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Pressure-proof shell structure for underwater technology, especially for deep sea technology.

Pressure-proof shell structure for underwater technology, especially for deep sea technology, is provided for enclosing at least partly a closed space. The shell structure (1) is of amorphous carbon and is in the form of a hollow buoyancy body or it forms a protective cover for the components, such as measuring sensors, of an underwater device.

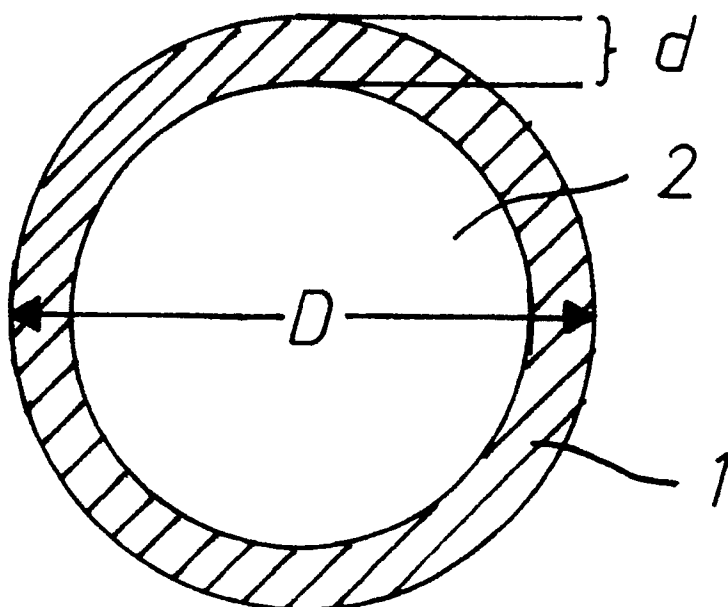


FIG. 1

The present invention relates to a pressure-proof shell structure for underwater technology, especially for deep sea technology, said shell being provided for at least partly enclosing a closed space.

The underwater technology sets special demands on the structures used therein owing to the fact that they are subjected to high pressures. These demands become especially important when the operation
5 takes place at the depths of 5 km and deeper.

It is of course possible to make structures pressure-proof by ensuring that they have sufficient strength. However, in this case a very important property needed in underwater technology, namely the lightness of structures is lost. The lighter the structures are, the easier it is to operate with them under water without the use of large buoyancy parts. There has been some drawbacks also in the manufacture of buoyancy parts
10 especially for the reason that the known buoyancy bodies having a low density can not for sure withstand deep sea conditions, either owing to the fact that the pressure is capable of damaging the hollow buoyancy bodies or on the other hand it compresses the buoyancy bodies manufactured of light material, which results in increased density and possibly even in the loss of their buoyant properties at the corresponding depth.

The object of present invention is to eliminate the drawbacks mentioned above and to accomplish a shell structure which can be used for various purposes in underwater technology, especially in deep sea technology, without increasing the resistance to pressure by compromising the lightness. For achieving this goal the shell structure according to the invention is characterized in that it is made of amorphous carbon.

The shell structure according to the invention can be used as a hollow buoyancy body, in which the
20 shell envelopes everywhere its hollow interior. The body of the above-mentioned type is preferably spherical and the thickness of the shell is substantially the same throughout the whole sphere. The shell structure according to the invention can also be used as a protecting cover for the components of an underwater device, such as protecting cover for electronic measuring sensors. The cover is light but it protects well the sensors at very high pressures, having at the same time such material properties that it
25 does not disturb the exploring of the exterior environment, because amorphous carbon transmits well various types of radiation and forms a sort of "transparent window" for them.

A shell structure used as a buoyancy body can also be incorporated in a larger buoyancy body and it can in this case be surrounded by a well-known buoyancy material of a different type for example.

The invention will be described in the following more closely in conjunction with the accompanying
30 drawing, wherein

- Fig. 1 shows one embodiment of the shell structure according to the invention in cross-section,
- Fig. 2 illustrates the manufacture of the structure of Fig. 1, and
- Fig. 3 shows another embodiment of the shell structure according to the invention in cross-sectional view.

It has been found that amorphous carbon used in the invention, known also by the name vitreous carbon, has surprisingly good properties when it is used in underwater technology. The properties and methods of manufacture of amorphous carbon are discussed for example in Finnish Patent No. 60380 and US-Patent No. 3,626,042. Amorphous carbon can be characterized by the following properties:

- density 0,8 to 1,6
- 40 - compression strength ca. 400 to 600 N/mm²
- modulus of elasticity 35 to 45 kN/mm²
- Poisson's ratio 0,39 to 0,48
- chemical composition at least 99,9% carbon

The above-mentioned values are of course for information and the invention is not restricted solely to
45 the use of such amorphous carbon having the properties within the ranges defined above.

Moreover, said material is amorphous only in the sense that crystals can not be detected by means of X-ray diffraction, that is, the obtained curve is characteristic of an amorphous material.

Among the above-mentioned properties especially the compression strength and density have proved excellent considering underwater technology, but also some further features are involved which will be
50 briefly discussed hereinafter.

Fig. 1 shows a shell structure according to the invention in cross-section. The structure can be used as a buoyancy body having a low density. The buoyancy body is hollow and a shell 1 envelopes it everywhere, thus enclosing its interior 2 entirely from the surroundings. The air present inside the body can thus be taken into consideration when calculating the density of the body. The body is spherical and its
55 outer surface and inner surface, that is, the inner face and the outer face of the body coincide as exactly as possible with concentric spherical surfaces and the wall thickness d of the shell 1 is thus constant throughout the whole sphere.

The relation of the thickness d of the shell to the outer diameter D of the sphere can of course vary

within a wide range when the desired thickness and pressure resistance of the sphere and certain a safety coefficient is taken into consideration. It can be calculated that said relation is directly proportional to the ratio between the desired pressure resistance and the compression strength. For example the ratio of 0,67 is sufficient to give enough strength to the body even at the depths below 5 km where a water pressure exceeds 50 MPa.

Said ratio is also large enough so as to avoid a risk of shell buckling as a result of the pressure on the shell, in other words, the structure has enough stoutness. By virtue of the low density of amorphous carbon the thickness of the shell does not, however, raise the total density of the body, and it is thus possible to reach total densities less than 0.5 by the above-discussed proportional values.

One important factor is still the large modulus of elasticity of amorphous carbon, which means that the material is stiff enough in order to not be compressed at high pressures, which otherwise would result in reduced density of the body and in the worst case in the loss of the buoyancy of the body. This has been a major drawback in the buoyancy bodies that have a very low density in normal pressure conditions and at relatively low depths.

The accompanying Fig. 2 shows the principle of manufacture of the spheres of Fig. 1. Amorphous carbon is generally prepared by carbonization (pyrolysis) of some polymers. The method of manufacture is disclosed in Finnish Patent No. 60380. The preparation takes place by carbonizing phenol-formaldehyde resin in a protective gas atmosphere according to a suitable temperature/time program. The resinous bodies can be moulded by means of a suitable mould into a desired shape, whereafter the resin will be hardened and the above-mentioned carbonization to amorphous carbon is carried out. During the process the body retains its outer appearance by shrinking ca. 20 to 30%. According to Fig. 2, the sphere can be formed of two hemispheres constituted of the hardened phenol-formaldehyde resin. The hemispheres 1a and 1b are joined together with a suitable pyrolyzable resin, such as with a hardenable phenolic resin. Before the pyrolysis, one of the hemispheres is provided with a small hole, through which the gases can escape from the inside of the sphere. Thereafter the pyrolysis is carried out in a protective gas in compliance with a predetermined temperature/time program. After the pyrolysis the hole can be blocked with a suitable resin, for example using epoxy resin. The hole will remain well closed in the operative circumstances of the shell structure, because the hole can be always closed in such a manner that the pressure exerted from the outside presses the resin against the hole more tightly.

Fig. 3 shows another embodiment of the shell structure according to the invention. The shell structure forms a protective cover for a component of an underwater device. The protective cover 1 has in this case the shape of a part of a sphere and its wall thickness is substantially constant throughout the whole surface of the shell structure. The shell structure can be attached to the rest of the surface of the underwater device and some suitable ways of fitting can be used for this purpose. In the case of Fig. 3 the shell structure serves as the shield for electronic measuring sensors 3. In addition to the lightness of the cover and the good protection against the external pressure, the cover does not cause any disturbances in the measurement itself, because the amorphous carbon forms a sort of "transparent window" for most types of radiation used in underwater measurements by means of electronic sensors.

The table below shows some results obtained with spherical buoyancy bodies that are similar to that in Fig. 1.

Table 1 Properties of spherical buoyancy bodies of amorphous carbon. Wall thickness ca. 4 mm in all spheres.

Sphere	1	2	3	4
Diameter (mm)	58.3	58.1	57.6	59.4
Volume (cm ³)	104.4	102.7	100.1	109.7
Weight of sphere (g)	39.5	40.0	40.0	51.0
Sphere density (g/cm ³)	0.380	0.389	0.400	0.465
Pressure resistance (bar)	957	925	960	1157

The results show that buoyancy bodies having a density below 0.5 can reach a pressure resistance exceeding 1000 bar (over 100 MPa). In addition, said density is also well retained at the pressure concerned. These results are unique in comparison to previous, known buoyancy bodies.

The invention is by no means restricted only to the embodiment shown in the foregoing description and in the Figures, but it can be modified within the scope of the invention defined by the claims. The shell structure can also be provided together with other buoyant material, for example in such a manner that it will be surrounded by other material, for example plastic material, within a larger buoyancy body. This plastic material can be for example of a well-known epoxy resin, which in addition comprises so-called glass microspheres with a diameter of 10 to 30 μm in order to lower its density. Said material is known by the name "syntactic foam". The buoyancy body of this type can be manufactured by casting in such a manner, that the spheres of amorphous carbon, which can be of different sizes, as well as the glass microspheres are embedded within the epoxy resin, by using a conventional technique.

The shapes of the shell structures are not either restricted in any way in the above description, although it is self-evident that spherical bodies or bodies having the shape of a part of a sphere have inherently optimum pressure resistance.

Claims

1. Pressure-proof shell structure for underwater technology, especially for deep sea technology, the shell being provided for at least partly enclosing a closed space, **characterized** in that the shell structure (1) is of amorphous carbon.
2. Shell structure as claimed in claim 1, **characterized** in that it is in the form of a hollow buoyancy body.
3. Shell structure as claimed in claim 2, **characterized** in that its outer surface is spherical.
4. Shell structure as claimed in claim 3, **characterized** in that the thickness (d) of the shell (1) is substantially constant throughout the whole sphere.
5. Shell structure as claimed in claim 1, **characterized** in that it forms a protective cover for the components (3) of an underwater device.
6. Shell structure as claimed in claim 5, **characterized** in that it serves as a protective cover for electronic measuring sensors (3), transmitting radiation utilized in the measurement.

7. Shell structure as claimed in claim 5 or 6, **characterized** in that it has the shape of a part of a sphere.
8. Shell structure as claimed in any of claims 1 to 4, **characterized** in that it is located within a larger buoyancy body, surrounded by other material, such as epoxy resin.
- 5 9. Shell structure as claimed in claim 8, **characterized** in that the material surrounding the shell further comprises glass microspheres.

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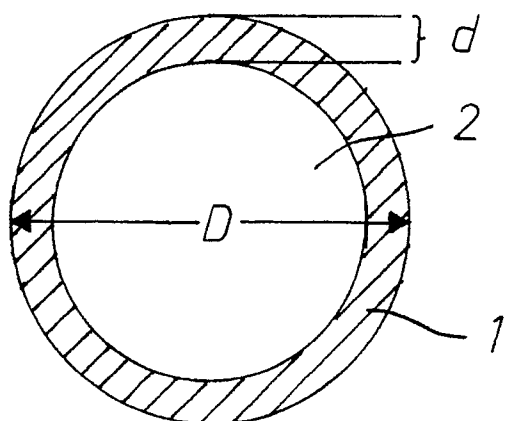


FIG. 1

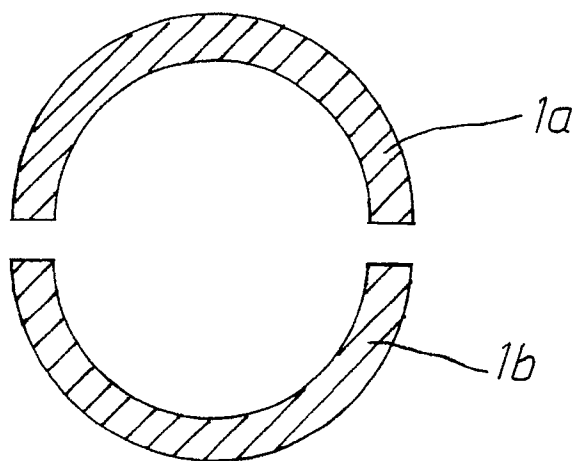


FIG. 2

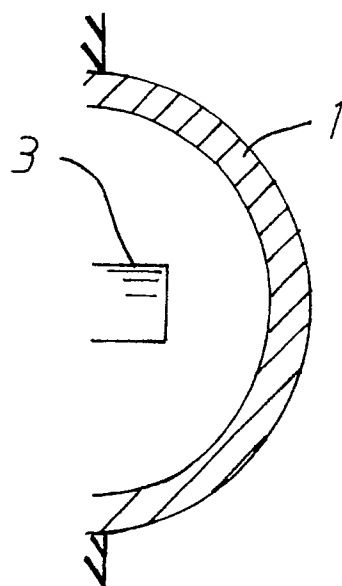


FIG. 3



EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-2 258 345 (BUTJUGIN ET AL) * page 1, lines 1 - 37 * page 3, line 39 - page 4, line 3 * - - - -	1-3.	B 63 B 3/13
A	RO-A- (USPEKHI KHIMII)vol. 40, no. 5, May 1971, & FIALKOV: "VITREOUS CARBON (Preparation, Properties and Applications)." * page 427, right-hand column, paragraph 2 * - - - -	1.	
A	US-A-4 550 015 (KORB ET AL) * column 1, lines 33 - 42 * - - - -	1.	
A	FR-A-2 572 986 (SOCIETE NATIONALE DES POUDRES ET EXPLOSIFS) * abstract; figure 1 * - - - -	2,5,8,9.	
A	WO-A-8 700 501 (HYDROVISION LTD) * abstract; figures 1-4 * - - - - -	2,7.	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B 63 B C 04 B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of search 24 April 91	Examiner DE SENA Y HERNANDORE
CATEGORY OF CITED DOCUMENTS X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: earlier patent document, but published on, or after the filing date D: document cited in the application L: document cited for other reasons ----- &: member of the same patent family, corresponding document			