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(54) **BORESCOPE COMPRISING FLUID SUPPLY SYSTEM**

(76) Inventors: **Michael P. Kehoskie**, Auburn, NY (US); **Thomas W. Karpen**, Skaneateles, NY (US); **Allan I. Krauter**, Skaneateles, NY (US); **Raymond A. Lia**, Auburn, NY (US); **Bradford Morse**, Syracuse, NY (US); **Kenneth Von Felten**, Freeville, NY (US)

Correspondence Address:
WALL MARJAMA & BILINSKI
101 SOUTH SALINA STREET
SUITE 400
SYRACUSE, NY 13202 (US)

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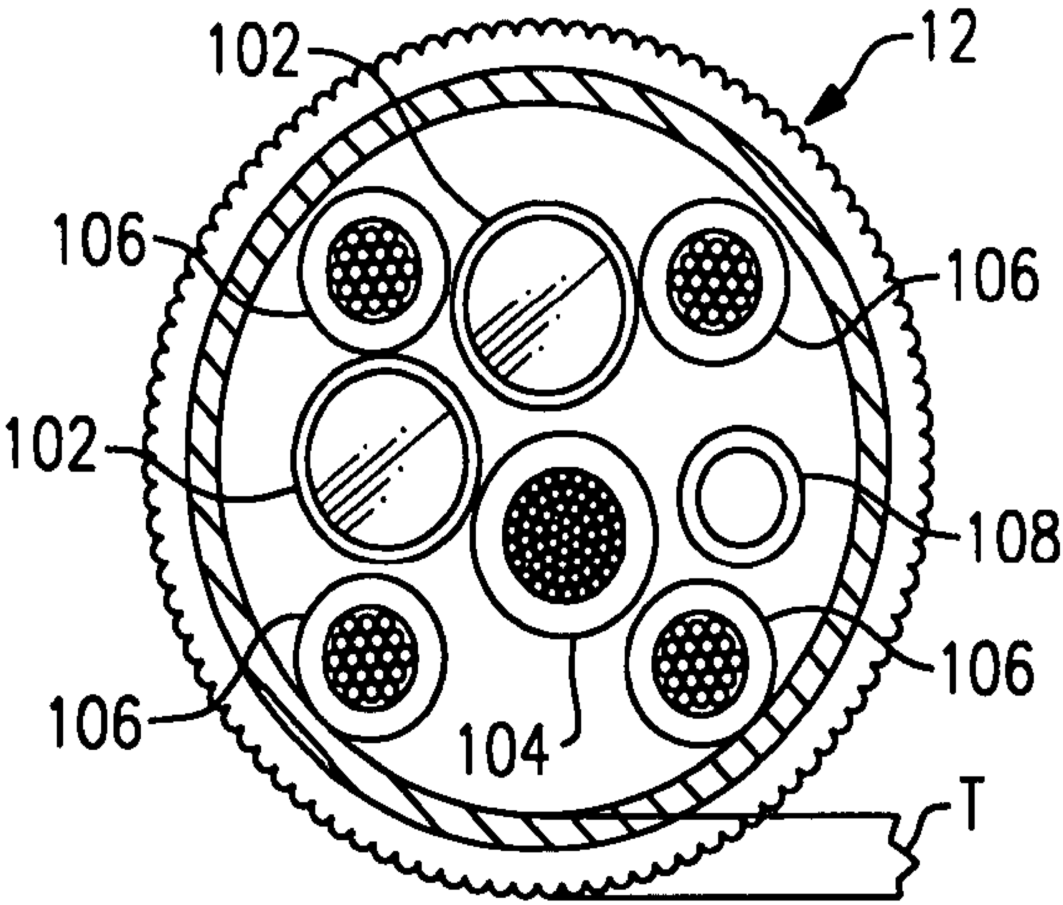
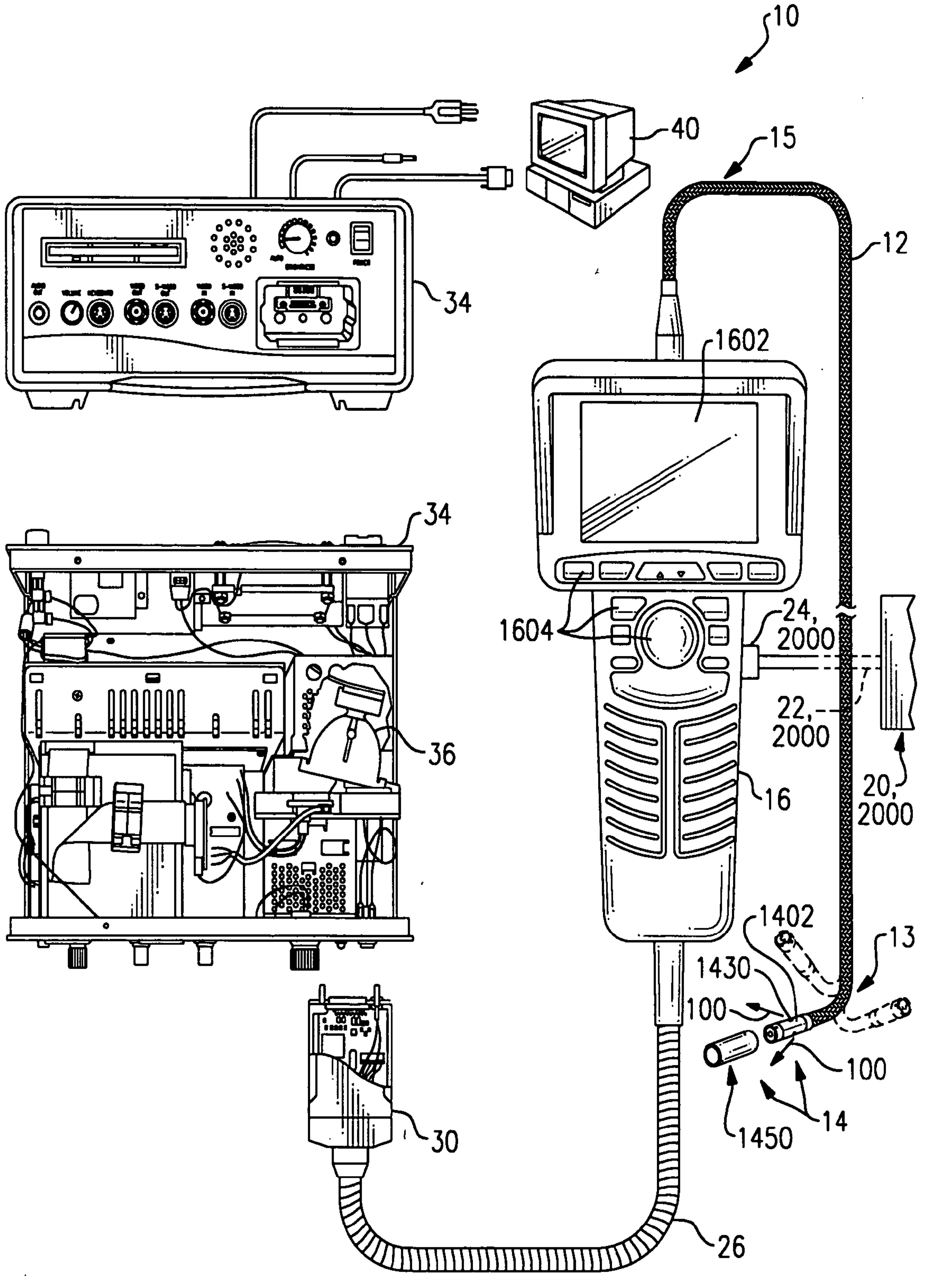
(57) **ABSTRACT**

A borescope device having an insertion tube, a camera head assembly, and a fluid supply system. The camera assembly includes through holes allowing fluid escape. The fluid supply system is controllable to force fluid through the through holes. The fluid supply system may be actuated to cool the camera head assembly.

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40
15
12
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1602
34
1604
24,
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100
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30
26

FIG.1a

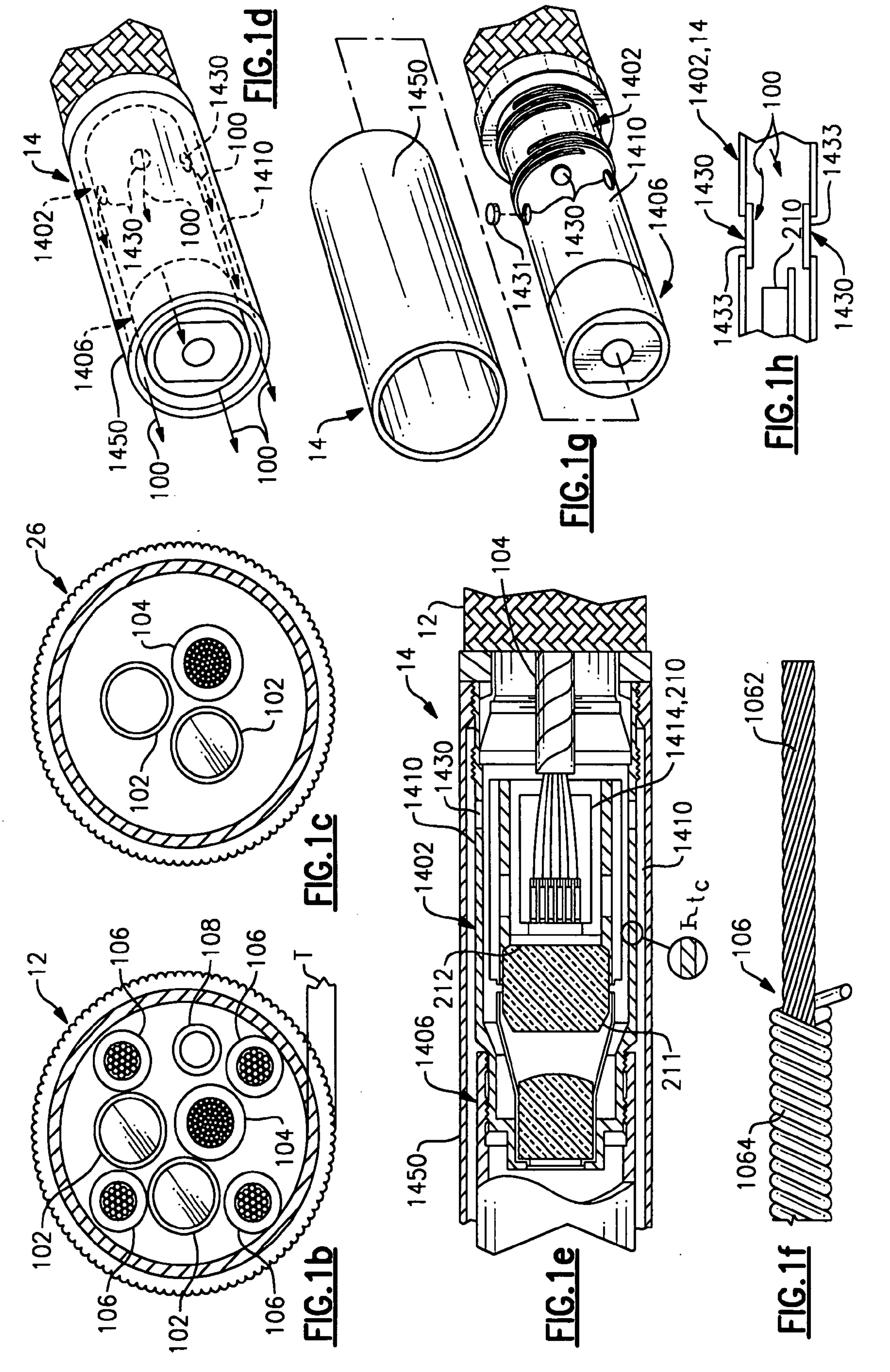
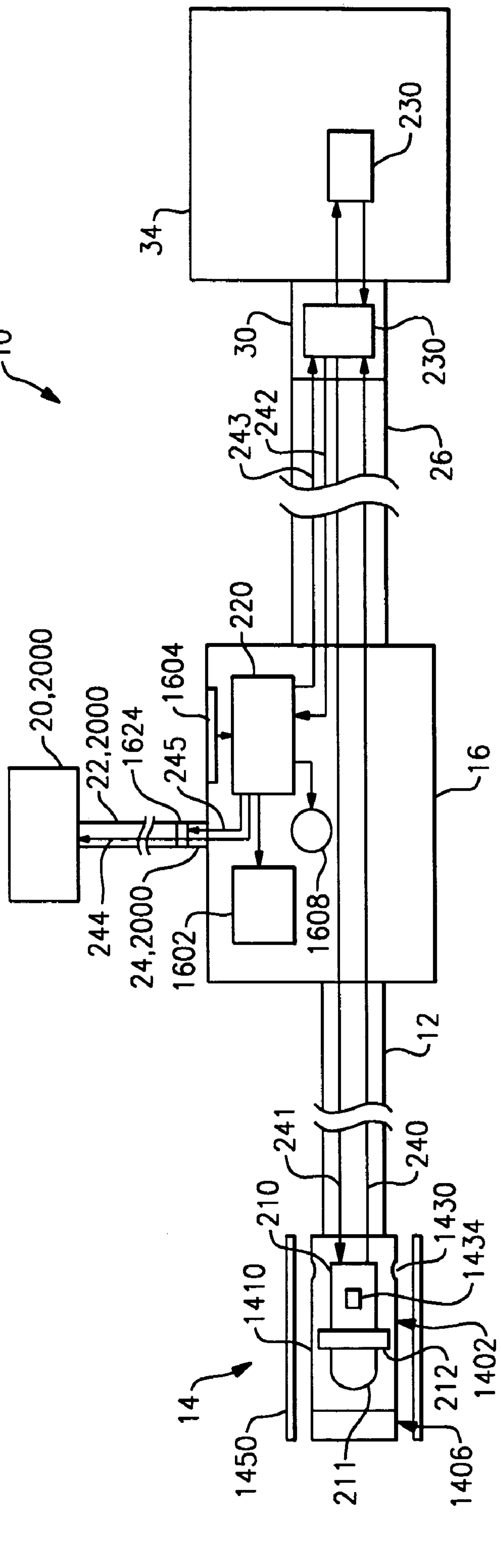


FIG.1b
FIG.1c
FIG.1d
FIG.1e
FIG.1f
FIG.1g
FIG.1h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230
30
243
242
26
220
20,2000
22,2000
1624
1604
245
16
244
24,2000
1602
1608
12
241
240
210
1430
1434
1410
1402
212
14
1450
211
1406

FIG.2

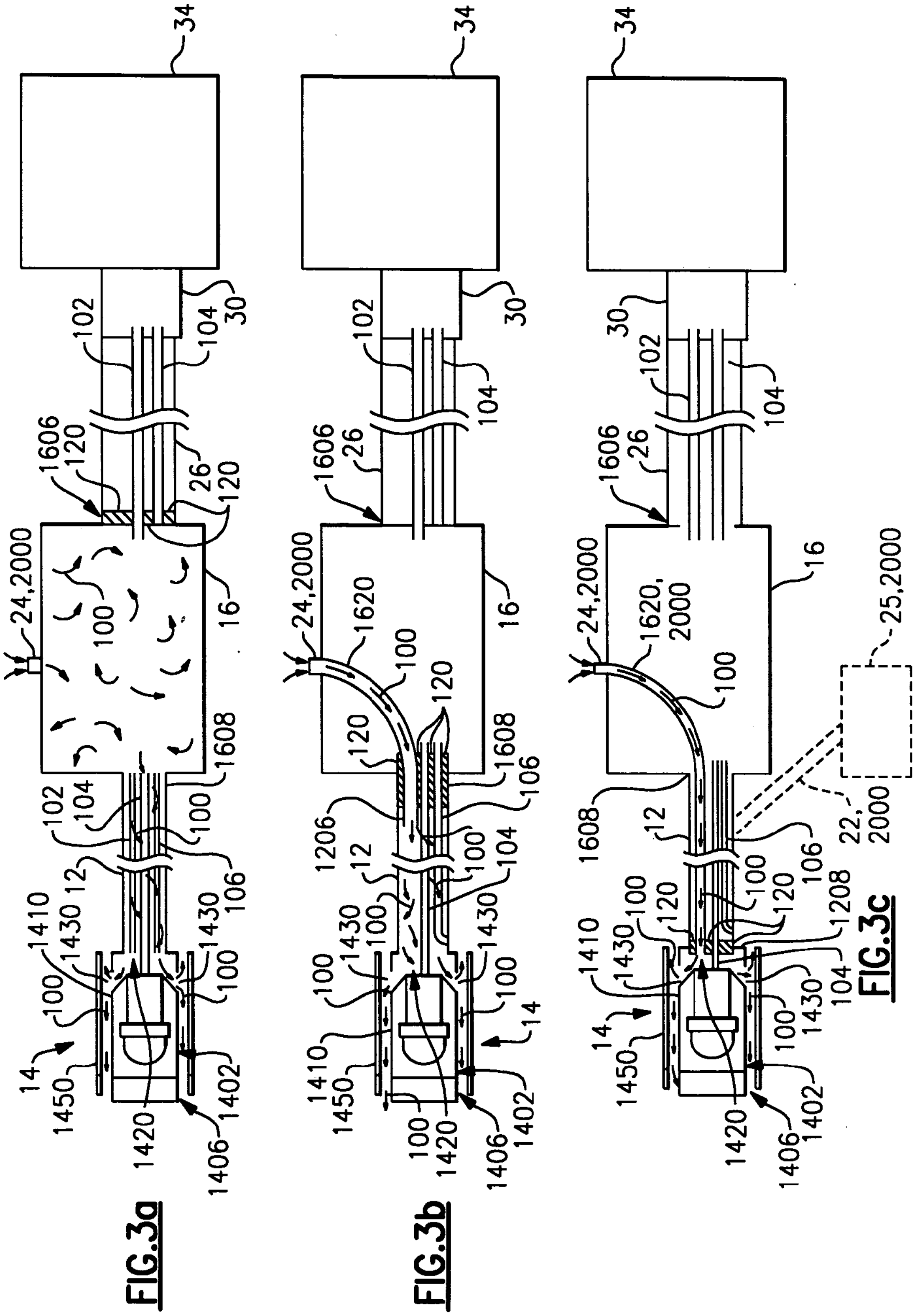

FIG.3a

FIG.3b

FIG.3c

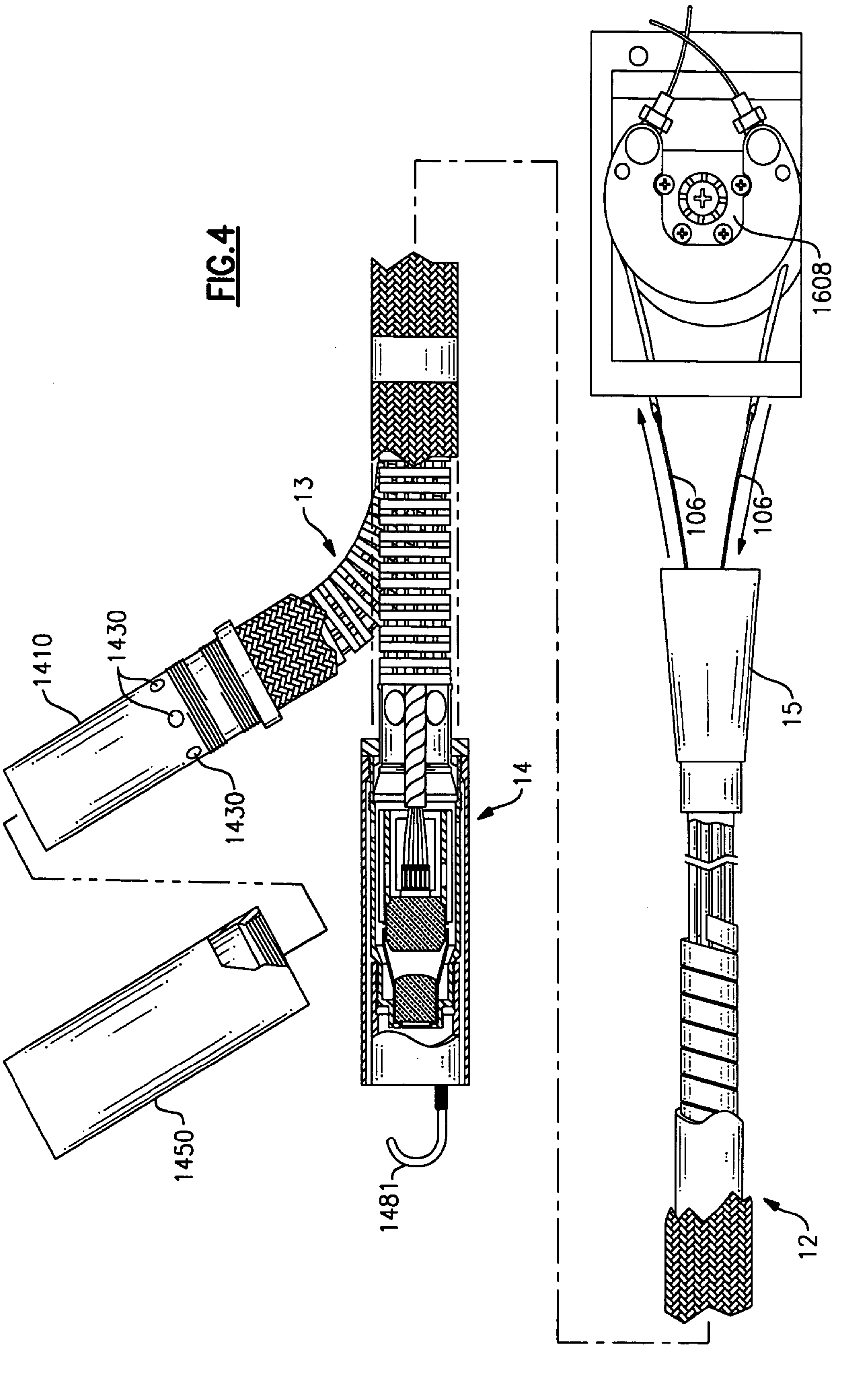

FIG.4

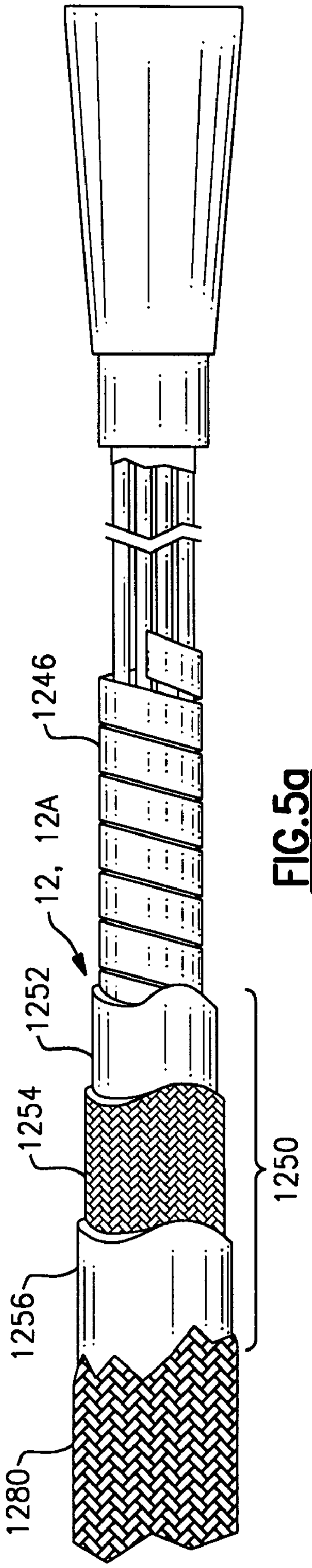

FIG.5a

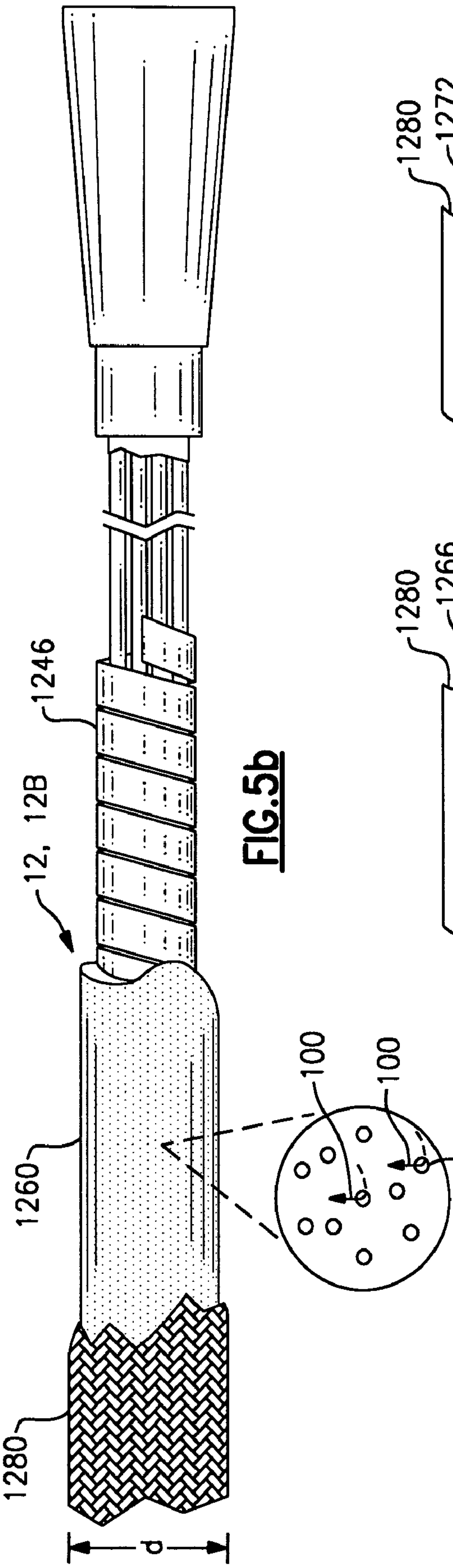

FIG.5b

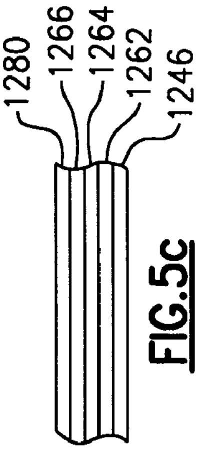

FIG.5c

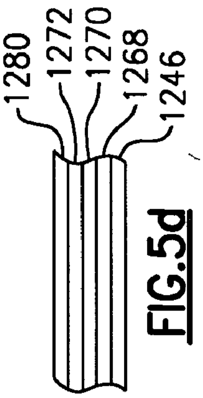

FIG.5d

BORESCOPE COMPRISING FLUID SUPPLY SYSTEM

FIELD OF THE INVENTION

[0001] The invention relates to insertion tube remote viewing devices generally and specifically to insertion tube devices configured for use in specialized operating environments.

BACKGROUND OF THE PRIOR ART

[0002] A borescope is generally characterized as an elongated insertion tube which can be flexible with a viewing head at its distal or forward end. The borescope can also include a control housing at its proximal end for controlling or steering the forward end. Such a borescope has a bendable tube steering section or articulation section at the distal end adjacent to the viewing head. One or two pairs of control articulation cables extend through the articulation section and then through the remainder of the flexible insertion tube. These cables connect with a steering control in the control section. One or both pairs of these cables are differentially displaced to bend the articulation section. The viewing camera head assembly can thus be remotely oriented to facilitate the inspection of an object. Borescopes are intended for visual inspection of mechanical devices such as jet engines or turbines, where it would be difficult or impossible to examine the device's internal elements directly. If the borescope must be maneuvered into narrow tortuous passageways, the insertion tube must be flexible and must allow corresponding bending and steering. In addition, the pathway to the object can be quite long, and so it is often necessary that the borescope insertion tube be fifteen meters or more in length.

[0003] While several types of borescopes have been proposed, present borescopes have been observed to fail in specialized operating environments such as high temperature, high pressure, and liquid operating environments.

[0004] There is a need for a borescope adapted for use in specialized operating environments.

SUMMARY OF THE INVENTION

[0005] According to its major aspects and broadly stated, the invention is a borescope having a fluid supply system which is especially useful in cooling the borescope.

[0006] In one embodiment, a borescope camera head assembly is provided which has a metal canister and an insulating sleeve. Fluid exit holes or outlet openings are provided in the canister and the sleeve is configured so that fluid exiting the holes is directed by the sleeve to flow along the thermally conductive outer surface of the canister.

[0007] A fluid supply system of the invention can include a conduit which extends from an air inlet position at a hand piece of the borescope to a position within the borescope's insertion tube. The fluid delivery conduit can also extend from a fluid inlet position in a hand piece entirely through the insertion tube to the camera head assembly.

[0008] The insertion tube of the borescope can be configured to minimize temperature losses by way of temperature conduction along a surface of the insertion tube. In one example of the invention, the insertion tube includes a multilayer insulation layer assembly including a mesh fiberglass layer interposed between two sealing nonporous polytetrafluoroethylene layers. The inclusion of thermally insulative material in the insertion tube, such as a layer having the thermal conductivity of less than 0.50 BTU-in/(hr-ft/(hr-ft^2-F°) reduces the entry of heat into the borescope through the insertion tube.

[0009] In another embodiment, the insertion tube is devoid of a fluid sealing layer and includes instead an insulating layer having micropores. The porous insulating layer allows fluid to escape through the walls of the insertion tube so that the insertion tube defines an insulating/cooling boundary layer, wherein the boundary layer reduces the entry of heat into the insertion tube. The porous insulating layer may have a thermal conductivity of less than 2.5 BTU-in/(hr-ft^2-F°).

[0010] An insertion tube according to the invention can have a light reflective outer surface which reflects energy to further discourage the entering of heat into the insertion tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] For a further understanding of these and objects of the invention, reference will be made to the following detailed description of the invention which is to be read in connection with the accompanying drawings, wherein:

[0012] **FIG. 1***a* is a physical layout diagram of a fluid delivering borescope of the invention;

[0013] **FIG. 1***b* is a cross section view of an insertion tube according to the invention;

[0014] **FIG. 1***c* is a cross section view of an umbilical cord according to the invention;

[0015] **FIG. 1***d* is a perspective view of a borescope camera head assembly according to the invention;

[0016] **FIG. 1***e* is a section view of a camera head assembly according to the invention;

[0017] **FIG. 1***f* is a side view of an articulation cable assembly according to the invention;

[0018] **FIG. 1***g* is an exploded perspective view of a camera head assembly according to the invention;

[0019] **FIG. 1***h* is a side view of a camera head assembly illustrating an embodiment of the invention including a bimetallic valve.

[0020] **FIG. 2** is a block electrical layout diagram of a borescope electrical and control system according to the invention;

[0021] **FIGS. 3***a*, **3***b*, and **3***c* are functional schematic diagrams illustrating various fluid supply systems of the invention;

[0022] **FIG. 4** is a side view of an exemplary insertion tube according to the invention;

[0023] **FIGS. 5***a*-**5***b* are side views of exemplary insertion tubes according to the invention;

[0024] **FIGS. 5***c*-**5***d* are cross section views of alternative insertion tubes according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] A borescope **10**, according to the invention, is shown in **FIG. 1***a*. Borescope **10** includes flexible insertion tube **12**, a camera head assembly **14**, and hand piece **16**. In accordance with the invention, fluid indicated by flow vectors **100** is forced down a length of insertion tube **12** and flows outwardly about head **1402** of camera head assembly **14** as indicated by fluid flow vectors **100** to cool electrical components of head assembly **14**, improving reliability and consistency of performance of the electrical components. Fluid is conveniently supplied to borescope **10** by a fluid supply **20** which, through feed tube **22**, is interfaced to connector **24** of hand piece **16**. When attached, fluid supply **20**, feed tube **22**, and connector **24** may be considered part of borescope **10**. As will be explained further herein, connector **24** may include a valve **1624** (**FIG. 2**) for use in regulating the flow of fluid from fluid supply **20**. A fluid supply system **2000** of the borescope of **FIG. 1***a* includes fluid supply **20**, feed tube **22**, and connector **24**. Fluid delivered by the fluid supply system can include, for example, a mixture of nitrogen and oxygen (e.g., air), water, nitrogen, carbon dioxide, or inert gases such as helium or argon. The fluid delivered can also comprise a chlorofluorocarbon which changes state while traveling through the borescope **10**. Borescope **10** may be part of the remote video inspection system described in U.S. patent application Ser. No. 10/768,761 filed Jan. 29, 2004 entitled, "Remote Video Inspection System" incorporated herein by reference.

[0026] Referring to aspects of borescope **10** in further detail, borescope **10** further includes umbilical cord **26**, power plug **30** and light box **34**. Disposed in light box **34** is a light source **36** which may be e.g., a 50-watt arc lamp, such as a type sold under SOLARC by Welch Allyn, Inc., Lighting Products Division, Skaneateles Falls, N.Y. Light box **34** may further carry an image processing circuit as will be described herein. Borescope **10** may further be in communication with a desktop monitor **40**. Monitor **40** may be in communication with borescope **10** via several communication circuitries of light box **34**.

[0027] Light source **36** of light box **34** directs light through umbilical cord **26**, through hand piece **16**, through insertion tube **12** and outwardly from camera head assembly **14**. As seen by umbilical cord cross section view of **FIG. 1***c*, umbilical cord **26** encases and supports fiber optic bundles **102**. As seen by insertion tube cross section view **FIG. 1***b*, insertion tube **12** also supports and encases fiber optic bundles **102**. Referring to further aspects of umbilical cord **26**, umbilical cord **26** further encases and supports wiring cable bundle **104**. Part of the wires of wiring cable bundle **104** are branched off within hand piece **16** as is suggested by the electrical block diagram of **FIG. 2** which will be discussed later herein. The remainder of the wires of bundle **104** extend through insertion tube **12** as is indicated by bundle **104** of insertion tube cross sectional view of **FIG. 1***b*. Referring to insertion tube **12**, insertion tube **12** as best seen in **FIG. 1***b* carries fiber optic bundles **102**, cable wiring bundle **104** (including flexible electrical conductors), articulation cable assemblies **106**, and working channel **108**. Articulation cable assemblies **106** provide for bending of insertion tube at distal end **13**. As seen in the detail view of **FIG. 1***f*, articulation cable assemblies **106** can be provided by a stranded cable **1062** encased by an outer spring conduit **1064**. Working channel **108** allows manipulation of a tool (e.g., a hook **1481** as seen in **FIG. 4**, a brush, or a magnet) extending from camera head assembly **14**. While borescope **10** having the insertion tube embodiment of **FIG. 1***b* includes fiber optic bundles **102**, it will be understood that the illumination system having light source **36** and bundles **102** can be replaced or supplemented by an illumination system comprising light sources such as a plurality of LEDs incorporated in head **14**. LEDs in head assembly **14**, like image sensor **212** (**FIG. 1***e*) and image signal conditioning circuit **210** (**FIG. 2**), may be powered by power delivery conductors of bundle **104**.

[0028] A functional block electrical layout diagram is shown in **FIG. 2**. Various electrical circuits are distributed throughout borescope **10**. In one typical layout scheme, borescope **10** includes an image signal conditioning circuit **210**, a hand piece control circuit **220** and an image processing circuit **230**. Image signal conditioning circuit **210** receives image signal clocking and controls signals from image processing circuit **230** for control of image sensor **212**, and conditions analog image signals generated by image sensor **212** so that the signals can be delivered to image processing circuit **230**. Image sensor **212** is typically a 2D color solid-state image sensor. Image processing circuit **230** may be partially distributed in power plug **30** and partially distributed in light box **34**. Among other functions, image processing circuit **230** receives analog image signals as transmitted by image signal conditioning circuit **210**, converts such signals into digital form utilizing an analog-to-digital converter and buffers frames of image data so that frames of image data can be subjected to various processing. The processing which may be performed by image processing circuit **230** can include such processing as single frame storage, measurement determination, and object recognition. Image processing circuit **230** can also perform such functions as overlaying of menu interface selection screens on displayed images, and transmitting output video signals to various displays such as hand piece display **1602** and monitor display **40**. In addition to housing image processing circuit **230**, power plug **30** and light box **34** also carry various electrical circuitries for delivering electrical power to various components of borescope **10**. Electrical communication between the various circuits is provided by signal lines **240**, **241**, **242**, and **243**, each of which represents one or more electrical conductors. Signal lines **244**, **245** to be discussed further herein also represent one or more electrical conductors.

[0029] Hand piece control circuit **220** (which may also be termed a video probe control circuit), among other functions, receives video signals from image processing circuit **230**, and displays such signals on display **1602** of hand piece **16**, receives user input and commands input via hand piece controls **1604** and interprets such inputs to perform various operations. One important function of hand piece control circuit **220** is to receive insertion tube control inputs. Hand piece control circuit **220** interprets user inputs to develop control signals for controlling control servomotor **1608** which moves articulation cables **1062** so that a distal end **13** of insertion tube **12** is moved into a desired orientation. Control circuit **220** may also adjust control signals input into fluid supply **20** and or connector **24** as will be explained further herein.

[0030] Image processing circuit **230** and hand piece processing circuit **220** are typically microprocessor based; that is, they are conveniently established utilizing one or a plurality of readily available programmable off-the-shelf microprocessor integrated circuit (IC) chips. Microprocessor IC chips often have on-board volatile and nonvolatile memory structures and are typically implanted in communication with external volatile and nonvolatile memory devices. Exemplary integrated circuit parts for use in realizing circuit elements of **FIG. 2** are listed in Table 1.

TABLE 1

Image Sensor 212	Sony ICX238EKU-E (NTSC) Sony ICX239EKU-E (PAL)
Image Processing Circuit 230	Rockwell Decoder BT829 Rockwell Encoder BT866 Xilinx FPGA Controller XC4020
Control Circuit 220	Hitachi HD64F3642AH

[0031] **FIGS. 1***d* and **1***e* show detailed views of a camera head assembly **14** which is cooled by the present invention. Camera head assembly **14** includes head **1402** and tip **1406**. Tip **1406**, normally of detachable construction includes various lenses which determine a field of view (e.g., straight view, right angle view, narrow right angle, wide right angle, etc.) while head **1402** carries camera components. More specifically, head **1402** includes metal canister **1410** which encapsulates lens **211**, image sensor **212** and IC chip **1414** in which the elements of the aforementioned image signal conditioning circuit **210** are incorporated. The inventors observed that the performance of image sensor **212** and circuit **210** degrades significantly when those components are subjected to higher temperatures such as temperatures above 185° (degrees) Fahrenheit. In the present invention, camera head assembly **14** is configured so that sensitive electrical components within the head **1402** can be cooled. In accordance with the present invention, as best seen in **FIGS. 3***a*-**3***c*, head assembly **14** has fluid inlet opening **1420** and fluid outlet openings **1430**. In the embodiment of **FIG. 3***a*, a fluid inlet opening **1420** is delimited by the interior circumference of a wall insertion tube **12** which will be explained is of a stacked construction. Fluid outlet openings **1430** of head assembly **14** are formed in the walls of canister **1410**. To the end that cooling fluid flowing out of outlet opening **1430** is directed along the outer surface of canister **1410**, a sleeve **1450** is provided which is fitted about canister **1410**. Sleeve **1450** operates to limit the flow of outlet cooling fluid so that the cooling fluid indicated by vectors **100** has a maximal cooling affect on canister **1410** and, therefore, the electrical components therein. Canister **1410** is heat-conductive so that the interior wall temperature of canister **1410** is substantially equal to that of the cooled outer walls of canister **1410**. In one example, canister **1410** comprises stainless steel and comprises a wall thickness, T_c, of from about 0.005 inches to about 0.010 inches. According to the invention, fluid indicated by vectors fluid flow **100** is also forced in close proximity with electrical components as is indicated by fluid flow vectors **100** as shown in **FIGS. 1***a*, **1***d*, **1***h*, **3***a*, **3***b*, and **3***c*.

[0032] In one variation of the invention, head **1402** incorporates a thermal sensing element for control of application of fluid about canister **1410**. For example, in one embodiment passive temperature responsive bimetallic valves **1433** as shown in **FIG. 1***h* may be disposed at the respective openings **1430** of canister **1410**. Such valves are in a normally closed position and automatically open when a temperature exceeds a predetermined level. In certain bimetallic valves, the amount of opening of the valve varies depending on sensed temperature.

[0033] In another embodiment, a thermistor **1434** in **FIG. 2** is disposed in or, alternatively, in proximity with image signal condition circuit **210** of head **1402**. A temperature indicating signal produced by thermistor **1434** may be in electrical communication with control circuit **220**. When the specific integration of **FIG. 2** is employed, the temperature information of thermistor **1434** may be sent to image processing circuit **230** via line **240**, which routes the information to control circuit **220** via line **242**. In response to the temperature indicating signal received from thermistor **1434**, control circuit **220** adjusts a fluid control signal input to fluid supply **20** via signal line **244** to adjust the delivery of fluid into head **1402** depending on the temperature of head **1402**. A fluid control signal input into fluid supply **20** may open a valve (not shown) of fluid supply **20** to increase a pressure of fluid within insertion tube **12** and head assembly **14** when a temperature sensed by thermistor **1434** exceeds a predetermined value. The control signal input into fluid supply **20** may also adjust a temperature of fluid supplied by fluid supply **20**. In the alternative or in addition, control circuit **220** may send to connector **24** via signal line **245** a fluid control signal which controls the opening of connector valve **1624** in response to the temperature indicating signal received from thermistor **1434**.

[0034] Rather than incorporating a dedicated thermistor **1434** for sensing temperature of head **1402** and there from regulating fluid characteristics, borescope **10** may sense the temperature of head **1402** by processing of image signals generated by image sensor **212**. Borescope can be configured so that image signals output by solid state image sensor **212** include temperature indicating signals. More specifically, the inventors noted that specific noise characteristics are observed in electrical signals generated by image sensor **212** above certain temperatures. For example, above a certain temperature that depends on system characteristics (e.g., type of image sensor, electrical packaging) unwanted vertical lines appear in a captured frame of image data. Above another certain temperature, an unwanted color shift is exhibited in a captured frame of image data. Accordingly, in a highly useful embodiment of the invention, image processing circuit **230** monitors frames of captured image data for noise characteristics indicative of a temperature in head **1402** exceeding a predetermined level. In response to image processing circuit **230** processing the image signals from image sensor **212** and determining that a temperature of head **1402** has exceeded a certain level, image processing circuit **230** by an appropriate communication to control circuit **220** may adjust fluid control signals transmitted in lines **244** and/or **245** to fluid supply **20** and/or valve **1624**. It is understood that control circuit **220** may regulate fluid flow and temperature in the embodiment where temperature is sensed by processing of image data in the same manner that control circuit **220** regulates fluid flow and temperature when temperature is sensed by monitoring a temperature indicating signal from thermistor **1434**. That is, regardless of the apparatus used in the sensing of temperature, control circuit **220** may transmit a control signal to fluid supply system **2000** which increases cooling fluid pressure (and, therefore, flow volume) when the temperature of head **1402** requires lowering. Control circuit **220** may also transmit a fluid control signal to fluid supply system **2000** which lowers a temperature of fluid supplied by fluid supply **20** when the temperature of head **1402** requires lowering.

[0035] In another aspect, check valves **1431** are disposed at openings **1430** as is indicated by **FIG. 1***g*. Check valves **1431** allow fluid to escape canister **1410** when insertion tube **12** and/or head **14** are pressurized, but close to seal canister **1410** when tube **12** and/or head **14** are not pressurized.

[0036] Referring to **FIGS. 3***a*-**3***c*, several alternative schemes for forcing fluid through borescope **10** are possible. In the embodiment of **FIG. 3***a*, the entire hand piece **16** is substantially pressure sealed. Forms of the term "seal" herein encompass perfect seals (no fluid escape) and structures which, though deviating from a perfect seal, are intended to allow a minimal amount of fluid escape. The joints, seams, and screw holes of hand piece **16** are pressure sealed. The interface **1606** between umbilical cord **26** and hand piece **16** is sealed as is indicated by sealant **120**. When fluid is input into a hand piece **16**, the fluid, as is indicated by arrows **100**, is forced outward through insertion tube **12** and eventually outward about camera head assembly **14** in the manner described with reference to **FIGS. 1***d* and **1***e*. Connector **24** defines a fluid input point in the embodiments of **FIG. 3***a*, **3***b*, and **3***c*.

[0037] In the embodiment of **FIG. 3***b*, a conduit **1620** extends from connector **24** to a position **1206** within insertion tube **12** and terminates within insertion tube (at prominal end thereof) in the embodiment shown. Interface **1608** between insertion tube **12** and hand piece **16** is sealed as is indicated by sealant **120**. In the embodiment of **FIG. 3***c*, a conduit **1620** extends from connector **24** at hand piece **16** all the way though insertion tube **12** and terminates at camera head assembly **14**. In the embodiment of **FIG. 3***c*, fluid entering connector **24** is forced through conduit **1620** to head assembly **14** where the cooling fluid flows in the manner described with reference to **FIGS. 1***d* and **1***e*. The interface **1208** between insertion tube **12** and camera head assembly **14** may be sealed to further encourage flow of coolant about head assembly **14** as is indicated by sealant **120** of **FIG. 3***c*. In yet another embodiment, feed tube **22** is directly interfaced to insertion tube **12** as is shown by dashes in feed tube **22** and fluid supply **25** of **FIG. 3***c*.

[0038] Sealant **120**, which is made to conform about bundles **102**, bundle **104**, working channel **108**, and cable assemblies **106** may be provided, for example, by epoxy sealant, or high temperature RTV. Bundles **102** are deleted from the view of **FIGS. 3***b* and **3***c* for simplicity purposes. Epoxy sealants which may be used may be e.g., type EP42HT, EP21TDCHT, EP42a+TND-2TG epoxies. The above epoxies, which all have operating temperatures of 350° (degrees) Fahrenheit or higher, are available from Masterbond, Inc.

[0039] Further aspects of the invention relating to the structure of insertion tube **12** are described with reference to **FIGS. 4-5***d*. As seen in **FIGS. 4-5***d*, an insertion tube **12**, according to the invention, is generally of a multi layer stacked up construction. In a typical prior art insertion tube, an insertion tube comprises polyurethane. The inventors discovered that at higher temperatures, polyurethane melts, damaging or destroying insertion tube **12**. The melting point of the polyurethane is typically in the range of 400° (degrees) Fahrenheit. In accordance with the present invention, insertion tube **12** is entirely devoid of polyurethane and entirely devoid of materials having a "low" melting point, e.g., a melting point of less than 400° (degrees) Fahrenheit. That is in one embodiment, layers **1246**, **1252**, **1254**, **1256**, **1270** (**FIG. 5***a*) as well as "lines"**102**, **104**, **106**, **108** (**FIG. 1***b*) all have a melting point of at least 400° (degrees) Fahrenheit so that borescope **10** is operational in high temperature conditions.

[0040] The inventors also found that the cooling of head **14** of borescope **10** becomes more challenging as insertion tube **12** becomes longer. Heat enters borescope **10** through insertion tube **12**. The amount of heat that enters borescope **10** increases as insertion tube is made longer. In accordance with the invention, in another aspect as will be described herein, insertion tube **12** may comprise at least one layer that has a thermal conductivity of less than about 0.50 BTU-in/(hr-ft^2-F°) e.g., fiberglass, which is available in a form having thermal conductivity of 0.27 BTU-in/(hr-ft^2-F°). In another embodiment, insertion tube **12** has at least one thermally insulating layer having a thermal conductivity of less than 2.5 BTU-in/(hr-ft^2-F°).

[0041] In the example of **FIG. 5***a*, insertion tube **12** includes an insulation layer assembly **1250**. Insulation layer assembly **1250**, in the embodiment of **FIG. 5***a*, comprises three layers. First layer **1252** is a nonporous seal layer comprising polytetrafluoroethylene. Second layer **1254** is an insulating layer comprising mesh (porous) fiberglass. Second layer **1254** is substantially thermally insulating. Third layer **1256** is another nonporous polytetrafluoroethylene seal layer. A three layer system can limit conduction through the interior and exterior layers by creating a thermal barrier. Referring to other layers of insertion tube **12**, layer **1246** is a monocoil. Layer **1246** increases the crush resistance of insertion tube **12**. Layer **1280** is a mesh tungsten layer. Tungsten layer **1280** increases the abrasion resistance and torsional stiffness of insertion tube **12**.

[0042] The multi-layer insulation layer assembly may be used in combination with any of the fluid input systems as shown in **FIGS. 3***a*-**3***c*.

[0043] Another embodiment of an insertion tube in accordance with the invention is shown in **FIG. 5***b*. In the embodiment of **FIG. 5***b,* the multilayer insulation layer assembly of **FIG. 5***b* is replaced with a single layer insulation assembly devoid of a sealing layer. In the embodiment of **FIG. 5***b,* insulating layer **1260** comprises a porous, non-sealing tube **1260**. Layer **1260** may have the structure as shown in **FIG. 5***b* in which micropores **1262** are dispersed throughout. Micropores **1262** may have diameters ranging from about 10 microns to about 100 microns. Micropores **1262** may be nonuniformly sized, and nonuniformly spaced. Micropores **1262** may also be randomly sized and randomly spaced. Micropores **1262** allow cooling fluid indicated by vectors **100** to escape there through. By the action of fluid escaping from micropores **1262**, an insulating/cooling boundary layer is formed along the outside surface of insertion tube **12**. The insulation/cooling boundary reduces heat entry into insertion tube **12** by way of convection. The insertion tube **12** of **FIG. 5***b* may be used in combination with any of the embodiments of **FIGS. 3***a*, **3***b*, and **3***c*.

[0044] In a variation of the invention, micropores **1262** are non-uniformly formed throughout the length of insertion tube **12** according to a specific dispersion pattern. In one example, insertion tube **12** is configured so that there is a progressively higher density of micropores **1262** from proximal end **15** of insertion tube **12** to distal end **13** of insertion tube **12** (**FIG. 4**). If insertion tube **12** is made to have a progressively higher density of micropores **1262** from proximal end **15** to distal end **13**, and the density progression is appropriately designed, fluid escapes from insertion tube **12** uniformly throughout the length of insertion tube **12**. Micropore "density" herein refers to the total area consumed by micropores **1262** per unit length. Therefore, a progressively higher density of micropores **1262** can be provided by increasing the number of micropores and/or increasing the average size of the micropores along the length of insertion tube **12**. Various examples of the invention are described with reference to Tables **2A**-**2D**.

TABLE 2A

Layer	Material	Trade Name	Thermal Conductivity	Maximum Operating Temperature	Thickness
Monocoil 1246	Stainless Steel		138.8 BTU-in/ (hr-ft^2-F. °)	2550° F.	0.010 in.
Layer 1252	Nonporous Polytetrafluoroethylene	TEFLON	2.08 BTU-in/ (hr-ft^2-F. °)	500° F.	0.010 in.
Layer 1254	Porous Fiberglass	TEFLON	0.27 BTU-in/ (hr-ft^2-F. °)	1200° F.	0.012 in.
Layer 1256	Nonporous Polytetrafluoroethylene	TEFLON	2.08 BTU-in/ (hr-ft^2-F. °)	500° F.	0.010 in.
Layer 1280	Tungsten braid		1130 BTU-in/ (hr-ft^2-F. °)	6100° F.	0.006 in.

[0045] The structure summarized in Table **2A** is shown in **FIG. 5***a*. The porous fiberglass layer provides a thermal barrier and limits the entry of heat into insertion tube by way of thermal conduction. The polytetrafluoroethylene layers seal the insertion tube, and limit the entry of fluid through the walls of insertion tube **12**.

TABLE 2B

Layer	Material	Trade Name	Thermal Conductivity	Maximum Operating Temperature	Thickness
Monocoil 1246	Stainless Steel		138.8 BTU-in/ (hr-ft^2-F. °)	2550° F.	0.010 in.
Layer 1260	Porous Polytetrafluoroethylene	SILKORE		Excellent high temp integrity	0.015 in.
Layer 1280	Tungsten braid		1130 BTU-in/ (hr-ft^2-F. °)	6100° F.	0.006 in.

[0046] The structure summarized in Table **2B** is shown in **FIG. 5***b*. Pressurized fluid is allowed to escape from the walls insertion tube **12** to provide an insulation/cooling boundary.

TABLE 2C

Layer	Material	Trade Name	Thermal Conductivity	Maximum Operating Temperature	Thickness
Monocoil 1246	Stainless Steel		138.8 BTU-in/(hr-ft^2-F. °)	2550° F.	0.010 in.
Layer 1262	Nonporous Meta-Phenelyneisophthalamide layers	NOMEX	0.715 BTU-in/(hr-ft^2-F. °)	428° F.	0.015 in.
Layer 1264	Porous Fiberglass		0.27 BTU-in/(hr-ft^2-F. °)	1200° F.	0.012 in.
Layer 1266	Nonporous Meta-Phenelyneisophthalamide	NOMEX	0.715 BTU-in/(hr-ft^2-F. °)	428° F.	0.015 in.
Layer 1280	Tungsten braid		1130 BTU-in/(hr-ft^2-F. °)	6100° F.	0.006 in.

[0047] The structure summarized in Table **2**C is shown in **FIG. 5***c*. The structure of **FIG. 5***c* is similar to the structure of **FIG. 5***a*, with the polytetrafluoroethylene layers replaced with meta-phenelyneisophthalamide layers.

TABLE 2D

Layer	Material	Trade Name	Thermal Conductivity	Maximum Operating Temperature	Thickness
Monocoil 1246	Stainless Steel		138.8 BTU-in/(hr-ft^2-F. °)	2550° F.	0.010 in.
Layer 1268	Nonporous Poly-paraphenylene terephthalamide	KEVLAR	0.277 BTU-in/(hr-ft^2-F. °)	797° F.	0.015 in.
Layer -in/(hr-ft^2-F. °)1270	Porous Fiberglass		0.27 BTU-in/(hr-ft^2-F. °)	1200° F.	0.012 in.
Layer 1272	Nonporous Poly-paraphenylene terephthalamide	KEVLAR	0.277 BTU-in/(hr-ft^2-F. °)	797° F.	0.015 in.
Layer 1280	Tungsten braid		1130 BTU-in/(hr-ft^2-F. °)	6100° F.	0.006 in.

[0048] The structure summarized in Table **2**D is shown in **FIG. 5***d*. The structure of **FIG. 5***d* is similar to the structure of **FIG. 5***a* with the polytetrafluoroethylene layers replaced with poly-paraphenylene terephthalamide.

[0049] Referring to further aspects of insertion tube **12**, in one embodiment insertion tube **12** may have an outer diameter "d," at (**FIGS. 5***a*, **5***b*) from about 4 mm to about 12 mm. Tube **12** (**FIG. 5***a*) may have a total thickness (the thickness of stacked up layers **1246**, **1280** and intermediate layers) from about 1 mm to about 5 mm in one example.

[0050] Insertion tube **12** can also have a construction in accordance with one or more of the embodiments described in U.S. patent application Ser. No. 10/763,131 filed Jan. 22, 2004 and entitled, "Inspection Device Insertion Tube" incorporated herein by reference.

[0051] Referring to aspects of fluid supply **20**, fluid supply **20** can take on a variety of forms. Fluid supply **20** can be provided, for example, by an air compressor, or an air cylinder. Fluid that is supplied by fluid supply **20** may be, for example, a mixture of nitrogen and oxygen (e.g., air), water, nitrogen, carbon dioxide, or inert gases such as helium or argon. Fluid supply **20** can be a standardly known industrial low pressure compressed air supply. Fluid supply **20** can also be a stand alone commercial compressor (electric or gas) as are known to skilled artisans.

[0052] While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawing, it will be understood by one skilled in the art that various changes in detail may be affected therein without departing from the spirit and scope of the invention as defined by the claims.

We claim:

1. A borescope comprising:

an insertion tube having a distal end;

at least one of an electrical conductor, a fiber optic bundle, and an articulation cable disposed within said insertion tube;

a camera head assembly disposed at said distal end of said insertion tube, said camera assembly having formed therein at least one fluid outlet opening;

a solid state image sensor disposed in said camera head assembly;

a lens disposed in said camera head assembly focusing an image onto said solid state image sensor; and a fluid supply system supplying fluid to said camera assembly through said insertion tube, wherein said fluid escapes said camera assembly through said at least one fluid outlet opening.

2. The borescope or claim 1, further comprising a check valve disposed at said fluid outlet opening.

3. The borescope of claim 1, wherein said insertion tube includes a multi-layer insulating layer assembly.

4. The borescope of claim 1, wherein said insertion tube includes a wall of multi-layer construction, wherein one of said layers comprises porous fiberglass having a thermal conductivity of less than 0.50 BTU-in/(hr-ft^2-F°).

5. The borescope of claim 1, wherein said insertion tube includes a layer having a plurality of micropores formed throughout a length thereof.

6. The borescope of claim 1, wherein said insertion tube includes a polytetrafluoroethylene layer having a plurality of micropores formed throughout a length thereof, said micropores being formed with progressively higher density from a proximal end of said insertion tube to a distal end of said insertion tube.

7. The borescope of claim 1, wherein said borescope further includes a hand piece having a fluid input point, and wherein said hand piece is pressure sealed in such manner that fluid entering said fluid input point is forced though said insertion tube toward said camera head assembly.

8. The borescope of claim 1, wherein said borescope further includes a hand piece having a fluid input point, and wherein said fluid supply system includes a conduit extending from said fluid input point and terminating at a position within said insertion tube.

9. The borescope of claim 1, wherein said borescope further includes a hand piece having a fluid input point, and wherein said fluid supply system includes a conduit extending from said fluid input point through said insertion tube to said camera head assembly.

10. The borescope of claim 1, wherein said fluid delivered by said fluid supply system is a mixture of oxygen and nitrogen.

11. The borescope of claim 1, wherein said fluid delivered by said fluid supply system is carbon dioxide.

12. The borescope of claim 1, wherein said fluid delivered by said fluid supply system is a chlorofluorocarbon, which changes state at or before said camera head assembly

13. The borescope of claim 1, wherein said camera head assembly includes a metal canister housing camera component and a sleeve disposed about said canister, and wherein said at least one fluid exit hole is formed in said canister.

14. The borescope of claim 1, wherein said borescope further includes a bimetallic valve disposed at said fluid outlet opening.

15. A method for cooling a borescope camera assembly having a metal canister encasing electrical components of said camera assembly, said method comprising the steps of:

forming through holes in said canister; and

disposing a sleeve about said canister, said sleeve being configured in a coordinated manner with said canister so that air flowing outward from said through holes is directed to flow along an outer surface of said canister and;

forcing fluid into said canister in such manner that said fluid flows out of said through holes.

16. The method of claim 15, wherein said disposing step includes the step of disposing a sleeve about said canister.

17. The method of claim 15, wherein said forcing step includes the step of forcing a mixture of oxygen and nitrogen into said canister.

18. A borescope camera head assembly comprising:

a metal canister;

a sleeve disposed about said canister;

an image sensor and electrical circuitry disposed within said canister;

a plurality of through holes formed in a wall of said canister, wherein said sleeve and said canister are complimentarily formed with said canister so that fluid flowing out of said canister is directed along a surface of said canister.

19. The borescope of claim 18, wherein said sleeve is configured to be detachably attachable to said canister.

20. The borescope of claim 18, wherein said assembly further includes a lens disposed within said canister.

21. The borescope of claim 18, wherein said camera head assembly includes a head assembly to insertion tube interface, wherein a cooling fluid delivery conduit is received at said interface, and sealant is formed about said conduit so that cooling fluid losses external to said camera head assembly are reduced.

22. An insertion tube remote viewing device comprising:

an insertion tube having a wall and carrying at least one of an articulation cable, a fiber bundle, and an electrical conductor, wherein said wall is of a multilayer stacked construction;

a fluid supply system; and

a camera head assembly disposed at a distal end of said insertion tube, wherein said multilayer wall is devoid of a sealing layer and includes a microporous layer having micropores formed therein, and wherein fluid delivered by said fluid supply system escapes from said micropores of said microporous layer.

23. The device of claim 22, wherein said multilayer insertion tube wall further includes a non-sealing abrasion resistant wire braid layer disposed about said microporous layer.

24. The device of claim 22, wherein said multilayer insertion tube wall further includes a nonsealing monocoil, wherein said microporous layer is disposed about said monocoil.

25. The device of claim 22, wherein said microporous layer has a melting point of at least 500° (degrees) Fahrenheit.

26. The device of claim 22, wherein said microporous layer consists of polytetrafluoroethylene.

27. The device of claim 22, wherein said micropores are formed with progressively higher density throughout a length of said insertion tube from a proximal end of said insertion tube to a distal end thereof.

28. An insertion tube remote viewing device comprising:

an insertion tube having a wall and carrying at least one of an articulation cable, a fiber bundle, and a wire bundle, wherein said wall is of a multilayer stacked up construction;

a fluid supply system; and

a camera head assembly disposed at a distal end of said insertion tube, wherein said multilayer wall of said insertion tube is devoid of material having a melting temperature lower than about 400° (degrees) Fahrenheit and wherein said insertion tube remote viewing device is configured to receive fluid from said fluid supply system.

29. The insertion tube remote viewing device of claim 28, wherein said multilayer wall includes a layer selected from the group consisting of nonporous polytetrafluoroethylene, meta-phenelyneisophthalamide, and poly-paraphenylene terephthalamide.

30. The insertion tube remote viewing device of claim 28, wherein said multilayer wall includes a layer of nonporous polytetrafluoroethylene.

31. The insertion tube remote viewing device of claim 28, wherein said multilayer wall includes a layer selected from the group consisting of nonporous polytetrafluoroethylene, meta-phenelyneisophthalamide, and poly-paraphenylene terephthalamide, and wherein said multilayer further includes a layer of porous fiberglass having a thermal conductivity of less than 0.50 BTU-in/(hr-ft^2-F°).

32. An insertion tube remote viewing device comprising:

an insertion tube having a wall and carrying at least one of an articulation cable, a fiber bundle, and a wire bundle, wherein said wall is of a multilayer stacked up construction;

a camera head assembly disposed at a distal end of said insertion tube;

a solid state image sensor disposed in said camera head assembly;

an image processing circuit that processes image signals of said solid state image sensor, wherein said multilayer insertion tube includes at least one layer having a thermal conductivity of less than 0.50 BTU-in/(hr-ft^2-F°), and wherein said insertion tube remote viewing device is configured to receive fluid from a fluid supply system.

33. The insertion tube remote viewing device of claim 32, wherein said multilayer insertion tube comprises a layer of porous fiberglass having a thermal conductivity of less than 0.50 BTU-in/(hr-ft^2-F°), and a nonporous layer of material layered adjacent to said porous fiberglass layer.

34. The insertion tube remote viewing device of claim 32, wherein said multilayer insertion tube comprises a layer of porous fiberglass having a thermal conductivity of less than 0.50 BTU-in/(hr-ft^2-F°), and a layer of nonporous material layered adjacent said porous fiberglass layer said nonporous material selected from the group consisting of polytetrafluoroethylene, meta-phenelyneisophthalamide, and poly-paraphenylene terephthalamide.

35. An insertion tube remote viewing device comprising:

an insertion tube having a wall and carrying at least one of an articulation cable, a fiber bundle, and an electrical conductor;

a camera head assembly disposed at a distal end of said insertion tube, said camera head assembly having a head portion and including a solid state image sensor, said solid state image sensor being disposed in said head portion of said camera head assembly;

a thermal sensor producing a temperature-indicating signal disposed to sense a temperature of said camera head assembly;

circuitry receiving said temperature-indicating signal produced by said thermal sensor and processing said temperature indicating signal to output a fluid control signal for sending to a fluid supply system, wherein said insertion tube remote viewing device is configured to receive fluid from a fluid supply system.

36. The insertion tube remote viewing device of claim 35, wherein said thermal sensor is provided by a thermistor.

37. The insertion tube remote viewing device of claim 35, wherein said thermal sensor is provided by said solid state image sensor.

38. The insertion tube remote viewing device of claim 35, wherein said circuitry includes an image processing circuit which processes frames of image data in said processing of said output fluid control signal.

39. The insertion tube remote viewing device of claim 35, wherein said fluid flow control signal adjusts at least one of a pressure and a temperature of fluid supplied by said fluid supply system.

40. The insertion tube remote viewing device of claim 35, wherein said fluid supply system includes a fluid supply, and wherein said insertion tube remote viewing device is configured so that said fluid supply receives said fluid flow control signal.

41. The insertion tube remote viewing device of claim 35, wherein said circuitry in processing said output signal monitors a temperature signal produced by a thermistor.

* * * * *

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[标]申请(专利权)人(译)	KEHOSKIE MICHAEL P KARPEN THOMASW一 KRAUTER ALLAN我 LIA RAYMOND一个 莫尔斯BRADFORD VON FELTEN KENNETH
申请(专利权)人(译)	KEHOSKIE MICHAEL P KARPEN THOMASW一 KRAUTER ALLAN我 LIA RAYMOND一个 莫尔斯BRADFORD VON FELTEN KENNETH
当前申请(专利权)人(译)	GE检测科技，LP
[标]发明人	KEHOSKIE MICHAEL P KARPEN THOMAS W KRAUTER ALLAN I LIA RAYMOND A MORSE BRADFORD VON FELTEN KENNETH
发明人	KEHOSKIE, MICHAEL P. KARPEN, THOMAS W. KRAUTER, ALLAN I. LIA, RAYMOND A. MORSE, BRADFORD VON FELTEN, KENNETH
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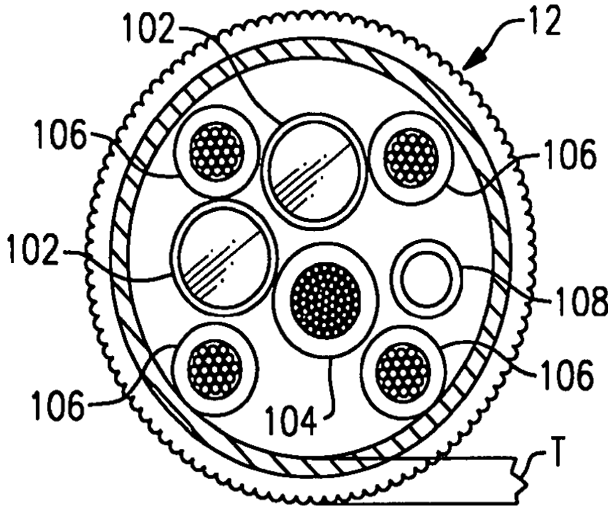
摘要(译)

一种管道镜装置，具有插入管，摄像头组件和流体供应系统。相机组件包括允许流体逸出的通孔。流体供应系统是可控制的，以迫使流体通过通孔。可以致动流体供应系统以冷却摄像头组件。



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