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3 INSTRUMENTED FIBER OPTIC TOW CABLE

5 STATEMENT OF GOVERNMENT INTEREST

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

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The instant invention relates to an instrumented cable using
14 optical fiber for many types of measurements, and more
15 particularly to measure the temperature profile of a body of
16 water as a function of depth using an instrumented fiber optic
17 tow cable and to measure a temperature profile for oil wells.

18 (2) Description of the Prior Art

19 There are several approaches for measuring temperature with
20 fiber-optic-based sensors that are already available in the prior
21 art. However, one of the main obstacles of using this technique
22 is to design a system that is sufficiently rugged to survive
23 deployment and retrieval through handling systems at high
24 tensions over a limited diameter sheave or a winch. Nonetheless,
25 the use of optical fibers to measure various physical parameters
26 such as light transmission in different media is on the increase
27 due to the compact size and the ease of operation of optical

1 fiber detectors in various environments. As an example, use of
2 optical fibers to measure the temperature profile of a body of
3 water as a function of depth is quite important as the water
4 temperature affects the propagation of acoustic waves in the body
5 of water and thus affects sonar performance. The temperature of
6 the water is also important to the fishing industry, because some
7 species of fish stay within water having very precise temperature
8 bounds. Still another area of interest is to measure temperature
9 profile in an oil well. It is thus desirable to integrate an
10 optical fiber tow cable as a detector for making measurements of
11 various parameters including temperature profile of a body of
12 water and/or and oil well using a state-of-the art tow cable with
13 optical fibers.

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SUMMARY OF THE INVENTION

16 In accordance with the principal object of the present
17 invention, an armored fiber optic cable is integrated with the
18 means for measuring temperature of a body of water and/or
19 obtaining temperature profile in an oil well. In the fiber
20 optic tow cable, a plurality of optical fibers enclosed in tubes
21 are interspersed among the armor wires comprising either a
22 typical double-plow steel wire or KEVLAR™ fiber tow cable as
23 taught by Holmberg in U.S. Patent No. 5,212,755; dated 18 May
24 1993, assigned to the United States of America as represented by
25 the Secretary of the Navy. A series of temperatures sensors are
26 incorporated into the optical fibers integrated in the tow cable.
27 This patent is incorporated by reference in subject patent

1 application. Subject invention further teaches the use of a
2 light source which illuminates on the optical fibers used and the
3 scattered light is received by a receiver which sends the signals
4 for processing in a processor to obtain temperature profile of
5 the body of water or that of an oil well as a function of depth.

6 It is an object of subject invention to integrate fiber
7 optic sensors into a state-of-the-art tow cable.

8 Still another object of subject invention is to use
9 temperature sensors in conjunction with the optical fibers to
10 measure a temperature profile of a body of water.

11 Still another object of subject invention is to use an
12 instrumented tow cable to measure a temperature profile of an oil
13 well.

14 Another object of subject invention is to use steel armor
15 wires to protect the optical fibers used in the system.

16 Another object of subject invention is to use KEVLAR™
17 fibers or wires to protect the optical fibers used in the system
18 for measuring temperature profile.

19 Still another object of subject invention is to use the
20 optical fibers fitted with temperature sensors in the outer most
21 layer wherein either armor steel wires or armor KEVLAR™ fibers
22 are used as armor wires.

23 Other objects features and advantages of the invention shall
24 become apparent as the description thereof proceeds when
25 considered in connection with accompanying illustrative drawings.

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2 BRIEF DESCRIPTION OF THE DRAWINGS

3 A more complete understanding of the invention and many of
4 the attendant advantages thereto will be readily appreciated as
5 the same become better understood by reference to the following
6 detailed description when considered in conjunction with the
7 accompanying drawings wherein:

8 FIG. 1 is a diagrammatic representation of an integrated tow
9 cable which uses armor steel wires; and

10 FIG. 2 is another diagrammatic representation of an
11 integrated tow cable which uses armor KEVLAR™ fibers.

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13 DESCRIPTION OF THE PREFERRED EMBODIMENT

14 Referring now to FIG. 1, a first embodiment of an
15 instrumented fiber optic tow cable system 10 according to the
16 teachings of subject invention is diagrammatically shown which
17 includes a steel armored, low strain fiber optic cable 12. Here,
18 low strain is defined as an amount of strain that is sufficiently
19 small so that the optical fibers are not strained to the point of
20 damage. Cable 12 is made of a cable core 14 which may also
21 contain electrical conductors (not shown) to carry electric power
22 and signals, a core jacket 16 to prevent water intrusion into the
23 cable core 14, armor wires 18, arranged in one or more layers,
24 and optical fibers 20 interspersed in the outermost layer to
25 expose the optical fibers 20 to the temperature of the fluid
26 under investigation. It should be noted that the temperature
27 sensors (not shown) are attached integrally to optical fibers 20.

1 It should also be noted that in embodiment 1 as shown in FIG. 1,
2 optical fibers 20 are enclosed in preferably steel tubes 22.
3 The method of enclosing optical fibers in stainless steel tubes
4 is standard in the telecommunications industry. The stainless
5 steel tube replaces one armor wire, and thus has a diameter equal
6 to or less than that of the replaced armor wire. Alternatively,
7 as shown in FIG. 1, in order to preserve their integrity, the
8 optical fibers 20 are surrounded by preferably steel armor wires
9 23 of smaller diameter than that armor wires 18. The bundle of
10 armor wires 23 replaces an armor wire 18 and has a diameter equal
11 to or less than the replaced armor wire 18. A KEVLAR™ braided
12 fiber-based sleeve (not shown) maybe placed around the outer
13 layer of armor steel wires to keep them together as one unit.
14 The method disclosed here is distinguished from the Holmberg
15 patent in that the steel tube (or steel armor wire bundle)
16 containing the optical fiber is located in the outer armor wire
17 layer. As mentioned before, one of the main obstacles of using
18 this technique is to design a system that is sufficiently rugged
19 to survive deployment and retrieval through handling systems at
20 high tensions over a limited diameter sheave or a winch. This
21 was sufficiently proven in tests with a 1.6" diameter steel cable
22 that was tested under realistic simulated handling conditions.
23 Specifically, for the 1.6" steel cable, repeated cyclic bend-
24 over-sheave tests at tensions of up to 22,000 lb over a 46"
25 diameter sheave were conducted successfully. A light source 26
26 is used to show light to the optical fibers 20 which scatter the
27 light to provide information about the temperature of the fluid.

1 The scattered light is received by receiver 28 and processed by
2 processor 30 to obtain the information about the temperature of
3 the fluid at a particular location. The preferred method is to
4 make use of Raman scattering effects to infer the distributed
5 temperature along the fiber. It is established in the prior art
6 that such methods can provide a distributed measurement with $\frac{1}{2}$
7 meter resolution along the fiber. In Instrumented Tow Cable
8 tests, the measurements differed from XBT (Expendable
9 Bathythermograph) measurements by 0.2°C (standard deviation) or
10 less. It should be noted that the KEVLARTM braid allows the
11 water or the fluid under investigation to impinge on the optical
12 fibers and the temperature detectors to measure the true
13 temperature at a particular location. It should also be noted
14 that processor 30 used for this analysis is a PC (personal
15 computer) based system and is commercially available and it may
16 also include a display unit (not shown). The second embodiment
17 of the integrated fiber optic tow cable system 40 is shown in
18 FIG. 2 which uses tow cable 42 which has a plurality of armor
19 KEVLARTM fibers 44, having optical fibers 46. Surrounded by
20 KEVLARTM fibers 48 as shown. The processing is done by using a
21 light source 26, a receiver 28 and a processor 30. It should be
22 noted that the optical fibers can be enclosed in steel tubes to
23 preserve their integrity instead of surrounding them by armor
24 wires. Although only one optical fiber is needed for operation of
25 the instrumented cable, in practice, more than one optical fiber
26 (enclosed in a steel tube or in a bundle of smaller armor wires)

1 is incorporated into the outer layer of armor wires for
2 redundancy.

3 It should be noted that the inventive concept of subject
4 invention is the concept of integration of optical fibers with
5 the system of measuring the temperatures at various depths of a
6 fluid. The system of measuring the temperatures using a light
7 source, a receiver and a processor can be varied without
8 deviating from the teachings of subject invention.

9 Another preferred method for measuring temperature is via
10 Raman scattering coupled with an adaptation of Optical Time
11 Domain Reflectometry (OTDR). This provides a direct measurement
12 of the temperature over cells determined by a type of time of
13 arrival processing of the scattered energy.

14 While there is shown and described herein certain specific
15 structure embodying the invention, it will be manifested to
16 those skilled in the art that various modifications and
17 rearrangements of the parts may be made without departing from
18 the spirit and scope of the underlying inventive concept. As an
19 example, armor wires could be either steel wires or KEVLAR™
20 fibers. Furthermore, the system for measuring the temperature of
21 the fluid as a function of depth of a fluid using a light source,
22 a receiver and a processor can be varied without deviating from
23 the teachings of subject invention.

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1 Attorney Docket No. 80095

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INSTRUMENTED FIBER OPTIC TOW CABLE

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ABSTRACT OF THE DISCLOSURE

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7 An integrated fiber-optic tow cable is described having both
8 optical fibers and armor wires located outside the cable core to
9 avoid high strain on the optical fibers when the cables is under
10 stress during deployment. The optical fibers have integral
11 temperature sensors near the outermost portion in order to
12 measure accurately the temperature of the fluid coming in contact
13 with temperature sensors. A beam of light is shown on the
14 optical fibers which is reflected by the optical fibers and
15 reaches the receiver and processed by the processor which may
also include a display unit.

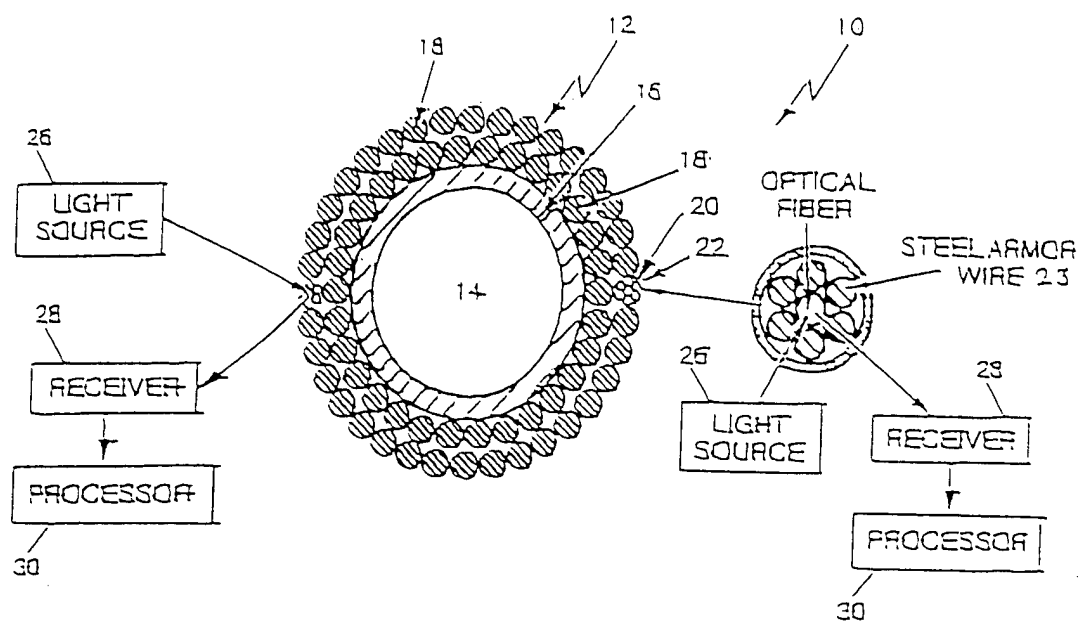


FIG. 1

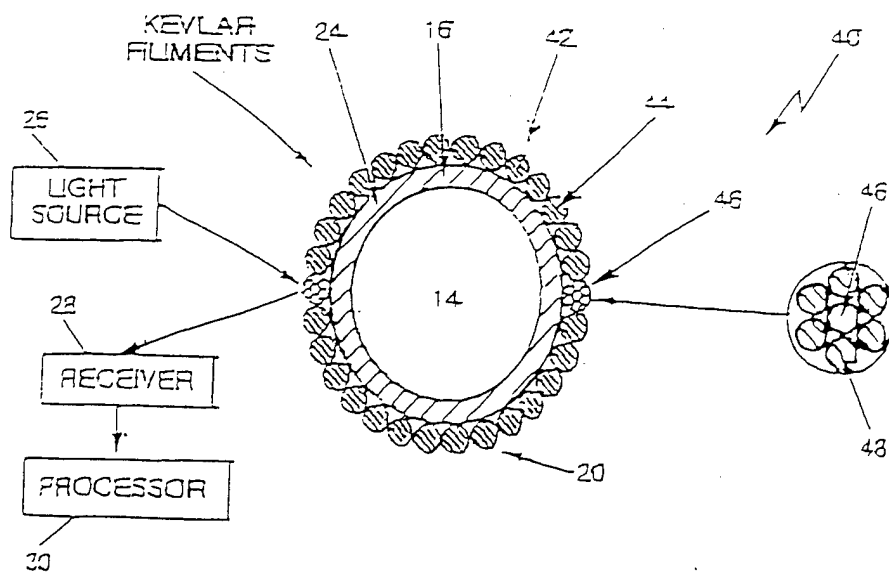


FIG. 2