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(54) Equipment for carrying out underwater operations.

(57) Equipment (1) for carrying out underwater operations includes a submersible working chamber (2) at one end of an access shaft (3) and ballast weights (W) for adjusting the buoyancy of the equipment so that it can float freely with the chamber (2) submerged to a working depth and with the shaft upright and projecting above the surface. Divers can descend to the submerged working chamber (2) from the surface at atmospheric pressure through the access shaft (3) and a first hatchway closed by a pressure-resistant hatch (7), and can then pressurise the chamber (2) to the ambient hydrostatic pressure by actuating air supply means (9, 9A, 10, 11) so that they can enter and leave the water through a second hatchway closed by a pressure-resistant hatch (8). The divers can subsequently open a valve (12) to discharge the pressure in the chamber (2) in order to undergo decompression to atmospheric pressure in the working chamber before returning to the surface through the access shaft (3).

EQUIPMENT FOR CARRYING OUT UNDERWATER OPERATIONS

The present invention relates to equipment for carrying out underwater operations.

Various types of equipment which allow underwater operations to be carried out or which provide underwater living quarters are known and generally fall into two broad categories.

They may take the form of diving bells which are tethered to a surface vessel and include a chamber which can be pressurised to the ambient hydrostatic pressure to enable divers to work from the bell when it is submerged and subsequently depressurised after it has been recovered to the surface in order that the divers can undergo decompression. Diving bells have the disadvantage of being expensive to build and to operate, in terms of the ancillary equipment necessary, the manning levels and the time lost between dives.

An alternative type of the aforesaid equipment is that described in GB-A-2 046 818. This document describes equipment including a submersible working chamber which is connected to a shaft intended to extend upwardly beyond the water surface. In use, the equipment is lowered into the water so that an aperture in the floor of the chamber surrounds and is sealed against the exposed head section of a foundation pile or the like, and the equipment is pumped dry whereby the chamber and the shaft are at atmospheric pressure and personnel from the surface can descend to and ascend from the chamber at will by means of the shaft. This equipment has the disadvantages of having to be anchored and tightly sealed to the head section or other structure and of not permitting divers to work outside the submerged chamber.

The object of the present invention is to provide equipment of the type mentioned initially which overcomes these disadvantages of the prior art.

According to the present invention, this object is achieved by equipment for carrying out underwater operations, of the type including a submersible working chamber connected to one end of an access shaft which is intended to extend upwardly so that its other end is above the water surface in use, wherein it includes:

- means for adjusting the buoyancy of the equipment so that it can float freely with the chamber submerged to a working depth and with the shaft upright or substantially upright and projecting above the surface to afford access between the surface and the chamber;
- respective pressure-resistant hatches for sealing first and second hatchways between the access shaft and the working chamber and between the working chamber and the outside, respectively, and
- means for supplying air or a breathing gas mixture to the working chamber in order to pressurise the chamber from atmospheric pressure to the ambient hydrostatic pressure at the working depth and for discharging the air or gas from the working chamber in a controlled manner in order to depressurise the chamber from the ambient pressure to atmospheric pressure, whereby, in use, a diver can descend to the submerged working chamber from the surface at atmospheric pressure through the access shaft and the first hatchway, can then enter and leave the water at the ambient hydrostatic pressure through the second hatchway after pressurisation of the working chamber, and can subsequently undergo decompression to atmospheric pressure in the working chamber before returning to the surface through the access shaft.

The access shaft or that portion thereof between the first hatchway and the surface is intended to remain at atmospheric pressure and substantially dry in use.

Preferably, the part of the equipment defining the working chamber is heavier than the access shaft so that the equipment will tend to float in more or less the correct attitude when it is in the water and the addition of relatively small amounts of ballast will adjust the buoyancy sufficiently to achieve the correct attitude and working depth. The buoyancy adjusting means may therefore comprise detachable weights which can be attached to the exterior of the chamber upon submergence and can be removed or jettisoned when the equipment is to be recovered at the surface.

Alternatively, the buoyancy adjusting means may comprise tanks which can be flooded with appropriate amounts of water to add ballast, the water being discharged or blown from the tanks by pressurised air or gas when not required. These tanks may take the form of external tanks or pressure vessels around the outside of the working chamber or they may comprise interspaces between inner and outer walls of the chamber.

The means for supplying air or gas to the working chamber and for discharging the air or gas therefrom may comprise at least one inlet valve connected to a source of pressurised air or breathing gas mixture, preferably carried by the equipment, and at least one discharge valve. The or each discharge valve enables the pressure in the chamber to be reduced in a carefully controlled manner, in accordance with an established decompression cycle, so that divers who have been working outside the chamber can undergo decompression before returning to the surface.

Preferably, there are two discharge valves, the first of which communicates with the atmosphere through a hose for the controlled depressurisation of the chamber and may have a slow rate of flow, and the second of which may have a fast rate of flow and can also serve as a flooding or trimming valve for enabling partial flooding of the working chamber in order to adjust or trim the buoyancy of the equipment to establish a precise working depth or to compensate for changes in weight due, for example, to the entry or departure of personnel in use. Any water admitted to the chamber to trim the buoyancy can subsequently be blown from the chamber through the second discharge valve by compressed air in a conventional manner. For this purpose, the second discharge valve may have an intake as close to the floor of the chamber.

Alternatively, the equipment may have trimming tanks similar to the ballast tanks described above.

Flotation means, such as air-filled bags or bodies of a material of high positive buoyancy may be fitted to the equipment adjacent the surface end of the access shaft to help ensure that the equipment floats at the correct attitude or, in some cases, actually to buoy up the equipment.

The access shaft normally has a watertight hatch at its surface end and may be of fixed length or may comprise a plurality of sealingly interconnectible sections. The latter embodiment allows the equipment to be used over a wider range of working depths than an embodiment with a fixed-length shaft and has the advantage that a shaft of the required length can be assembled at the site of operations, perhaps as the equipment is being lowered into the water.

One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a side elevational view of equipment according to the present invention for carrying out underwater operations, in a condition of use, and

Figure 2 is a diagrammatic longitudinal sectional view of the equipment taken along the line II-II of Figure 1, on an enlarged scale.

In the drawings, equipment for carrying out underwater operations, generally indicated 1, comprises essentially a submersible working chamber 2 connected to one end of a tubular access shaft or manway 3. The part of the equipment 1 defining the chamber 2 is heavier than the access shaft 3 so that, when the equipment 1 is in the water, it floats with the chamber 2 submerged and with the access shaft 3 more or less upright so that its end portion opposite the chamber 2 projects above the surface of the water, as shown in Figure 1. This opposite, surface end of the shaft 3 is closed by a watertight entry hatch 4 and is provided with external attachments 5 engageable by a crane, davit, tow rope or the like for handling and moving the equipment 1.

A ladder 6 is mounted inside the shaft 3 and extends from the entry hatch 4 to a hatchway between the shaft and the working chamber 2. The latter hatchway is closed by a hatch 7 which is arranged to open into the chamber 2 so as to withstand increases of the pressure in the chamber relative to that in the shaft. In some cases, the shaft 3 may house a lift, for example, in the form of a platform or cage, but the ladder 6 may still be present for emergency use.

The working chamber 2 communicates with the outside through a hatchway which is closed by a hatch 8 and, in the illustrated embodiment, is in the floor of the chamber. The hatch 8 is arranged to open outwardly of the chamber 2 so as to withstand ambient hydrostatic pressures in use.

Each of the hatches 4, 7, 8 is of the type with a catch or closure mechanism 4A, 7A, 8A which can be operated from both sides of the hatch. Each hatch 4, 7, 8 has an O-ring seal or gasket (not shown) which is pressed against a machined annular surface of the hatchway when the hatch is closed so as to ensure an effective water-and pressure-tight seal.

The working chamber 2 is provided with an air inlet valve 9 (see Figure 2) connected to a source of pressurised air or breathing gas mixture for supplying the air or gas to the chamber 2 in order to pressurise it to the ambient hydrostatic pressure in use. The pressurised-air or -gas source is constituted by at least one cylinder 10 carried on the outside of the chamber. Alternatively or in addition, the pressurised air or gas may be supplied to an air inlet valve 9A from the surface through a so-called umbilical hose 11.

Two discharge or vent valves 12, 13 (Figure 2) are also provided for discharging the pressure in the chamber 2 to the outside. A first discharge valve 12 has a slow rate of flow and is connected to the atmosphere by a hose 14 so that the pressure in the working chamber 2 can be reduced from the ambient hydrostatic pressure to atmospheric pressure at a carefully controlled rate. The second discharge valve 13 has a fast rate of flow and is connected within the chamber 2 to one end of a rigid pipe or a flexible hose 15 resistant to collapse under suction. This second discharge valve 13 permits the rapid venting of pressure from the chamber 2 but also serves as a trimming valve which enables the partial flooding of the chamber in order to adjust or trim the buoyancy of the equipment to establish the precise working depth of the chamber 2 upon initial submergence and to compensate for any weight changes in use. Water admitted to the chamber 2 for trimming purposes is discharged or blown from the chamber 2 after use by means of the same valve 13, through the pipe or hose 15 whose free end 15A is disposed at short distance, for example about 150mm, above the floor of the chamber 2 so as to be immersed in the water. The hose 15 can be flexed to lift its free end 15A clear of the water if the air pressure in the chamber 2 is to be reduced without discharging any water; for the same purpose in the case of a rigid pipe, it may be possible to disconnect or isolate the pipe from the valve 13.

A further valve 16 may be provided, for example, in the roof of the chamber 2, to enable the chamber to be pressurised or depressurised from the outside in an emergency.

The valves 9, 9A, 12, 13, 16 are preferably of a type which can be operated from both the inside and the outside of the chamber 2, as shown diagrammatically in Figure 2. The valves 9, 9A, 12, 13 are normally set with their external controls open whereby the valves can be opened and closed entirely from within the chamber by their internal controls, whilst the valve 16 is normally set with its internal control open and its external control closed so that it can only be operated from outside in an emergency.

In a conventional manner, the working chamber 2 is fitted out with ancillary equipment such as depth gauges, internal and external pressure gauges, interior lights, controls for exterior lights 17, communications equipment, divers' life support systems and, preferably, heating apparatus, none of which is shown. Any power necessary for the ancillary equipment is normally supplied from the surface by umbilical cables, although in some cases back-up batteries may be carried on the outside of the chamber. The heating apparatus may be of the hot-water type and be supplied through an umbilical hose from the surface, of the electrical type or of the chemical or catalytic type.

In use, the apparatus and implements required by the divers who are to carry out the underwater operations are placed in the working chamber 2 and the equipment 1 is lowered into the water at the site of operations from a surface support vessel, barge, oil rig, quayside or the like, with the hatches 4 and 8 closed. The equipment 1 is ballasted, before or when it is lowered into the water, to adjust its buoyancy so that it floats with the working chamber 2 submerged at the desired working depth, for example 12 m, and with the access shaft 3 extending vertically and projecting above the surface, for example, by about 2 m.

The equipment 1 is ballasted by the addition of removable weights W which are attached to the outside of the chamber 2 in a symmetrical or balanced manner and correspond approximately to the amount of ballast required to attain the desired working depth. Once the divers have entered the working chamber 2, as described below, any final adjustment or trimming of the buoyancy necessary to attain the exact working depth can be made by means of the valve 13.

When the equipment 1 is floating stably with the chamber 2 at substantially the desired working depth, the divers descend from the surface to the chamber 2 by opening the entry hatch 4, climbing down the ladder 6 (or by being lowered in the lift if present), and entering the chamber 2 through the hatch 7, all at atmospheric pressure. A ladder 18 is mounted on the outside of the end portion of the shaft 3 which projects above the surface so that the divers can reach the entry hatch 4 from a boat or pontoon alongside the equipment if necessary. The ladder 18 extends towards the chamber 2 as a series of rungs 19 on the outside of the shaft 3 for use by the divers when underwater.

Once the divers are in the chamber 2 and any necessary trimming of the buoyancy has been effected by means of the valve 13 to establish the exact working depth, the hatch 7 is closed and the air inlet valve 9 or 9A is opened to pressurise the chamber 2 to the ambient hydrostatic pressure.

After the chamber 2 has been pressurised to the correct hydrostatic pressure, the hatch 8 can be opened without any risk of undesired flooding of the chamber and the divers can leave and return to the chamber at will in order to perform the required operations. Upon the completion of the operations, or at the end of the divers' permitted working period, the divers return to the chamber 2 and, after closing the hatch 8, open the discharge valve 12 to begin a controlled reduction of the pressure in the chamber to atmospheric pressure, in strict accordance with decompression tables for the working depth.

Once the pressure in chamber 2 reaches atmospheric pressure, the hatch 7 can be reopened and the divers can climb the ladder 6 to the surface. Another crew of divers may then enter the equipment 1 and repeat the cycle of operations.

When the equipment 1 is to be recovered after use, any water in the chamber 2 may be blown out through the discharge valve 13 by compressed air and the weights W removed so that the equipment can be lifted out of the water. The equipment may be towed to a different site of operations in ballast without being removed from the water.

With an access shaft 3 of fixed but manageable length, it is envisaged that the equipment 1 may be used over a range of working depths of the chamber 2 of, for example from 10 m to 20 m. Greater depths may be achieved, for example, with the use of an access shaft which can be assembled at the site of operations from a plurality of sealingly interconnectible sections. Furthermore, the divers from the chamber 2 may work at depths considerably greater than the working depth of the chamber 2, using the chamber 2 as a "decompression stop" before returning to the surface.

The equipment according to the invention allows divers safely to descend to and ascend from the submerged working chamber at atmospheric pressure, while permitting them to work from the chamber at the ambient hydrostatic pressure and to carry out the necessary decompression at the working depth before they return to the surface. The equipment thus avoids the risks of decompression sickness involved in surface decompression techniques and the need for expensive diving bells and ancillary equipment to transfer the divers to the surface under pressure.

Claims

1. Equipment (1) for carrying out underwater operations, of the type including a submersible working chamber (2) connected to one end of an access shaft (3) which is intended to extend upwardly so that its other end is above the water surface in use, characterised in that it includes:
- means (W, 13) for adjusting the buoyancy of the equipment (1) so that it can float freely with the chamber (2) submerged to a working depth and with the shaft (3) upright or substantially upright and projecting above the surface to afford access between the surface and the chamber (2);
- respective pressure-resistant hatches (7, 8) for sealing first and second hatchways between the access shaft (3) ahd the working chamber (2) and between the working chamber (2) and the outside, respectively, and means (9, 9A, 10, 11) for supplying air or a breathing gas mixture to the working chamber (2) in order to pressurise the chamber from atmospheric pressure to the ambient hydrostatic pressure at the working depth and for discharging the air or gas from the working chamber (2) in a controlled manner in order to depressurise the chamber from the ambient pressure to atmospheric pressure, whereby, in use, a diver can descend to the submerged working chamber (2) from the surface at atmospheric pressure through the access shaft (3) and the first hatchway, can then enter and leave the water at the ambient hydrostatic pressure through the second hatchway after pressurisation of the working chamber, and can subsequently undergo decompression to atmospheric pressure in the working chamber before returning to the surface through the access shaft.

2. Equipment according to Claim 1, wherein the part of the equipment (1) defining the working chamber (2) is heavier than the access shaft (3) whereby the equipment tends to float in more or less the correct attitude when it is in the water.

3. Equipment according to Claim 1 or Claim 2, characterised in that the buoyancy adjusting means comprise detachable weights (W) which can be attached to the exterior of the chamber (2) upon submergence and removed or jettisoned when the equipment (1) is to be recovered at the surface.

4. Equipment according to Claim 1, Claim 2 or Claim 3, characterised in that the air or gas supply and discharge means comprise at least one inlet valve (9, 9A) connected to a source (10, 11) of pressurised air or gas and at least one discharge valve (12, 13).

5. Equipment according to Claim 4, characterised in that pressurised-air or -gas source comprises at least one cylinder (10) carried by the equipment.

6. Equipment according Claim 4, characterised in that the pressurised-air or -gas source is at the surface and is connected to the at least one air inlet valve (9A) by a hose (11).

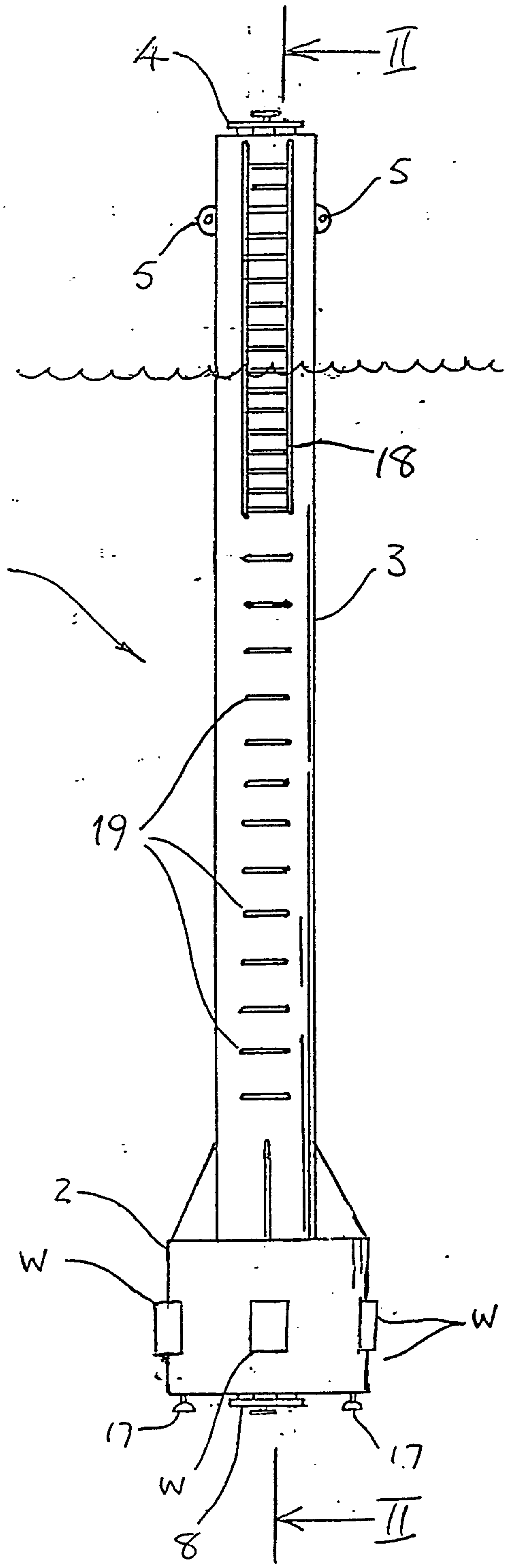
7. Equipment according to Claim 4, characterised in that it has a first discharge valve (12) which communicates with the atmosphere through a hose (14) for the controlled depressurisation of the working chamber (2), and a second discharge valve (13) which is adapted to act as a trimming valve for enabling the partial flooding of the working chamber (2) and the discharge of water therefrom in order to adjust or trim the buoyancy of the equipment (1).

8. Equipment according to Claim 7, characterised in that the second discharge valve (13) has an intake (15A) close to the floor of the chamber (2).

9. Equipment according to Claim 8, characterised in that the second discharge valve (13) is connected within the chamber (2) to one end of a rigid pipe or flexible hose (15) whose opposite, free end (15A) constitutes the intake and is disposed a short distance above the floor of the chamber (2).

10. Equipment according to any of the preceding claims, characterised in that it includes a watertight entry hatch (4) at the end of the access shaft (3) which is above the surface in use.

Fig.1



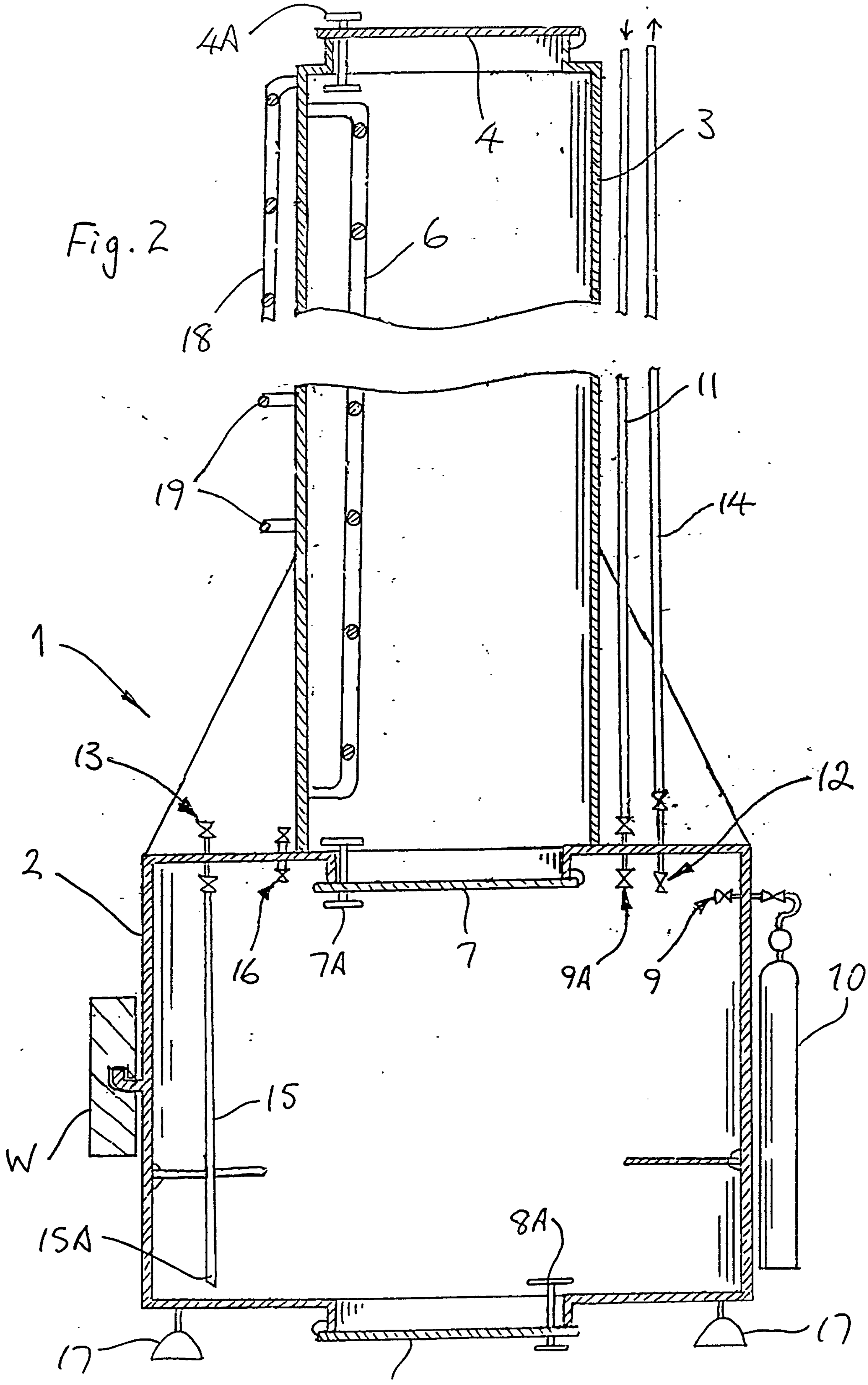


Fig. 2
4A
4
3
6
18
11
19
14
1
13
12
2
16
7A
7
9A
9
10
15
W
15A
8A
17
8
17

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 30 2290

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- 912 263 (MALARTRE) * Whole document * ---	1,2	B 63 C 11/38
A	US-A-1 963 996 (LAKE) * Page 4, lines 13-56; Figures 3,7 * ---	1,4	
A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 201 (M-325)[1638], 14th September 1984; & JP-A-59 91 231 (TAISEI KENSETSU K.K.) 25-05-1984 -----	1,4	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B 63 C E 02 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30-05-1990	VISENTIN, M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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