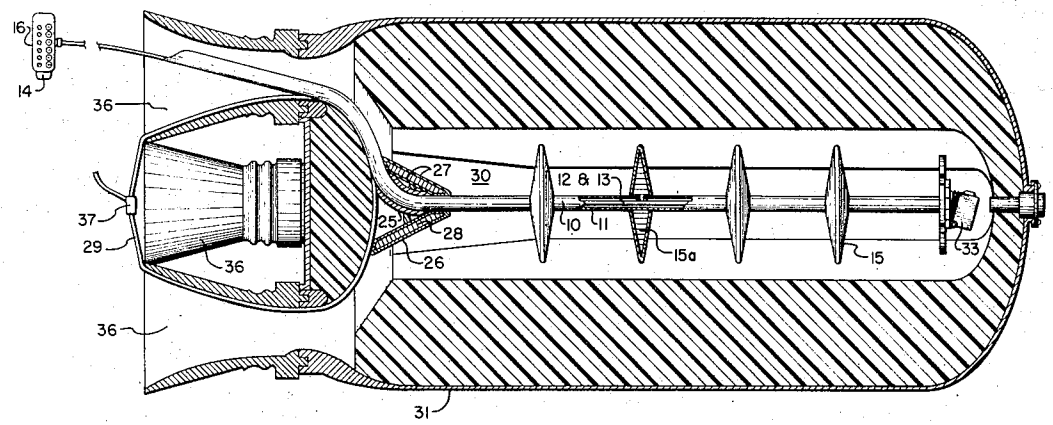


FIG 1

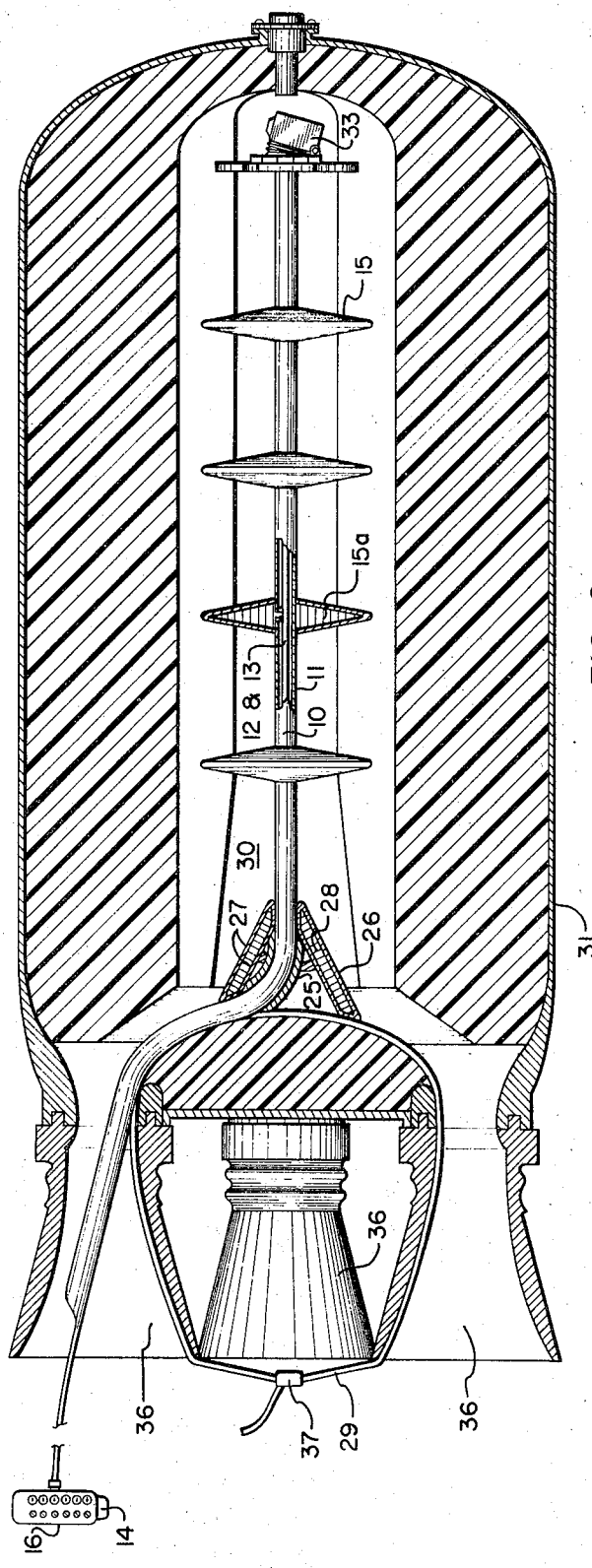

33
15
15a
12 & 13
11
10
30
27
28
26
25
31
36
36
36
37
29
16
14

FIG 2

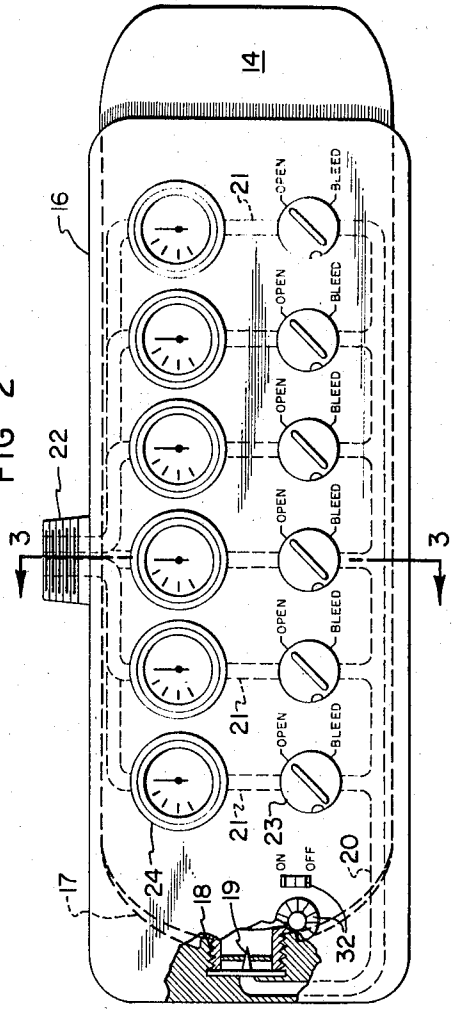

14
16
21
OPEN
BLEED
22
3
3
21-1
21-2
23
ON
OFF
20
17
24
18
19
32

FIG 3

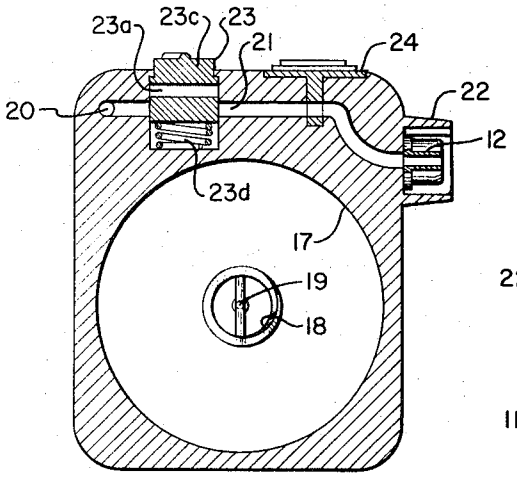


FIG 5

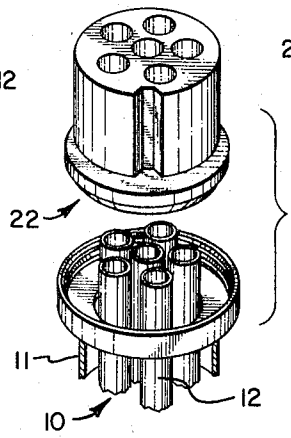


FIG 6

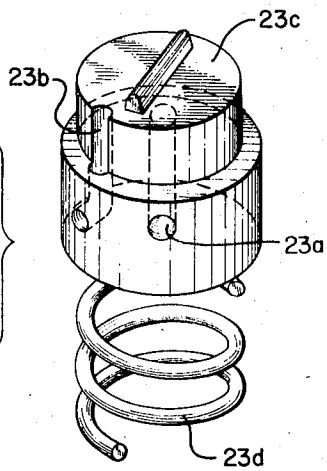


FIG 4

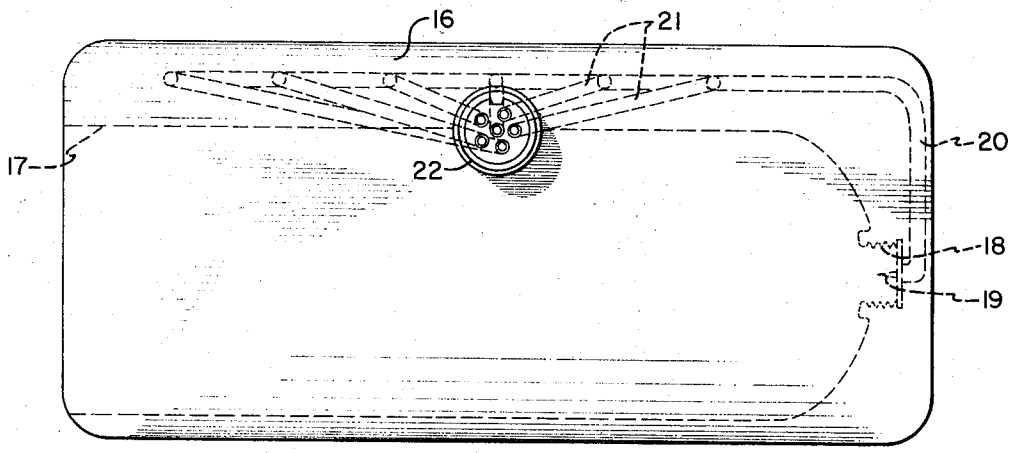
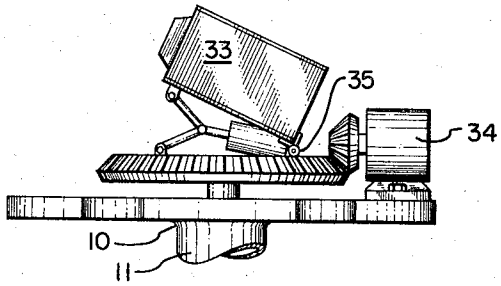


FIG 7



INSPECTION INSTRUMENT

BACKGROUND OF THE INVENTION

This invention relates broadly to inspection devices, and more specifically to those that must be very portable and extensible in one direction for inspecting elongated cavities. The invention herein described was made in the course of or under Contract AF 04(694)–926 with the U.S. Air Force.

Sometimes it is necessary to inspect an elongated cavity in a substantially stationary object wherein the amount of room at the entrance to the cavity is restricted, so that the inspection instrument must be very compact and extensible to many times its storable length. An example of this is an experimental solid propellant rocket having a central bore in the propellant. When experimental propellant is used in such a rocket, it must be inspected periodically to assure that undesirable effects, such as cracking, have not occurred as a result of aging. Such an effect must be known before the rocket is fired, because the greatly increased burning surface created by the fractures can make the rocket potentially dangerous. If the rocket is of a type having a plurality of thrust nozzles and an axial cavity in the propellant, any inspection device that is supported outside such a rocket motor would have to enter one of the nozzles and then execute two substantially 90° turns in order to enter the axial cavity. Inspection of other types of solid propellant rocket motors having single nozzles also is usually very difficult without removing the motor from its storage place.

SUMMARY OF THE INVENTION

The present invention, which satisfies this need, is an inspection instrument having an observing means supported on the outer end of a cable that comprises a plurality of pneumatic tubes and electrical conductors encased in a flexible sheath. This cable passes through a sleeve, one end of which enters an inflatable support at its base, curves through about 90°, and penetrates the top of the inflatable support. The support is a hollow cone made of two parallel layers of flexible material spaced apart by fibers anchored in the layers or sheets, the parallel sheets being sealed at their edges to enclose an annular, conical volume which is to be inflated. The control end of the cable is fastened to a control box that contains connectors to a source of electrical power and to a source of pressurized gas. This box also contains switches, valves, or other control means for regulating the flow of electrical power and gas to the cable. A series of annular, inflatable braces of nonelastic, thin, flexible material is concentrically fixed to the cable and each is inflatable via one of the pneumatic tubes. The inflatable support may be anchored to the rocket or to some other stationary part by means of a strap.

When a rocket having a plurality of nozzles and a central cavity is to be inspected, the inflatable support is centered inside the aft closure, anchored to the rocket by means of a strap, and inflated. Gas is then metered into the pneumatic tube that communicates with the interior of the inflatable brace nearest the free end of the cable and outside the inflatable support. The desired height of the observing device in the cavity is achieved simply by threading the cable through the sleeve, and the inflatable braces may be inflated serially as they emerge through the inflatable support. Rigidity is imparted to the cable by inflating its sheath. Since this eliminates stress on the pneumatic tubes of the cable, their walls can be of minimal thickness for compactness when stored. Orientation and other operations of the observation means are accomplished by appropriate well-known devices.

Objects of the invention are to provide an instrument for inspecting bores that is very portable; convenient to use; and that will not damage the propellant inside the rocket motor. Important features of the invention are that it is simple in construction, easy to manufacture, and inexpensive to make.

Other objects, features, and advantages of the invention will become apparent as the following description is read with reference to the accompanying drawings, wherein the same parts are designated with the same numbers throughout the disclosure.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a longitudinal section of a typical solid-propellant rocket motor with the invention installed therein;

FIG. **2** is a top view of the control box;

FIG. **3** is a cross section of the control box;

FIG. **4** is a side elevation of the control box, showing the cable connector;

FIG. **5** is a perspective detail showing both parts of the cable connector;

FIG. **6** is a perspective detail of a typical valve; and

FIG. **7** is a side elevation of the camera and associated devices for orienting it as desired.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. **1**, the invention has a cable **10** having an outer sheath **11** that encloses a plurality of pneumatic tubes **12** and electrical conductors **13.** Each of the pneumatic tubes **12** leads from a bottle **14** of pressurized gas, or other source of gas, to a specific, inflatable brace **15.** One of them connects the source of gas **14** with the inflatable base or support **26.** Each inflatable brace **15** is annular, concentrically surrounding the cable **10.** It is essentially disk shaped and is somewhat thickened at the center to prevent buckling.

A control box **16** (FIGS. **2, 3,** and **4**) has a cavity **17** to receive the gas bottle **14.** A threaded orifice **18** may engage threads on the end of the bottle **14,** and a puncture point **19** ruptures a diaphragm, not shown, in the end of the bottle **14,** when the threads have engaged sufficiently to form a gastight seal. A main duct **20** leads from the threaded orifice **18** to a plurality of branch ducts **21,** each of which connects at its other end, via a connector **22** (See FIG. **5**) to a selected tube **12.** Intermediate each branch duct **21** is a valve **23** and a flow meter **24.** A detail of a valve **23** is shown in FIG. **6.** It has a through passage **23***a* that is alignable with a branch duct **21** in "open" position and a bleed orifice **23***b* alignable with a branch duct **21** when an associated device is to be deflated. In either case, the valve member **23***c* must be pressed against the spring **23***d*. Each of the inflatable braces **15** is made of a thin, flexible material that is nonelastic so that it has a fixed form when fully inflated, and, further, has fibers **15***a* passing between opposite walls to promote dimensional stability.

The cable **10** passes through a curved sleeve **25** that is fixed in a base or support **26** having the form of a hollow cone. This hollow cone is made of two parallel sheets **27** of thin, flexible material that is nonelastic. They are sealed together at their top and bottom edges to form a closed, annular, inflatable space. Dimensional stability of the base **26** is further insured by a multiplicity of fibers **28** that extend between the sheets **27** and are embedded therein at their ends. Material of this nature is commercially available. A buckle equipped strap **29** is fastened to the base of the support **26,** whereby the support **26** may be centered and firmly attached inside the cavity **30** of the rocket motor **31.** The control box **16** also has electrical controls **32** attachable to a source of electric power, to the television camera **33,** and to its horizontal electrical step motor **34** and vertical actuator **35,** respectively. The electrical conductors are not shown. The television camera **33** and its step motor **34** and actuator **35** are of types well known in the art and are commercially available.

The invention may be practiced by first threading one end of the strap through one nozzle **36** of the rocket motor **31** and allowing it to slide down through the opposite nozzle **36.** The two ends of the strap **29** are then adjusted until the base **26** is centrally located as desired. This may be done by matching an index mark on the strap **29** with the edge of one of the nozzles **36.** The strap **29** is then firmly fastened in place by its buckle **37.** Gas from the gas bottle **14** is then allowed to pass through the valve **23** associated with the inflatable support **26.** The cable **10** is stiffened by inflating its sheath **11** in the same manner, and is then moved through the sleeve **25** until the first inflatable brace **15** is free of the top thereof. This can be determined by a scale, not shown, on the cable **10,** using the edge of the nozzle **36** as an index means. The valve **23** associated with that first inflatable brace **15** is then opened and the gas is allowed to flow until the corresponding flow meter **25** indicates that this brace **15** is fully pressurized. The remaining inflatble braces **15** are inflated in turn as needed, in the same manner. When the top of the cable **10** has reached the desired height in the cavity **30,** the camera **33** may be oriented as desired, horizontally by the step motor **35** and vertically by the pneumatic actuator **35.** It may be operated by the conventional electrical controls **32** (See FIG. **7**).

When the inspection is completed, the main valve **23a** is closed, the cable **10** is withdrawn through the sleeve **25,** and the inflatable braces **15** are deflated one by one in reverse order to that of their inflation as they approach the sleeve **25.** Each valve **23** is equipped with a discharge position for this purpose, which opens its corresponding branch duct to the atmosphere.

The base and cable sheath **11** are then deflated in the same manner, the buckle **37** is unfastened, and the inspection instrument is withdrawn from the rocket motor **31.**

An invention has been described that advances the art of inspecting elongated cavities. Although the preferred embodiments have been described with considerable specificity with regard to detail, it should be understood that many such details may be altered without departing from the scope of the invention as it is defined in the following claims.

The invention claimed is:

1. A bore inspection instrument comprising:

an inflatable base;

means for anchoring the base to some stationary part adjacent the bore to be inspected;

a cable held by the base, capable of sliding motion relative thereto, and including pneumatic tubes;

inflatable braces attached to the cable, each being attached to a tube therein;

means for controlling fluid flow, attached to the tubes of the cable and attachable to a source of gas, for controlling inflation of the base and of the inflatable braces; and

observation means attached to the end of the cable opposite the end attached to a control means.

2. The inspection instrument of claim **1** wherein the base comprises:

a hollow, inflatable cone made of two parallel sheets of thin, flexible nonelastic material, sealed at their edges, and fibers that extend from one sheet to the other, the ends of the fibers being embedded in the sheets; and

a curved sleeve fixed in the cone and passing therethrough, one end of the sleeve penetrating the top of the cone and the other end extending from the bottom thereof.

3. The inspection instrument of claim **1** wherein the observation means is a television camera.

4. The inspection instrument of claim **1** wherein the means for controlling fluid flow comprises:

a control box having a threaded cavity for receiving a threaded bottle of compressed gas, and a system of ducts having branch ducts leading from the gas bottle cavity wherein each branch duct is connectable to one of the tubes of the cable; and

a valve in each branch duct capable of opening and closing its duct to the source of gas, and of opening the portion of its duct that lies adjacent the cable to the atmosphere.

5. The inspection instrument of claim **4** further including:

a flow meter in each branch duct for determining when its associated inflatable device has been inflated; and

a connector for connecting the branch ducts to the tubes of the cable.

6. The inspection instrument of claim **1** wherein the cable comprises an outside sheath and pneumatic tubes inside the sheath; and wherein the inflatable braces are disks concentric about the cable and attached thereto at intervals such that the segment of the cable between any two adjacent braces is resistant to bending.

7. The inspection instrument of claim **6** wherein the inflatable braces have fibers passing between opposite walls and embedded therein to maintain dimensional stability thereof when inflated.

8. The inspection instrument of claim **6** wherein the sheath of the cable is connectable to a source of gas and is inflatable, whereby stiffness may be imparted thereto to facilitate its extension into a cavity and whereby pressure outside and within the pneumatic tubes may be substantially equalized so that their walls may be of minimal thickness for compactness when collapsed and folded.

9. The inspection instrument of claim **8** wherein the cable includes electrical conductors connectable at one end to the television camera, and the instrument further includes electrical controls connected to the electrical conductors and also connectable to a source of power.

10. An instrument for inspecting elongated cavities comprising:

an inflatable base comprising two annular, conical sheets of thin, flexible, nonelastic material, sealed at their edges, fibers having their ends embedded in the sheets to space them apart when the base is inflated, and a curbed sleeve fixed in the cone so that it penetrates the top of the cone and extends from the bottom thereof;

a strap and fastening means attached to the inflatable base, for anchoring it to some fixed part adjacent the cavity being inspected;

a cable having an outer sheath and tubes and electrical conductors inside the sheath, the cable being held by the base for sliding motion therein;

a plurality of inflatable disks fixed concentrically on the cable, being spaced apart so that the segment of the cable between adjacent disks is bend resistant, and each disk being in sealed relationship with one of the tubes for inflation thereby;

a control box having a threaded cavity to receive a threaded gas bottle, and having a main duct leading from the cavity to a plurality of branch ducts; a puncture point in the end of the cavity for opening a gas bottle; a valve in each branch duct; a flow meter in each branch duct; a valve in the main duct; a connector for connecting each branch duct to one of the tubes of the cable; and electrical conductors attachable to a power source and to the electrical conductors of the cable; and

a television camera on the end of the cable, opposite that which is attached to the control box, and two mutually perpendicular step motors attaching the camera to this cable end, for orienting the camera.

* * * * *