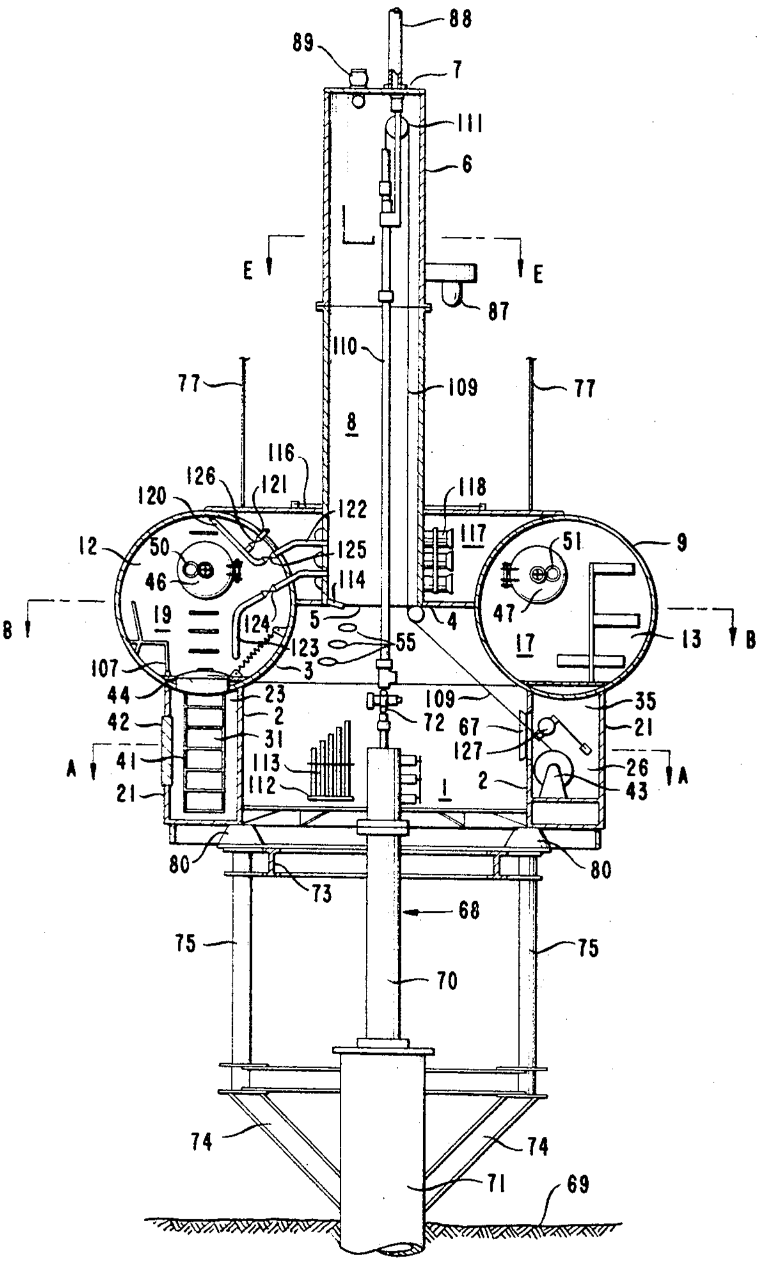
Nov. 5, 1968 F. J. CHATE ET AL 3,408,822

DIVING METHOD AND APPARATUS

Filed Aug. 5, 1966 4 Sheets-Sheet 1



F I G. 1

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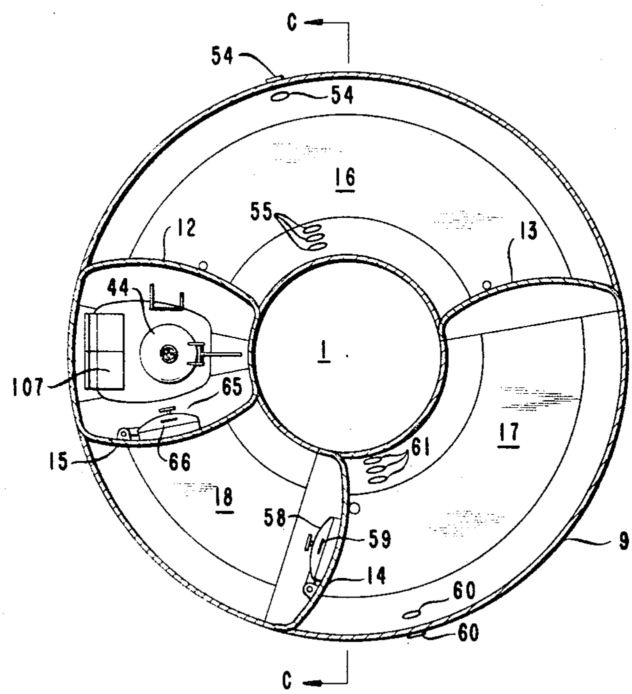
THEIR AGENT



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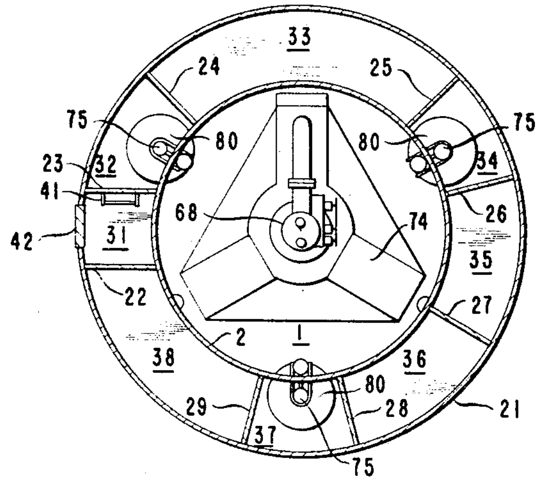

F I G. 3

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DIVING METHOD AND APPARATUS

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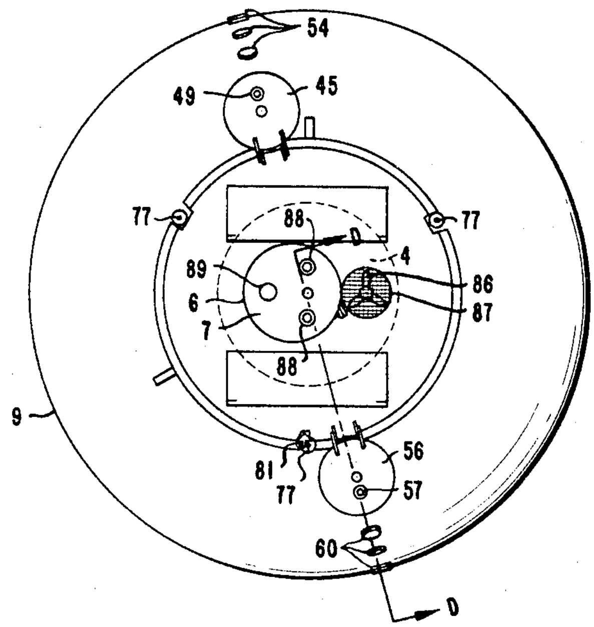

FIG. 4

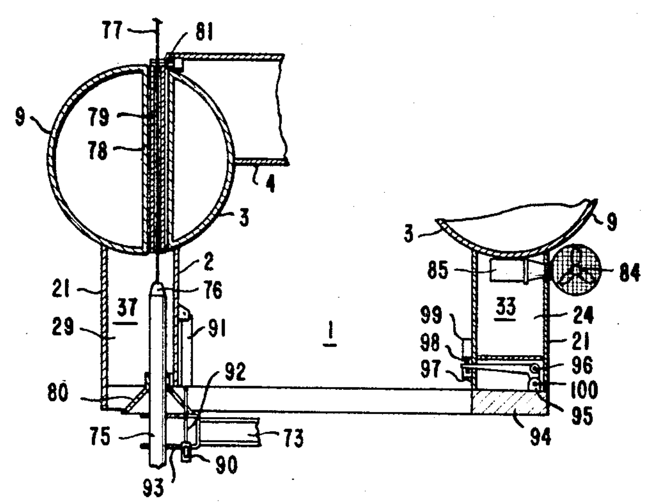

FIG. 5

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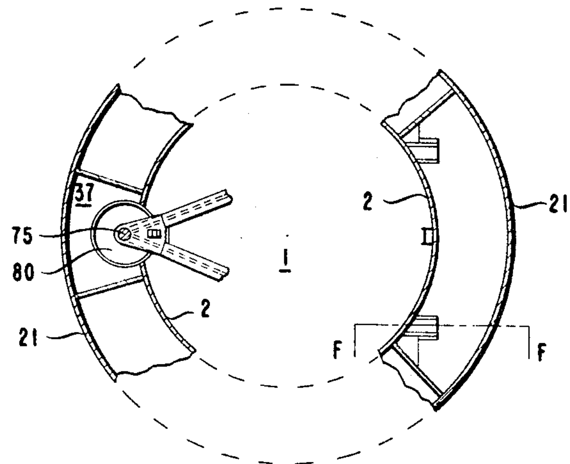

FIG. 6

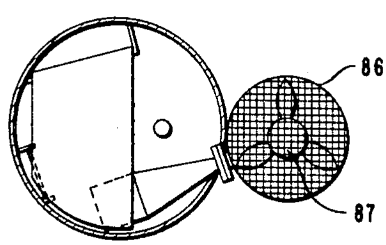

FIG. 8

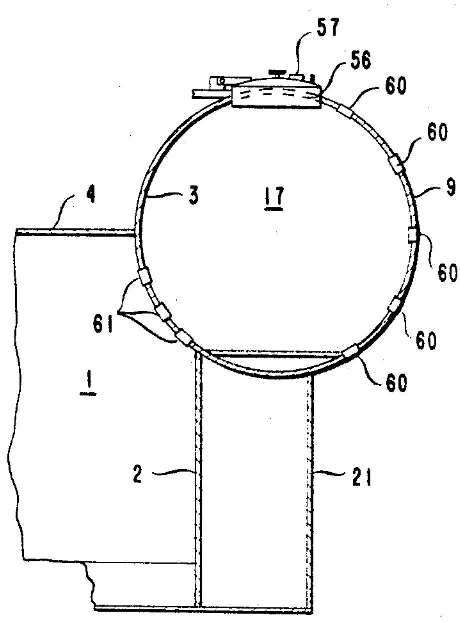

FIG. 7

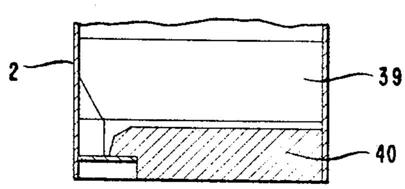

FIG. 9

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DIVING METHOD AND APPARATUS

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Claims priority, application Netherlands, Aug. 6, 1965, 6510238
13 Claims. (Cl. 61—69)

ABSTRACT OF THE DISCLOSURE

A method and apparatus for carrying out underwater operations with the aid of diving apparatus provided with at least a living compartment, a decompression compartment, a water-lock compartment and a working compartment. The diving apparatus is lowered into the water to an operating depth at which a gas pressure approximately equal to the static water pressure at the operating depth is maintained in the working compartment. A predetermined substantially constant gas pressure higher than atmospheric pressure and lower than the water pressure at the operating depth is maintained in the living compartment. Divers in the diving apparatus move periodically from the living compartment via the decompression compartment to the working compartment and vice versa as gas and water is selectively supplied and discharged to and from the water-lock compartment so as to maintain a desired pressure in the water-lock compartment.

The invention relates to a method and diving apparatus for carrying out underwater operations in particular to a depth of approximately 300 meters.

It is known that in diving operations it is necessary to bring the diver gradually from the water pressure at the operating depth back to the atmospheric pressure (decompression). This decompression is time-consuming, increasingly so as the water pressure at the operating depth becomes higher. The decompression time depends on the nature of the gas mixture breathed in by the diver, on the time spent by the diver under the high pressure, and on the degree of the pressure exerted on the diver.

In order to substantially shorten the time required for decompression it is advantageous not to decompress to atmospheric pressure, but to a higher pressure viz. to an intermediate pressure lying between atmospheric pressure and the water pressure at the operating depth, for example, to a pressure of 6 atma. The diver can remain at this intermediate pressure in between the operations. Subsequently compression can be applied again, for example to 30 atma. whereupon the diver can continue his activities. This work period can, if desired, be followed on one or more occasions by decompression to the intermediate pressure, a rest period at the intermediate pressure, compression and a following work period.

The object of the invention is to provide a method and diving apparatus by means of which the operations may be carried out in the manner described above.

The invention, therefore, relates to a method for carrying out underwater operations with the aid of a diving apparatus provided with a living compartment, a decompression compartment, a water lock compartment and a working compartment, in which method the diving apparatus is lowered into the water to a certain depth (operating depth) at which depth a gas pressure approximately equal to the static water pressure at the operating depth is maintained in the working compartment, a gas pressure higher than atmospheric pressure and lower than the water pressure at the operating depth is maintained in the living compartment, and divers present in the diving apparatus move periodically from the living compartment via the decompression compartment and the water lock compartment to the working compartment, and vice versa, the divers carrying out the desired operations, for example on an oil or gas well in the sea bottom, in the working compartment.

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The invention moreover relates to a diving apparatus comprising a living compartment, a decompression compartment, a water lock compartment and a working compartment, sealable manholes between the said compartments, means for controlling the gas pressure in the working compartment, means for maintaining in the living compartment a suitable breathing gas mixture having a pressure higher than atmospheric and lower than the static water pressure at operating depth, means for controlling the gas pressure in the decompression compartment, and means for supplying or discharging gas or water having a desired pressure to or from the water lock compartment.

In order to ensure that the operations to be carried out underwater proceed as smoothly and efficiently as possible, it is desirable for a supervisor's compartment to be present also, in addition to means for maintaining in the supervisor's compartment a suitable breathing gas mixture at approximately atmospheric pressure. From this supervisor's compartment supervisory personnel can control, guide and direct the operations to be carried out by the divers, the said supervisory personnel working under conditions of normal pressure and normal air in the supervisor's compartment.

The invention will now be elucidated with reference to the diagrammatic drawing in which

FIGURE 1 shows a lateral view of a longitudinal section of the diving apparatus;

FIGURE 2 shows a top-plan view of a cross-section B—B of the diving apparatus;

FIGURE 3 shows a top-plan view of a cross-section A—A of the diving apparatus;

FIGURE 4 shows a top-plan view of the diving apparatus;

FIGURE 5 shows a fragment of a lateral view of a longitudinal section C—C of the diving apparatus;

FIGURE 6 shows a fragment of a bottom-plan view of the diving apparatus;

FIGURE 7 shows a lateral view of a longitudinal section D—D of the diving apparatus;

FIGURE 8 shows a top-plan view of a cross-section E—E of the diving apparatus;

FIGURE 9 shows a fragment of a lateral view of a longitudinal section F—F of the diving apparatus.

The diving apparatus according to the invention comprises a substantially bell-shaped working space **1**, substantially bounded by a preferably cylindrical side wall **2**, a wall **3** connecting to this latter on the upper side, having the shape of part of a torus surface, and an upper wall **4**, the bottom side being left open. In the upper wall **4** a hole **5** is arranged, preferably excentrically. To this a pipe **6**, provided with an upper wall **7**, is connected in order to increase the useful working space. The working space present in the pipe **6** is indicated by the reference numeral **8**. To the upper end of the cylindrical side wall **2**, a hollow torus-shaped element **9** is secured, for example, by means of a welded joint. A part of the wall of this torus-shaped element **9** forms the said wall **3** of the working space **1**. A number of substantially radial bulkheads **12, 13, 14, 15**, shown in FIGURE 2, divide the torus-shaped element into a supervisors' compartment **16**, a living compartment **17**, a decompression compartment **18** and a water-lock compartment **19**, respectively.

A second cylindrical side wall **21** (FIGURES 1 and 3) is arranged round, and at some distance from the cylindrical side wall **2**, so that an annular space is formed between the two side walls **2** and **21**, which space is divided by means of radial bulkheads **22, 23, 24, 25, 26, 27,** 28 and 29 into compartments indicated by the reference numerals 31, 32, 33, 34, 35, 36, 37, and 38 respectively. In the lower part of the said annular space are situated three trimming tanks 39 and ballast 40 (see FIGURE 9). In the compartments 32, 34 and 37 are guide means which will be discussed later. Compartment 31 serves as a passage through which the divers can pass from the water-lock compartment 19 to the working space 1, and vice versa. For this purpose a ladder 41 is arranged in the compartment 31. Between the water-lock compartment 19 and the compartment 31 is a door 44, through which divers can pass from the compartment 19 to the compartment 31 and vice versa. The compartment 31 is provided with a door 42 in the wall 21, which leads outside. The main power plant and instruments (not shown) are situated in the compartment 33 and in the compartment 35 there is a hydraulically operated winch 43 and ancillary equipment (not shown) for carrying out work on a well on the sea bottom. In the compartment 36 are arranged the required electric batteries (not shown) and in the compartment 38 the water pumps and the trimming pump (not shown).

In the supervisors' compartment 16 are arranged the controls, for example, for controlling the gas mixtures, for controlling gas pressures, for controlling the diving bell's buoyancy, for operating the water-lock compartment, for operating the winch, for operating and controlling the diving apparatus' propulsion equipment (not shown). The supervisors' compartment 16 also contains emergency controls, lighting systems, intercommunication systems and power plants (not shown). The supervisors' compartment 16 is provided on the upper side with a door 45, while the radial bulkheads 12 and 13 are likewise equipped with doors indicated by the reference numerals 46 and 47, respectively. These doors 45, 46 and 47 serve inter alia to facilitate escape in emergencies. All doors 45, 46 and 47 are provided with portholes, indicated by the reference numerals 49, 50 and 51, respectively. The portholes 50 and 51 (FIGURE 1) are necessary for inspecting the water-lock compartment 19 and the living compartment 17, from within the supervisors' compartment 16. The porthole 49 (FIGURE 4) in the door 45 serves for checking, after the diving apparatus has been hauled up, whether the diving bell is fully above water so that the door 45 can be opened without the risk of flooding the supervisors' compartment 16.

A number of portholes are arranged in the walls of the supervisors' compartment 16, viz. a number, indicated by the reference numeral 54, on the inside, and a number indicated by the reference numeral 55 on the outside. The portholes 54 on the outside are used for navigational purposes, and those on the inside for use in carrying out operations on the sea bottom, for example, work on a well in the sea bed. All pipes and cables are passed into the supervisors' compartment 16 through at least one aperture (not shown) in the wall of the supervisors' compartment, which aperture is preferably arranged on the bottom side or the inner side of the supervisors' compartment 16, in order to reduce the risk of damage to a minimum. Cable or pipe connections between the compartments in the hollow torus-shaped element 9 are passed through openings in the radial bulkheads in the element 9.

The living compartment 17 (FIGURE 7) is provided on the upper side with a door 56 in which a porthole 57 is arranged. As explained already, radial bulkhead 13 (FIGURE 1) contains the door 47, which provides access to supervisors' compartment 16 from the living compartment 17, and vice versa. In the radial bulkhead 14 (FIGURE 2) is a door 58, which provides access to the decompression compartment 18 from the living compartment 17, and vice versa. A porthole 59 is arranged in the door 58. Portholes are also arranged in the wall of the living compartment 17, viz. portholes 60 on the outside and portholes 61 on the inside.

In the radial bulkhead 15 (FIGURE 2) is a door 65, which provides access to the water-lock compartment 19 from the decompression compartment 18 and vice versa. A porthole 66 is arranged in the door 65. The decompression compartment 18 contains, for example, compressors for breathing equipment and a compressor for discharging oxygen-helium to above the surface of the water (not shown). These compressors are operated from the supervisor's compartment 16; appurtenant valves (not shown) can, however, be hand-operated in the decompression compartment 18, a feature which can be of importance in emergencies.

The supervisor's compartment 16, the living compartment 17 and the decompression compartment 18 are preferably insulated with heat-insulating material, for example, glass wool covered for Formica.

The door 44 (FIGURE 2) provides access to the compartment 31 from water-lock compartment 19 and vice versa. In the water-lock compartment 19 are arranged telephone connections and a breathing manifold. The breathing control valves are provided with remote control, but if necessary they can be hand-operated from within the water-lock compartment, which may be desirable in the case of emergencies.

The compartment 35 is provided with a door 67 (FIGURE 1), providing access to the working space 1, through which door the tools can be reached when the diving apparatus is situated above the well on the sea bottom. Compartments 35, 36 and 38 can likewise be reached via sealable manholes (not shown).

The diving apparatus is provided on the upper side with an upper wall 116 (FIGURE 1), which connects with the upper part of the torus 9. As a result a closed space 117 is formed within the walls 4 and 116 and the inside part of the torus 9, in which space necessary gas cylinders 118, for example, nitrogen, oxy-helium and oxygen cylinders, are stored.

With reference to FIGURE 1, the reference numeral 68 indicates the conventional well head, present on the sea bottom 69, of a well drilled in the sea bottom 69 (oil or gas well). The reference numerals 70 and 71 respectively indicate the conventional inside and outside tubes of the well. The well head can be equipped with conventional blow-out preventers 72. The well head 68 is provided with a steel framework 73, which is rigidly secured to the well head 68 by means of a supporting structure 74 and guide rods 75. The guide rods 75 are provided at their upper ends with a conical part 76 (FIGURE 5). To the conical part 76 of each guide rod 75 an appropriate guiding cable 77 is secured, which cables lead vertically upwards to a ship (not shown). The diving apparatus according to the invention is provided with a number of cable ducts 78, for instance three. Each duct 78 is preferably provided with a bush 79, through which a cable 77 is passed. The upper side of diving apparatus is provided with cable cutters 81, each of which grips round the cable 77, and which can be used in emergencies to cut through the cables 77. For the sake of clarity only one cable cutter 81 is shown in FIGURE 4. It should be noted that the guide cables can be omitted if desired. In this case the diving apparatus is directed only by accurate maneuvering with the aid of propellers which can be fastened to the diving apparatus.

A number of funnel-shaped elements 80, which can grip round the guide rods 75, are arranged against the outer side of the lower part of the wall 2 of the working space 1.

In addition to the guide system described above the diving apparatus is also provided with three propellers 84, arranged on the same level along the wall 21 at equal distances from one another. Only one of these propellers is shown in the drawing (FIGURE 5). Each propeller 84 is powered by a reversible hydraulic motor 85, the speed of which can be controlled by means of a flow control valve (not shown). Each propeller 84 gives a horizontal force, the magnitude of which is determined by the rotational speed of the propeller. By means of the said three propellers 84 and accurate controlling of the speed of each propeller 84, the diving apparatus can be propelled through the water in any desired horizontal direction and, moreover, rotated around its vertical axis.

The diving apparatus is also provided with a propeller 86 for moving the diving apparatus in a vertical direction, which propeller 86 is powered by a reversible and adjustable hydraulic motor 87. This propeller 86 and motor 87 are secured to the outside of the pipe 6 (FIGURES 1 and 4). By controlling the buoyancy of the driving apparatus in such a way that the apparatus is suspended in the water it is possible, by means of propeller 86, to obtain a closely controlled vertical movement of the diving apparatus. In the event that there is a breakdown in the supply of nitrogen to the diving apparatus this propeller 86 can be of use since it can be brought into action immediately to compensate for the loss in buoyancy caused by the said breakdown.

It is possible to secure to the diving apparatus a safety cable attached to the ship in order to be able to hoist the diving apparatus out of the water in case of emergency, but a cable of this type is preferably not used so as to prevent the ship's movements from being transferred to the diving apparatus. A hose or cable 88, leading to the ship, is secured at the upper side of the pipe 6. This cable 88 serves for the supply or discharge of gas and/or electricity. There are, for example, two of these cables 88 present (see FIGURE 4).

The diving apparatus is kept in an upright position by pumping water ballast between three trimming tanks by means of a pump.

A point of light 89, which acts as a beacon, is preferably arranged on the upper wall 7 of pipe 6.

The buoyancy of the diving apparatus is controlled by means of a liquid level controller (not shown), which regulates the water level in the space 8, in such a way that the diving apparatus always possesses the correct buoyancy.

The diving apparatus is provided with an anchoring system for anchoring the diving apparatus firmly to the steel framework 73. This anchoring system comprises three cylinders 91 arranged at equal distances from each other along the inner side of the wall 22 and each containing a piston (not shown), to which a rod 92 is attached bearing a locking device 90 at the end. The steel framework 73 is provided with three slots 93 arranged at equal distances from each other, each of which can interlock with a locking device 90. Once the diving apparatus has been lowered onto the steel framework 73, the rods 92 are driven downwards by means of pressure fluid which is compressed behind the pistons in the cylinders 91. The rods 92 then slide into the appropriate slots 93. After the rods 92 have been pushed into the slots 93 the locking devices 90 are forced hydraulically in a radial direction outwards so that they grip behind the bottom side of the steel framework 73, whereupon pressure fluid is compressed behind the other sides of the pistons into the cylinders 91 so that the rods 92 are driven upwards to some extent with the result that a rigid connection is obtained and the diving apparatus is thus anchored firmly to the steel framework 73.

The ballast of the diving apparatus consists of three iron ballast plates 94. Each ballast plate 94 is equipped with three supports. One of the supports is a hook 95, which grips round a pin 100 on the ballast plate 94, which hook 95 is hingeable round a hinge 96. A breaking pin 97 holds the hook 95 in the correct position. If it is desired to discharge the ballast the breaking pin 97 can be broken by means of a hydraulically powered piston 98 moving in a cylinder 99. If it is not possible to break the breaking pin 97 by means of the piston 98 and explosive charge can be used to break the breaking pin 97. Once the pin 97 has been broken the hook 95 will swing around the hinge 96 with the result that the pin 100 will leave the hook 95 and the ballast plate 94 will fall freely downwards.

In order to facilitate steering the diving apparatus under the water the superivsors' compartment 16 is provided with two water levels arranged normal to each other, with a meter for measuring the speed in a vertical direction, comprising a Pitot tube and a depth gauge (not shown).

The operation of the diving apparatus described above will now be discussed. Let it be assumed that the diving apparatus is situated on deck of a ship (not shown), which is lying approximately above the point on the sea bottom where it is desired to carry out certain operations. Let it be assumed for example that certain operations have to be carried out on an oil or gas well in the sea bottom, or that certain opertaions have to be carried out at a well head 68 of such a well.

The diving apparatus is lowered into the water from the ship for example by means of a crane. Owing to the fact that the working space 8 in the pipe 6 is filled with gas for example nitrogen, as is the enclosed space 117, the diving apparatus will remain floating on the water in such a manner that it will extend a considerable distance above the surface of the water. The supervisors will now board the diving apparatus through a door 45 on the upperside of the supervisors' compartment 16, whereupon the door 45 is hermetically sealed. For safety reasons there will normaly be at least two supervisors present in the supervisors' compartment 16. In order to ensure that the supervisors are able to work under the most favorable conditions the supervisors' compartment 16 is kept filled with air at atmospheric pressure. The task for one of the supervisors is to supervise the operations as a whole and moreover to steer the diving apparatus. The other supervisor has the task of supervising the respiration mixtures and observing the movements of the divers.

At the moment when the supervisors enter the diving apparatus the divers (at least two in number) are already present in the living compartment 17, which is kept filled at all times with a suitable breathing gas mixture, for example a mixture of oxygen and helium, at a pressure higher than atmospheric, for example approximately 6 atma. If the divers are not yet present they can enter the living compartment 17 via the doors 42 and 44, the water-lock compartment 19, door 65, decompression compartment 18 and door 58. In this latter case they will require an aqualung or temporary air supply through a hose. The divers therefore finally arrive in the living compartment 17, and if desired the doors 58 and 65 may be open. The water-lock compartment 19, decompression compartment 18 and living compartment 17 thus communicate with each other while in all these compartments 17, 18 and 19 a suitable breathing gas mixture, for example a mixture of oxygen and helium, is present at a pressure of approximately 6 atma.

One of the supervisors subsequently opens a valve (not shown) in the upper part of the working space 8 in the pipe 6, and a water supply to the enclosed space 117, whereupon the diving apparatus begins to sink as a result of the water entering the spaces 8 and 117. As soon as the diving apparatus is just below the surface of the water the buoyancy of the diving apparatus is so adjusted as to ensure that it is still just positive. The propeller 86 is now activated so that the diving apparatus begins to move downwards as a result of the action of the propeller 86.

While moving downwards the diving apparatus is guided by the guide cables 77 which are stretched vertically between the ship and the well head 68. While the diving apparatus is proceeding downwards the divers enter the decompression compartment 18 from the living compartment 17, whereupon they hermetically seal the door 58 between these 2 compartments. The pressure in the decompression compartment 18 and the water-lock compartment 19 is now gradually raised by the supply, for example from the ship, of for example oxygen and helium. The pressure is raised until it is equal to the water pressure at the depth where the desired operations are to be carried out, for example equal to the water pressure in the neighborhood of the well head 68. Thus, if the water pressure near the well head 68 is 32 atma., the pressure in the decompression compartment 18 and the water-lock compartment 19 will be gradually raised from 6 to 32 atma. One of the supervisors in the supervisors' compartment 16 keeps a constant check on the correct composition of the helium/oxygen mixture and corrects it whenever necessary.

Once the diving apparatus has reached the well head 68 one of the supervisors brings the horizontal propellers 84 into operation in order to counteract the influence of horizontal currents. The funnel-shaped elements 80 receive the guide rods 75 and the diving apparatus moves down the guide rods 75 until it comes to rest on the steel framework 73. One of the supervisors then set the anchoring system in motion, i.e. the supply of pressure fluid to cylinders 91 causes the rods 92 to move axially downwards in such a way that the ends thereof interlock with the slots 93, whereupon the supply of pressure fluid causes the locking devices 90 to move radially outwards, and finally the rods 92 are moved upwards to some extent so that the diving apparatus is firmly anchored to the steel framework 73.

The working spaces 1 and 8 are now further filled with nitrogen so that the water is completely displaced from these spaces. Since it is assumed, as stated above, that the water pressure at the well head 68 has a value of 32 atma. the pressure of the nitrogen in the working spaces 1 and 8 will also have to be 32 atma.

While the diving apparatus is being anchored to the steel framework 73 the divers leave the decompression compartment 18 and enter the water-lock compartment 19, whereupon they hermetically seal the door 65 behind them. As stated above, the water-lock compartment 19 contains a mixture of helium and oxygen at a pressure of 32 atma. which mixture is breathed in by the divers.

The breathing compressors are now started by the supervisors and the divers put on their working suits and helmets, whereupon they breath in a suitable respiratory mixture of for example oxygen and helium at 32 atma. The divers now sit down on a seat 107, to which they strap themselves. One of the supervisors in supervisors' compartment 16 now starts a water pump (not shown), in order to fill the water-lock compartment 19 with water. In addition he activates a compressor (not shown), which passes the oxygen/helium mixture through a line from the water-lock compartment 19 to the decompression compartment 18, from where it flows through a line to the ship.

While the water-lock compartment 19 is being filled with water the divers check that their helmets are operating properly and that the telephone connections present are functioning correctly. If they discover any leak they press a button which passes a signal to the supervisors indicating that the filling of the water-lock compartment 19 with water must be stopped. One of the supervisors in the supervisors' compartment 16 observes the divers in the water-lock compartment 19 via portholes between the supervisors' compartment 16 and the water-lock compartment 19. As soon as the water-lock compartment 19 is completely filled with water the latter flows over via lines 120 and 121 to a signal tank (not shown), which is arranged, for example in supervisors' compartment 16, whereupon the supervisor stops the water pump. The connecting line 121 is then closed by means of a valve 126, and a line 122 connecting with the working space 8 is opened by means of a valve 125, so that the water in the water-lock compartment 19 is displaced by nitrogen from the working space 8, the water flowing off to the outside through a line 123, which is provided with a valve 124. It should be noted that the valves 124, 125 and 126 can be provided with remote control and can also be situated outside the water-lock compartment 19. Once all the water has been displaced from the water-lock compartment 19 only nitrogen having the same pressure as the nitrogen in the working space 1, i.e., 32 atma., remains

in the water-lock compartment 19. The divers invariably breathe in through their masks a mixture of for example oxygen and helium having a pressure of 32 atma. Once the water-lock compartment 19 has been completely filled with nitrogen the divers open the door 44 and from the water-lock compartment 19 enter compartment 31, which serves as a passage, via the ladder 41.

From compartment 31, the divers enter the working space 1 after having lowered a hydraulically operated working platform (not shown) into the working space 1. As already stated compartment 35 contains a hydraulically powered and controlled winch 43, together with auxiliary equipment (not shown). In addition, compartment 35 also contains a counter wheel 127, which serves to determine the amount of cable 109 payed out from the winch 43. The cable 109 is passed through a rubber gasket (not shown) in the door 67. The compartment 35 is normally filled with nitrogen which is held at a pressure approximately equal to the water pressure at the level at which the operations are being carried out.

The divers who are now in working space 1, now equalize the gas pressures in compartment 35 and working space 1, whereupon they open the door 67. The cable 109 is now loosened from the door 67, and a so-called lubricator 110, by means of which the desired operations, known per se, at the well head can be carried out, is secured to the end of the cable 109, which is passed over pulley 111. Measuring equipment in the supervisors' compartment 16 indicates the weight borne by cable 109 and the amount of cable 109 payed out. The supervisors in the supervisors' compartment 16 can regulate the speed and direction of rotation of the winch 43 and can apply a band brake (not shown) in order to permit the equipment to remain suspended at a given depth in the well for a longer period of time.

After the operations with the lubricator 110 have been carried out the lubricator 110 is disconnected and fixed in a clamp 114. Subsequently, the cable 109 is passed again through the door 67 whereupon the latter is hermetically sealed.

With the aid of the correct equipment the divers, working in cooperation with the supervisors, who are invariably present in the supervisors' compartment 16 can carry out all kinds of operations, known per se, at the well. Since these operations are known per se, they will not be discussed in any further detail here. For the purposes mentioned all kinds of equipment may be carried in the working spaces 1 and 8, for example another winch (not shown). By the way of example a tool rack 112 with the appropriate tools 113 is shown in the drawing.

It is to be noted that the diving apparatus described above is not only suitable for carrying out operations on underwater oil or gas wells, but is also suitable for carrying out other underwater operations. The divers who are provided, via their masks, with a mixture, for example of helium and oxygen having a pressure equal to the water pressure at the level at which the divers carry out their operations, can, if desired, also enter the water outside the working space 1 and carry out any operations required in the water in the neighborhood of the diving apparatus.

At a given moment the divers will wish to return from the working space 1 to the living compartment 17. For this purpose they leave the working space 1 and enter water-lock compartment 19 via compartment 31 and door 44. After the divers have entered water-lock compartment 19 they seal the door 44 hermetically behind them. The supervisors present in supervisors' compartment 16 activate a water pump (not shown) so that water is passed into the water-lock compartment 19, and this displaces the nitrogen from water-lock compartment 19 into the working space 1. As soon as the water-lock compartment 19 is completely filled with water, the water pump is stopped, whereupon the oxygen/helium connection 121 with the decompression compartment 18 is effected, the supply of oxygen/helium to the decompression compartment 18 is opened, and the water discharge line from the water-lock compartment 19 is opened. As a result the water-lock compartment 19 is filled with an oxygen/helium mixture with a pressure of 32 atma. which displaces the water from the water-lock compartment 19. After all the water has been displaced from the water-lock compartment 19, the divers remove their masks and working suits, whereupon they breathe in the oxygen/helium mixture of 32 atma. directly from the water-lock compartment 19. The divers leave their masks and working suits behind in the water-lock compartment 19, open the door 65 and enter the decompression compartment 18. In the decompression compartment 18 there is likewise a mixture of oxygen and helium having a pressure of 32 atma., and this the divers freely breathe in.

The supervisors present in supervisors' compartment 16 now start a compressor which causes the pressure of the oxygen/helium mixture to fall very gradually from the original value of 32 atma. to 6 atma. This decompression must be effected very gradually in order to ensure that the divers suffer no harmful consequences to their health. For this reason the supervisors invariably watch the divers during the decompression by means of television equipment (not shown). Once the pressure of 6 atma. has been reached in the decompression compartment 18 the compressor is stopped and the divers proceed via door 58 to the living compartment 17 where they can rest, if required, and recover and/or have something to eat. Food is available in the living compartment 17 in containers which have been brought to the same pressure as the pressure prevailing in the living compartment 17. If necessary, the divers can proceed after some time in the manner described to the working space 1 in order to continue the operation, after which they can return in the manner described to the living compartment 17. If necessary, this pattern of proceeding from living compartment 17 to working space 1, carrying out of operations there, returning to living compartment 17, and resting in living compartment 17 can be repeated a relatively large number of times.

The great advantage of moving from the working space 1. where the prevailing pressure is 32 atma., to living compartment 17, where the prevailing pressure is 6 atma., is that decompression takes considerably less time if it only has to be effected to a pressure higher than 1 atma., for example 6 atma., and not to 1 atma.

After the operations have been entirely completed and the divers have proceeded to the living compartment 17, in which they breathe indirectly an oxygen/helium mixture at a pressure of 6 atma., it may be necessary to raise the diving apparatus again to the surface.

For this purpose the supervisors, present in supervisors' compartment 16, open the valve (not shown) mentioned above, in the upper part of pipe 6. The result of this is that nitrogen escapes from the working spaces 1 and 8 and that the water flows into the working spaces 1 and 8. The quantity of water flowing into the working spaces 1 and 8 is so controlled that the diving apparatus is given a slightly negative buoyancy. The supervisors subsequently hydraulically operate the anchoring system in such a way that the rods 92 are moved downwards to some extent, whereupon the locking devices 90 are drawn in hydraulically. The rods 92 are subsequently displaced hydraulically in an upward direction out of the slots 93, with the result that the diving apparatus is disconnected from the platform 73. The diving apparatus is subsequently moved upwards, either by means of the propeller 86, or by giving the diving apparatus a comparatively slight positive buoyancy by removing a small quantity of water from the working spaces 1 and 8. While the diving apparatus is being raised the funnel-shaped elements 80 move upwards along the guide rods 75 and subsequently leave them. The diving apparatus now moves

gradually upwards along the guide cables 77 to the surface of the water.

Once the diving apparatus has reached the surface of the water it is hoisted on board the ship. If desired the supervisors can then leave the supervisors' compartment 16 via door 45. If desired, the divers can remain in the living compartment 17 until the diving apparatus is lowered again for a subsequent descent. In order to give the divers sufficient room to move around, the doors 58 and 65 may remain open. Food may be supplied to the divers in closed containers which have been brought to the pressure prevailing in the living compartment 17, for example 6 atma. In order to pass the food containers into the living compartment 17 from outside use is made of the water-lock compartment 19, which serves as a shuttle.

If the divers wish to leave the diving apparatus they enter the decompression compartment 18, whereupon the doors 58 and 65 are closed. The pressure in the decompression compartment 18 is thereupon gradually reduced to atmospheric pressure. The pressure in the water-lock compartment 19 is also reduced to atmospheric pressure. The divers then open door 65, enter water-lock compartment 19, open the door 44 and proceed by ladder 41 into compartment 31, whereupon they leave the diving apparatus via door 42.

It is to be noted that the decompression compartment 18 and the water-lock compartment 19 can, if desired, be interchanged, so that the water-lock compartment 19 is adjacent to the living compartment 17 and that the decompression compartment 18 is adjacent to the supervisors' compartment 16.

We claim as our invention:

1. A method for carrying out underwater operations with the aid of a diving apparatus provided with a living compartment, a decompression compartment, a water-lock compartment and a working compartment, which diving apparatus is lowered into the water to a certain depth (operating depth), at which depth a gas pressure approximately equal to the static water pressure at the operating depth is maintained in the working compartment, a predetermined substantially constant gas pressure higher than atmospheric pressure and lower than the water pressure at the operating depth is maintained in the living compartment, and divers present in the diving apparatus move periodically from the living compartment, via the decompression compartment and water-lock compartment to the working compartment and vice versa while selectively supplying and discharging gas and water to and from said water-lock compartment so as to maintain desired pressure therein, the divers carrying out the desired operations in the working compartment as it surrounds at least the top of an underwater well installation near the sea bottom.

2. A diving apparatus for carrying out underwater operations, comprising a living compartment, a decompression compartment, a water-lock compartment and a working compartment, sealable manholes between the said compartments, means for controlling the gas pressure in the working compartment, means for maintaining in the living compartment a suitable breathing gas mixture, having a predetermined substantially constant pressure higher than atmospheric and lower than the static water pressure at the operating depth, means for controlling the gas pressure in the decompression compartment and means for selectively supplying and discharging gas and water having a desired pressure to and from the water-lock compartment.

3. A diving apparatus as claimed in claim 2, characterized in that the working compartment is situated in a substantially bell-shaped element.

4. A diving apparatus as claimed in claim 3, characterized in that a supervisors' compartment is present and includes means for maintaining a suitable breathing gas

mixture of approximately atmospheric pressure in the supervisors' compartment.

5. A diving apparatus as claimed in claim **4**, characterized in that a sealable manhole is present between said supervisors' compartment and said living compartment.

6. A diving apparatus as claimed in claim **2**, characterized in that the living compartment, decompression compartment and water-lock compartment are arranged in a hollow torus-shaped body.

7. A diving apparatus as claimed in claim **6**, characterized in that a supervisors' compartment is present and is also arranged in the said hollow torus-shaped body.

8. A diving apparatus as claimed in claim **7**, characterized in that the end walls of the said living compartment, decompression compartment, water-lock compartment and supervisors' compartment consist of radial bulkheads arranged in the hollow torus-shaped body.

9. A diving apparatus as claimed in claim **6**, characterized in that the working compartment is situated in a substantially bell-shaped element and the hollow torus-shaped body is on the upper side of the substantially bell-shaped element serving as a working compartment.

10. A diving apparatus as claimed in claim **2**, characterized in that the bottom side of said diving apparatus is provided with anchoring means for anchoring said apparatus to an underwater installation.

11. A diving apparatus as claimed in claim **10**, characterized in that the anchoring means are provided with hydraulic controls.

12. A diving apparatus as claimed in claim **2**, characterized in that said apparatus is provided with guide means adapted to cooperatively engage cable guide means extending from an underwater installation to the surface.

13. The apparatus of claim **2** wherein all of said compartments are in close proximity to each other.

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