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Leemann

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[54] **DIVING TIME MEASURING DEVICE**

[76] Inventor: **Karl Leemann,** Wehntalerstrasse 142, CH-8057, Zurich, Switzerland

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[52] **U.S. Cl.** **73/389,** 73/300, 73/412, 73/418

[51] **Int. Cl.** **G01l 7/04,** G01f/23/14

[58] **Field of Search** 73/300, 389, 73/388, 418, 412

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Primary Examiner—Donald O. Woodiel
Attorney, Agent, or Firm—Flam & Flam

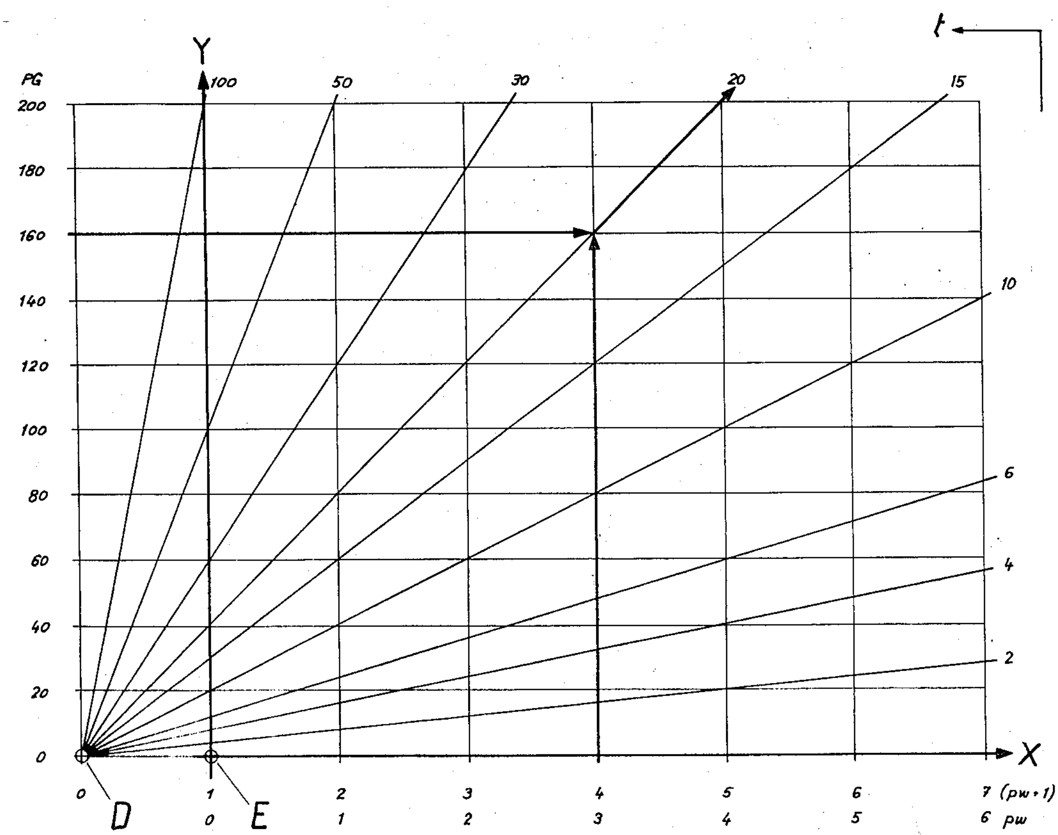
[57] **ABSTRACT**

A diving time measuring device indicates the remaining diving time available to a diver with a specified initial volume V_A of breathable gas. The device includes a first pressure responsive means sensitive to the pressure difference P_G between the gas supply pressure and the surrounding water pressure. This is rigidly connected to a second pressure responsive means that is responsive only to the water pressure P_W. The two means are arranged so that an arm, attached to the second pressure responsive means, moves in orthogonal directions in response respectively to the pressure difference and to the water pressure. The relative orthogonal displacements of the arm designate the remaining available diving time t in accordance with the formula

$$t = V_G/V_A \cdot P_G/(P_W+1)$$

wherein V_A is the average volume of gas used by the diver per unit time.

7 Claims, 5 Drawing Figures



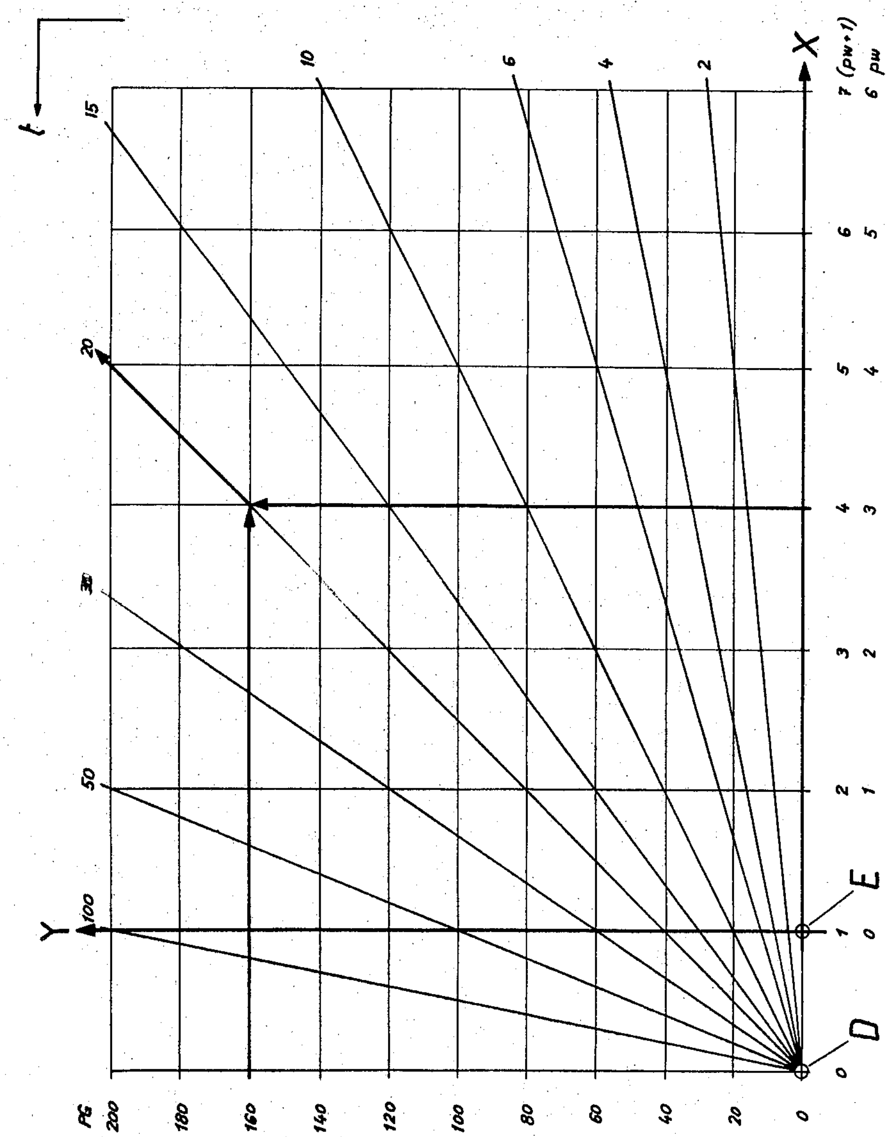


Fig. 1

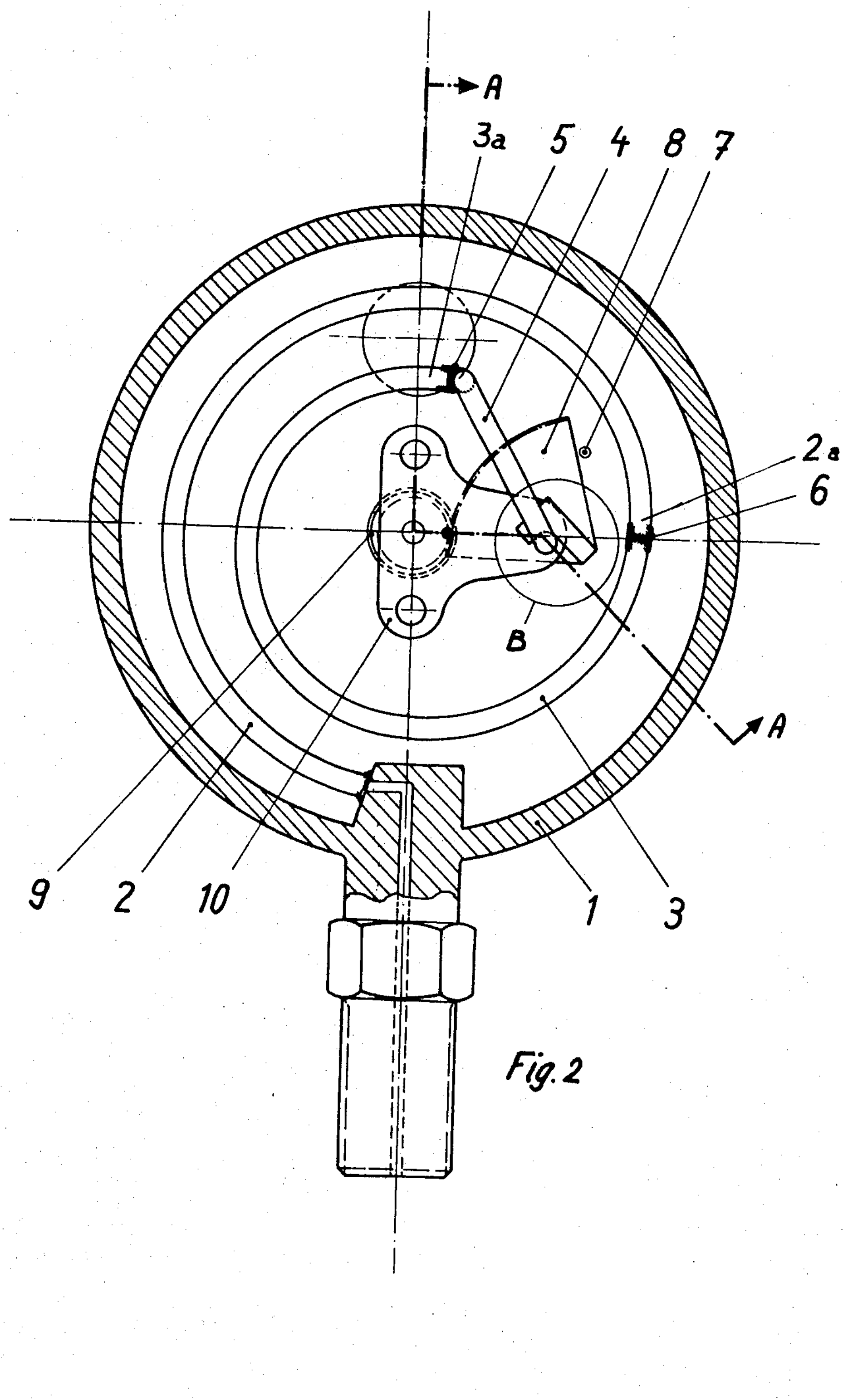


Fig. 2

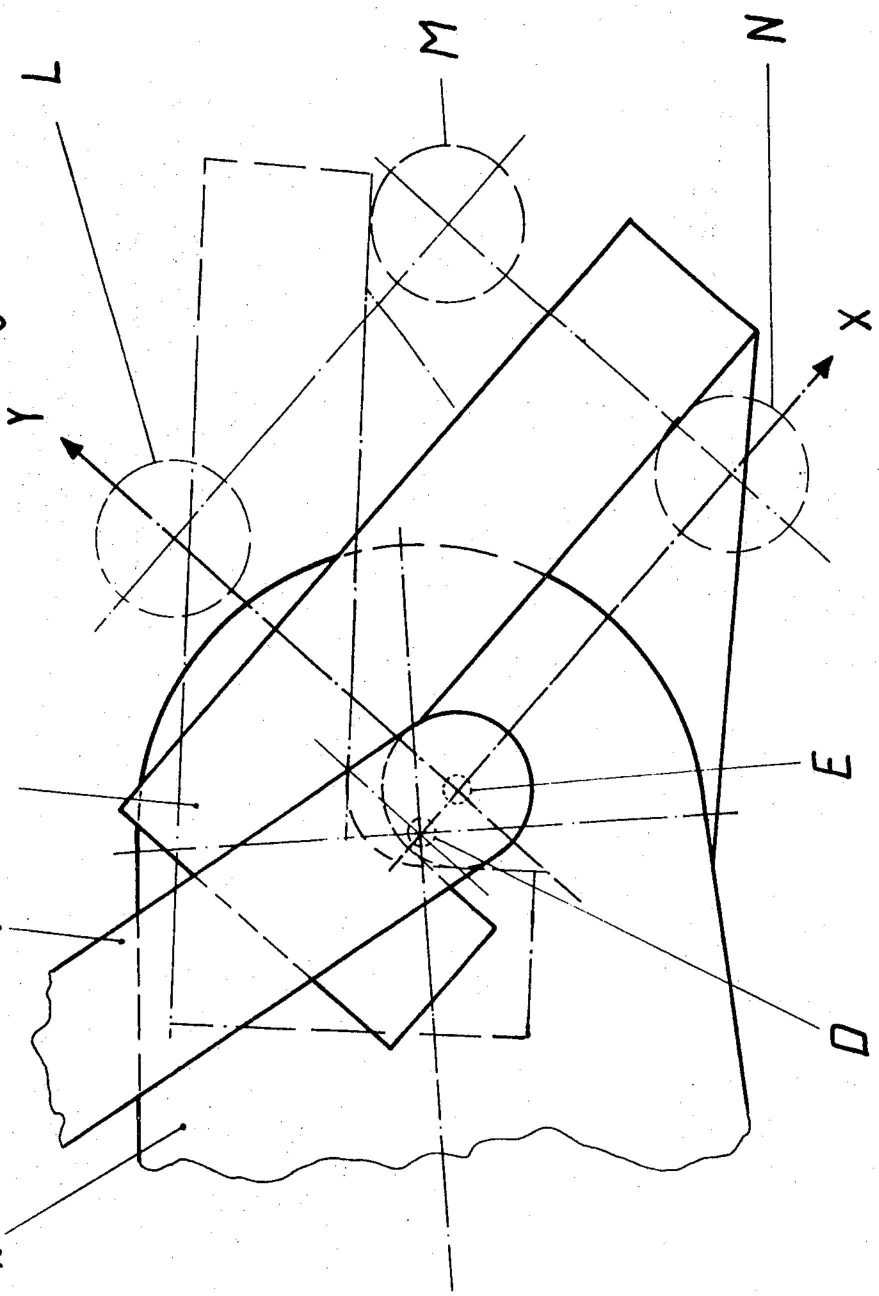


Fig. 3

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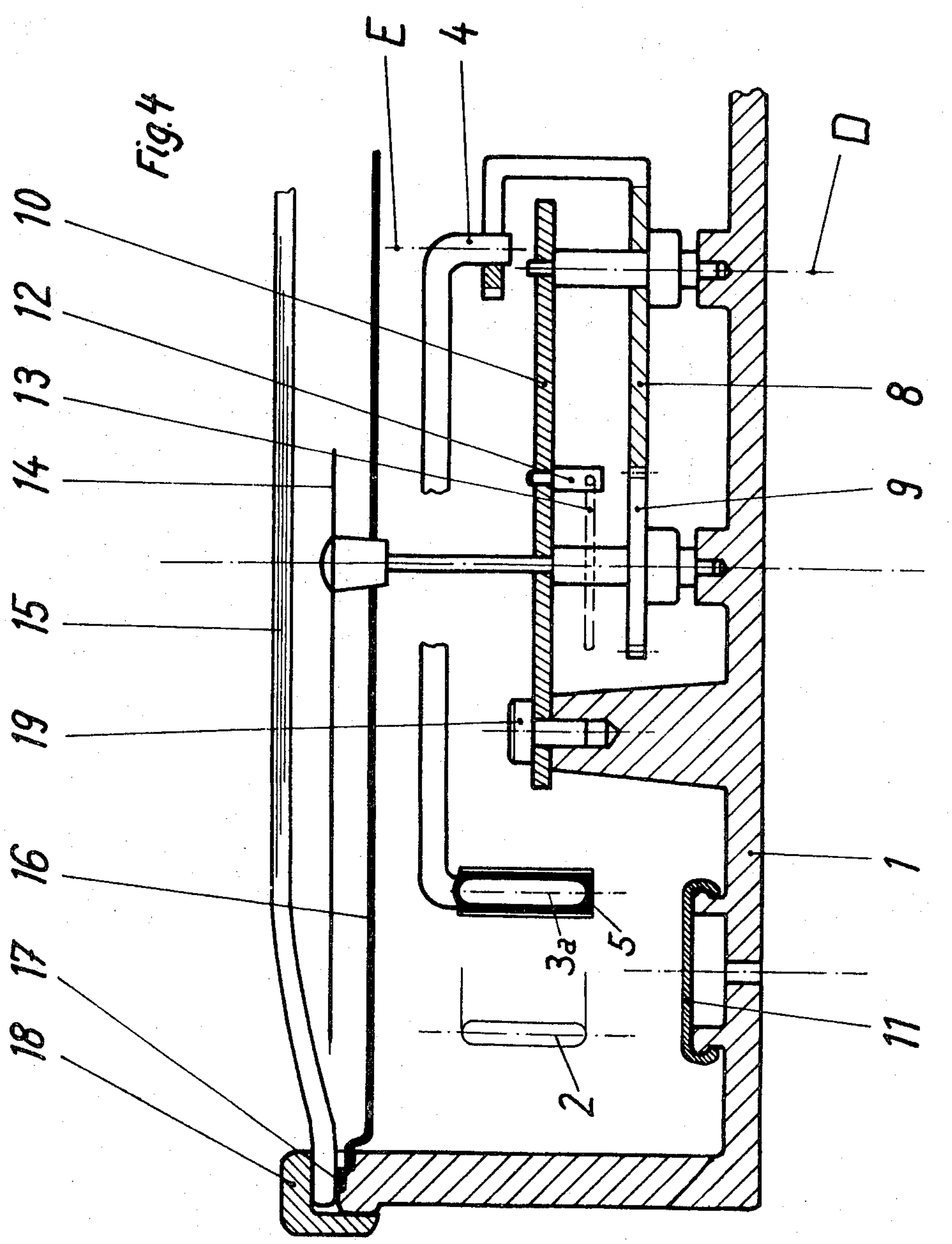

Fig.4

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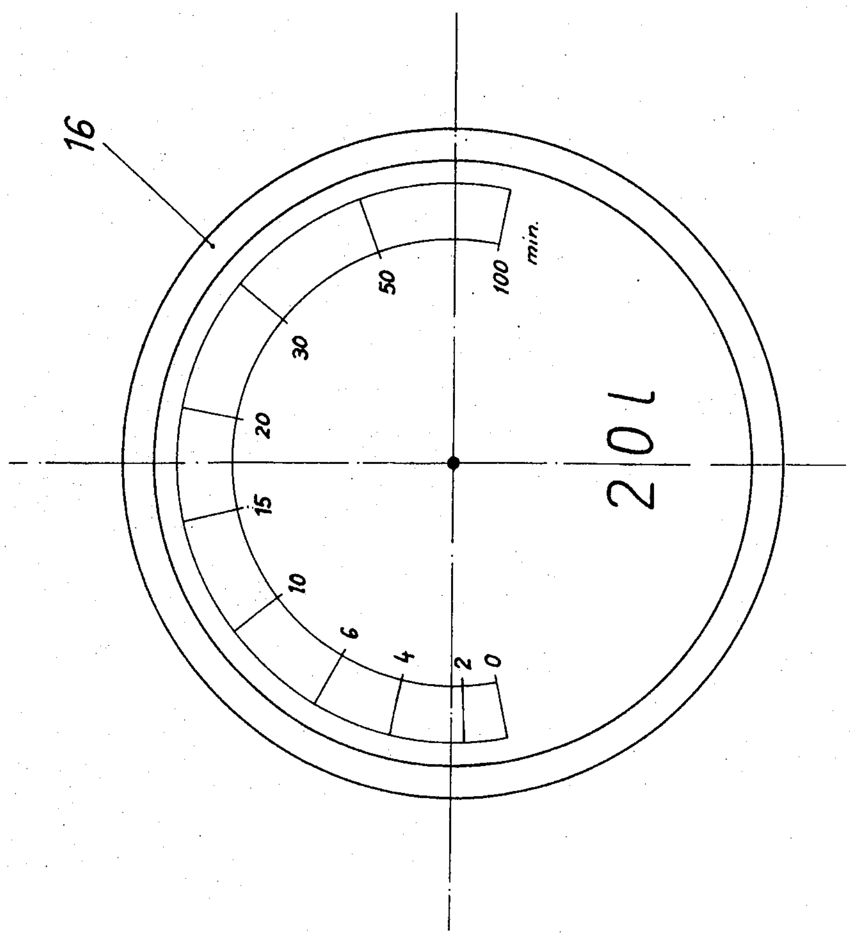

Fig. 5

DIVING TIME MEASURING DEVICE

The invention concerns a diving time measuring device, to advise a diver with a stated gas supply, at a stated water depth, of the diving time still at his disposal.

When diving under water, it is known that for breathing either compressed air, or a compressed gas of a specific combination is used, which is contained in a bottle, or a tank, which the diver carries. In the following, the expression "gas" is meant to comprise any of the media used for breathing.

Up till now, a diver must work, during diving, always with a manometer for the gas reserve, with a depth measuring device to advise him of the diving depth. The diver must then estimate, or possibly roughly calculate, the possible diving time, still at his disposed at his present diving depth with the still present gas supply, and he must do this, while his attention is needed for the diving work and the possible danger moments present while diving. But knowledge of the still available diving time is very important for a diver, especially in connection with the time necessary for decompression, when coming up. No device has been known up to this time, which permits the diver to read immediately the diving time still at his disposal.

The task of this invention was, to create a device, which shows directly the still remaining diving time at a specific diving depth, in connection with gas pressure, bottle volume and diving depth, and assuming an average use of gas per minute by the diver, which is known by experience.

The diving time measuring device to advise a diver with a specific gas supply at a specific water diving depth of the diving time still at his disposal is, according to the invention, characterized in that a first organ or means is provided, which is under the impact of the gas supply pressure and exposed to the water pressure, and which converts the change in the difference between gas pressure and water pressure in a movement of a part of said organ, and that said part of the organ is rigidly connected with a second organ, that is exposed to the water pressure only, which second organ converts the pressure change in the water at different diving depths in a movement of a part of this second organ, which part of the second organ, due to the mentioned rigid connection, at a simultaneous change of the said pressure difference and the water pressure executes a movement combined of the two single movements, which serves as the advice to the diver. The organs are furthermore so arranged and connected with each other, that the directions of the single movements due to pressure difference change and water pressure change, are orthogonal to each other whereby the position, at a given moment, of the advice part of the second organ is determined, in relation to a zero position for said pressure difference and water pressure, by the vertical distances, whose relation to each other results in a value for the diving time t in accordance with the formula $t = V_G/V_A \cdot P_G/(P_W + 1)$, wherein P_G is the pressure difference between gas pressure and water pressure, P_W the water pressure and V_G/V_A a constant, which results from the beginning gas supply volume V_G and the gas use V_A of the diver per time unit.

In a practical execution of the object of the invention the first organ, which is under the impact of the gas supply pressure and exposed to the water pressure, is a Bourdon pipe or tube, arranged in a housing, whose one end is connected with a supply pipe, located in a housing part, which is destined to be connected with a gas supply bottle, and whose other end, which forms the part moved by the change of the pressure difference, can move back and forth in the said one direction through the extension and contraction of the pipe, which is on the inside under the impact of the gas pressure, and exposed on the outside to the water pressure. Practically, the second organ, which is exposed to the water pressure only, is another Bourdon pipe, which is evacuated, and whose one end is rigidly connected with the said other end of the first pipe, and whose free end, which forms the part moved by the change in the water pressure, can move back and forth in the mentioned other direction, perpendicular or orthogonal to the first direction, through extension and contraction of the pipe, which is exposed on the outside to the water pressure, whereby the free pipe end, which serves to notify the diver, due to the rigid connection of the Bourdon pipes, executes a movement which is composed of the two mentioned individual movements. In a preferred execution, the housing surrounding the two Bourdon pipes has an opening, closed by a diaphragm, and is filled with a corrosion preventing medium, over which medium the water pressure, pressing upon the diaphragm, affects the Bourdon pipes.

In a further execution, the moving end of the Bourdon pipe, which serves to notify the diver, can, for the purpose of making it possible to read the diving time directly from a dial, be connected, by means of a rigidly fastened transfer arm, with a lever rotatable around an axis, a part of which lever is practically formed as a tooth segment, which interlocks with a cog wheel at the end of a shaft that moves a hand over a dial.

Further details and advantages of the invention can be learned from the description and the drawings, in which a form of the object of the invention is represented as an example only. It is:

FIG. 1 is a diagram of the diving time;

FIG. 2 a horizontal section through the diving time measuring device;

FIG. 3 a detail B of FIG. 2 at a larger scale;

FIG. 4 a section through the diving time measuring device according to line A—A in FIG. 2;

FIG. 5 the dial of a diving time measuring device.

The formula for the construction of the diving time measuring device to determine the diving time t is as follows:

for gases at a constant temperature:

$$P_1 \cdot V_1 = P_2 \cdot V_2 \tag{a}$$

whereby P is the absolute pressure and V the volume.

In the housing of the diving time measuring device two Bourdon pipes are exposed to the water pressure P_W, which is however not the absolute pressure.

For the absolute pressure, the value P_W must be increased by I, i.e., by the pressure at the earth surface of 1 kg/cm^2; the absolute water pressure is therefore $P_W + 1$. One of the Bourdon pipes is on the inside under the gas pressure of the gas supply, and is simultaneously exposed on the outside to the water pressure. Therefore it can only "show" the pressure difference P_G between gas pressure and water pressure P_W which is done by a movement of its pipe end connected with the second Bourdon pipe. The absolute gas pressure of the gas supply has therefore the formula: P_G absol. $= P_G + P_W + 1$ = notified pressure difference + absolute water pressure.

Besides the aforementioned, the following terms are used in the formula:

P_G = advised pressure difference between gas pressure and water pressure in kg/cm^2,

P_W = advised water pressure in kg/cm^2; also the terms:

V_G = bottle bolume in liters.

V_A = use of breathing air at normal pressure (1 atmosphere) in liters/min.

In accordance with the above mentioned reference:

$$P_1 \cdot V_1 = P_2 \cdot V_2$$

the gas volume V_E, present at expansion upon the absolute water pressure $P_W + 1$ can be determined, by using the aforementioned term for the absolute gas pressure of the gas supply.

It is: $G(P_W + 1)\ V_E = (P_G + P_W + 1)\ V_G$ (b)

$$V_E = V_G(P_G+P_W+1)/P_W+1 \quad \text{(c)}$$

The gas volume V_V available for breathing results by reduction of V_E by the bottle volume V_G, because the bottle containing the gas supply contains at the end still gas with the pressure $P_W + 1$. Thus results:

$V_V = V_E - V_G$ and with the term (c)

$V_V = V_G(P_G + P_W + 1)/P_W + 1 - V_G = V_G(P_G + P_W + 1) - V_G\ (P_W + 1$the $P_W + 1$

$V_V = V_G \cdot P_G/P_W + 1$ (d)

If the term (d) for the available gas volume V_V is divided through the value V_A for the breathing air use per minute, the following result is obtained for the still available diving time $t = V\ V/A$:

$$t = V_G \cdot P_G/V_A(P_W + 1) = V_G/V_A \cdot P_G/P_W + 1 \quad \text{(e)}$$

The bottle volume V_G is a constant quantity, and the breathing air use V_A can also be considered a constant quantity, whereby for adult persons an average value of V_A = 40 liters/minute is considered.

Consequently, the diving time t depends upon the marked pressure difference P_G between gas pressure and water pressure, and the water pressure P_W. The diving time diagram represented in FIG. 1 shows the still available diving time t in accordance with the pressure difference P_G and the water pressure P_W. Upon the vertical axis of the coordinating cross in FIG. 1, the values for the pressure difference P_G, and upon the horizontal axis the values for the water pressure P_W are shown, which begin at point E of this axis with zero. For the absolute water pressure RM P_W + 1, the zero point is therefore at D of this axis, whereby the distance DE is equal to one atmosphere. According to the aforementioned term for the diving time t, the lines for the same diving time extend therefore from point D in the diagram shown in FIG. 1. FIG. 1 shows the calculation of the diving time t in an example. If the bottle volume V_G is 20 liters, and the use of breathing air V_A **40** liters/minute, then the still available diving time t is = 20/40 · 160/3+1 = 20 minutes, at a pressure difference between gas pressure and water pressure -which the Bourdon pipe in the device shows- of, for instance, P_G = 160 kg/cm^2, and a present diving depth of 30 m, in accordance with P_W = 3 kg/cm^2. This value, which can be read off, according to FIG. **1**, is marked in arrows.

The diving time measuring device shown in FIGS. **2** to **5** has a housing **1**, which can be connected with a, not represented, gas supply bottle, whereby through the housing part destined to be connected, a pipe for the gas is provided, to which a Bourdon pipe **2** is connected, by soldering the pipe and within the housing in such way to the Bourdon pipe, that the interior of the Bourdon pipe is under the gas pressure of the gas supply in the not represented bottle. A second Bourdon pipe **3** is connected with the end of the first Bourdon pipe **2** in such way, that the two pipes are rigidly connected with each other by means of a connecting piece **6**, so that the Bourdon pipe **3** follows all movements of the Bourdon pipe **2**. The end of the second Bourdon pipe **3** is rigidly connected by means of a connecting piece **5** with a transfer arm **4**. As can best be seen from FIG. **4**, this transfer arm has an angular end, directed downwards, which lies laterally against a surface of the upper leg of a lever **8**, which can be swung around an axis D (FIGS. **3** and **4**). The lower leg of the U-shaped lever is toothed, as can best be seen from FIG. **2**. The upper leg of the lever **8** forms a slot for the transfer arm end **4**, which can slide along the lateral surface of this slot. When the end of the transfer arm **4** is in the zero position of the device, the distance between the center axis E of this arm end and the swinging axis D for the lever **8** must equal the distance, which the end of the transfer arm **4** passes at a water pressure difference of **1** atu. i.e., the distance DE in FIGS. **3** and **4** corresponds to the distance DE in the diagram according to FIG. **1**.

The tooth segment, which forms the lower leg of the lever **8**, interlocks with a cog wheel **9**, which is mounted upon a pointer shaft provided in the housing, upon which a pointer **14** is fixed, which moves over a dial **16**. A bearing plate **10** serves as a bearing for the pointer shaft and the swinging axis for the lever **8**. In the bearing plate **10** a spring carrier **12** is fastened, to which the one end of a helical spring **13** is fixed, which presses against the pointer shaft, and which keeps the parts of the device, consisting of cog wheel, tooth segment with groove and transfer arm, which are in gripping connection, free of play, and presses them in the direction of the zero position.

A diaphragm **11** closes an opening in the housing **1**, so that the water pressure can affect the interior of the housing through the opening and over the diaphragm, which interior is filled with a corrosion preventing liquid, for instance vaseline, through which the water pressure finally affects the Bourdon pipes. The housing **1**, which is open at the top, is covered by a glass **15**, through which the position of the hands on the dial can be read, and the glass rests upon a packing **17**, fastened to the housing, and is held by a closing ring **18**, which makes it possible, to exchange in a very simple way the glass and the dial below it, so that the dial may be exchanged against another with an altered scale. If the here described device is used with gas supply bottles of different size, the bottle volume V_G, mentioned in the formula for the diving time t, must be considered in an accordingly changed scale.

In the zero position of the device, the tooth segment of the lever **8** is pressed against a projection **7** by means of the spring **13**. The bearing plate **10** is fastened to the housing **1** by means of fastening bolts **1, 9**.

The device functions as follows:

The diving time measuring device shows the value for the diving time $t = 0$, when there is surrounding pressure in the bottles for the gas supply. If the bottles are under high gas pressure, the gas pressure in the interior affects the Bourdon pipe **2**, which is exposed to the outer water pressure over the opening in the housing, which is closed by a diaphragm. The end of the Bourdon pipe **2** at the connecting piece **6** moves in a certain direction, if the gas pressure is increased, and in the same direction moves also the angular end of the transfer arm **4**, which is rigidly connected with the second evacuated Bourdon pipe **3** by means of the connecting piece **5**. This Bordon pipe is to be considered stiff at unchanged water pressure, and that is the reason, that the movement of the end of the Bourdon pipe under gas pressure is executed in exactly the same way by the angular end of the transfer arm **4**. This movement of the transfer arm end **4** is done in the direction Y according to FIG. **3**, which represents a sectional enlargement of the corresponding part in FIG. **2**. In the Y-direction, the end of the transfer arm **4** follows the change in the pressure difference between gas pressure and water pressure. The direction of the movement Y goes through the center point E of the transfer arm end **4**. In the diagram according to FIG. **1**, this direction of the movement corresponds to the movement direction of the Y-axis, starting from point E.

The evacuated Bordon pipe **3** follows only the change in the water pressure, and contracts, when the water pressure is increased, so that the pipe end at **5**, and in the same way the transfer arm end **4** at point **5**, executes a movement in the direction X in FIG. **3**. The two Bourdon pipes must be so arranged and connected with each other, that the movements in the directions Y and X are orthogonal to each other, corresponding to the two coordinates X and Y in the diving time diagram according to FIG. **1**.

At a full gas pressure of 200 atu, but no water pressure, the transfer arm end **4** has moved into the position L according to FIG. **3**. When, in the course of this, the transfer arm end **4** slides along the groove surface of the lever **8**, the tooth segment rotates around the point D and transmits the movement over the cog wheel to the pointer, which, in the position E in FIG. **3**, according to the diagram of FIG. **1**, shows 100 minutes for the diving time t.

With diving, and thus increasing water pressure, the pressure difference P_G gets smaller, so that the movement in the Y-direction is reversed. With increasing diving depth, the transfer arm end **4** moves due to the movement of the evacuated Bourdon pipe in the direction X from position L into position M in FIG. **3**. This position M corresponds, at full water pressure and gas pressure, a notification of 14 minutes for the diving time t in the diagram according to FIG. **1**. With decreasing pressure difference P_G, caused by constant use, the transfer arm end **4** moves, at even water pressure, i.e., the same diving depth, out of the position M into the position N according to FIG. **3**, whereby the notification for the diving time t moves towards zero. At a simultaneous change in the pressure difference P_G and the water pressure P_W, the transfer arm end **4** makes a movement combined of the two single movements. At each movement, the transfer arm end slides along the groove surface, and the respective position of the lever **8** is transmitted to the pointer.

Since the lines for the same diving time t in the diagram according to FIG. **1** extend from the zero point D for the absolute water pressure, the result is a great simplicity in the transfer of the position of the transfer arm end, at the respective pressures, into a swinging postion of the lever **8** and thus into an according position of the pointer, because the centre of rotation D for the lever **8** is at a distance from the center axis E of the transfer arm end moving the **1** ever, which corresponds to the moving distance of the transfer arm end at a water pressure difference of 1 atu.

I claim:

1. Diving time measuring device for indicating the still available diving time for a diver, with a specific initial gas supply at a specific water diving depth, characterized by a first pressure responsive means responsive to the difference in pressure between the gas supply and the water pressure, which first means converts the change in said pressure difference into a movement of a part of said first means, and that the said part is rigidly connected to a second pressure responsive means that is exposed to the water pressure only, which second means converts the pressure change in the water at different diving depths into a movement of a part of said second means, which part of the second means, due to the rigid connection, in response to a simultaneous change of said pressure difference and water pressure, executes a movement combined of both individual movements, the means being so arranged and connected with each other, that the directions of the individual movements caused by a change in the pressure difference and water pressure are orthogonal to each other, whereby the position of the said part of said second means indicates the diving time t in accordance with the formula $t = V_G/V_A \cdot P_G/(P_W + 1)$, wherein is P_G the pressure difference between gas pressure and water pressure as sensed by said first means, P_W the water pressure as sensed by said second means, and V_G/V_A is a constant established by the initial gas supply volume V_G and the amount of gas V_A used by the diver per time unit.

2. Diving time measuring device according to claim **1** characterized in that the first means is a Bourdon tube arranged in a housing, whose one end is connected with a supply pipe in a part of the housing destined to be connected with a gas supply bottle, and whose other end, which forms the part moved by a change in the pressure difference, can move back and forth in one direction through extension and contraction of a tube which is affected at the inside by said gas supply pressure and exposed on the outside to the water pressure, and that the second means is a second Bourdon tube which is evacuated, and whose one end is rigidly connected with the said other end of the first tube, and whose free end, which forms the part moved by the change in the water pressure, can move back and forth in the other direction which is orthogonal to the first direction, through extension and contraction of the tube which is exposed at the outside to the water pressure, whereby the free end of the second tube, which serves as an indicator, can execute a movement composed of the two said individual movements due to the rigid connection of the Bourdon tubes, and that, furthermore, the housing has an opening closed by a diaphragm and is filled with a corrosion preventing medium, through which the water pressure which presses upon the diaphragm affects the Bourdon tubes.

3. Diving time measuring device according to the claim 1 characterized in that the moved part of the second means, is in connection with a level that can swing around an axis, and that a pointer, moved by the lever, and a dial are provided in the housing, which dial has a scale for direct reading of the diving time t.

4. Diving time measuring device according to claim 3 characterized in that the end of the evacuated Bourdon tube serving as the indicator is rigidly connected with a transfer arm, whose angular end presses laterally against a surface of a grooved upper leg of the lever, which can be swung around the axis, and can slide along this groove surface, and that the lever is U-shaped and its lower leg forms a tooth segment through which the swing axis extends parallel to the angular end of the transfer arm, and that the distance between the center axes of the angular arm end in its zero position, corresponding to 0 atmosphere water pressure P_W, and the parallel swinging axis is equal to the distance passed by the end of the transfer arm at a water pressure difference of 1 atmosphere, which causes the swinging axis to be located at the zero point for the absolute water pressure $P_W = 1$.

5. Diving time measuring device according to claim 4 characterized in that the tooth segment interlocks with a cog wheel, which is fastened to a pointer shaft mounted in the housing, upon which pointer shaft the pointer is fixed, and that a spring, mounted in the housing, presses against the pointer shaft, which keeps the connected parts, consisting of cog wheel, tooth segment with groove and transfer arm, free of play and pressed in the direction of the zero position.

6. Diving time measuring device according to claim 3, characterized in that the dial in the housing is exchangeably arranged, in order to exchange dials with different scales in accordance with different initial gas volumes V_G, and different gas use V_A.

7. A device for indicating the diving time still available to an underwater diver with a specified initial volume of breathable gas, comprising;

a housing,

a first pressure responsive means within said housing and responsive to the difference in pressure between the gas supply pressure and the environmental water pressure,

a second pressure responsive means within said housing and responsive only to the environmental water pressure,

a moveable arm interconnected to said first and second pressure responsive means so as to move in a first direction only upon changes in pressure difference sensed by said first means and to move in a second direction orthogonal to said first direction only upon changes in environmental water pressure sensed by said second means, and

lever means for converting said orthogonal motions of said arm to movement of an indicator that signifies the angular direction of a vector having first and second orthogonal components determined by the displacements of said arm along the corresponding first and second orthogonal directions, said angular direction being proportional to the remaining available diving time.

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