Serial Number 09/592,509

Filing Date 12 June 2000

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Attorney Docket No. 78872

FAT-LINE TOWED-ARRAY FORCE MEASUREMENT APPARATUS

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

This patent application is co-pending with one other patent application entitled THIN-LINE TOWED-ARRAY FORCE MEASUREMENT APPARATUS AND METHOD (Attorney Docket No. 78871) by the same inventor as this application.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates generally to fat-line towed-arrays, and more particularly to an apparatus for measuring the force applied to fat-line towed-arrays during flushing cycles.

(2) Description of the Prior Art

Submarines deploy fat-line towed-arrays using a process known as flushing, wherein water is pumped into the fat-line stowage tube to exert pressure upon and hence deploy the fat-line towed-array. Deployment success can be determined by measuring the flushing water force applied to the fat-line towed-array.

Since effective deployments are critical to successful submarine missions, it is essential to maintain a method to evaluate the flushing mechanics and effectiveness. There is currently no reliable method to evaluate a submarine's flushing procedure. What is needed is an apparatus and method that measure and evaluate the flushing process effectiveness.

SUMMARY OF THE INVENTION

It is a general purpose and object of the present invention to provide a means of measuring the effectiveness of a submarine's flushing procedure for fat-line towed-arrays. It is a further object to use a combination of tension and bending sensors and measurements to evaluate the flushing system. It is another object to provide such tension and bending sensors as modules that can be connected to a fat-line towed-array. It is yet a further object to integrate the sensors with a tow cable for communication to a data processing system for evaluation.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

These objects are accomplished with the present invention by sensors in the standard fat-line towed-array configuration at the typical telemetry positioning. Tension sensors located within a modified fat-line towed-array bulkhead measure axial tension applied to the front of the towed-array during the flushing cycle. Bending sensors mounted further downstream along the fat-line canister walls, measure the bending load during the flushing cycle. The sensor outputs are encoded and digitized before being transmitted through a tow cable for further data conditioning and processing. The tension and bending sensor data provide information to evaluate the force exerted on the fat-line towed-array thereby allowing a measure of the deployment capability and effectiveness.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings, wherein like reference numerals refer to like parts and wherein:

FIG. 1 provides a diagram of the general layout of the tow vessel, towed array and tow cable;

FIG. 2 shows a cross-sectional view of the sensor configuration contained within the fat-line towed-array; and

FIG. 3 shows a view of the tension shaft for sensing tension applied to the bulkhead.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a basic system configuration. The measurement sensors are physically located within the fat-line towed-array **10**, at the fat-line towed-array end nearest the nose cone assembly **12**. The tow cable **14** provides an electrical connection to signal conditioning electronics **16** that amplify and filter signals, and interface to a computer **18**. Electronics **16** and computer **18** are located on a tow vessel **19** joined to tow cable **14**. The computer **18** collects the system sensor data and performs the final processing to evaluate system performance.

In FIG. 2 there is shown a redesigned bulkhead **20** incorporating the tension sensors and bending sensors. The bulkhead **20** joins two sensor canisters at the bulkhead coupling **22**. The coupling **22** is the same width as the first canister wall **24** and second canister wall **26**, thereby allowing the bulkhead **20** to fit inside the towed-array sectional elements while allowing a strong coupling between the two sections. Forward bulkhead portion **28** is cylindrical with a tension shaft mounting cylinder **30** having a smaller diameter extending aftward. A forward bulkhead cavity **32** is formed within the main body of the forward bulkhead portion **28**, and a tension shaft aperture **34** formed through the shaft mounting cylinder **30**. Screw **36** to the right of the coupling **22** secure the first canister wall **24** to forward bulkhead portion **28**. Aft bulkhead portion **38** is a hollow cylindrical structure having a forward bulkhead receiving cavity formed therein. Upon assembly, the forward bulkhead receiving cavity receives the shaft mounting cylinder **30**. The second canister wall **26** is secured to the aft bulkhead portion **38** using screws **40** aft of the coupling **22**. Double O-rings **42** are provided in slots formed in the forward bulkhead portion **28** and the aft bulkhead portion **38** on either side of the coupling **22** to prevent water leakage into the canister walls **24, 26**. O-rings **44** prevent liquid from entering the bulkhead between the forward bulkhead portion **28** and the aft bulkhead portion **38**. The forward bulkhead portion **28** contains an alignment key **46** or pin that is inserted into a slot in the aft bulkhead portion **38** to prevent the aft bulkhead portion **38** from rotating; however, the forward bulkhead portion **28** and the aft bulkhead portion **38** are not otherwise attached.

A disk shaped end cap **48** is secured to the aft bulkhead portion **38** using a screw **50**. End cap **48** has a threaded tension shaft receiving aperture **52** formed at its center.

A tension shaft **54**, shown in more detail in FIG. 3, extends through the first bulkhead portion **28** shaft mounting cylinder **30** to the tension shaft receiving aperture **52**. The tension shaft **54** allows sensor mounting for measuring tension in orthogonal directions between the two bulkhead sections. The tension shaft **54** is a single unit with a head **56**, a sensor mounting section **58**, a threaded section **60**, a hollow core **62**, feed apertures **64**, and a decoupling groove **66**. The tension shaft head **56** can be circular but it can also be square or hexagonal in cross-section to allow the use of a wrench for fastening. Hollow core **62** is formed in the center of shaft **54** and traverses the entire tension shaft length. Preferably core **62** is cylindrical in shape to avoid chafing cables running therethrough. The sensor mounting section **58**, adjacent to the head **56**, has a square cross-section with smooth surfaces on all sides for mounting tension sensors **68**. Because the mounted sensors **68** provide outputs for recording, each side of the rectangular sensor mounting section **58** contains feed aperture 64 in communication with the hollow core 62 for transporting wiring.

A decoupling groove 66 in the tension shaft 54 decouples the sensor mounting section 58 from the circular threaded section 60. The threaded section 60 maintains a circular cross-section with threads for securing the tension shaft 54 to the end cap 48 threaded tension shaft receiving aperture.

The tension shaft 54 is mounted with tension shaft head 56 flush against the tension shaft mounting cylinder 30 and the sensor mounting section 58 extending into the tension shaft core 62. Sensor mounting section 58 does not contact the tension shaft mounting cylinder 30 in order to prevent interference with the sensors 68.

The forward bulkhead portion 28 and end cap 48 are separated by a space 70 that aligns with the tension shaft decoupling groove 66, and the forward bulkhead portion 28 and end cap 48 are not otherwise connected or attached.

Bending sensors 72 and electronics 74 are positioned within the measurement module canister. The bending sensors 72 are located on the second canister wall 26 where they measure the towed-array element bending caused by the fluid flow. The bending sensors 72 are electrically coupled by wire 76 to the sensor electronics 74. Electronics 74 are also coupled by wire 78 to the tension sensors 68. The sensor electronics 74 digitize and encode the sensor measurements for transmission through cable 80 to the tow cable 14 as shown in FIG. 1, to the signal conditioning unit 16.

The flushing fluid travels in the direction shown **82**, and exerts pressure on the nose cone assembly that is measured by the tension sensors **68**. The flushing liquid applies stress to the nose cone assembly and fat-line towed-array sections, and as the flushing liquid passes along the sides of the fat-line towed-array sections, tension is applied to the towed-array sections, including the two sections joined by the modified bulkhead. With the first fat-line towed-array section connected to the forward bulkhead portion, and the second fat-line towed-array section connected to the end cap, the tension caused by the fluid flow is translated to the bulkhead sections and hence the tension shaft **54** that joins the two bulkhead sections. Measurement devices located on the tension shaft **54** record the tension applied to the bulkhead sections.

In a preferred embodiment, tension sensors **68** and bending sensors **72** use strain gages as the active elements. For measuring tension, a single strain gage is attached to each of the four sides of the rectangular tension shaft sensor mounting section **58**, thereby comprising two orthogonal wheatstone bridge configurations with two strain gages in each wheatstone bridge, providing two tension differential outputs to the sensor electronics. The strain gages are attached using epoxy. The bending sensors **72** are embodied as four additional strain gages, wheatstone configured to measure bend in two orthogonal directions. The bending sensors **72** are mounted on the interior walls of the second measurement module element using epoxy. Two strain gages comprise the first wheatstone bridge sensor, while a second strain gage pair form the orthogonal wheatstone bridge. The bending and tension sensors utilize the tension shaft hollow core **62** to transport the strain gage wiring **78** to the standard bulkhead connector fixture and hence the sensor electronics **74**. The sensor electronics digitize and encode the tension and bend measurements for transmission to the signal conditioning electronics **16** that amplify and filter the digitized measurements. The computer **18** processes the tension and bend measurements for various fluid flow rates to determine the fluid effectiveness for fat-line towed-array deployment.

The advantage of the present invention over the prior art is that the disclosed invention provides a novel apparatus and method of measuring the effectiveness of fluid flow to deploy fat-line towed-arrays.

What has thus been described is an apparatus for measuring the force applied to the fat-line towed-array during a flushing cycle. Tension sensors reside in a modified bulkhead structure to measure axial tension applied to the front of the fat-line towed-array during the flushing cycle. Bending sensors mounted further downstream along the fat-line canister interior walls measure the bending load during the flushing cycle. The sensor outputs are encoded and digitized before being transmitted through a tow cable for further data conditioning and processing. The tension and bending sensor data provide information to evaluate the force exerted on the towed-array, thereby allowing a measure of the deployment capability. Measurements taken at various fluid flow rates provide data regarding deployment effectiveness.

Obviously many modifications and variations of the present invention may become apparent in light of the above teachings. For example, although strain gages were used as the sensors in the example provided, other sensing elements may be utilized. The strain gages may be configured differently than the wheatstone configurations described, and more than two groups of tension and/or bending sensors may be utilized. Although the strain gages were secured using epoxy, other adhesives or methods may be used. The digitizing and encoding electronics may be located within the fat-line towed-array canister, or at another location. There are many different bulkhead configurations that can be modified for the tension measurements. The procedure for securing the sensors to the tension shaft or canister wall can vary and is application dependent. Although the bulkhead plates described in the preferred embodiment were designed of aluminum, other materials may function equivalently. The signal conditioning functionality may be incorporated in the computer or in the sensor electronics.

In light of the above, it is therefore understood that the invention may be practiced otherwise than as specifically described.

Attorney Docket No. 78872

FAT-LINE TOWED-ARRAY FORCE MEASUREMENT APPARATUS

ABSTRACT OF THE DISCLOSURE

An apparatus for measuring tensile and bending forces applied to a fat-line towed-array. Tension sensors are configured within a modified fat-line towed-array bulkhead to measure axial tension applied to the front of the fat-line towed-array, while bending sensors mounted further downstream along the fat-line canister interior walls, measure the bending load. The sensor outputs are encoded and digitized before transmitted through a tow line for further data conditioning and processing. The tension and bending sensor data provide information to evaluate the force exerted on the towed-array, allowing a measure of the deployment capability. Measurements taken at various fluid flow rates provide data regarding deployment effectiveness.

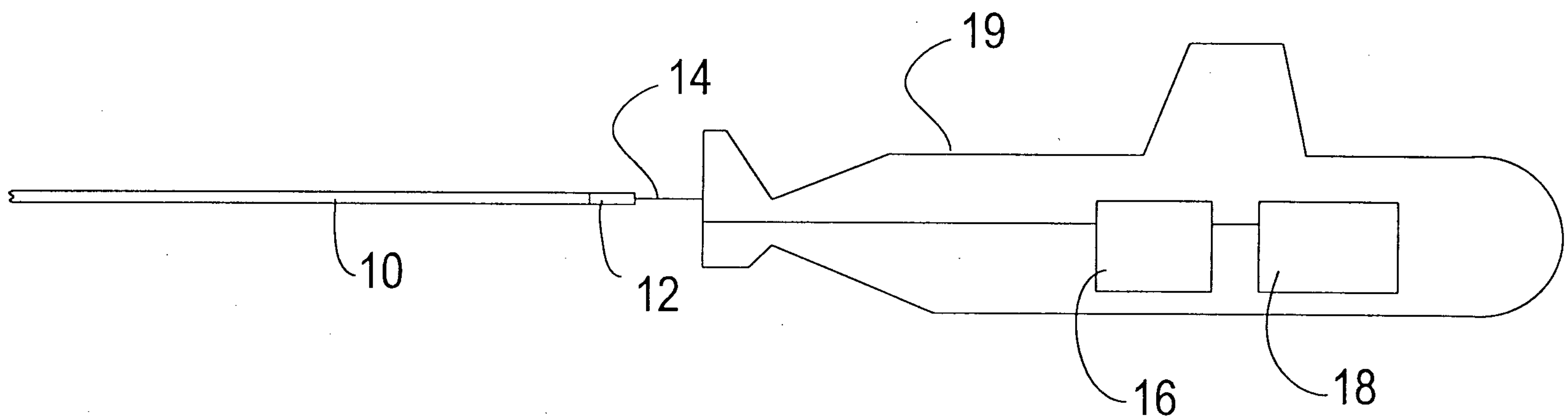

FIG. 1

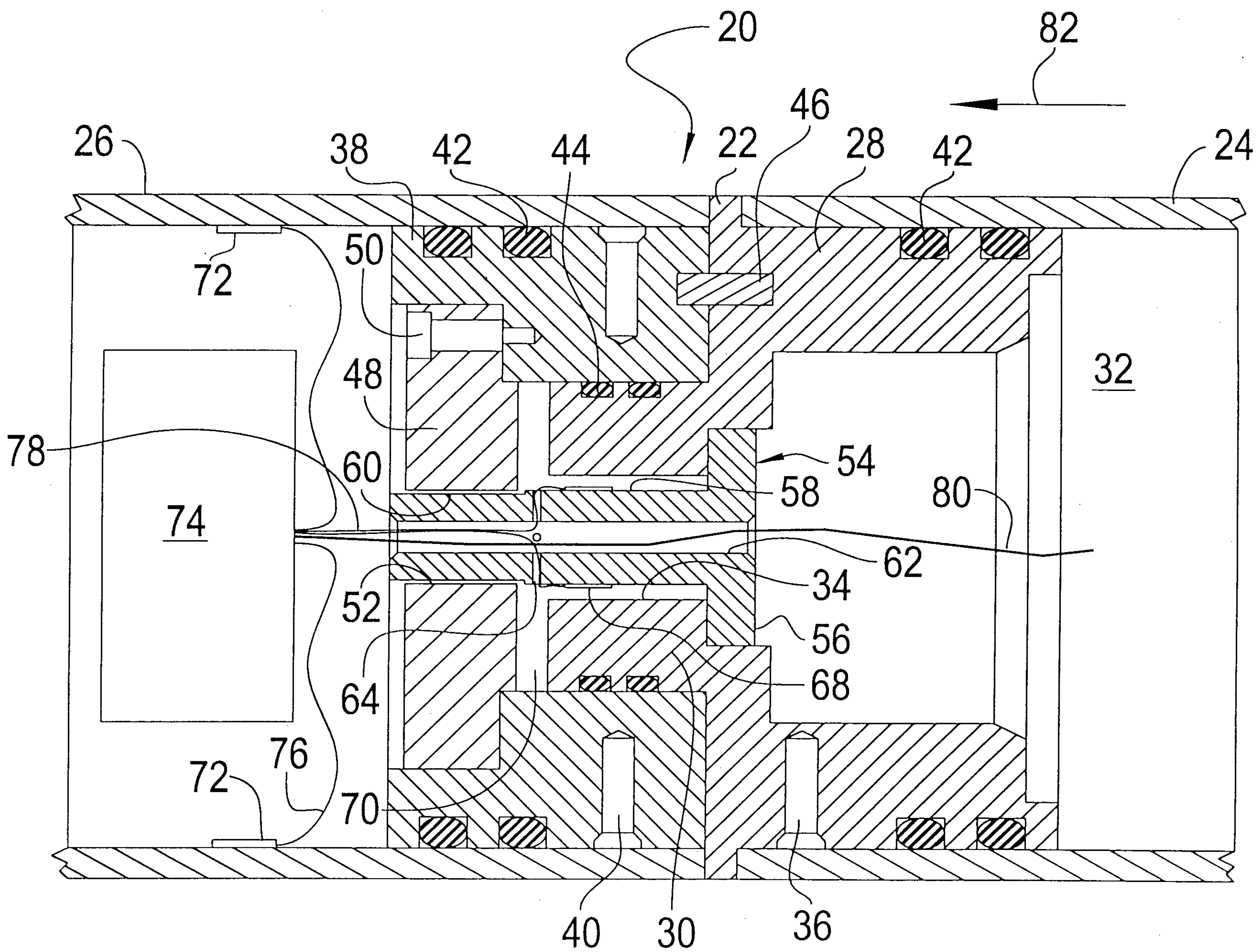

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FIG. 2

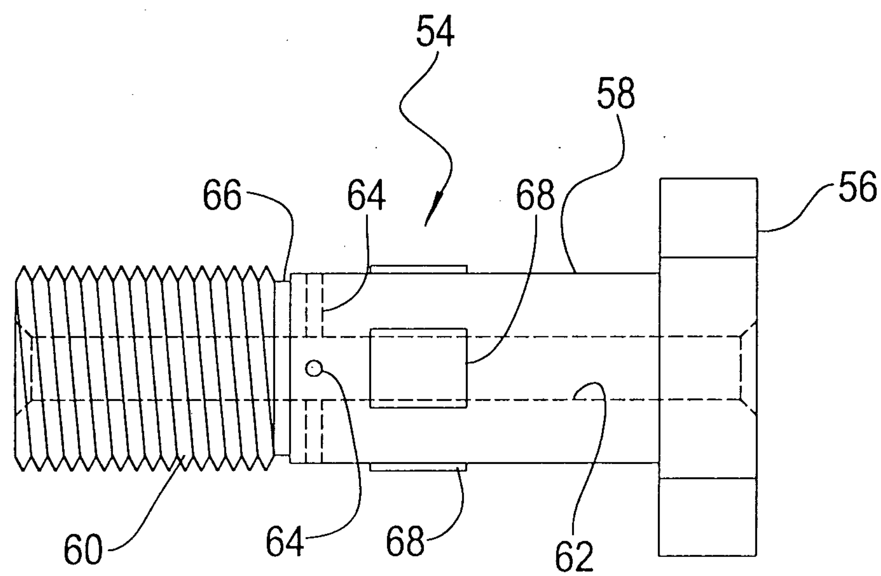

FIG. 3