



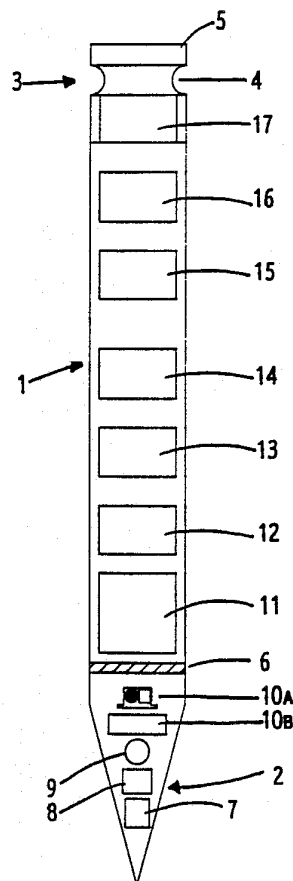
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁵ : G01V 1/16, 1/38</p>	<p>A1</p>	<p>(11) International Publication Number: WO 91/06878 (43) International Publication Date: 16 May 1991 (16.05.91)</p>
<p>(21) International Application Number: PCT/NO90/00158 (22) International Filing Date: 22 October 1990 (22.10.90) (30) Priority data: 894262 26 October 1989 (26.10.89) NO (71) Applicant (for all designated States except US): DEN NOR-SKE STATS OLJESELSKAP A.S [NO/NO]; Postboks 300, Forus, N-4001 Stavanger (NO). (72) Inventors; and (75) Inventors/Applicants (for US only) : SVENNING, Bjørnar [NO/NO]; Havsteinflata 12D, N-7021 Trondheim (NO). BERG, Eivind [NO/NO]; Væretreå 75, N-7053 Ranheim (NO). (74) Agent: LÆRUM, Martin; Den norske stats oljeselskap a.s, Postboks 300, Forus, N-4001 Stavanger (NO).</p>		<p>(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US. Published <i>With international search report.</i> <i>In English translation (filed in Norwegian).</i></p>

(54) Title: SEISMIC DEVICE

(57) Abstract

Device comprising instruments for the collecting and recording of signals in seismic exploration of the formation off-shore. The intermediate main portion (1) is approximately cylindrically shaped and is connected to a pointed end (2) via a vibration absorbing spacer (6). The other end of the intermediate main part is connected to a top part designed for insertion/pulling and other ways of handling the device, where the pointed end at least comprises geophones and a hydrophone is placed in or near the upper end of the device, and the other instruments of the device are situated in the middle main portion.



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SEISMIC DEVICE

TECHNICAL FIELD

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The present invention relates to a device and a method for execution of marine explorations of the kind which are indicated in the preambles of the main claims. Basically, the invention concerns seismic exploration of the substratum offshore where pressure and shear waves from the substratum are measured in response to the releasing of pressure and/or shear wave energy.

BACKGROUND ART

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Marine seismic exploration are usually carried out by a seismic cable provided with several hydrophones being towed at a certain depth. Pressure waves are released in the vicinity of the cable in several ways. This usually takes place by means of air guns. The pressure wave energy travels downwards through the substratum, but parts of the pressure waves are reflected from areas where there are acoustic impedance features in the substratum. The hydrophones record the reflected pressure waves in the water and transform this information into electric signals which are received and processed on the seismic ship which tows the cable. Using this method only reflected and/or converted shear to pressure wave energy is recorded. However, it is known that down in the formation both pressure waves and shear waves will be reflected. The shear waves do not travel in water and cannot therefore be detected by a hydrophone cable. Moreover, with today's conventional hydrophone technology, it is not possible to detect the directions of the measured signals, and this severely complicates possibilities for three-dimensional data collection.

DISCLOSURE OF INVENTION

The objective of the invention is to provide a new and improved device and method for the recording of three-dimensional pressure and shear waves which travel in the substratum.

The new distinctive features of the invention are disclosed in the characterizing part of the two main claims. Further advantageous features are disclosed in the dependent claims.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be more closely described in the following, with reference to the accompanying drawings where:

Fig. 1 shows a schematical drawing of a geopole according to the invention.

Fig. 2a illustrates a sub sea vessel after the laying out of poles on the sea-bed, seen from above.

Fig. 2b illustrates execution of a seismic exploration.

Fig. 2c illustrates a magazine for poles according to the invention.

MODES FOR CARRYING OUT THE INVENTION

The device shown in fig. 1 has a pole-like shape and comprises a cylindrical portion 1, a lower conically shaped or pointed end 2 and an upper portion 3. The upper portion 3 is compatible to equipment for inserting the pole down into, or pulling it out of the sea bed. In the shown embodiment, the upper portion is designed with a narrowing part 4 and an upper flange 5. This design is advantageous in that the

flange 5 can be utilized as a striking organ for forcing the pole down into the sea bed. The narrow part 4 is useful for instance when an engaging organ on a submarine is to pull up the pole from the sea bed, by making contact with the underside of the flange.

The pointed end 2 of the pole is insulated from the rest of the pole by a vibration insulating spacer 6. In a preferred embodiment the spacer 6 is made of an elastomer.

The actual point is shown in fig. 1 with a substantially conical shape which makes it easier for the pole to penetrate down into the sea bed. Other forms of embodiment are also applicable, for example a point divided into two with a lower cone shape ending in a shoulder and thereafter progressing into a new cone portion. Within the scope of the invention, other embodiments of the point can also be conceived.

The cylindrical part 1 of the pole constitutes the main volume of the pole and comprises a substantial part of all the equipment. The actual pole should be made of a metal, suitable an aluminium alloy.

The pointed end of the pole comprises, in a preferred embodiment, three geophones 7-9 arranged three-dimensionally in an x, y and z direction. The geophones 7-9 which as such are of a known type per se being commercially available, and will therefore not be more closely described. It is important that the geophones 7-9 are given good contact with the pointed end 2 of the geopole and this can be achieved by the geophones being moulded into the pointed end by means of a polymer material.

In the pointed end 2 an electronic angle gauge 10 is also placed, which, based on the force of gravity forms the angle of the pole with the vertical axis. The end comprises

further a compass 11 by which the rotation of the pole in the plane can be read. By means of these instruments, the exact position of the pole can be decided, which is necessary in order to decide the direction of the measured signals.

The cylindrical portion 1 of the pole contains the other equipment components. The location of the various components is decided by several factors. An important factor is that the pole's centre of gravity shall be as close as possible to the pointed end 2. It is also desirable that components which are in direct contact with each other are also localized next to each other.

In the shown embodiment, a battery 11 which can provide power to the other systems is placed at the lowermost part of the cylindrical portion. Rechargeable lithium batteries are the preferable choice. Suitably the batteries will be recharged above the sea. If recharging should take place under the water, dependence on conductive couplings should be avoided in stead, recharging should take place by induction in a coil which is placed in the cylinder wall or is fitted into the engagement flange 5.

Above the battery, in the next unit, a processor 12 is placed, which at least processes signals from the geophones 7-9, from the electronic angle gauge 10a/the compass 10b and from a hydrophone which will be more closely described later.

In a next unit placed above the processor 12 a memory unit 13 is placed. Seismic data, as well as background information about angle and direction is stored partly in the processor 12 and partly in the memory part 13.

The pole comprises further a power supply unit 14 for supply of power to the various units.

The pole comprises further an acoustic communications system 15 which can fulfil several functions. When several poles stand together in a pattern on the sea bed, it is necessary that it is possible to start/stop the collection of data of all of the poles at the same time. This can be done via acoustic signals which are detected by the geopole's receiver. Moreover it will be desirable that the poles are able to transmit acoustic signals when the poles are gathered in again. The acoustic communications system 15 can handle small amounts of data and can communicate across larger distances.

Further, the pole comprises an optical or magnetic reader 16 which makes possible rapid reading of the results of the seismic collections. Read-off will, in the embodiment which is shown in fig. 1, be able to take place after the poles are gathered in again.

The uppermost unit in the pole comprises a hydrophone 17 which is a transducer for pressure waves. Pressure and shear waves (P and S waves) which are reflected from the sediments, are detected by the three-dimensional geophones placed in the lower pointed end 2 of the geopole, while the hydrophone 17 only detects pressure waves in the water layer. When measurements from the hydrophone and from the 3 geophones 7-9 are correlated, and taking into consideration the distance between the hydrophone 17 and geophones 7-9, it is possible to separate upwardly travelling, reflected P-waves and S-waves from the P-waves which are reflected from the sea surface.

Without it in any way being considered to limit the invention, typical dimensions for a pole could be a length of approximately 1 m and a diameter of approximately 10 cm. The pole, when in use, shall be forced well down into the sea bed so that the pointed end 2 provides good contact with the sea bed. With the dimensions of the geopole which are

mentioned above, it will, typically, be forced approximately 20-40 cm down into the sea bed. The depth is moreover strongly dependent on the nature of the sea bed. Soft bed requires deeper penetration and vice versa.

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In the following, a preferred method for utilization of several geopoles in seismic exploration of off-shore substratum will be described with reference to Fig. 2a-2c.

10 In a preferred embodiment the poles, as shown in Fig. 2a, will prior to the exploration be inserted into the sea bed 20 in a definite pattern. In Fig. 2a an example is shown of such a pattern where the poles 21 are placed in the corners in a quadratic square pattern. A regular and rectangular
15 square pattern can also be possible and is dependent on the purpose of the survey.

In laying-out of two-dimensional geopole arrays on the sea bed, it is possible to achieve three-dimensional data
20 collection which is important in order to make true three-dimensional depiction of the substratum possible.

In some situations it will be advantageous to have the geophones 21 placed in groups, so that the mutual distance
25 between the poles 21 varies for each group. This will be particularly advantageous when it is desirable to specially survey local parts of the substratum.

The laying out of the geopoles is a time-demanding and
30 somewhat difficult operation, not least because it is desirable that the poles are set out in a fairly accurate position. In Fig. 2a-2b it is indicated that the laying-out can be carried out by means of a submarine vessel 22. The poles can be stored in a magazine 23 in the submarine vessel
35 22. The magazine is shown in larger scale in Fig. 2c, and as the submarine vessel 22 moves along a line, poles are forced one by one into the sea bed.

After the poles 21 are placed out in the desired pattern, the seismic exploration can start by means of a seismic ship in the form of a submarine vessel 22 as shown in Fig. 2a-2b or a surface vessel.

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The seismic ship will be provided with a source for generating wave and shear energy down in the formation in the vicinity of the poles 21. The energy source can come from many generators known per se. An air cannon which is the most usual source in marine surface seismology is suitable, even although it generates "secondary sources" (bubble effects) which will increase with increasing sea depth. Explosive sources are another well tried energy source which gives very good results. The explosives can be laid out on the sea bed or drilled a few metres down into the formation.

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When using an underwater vessel 21, a marine bed vibrator 24 will be particularly advantageous. A modified version of existing vibrators can be used, in that it is pushed or is sucked towards the sea bed and functions as land seismic vibrators in operations.

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The advantage of placing a vibrator on the sea bed is that it then becomes possible to make a greater part of the energy penetrate down into the sea bed and moreover achieve control and flexibility of the transmitted source signatures.

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In the following a seismic exploration according to the invention will be described more closely.

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A pressure, or combined pressure and shear wave is generated from a source and travels from the sea bed 20 and down into the substratum. In areas where there is a division in acoustic impedance between the layers in the formation, for example the points 25 and 26, a part of the energy will be

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reflected upwards as a combination of shear and pressure waves. They are indicated in Fig. 2 as wave 25a, 26a from the points 25 and 26 and the waves are recorded by the poles' geophones and hydrophones. The shear waves do not travel in water and they will transform into pressure waves at the sea bed 20 and travel further upwards illustrated in Fig. 2b as the waves 25b, 26b which will reach the water surface 27 where a part of them will be reflected back towards the sea bed as the waves 25c, 26c. The objective of the poles' hydrophones together with the geophones is exactly to be able to record downwardly travelling reflection waves from the surface together with the upwardly travelling reflection waves on the sea bed. Since geophones and hydrophones have a known orientation and distance of depth between each other, it is possible to separate upwardly and downwardly travelling waves.

Such a separation will be necessary because multiples or reflections from the sea surface will arrive at various points of time and will dominate the measurements more than in conventional collection.

After the seismic ship has generated the wave energy from one position, the ship changes position and generates new wave energy. The changing of position of the seismic ship each time wave energy is generated will take place in a predetermined pattern.

CLAIMS

1. Device comprising instruments for the collection and recording of signals in seismic exploration off-shore, characterized in that it comprises an intermediate main portion (1) which is approximately cylindrically shaped and which is connected to a pointed end (2) via a vibration absorbing spacer (6), in that the intermediate main portion's other end is connected to a top portion designed for installing/pulling and other ways of handling the device, in that the pointed end at least comprises geophones and that a hydrophone is placed in or near the upper end of the device and in that the other instruments of the device are placed in the intermediate main portion.
2. Device according to claim 1, characterized in that the vibration absorbing spacer (6) is made of an elastomer.
3. Device according to claim 1, characterized in that
- three geophones arranged in x, y and z directions, an electronic angle gauge (10a) which indicates the angle of the device with the vertical axis and a compass (10b) which gives the pole's rotation in the plane are placed in the pointed end (2),
 - in that a battery (11), a processor (12) which at least processes signals from the geophones (7-9), the angle gauge (10a), the compass (10b) and the hydrophone (17), a memory unit (13) for whole or partial storage of information, a power supply unit (14) for the supply of power to the various units, an acoustic communications system (15) for receiving and transmitting signals, an optical reader (16) which enables collected measurements to be read and the

hydrophone (17) for recording pressure waves, are placed in the intermediate main portion (1).

4. Device according to claim 3, characterized in that the communications system's receiving of signals makes possible start/stop in the recording of signals and when transmitting signals the gathering in of the poles becomes simplified.
5. Method for execution of seismic exploration off-shore, characterized in that
- freely standing poles (21) containing equipment for the recording of pressure and shear waves are inserted into the sea bed in a predetermined pattern by means of an underwater vessel so that the pointed end of the pole which contains the geophones is forced down into the sea bed for good contact with the formation,
 - in that, with a seismic ship, one or more pressure and/or shear waves are generated down in the formation from at least one position in the vicinity of the poles,
 - in that pressure and shear waves are recorded by the geophones of the pointed end,
 - in that pressure waves are recorded by the hydrophone and
 - in that the processing of the collected data takes place in a processor in the pole.
6. Method according to claim 4, characterized in that the poles (21) are placed in the corners in a quadratic or rectangular pattern.
7. Method according to claim 4, characterized in that the poles (21) are placed in groups so that the mutual distance between the poles (21) varies for each group.

8. Method according to claim 4, characterized in that the seismic ship is a submarine (22) and in that one or several vibrators (24) on the underside of the submarine are used as a seismic source.

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9. Method according to claim 4, characterized in that the seismic ship generates wave energy from different positions around the layed out poles in a predetermined pattern.

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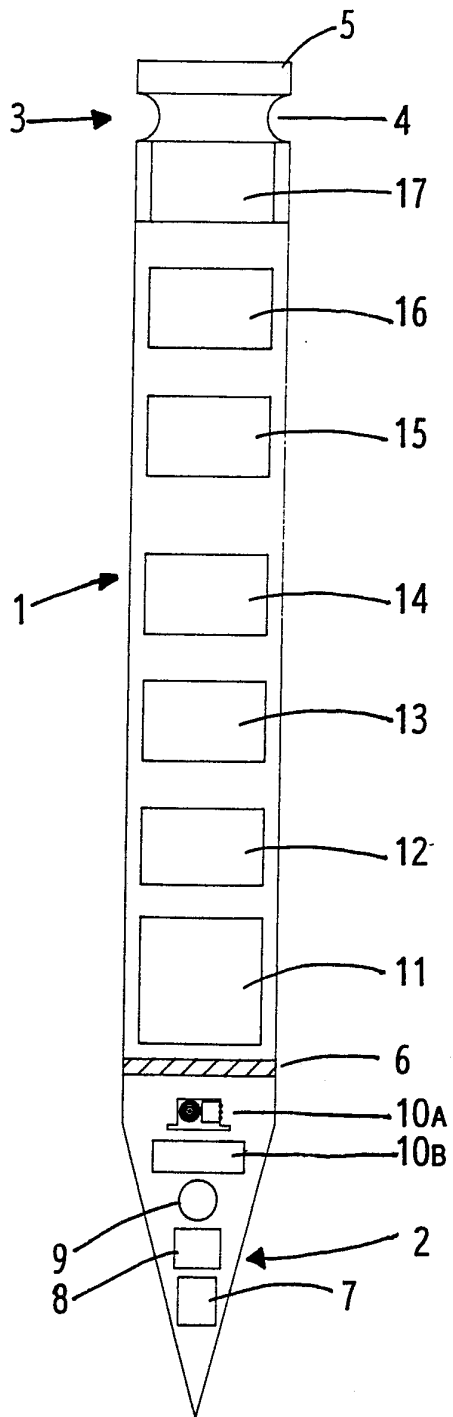


FIG. 1

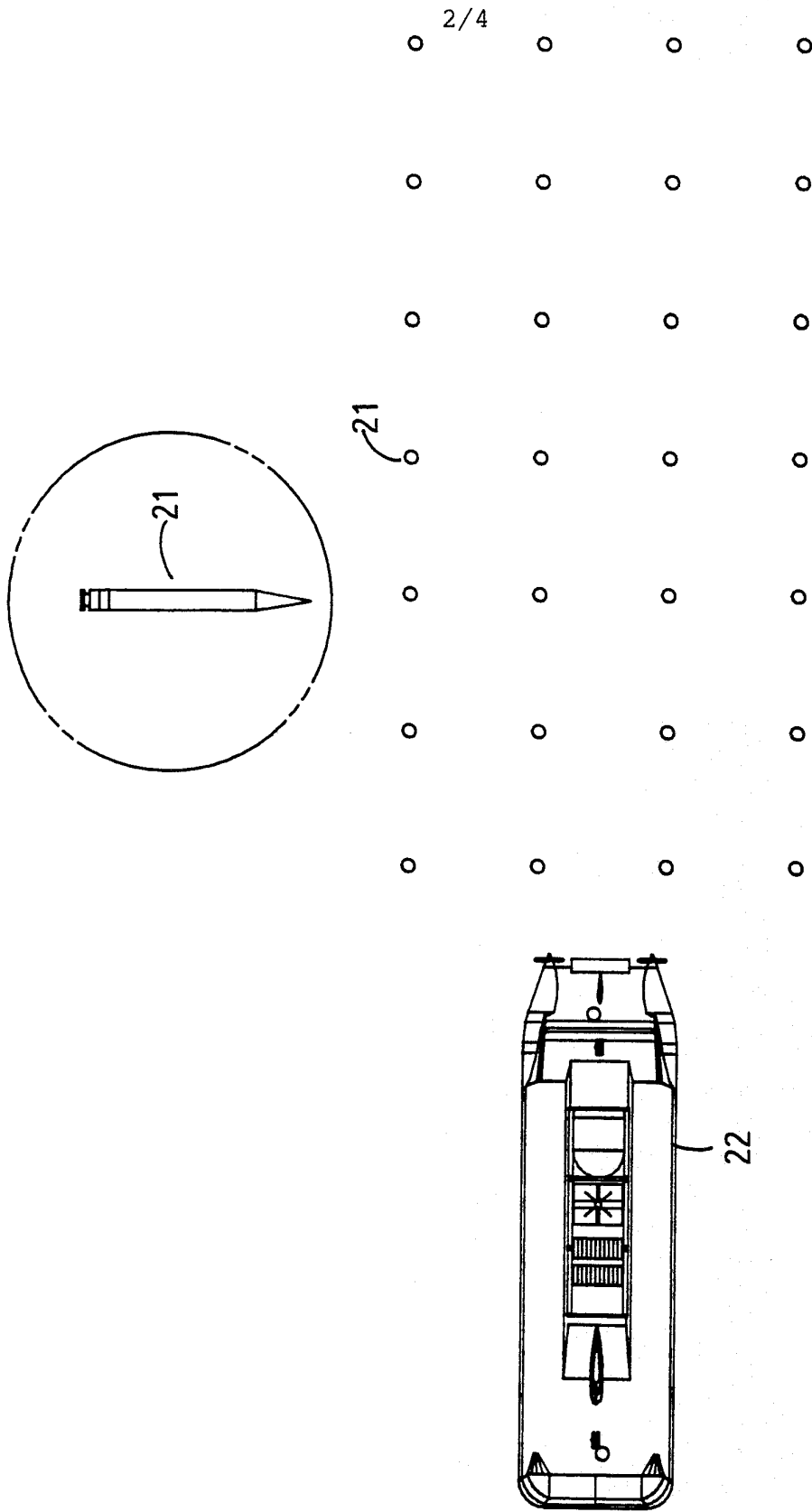


FIG. 2A

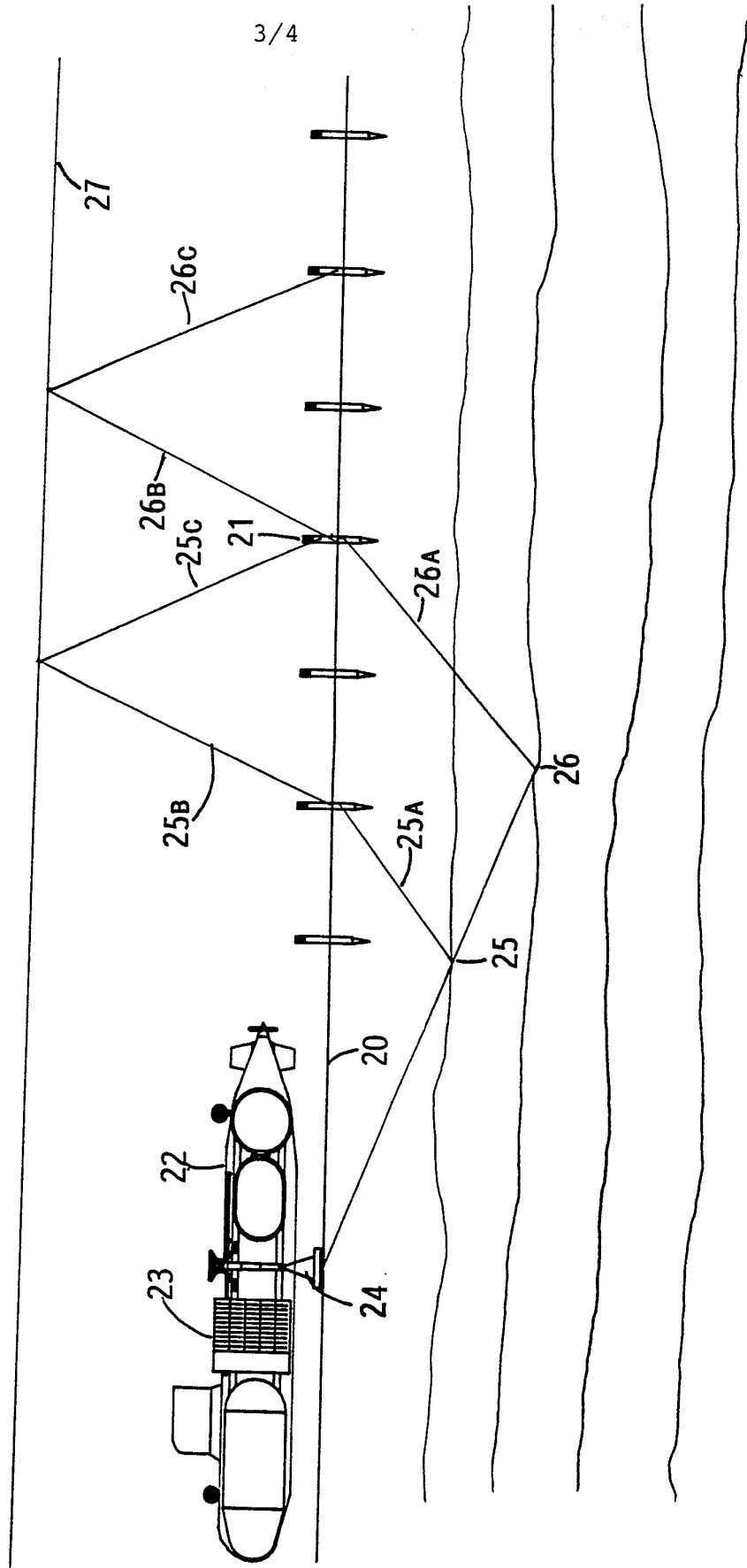


FIG. 2B

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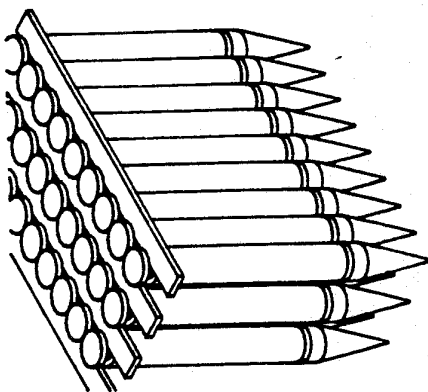
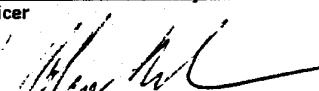


FIG. 2c

INTERNATIONAL SEARCH REPORT

International Application No **PCT/NO 90/00158**

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC5: G 01 V 1/16, G 01 V 1/38		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC5	G 01 V	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched ⁸		
SE,DK,FI,NO classes as above		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
Y	US, A, 4163206 (E.M. HALL JR.) 31 July 1979, see column 3, line 55 - column 4, line 28; column 5, line 10 - line 22; figure 8	1-2,5-9
A	--	3-4
Y	US, A, 4134097 (C.S. COWLES) 9 January 1979, see column 2, line 17 - line 65	1-2,5-9
A	--	3-4
Y	US, A, 4405036 (K.R. WENER ET AL) 20 September 1983, see column 3, line 26 - column 4, line 13	1
Y	US, A, 4516227 (K.R. WENER ET AL) 7 May 1985, see column 3, line 48 - column 5, line 37	1
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<p>* Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"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)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"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</p> <p>"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"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.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
31st January 1991	1991 -02- 04	
International Searching Authority	Signature of Authorized Officer	
SWEDISH PATENT OFFICE	Stefan Svahn 	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
Y	US, A, 4870625 (D.R. YOUNG) 26 September 1989, see column 2, line 57 - column 3, line 9; column 3, line 37 - line 61; column 5, line 38 - column 6, line 36 --	5-9
A	US, A, 3987404 (T.E. WOODRUFF) 19 October 1976, see abstract --	3
A	US, A, 4323988 (A.S. WILL) 6 April 1982, see column 3, line 35 - line 38 -- -----	3

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/NO 90/00158**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the Swedish Patent Office EDP file on **90-12-28**. The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4163206	79-07-31	CA-A- 1080342	80-06-24
		DE-A- 2717964	77-11-10
		FR-A-B- 2349147	77-11-18
		GB-A- 1577417	80-10-22
		JP-A- 53004585	78-01-17
		NL-A- 7704341	77-10-25
US-A- 4134097	79-01-09	CA-A- 1095160	81-02-03
		GB-A- 1584503	81-02-11
US-A- 4405036	83-09-20	NONE	
US-A- 4516227	85-05-07	NONE	
US-A- 4870625	89-09-26	NONE	
US-A- 3987404	76-10-19	NONE	
US-A- 4323988	82-04-06	NONE	