

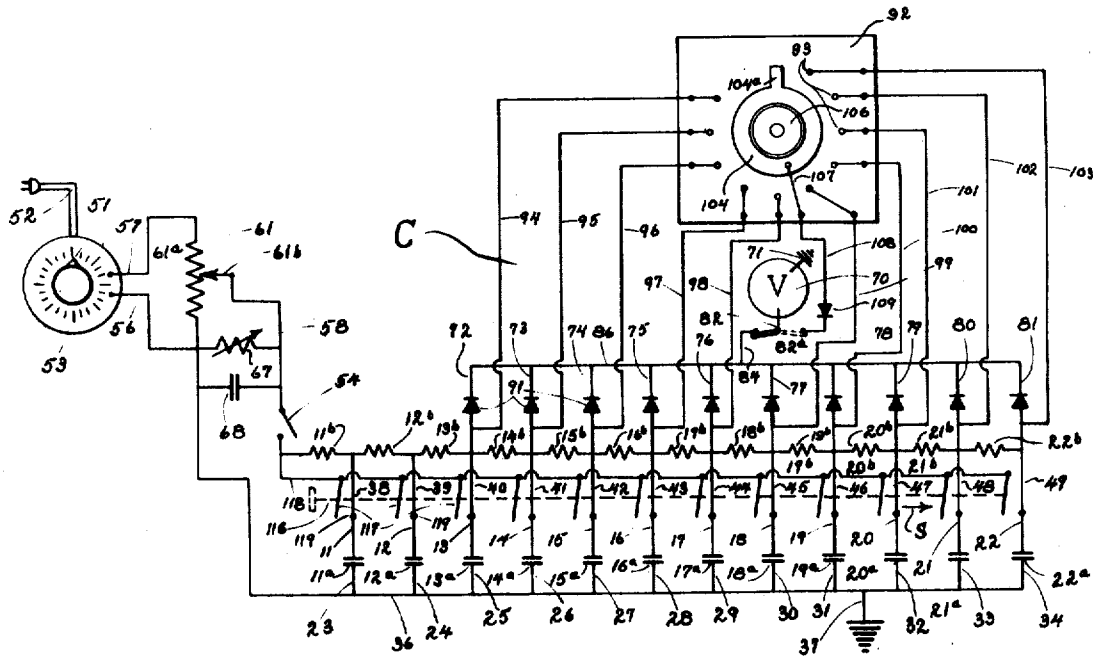
[54] **ANALOG COMPUTER FOR
DECOMPRESSION SCHEDULES**
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128/204; 320/1

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[57] **ABSTRACT**
A device for computing a diver's decompression schedule which comprises a variable voltage D.C. power supply connected to the leading set of a plurality of resistor capacitor sets serially connected in electrical cascading relationship. Metering means are connected to at least a majority of the sets for indicating the highest voltage of the capacitors of the sets, both the metering means and power supply being calibrated in units of water depth for cascade charging the capacitors sequentially with time at a voltage corresponding to the time and depth of the dive and for cascade discharging of the capacitors sequentially with time to thereby produce a readout on the metering means to provide an ascent schedule for the diver.

9 Claims, 2 Drawing Figures



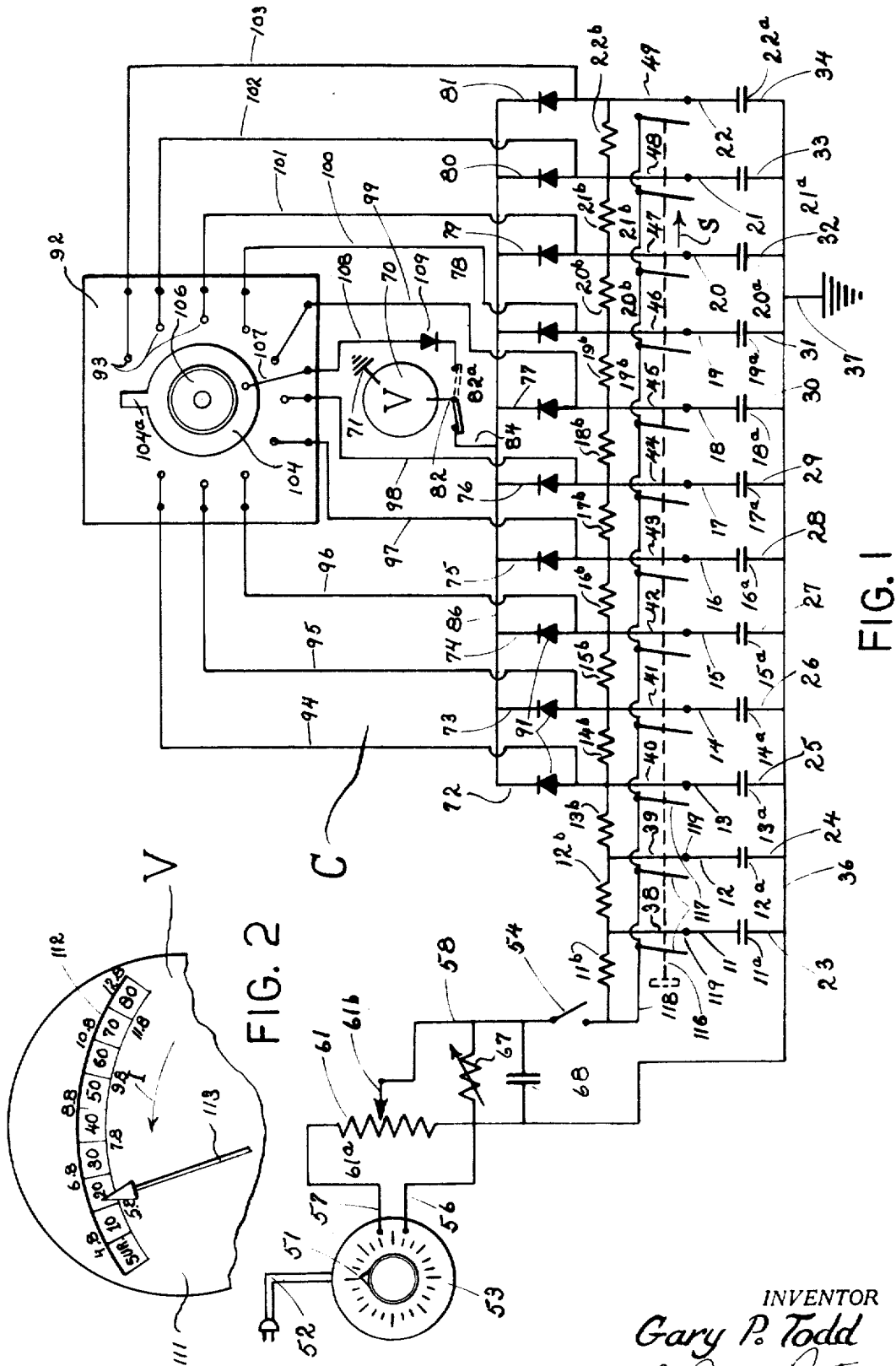


FIG. 1

FIG. 2

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ANALOG COMPUTER FOR DECOMPRESSION SCHEDULES

This invention relates to underwater diving and more particularly to a computer for programming a decompression schedule for a diver.

In diving operations in water by a person breathing pressurized air, the inert gas component of the air or N_2 goes into solution in the body in an amount determined by both the depth of the dive and the time spent by the diver under pressure corresponding to the depth. The amount of inert gas or N_2 absorbed by the body continues until the condition known as saturation occurs. During the ascent of a diver, as the pressure on the diver is reduced, the excess of inert gas in the diver's body is expelled until the concentration of inert gas in the body returns to equilibrium at atmospheric pressure. However, if the pressure on the diver's body is reduced too quickly as the diver ascends, the escape of the inert gas from the body occurs in an abnormal manner even to the extent of forming bubbles in the body as bubbles form in a carbonated beverage when the cap is removed. Such abnormal expulsion of the inert gas causes what is known as decompression sickness usually referred to as the "bends" which not only can cause injury but if too severe, death.

In order to avoid this decompression sickness, a diver remaining at a certain depth is required to follow a decompression time schedule in which his ascent is made by rising to various depths and remaining at those depths for specified periods of time. Most diving schedules or tables have been formulated using the classical Haldane model and modifying it from empirical data. Such present day decompression schedules or tables have inherent limitations and deficiencies and must be used with caution. In the use of such present day tables, it is necessary to include certain safety factors resulting in greater amounts of time being spent under compression than should be necessary. As can be understood, the inclusion of such a safety factors results in the loss of useful time for the diver as well as failing to cop compensate positively for the risk in operational diving.

Accordingly, a primary purpose of this invention is to provide a new and novel computing device for programming a diver's decompression schedule.

Another object of this invention is to provide a new and novel analog computer for calculating a decompression schedule for a diver for any diving time and depth within a wide range.

A further object of this invention is to provide a new and novel analog computer for programming a diver's decompression schedule which eliminates virtually all unnecessary diver's time during ascent or decompression and which, at the same time, produces a maximum degree of safety for the diver during decompression.

A still further object of the invention is to provide a new and novel analog computer for programming a diver's decompression schedule which is simple and inexpensive in construction, which may be operated by a relatively unskilled individual and which permits the rapid calculation of a decompression schedule.

A still further object of this invention is to provide a new and novel analog computer for programming a diver's decompression schedule which is rugged in construction, which is composed of a minimum of parts

and which may be utilized for either air dives wherein pressurized atmospheric air is used or a mixture of O_2 and other non-reactive or inert gases such as helium and the like.

Other objects and advantages of the invention will become apparent for from the following description taken in connection with the accompanying drawing.

In general the object of this invention and other related objects are accomplished by providing a plurality of resistor-capacitor sets serially connected in an electrical cascading relationship together with a variable voltage D.C. power supply connected by means including a switch across the leading set of the plurality of sets for cascade charging sequentially of the capacitors in the plurality of sets proportionately with time. The D.C. power supply is arranged to provide a voltage corresponding to a selected water depth and metering means calibrated in units of water depth are connected to the capacitors in at least the majority of sets for monitoring the voltage of all of the capacitors to indicate in units of water depth the highest voltage of the monitored capacitors. A discharge resistor is also connected across the leading resistor-capacitor set between the leading set and the power supply for cascade discharging of the capacitors in the sets sequentially and proportionately with time.

The novel features which are believed to be characteristic of the invention are set forth with particularity in the appended claims. The invention, itself, however, both as to its organization and method of operation may be best understood by reference to the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic wiring diagram of the analog computer of the invention; and

FIG. 2 is a front view of a meter incorporated in the analog computer of FIG. 1.

Referring now to the drawing, the analog computer of the invention, designated generally in FIG. 1 by the letter C, includes a plurality of resistor-capacitor sets or ranks 11-22, which in the illustrated embodiment are 12 in number. Each of the resistor capacitor sets 11-22 include a capacitor 11a-22a and a resistor 11b-22b respectively. One side of the capacitors 11a-22a are connected by means of conductors 23-34 respectively to a common conductor 36 grounded as shown at 37. The other side of the capacitors 11a-22a are connected by conductors 38-49 to one side of each associated resistor 11b-22b respectively and to one side of the resistor of the next successive set so as to serially connect the resistor-capacitor sets 11-22 in electrical cascading relationship.

The analog computer C also includes a variable voltage D.C. power supply 51 arranged to be connected to a suitable source of power by means of conductors 52. If desired, however, an integral source of power may be provided such as a battery or the like. The D.C. power supply 51 is arranged to provide a voltage corresponding to a selected water depth as will be explained hereinafter. To this end the D.C. power supply may be provided with a manual regulating knob 53 by means of which the desired output voltage on the power supply 51 is selected.

Means including a switch 54 are provided for connecting the D.C. power supply 51 across the leading set

11 of the plurality of resistor-capacitor sets 11-22 for cascade charging sequentially of the capacitors of the plurality of sets proportionally with time. More specifically, conductors 56, 57 are connected at one end as shown in FIG. 1 to the power supply 51, conductor 56 being connected to the grounded or common conductor 36 connected to one side of the sets 11-22 and conductor 57 being connected to a conductor 58 connected to the other side of the sets 11-22 preferably through a variable resistor or potentiometer 61 for a purpose to be explained hereinafter.

The potentiometer 61 includes a resistance 61a connected at one end to the power supply conductor 57 and at its other end to the ground conductor 36. The potentiometer 61 also includes a movable contact 61b so that the power supply conductor 57 is connected through a selected amount of resistance to conductor 58 thereby permitting the voltage applied to the leading resistor-capacitor set 11 to be reduced to a value corresponding to the partial pressure of the inert gas component of air supplied to a diver. By way of example, in an "air dive" the output voltage of the power supply 51 or the input voltage to the sets 11-22 is reduced 20 percent as nitrogen or N_2 comprises approximately 80 percent of atmospheric air.

Associated with the power supply 51 is a discharge resistor 67 preferably of the variable type which is connected at opposite ends to conductor 58, and the junction of conductors 36, 56. Thus the discharge resistor 67 is arranged to be connected across the leading resistor-capacitor set 11 by the connecting means including the conductors 36, 58 and switch 54. The discharge resistor 67 permits cascade discharging of the capacitors 11-22 sequentially and proportionally with time.

A charging capacitor 68 is also provided in association with the power supply 51 which is connected across conductors 36, 58 in electrical parallel relationship with the discharge resistor 67. The capacitor 68 is charged in accordance with the voltage output of the D.C. power supply 51 and applies this output voltage as reduced by the potentiometer 61 to the leading set 11 for cascade charging of the capacitors 11a-22a of the plurality of sets 11-22.

The analog computer C includes metering means, preferably calibrated in units of water depth, for monitoring the voltages of at least the majority of the capacitors 11a-22a of the plurality of sets 11-22 to indicate in units of water depth the highest voltage of the monitored capacitors. In the preferred embodiment, at least one set 11 and preferably two sets 11, 12 are provided between the D.C. power supply 51 and the majority of sets connected to the metering means so that the metering means are connected to sets 13-22 as shown in FIG. 1.

More specifically, the metering means include a high impedance voltmeter 70 grounded at one side at 71 as shown. A plurality of conductors 72-81 are also provided each connected to one of the capacitors 13a-22a through conductors 40-49 respectively. The metering means also includes a connector switch 82 preferably of the single pole, double throw type having a movable contactor 82a and connected to the other side of the voltmeter 70. One pole of the connector switch 82 is connected by means of conductor 84 to a common conductor 86 connected to all of the conductor 72-81

so that in the solid line position of the connector switch contactor 82a all of the capacitors 13a-22a are monitored to indicate on the voltmeter 70 the highest voltage present on the monitored capacitors 13a-22a. In the preferred embodiment, the conductors 72-81 each contain a diode 91 preferably of the type which has a very low forward resistance and a very high reverse resistance for proper functioning of the voltmeter 70 in monitoring the sets 13-22 in the solid line position of the movable contactor 82a.

In order to alternately provide selective monitoring of the capacitors 13a-22a in the sets 13-22 respectively the analog computer C includes a selector switch 92 having a plurality of terminals 93. The conductors 72-81 are each connected to one of the selector switch terminals 93 on the side of the diode 91 opposite the common conductor 86 by conductors 94-103 respectively and means are provided for connecting all of the selector switch terminals 93 to the connector switch 82. More specifically, the selector switch 92 includes a rotatably mounted annular contactor 104 having a radial extension 104a for contacting engagement with each of the terminals 93 upon indexing movement of the contactor 104 by suitable means such as a manual operating knob 106. A stationary contact strip 107 is also provided which is maintained in engagement with the rotatable contactor 104 in any rotary position and the strip 107 is connected by means of conductor 108 through a diode 109 to the other pole of the connector switch 82. In the dotted line position of the connector switch contactor 82a the voltmeter 70 is connected to the selector switch 92 and the selector switch 92 may be indexed to the desired position to obtain a readout on the voltmeter 70 for the voltage of each of the capacitors individually in the sets 13-22.

As will be explained hereinafter, the voltmeter 70 is preferably calibrated in units of water depth to permit a direct readout of the ascent schedule for a diver. As shown best in FIG. 2, the dial face 111 of the voltmeter 70 is provided with an arcuate strip 112 divided into uniform sections in each of which is indicated the depth, in increments of 10 feet, to which a diver may safely ascend as the dial indicator 113 moves in the direction of the arrow I during the cascade discharging of the monitored capacitors 13a-22a in the sets 13-22 respectively. The numerals adjacent each dividing line for the sections in the strip 112 represent the highest voltage monitored by the voltmeter 70.

The analog computer C also includes a normally open switch 116 which is preferably manually operated and which includes a plurality of gang operated contactors 117 each associated with one of the sets 11-22. All of the movable contactors 117 are connected to a conductor 118 arranged to be connected to the conductor 58 through switch 54. Movement of the switch 116 to the right in the direction of the arrow S from the normally open position of FIG. 1 moves all of the contactors 117 simultaneously into contacting engagement with a terminal 119 on each of the conductors 38-49 in the sets 11-22 to connect the capacitors 11a-22a respectively to the power supply 51 in the closed position of switch 54.

In the operation of the analog computer of the invention, the various components of the computer C are selected to provide a selected saturation time for all of

the capacitors 11a-22a in the sets 11-22 respectively in relationship to the time for a diver to become completely saturated, that is, the time for a diver's body to absorb the maximum amount of nitrogen in the body system reliably estimated to be approximately 40 hours. By way of example, if the computer C saturates in 200 minutes this would provide a 12:1 ratio so that the passage of 5 seconds when the computer C is in use would be equivalent to 1 minute of saturation time for the diver.

In addition, the computer C is calibrated so that the voltages may be expressed in units of water depth or feet of water and, in the illustrated embodiment, 1 volt is equivalent to 10 feet of water. The voltage divider or potentiometer 61 is then set, as previously described, to provide a reduction of 20 percent in the voltage output of power supply 51 this being the percentage of nitrogen in atmospheric air. The capacitors 11a-22a of the resistor-capacitor sets 11-22 respectively are then initially charged uniformly at 3.3 volts or 33 feet of sea water which is the equivalent of atmospheric pressure by setting a voltage of 3.3 volts on the power supply 51 and moving the switch 116 to the closed position, as previously described, with the switch 54 in the closed position. The switches 54, 119 are then both opened so that this initial charge of 3.3 volts remain on all of the capacitors 11a-22a.

The power supply 51 is then set for an output voltage corresponding to the depth of dive which, by way of example may be 9.3 volts for a 60 foot dive this being the sum of 3.3 volts for atmospheric pressure and 1 for each 10 feet of dive or 6 volts. Switch 54 is then closed and maintained in the closed position for the time of dive, the time of dive being controlled by the use of a suitable timer. However, as in the illustrated embodiment, a 12:1 ratio between real time and computer time is employed, each 5 seconds which the switch 54 remains closed would be equivalent to 1 minute for the time of dive. Therefore, if a 30 minute dive is to be performed, the switch 54 would be maintained in the closed position for 2½ minutes. During the time the output voltage of the power supply 51 is supplied to the sets 11-22, capacitor 11a of set 11 saturates rather quickly (approximately 5 seconds) and each of the successive capacitors begin to saturate but at a successively lower rate for the succeeding capacitors with the voltage spilling over into the next successive capacitor according to the difference in voltage between capacitors.

After the time of dive is completed and ascent of the diver is to begin, connector switch 82 having been positioned in the solid line position of FIG. 1, the depth indicated by the needle 113 on the strip 112 of the voltmeter 70 is read and the voltage of the power supply 51 is reduced to the level indicated on the voltmeter 70 to begin the desaturation or cascade discharging of the capacitors 11a-22a into the discharge resistor 67. As has been explained, the voltmeter 70 will read the highest voltage in all of the monitored capacitors of 13a-22 and the depth figure indicated on the voltmeter 70 will be the first safe stop during the diver's ascent. Preferably, the reduction in voltage on the power supply 51 is accomplished by reducing the voltage each 5 to the indicated depth on the voltmeter at the end of 5 second intervals since it is anticipated that

1 minute would be require by the diver to ascend between each 10 foot stop.

In the event the needle 113 moves in the direction of arrow I as the capacitors discharge to the new lower section in 10 foot increments in less than 5 seconds, the reduction in voltage of the power supply 51 should continue so that when decompression is actually required a depth will be reached at which the meter will not drop to the next shallower stop within the 5 second period and that depth will become the first decompression stop remaining so until the voltmeter 70 goes to the next stop depth.

At each stop depth, the voltage on the power supply 51 is kept at the depth of that stop until the voltmeter 70 indicates it is safe to ascend to the next shallower stop. The duration of each stop is recorded and ascent is continued at the beginning of the next full 5 seconds as explained above.

The table below is representative of the manner in which the computer C and the voltmeter 70 are calibrated. For instance, where the diver is at the 60 foot depth during ascent, the departure pressure is 98 feet of water or 9.8 volts so that when the voltmeter needle 113 passes the dividing line between the 60 and 50 foot stop depths corresponding to a voltage of 9.8 volts, the diver is then permitted to ascend to the 50 foot stop depth.

TABLE I

Depth (feet)	ABS. Pressure (ft. of H ₂ O)	N ₂ Pressure (ft. of H ₂ O)	Departure Pressure (ft. of H ₂ O)
0	33	26	—
10	43	34	48
20	53	42	58
30	63	50	68
40	73	58	78
50	83	66	88
60	93	74	98
70	103	82	108
80	113	90	118
90	123	97	128
100	133	105	138
110	143	113	148
120	153	121	158
130	163	129	168
140	173	137	178
150	183	145	188

By compiling the first stop depth for a dive having a predetermined depth and duration together with the various stop depths during ascent and the time at each stop depth, a complete ascent schedule may be programmed very quickly since the ratio between real time and computer time is such that dives of any depth or duration over a wide range with a maximum of safety and a minimum of loss time may be programmed in a relatively short space of time. The computer C of the invention may be readily minaturized and operated by a relatively unskilled operator since the calibration of the computer is such that although voltages are determinative of the results, all of the settings and readings are in feet making it relatively simple and easy to compile a diver's ascent shedule. The selector switch 92 is preferably included in the computer C so that when the connector switch 82 is moved to the dotted line position of FIG. 1, the switch 92 may be indexed throughout all of the terminals 93 as the time for the dive to end approaches to indicate generally where the first stop depth of any duration may be expected. It has

been found that by providing sets 11, 12 which are not connected to the voltmeter 70 and selector switch 92, a more accurate reading is obtained in that the capacitors 11a, 12a of these two sets saturate rather quickly in approximately 5 seconds and will follow the diver's ascent so rapidly as to be of relatively little value except in fast ascents.

While there has been described what at present is considered to be the preferred embodiment of the invention, it will be understood by those skilled in the art that various changes and modifications may be made therein without departing from the invention.

Having thus described the invention, what is claimed is:

1. An analog computer for programming a decompression schedule comprising, in combination, a plurality of resistor-capacitor sets interconnected together with the resistors in said sets in serially connected relationship and with the capacitors in said sets in parallel connected relationship for cascade charging of said capacitors, a variable voltage D.C. power supply for providing a voltage equivalent to a selected water depth, means for connecting said D.C. power supply across the leading set of said resistor-capacitor sets for cascade charging sequentially of the capacitors in said sets proportionally with time to simulate the time spent by a diver at a predetermined diving depth, metering means for monitoring the voltages of at least the majority of capacitors of said plurality of sets to continuously indicate the highest voltage of said monitored capacitors and means for cascade discharging sequentially of the capacitors in said plurality of sets proportionally with time to provide a timed ascent schedule for a diver corresponding to the voltage readout on said metering means.

2. An analog computer in accordance with claim 1 wherein said metering means is calibrated in units of water depth to permit a direct readout of the ascent schedule for said diver.

3. An analog computer in accordance with claim 1 wherein said connecting means includes a variable re-

sistor for reducing the voltage applied to said leading resistor-capacitor to set by said D.C. power supply to a voltage level corresponding to the partial pressure of the inert gas component of air supplied to said diver.

4. An analog computer in accordance with claim 1 including a normally open switch for connecting all of the capacitors in said plurality of sets to said D. C. voltage supply for simultaneously charging all of said capacitors to a voltage corresponding to atmospheric pressure.

5. An analog computer in accordance with claim 1 wherein said metering means includes a voltmeter, a plurality of conductors each connected to one of said capacitors in said majority of resistor-capacitor sets and a connector switch for connecting all of said plurality of conductors to said voltmeter for indicating the highest voltage on said monitored capacitors.

6. An analog computer in accordance with claim 5 including a selector switch having a plurality of terminals, means for connecting each of said terminals to one of said capacitors in said majority of resistor-capacitor sets, means for connecting all of said selector switch terminals to said connector switch, said connector switch being movable between a first position for connecting said voltmeter to said plurality of conductors and a second position for connecting said voltmeter to said selector switch to obtain a readout on said voltmeter of the voltage on each of said capacitors individually by selective positioning of said selector switch.

7. An analog computer in accordance with claim 6 including a diode in each of said plurality of conductors for connecting said capacitors to said voltmeter.

8. An analog computer in accordance with claim 7 wherein said plurality of resistor-capacitor sets includes at least one set between said D. C. power supply and said majority of sets connected to said metering means.

9. An analog computer in accordance with claim 8 wherein two serially connected resistor-capacitor sets are provided between said D. C. power supply and said majority of sets connected to said metering means.

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