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FORMULARIO ÚNICO DE SOLICITUD DE PATENTE

SOLICITUD DE:

☒ Patente de Invención.

☐ Patente de Modelo de Utilidad.

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SOLICITANTE
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Domicilio: Rio de Janeiro- RJ,
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Lugar de Constitución: Sociedad constituida
y existente bajo las leyes de Brasil.

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Fax:

E-mail:

IDENTIFICACIÓN

C.C.

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NIT

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C.E.

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Otro

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Cual

Número

3
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O APODERADO

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Número 438.019 T.P 31.929

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Título (54)

**TRANSDUCTOR OPTICO Y MÉTODO PARA LA MEDIDA SIMULTANEA
DE PRESIÓN Y TEMPERATURA EN POZOS DE PETROLEO Y GAS**

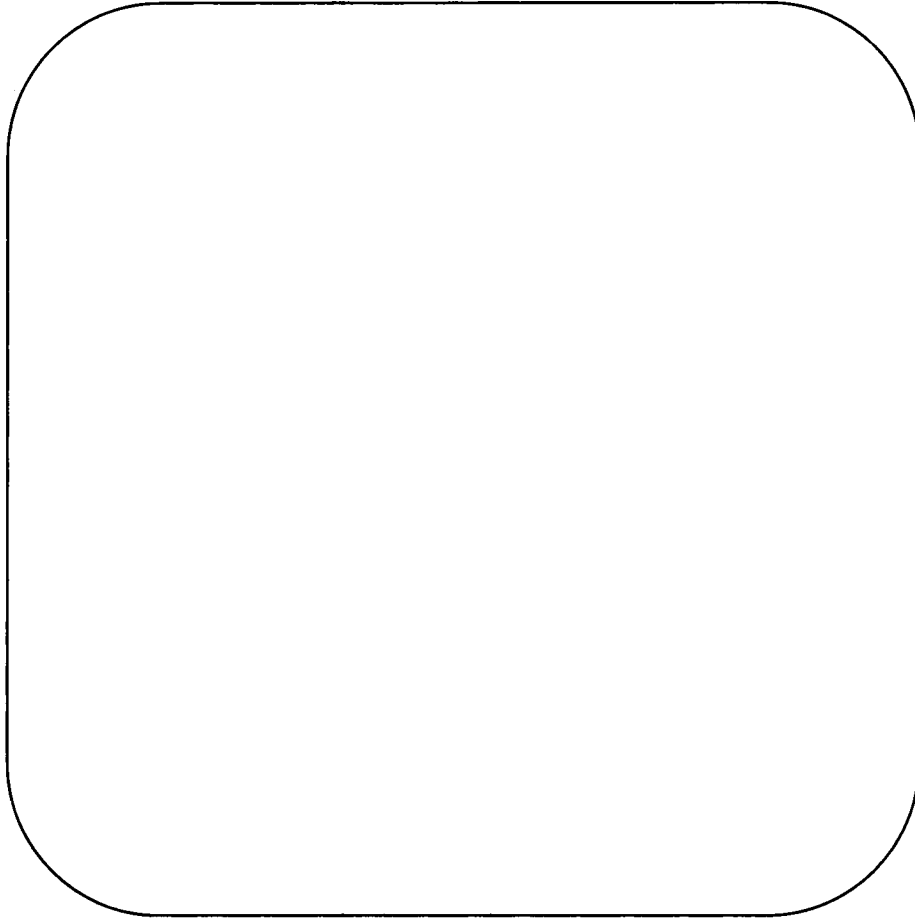
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6 Clasificación Internacional (51) <u>G01D 5/26</u>			
7 Prioridad SI ☒ NO ☐	(33) País de Origen	(32) Fecha	(31) Número de Solicitud
	<u>BR.</u>	<u>10 de agosto de 2004</u>	<u>PI 0403240-3</u>
8 Para publicar a partir de la fecha de la presente solicitud a los: 6 meses ☐ 12 meses ☐ 18 meses ☒ Otro ☐ Cual _____			
9 Comprobante de pago No.: <u>05.53.305</u> " " <u>05.51.280</u>		Fecha: <u>18 de julio de 2005</u> <u>11 de julio de 2005</u>	
10 Anexos: ☒ Comprobante de pago de la tasa de presentación de la solicitud. ☐ Comprobante de pago de la tasa por concepto de excedente de palabras en la publicación. ☒ Comprobante de pago por reivindicación de prioridad. ☒ Documento que acredita la existencia y representación legal cuando el solicitante sea persona jurídica. ☒ Poderes, si fuere el caso. ☐ Certificado de la fecha de presentación de la solicitud prioridad expedida por la autoridad correspondiente y una copia certificada de la primera solicitud si se reivindica prioridad. ☐ Traducción simple de la primera solicitud, si se reivindica prioridad. ☐ Documento de cesión del inventor al solicitante o a su causante. ☒ Resumen ☒ Descripción de la invención. ☒ Una o más reivindicaciones. ☒ Dibujos y/o planos necesarios ☐ De ser el caso, copia del contrato de acceso. ☐ De ser el caso, documento que acredite la licencia o autorización de uso de conocimientos tradicionales de las comunidades indígenas. ☐ De ser el caso, certificado de depósito del material biológico. ☐ Arte final 12x12 ☐ De ser el caso, información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante, relacionadas parcial o totalmente con la invención de esta solicitud.			

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FIGURA CARACTERÍSTICA



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Solicito la concesión de la patente,

NOMBRE:

EMILIO FERRERO

FIRMA :

A handwritten signature in black ink, appearing to read "Emilio Ferrero".

C.C. 438.019 de Usaquén T.P. 31.929

OC/mrm-ID-462

Poder con certificado consular para patentes, modelos de utilidad, diseños industriales, marcas de fábrica, nombres comerciales, enseñas, lemas comerciales, licencias y nombres de dominio de Internet.

Power-of-Attorney with consular certificate for patents, utility models, industrial designs, trademarks, commercial names trade emblems, slogans, licenses and internet domain names.

PODER

POWER-OF-ATTORNEY

Yo (nosotros), abajo firmado (s)I (we), the undersigned

PETRÓLEO BRASILEIRO S/A - PETROBRAS

domiciliado (s) en/of Av. República do Chile, nº 65

RIO DE JANEIRO, BRASIL

por el presente nombramos a EMILIO FERRERO, tpa. 31929; GONZALO PERDOMO, tpa. 831; LUZ CLEMENCIA DE PAEZ, tpa. 23555 y GERMAN CAVELIER, tpa. 832, domiciliados en la Carrera 4ª N° 72-35, Bogotá, Colombia, el primero como principal y los demás como suplentes, en su orden, y confiero (conferimos) poder a los abogados arriba nombrados para obtener la protección de mi (nuestra) propiedad industrial y contra la competencia desleal, a cuyo efecto autorizo (amos) a los dichos apoderados para que me (nos) representen ante cualesquiera entidades o personas, ejerzan o no jurisdicción, especialmente ante las del orden administrativo, contencioso-administrativo y judicial, así como los tribunales de arbitramento, en todo lo concerniente a los siguientes asuntos: a) Obtención de patentes de invención, modelos de utilidad y diseños industriales; el registro de marcas de fábrica, colectivas, defensivas, de servicio, lemas comerciales, nombres comerciales, enseñas, variedades vegetales y denominaciones de origen; su renovación, traspaso, cambio de nombre o domicilio, cancelación voluntaria; y el registro de licencias de uso de esos derechos; b) Las acciones de competencia desleal, protección del consumidor, oposiciones u observaciones, cancelación administrativa y judicial, nulidad, medidas cautelares, concesión de licencias, la tutela, la protección de secretos industriales, y en general los juicios civiles, penales, administrativos o contencioso-administrativos relacionados con estos derechos; acciones y procesos que promovamos o se nos promuevan; c) registros de nombre de dominio de internet, su renovación, traspaso, cambio de nombre, cambio de domicilio y demás actos relacionados con su administración. Y para que en todos los asuntos arriba determinados, puedan sustituir este mandato, transigir, conciliar, admitir los hechos del proceso, desistir, cancelar, recibir, renunciar, ser contactos administrativos y de pago y ratificar los actos de agentes oficiosos.

do hereby appoint EMILIO FERRERO, tpa. 31929; GONZALO PERDOMO, tpa. 831; LUZ CLEMENCIA DE PAEZ, tpa. 23555 and GERMAN CAVELIER, tpa. 832, domiciled at Carrera 4ª N° 72-35, Bogotá, Colombia, the first as principal and the others as alternates, in the order of their appointment, as my (our) attorneys-at-law so that they may obtain the protection of my (our) industrial property and against the unfair competition, for which purpose I (we) authorize the said attorneys to represent me (us) before any authorities or persons, with or without jurisdiction, specially those administrative, administrative contentious and judicial, as well as before Arbitration Court, in all matters concerning the following: a) Obtainment of patents, utility models and industrial designs; the registration of trademarks, collective, defensive and service marks, slogans, commercial names, trade emblems, vegetal varieties and denominations of origin; its renewal, assignment, change of name or domicile, voluntary cancellation; and the registration of licenses of use of the above rights; b) Actions of unfair competition, protection to the consumer, oppositions or observations, administrative Court cancellation, nullity, infringement, granting of licenses, the action for writ mandamus, the protection of trade secrets, and in general the civil, penal, and administrative suits relating to those rights; actions and suits instituted by me (us) or against me (us); c) registration of internet domain names, renewal, assignment change of name or domicile and any other activity related their management. And that in all the above matters they may substitute this Power of Attorney, compromise, conciliate, admit the facts of the case, desist, cancel, receive, resign, act as administrative and/ or payment contacts and ratify acts done by representatives without a power of attorney.

Dado y firmado hoy/Given and signed this

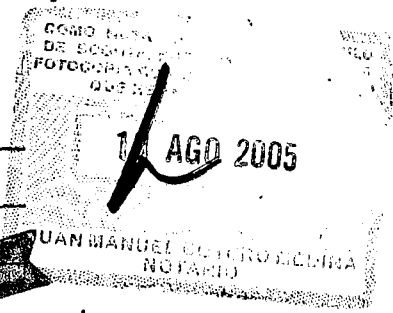
September 06, 2000

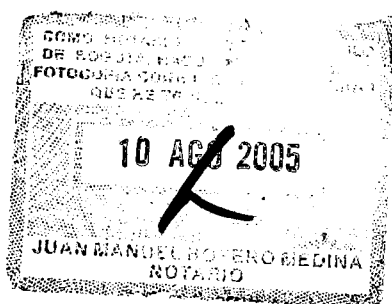
en/in Rio de Janeiro

por/by CARLOS SOLIGO CAMERINI

Firma

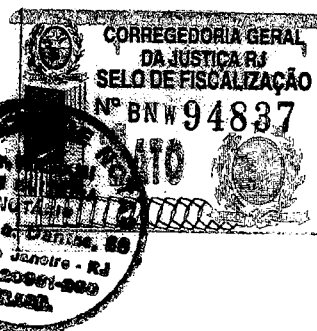
Signature





WILLIAM DE OLIVEIRA
171 Office de Notas - Matriz - Notario: WILHAMI DE OLIVEIRA
Rua Senador Dantas, 57 - RJ - Tel. 544-0277 - NG 190259
Excoedendo por semelhanca a(s) firma(s): #
CARLOS GILBERTO CAMERINI-785/28. #=====

Rio de Janeiro, 12 de Setembro de 2000 as 11:30:26
Em Teu Nome da Verdade
RAFI, ANTONIA DE ALBUQUERQUE - Substituto - RAJC - 1
Válida somente com selo de fiscalização. Total 2,47



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CONSULADO GENERAL DE COLOMBIA

CONSULADO DE COLOMBIA
No. 70/00.

El Suscrito Cónsul General de Colombia en Rio de Janeiro, visto los documentos presentados por los interesados, CERTIFICA: Que la Señora MARIA ANTONIA DE JESUS CORREIA, quien como Escribiente Sustituta de la Notaría 22°. de Rio de Janeiro, Brasil, autenticó la firma del signatario del poder precedente, ejercía en la fecha las funciones indicadas y su firma corresponde a la registrada en este Consulado.

Que la Compañía PETROLEO BRASILEIRO S.A. – PETROBRAS, es una sociedad constituida de acuerdo con las leyes del Brasil y cumple su objetivo conforme a las mismas.

Que el Señor CARLOS SOLIGO CAMERINI, quien en su caracter de SUPERINTENDENTE GENERAL DEL CENTRO DE PESQUISAS Y DESARROLLO de la citada Compañía, confiere el poder precedente y cuya firma fué autenticada ante la Notaría 22°. de Rio de Janeiro, Brasil, es su representante legal en este país.

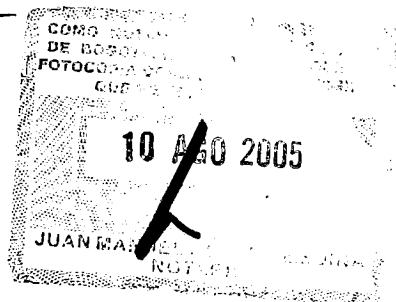
El Cónsul no asume responsabilidad por el contenido de este documento.

Rio de Janeiro, 14 de septiembre de 2000.

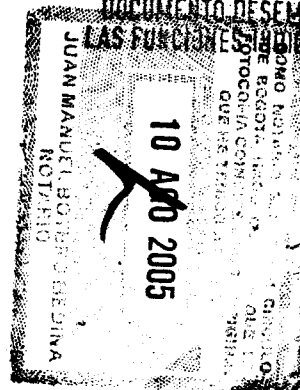


[Signature]
JUAN LOZANO P.
Cónsul General de Colombia.

PAGADO IMPUESTO DE TIMBRE
US\$ 7,00 (SIETE DÓLARES)
PAGADO DERECHOS CONSULARES
US\$ 100,00 (CIEN DÓLARES)



438547
Leon Luzano
CUYA FIRMA APARECE EN EL
DOCUMENTO DESEMPEÑA
LAS FUNCIONES SIGUIENTES.



7000 SET 20 P 11:04

~~JEFE DE LEGALIZACIONES
SANTAFE DE BOGOTA D.C.~~

66
TRADUCCION OFICIAL NO. 200928 de un documento escrito en Portugués, el cual, para su identificación se sella con el sello de María Eugenia Sanint, Traductora Oficial según Resolución No. 851 del Ministerio de Justicia.

LEGALIZACIONES

Escritas en PORTUGUES, al pie de un PODER escrito en ESPAÑOL, otorgado por PETRÓLEO BRASILEIRO S/A-PETROBRAS, a EMILIO FERRERO y otros.

NOTARIA 22 - NOTARIO WILHAMI DE OLIVEIRA

Notaria 22 - Matriz - Notario: Wilhami de Oliveira

Rua Senador Dantas, 39 - Rio de Janeiro- No. 190259

Reconozco por semejanza la firma de : CARLOS SOLIGO CAMERINI -785/28

Rio de Janeiro, 12 de septiembre de 2000 -11:30:26

En fe de lo cual firmo el presente

(Firma Ilegible)

MARIA ANTONIA DE JESUS CORREIA -Suplente - MAJC -1

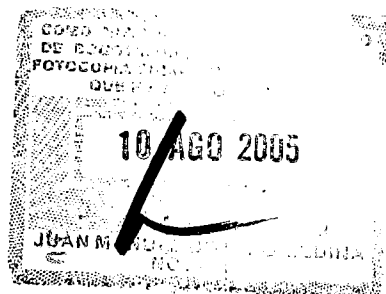
Válido únicamente con el sello de Control - Total derechos: 2,47

Sello de la Corregiduría General de Justicia

SELLO DE CONTROL

No. BN w 94837

Sello del Notario



EN ESPAÑOL, la legalización de la firma anterior por el Consulado General de Colombia en Río de Janeiro, bajo el No. 70/00 de fecha del 14 de septiembre de 2000

EN ESPAÑOL, la legalización de la firma anterior por el Ministerio de Relaciones Exteriores de Colombia, bajo el No. 438547 de fecha del 20 de septiembre de 2000.

ES TRADUCCION FIEL Y COMPLETA.

Traductora: María Eugenia Sanint

Bogotá, 25 de septiembre de 2000

DEL MINISTERIO DE JUSTICIA

COMO NOTARIO SEXTO DEL CIRCUITO DE BOGOTA, HAGO CONSTAR QUE LA(S) FIRMA(S) *[Firma]*

COINCIDE(N) CON LA FIRMA REGISTRADA POR EL (ELLOS) EN ESTA NOTARIA SANTIFE DE BOGOTA, 26 SET. 2000

CODEX JURIS CIVILIS

NO SE ASU
RESPONSABILIDAD

1000 SET 27

JOSÉ DE LEÓN I. GÓMEZ
SANTIFE DE BOGOTA

COMO NOTARIO SEXTO DEL CIRCUITO DE BOGOTA, HAGO CONSTAR QUE LA(S) FIRMA(S) *[Firma]*

COINCIDE(N) CON LA FIRMA REGISTRADA POR EL (ELLOS) EN ESTA NOTARIA SANTIFE DE BOGOTA, 10 AGO 2005

JUAN MANUEL BATE RO MEDINA
NOTARIO

MINISTERIO DE RELACIONES
EXTERIORES

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OPTICAL TRANSDUCER AND METHOD FOR THE SIMULTANEOUS MEASUREMENT OF PRESSURE AND TEMPERATURE IN OIL AND GAS WELLS

FIELD OF THE INVENTION

5 The present invention relates to an optical transducer for the simultaneous measurement of pressure and temperature in oil and gas wells, more specifically, to an optical transducer that uses, for such measurement, at least two Bragg gratings in a same optical fiber, at least one of such fibers being attached onto an elastic membrane. The invention relates still to the method for the simultaneous
10 measurement of pressure and temperature in oil and gas wells using the described transducer.

BACKGROUND INFORMATION

 Among the commercially available sensor technologies useful for downhole monitoring of pressure, temperature and other parameters are the Permanent
15 Downhole Gage (PDG's) using quartz crystal technology and the Strain Gage the features of which are: require on-board electronics, are active sensors, show low reliability and higher than 3 psi/year drift in the measurement. Such equipment undergo electromagnetic interference, do not allow distributed installation (multiplexed) and are costly. For applications required to outweigh such
20 specifications, the optical technology is the most recommended to overcome such problems.

 In view of the high cost of well intervention and production interruption, the system installed in the well should have a high reliability (of at least twenty years). The optical sensors technology makes possible to attain such requirement.

25 Optical fibers bear some features such as: they can withstand high temperatures (silica up to 1,000°C), showing high transmission rates and low losses at high distances (relating to the attenuation of transmitted/received signal), as well as electrical insulation and no electromagnetic interference.

 That is why it is stated that optical sensors have several benefits relative to
30 commercially available sensors, such as low hysteresis, repeatability, reproducibility, mechanical strength, twenty years working life (high reliability), passive technology, that is, no need of on-board electronics for operation, easiness of implementation at large distances (longer than 20 km) without any

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need of a repeater for automation systems (simple telemetry at large distances), being immune to EMI/RFI noise, are of small size, operate at high temperatures and are naturally explosion-proof (low intensity laser beam approximately lower than 100 mW).

5 Among the available optical sensors technologies the state-of-the-art technique known as Fiber Bragg Gratings (FBG) is interesting in view of the possibility of combining a huge variety of transducers (pressure, temperature, pH, position, flow rate, etc) in a single fiber.

 Fiber Bragg gratings are fairly suitable to be used as sensing elements. 10 When a Bragg grating receives a broadband ($C_1 + C_2$) beam of light (laser), it reflects a narrow light band in a certain wavelength. However, the mensurands (physical parameters), such as the change in strain induced by a change in pressure or in the outer temperature, yield a change in the refractive index (temperature) and in the geometric spacing of the grating, which leads to a change 15 in the wavelength values of the light reflected by the gratings. The magnitude of the mensurands is directly related to the wavelength reflected by the Bragg grating and can be determined by detecting the wavelength change of the reflected light. +

 Optical fiber sensors are optical sensors using fibers as the connecting medium for light between the mensurands (temperature/pressure) and the 20 measurement region.

 Thus, the principle for the measurement of pressure and temperature using optical fiber sensors involves injecting light using a broadband laser source through the optical fiber up to the grating and at the outlet, evaluating the main features of the returned light/wavelength and intensity that have been altered by 25 the medium.

 Among the measurement technologies, Fiber Bragg Gratings (FBG) is the one of highest potential for multifunctional and nearly distributed sensor systems for applications in the permanent downhole and reservoir monitoring.

 The concept at the basis of the FBG technique is that upon designing a 30 localized grating in a certain region of the fiber, typically of 1 to 10 mm length, according to a pre-defined wavelength, a certain wavelength of the incident light is affected (FBG filter). As a result of the medium perturbations, a change is caused

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in the absolute value of the wavelength, directly related to the physical parameters at the origin of such change.

Optical sensors represent a breakthrough relative to state-of-the-art systems, as have been the present quartz (PDG) sensors relative to the first strain-gauge sensors during the evolution of such systems.

The main feature of the optical sensor is the fact that it is completely passive, that is, it does not need any on-board electronics for the transduction of the measured parameter, needing only a mechanical element coupled to the FBG element, which is the fiber itself. All the electronics and optical source are placed at the surface, being easily replaced in case of failure or updated without any well work-over. The increased reliability of downhole sensors means, besides the economical advantage, the viability of other technologies, such as smart completion, reservoir monitoring (HtxHp – High temperature, high pressure wells) and artificial lift.

Optical sensors can be classified as extrinsic and intrinsic. In the first category are those where the fiber is used just to guide the light and the optical effect to be measured occurs out of the fiber. In the second case the fiber serves also as the medium where the coupling between the mensurand and the fiber occurs, this rendering this category of sensors mechanically more attractive.

Sensors can also be categorized as for the optical effect to be measured, including a change in intensity, in the polarization, in the spectrum or in the phase of the light wave.

The main features of the optical-technology sensors are:

- Interferometric: those are made up of mechanical systems (microoptics), being susceptible to high intensity mechanical vibrations; do not allow multi-point installation nor high vibrations, have low reliability and high cost.
- Single point FBG: do not allow multiplexing, rendering difficult downhole installation because of the number of required penetrations, are not temperature limited (above up to 150°C).
- The multi-point FBG technology, besides the above features, encompasses the possibility of placing multiple kinds of sensors connected to a single fiber (multiplexed) and placed at specific points, and further having lower cost as compared to state-of-the-art sensors.

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The recent patent literature points out a few relevant documents on the multi-point FBG technology.

Thus, US patent 6,016,702 teaches a pressure sensor with temperature compensation for a point where an optical fiber is attached onto a compressible bellows in a location along the fiber and to a rigid structure at a second location along said fiber, with a Bragg grating contained in the fiber between these two fiber attachment locations, the grating being under tension. As the bellows structure is compressed as a result of a change in the outer pressure, the tension on the fiber grating is reduced, this causing a change in the wavelength of the light reflected by the grating. However, temperature compensation should be carried out by isolating the temperature-monitoring grating in a pressure-isolated chamber, this adding costs to the equipment.

The proposed sensor can be used as a one single or a plurality of sensors, serially connected along a single optical fiber. Upon mounting the sensors in series, the optical fiber crosses a passage at the end of a bellows structure for interconnection to the following pressure sensor. The several pressure and temperature signals from the multiple pressure sensors can be differentiated using wavelength division multiplexing (WDM). Thus, each Bragg grating operates at a central wavelength λ within a wave amplitude ω that is not superimposed to the amplitude of the other Bragg grating sensors. Therefore, optical signals for the temperature and pressure of each of the sensors serially connected can be easily differentiated on the basis of the received wavelength. TDM (Time Division Multiplexing) techniques can also be used to differentiate among optical signals of different Bragg grating sensors. However, the sensor of said US patent does not describe nor suggests the transducer proposed in the present application, said transducer using two Bragg gratings in a same optical fiber and having at least one of the gratings attached onto an elastic membrane.

The fiber grating pressure sensor technology taught in US patent 6,278,811 comprises a pressure-detection device that can be elastically strained as a function of the applied pressure, and an optical fiber that is wrapped at least once around said device and where at least a portion of its length is fused to the device, so that the elastic deformation of the device generates a corresponding axial strain along a longitudinal axis of the fiber caused by the applied pressure.

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The shape of the device may be a solid cylindrical shape or either has an axial orifice formed therein. The fiber contains at least one grating impressed therein. The grating has a characteristic wavelength that changes with the applied pressure.

5 The device is made of silica or quartz. The technology described in said patent can be used as a single sensor or as a plurality of distributed or multi-point sensors.

10 US patent 6,519,388 teaches a Bragg grating configuration that allows the grating to be used in compression without requiring optical pins or a mechanical support structure and/or that is suitable for reducing the core to cladding coupling. According to the technology taught in this US patent, a tube-encased optical fiber containing a Bragg grating comprises an optical fiber having at least one Bragg grating embedded therein, and a tube, the optical fiber and the Bragg grating being encased therein along a longitudinal axis of said tube, the tube being fused to at least a portion of the fiber in a location where at least a portion of the Bragg grating is located. The tube is made of a glass material and fused to the optical fiber on opposite axial sides of the Bragg grating. The encased grating allows the grating to be compressed without buckling the fiber.

15 US patent application 2002/0194917 A1 refers to a pressure fiber grating sensor including an optical sensing element which includes an optical fiber having a Bragg grating impressed therein which is encased within and fused to at least a portion of a glass capillary tube. A temperature Bragg grating can be used for the measurement of temperature and allow the temperature-corrected pressure measurement. The sensor can be suspended in the interior of an outer cladding by a fluid, spacers or other means.

20 US patent 6,439,055B1 teaches a pressure sensor assembly for assessing the pressure of a fluid in a harsh environment including a pressure sensor suspended within a fluid filled housing. The assembly includes a pressure-transmitting device, which transmits the pressure of the fluid to sensor and keeps the fluid within the housing in a void free condition. The pressure sensor assembly maintains the sensor in a near zero base strain condition and further protects the sensor from shock and vibration. The pressure sensor assembly further includes bumpers that limit the movement of the sensor within the housing.

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US patent application 2003/0094281 A1 teaches a monitoring system and method for monitoring a predetermined set of physical characteristics associated with a structure using the monitoring system. The system is distributed in the structure and comprises a distributed optical sensing device, further comprising a
5 fiber optic cable; a light source operatively in communication with the fiber optic cable; a light detection device, operatively in communication with the fiber optic cable, for measuring the light received at the light detection device from the fiber optic cable; and a data processor capable of using the light measured to calculate a predetermined set of physical parameters describing the predetermined set of
10 physical characteristics.

However, in spite of the existing developments in the technologies of single and multi-point pressure transducers using Fiber Bragg gratings, there is still the need of an optical transducer for the simultaneous measurement of downhole pressure and temperature, said transducer comprising at least two Bragg gratings
15 in the same optical fiber, wherein one of the gratings, which is compatible with the operation temperature, is attached onto an elastic membrane, the attachment assuring that the membrane conveys efficiently to one Bragg grating the strains undergone by such membrane resulting from pressure and temperature changes, while the other Bragg grating is attached or not to the membrane, such transducer
20 being described and claimed in the present application.

SUMMARY OF THE INVENTION

Broadly, the invention is directed to an optical pressure and temperature transducer for the simultaneous measurement of downhole pressure and temperature, said transducer being part of a system that comprises a light emitter
25 propagating along the core of an optical fiber containing Bragg gratings impressed in the same, until the light meets a Bragg grating that reflects a portion of said light, said transducer comprising a predominantly cylindrical body, including an elastic membrane for attaching at least one Bragg grating, and at least one more Bragg grating impressed on the same optical fiber, and wherein said body is:

- 30 a) Bored along the main axis in order to allow the passage of an optical fiber and assure access to both ends of the said optical fiber;

- b) Provided with two symmetry planes in order to facilitate to be installed and serially connected with other sensors of the same kind or other optical fiber transducers and sensors;
- c) Provided with a central access and respective sealing, perpendicular to the main axis of said body, on the opposite side of said membrane, to allow the attachment of at least one Bragg grating to the membrane; and
- d) Provided with sealing means against the outer pressure, at the inlet and at the outlet of the optical fiber and in the central cylindrical bore, whereby the elastic membrane conveys the strain that is proportional to the pressure and temperature conditions to which is submitted the transducer having at least one Bragg grating, the portion of non-reflected light by the Bragg gratings following along the remaining length of the optical fiber, where said fiber can be utilized to interrogate other sensors and transducers connected along the same optical fiber or in one or more optical fibers coupled to said one.

And the method for the simultaneous measuring of borehole temperature and pressure using the inventive transducer comprises providing an optical fiber containing at least two Bragg gratings sensitive respectively to temperature and pressure; causing a change in the refractive index of the gratings and strain in the elastic membrane resulting from the temperature and pressure conditions to which is submitted the transducer through the elastic membrane; conveying the change in refractive index of the grating caused by the change in the outer temperature and the strain caused in the grating by the change in outer pressure; from the measurement of the changes in the values of Bragg grating wavelength, recovering the value of the pressure and temperature by means of a calibration curve.

Thus, the invention provides an optical transducer for the simultaneous measurement of downhole pressure and temperature that utilizes two Bragg gratings contained in the same optical fiber.

The invention provides further an optical transducer for the simultaneous measurement of downhole pressure and temperature where at least one Bragg grating impressed on an optical fiber is attached on an elastic membrane.

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The invention provides further an optical transducer for the simultaneous measurement of downhole pressure and temperature where the portion of light not reflected by the Bragg gratings of said transducer follows along the remaining of the said optical fiber, for interrogating other sensors and transducers connected along the same optical fiber or to one or more optical fibers coupled to the same.

The invention provides still a method for the simultaneous measurement of downhole pressure and temperature using the described optical transducer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1A attached illustrates a top view of one mode of the optical transducer according to the invention where a Bragg grating is attached onto the elastic membrane and the other Bragg grating is out of the membrane.

FIGURE 1B attached is a cut along the BB axis of the same transducer.

FIGURE 1C attached is a side view of the same transducer.

FIGURE 2A attached illustrates a top view of another mode of the optical transducer of the invention.

FIGURE 2B attached is a cut along the BB axis of the same transducer.

FIGURE 2C attached is a side view of the same transducer.

FIGURE 2D attached illustrates one mode of the same transducer where the two Bragg gratings are attached onto the elastic membrane.

FIGURE 6 attached illustrates a graph of the calibration of the inventive transducer for the temperature grating.

FIGURE 7 attached illustrates a graph of the calibration of the inventive transducer for the pressure grating.

DETAILED DESCRIPTION OF THE PREFERRED MODES

The invention refers therefore to an optical transducer for the simultaneous measurement of downhole pressure and temperature comprising a predominantly cylindrical body, bored along the main axis to allow the passage of an optical fiber, said transducer having two symmetry planes and a central cylindrical bore for attachment of at least one Bragg

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grating, and sealing means against the outer pressure at the inlet and the outlet of the fiber and in the central cylindrical bore.

The main feature of the sensor construction is the way of mechanical transduction of the physical parameters pressure and temperature into wavelength change. Such transduction is carried out by means of the mechanisms of temperature and pressure.

In the present specification, the following terms have the meaning as detailed below.

Transducer, according to the metrology vocabulary, should be understood as the element that effects the transduction (conversion) of a physical parameter into another (Pressure/Temperature into Wavelength Change of the Optical Signal)

According to the same glossary, sensor means the element that undergoes the change/transformation as a function of the change in any physical parameter.

One aspect of the invention is an optical transducer for the simultaneous measurement of pressure and temperature under downhole operation conditions, useful for single point configuration.

Another aspect of the invention is an optical transducer for the simultaneous measurement of pressure and temperature under downhole operation conditions, useful for multi-point configuration.

The transducer of the invention uses the FBG technology.

The Bragg gratings are designed so as to produce a periodic modulation in the refractive index of the optical fiber core along the length of said fiber. The grating reflects a range of wavelength whose value at the peak of the spectrum, λ_B , corresponds to nearly three times the value of the spatial period Λ of the index modulation, according to $\lambda_B = 2n \Lambda$, with $n \approx 1.5$ being the refractive index of the optical fiber core.

The behavior of the Bragg gratings is similar to that of a resonating filter system, that is, the wavelength values satisfying the resonance condition are affected while the remaining are ignored.

The Bragg gratings useful for the purposes of the invention comprise the gratings prepared prior to their installation in the pressure and temperature transducer.

The Bragg grating is prepared by locally exposing the optical fiber core to an interference pattern of two ultraviolet light beams so oriented relative to the optical fiber longitudinal axis that, for the grating, the maxima and minima of the interference pattern extend along a small portion of the optical fiber in directions
5 normal to the longitudinal axis and that the periodicity is that desired for the particular grating.

The sensor is made up of a monomode optical fiber usually for a wavelength in the range of 1,300 nm to 1,550 nm containing the FBG impressed in the fiber core at any position along the fiber.

10 The FBG mechanically coupled to the transducer is interrogated using an optical system made up of a source of light – that can be a broadband (C1 + C2) or a tunable laser or either a source of light with a broad emission band such as a LED or an ASE source – coupled to the fiber core, and a Bragg wavelength measurement system – that can be a spectrum analyzer or a wavelength
15 measurement system, or either through intensity change (convolution of the FBG signal with that of the fixed filter of same wavelength at the surface).

For measuring the signal, transmission or reflection can be used. For downhole applications or any difficult access equipment, the measurements are run in reflection. Based on the measurement of the Bragg wavelength of the
20 grating, the desired mensurand value is recovered through a calibration curve that should be drawn in the laboratory prior to installing the sensor in the field.

The optical pressure and temperature transducer uses as sensor element for both parameters, optical fibers containing Bragg gratings (FBG). The relevant parameter to be measured is the spectral position of the reflection peak for
25 determining the wavelength of the return signal characteristic of each sensor, such signal depending in a known manner on the strain condition and temperature to which is submitted the FBG. The pressure is obtained by measuring an optical fiber containing an FGB, attached onto a membrane designed to be strained within the elastic limit of the metal used to make it, and at the operation range designed
30 for the transducer. Such sensor is submitted to the effects of pressure and temperature, with the second effect being necessarily compensated so as to isolate the portion relative to pressure.

According to the invention, the optical transducer for the simultaneous measurement of downhole pressure and temperature using an optical fiber containing two Bragg gratings where at least one of such gratings is attached on an elastic membrane comprises two modes.

5 Thus, a first mode comprises one of the gratings attached onto the membrane, generally at the center of the membrane, while the other grating is placed out of the membrane. In this way, the grating, which is out of the membrane, is submitted to the effect of temperature only. When the outer pressure increases, the membrane is strained and stretches the fiber in the region
10 of the Bragg grating, causing a strain along the main axis of the optical fiber. This is what it is desired to measure. The change in the Bragg grating wavelength is proportional to the strain and is also proportional to the temperature. If there is only one grating it is not possible to determine how much of the wavelength change is due to the temperature and how much is due to the pressure.

15 Therefore the option is to have a second grating, which would not depend on pressure but on temperature only. In order to make it work, the temperature at both locations of the sensor should be the same.

The equation describing such a system is equation (1) below.

$$\Delta \lambda_1 = f_1 (P) + g_1(T) \quad (1)$$

20
$$\Delta \lambda_2 = g_2 (T).$$

However, mainly when there are transitions from one temperature to the other, the temperature values in the two gratings are different. The temperatures will be the same only after being evened.

One of the drawbacks to implement such mode is the calibration, which can
25 be slow until attaining the temperature evenness in the two gratings. The membrane is very thin, and the stabilization brought by the outer temperature is quicker. The temperature grating is more distant from the outer medium and takes longer to stabilize. The temperature is measured by means of another FBG mechanically decoupled from the transducer body. This second sensor is attached
30 onto a small metallic anchoring part.

In order to try to overcome the drawback of the temperature evenness a second mode of the optical transducer of the invention comprises attaching both Bragg gratings to the membrane.

The attachment by means of an adhesive or any other device should be carried out so that one of the gratings is at the center of the membrane as in the first mode, while the second grating is necessarily placed out of the center. Both gratings undergo the effect of pressure, only at different intensities. However, the effect of the temperature is the same for both gratings.

The equation of the second mode of the optical transducer is equation (2) below:

$$\Delta \lambda_1 = f_1 (P) + g (T) \quad (2)$$

$$\Delta \lambda_2 = f_2 (P) + g (T)$$

As can be seen from equation (2), the difference between $\Delta \lambda$ s depends only from P, and a $f_3(P)$ will be obtained, which is determined through calibration, the substitution being made in λ_1 or λ_2 .

Such approach assures that both gratings are always at the same temperature, this allowing the correct simultaneous measurement of pressure and temperature. Even if the parameter "g" were not the same for both equations, the mathematical solution would be possible, but "g" being the same makes the solution easier.

The behavior of Temperature and Pressure according to this mode is outlined below.

Temperature: the FBG grating responsible for the temperature measurement can be coupled according to two ways: (i) encapsulated in a metallic tube housed in the interior of the sensor body, in close proximity to the membrane. The metallic tube performs the thermal coupling between the temperature of the medium and the temperature of the grating; (ii) attached onto the membrane together with the pressure grating.

This latter configuration improves the thermal coupling between the temperature sensing grating and the measurement of pressure of the outer medium, such measurement being required to correct the measurement of pressure transduction (pressure vs. change of the pressure grating wavelength).

Such configuration effectively corrects (cancels) the effects of the temperature change on the pressure grating.

Pressure: The FBG grating is responsible for the transduction of the pressure change of the outer medium, which results in a membrane strain, the

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membrane in turn conveying such strain to the pressure grating. Such strain on the grating shifts the wavelength in a way that is related to pressure strains. Since the thermal effects affect the wavelength, measurements should be corrected in view of such effects (thermal changes) undergone by the pressure grating.

5 Processing of the temperature measurement is carried out by means of the measurement of the wavelength change, since the value of the wavelength measurement impressed under ambient temperature conditions is known. Therefore the changes are computed and corrected using a simple algorithm for transforming the wavelength changes into temperature degrees. Such algorithm
10 calculates the temperature on the basis of the constants of the temperature calibration of the sensor.

 Processing of the pressure measurement is carried out by measuring the wavelength change, since the value of the wavelength measurement impressed under ambient temperature and atmospheric pressure conditions is known.
15 Therefore the changes are computed and corrected using a simple algorithm that corrects the temperature changes in the wavelength by measuring the changes in wavelength as a function of the pressure/strain of the outer membrane (indirect measurement). This algorithm calculates the pressure on the basis of the constants of pressure calibration (membrane construction) of the sensor

20 In both modes described below for the pressure and temperature transducer, the elastic membrane is a thin membrane, the thickness of which is a function of the measurement range of the mensurand. The thickness of the elastic membrane is homogeneous. Alternatively, the thickness is variable throughout the membrane.

25 The invention will be described below with reference to the attached Figures.

 Figure 1A illustrates an upper view of one mode of the optical transducer according to the invention where one Bragg grating is attached on the elastic membrane and the other Bragg grating is out of the membrane. This mode of the
30 present transducer, generally designed by numeral **100**, comprises a body **10a**, bored along the main axis to allow the passage of an optical fiber **30** so as to secure access to both ends of the said optical fiber **30**.

The body **10a** is provided with: (i) two symmetry plans for making easier for the sensor to be installed and serially connected to other sensors of the same kind or other transducers and optical fiber sensors; (ii) an elastic membrane **50** and attached on said membrane, at least one Bragg grating **60** contained in the optical fiber **30**; and (iii) a longitudinal passage **31** for the optical fiber **30** throughout the transducer body **10a**.

The elastic membrane **50** is a thin plate in the transducer body **10a**.

Alternatively, the elastic membrane **50** is not an integral part of the body **10a** of transducer **100** and is attached onto said body by means of any known device.

The sealing means for effecting the sealing in the cross-section direction of the optical transducer **100** is a circular stop or sealing **70**, illustrated in Figure 1B.

For the setting up of transducer **100**, the Bragg grating **60** contained in optical fiber **30** is attached onto elastic membrane **50** by means of any attaching device and then the stop **70** is screwed in body **10a** to achieve the sealing. Thus, stop **70** generally makes easier the setting up of the optical transducer **100**.

Figure 1C is a side view of the same transducer, with the longitudinal passage **31** for optical fiber **30**.

The interior of the body **10a** is fitted with a chamber **80** for accommodating sealing means (not represented), designed for sealing transducer **100** from the outer medium. In transducer **100**, the optical fiber **30** crosses said sealing means and the longitudinal passage **31** of the body **10a**, so that at the end of the setting up, transducer **100** with the optical fiber **30** containing the Bragg gratings **60** is tight. Alternatively, if transducer **100** is used without being connected to any other transducer, one of its ends is completely sealed by a cap (not represented).

Figures 1B and 2B are BB cuts that illustrate modes of the transducer **100**, **200** of the invention with a Bragg grating **60b** designed for the measurement of pressure attached onto the elastic membrane **50** and another Bragg grating **60a** designed for the measurement of temperature being not attached onto the said membrane **50**. In this mode grating **60a** is protected by a metallic shield **61**, which also increases the effect of temperature experienced by grating **60a**.

Alternatively, metallic shield **61** is dispensed with and fiber **30** is encapsulated in a protecting tube (not represented).

Figure 2A illustrates an upper view of another mode of the optical transducer of the invention. The transducer, generally designed by numeral **200**, is made up of a cylindrical body **10b**.

Figure 2C is a side view of the same transducer **200** with the passage **31** of the optical fiber **30**. Figure 2D illustrates a mode of the said transducer where both Bragg gratings are attached on the elastic membrane.

Figure 2D illustrates one mode of transducer **100** having both Bragg gratings **60a**, **60b** contained in the same optical fiber **30** attached onto elastic membrane **50**. In this mode, one grating **60a** is attached at the center of the membrane **50** and another grating **60b** is attached so as to be out of the center of membrane **50**.

Transducers **100** and **200** differ only by the configuration to be coupled to outer sealing means.

Figures 3 and 4 refer to the calibration of transducer **100** of the invention. Broadly, it is observed that the change in reflection wavelength for transducer **100** shows a linear behavior of the wavelength change as a function of the physical parameters (temperature and pressure) when one of the mensurands, pressure or temperature, is changed while the other one is kept constant.

Figure 3 illustrates a graph of the calibration of the inventive transducer for the temperature grating. This Figure illustrates the dependencies of the wavelengths of the pressure and temperature sensors. Excellent linearity is observed, besides a higher sensitivity for the sensor attached onto the membrane. This is due to the addition of the effects of higher refractive index of the fiber, present in both sensors, and the thermal expansion of the membrane material.

Figure 4 illustrates a graph of the transducer calibration for the pressure grating based on a measurement system employing the measurement of the wavelength change.

The values of wavelength change making up the graph illustrated in Figure 4 include measurements carried out at 25, 34, 45 and 76°C using a measurement system based on wavelength change. Thus the illustrated data demonstrate that

transducer **100** did not show any hysteresis and that its response is linear, the sensitivity being independent of temperature.

The configuration of sensors **100, 200** illustrated in Figures 1A, 1B, 1C and 2A, 2B, 2C and 2D allows a plurality of said transducers **100, 200** having at least
5 one Bragg grating **60b** attached onto an elastic membrane **50** to be serially connected by means of the commonly shared optical fiber **30** so that multiple pressure and temperature sites can be measured in the mode of distributed sensors. Any multiplexing techniques can be employed for distinguishing the signal of one sensor from the signal of another one, such as wavelength-division
10 multiplexing (WDM) or time-division multiplexing (TDM), or any other multiplexing techniques. In this case, the grating **60a, 60b** in each sensor can have a different reflection wavelength.

CLAIM:

1. An optical transducer for the simultaneous measurement of downhole pressure and temperature, said transducer being inserted in a system comprising a light emitter, the emitted light propagating along the core of an optical fiber **30** containing Bragg gratings **60a**, **60b**, until said light meets a Bragg grating **60a/60b** able to reflect a portion of said light, wherein said transducer comprises a predominantly cylindrical body **10a/10b**, including an elastic membrane **50** for attaching at least one Bragg grating **60a/60b**, at least one more Bragg grating **60b/60a** contained in the same optical fiber **30**, and wherein said body **10a/10b** is:
 - a) Bored along the main axis to allow the passage of an optical fiber **30** via longitudinal passage **31** so as to secure access to both ends of said optical fiber **30**;
 - b) Provided with two symmetry planes in order to facilitate to be installed and serially connected with other sensors **100**, **200** of the same kind or other optical fiber transducers and sensors;
 - c) Provided with a central access and respective stop **70**, perpendicular to the main axis of said body **10a**, **10b**, on the opposite side of said membrane **50**, to allow the attachment of at least one Bragg grating **60a**, **60b** to said membrane **50**; and
 - d) Provided with sealing means against the outer pressure, at the inlet and at the outlet of the optical fiber **30** and in the central cylindrical bore, whereby the elastic membrane **50** conveys the strain that is proportional to the pressure and temperature conditions to which is submitted the transducer having at least one Bragg grating **60a**, **60b**, the portion of non-reflected light by the Bragg gratings following along the remaining length of the optical fiber **30**.
2. An optical transducer according to claim 1, wherein one Bragg grating **60b** is attached to elastic membrane **50** while the other Bragg grating **60b** is out of said membrane.
3. An optical transducer according to claim 2, wherein Bragg grating **60b** attached to elastic membrane **50** is the grating designed for pressure measurement.
4. An optical transducer according to claim 2, wherein Bragg grating **60a** out of the elastic membrane **50** is the grating designed for temperature measurement.

5. An optical transducer according to claim 4, wherein a metallic shield 61 protects the temperature Bragg grating 60a.
6. An optical transducer according to claim 4, wherein alternatively a protecting tube encapsulates the temperature Bragg grating 60a.
- 5 7. An optical transducer according to claim 1, wherein both Bragg gratings 60a, 60b are attached onto the elastic membrane 50.
8. An optical transducer according to claim 7, wherein the effect of temperature is the same for both Bragg gratings 60a, 60b attached onto the elastic membrane 50.
- 10 9. An optical transducer according to claim 1, wherein the Bragg grating(s) 60a, 60b are attached onto the elastic membrane 50 by means of any device.
10. An optical transducer according to claim 9, wherein the Bragg grating(s) 60a, 60b are attached onto the elastic membrane 50 by gluing with a polymeric adhesive.
- 15 11. An optical transducer according to claim 1, wherein the body 10a, 10b comprises symmetrical chambers 80, designed to accommodate sealing means against the outer pressure.
12. An optical transducer according to claim 1, wherein the thickness of elastic membrane 50 is uniform.
- 20 13. An optical transducer according to claim 1, wherein the thickness of elastic membrane 50 is variable.
14. An optical transducer according to claim 1, wherein elastic membrane 50 is integral to body 10a/10b.
15. An optical transducer according to claim 1, wherein elastic membrane 50 is coupled to body 10a/10b.
- 25 16. An optical transducer according to claim 1, wherein said transducer is used in the single mode.
17. An optical transducer according to claim 1, wherein a plurality of said transducers having at least one optical fiber 30 containing a Bragg grating 60b attached onto an elastic membrane 50 is serially connected through the common optical fiber 30 in order to effect measurement of multiple pressure and temperature locations in the mode of distributed sensors.
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18. An optical transducer according to claim 17, wherein said transducer is serially connected to other transducers and sensors of the same kind.
19. An optical transducer according to claim 17, wherein said transducer is connected in series to transducers and sensors of different kinds.
- 5 20. An optical transducer according to claim 1, wherein the connection in series is carried out through the same optical fiber **30**.
21. An optical transducer according to claim 17, wherein the connection in series is carried out through other optical fiber(s) **30a**, **30b**, **30n** coupled to said optical fiber **30**.
- 10 22. An optical transducer according to claims 17, 18, 19, 20 and 21, wherein WDM/TDM multiplexing techniques are used to distinguish the signal of one sensor from that of another sensor.
23. A method for the simultaneous measurement of downhole temperature and pressure with the aid of the optical transducer according to claim 1, wherein
- 15 said method comprises:
- a) providing an optical fiber **30** containing at least two Bragg gratings **60a**, **60b**, said gratings being sensitive respectively to temperature and pressure;
 - b) causing a change in the refractive index of said gratings **60a**, **60b** and a strain in said elastic membrane **50** resulting from the temperature and pressure conditions to which is submitted said transducer;
 - 20 c) through said elastic membrane **50**, conveying the temperature (refractive index) change and strains (spatial geometry of the grating) to said Bragg gratings **60a**, **60b**;
 - 25 d) from the measurement of Bragg wavelength changes, recovering the temperature and pressure values by means of a calibration curve.

ABSTRACT

OPTICAL TRANSDUCER AND METHOD FOR THE SIMULTANEOUS MEASUREMENT OF PRESSURE AND TEMPERATURE IN OIL AND GAS WELLS

5 An optical transducer **100, 200** for the simultaneous measurement of
downhole pressure and temperature in a single- or multi-point configuration is
described, said transducer comprising a predominantly cylindrical body **10a/10b**
including an elastic membrane **50** onto which is attached at least one Bragg
grating **60a/60b**, and at least an additional Bragg grating **60b/60a** contained on the
10 same optical fiber **30**, and where said body **10a/10b** is: a) bored along its main
axis; b) provided with two symmetry planes designed to make easier to install and
serially connect said transducer with other transducers **100, 200** of the same kind
or to other optical fiber transducers and sensors; c) provided of a central access
and respective sealing **70**, to allow the attachment of at least one Bragg grating
15 **60a, 60b** to elastic membrane **50**; and d) provided of sealing means against the
outer pressure. In transducer **100, 200**, the elastic membrane **50** conveys the
strain proportional to the pressure and temperature conditions to which is
submitted said transducer to at least one Bragg grating **60a/60b**, the portion of
light not reflected by the Bragg gratings **60a, 60b** following along the remaining of
20 the optical fiber **30**. The invention encompasses still the method for the
simultaneous measurement of downhole pressure and temperature in a single- or
multi-point configuration with the aid of the described optical transducer(s).

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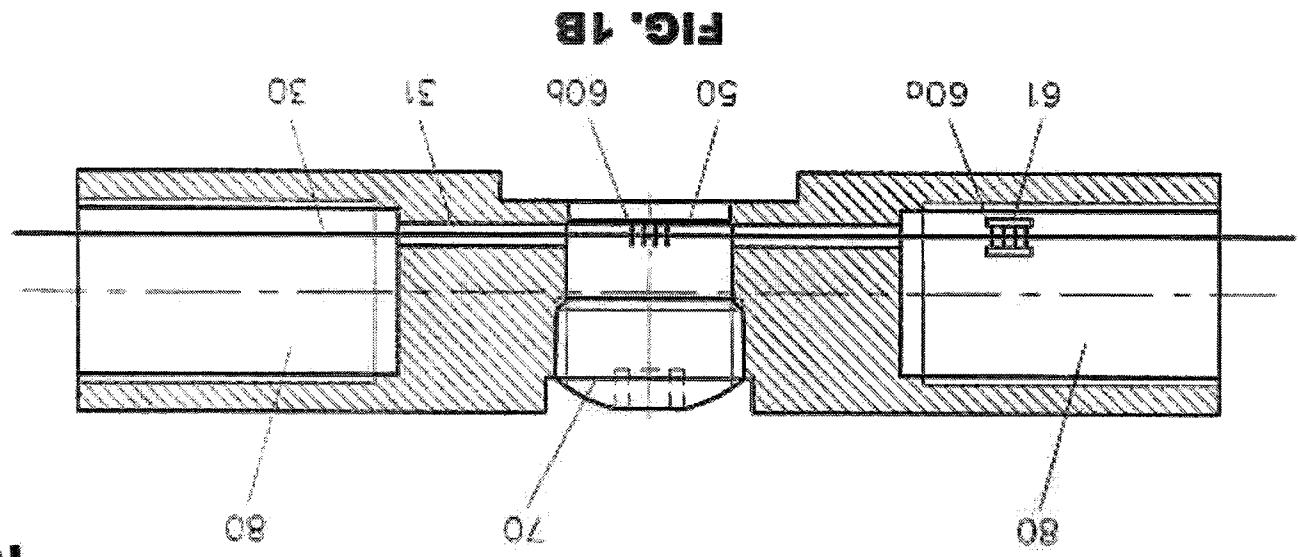
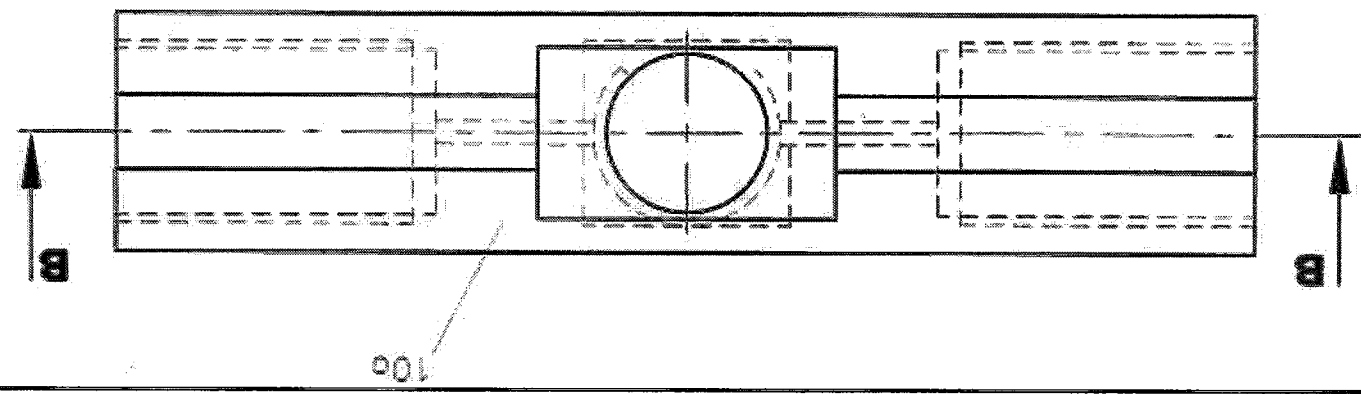
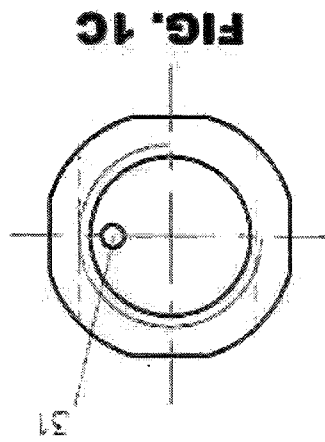


FIG. 2B

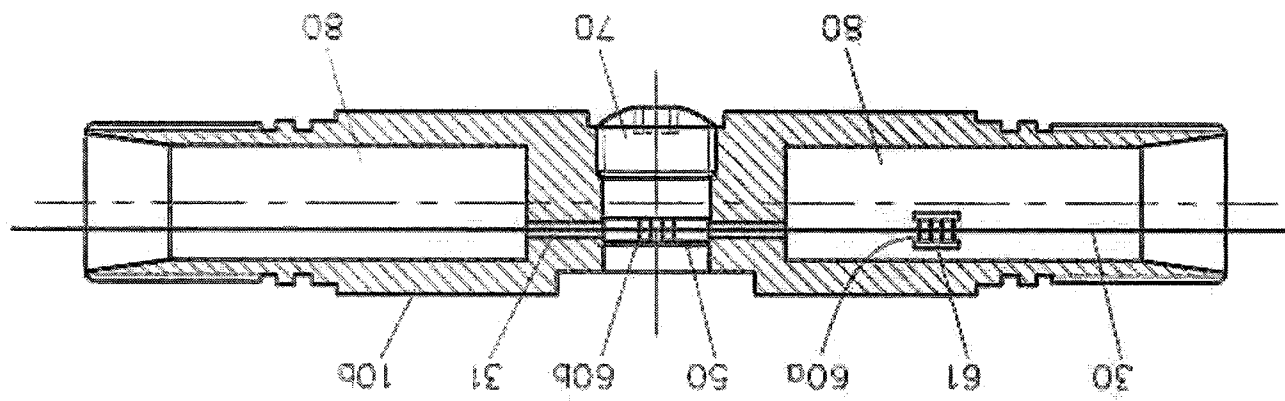


FIG. 2A

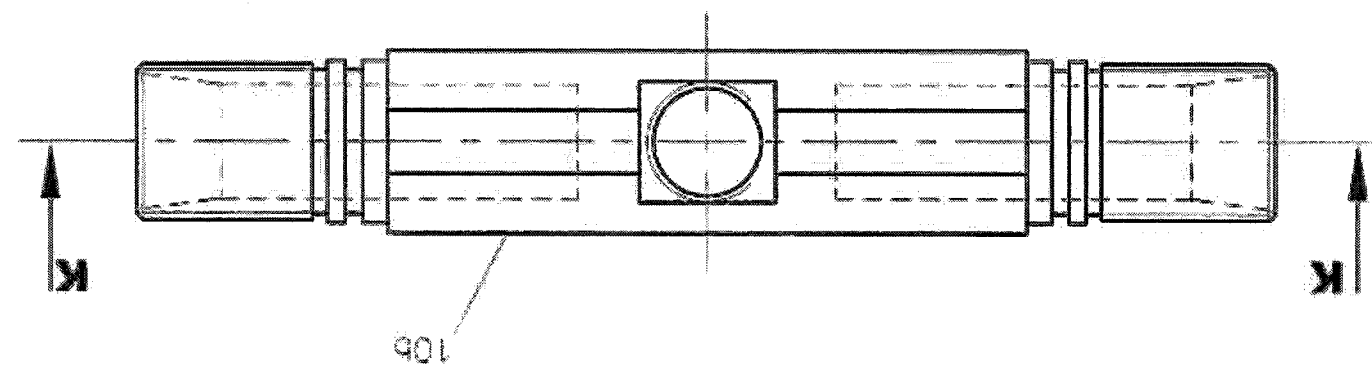


FIG. 2C

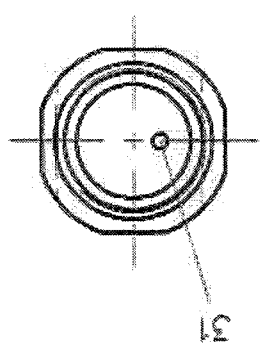
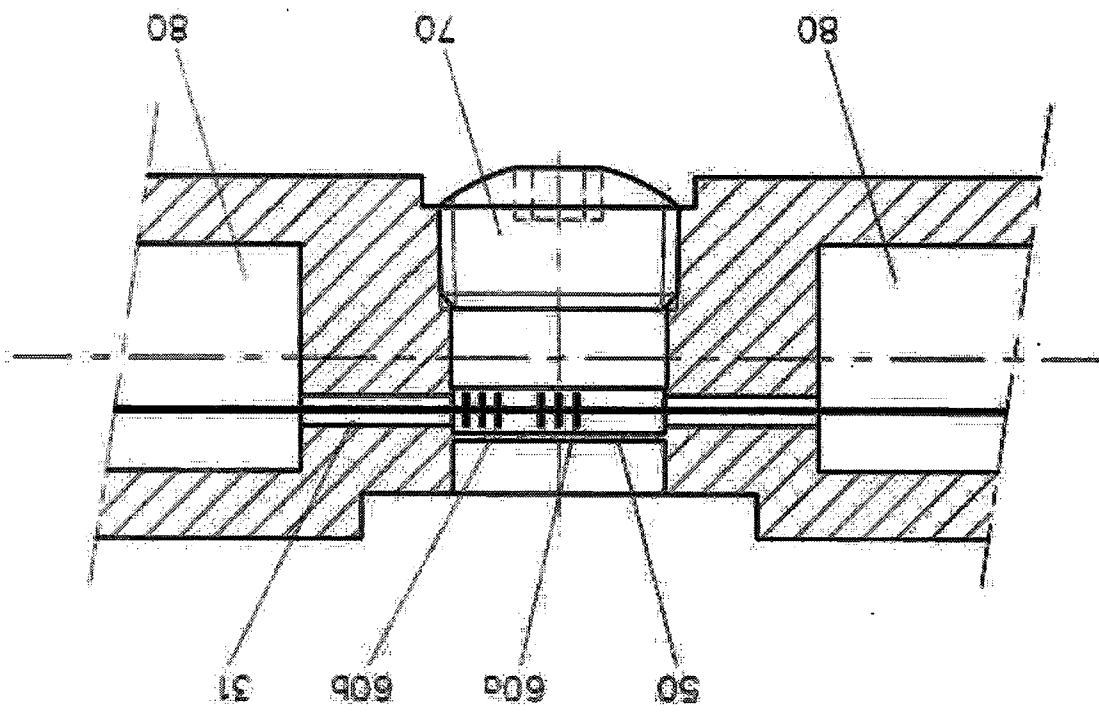


FIG. 2D



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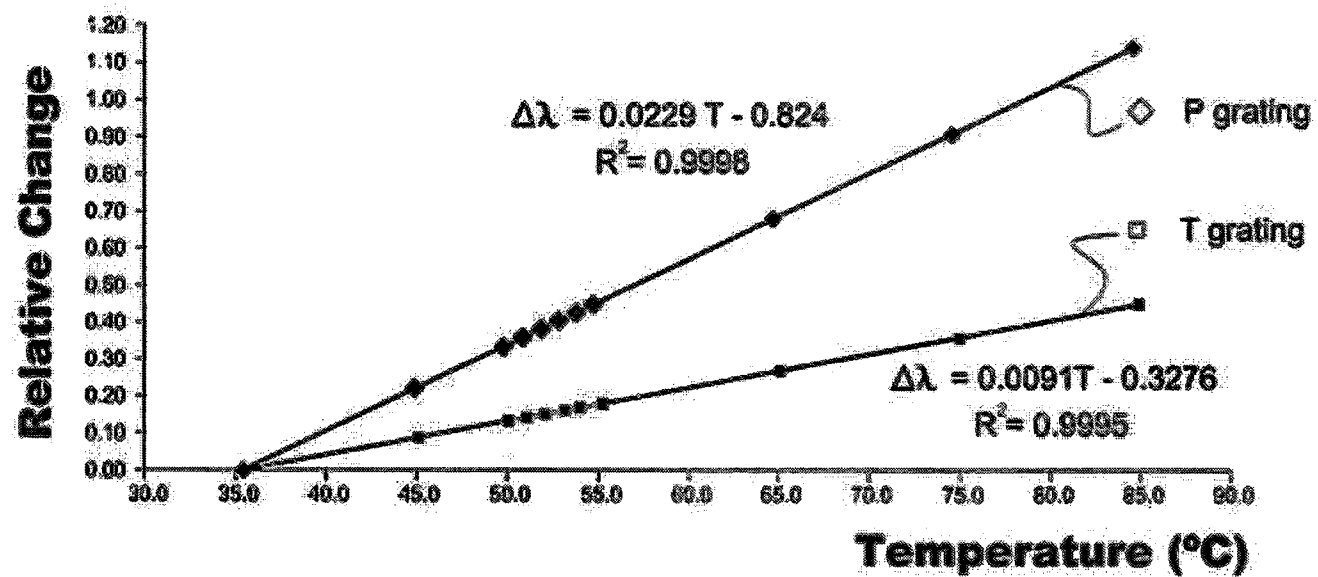


FIG. 3

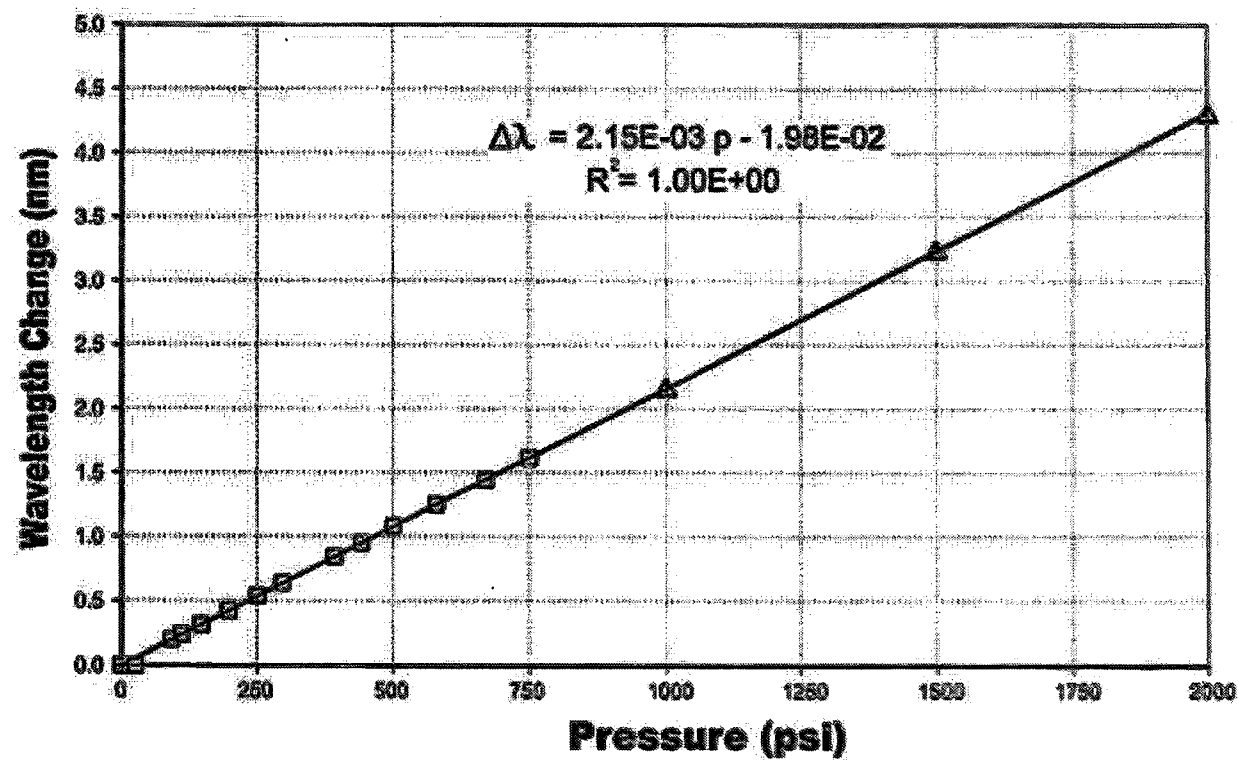


FIG. 4

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SUPERINDUSTRIA Y COMERCIO

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Dependencia: 2008 DIVISION DE NUEVAS CREACIONES

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 800176089-2

RECIBO OFICIAL DE CAJA : 05 - 53,305
FECHA : JULIO 18 DE 2005

***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PGO	Vr. PAGO
CAVELIER ABOGADOS	CONSIGNACION	BANCO POPULAR	050-00110-6	31589394	18/07/2005	53,445,000.00

***** CONCEPTO *****

CANT.	RENTISTICO	CONCEPTO	TOTAL CONCEPTO
1	50005-01-01 SOLICITUDES	1 TRAMITES DE SOL. DE PATENTE DE IN	443,000.00
		TOTAL :	\$ 443,000.00

SON: CUATROCIENTOS CUARENTA Y TRES MIL PESOS

RESPONSABLE :



RECIBO DE CAJA APLICADO AL EXPEDIENTE No. _____

Colo 00795-801-025-3

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 800176089-2

SUPERINDUSTRIA Y COMERCIO
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Dependencia: 2020 DIVISION DE NUEVAS CREACIONES

RECIBO OFICIAL DE CAJA : 05 - 51,280
FECHA : JULIO 11 DE 2005

***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PGO	Vr. PAGO
CAVELIER ABOGADOS	CONSIGNACION	BANCO POPULAR	050-00110-6	40116713	11/07/2005	65,740,000.00

***** CONCEPTO *****

CANT.	RENTISTICO	CONCEPTO	TOTAL CONCEPTO
1	50005-01-01	SOLICITUDES	
		82 INVOCACION DE UNA PRIORIDAD EN NU	124,000.00
		TOTAL :	\$ 124,000.00

SON: CIENTO VEINTICUATRO MIL PESOS

RESPONSABLE :



RECIBO DE CAJA APLICADO AL EXPEDIENTE No. _____

Colo 00795-801-025-3

REQUISITOS NECESARIOS PARA PRESENTACION Y AGILIZACION DEL TRAMITE

	USUARIO	RADICADOR
PATENTE DE INVENCION ☒	()	(☒)
MODELO DE UTILIDAD	()	(☒)
- Indicación de que se solicita la concesión de una patente.	()	(☒)
- Datos de identificación del solicitante o de la persona que se presenta la solicitud.	()	(☒)
- Descripción de la invención.	()	(☒)
- Dibujos de ser estos pertinentes.	()	(☒)
- Comprobante de Pago de las tasas establecidas.	()	()
COMPLETA ☒	()	()
INCOMPLETA	()	()
DISEÑO INDUSTRIAL ()		
- Indicación de que se solicita el registro de Diseño Industrial	()	()
- Datos de identificación del solicitante o de la persona que presenta la solicitud.	()	()
- Representación gráfica o fotográfica del Diseño Industrial o muestra del Material que incorpora el diseño.	()	()
- Comprobante de pago de las tasas establecidas	()	()
COMPLETA ()	()	()
INCOMPLETA	()	()
ESQUEMA DE TRAZADO ()		
- Indicación de que solicita el registro de un Esquema de trazado.	()	()
- Datos de identificación del solicitante o de la persona que presenta La solicitud.	()	()
- Representación gráfica del esquema de trazado	()	()
- Comprobante de pago de las tasas establecidas.	()	()
COMPLETA ()	()	()
INCOMPLETA	()	()

Firma Responsable: 

Fecha: