

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
18 September 2008 (18.09.2008)

PCT

(10) International Publication Number
WO 2008/112331 A1

(51) International Patent Classification:

E21B 47/06 (2006.01) **E21B 17/02** (2006.01)
E21B 47/12 (2006.01) **E21B 43/12** (2006.01)

(21) International Application Number:

PCT/US2008/050167

(22) International Filing Date: 4 January 2008 (04.01.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

11/716,503 10 March 2007 (10.03.2007) US

(71) Applicant (for all designated States except US): **BAKER HUGHES INCORPORATED** [US/US]; P.O. Box 4740, Houston, TX 77027 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **FIRMIN, Cully** [US/US]; 118 Nova Drive, Broussard, LA 70518 (US).
LAFLEUR, Louis, F.; 5114 LaPremiere Drive, Maurice, LA 70555 (US).

(74) Agent: **DUPHORNE, Darin, H.**; Baker Oil Tools Division - Baker Hughes Inc., Division Intellectual Property Counsel, P.O. Box 4740, Houston, TX 77027 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL,

[Continued on next page]

(54) Title: A UNITIZED MULTI-GAUGE MULTI-CIRCUIT GAUGE CLUSTER, SYSTEM ARRAY AND GAUGE CARRIER FOR PERMANENT DOWN-HOLE PRODUCTION TUBE MONITORING

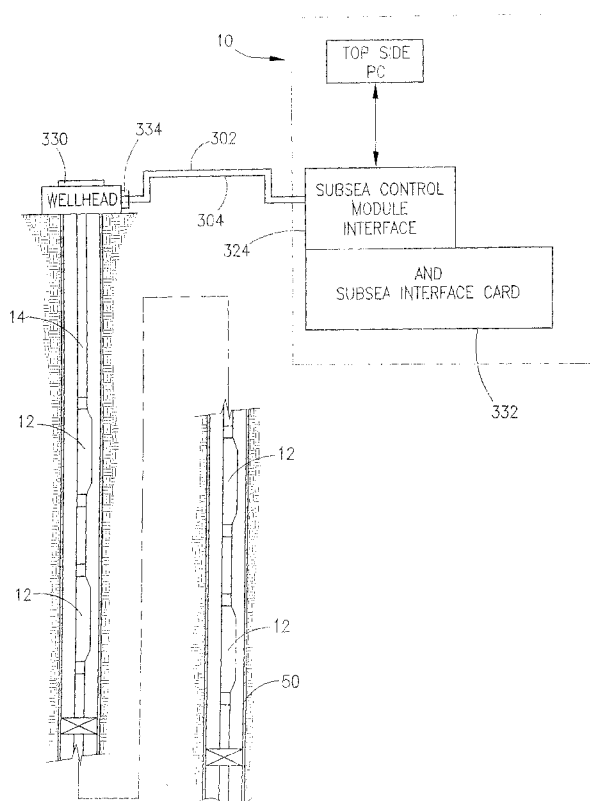


Fig. 1

(57) Abstract: A multi-gauge multi-circuit gauge cluster system array and gauge carrier with and without an expanding bore flow meter for permanent down-hole production tube monitoring is disclosed. The system includes a two circuit array of up to (64) gauges in dual and quad configurations for locating permanently in a production string for surface computer monitoring of a variety of down-hole well parameters, the system further including innovative through bore side pocket mandrel gauge carriers cooperative with the gauge clusters and accommodations for interconnecting the gauge cluster internally or to remote carriers. The system reduces gauge failure, provides improved redundancy and integrity verification.



NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG,
CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

— *before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments*

Published:

— *with international search report*

**A UNITIZED MULTI-GAUGE MULTI-CIRCUIT GAUGE CLUSTER, SYSTEM
ARRAY AND GAUGE CARRIER FOR PERMANENT DOWN-HOLE
PRODUCTION TUBE MONITORING**

APPLICATION FOR PATENT

INVENTOR: Cully Firmin and Louis F. Lafleur

INVENTION: A unitized multi-gauge multi-circuit gauge cluster, system array and gauge carrier for permanent down-hole production tube monitoring

SPECIFICATION

1. FIELD OF THE INVENTION

This invention relates generally to production well electronic monitoring gauges and more particularly to a production well monitoring system providing gauge assembly integrity, complex multi-gauge bundling, expansion type flow metering and unlimited sensor array configuration.

2. GENERAL BACKGROUND

Down-hole production tube monitoring is an essential element of the production phase of an oil and gas well. The flow of hydrocarbons flowing from the well must be continuously monitored to insure maximum output. One aspect of down-hole monitoring involves the monitoring of heavy paraffin, scale deposits and the like that tend to build up on the inner walls of the production tubing thus forming flow restriction. Generally, various chemicals, pumped down-hole through capillary tubing running alongside the production string, are injected into the string at various points to help

remove such flow restrictions. In order to determine the need for such chemical injection and its effectiveness as well as a great many other important aspects of evaluating the well's productivity, reservoir engineers rely on temperature and pressure readings taken from sensors located along the well flow path.

Reservoir engineers depend on the reliability of these pressure/temperature gauges in determining what action to take to maintain maximum production rates. Therefore, it is essential that multiple gauges, forming an array, be highly accurate and compatible with each other in a manner whereby their tolerances are not cumulative and thus do not produce any significant error. Since so much depends on these gauges and the fact that they are installed within the production flow line any failure results in incorrect decisions due to faulty readings or the loss of production when the flow line must be withdrawn for replacement of the gauges. Therefore, a finite study of the down-hole pressure/temperature measurement process has indicated a number of factors that lead to incorrect gauge readings.

In many cases down-hole pressure/temperature gauges are assembled and installed into a gauge carrier sub in the field or pre-assembled for transport to the job site using gauges and connections that allow for future replacement in the field.

The hostile environment, involving very high temperatures of up to 200 degrees C. and up to 35,000 PSI combined with high impacts, in which these gauges must operate seem to require gauge replacement on a frequent basis. Such replacement in many cases

requires removal of the production string resulting in lost oil or gas production. Many operators have resorted to specifying redundancy for all gauges to help insure reliability.

Further, most instrument operators purchase their gauges from gauge manufactures and rely on their individual standard reliability tolerance. It has been determined that the numerous mechanical electrical data cable high pressure compression seal connections used to couple the gauges together into an array and the exposure of such numerous high pressure compression seal connection to impacts, high heat and pressure are the primary cause of gauge failures. When a number of gauges are installed in an array in which the gauges have not been selectively paired and thus known to have complementary tolerances this may produce very large error readings. Likewise, when gauges are installed or bundled into gauge carriers in the field that have not been previously tested as an array, large errors are more evident.

Gauge carriers have been developed for use in transporting and housing temperature/pressure gauges in down-hole environments. However, most such gauge carriers utilize single temperature/pressure gauges bundled into a single carrier and electrically connected to cables leading to the surface. Those gauge carriers that are designed for permanent down-hole locations include annulus mountings as well as the more preferred full or near full bore side-pocket mandrel types. These so-called pocket mandrel gauge carriers are fabricated in a variety of ways that attempt to insure full production flow through the sub while providing sensor exposure to the production flow and/or the annulus pressure whenever necessary while limiting the gauge sensor's exposure

while protecting the sensor and its couplings from harm as much as possible. In some cases gauge or sensor arrays include multiple gauge carriers located hundreds of feet apart with each gauge carrier fitted with a single gauge or multi-gauges connected in multiple circuit configurations. Such multi-gauge, multi-circuit configurations are simply groupings of single gauges and thus run the same risk of leakage and inaccuracies discussed above. Such circuit or sensor arrays are limited with regard to the number of gauges that can be carried in a single carrier due to limited space for any given size production tube bore and to the number of gauges permitted in a single circuit. Most circuits are severely limited in number with sampling rates drastically reduced accordingly.

To date there has been little or no attempt within the art to unitize such multi-gauge, multi-circuit gauge arrays in a manner that maximizes the available space thus allowing more gauges per carrier, or improving the circuitry to allow for virtually unlimited numbers of gauges in a single circuit array. Further, the prior art has not addressed the need to reduce the number of connections used to connect multi-gauges in a single carrier, the potential for leaks, or the need to use matched sets of highly accurate gauges working in unison to provide a highly durable and accurate system.

In addition there is a need to provide a full bore flow meter in conjunction with the down-hole temperature/pressure gauge monitoring system to monitoring the oil and gas flow through the production tube without restriction. The prior art provides various inline flow meters. However, such meters are not adaptable to the rigors of permanent down-hole monitoring or design to work with temperature/pressure gauges.

3. SUMMARY OF THE INVENTION

A multi-gauge multi-circuit high pressure/temperature gauge carrier array and flow meter for permanent down-hole production tube monitoring system is disclosed. The system includes a phased array of multiple gauges located permanently in a production string for surface computer monitoring a variety of down-hole well parameters. The system further includes innovative full flow, through bore, side pocket mandrels and methods for making the same. The mandrel pockets are designed to accommodate a plurality of parallel gauge clusters and multiple circuit connections within the same gauge cluster and the within the mandrel. Other embodiments allow for interconnection with other gauge clusters located within mandrels further up or down the production string. Additional embodiments include gauge clusters that include both circuit terminations and traveling circuits passing through the gauge clusters to other gauge assemblies. Novel gauge sensor probes and sealing methods are also disclosed.

It is therefore an object of the present invention to provide down-hole gauge clusters of up to eight gauges and/or circuit connections within a single gauge carrier.

It is another object of the invention to provide a through bore side pocket mandrel adapted to received such multiple gauge and/or circuit connection clusters.

It is still a further object of the invention to provide a system for connecting a large number of such gauge clusters in a phased array.

It is also an object of the invention to provide an improved data transmission cable and gauge sealing method.

Another object of the invention is to provide redundancy and improved reliability.

4. BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the nature and objects of the present invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which, like parts are given like reference numerals, and wherein:

FIG. 1 is a vertical cross section view of a well bore production string with a plurality of gauge carriers and surface monitoring systems;

FIG. 2 is a vertical cross section view of a conventional prior art full bore offset mandrel gauge carrier;

FIG. 3 is a front view of the conventional prior art full bore offset mandrel gauge carrier shown in Fig. 2;

FIG. 4 is an end view of the conventional prior art full bore offset mandrel gauge carrier as seen in Fig. 3;

FIG. 5 is an exploded view of a conventional prior art full bore offset mandrel gauge carrier for housing a circuit splitter assembly and a pair of gauge assemblies;

FIG. 6 is an exploded view of a prior art arrangement used for housing a circuit splitter in one mandrel carrier and a pair of gauge assemblies in a second gauge carrier;

FIG. 7 is a vertical cross section view of a typical prior art arrangement for exposing a gauge probe to the pressure and temperature of the fluids flowing through the offset mandrel carrier;

FIG. 8 is a horizontal cross section view of the gauge carrier seen in Fig. 7 taken along sight line 8-8 with a single gauge assembly;

FIG. 9 is a horizontal cross section view of the gauge carrier seen in Fig. 7 taken along sight line 9-9 with two gauge assemblies;

FIG. 10 is a side view of a typical prior art down-hole instrument data transmission cable shown stripped out for connection to a gauge assembly;

FIG. 11 is a partial cross section view of a typical data transmission cable connection arrangement to a down-hole gauge assembly;

FIG. 12A is partial cross section view of a typical prior art arrangement for connecting a pair of gauge assemblies located in parallel in a single gauge carrier;

FIG. 12B is a continuation partial cross section view of Fig. 12A;

FIG. 13 is an isometric view of the prior art dual parallel gauge arrangement seen in Fig. 12A and 12B;

FIG. 14 is an isometric view of an improved prior art dual parallel gauge assembly for the gauge assembly seen in Fig. 13;

FIG. 15 is an isometric view of the preferred embodiment of a dual gauge instrument cluster assembly;

FIG. 15A is an isometric view of an alternate embodiment of a gauge instrument cluster assembly

FIG. 15B is an isometric view of an alternate embodiment of a gauge instrument cluster assembly

FIG. 15C is an isometric view of an alternate embodiment of a gauge instrument cluster assembly

FIG. 15D is an isometric view of an alternate embodiment of a gauge instrument cluster assembly

FIG. 15E is a top view of an alternant version of the preferred embodiment;

FIG. 15F is an isometric view of the alternate version of the preferred embodiment of Fig. 15E;

FIG. 15G is an end view of the preferred embodiment shown in Fig. 15F;

FIG. 15H is a top view of an alternant version of the preferred embodiment;

FIG. 15J is an isometric view of the alternate version of the preferred embodiment of Fig. 15H;

FIG. 15K is an end view of the preferred embodiment shown in Fig. 15H;

FIG. 15L is a top view of another alternant version of the preferred embodiment;

FIG. 15M is an isometric view of the alternate version of the preferred embodiment of Fig. 15L;

FIG. 15N is an end view of the preferred embodiment shown in Fig. 15M;

FIG. 16 is an isometric view of the offset full-bore gauge carrier mandrel with cabling;

FIG. 17 is an isometric view of the offset full-bore gauge carrier mandrel seen in Fig. 16 with cover being removed;

FIG. 18 is an isometric view of a single gauge and data transmission cable connection;

FIG. 19 is an isometric view of a unitized dual gauge assembly and data transmission cable connection;

FIG. 20 is an isometric view of a unitized combination parallel gauge assembly and data cable

connection;

FIG. 21 is an isometric view of a unitized gauge assembly and circuit splitter connection;

FIG. 22 is a cross section view of electrical connections extending between gauge assemblies located in separate carrier mandrels;

FIG.23 is a cross section view of the gauge carrier mandrel with connection and porting to internal fluid flow;

FIG.24A is a partial vertical cross section view of a parallel gauge assembly with two connection ports in the same carrier mandrel;

FIG.24B is a continuation of the partial vertical cross section view of a parallel gauge assembly seen in Fig. 24A showing the second connection port in the same carrier mandrel;

FIG. 25 is a cross section of the gauge carrier mandrel with unitized combination gauge and dual circuit splitter;

FIG.25A is a top view of the gauge carrier mandrel with unitized combination gauge and dual circuit splitter;

FIG.26 is a top view of a combination unitized dual gauge assembly and dual circuit splitter;

FIG. 27 is a partial cross sectional view taken along sight lines 27-27 of the unitized combination gauge assembly and dual circuit splitter assembly shown in Fig. 26; FIG. 28 is partial cross-section view of the gauge carrier with the gauge assembly shown in Fig. 26 with its gauge connection porting and dual exit in cables; FIG. 29 is partial cross-section view of the gauge carrier with an alternative gauge and data cable splitter assembly with its gauge connection porting and dual exit in cables; FIG. 30 is a partial cross section view of the gauge assembly shown in Fig. 29 taken along sight lines 30-30; and FIG. 31 is an isometric assembly view of a multi-channel, multi cluster gauge array.

5. DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

001 Monitoring the production flow of petroleum well is a common practice by reservoir engineers. In many cases permanent down-hole monitoring systems are deployed for monitoring multi-zone reservoirs and multilateral wells. Such systems may also be integrated with down-hole flow control devices in order to provide a response to the intelligence data gathered by down-hole instrumentation generally known as instrument sensors or simply as down-hole gauges. Such monitoring systems as pressure/temperature gauge assemblies, densitometers and flow meters are capable of recording data regarding the reservoir pressure and temperature, flow rates, fluid friction, sand detection, chemical properties and micro-seismic activity. For purposes of this disclosure the data gathering instrumentation sensors are referred to as down hole gauges

generally intended for permanent location at various intervals in a producing oil or gas well.

002 As shown in Fig. 1, the aforementioned systems include a surface data computer system 10 with a proprietary topside or sub-sea interface card (SIC) 332 and Sub-sea Electronics Module (SEM) 324. the computer system 10 may be located adjacent the well site or the data may be transmitted to remote locations for analysis. The computer system 10 communicates with sensor gauges positioned within gauge carriers 12 located at intervals along the production drill string 14 by way of electrical or fiber optic cables or other such communication systems controlled by the surface computer communications system 10. The above-mentioned proprietary Sub-sea interface cards 332, also seen in Fig. 31, are designed for use with commercially available SEMs 324 for use with multiple instruments attached to a single cable. In use the down-hole instruments or gauge assemblies digitize pressure, temperature and reference frequencies from one or more quartz transducers. This information is assembled into data packets that are transmitted to the proprietary sub sea interface card 332. In this installation, multiple down-hole gauges can transmit packets independently on the same cable. The proprietary sub sea card 332 reads the digital data packet, appends the card's status information and stores the data in MODBUS registers. On request the proprietary sub sea card 332 transmits the data to the topside system 10. The topside system 10 requests a data packet, reads it and converts it to engineering units. This down-hole digitization of signals allows for extremely high resolution.

003 Side pocket mandrel subs with full through bores are the preferred gauge carriers 12 for the gauge clusters disclosed herein and are generally coupled into the production string at desired zones along the well bore separated in many cases by hundreds of feet of tubing. These pocketed sub gauge carriers 12 and their unlimited gauge clusters assembly configurations constitute the basis for this invention. The gauge carrier or mandrel 12 may be formed in a variety of ways. However, the concept design is such that volumetric flow through the mandrel is unimpeded and is thus equal to the flow of the production tubing into which it is connected. As seen in Fig. 2 and Fig. 3, a side pocket 20 is provided along one side of the mandrel 12 in a manner that allows a gauge or instrument cluster assembly 28 to be fitted therein. A sensor portion 30 of the gauge is fixed within a port 32 that is in fluid communication with the production bore 34 extending through the mandrel. The gauge assembly 28 is connected to the wiring 18 or other communication systems leading to the surface computer system 10. The wiring 18 is strapped to the casing and enters the pocket 20 via channels 22, shown in Fig. 4. It is necessary to provide a well designed sealing system 24 and a rigid data transmission cable termination housing 26 for the gauge assembly 28. The gauge assembly 28, its sensor 30, and the termination assembly 27 are protected and held securely in place by a pocket cover 29. Blocks or pads may be used to further isolate and hold the gauge assembly 28 in position within the pocket. 20.

004 Looking now at Fig. 5, we see that in some cases it may be desirable to utilize a data transmission cable 40 extending from the surface of the well bore to multiple gauge

assemblies 28. This is accomplished through the use of a data transmission cable splitter 42. The splitter 42 is a sealable housing having terminations therein which allows the data transmission cable 40 to be separated into two separate data transmission cable circuits 44 upon exiting the splitter 42 for connection to separate gauge or instrument assemblies 28 located in parallel with each other or one above the other within the same carrier mandrel 12. However, in most cases the splitter 42 is so large it is located in its own carrier mandrel as shown in Fig. 6, rather than provide a special extended length mandrel as shown in Fig. 5. In either case the gauge assemblies are generally of a size that permits only one to fit within the side pocket 20 of the mandrel 12 as seen in Fig. 7 and Fig. 8. As further shown in Fig. 8, the gauge assembly 28 is confined within the side pocket 20 adjacent the mandrel bore 34 and the gauge carrier or mandrel assembly 12 is further limited by the internal diameter of the production casing 50. In some cases some manufacturers have been successful in placing two gauge assemblies 28 in parallel within the side pocket 20, as shown in Fig. 9. However, this is the exception rather than the common practice and requires the use of what has come to be known as mini-gauges.

005 Viewing Fig. 10 and Fig. 11 may provide a better understanding of the termination of wiring or cabling 18 with the gauge 28. The typical down-hole gauge data transmission cable 18 is composed of several layers of insulation "a-d" before exposing the core conductor material 60 for terminal connection. Sealing the various layers of insulation and thus providing a secure high-pressure seal requires significant field preparation. The data transmission cable termination housing 26 includes a tubular

housing assembly 68 with a threaded compression fittings 62 at each end and a internal compression fitting 66 located within the tubular housing assembly 68 and a spring loaded or biased plug-in type connector within the thimble and boot assembly 64 utilizing an electrical spring contact hidden within the boot and soldered to a data transmission cable wire conductor. The data transmission cable wiring 18 is ultimately connected to the gauge 28.

006 These numerous connections take considerable time to make up and the multiple connections make them vulnerable to vibration, shock and pressure failure. Therefore, it became obvious that redundancy was needed to insure a high level of reliability. To accomplish the desired reliability, the need arose to miniaturize the gauges and unitize them in combination with a splitter housing in a manner whereby dual gauges are configured as seen in Figs. 12A, 12B, and 13 which approximate the diametrical size of conventional single gauges generally available on the commercial market and thus fit within the pocket 20 of the carrier 12.

007 The gauge or instrument assembly 110 illustrated in Fig. 13, represents applicant's first generation unitized or modular dual gauge and splitter assembly with down-hole temperature and pressure sensing gauges. As seen here, the unitized modular gauge assemblies generally consist of an external data cable sealing assembly arrangement connected to the upper gauge or sensor assembly. The sealing assembly 26 better seen in Fig. 12A includes a body a compression fitting 112 for anchoring the data transmission cable sleeve 114 not shown with the bushing reducer 116 that is in turn

threadably secured to elongated bell reducer 120. Another compression connector 112 and bushing reducer 116 is used to connect one end of an elongated bell reducer 120 with the opposite end of the nipple being TIG welded to one end of the upper body sensor 122. A pair of tubular instrument sub-assemblies 124, as seen in Fig. 12B, 13 are prepared consisting of tubular electronic housing members 126 electron beam (EB) welded at one end of the sub instrument assemblies 124 to a tubular transducer bellows adapter 128 with the opposite end of the electronic member 126 being Electron Beam welded to a tubular electronics pressure housing 130. In this case a pair of electronic pressure housings 130 are then fitted with the elongated bell reducer 120 and TIG welded. The reducer 120 is also fitted with compression connectors 112 and pipe bushing reducer fittings 116. Each of the electronics pressure housings 130 and their reducer fittings are then TIG welded into respective bores in the upper sensor body 122.

The open end of each of the transducer bellows adapters 128 is then fitted back to back with a compression fitting 112, an autoclave fitting 129 and a bushing reducer 116 threadably secured thereto. The autoclave fittings 129 being threadably secured to a lower body portion 134 that also includes a pressure nipple 136 extending there from. A ridged tube member 137 passes through the fittings 116, 112, and 129 between the transducer bellows adapter 128 and the lower sensor body portion 134 as shown in Fig. 12B.

008 As seen in cross section in Fig. 12A, data cable conductor sealing and termination is made within the sleeve assembly 26 previous disclosed in Fig. 11, except the fittings are

being welded at "B" to secure the threaded fittings thus preventing loosening due to temperature and pressure compression and expansions acting on the assembly 26. The mechanical sealing arrangement shown here is completely integrated and does not require the separate cable-head and Y-block components typical of other gauge assembly designs permanently installed in production well strings. The procedure also reduces or eliminates failure due to high-frequency vibration typical of a high capacity multi-phase well. Welding can only be done on the termination sleeve assembly 26 at points labeled "A". welding was used on all but the most delicate and sensitive points labeled "B" where Electron Beam (EB) welding was used to preserve the electronics within the sub-assemblies 124 as further seen in Fig. 12B to insure a more positive high pressure compression seal of all electronic components.

009 Although effective most of the time, the prior gauge assemblies 110, seen in Fig. 13, with their extended, vulnerable termination housing assemblies 26 and so many compression connector elements 112, 116, and 120 and assemblies 124 depending on welds "A" to secure their threaded connections, in many cases, were still time consuming to makeup and still subject to high temperature and pressure failures resulting from vibrations and impacts. Due to the possibility of failure, a redundant gauge is often paired in tandem with the active gauge assembly and connected in a side-by-side or parallel configuration using a common sensor pressure nipple 136 for both gauges. This nipple extends from the lower sensor body portion 134. The dual gauge assembly and dual channel circuitry provides full redundancy throughout the system. Such backup

using plural gauges increases the number of data cable connection assembly fittings and thus increases their exposure to potential harm.

010 Turning now to the second generation of unitized temperature and pressure gauge assemblies 140 illustrated in Fig. 14, we see the revised gauge assembly 140 includes a rectangular or cylindrical shaped upper termination/connection housing assembly (integrated pressure block) 142 and a lower sensor housing common to two gauges assemblies and end cap(pressure) block 144, connected by sub-assemblies 124. The rectangular pressure blocks 142, 144, have beveled or contoured corners 143 as seen in Fig. 14, which make the gauge assembly 140 compatible with the space requirement of the carrier pocket 20 described in Fig. 9.

011 As seen in Figs. 15, the instrument cluster or gauge block assembly 149 represents the latest improved version of the previous gauge block assembly 140 and eliminates many of the exposed fittings used in previous versions and further includes several new features. For example the data transmission cable and seal assembly 26 seen in fig. 12 A has now been shortened considerably and housed within a tubular fitting attached to the elongated termination/connection block or housing 142, 147. However, in later versions the termination/connection block or housing 166 has also been shortened considerably as seen in Fig. 15C and 15D.

012 It should be understood that a wide variety of unitized instrument complexes might be had by using a permanently welded gauge cluster that includes multi-channel transmission cables for gauge termination as well as data transmission cable passing

through the cluster to other gauge cluster assemblies. For example a cluster having a single gauge assembly 150 attached to connection/termination housing assembly 147 may have a single channel data transmission cable 154 entering and leaving the cluster assembly while providing an internal splice tap connection to the gauge assembly 150 as seen in Fig. 15A. The connection/termination housing assembly 147 includes an upper portion and a lower interface portion which when mated forms a sealed elongated contoured block unit having internal cavities and porting for making internal wiring connections prior to permanently sealing the assembly.

Note: transmission cables may enter and exit any connection/termination housing assembly 147 from either or both ends.

013 In some cases it may be desirable to combine dual gauge assemblies (parallel gauges having a common sensing element) as seen in Fig. 15 and single gauge assemblies 150 in a single cluster assembly connected to a single channel transmission data cable 164 as shown in Fig. 15B. Such dual gauge assemblies 149 may also utilize a local single gauge sensor assembly 177 and a fluidic sensor connection 159 extending from a dual gauge assembly 149 to a remote location.

014 In some cases it may also be desirable to have a data transmission data cable 154 feeding the gauge assembly complex located in parallel adjacent the gauge assemblies 140, 150 as shown in Fig. 15C.

015 In other cases it may be useful to have plural independent transmission cables 154, 155 connected independently, within the connection/termination block 166, to

the parallel gauge assemblies having a common sensor connector 159 as shown in Fig. 15D.

016 Various arrangements for such unitized instrument complexes that include clusters of single and dual gauge sensor assemblies located in tandem to each other in combination with transmission data cable termination and splicing connections contained in a single welded assembly are shown in Figs 15E-15N. As shown in Fig. 15E the most recent or most preferred embodiment shown in Figs.15 may be expanded to include multiple channel circuits and a plurality of gauge assembly configurations. As seen here in Fig.15E and Fig.15F, assembly 163 has two incoming cables 154, 155, and two dual gauge assemblies 188,189. The gauge assemblies 154, 155 are arranged diagonally in tandem pairs or individually in a staggered manner when connected to the connection/termination block or housing 167 and or its interface adaptor 166 as seen in Fig.15G. In this case one of the gauges assemblies is fitted with a fluid fitting 159 for connection to a port in the side pocket mandrel 200, seen in Fig.16. The second gauge assembly is also fitted with a fluid fitting and tubular extension 170 to allow for connection to porting in the side pocket mandrel 200 further along the mandrel thereby allowing readings to be taken at two points on the same mandrel by two individual circuits each having independent and or redundant gauge assemblies.

017 Looking now at Fig.15H, Fig.15J and Fig.15K we see the side-by-side gauge cluster assembly 180 having two data transmission cable circuits 154,155 entering the assembly

and two data transmission cable circuits 181, 182 leaving the assembly extending to other down hole instrument clusters located up or down the production string. In addition we have two independent gauge assemblies without redundancy. This arrangement allows the exiting cables 181 and 182 to be located at opposite corners of the interface adapter 166 and the independent gauges assemblies 151, 151' to be located in parallel along the upper edge. However, other arrangements are also possible.

018 Turning now to Fig. 15L and Fig. 15M we see that a full complement of gauges may be had as demonstrated by the gauge cluster assembly 187. In this case we have two data transmission cable circuit cables 154,155 entering the assembly and four data transmission cable circuits 181-184 leaving the assembly and two dual gauges assemblies 188, 190. This arrangement as seen in Fig. 15N utilizes up to eight ports into the upper adapter bloc 166. It should be noted that the dual gauge assembly 190 contains porting 192 to allow for well annulus fluid or gas access to the gauge assembly sensor.

019 Looking now at Fig. 16 we see an improved side pocket mandrel gauge carrier assembly 200 capable of containing the latest generation of unitized gauges cluster or circuit splitters having multiple gauge or instrument assemblies. As seen in Fig. 17, the carrier assembly 200 utilizes a much shorter side pocket 210, than in previous assemblies thus allowing space on the carrier assembly 200 for secondary transverse channels 202 for connecting bulkhead fittings 224, 232 as seen in Figs, 18-21. These bulkhead fittings 224, 232 connect the instruments and gauges fluidicly to internal porting, within the gauge carrier, leading to the through bore 34 as seen in Fig. 25.

Longitudinal channels 204 are also provided for cables 206, 207 which may also simply pass through the pocket and parallel outgoing cables 208, 209. As shown in Fig. 17 one end of the carrier pocket 210 contains a first primary bulkhead 212 having porting for communication with internal fluid flow through the carrier. An additional longitudinal channel 211 may be provided along each side of the pocket 210 for allowing non-terminating cables leading to other carriers to be channeled past the carrier 200.

020 The carrier pocket 210 may be fitted with a wide range of unitized clustered gauge assemblies or instruments 214 and secured in place with cover 216 includes internal rubber pad 213 for clamping the gauge assembly 214 in position.

021 As seen in Fig. 18 the miniaturized, unitized gauge or instrument assembly 214 seen in Fig. 19 may be a single gauge unit assembly 220 having a data transmission cable termination connection assembly 222 and a fluid sensor bulkhead fitting 224. The unitized gauge assembly 214 may also include a pair of gauges connected in parallel with a common upper connection block 142 with recessed data transmission cable connection assembly 156, and a common sensor housing interface adaptor 166 with a common fluid sensor bulk head connector fitting 232 as previously discussed and now shown in Fig 19.

022 In addition, current unitized assemblies may include an assembly 236 having a pair of parallel gauges with a common connection head block 142 and a combination of instruments or gauge assemblies 220, 220' each having their own fluid sensor connectors 224 as shown in Fig. 20.

023 Other assemblies such as gauge assembly 238, include a single gauge or instrument 220 in combination with a splitter head block 142 as seen in Fig. 21 whereby a transmission data cable 240 is divided or split into two circuits with one terminating at the gauge assembly 220 with another data transmission cable 242 exiting the upper connection/termination block 142 and traveling on to a remote gauge assembly located in another gauge carrier assembly 200 further up or down hole.

024 By utilizing the unitized gauge designs, it is now possible to located a gauge assembly 236 as shown in Fig.20 or any combination of instrument or gauge assemblies as desired in side pocket carrier mandrels 200 spaced a considerable distance apart as seen in Fig. 22 and connected in a manner whereby a pressure gauge in one carrier is coupled fluidicly to a pressure port located in a lower carrier and thus, for example, providing a pressure differential between the two gauges rather than simply monitoring the pressure at various points along the production string. This may also be accomplished within a single carrier, as shown in Fig. 23, where one gauge 220 is connected fluidicly to the through bore 34 by internal porting to the flow stream of the well at a first internal porting 30, 32 at transverse channel 202 shown in Fig. 24A, while a second gauge 220', shown in Fig.24B, is connected fluidicly by tubing 250 to a second internal porting 30, 32 at a second transverse channel 252 located at a lower point along the same carrier 200.

025 Using the arrangement shown in Figs. 24A and 24B a flow meter may be utilized down-hole to determine the volume of fluids passing through the production tubing

string. Such a flow meter may also be included in the gauge carrier as seen in Fig. 25. As seen here, the gauge carrier 320 also includes an internal expanded bore portion 255 extending for distance $\emptyset$ along the central bore 34. In this case as seen in Fig. 25A, one pressure gauge 220 is connected to an internal fluid porting 30,32 at traverse channel 202 and a second gauge 220' is connected to an internal fluid porting 30,32 at transverse channel 252. A flow rate is thus determined by the pressure differential between the constant flow rate pressure and the pressure in the expanded area 255.

026 The ability to form the expanded area 255 within the gauge carrier 320 without welding and thus maintaining the structural integrity of the carrier is an important feature because attempts to utilize common practices using the submerged arc EDM process failed.

027 Inconsistencies in tolerances due to EDM wire sag over the exceptional long length of the carrier bore were considered impossible to overcome. Therefore, a new process was developed using a buoyant electrode for precision horizontal sinker EDM applications.

028 So far we have illustrated and discussed the natural progression of the art and the issues involved in combining one or two gauges in a variety of configurations and combinations with a circuit splice termination housing as a single unitized assembly. However, as seen in Fig. 26, we see that it is also possible to combine more than two gauges or instruments in a plurality of configurations with multiple data transmission cable

circuit splitting and termination connections within a single unitized gauge cluster assembly for insertion in a single side-pocket gauge carrier.

029 In Fig. 26 we show an example of two circuit cables 302 and 304 entering the gauge assembly 300 at the gauge block 301 and two circuit cables 306, 308, leaving the assembly, as well as, two parallel gauge assemblies 310 arranged obliquely or in a diagonal manner as seen in Fig. 27. This arrangement also allows the assembly to fit securely within the pocket 305 of a side pocket mandrel 200 as shown in Fig. 28.

030 Other variations of the unitized gauge assembly may include at least six gauges or combinations of up to eight gauges and cables extending from the circuit splitter and termination gauge block 301, as shown arranged obliquely in diagonal pairs in Fig. 30 so as to fit easily in the gauge carrier as seen in Fig. 29. As shown in Fig. 29, the combination includes two entering cables 302 and 304 connected to the gauge block 322 where circuit termination is made for the gauges 310. Each of the circuits 302 and 304 are split within the gauge block 322 into two circuits exiting the gauge block 322 as cables 306, 308, 312 and 314 for connection to additional gauges further down-hole.

031 It should be understood that data transmission cable circuit splitting may be had using mini-gauges and unitized connection blocks with any combination of gauges and data transmission cable connections. An example of how the circuits may be arranged utilizing an indefinite number and types of instruments and gauges in circuit arrays is shown in Fig. 31. In this example we have the surface computer system 10 connected to two data

transmission cable circuits 302,304 leading to a first gauge block 322 as shown in Fig. 29. In addition to the termination of one circuit for the gauge assembly 310 we also have four additional data cable circuits, two circuits 306, 314 leading to the gauge assembly 236, and two circuits 308, 312 leading to gauge assembly 322 which in turn is connected to a traveling circuit extending further down-hole to additional gauges such as gauge assembly 214 making up the multiple circuit gauge array.

032 Further, in operation a proprietary telemetry platform combined with an innovative electronics design eliminates the need for intricate down-hole microprocessors and related support components that are notorious for premature gauge failures at elevated temperatures. The integrated electronic technology system utilizing the gauges as taught herein supports up to 64 intelligent completion devices (gauges or instruments) on a single conductor including multiple gauge assemblies, flow meters, valve controls, and other down-hole well monitoring instruments. Other system performance enhancements inherent to gauge design include fast polling modes exceeding 10 samples per second for select devices and enhanced resolution modes that permit the use of non-intrusive venturi type flow meter assembly 320 seen in Fig. 25. Adjustable period-counting gate durations assure the highest resolution attainable for a selected sample rate.

033 Multiplexing using the gauges disclosed herein is as follows:

As seen in Fig. 1, a single electrical penetration through the tubing hanger 330 is provided for supporting communication links 334 passing through the tubing hanger

330. These communication links are capable of connecting serial links to support redundant communications to multiple (at least three) combined pressure/temperature or flow meter down-hole gauges. The Sub-sea Control Module (SCM) 324 fully interfaces with the down-hole pressure, temperature and flow meter instruments or gauges via the redundant serial links. A plurality of serial data transmission lines connecting the SCM 324 to the down-hole sensors or gauge assemblies may be redundant. Therefore, no single fault in any of the redundant serial data transmission lines will result in a loss of functionality of the entire down-hole gauge sensor assembly at any given location. The control computer also communicates with the down-hole gauges via the SCM interface. An SEM 326 or gauge sensor channel failure does not affect the correct reading of the gauge sensors by the operational SEM 326 and sensor channel. One or more of the SEMs 326 located within in the SCM 324 is connected to signal channels/circuit cables 302 and 304 as seen in Fig. 31. Redundant gauges within each of the gauge cluster assemblies also communicate to the SCM/SEM 324/326 via a (redundant) serial link to the electronic interface equipment. Connectors 334 located with in the tubing hanger 330 carry serial transmissions to the SCM/SEM. The Sub-sea Control System (SCS) 328 remotely controls the down-hole gauges, turns power on/off to the gauge sensors, and reads their status and produces alarms. Down-hole sensor proprietary software is fully integrated into the SCS 328, providing the ability to upload and use the sensor's calibration coefficients for the correct calculation of the readings in engineering units. The SEM 326 also provides

input supply overload protection to isolate it from the rest of the system in case a fault occurs within the SEM. It should be noted that an SEM 326 fault does not affect any SEM connected to the same power/signal channel. Computer system 10 also provides overload protection for the remote digital/analog input and output. A faulty gauge sensor or a down-hole control valve does not affect the correct operation of the SEM 326 or any other sensor. The SCM/SEM 324/326 fully interfaces with down-hole pressure/temperature gauges, that are configured to provide digitized net outputs of Pressure, Temperature Flow and Fluid Density from each zone completed. The system provides an array having clusters of unitized gauge complexes with dual, triple, quad or even greater numbers of down hole parallel gauge assemblies, that together with diagnostic data represent the data transmission of less than 128 x 16 byte packets for any one data set, collected in any single well.

034 Sampling Rates and Data Storage

- a) Data storage rate for the down-hole gauges are capable of fast scans greater than 10 values/second.
- b) The sampling rate is configurable from topside and can be triggered by a particular event or from a topside command.
- b) The fast scan data can be stored in the SEM memory and uploaded from a topside command. A minimum of six gauge sensors provides simultaneous monitoring in fast-scan mode.
- c) It is possible to set the individual scan rate of between 1 an 35 sensors

connected to the same SCM, such that the reading update for these sensors is less than 1 second. These sensors in fast scan do not degrade the overall scan rate of the channel to which they are connected.

035 Reliability of the down-hole gauge assemblies and associated disclosed technology has proven to be remarkably reliable. Using the "Relex" [®] software reliability package and MIL-HDBK 217-FN2 models show a 90 percent survival probability of nearly 17 years at a temperature of 350 degrees F.

036 Because many varying and different embodiments may be made within the scope of the inventive concept herein taught, and because many modifications may be made in the embodiments herein detailed in accordance with the descriptive requirement of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in any limiting sense.

WHAT IS CLAIMED IS:

- 1 A permanent down-hole production well monitoring system comprising:
 - a) a surface data computer system having electronic interface connected to a plurality of down-hole instrument clusters located within a production string each of the instrument clusters comprising a unitized complex having a plurality of parallel gauge assemblies;
 - b) at least one data cable connected to each unitized gauge complex internally connected to at least one of the gauge assemblies;
 - c) a high pressure compression assembly means for sealing an electrical data cable within a portion of the unitized gauge complex;
 - d) a means connected to at least one of the gauge assemblies located within the unitized complex for sensing flow characteristics including temperature and pressure of the production well; and
 - e) a tubing sub mandrel having a full through bore and a side pocket contoured to receive at least one of the instrument clusters.
2. The permanent down-hole production well monitoring system according to claim 1 wherein at least one of the gauge assemblies is redundant and shares a common sensory input with an adjacent gauge assembly.

3. The permanent down-hole production well monitoring system according to claim 1 wherein the unitized gauge complex comprises:
 - a) an elongated termination/connection housing assembly having a permanently sealed wiring cavity and internal porting therein;
 - b) at least one tubular data transmission cable seal housing attached to the termination/connection housing assembly;
 - c) at least three tubular gauge assemblies located in parallel connected at one end to the termination/connection housing assembly; and
 - d) an external fluidic sensing element and housing assembly common to at least two of the tubular gauge assemblies located at an end of the gauge assemblies opposite the termination/connection housing.
4. The permanent down-hole production well monitoring system according to claim 1 wherein the high-pressure compression seal assembly is a biased plug-in connection assembly.
5. The permanent down-hole production well monitoring system according to claim 1 wherein the means connected to at least one of the gauge assemblies for sensing flow characteristics of the production well comprises temperature and pressure sensing elements.

6. The permanent down-hole production well monitoring system according to claim 3 wherein the unitized gauge complex further comprise at least one tubular data cable seal housing locate in parallel to the gauge assemblies attached to the termination housing.
7. The permanent down-hole production well monitoring system according to claim 3 wherein the external fluidic sensing element is a fluidic connection to porting located within the tubing mandrel carrying the unitized gauge assembly.
8. The permanent down-hole production well monitoring system according to claim 3 wherein the external fluidic sensing element is a fluidic connection to remote tubing mandrels containing instrument clusters.
9. The permanent down-hole production well monitoring system according to claim 3 wherein the gauges clusters comprise a plurality of gauge assemblies and data transmission cable assemblies attached to the termination/connection housing in a parallel diagonal arrangement.
10. The permanent down-hole production well monitoring system according to claim 7 wherein the side pocket portion of the tubing mandrel is size cooperative with the

gauge cluster to be installed therein, the gauge cluster located and secured within the side pocket with resilient pads and a removable cover.

11. The permanent down-hole production well monitoring system according to claim 7 wherein the tubing mandrel further comprises external longitudinal channels extending externally along the length of the tubing mandrel that are cooperative with data transmission cables and fluidic tubing leading to fluidic sensing elements within remote gauge clusters.
12. The permanent down-hole production well monitoring system according to claim 11 wherein the tubing mandrel further comprises transverse channels and threaded internal fluidic porting located within the side pocket and transverse channels leading to the longitudinal through bore of the mandrel.
13. The permanent down-hole production well monitoring system according to claim 12 wherein the side-pocket tubing mandrel further comprises an expanded portion of the internal longitudinal bore of the side-pocket mandrel forming a flow meter.
14. The permanent down-hole production well monitoring system according to claim 12 wherein the internal port located in at least one of the transverse channels

communicates fluidicly with the internal through bore of the expanded portion of the tubing mandrel.

15. A production well monitoring system having a permanent down-hole gauge cluster assembly comprising an elongated unitized connection/termination block assembly, a plurality of parallel gauge assemblies connected to the connection/termination block in a staggered manner each of the gauge assemblies having a sensing means for measuring production flow conditions down hole, the gauge cluster located within a side pocket mandrel having means for securing the cluster therein, the unitized connection/termination block assembly having at least one data transmission cable seal termination assembly.
16. The production well monitoring system according to claim 15 wherein said tubular gauge assemblies include a pressure gauge and a temperature gauge.
17. The production well monitoring system according to claim 16 wherein said pressure gauge includes a bulkhead high-pressure fluid fitting located at one end.
18. The production well monitoring system according to claim 15 wherein said connection/termination block assembly and gauge assembly further comprises a plurality of dual gauge assemblies located in tandem.

19. The production well monitoring system according to claim 15 wherein said connection/termination block assembly and gauge assembly further comprise a plurality of data transmission cable sealing and connection/termination assemblies located adjacent and parallel to said tubular gauge assemblies.
20. The production well monitoring system according to claim 15 wherein said connection/termination block assembly and gauge assembly further having means therein for terminating an electrical circuit at said tubular gauge assemblies and further connecting a plurality of electrical circuits entering said connection/termination block assembly to a plurality of electrical circuits leaving said connection/termination block assembly.
21. The production well monitoring system according to claim 20 wherein the tubular gauge assemblies and adjacent data transmission cable seal housings are attached to the connection/termination block assembly in a staggered manner.
22. A method for assembling a permanent down-hole gauge cluster within a through bore, side pocket gauge mandrel, having a flow meter therein, comprising the steps of connecting the porting intersecting the longitudinal central bore of the mandrel to at least one of the gauge assemblies located in the gauge cluster and connecting the

porting intersecting an expanded portion of the central longitudinal bore of the mandrel to a second gauge assembly.

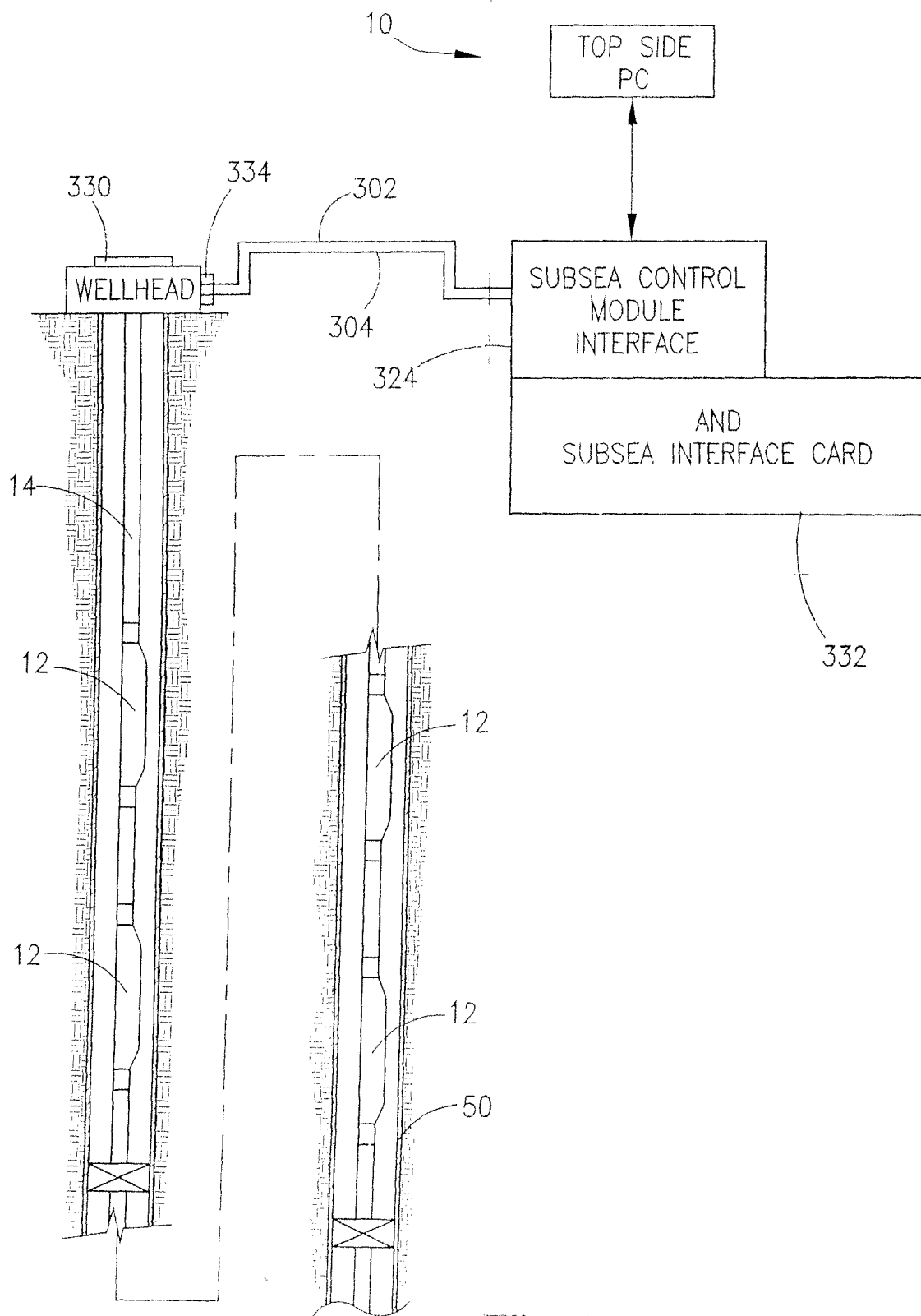
23. A production well monitoring system having permanent down-hole gauge clusters comprising a down-hole gauge array having a plurality of gauge clusters of up to 64 individual gauge assemblies connected to a single data transmission cable circuit with polling modes of up to 10 samples per second, and adjustable period, counting gate durations.

24. The production well monitoring system according to claim 23 further comprises isolated operational redundancy of system electronics and transducers at all installation points within the production string.

25. The production well monitoring system according to claim 23 wherein the system further comprises redundancy in a manner whereby each of the gauge assemblies operates individually, providing independent sensor measurements for data redundancy and integrity verification.

26. The production well monitoring system according to claim 23 wherein the system further comprises densitometers and flow meters incorporated in a parallel quad gauge assembly.

27. The production well monitoring system according to claim 23 wherein the system further comprises a sub-sea computer interface card for receiving digital data packets from a plurality of independent down-hole gauges in the array, the interface card having means for reading the digital packets and converting the data packets to frequencies, appending the status information and storing derived data in MODBUS registers for transmission to a top-side computer and further converting the frequencies to engineering units.

***Fig. 1***

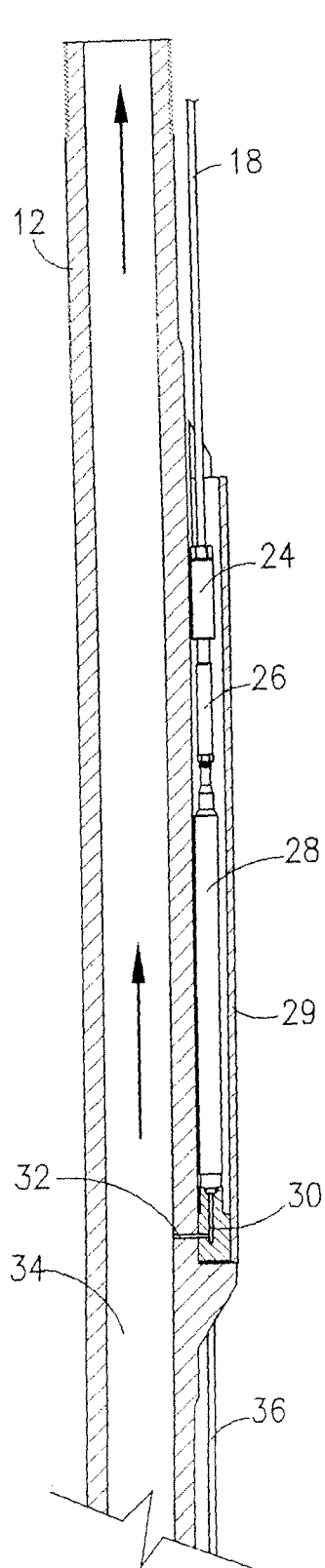


Fig. 2
PRIOR ART

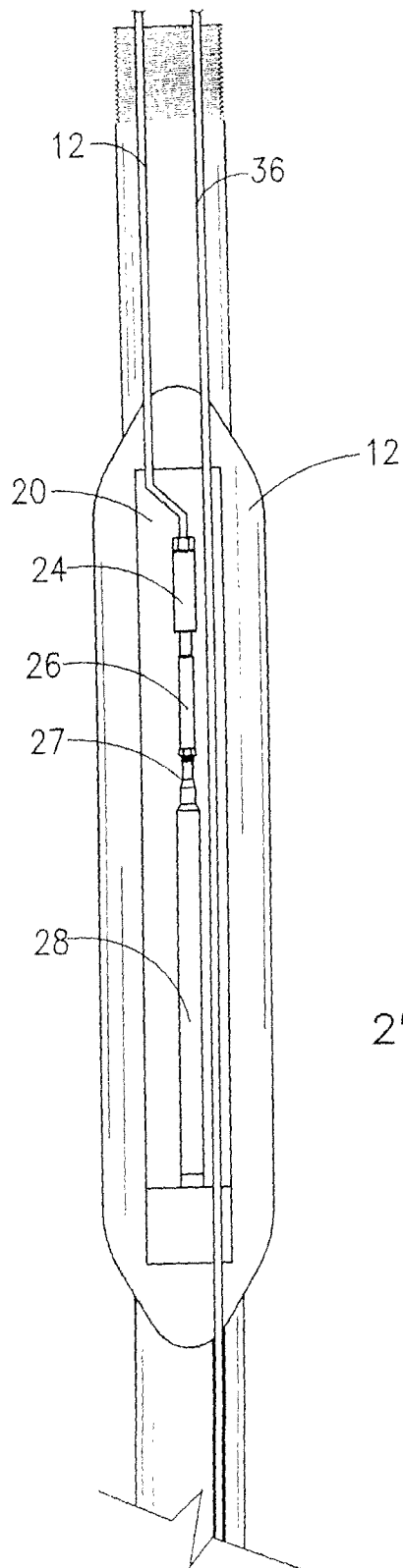


Fig. 3
PRIOR ART

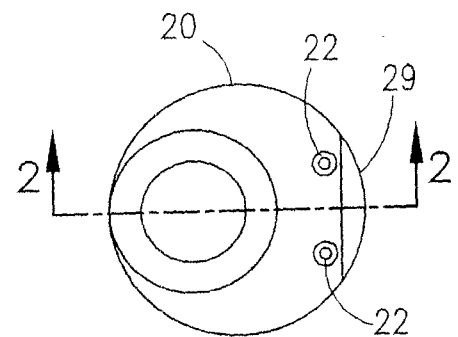


Fig. 4
PRIOR ART

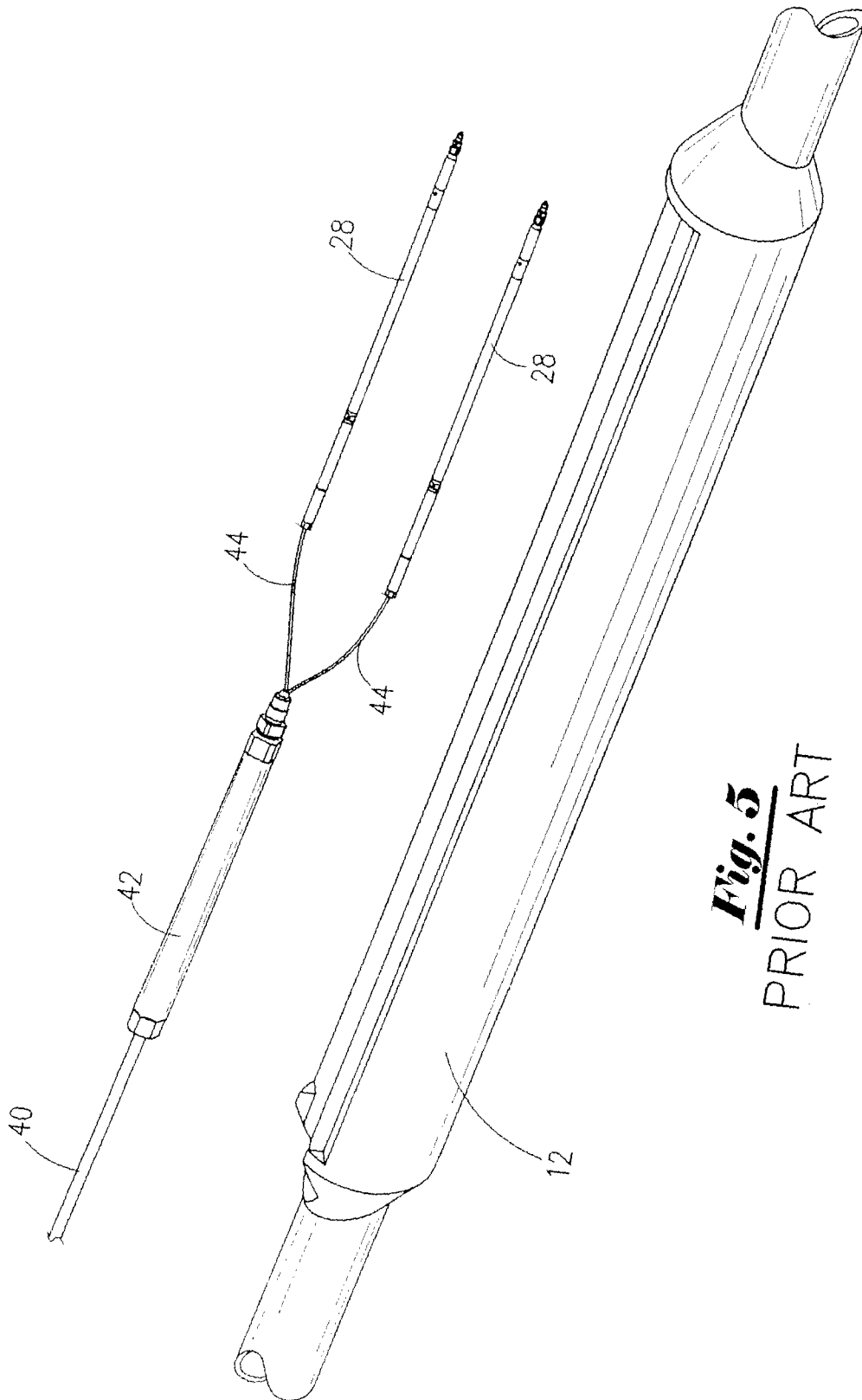


Fig. 5
PRIOR ART

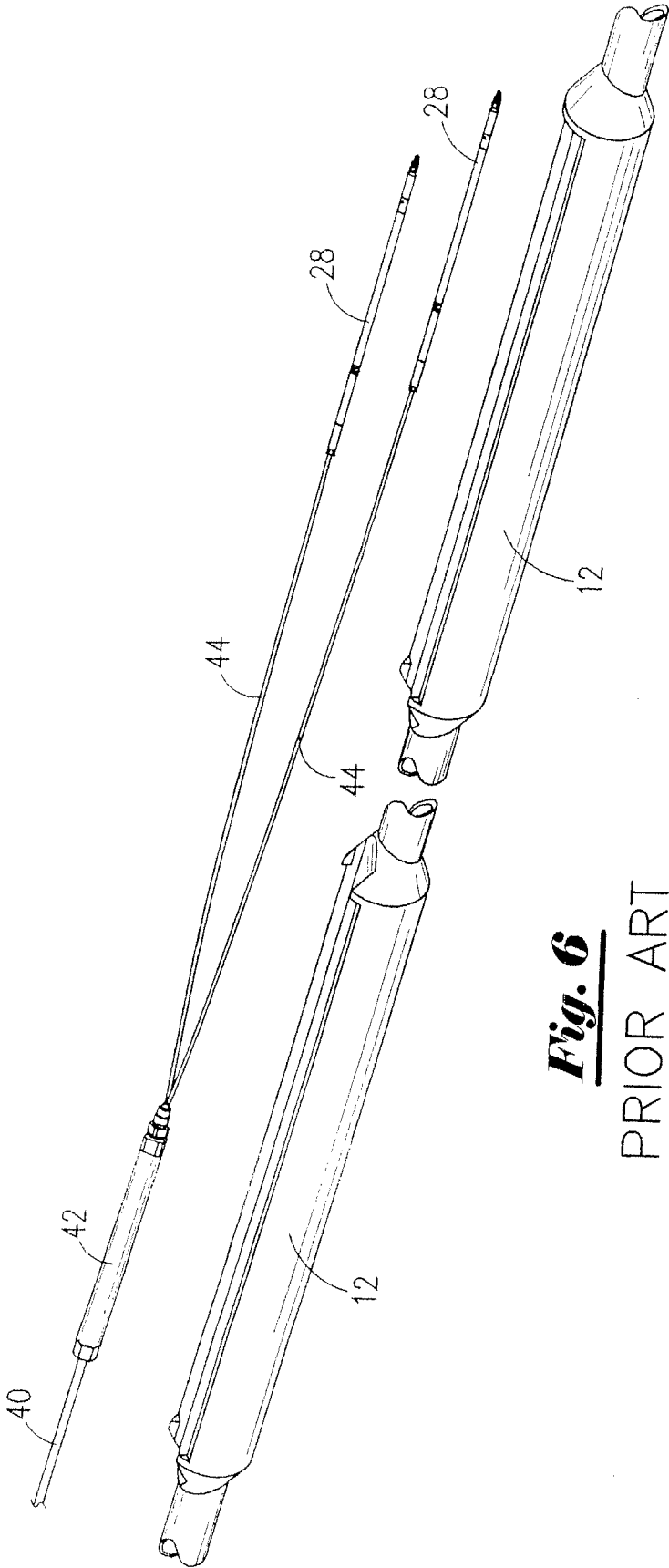


Fig. 6
PRIOR ART

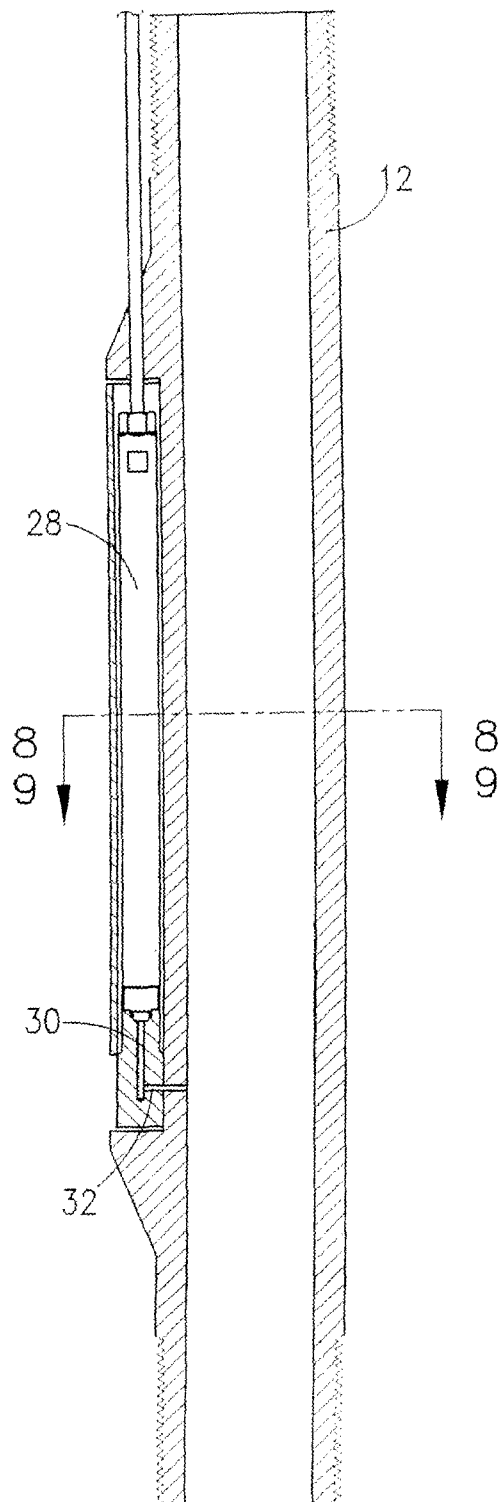


Fig. 7
PRIOR ART

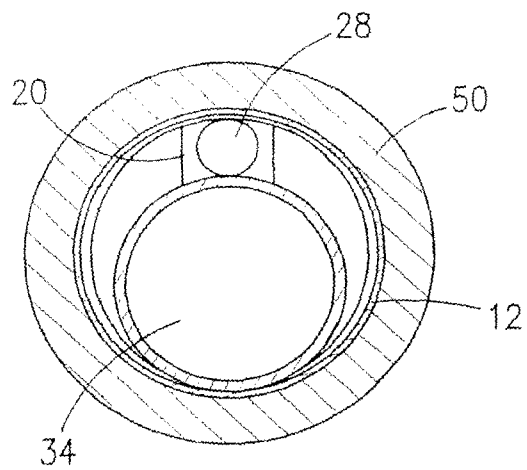


Fig. 8
PRIOR ART

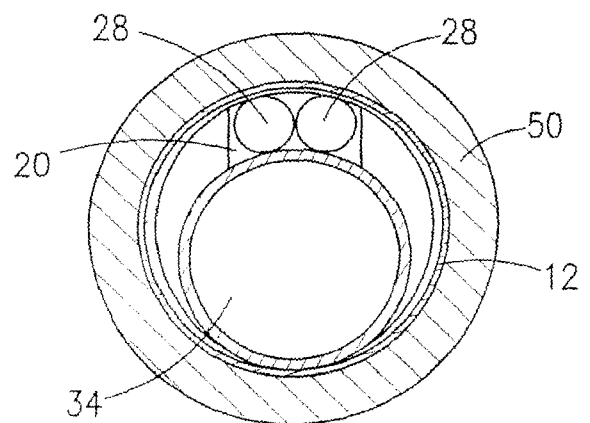


Fig. 9
PRIOR ART

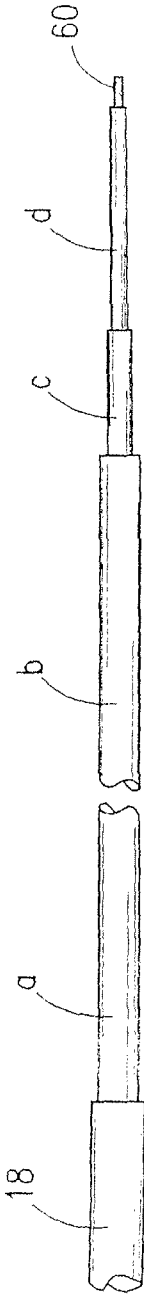


Fig. 10
PRIOR ART

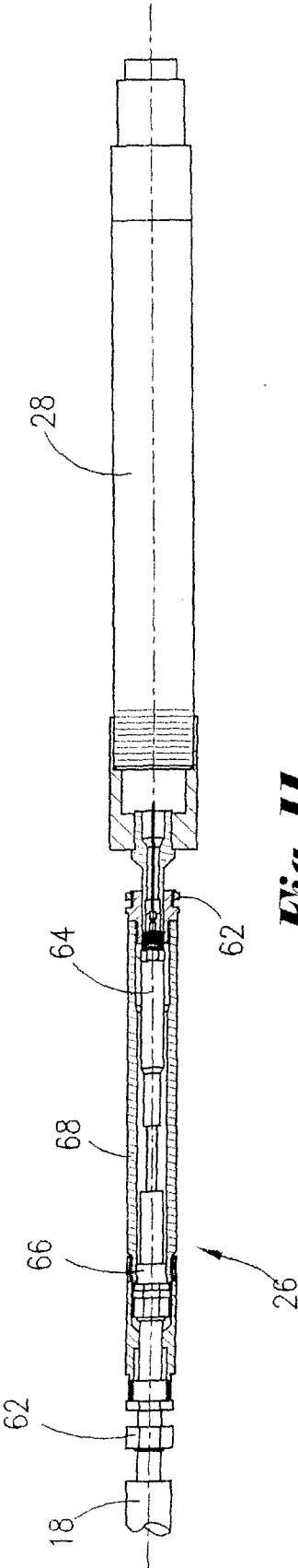


Fig. 11
PRIOR ART

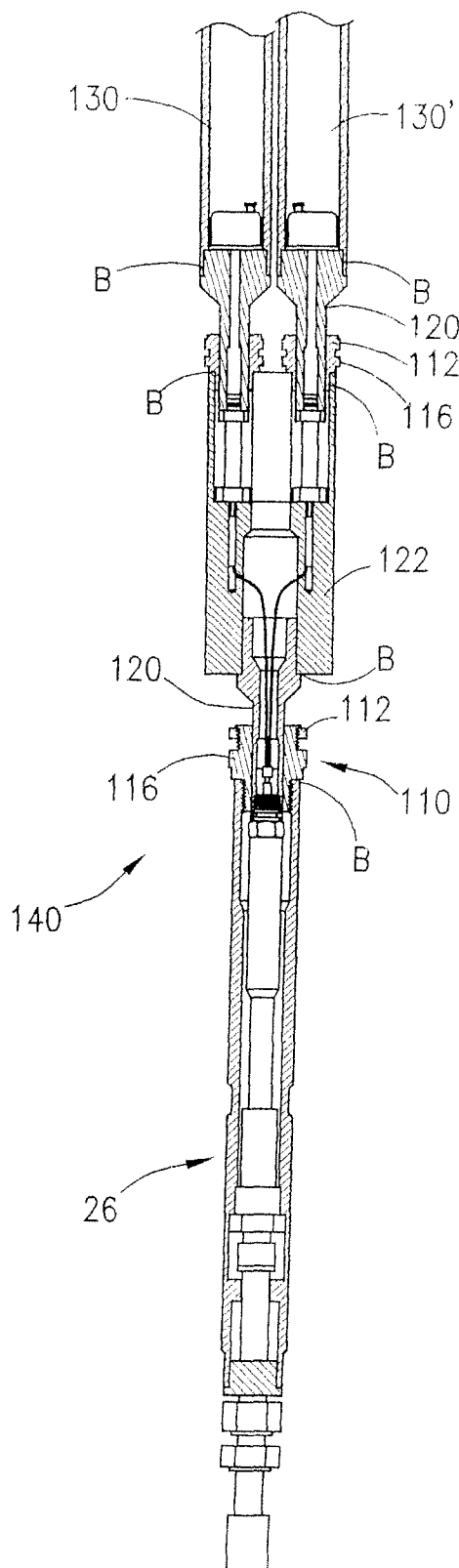


Fig. 12A
PRIOR ART

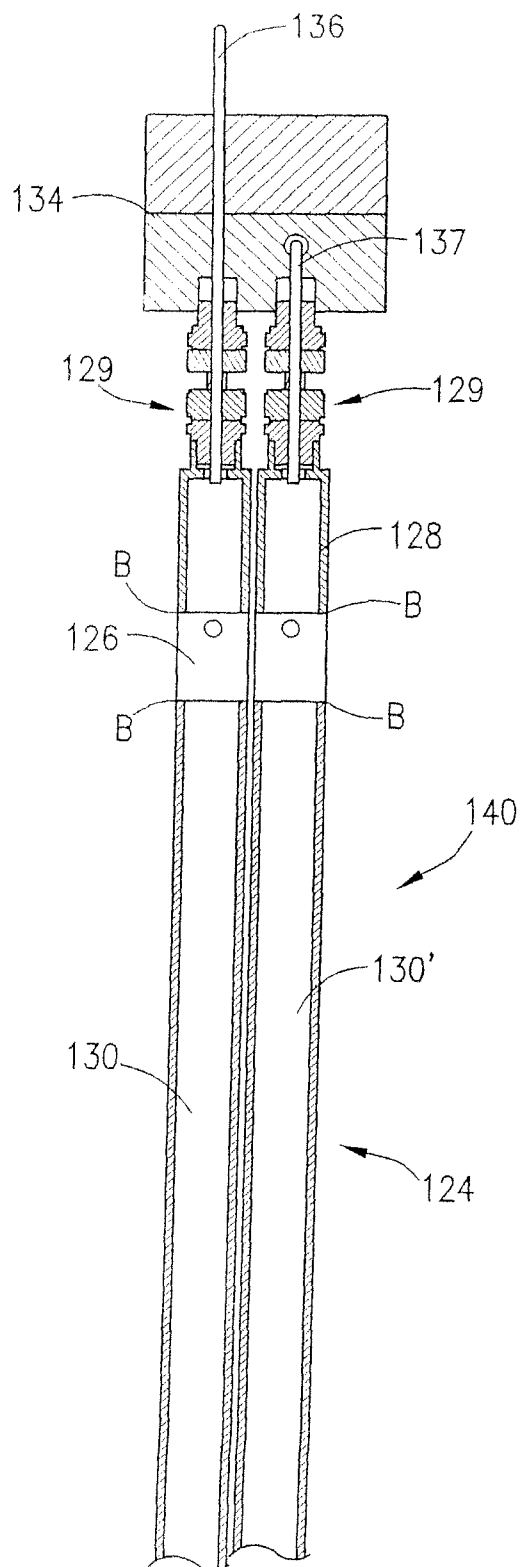
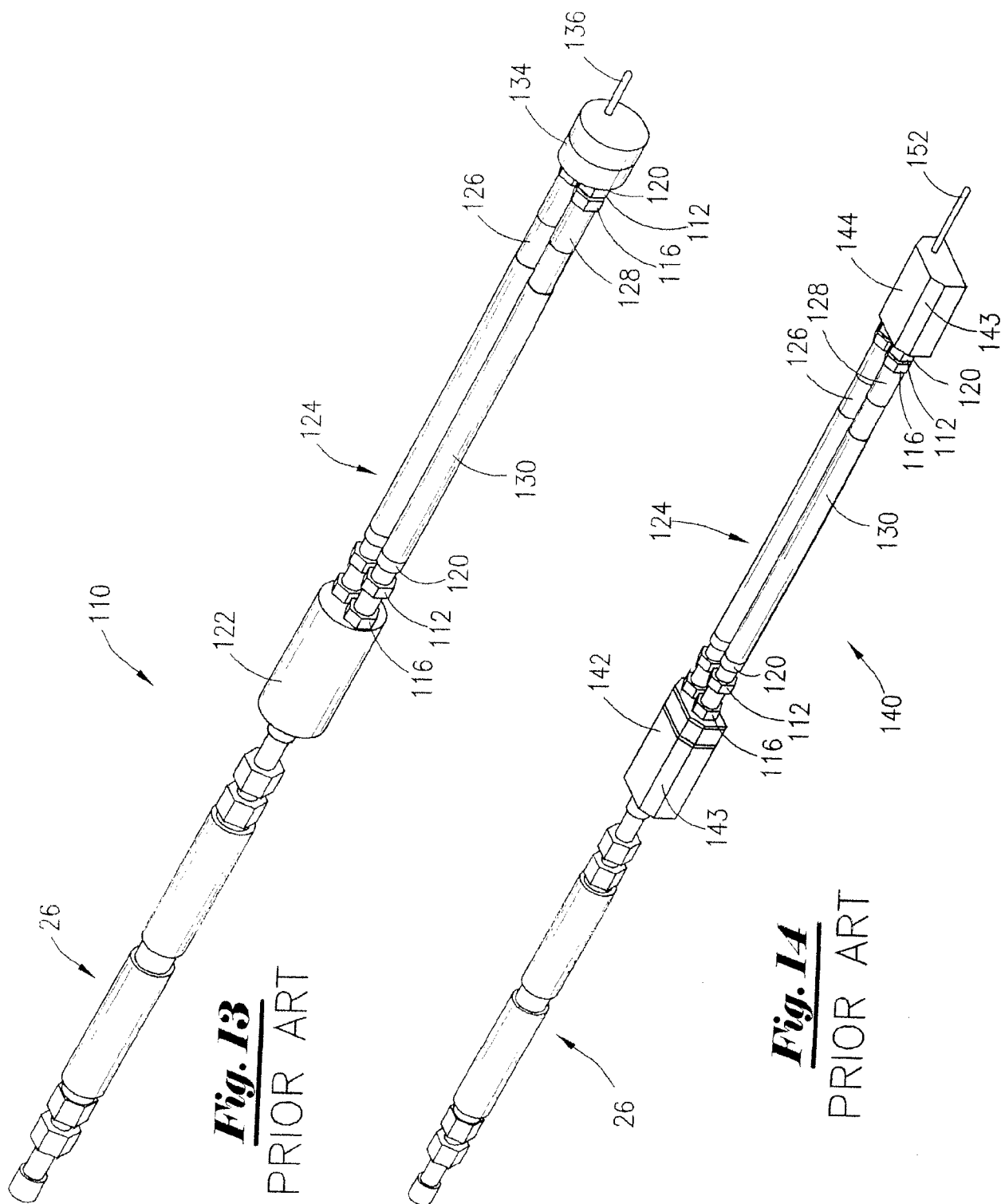


Fig. 12B
PRIOR ART



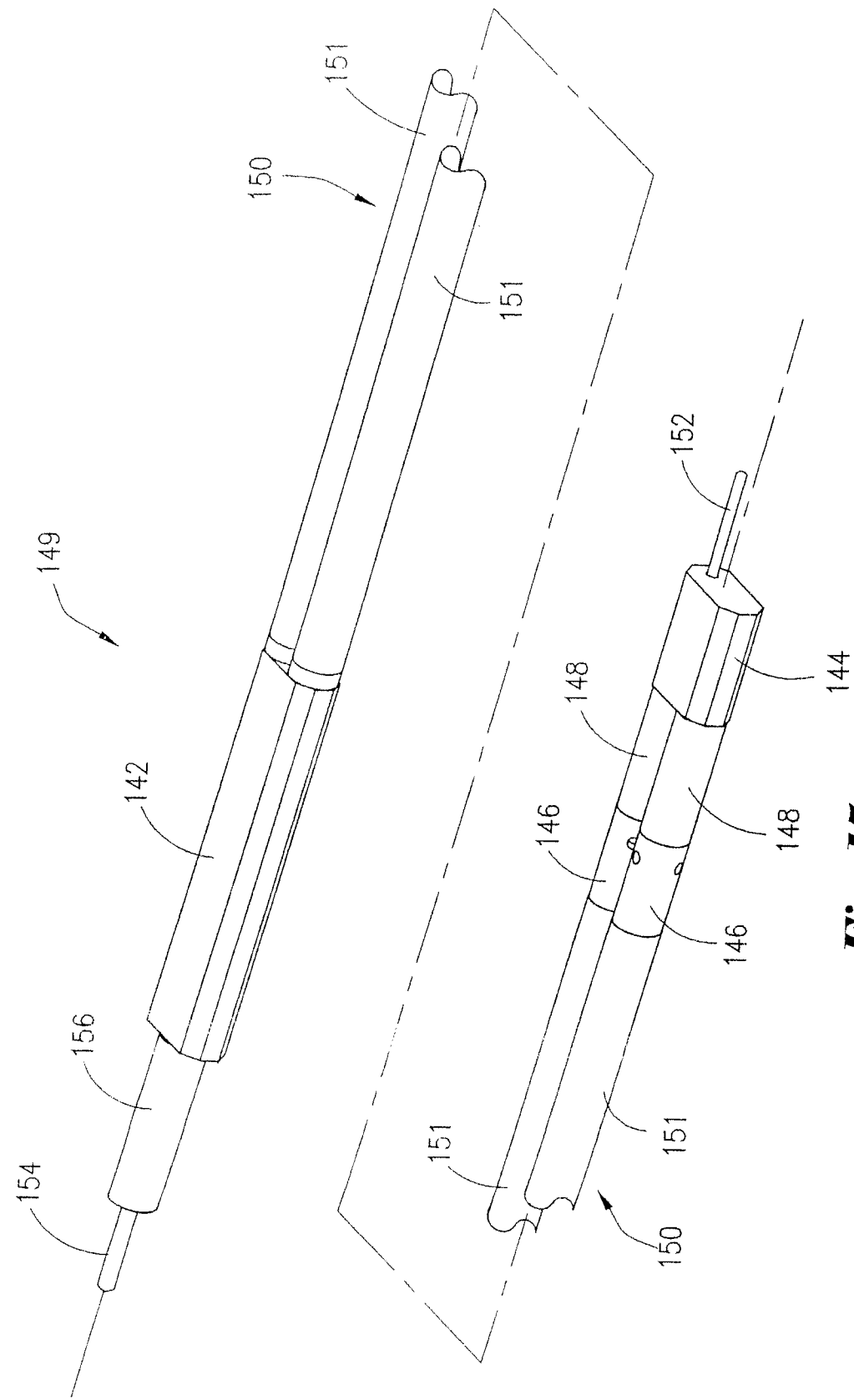
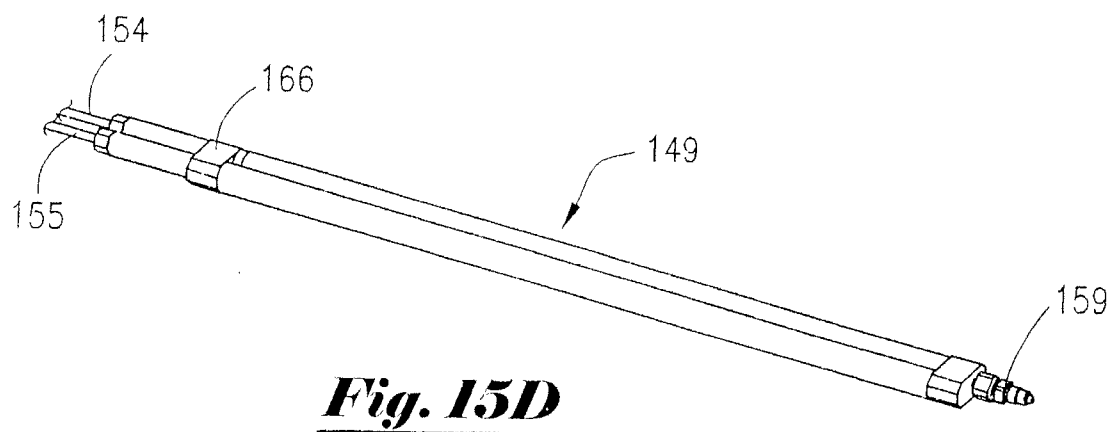
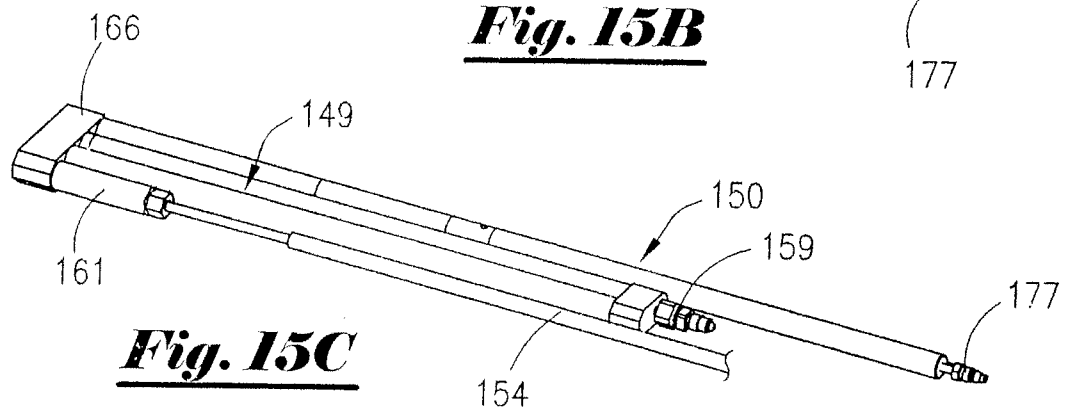
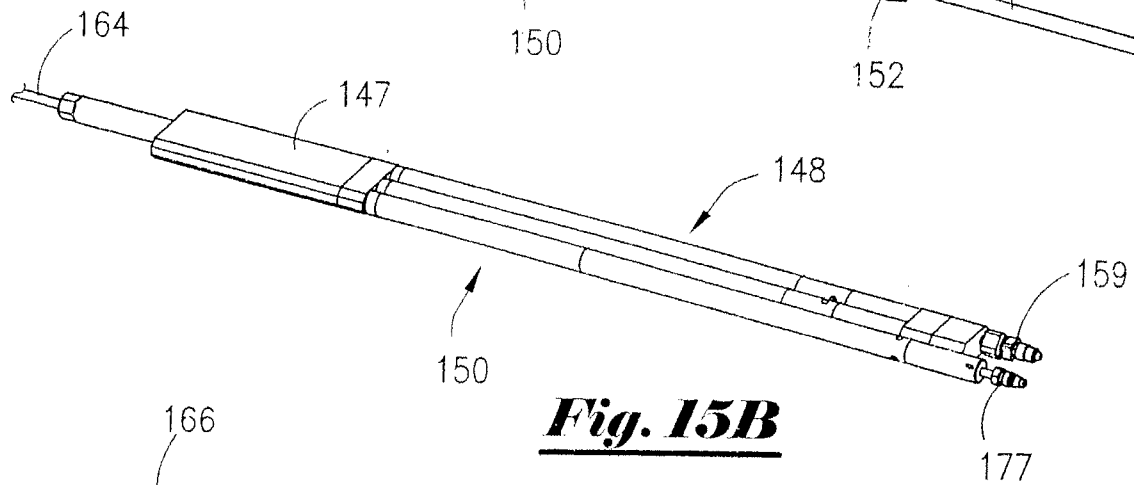
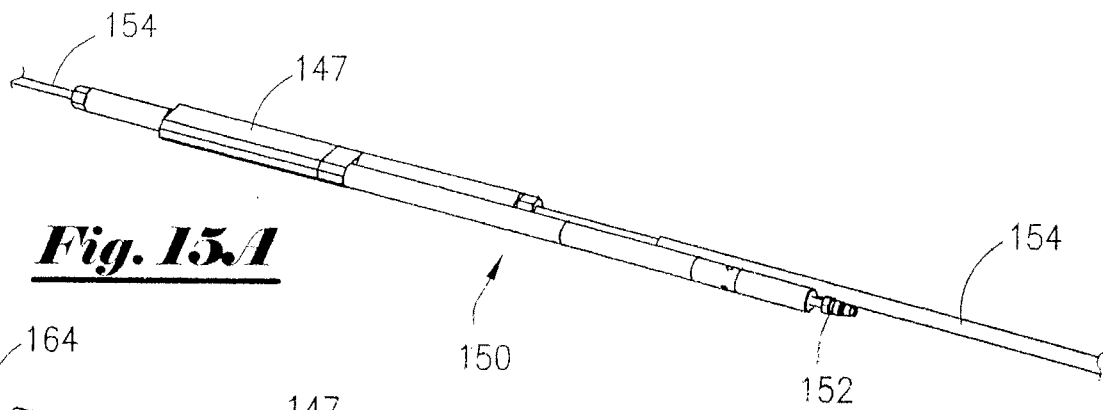


Fig. 15



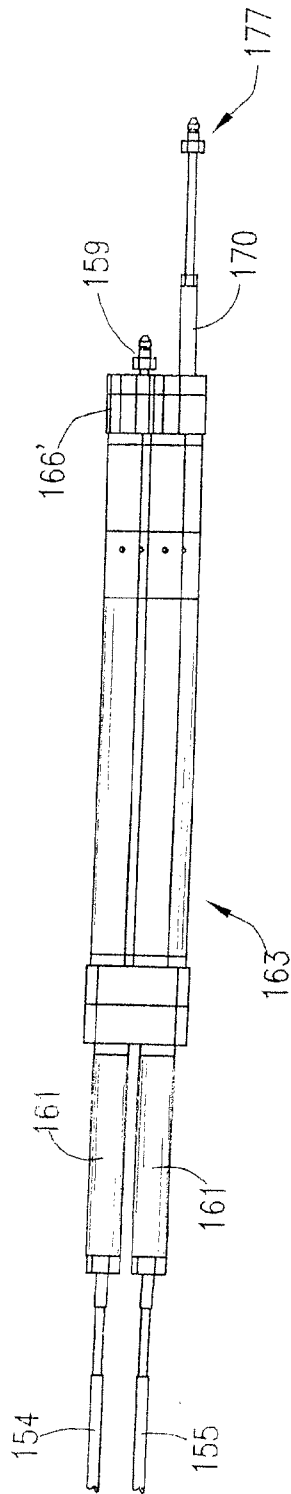


Fig. 15E

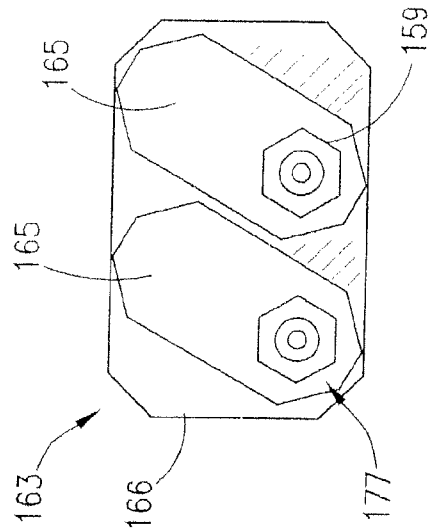


Fig. 15G

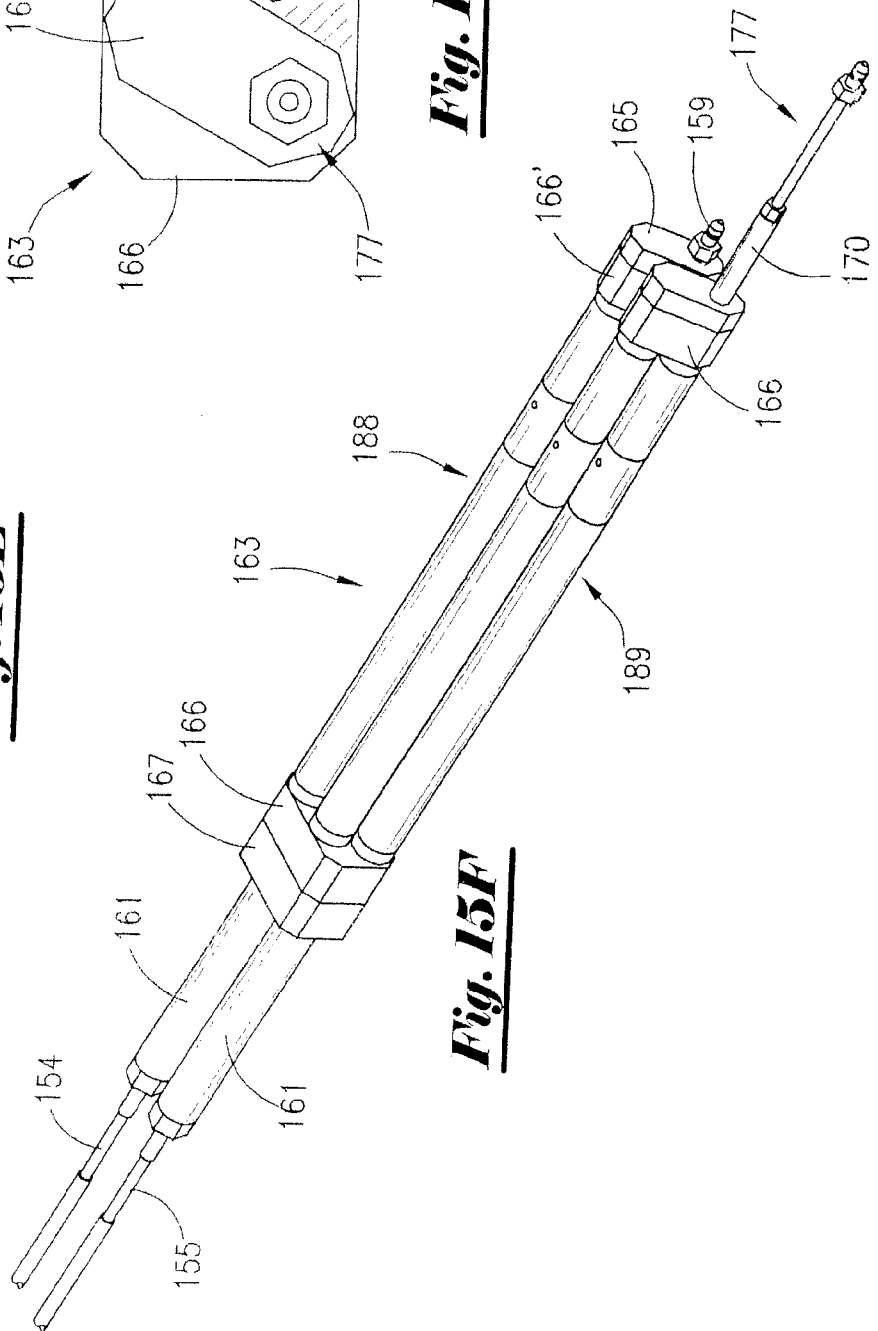
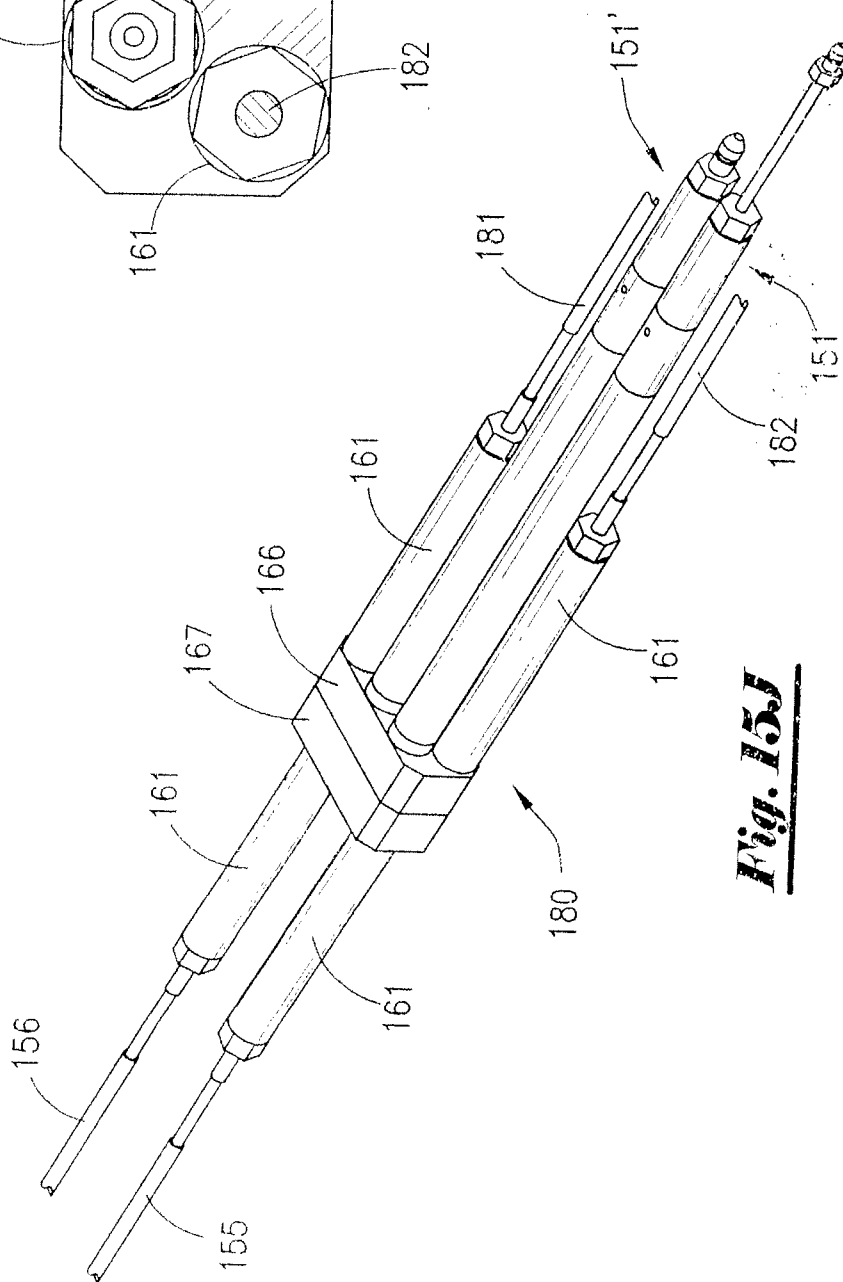
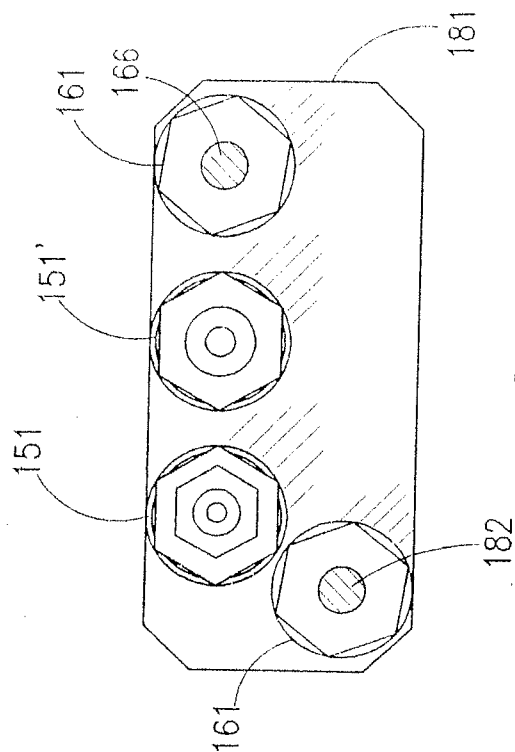
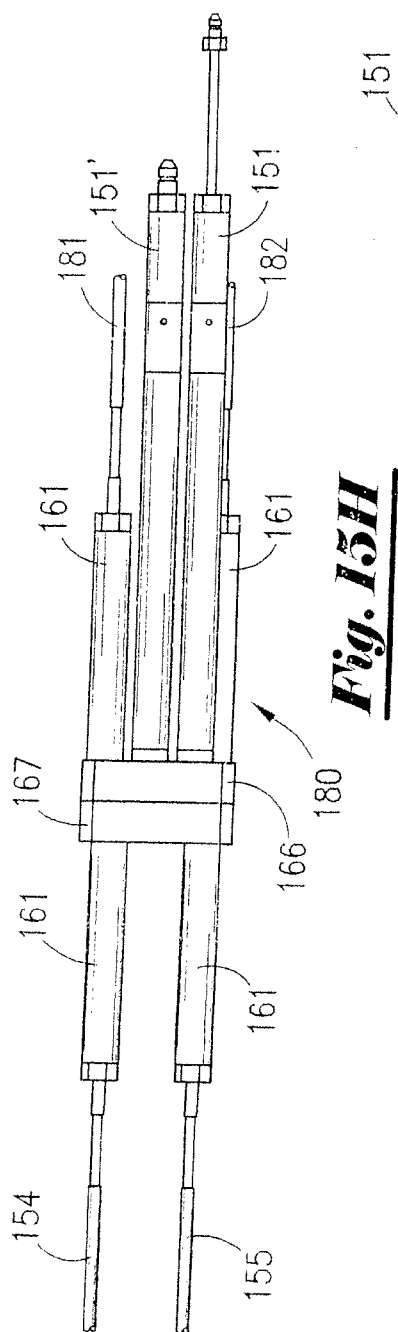


Fig. 15F



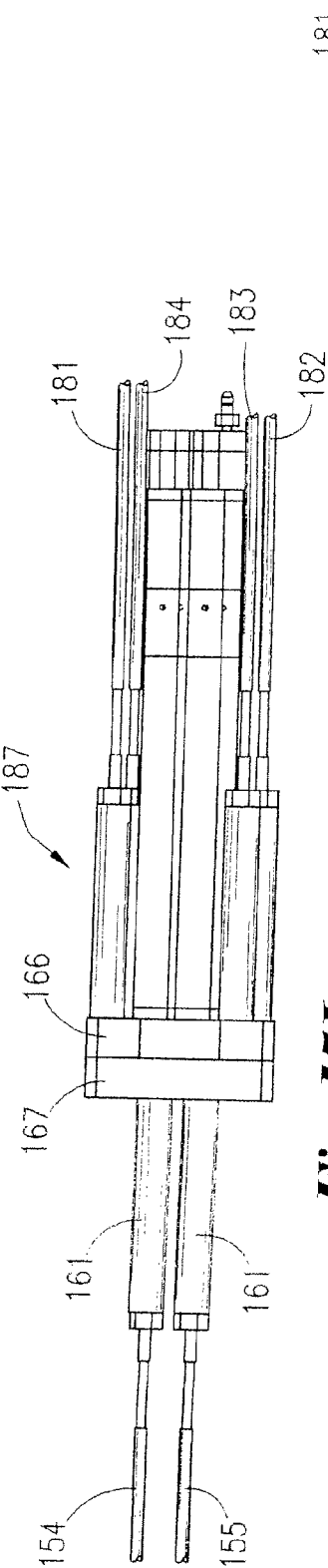


Fig. 15L

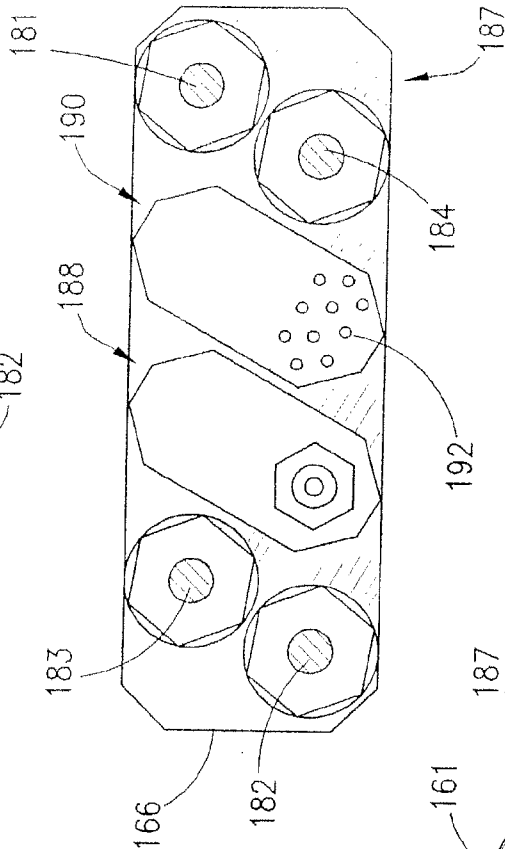


Fig. 15N

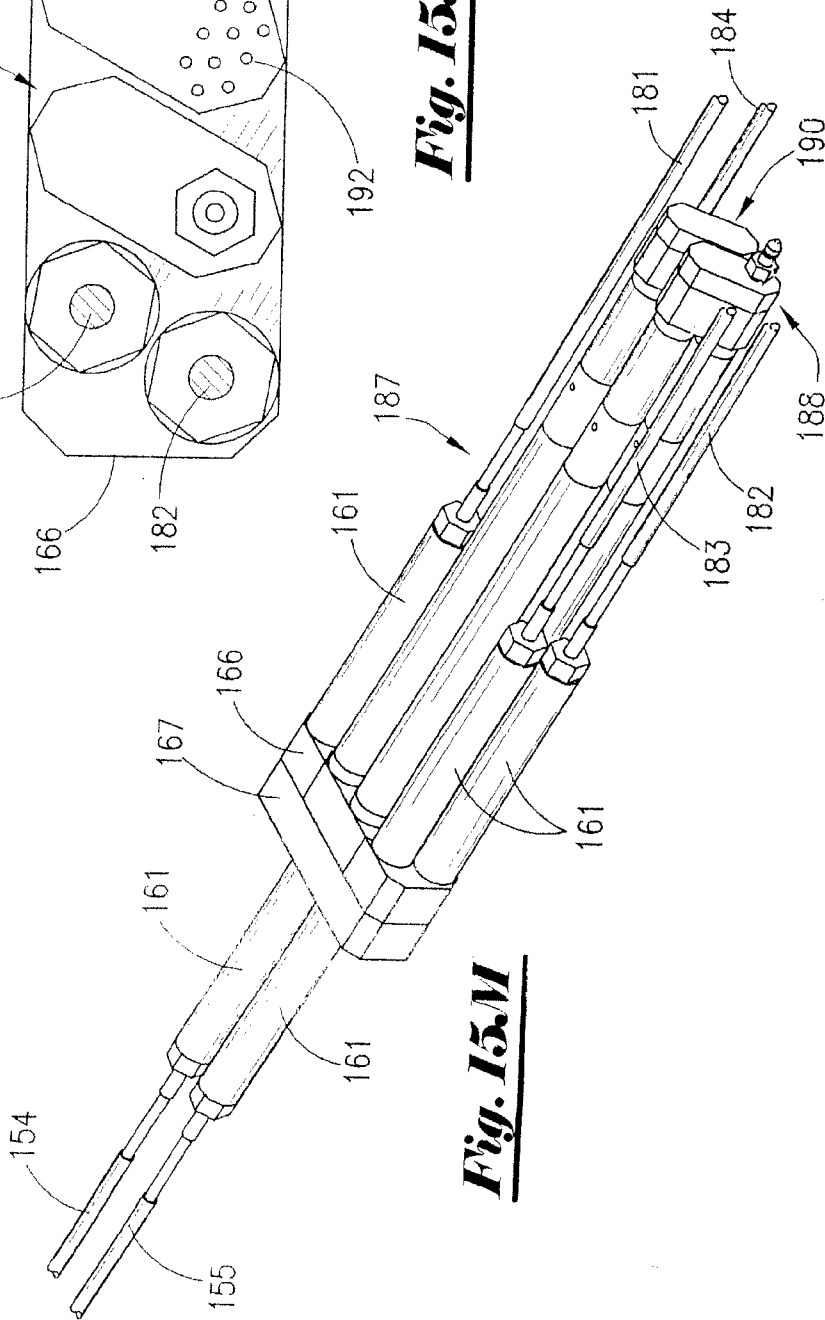
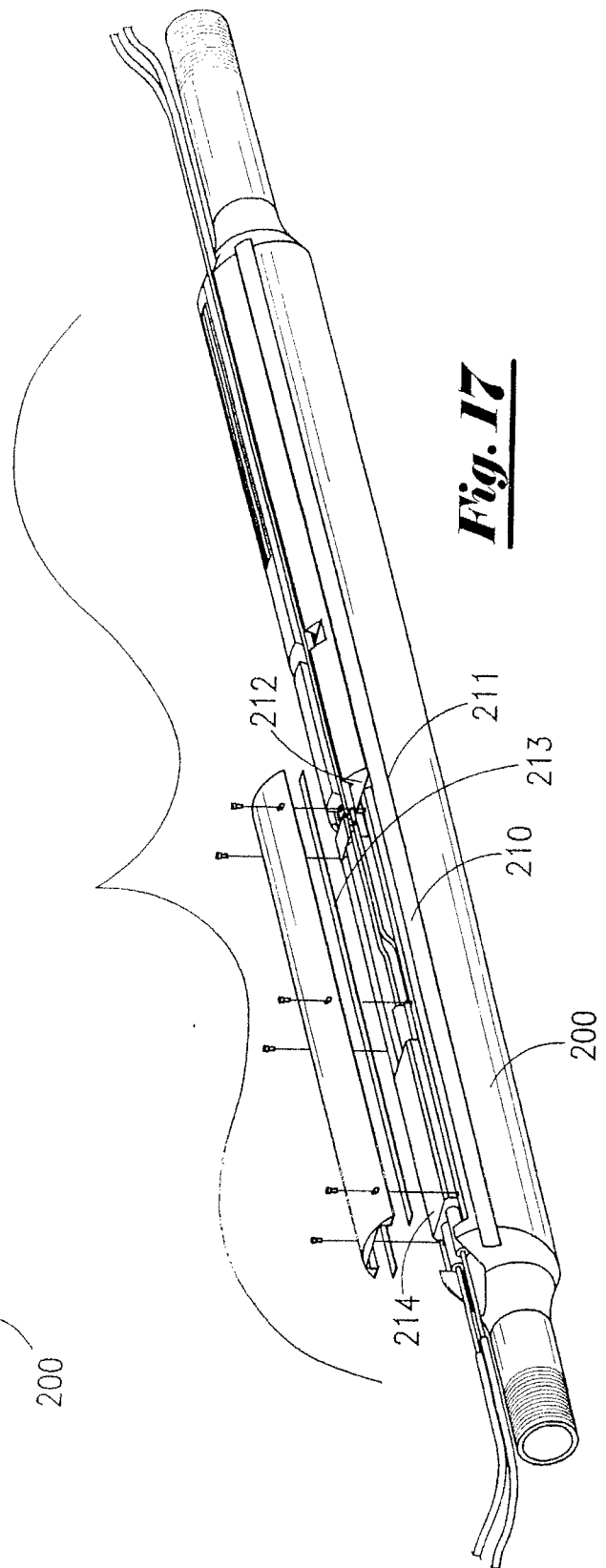
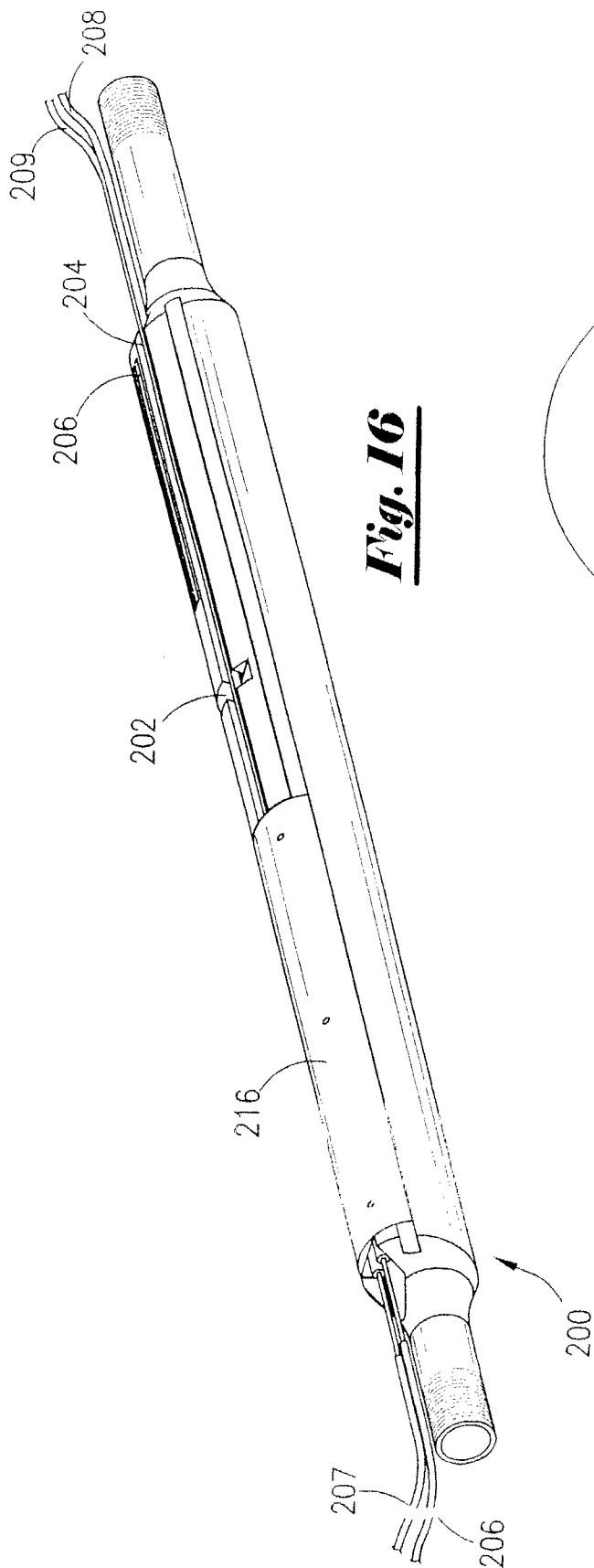


Fig. 15M



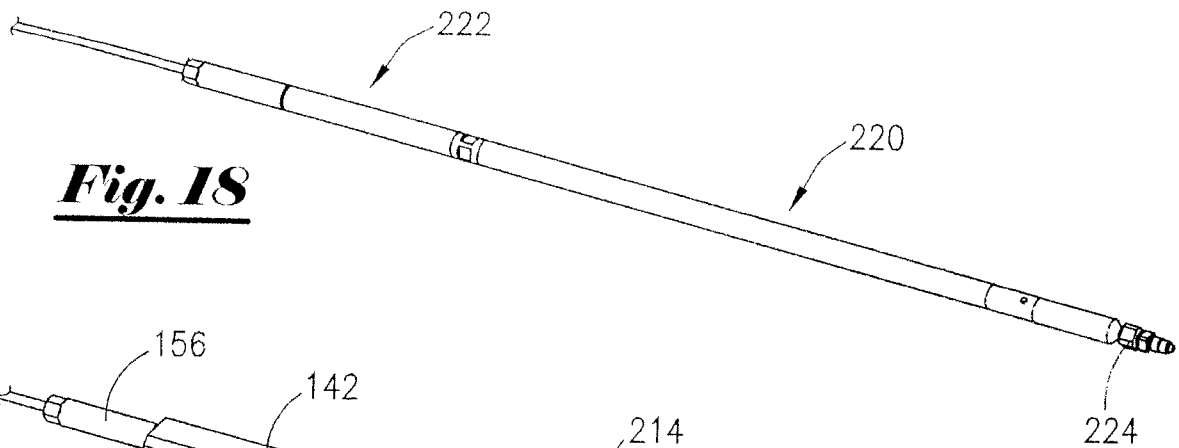


Fig. 18

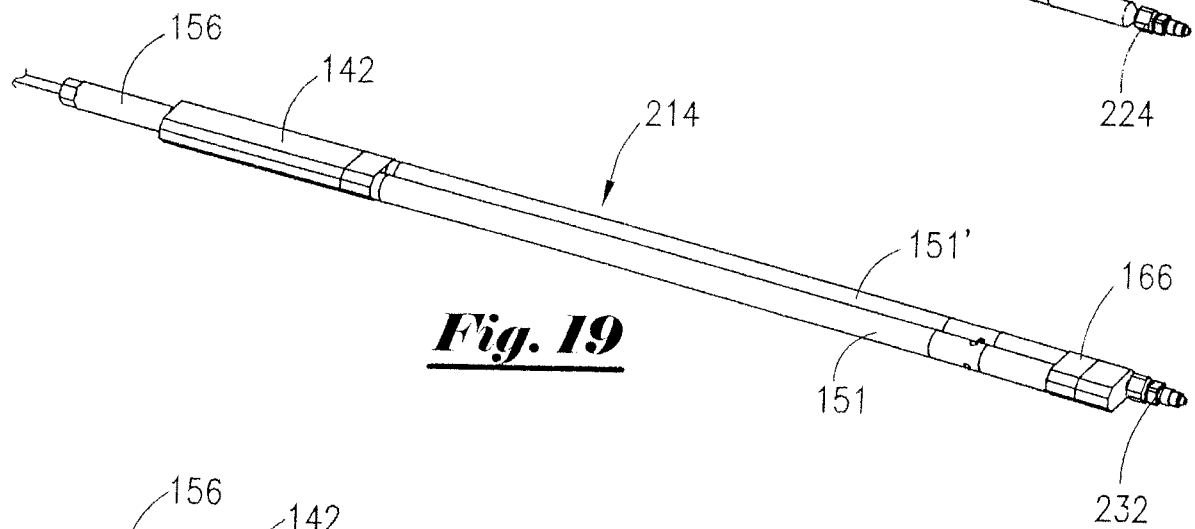


Fig. 19

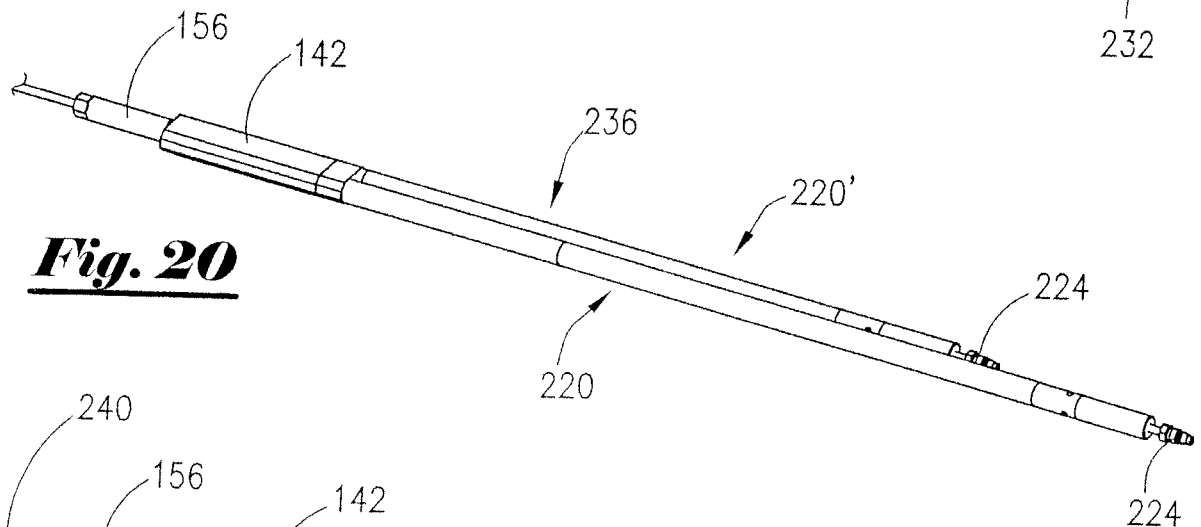


Fig. 20

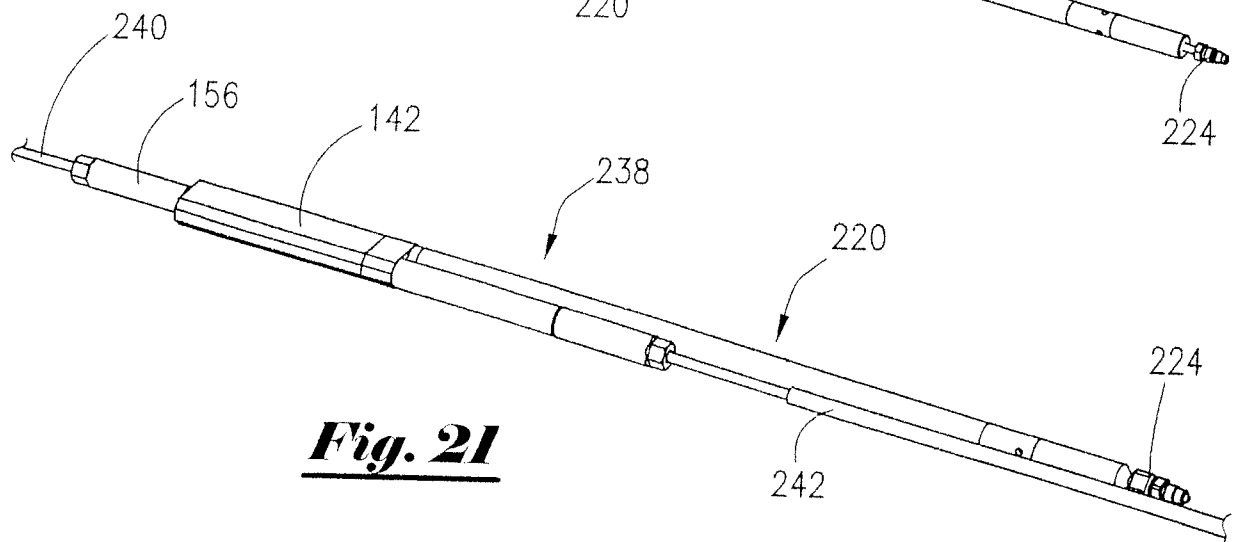


Fig. 21

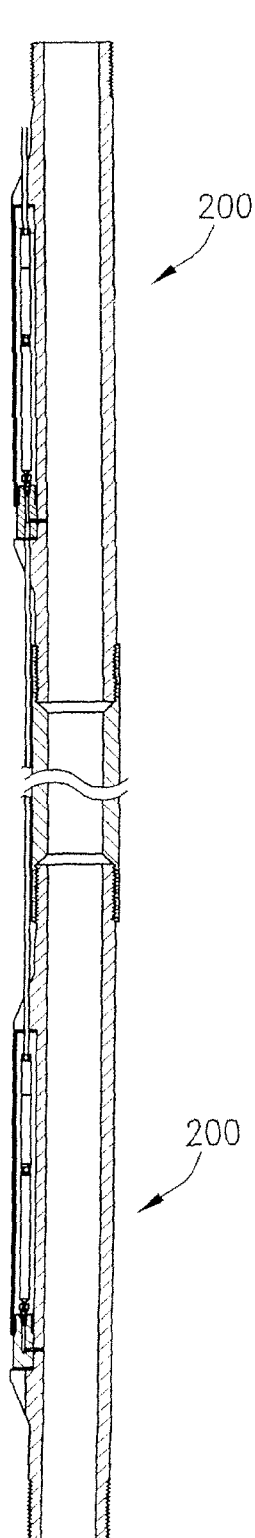


Fig. 22

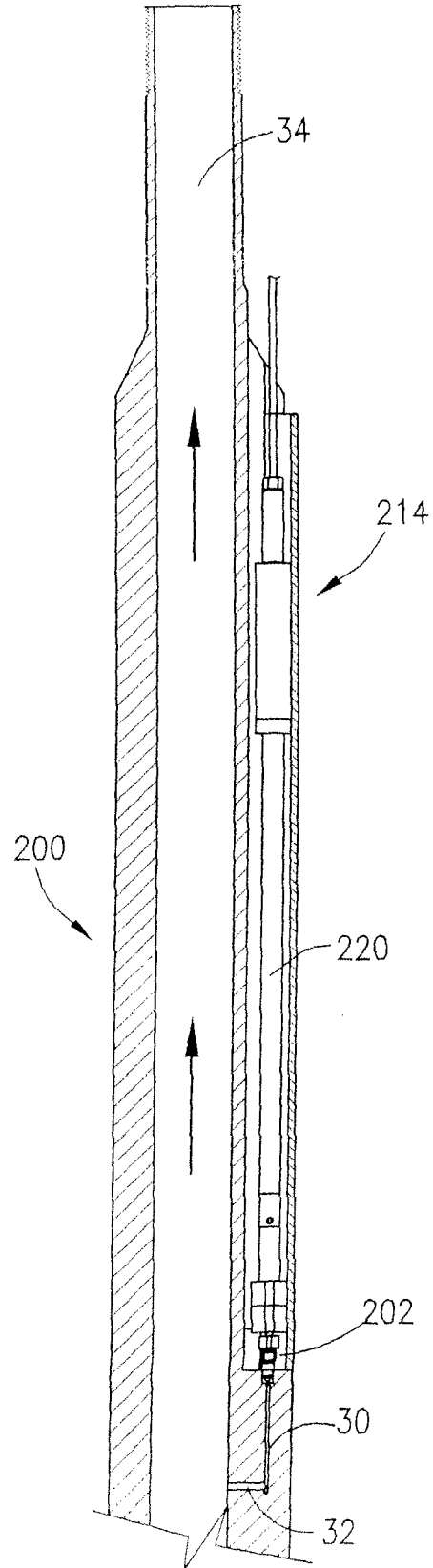


Fig. 23

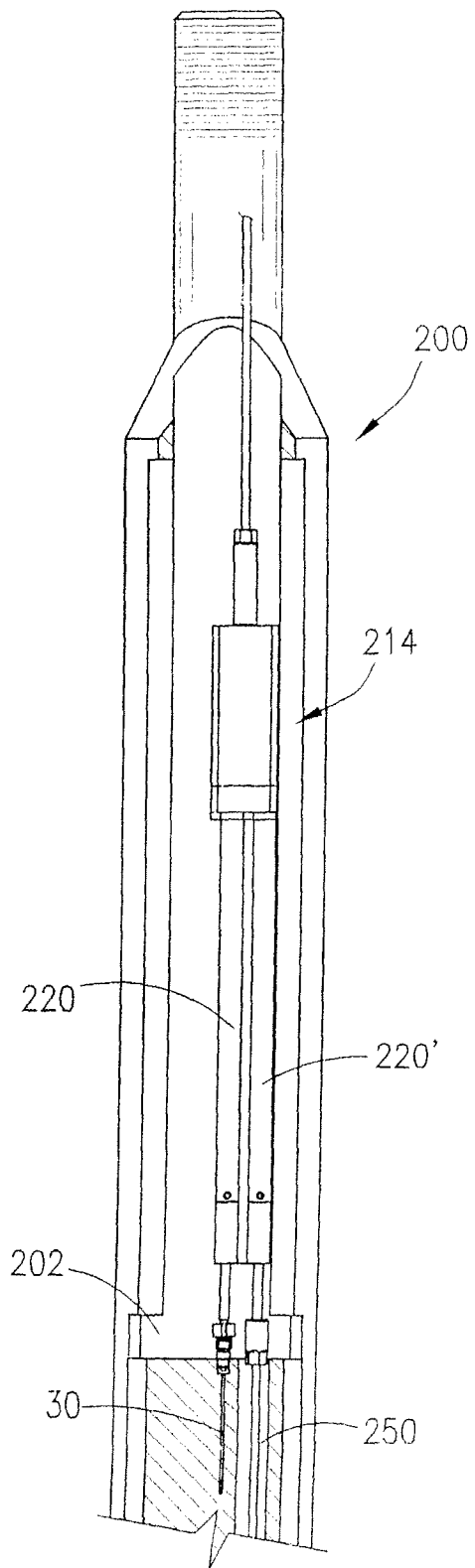


Fig. 24A

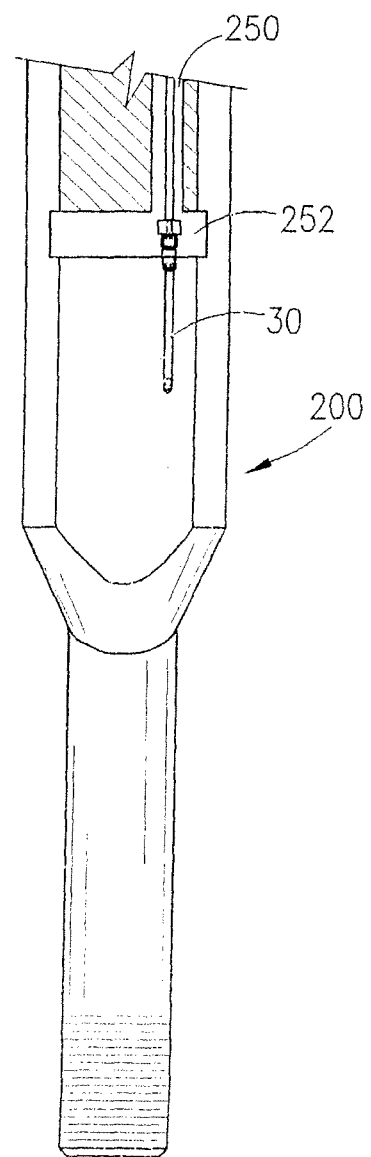


Fig. 24B

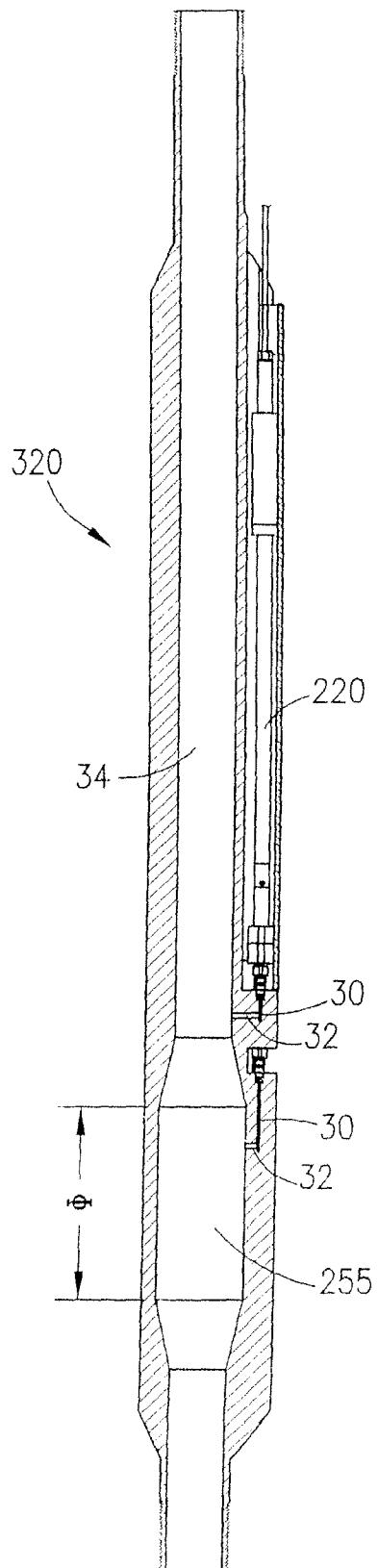


Fig. 25

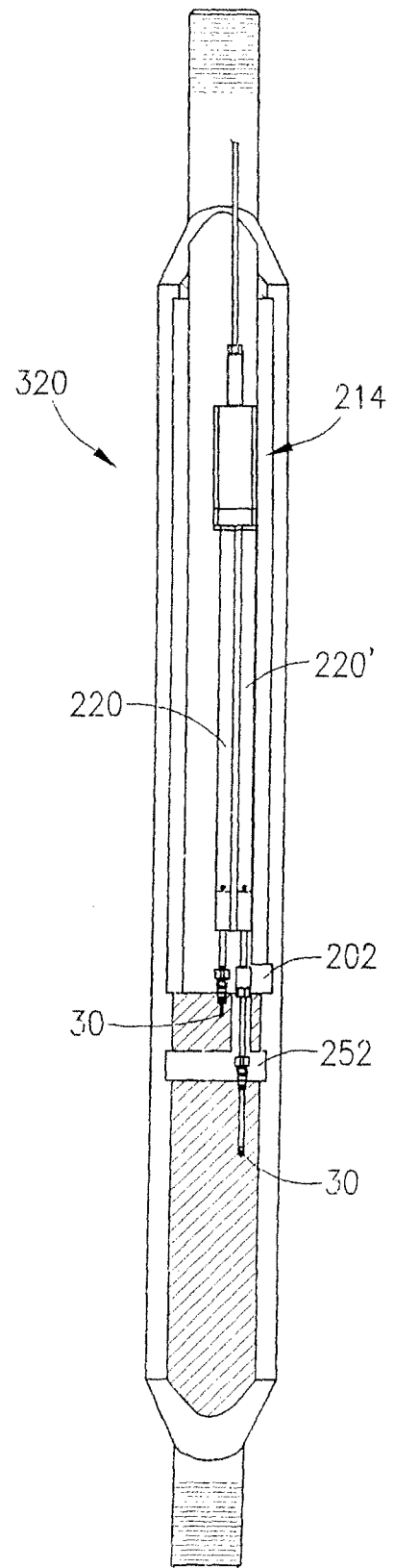
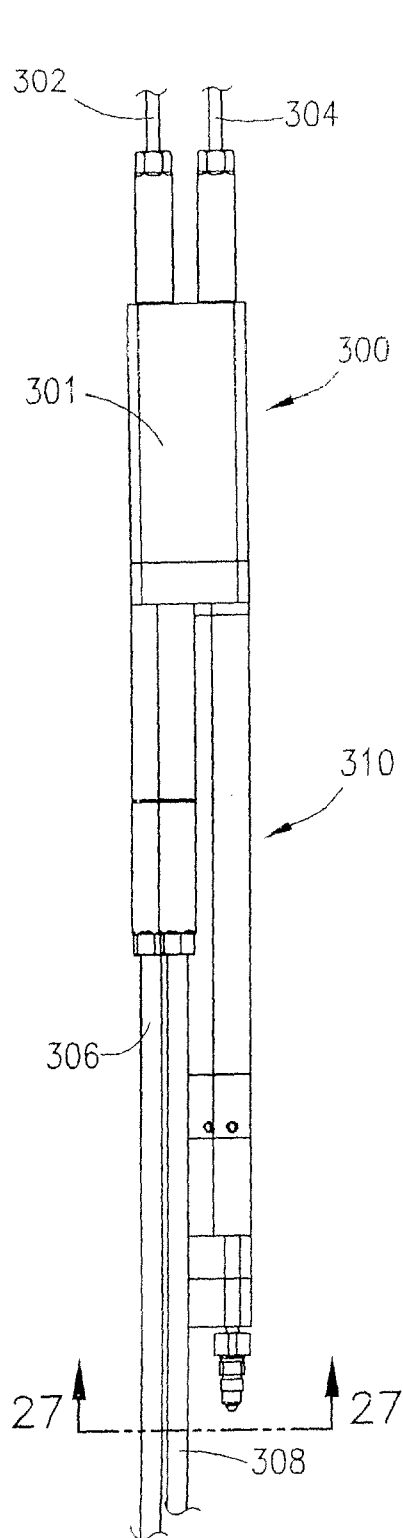
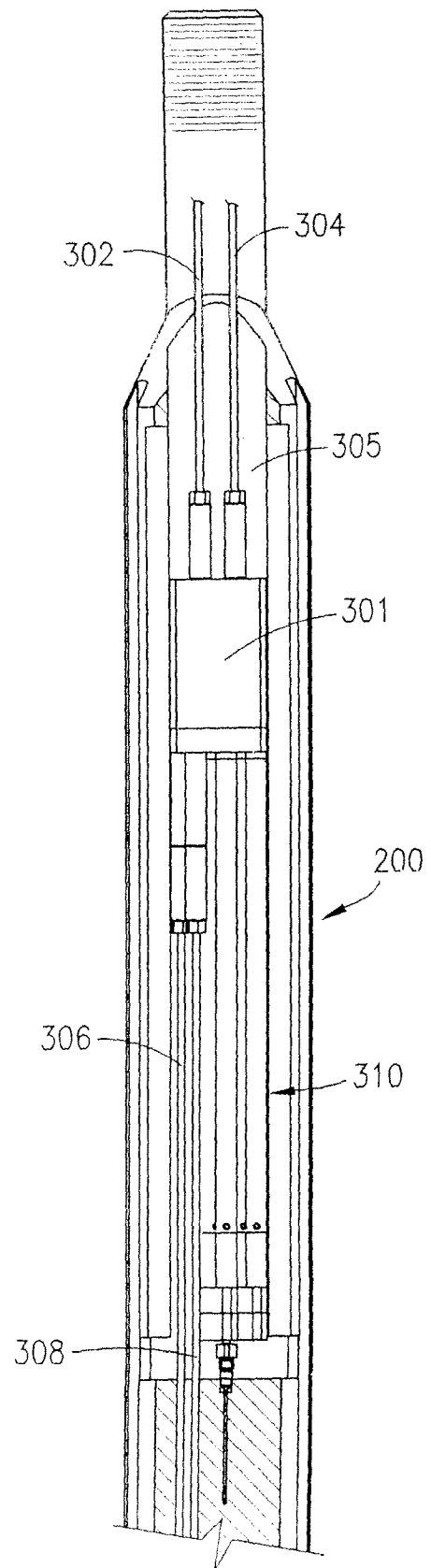


Fig. 25A

**Fig. 26****Fig. 28**

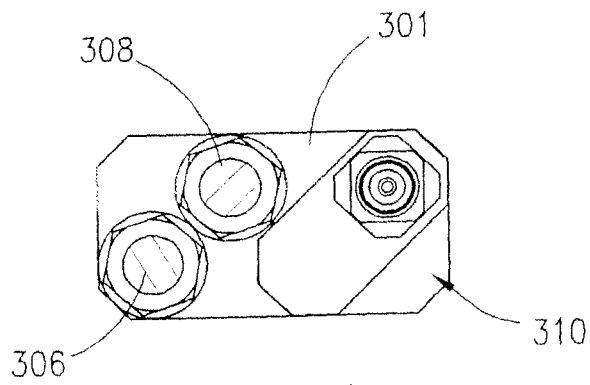


Fig. 27

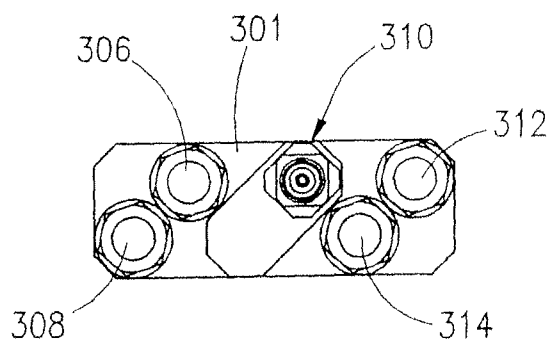


Fig. 30

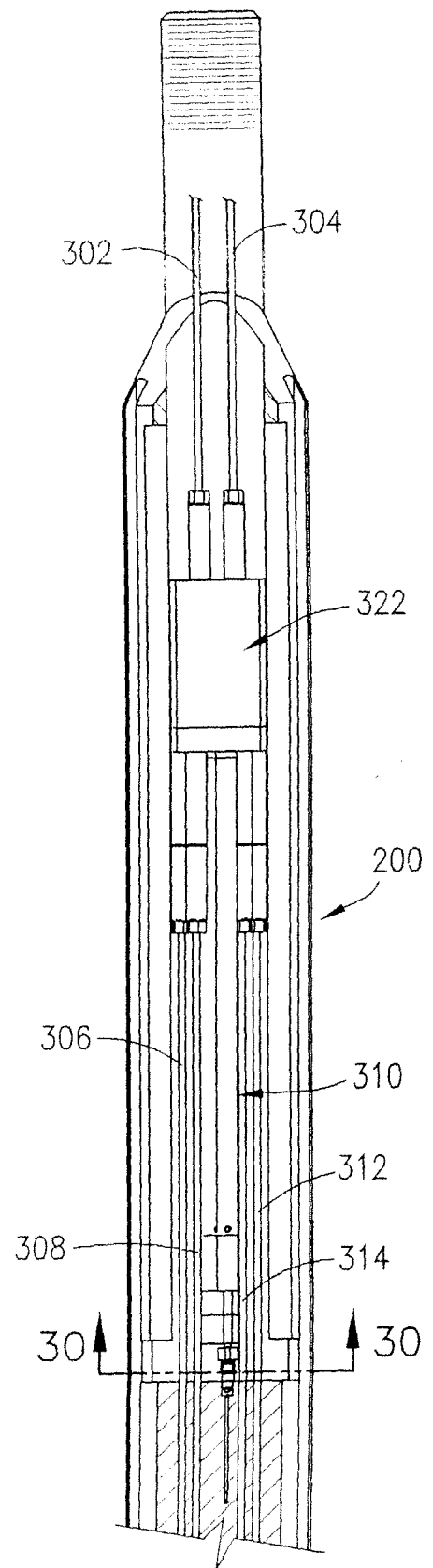


Fig. 29

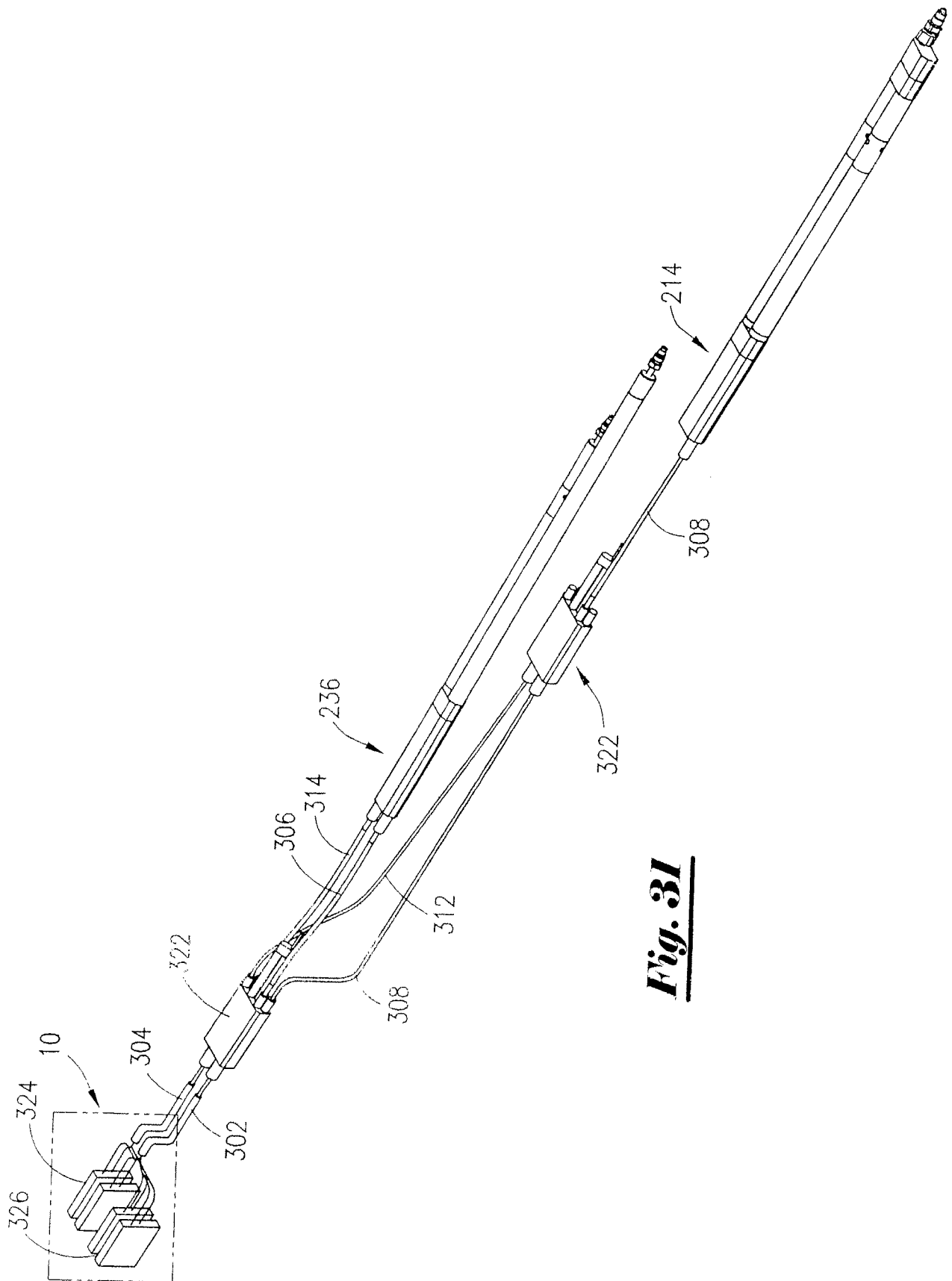


Fig. 31

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2008/050167

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B47/06 E21B47/12 E21B17/02 E21B43/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/164240 A1 (VINEGAR HAROLD J [US] ET AL VINEGAR HAROLD J [US] ET AL) 4 September 2003 (2003-09-04)	1, 3-22
Y	citing US2004263350 paragraph [0002] paragraphs [0048] - [0082] the whole document	2
Y	US 2004/263350 A1 (VINEGAR HAROLD J [US] ET AL VINEGAR HAROLD J [US] ET AL) 30 December 2004 (2004-12-30) the whole document	2

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

Date of the actual completion of the international search

26 May 2008

Date of mailing of the international search report

26/08/2008

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

van Berlo, André

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/US2008/050167

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-22

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-22

Production well monitoring with side pocket mandrel

2. claims: 23-27

Production well monitoring with single cable circuit with
polling modes

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2008/050167

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003164240	A1	04-09-2003	NONE
US 2004263350	A1	30-12-2004	NONE