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Soult

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[45] **May 22, 1973**

[54] **ELECTRONIC MONITORING CONTROL AND DISPLAY APPARATUS FOR BREATHING GAS SYSTEM**

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[52] **U.S. Cl.** **340/279,** 340/321, 340/379

[51] **Int. Cl.**.....**G08b 21/00,** G08b 23/00

[58] **Field of Search**.....340/321, 240, 379, 340/237, 279; 128/192, 142.2, 147; 40/129 A, 130 L, 130 N, 132 C, 132 E; 73/300

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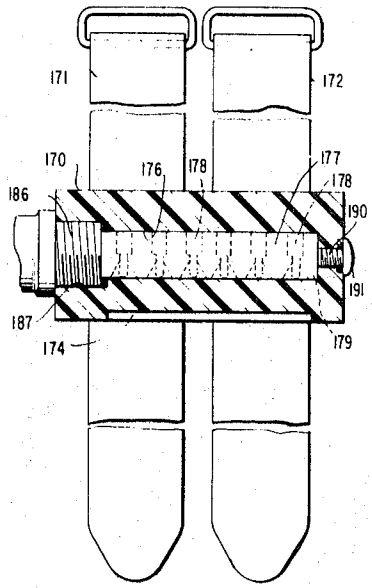
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Primary Examiner—John W. Caldwell
Assistant Examiner—Daniel Myer
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[57] **ABSTRACT**

Apparatus for providing a visual display of sensed conditions in a breathing gas system and including a housing having an elongated viewing window and a plurality of miniature color coded lamps mounted on a carrier member within the housing adjacent the viewing window. The lamps are connected to a source of operating current, through a connector which seals the housing, and means are provided for selectively electrically energizing the lamps in accordance with digital signals applied thereto.

8 Claims, 5 Drawing Figures



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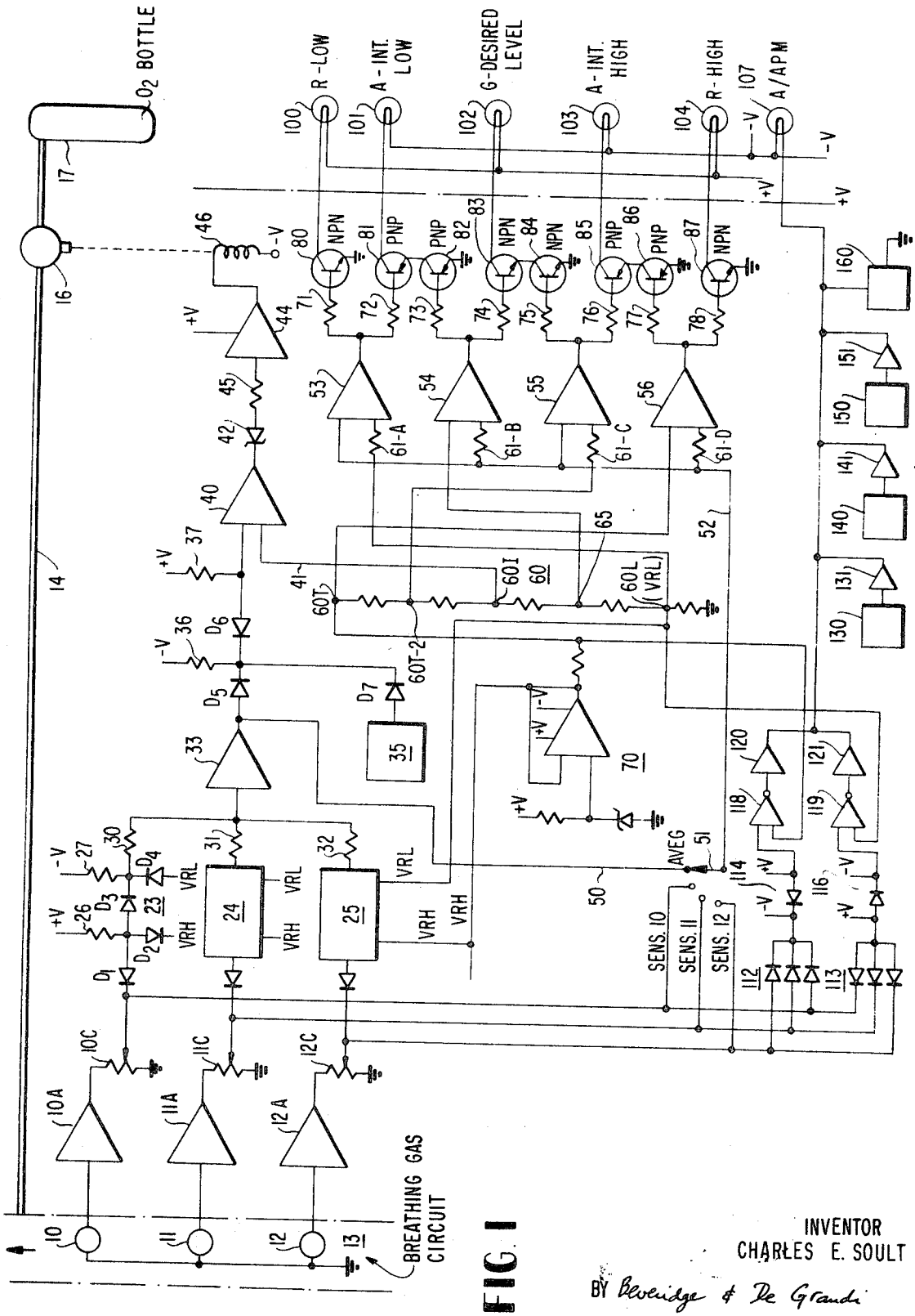


FIG. 1

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FIG. 3

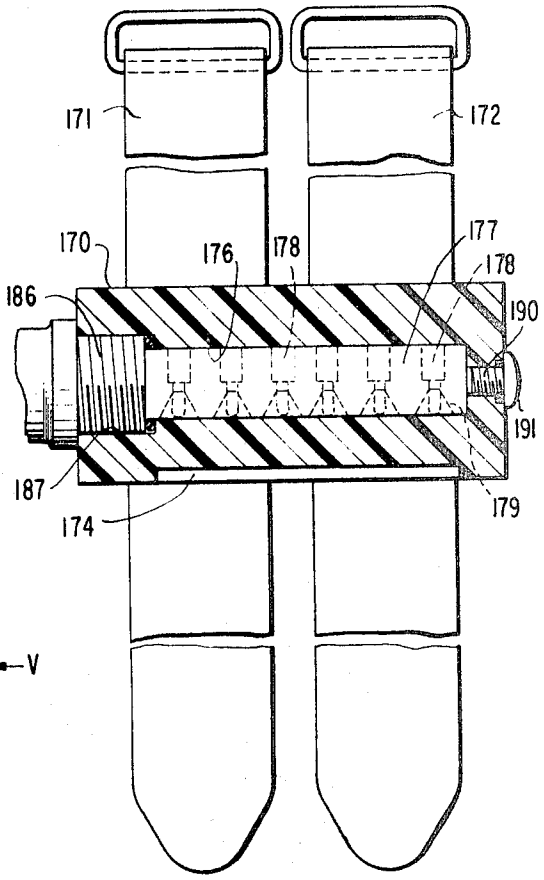


FIG. 2

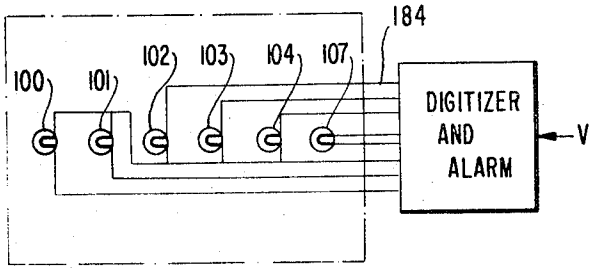
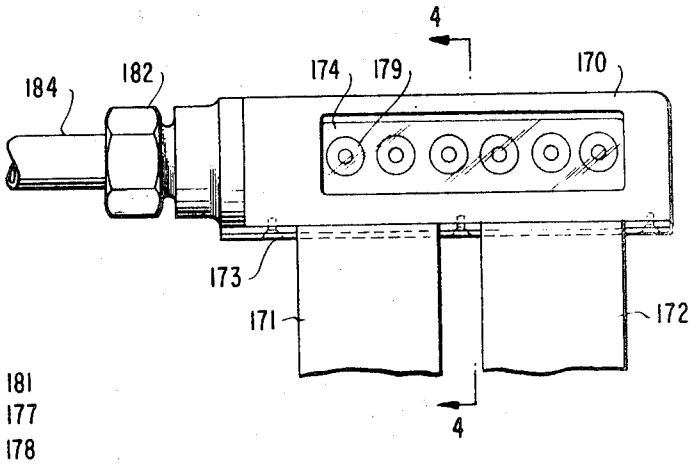


FIG. 4



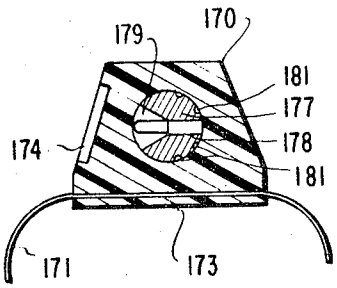


FIG. 5

ELECTRONIC MONITORING CONTROL AND DISPLAY APPARATUS FOR BREATHING GAS SYSTEM

BACKGROUND OF THE INVENTION:

Conventionally, systems for displaying conditions of vital gas parameters in closed and semi-closed breathing systems have been by means of analog meters, usually of the mechanical type but more recently, with the advent of improved partial oxygen pressure sensor and electrical control systems and improvements in batteries for supplying power, electrical meters have been used for presenting to the user the vital oxygen parameters as measured by improved partial oxygen pressure sensors. Other gas parameters, such as pressure of oxygen at the oxygen bottle, pressure of diluent gas at the diluent gas bottle measured by conventional pressure gauges which are suitably located for observation by the user. The present invention is directed to improvements in the display of vital data in breathing gas systems to eliminate ambiguity in such displays; to present all vital data concerning the breathing gas system to a user in a manner such that the user may quickly and easily isolate dangerous conditions for corrective action; to provide an alarm system which is operable when any of a plurality of vital parameters in the breathing gas system may be at a dangerous condition or level or at least when the output signals of sensors or transducers are such as to signify a dangerous condition; to provide the user with such information without the need of any significant interpretation by the user; to provide an improved automatic control system for the makeup oxygen supply to the breathing gas circuit which conserves the use of oxygen and hence extends the uninterrupted time period a user may use the system; and to provide an electrical system for such control which is relatively simple and economical.

The above and other objects, advantages and features of the invention will become more apparent from the following description taken in conjunction with the accompanying drawings wherein:

FIG. 1 is an electrical block diagram incorporating the invention.

FIG. 2 is a more simplified block diagram of a digital lamp display circuit as used in the invention,

FIG. 3 is a top view of a digital wrist display device as embodied in the invention, and

FIGS. 4 and 5 are side and end elevational views, respectively, of the wrist display device as embodied in the invention.

Referring now to FIG. 1 of the drawings, a plurality of sensors, as for example three galvanic partial oxygen pressure (PO_2) oxygen sensors **10, 11** and **12** of the type generally disclosed in Rutkowski application, Ser. No. 831,152 filed June 6, 1969 and assigned to the assignee of the present invention, for example, it being understood that any other type of oxygen sensors of the electrochemical cell type may be used in place of the type disclosed in the above-referenced patent application. Such sensors **10, 11** and **12** are shown included within a breathing gas circuit designated generally by the numeral **13** which may, in general, be either a closed or open circuit breathing system, and as an example, will be described in connection with a closed circuit breathing system for underwater breathing apparatus in which the breathing gas circuit includes a carbon dioxide removal unit, (not shown) with a mouthpiece (not shown) for supplying the conditioned gases moving in breathing gas circuit **13** to a user. In addition, such a breathing gas system may include pressure control diaphragm means (not shown) as well as diluent oxygen control and supply means, likewise not shown. Such apparatus, for the purposes of this invention, are deemed to be conventional. Reference, however, is made to the application of Frederick Parker et al., Ser. No. 6,387, filed Jan. 28, 1970 and assigned to the assignee of the present invention for a detailed disclosure of such an underwater breathing system for which the invention is particularly well adapted, such application being incorporated herein in its entirety.

As diagrammatically shown in FIG. 1, the breathing gas circuit **13** has connected thereto a pipe **14** which leads from a normally closed oxygen control valve **16** which, in a manner to be described more fully hereinafter, controls the periodic supply of oxygen, when needed, from oxygen bottle **17** to breathing gas circuit **13** via pipe **14.**

THE CONTROL CIRCUIT

The output voltages from galvanic oxygen sensors **10, 11** and **12** are amplified by conventional differential amplifiers **10***a*, **11***a*, and **12***a*, respectively, the gain of such amplifiers being fixed at a selected level. Sensors **10, 11** and **12** are each individually calibrated by potentiometer means **10***c*, **11***c* and **12***c* respectively, and if it is not possible to calibrate a given sensor, this is an indication that such sensor must be replaced.

The amplified and calibrated signals appearing at the wipers of potentiometers **10***c*, **11***c* and **12***c*, respectively, are passed to limiting circuitry **23, 24** and **25,** respectively with the details of one such limiting circuitry being shown at **23.** The limiting circuitry **23** comprises resistors **26** and **27** and diodes D_1, D_2, D_3 and D_4. As illustrated, the cathode of diode D_2 is connected to a voltage V_{RL} representing the lowest possible oxygen level voltage. If any of the sensor voltages are lower than the lowest permissible voltage, they are rejected in favor of the lower limit. If any of the voltages are higher than the highest permissible voltage limit, the higher voltage is rejected in favor of the higher limit. In between these two voltage limits, e.g. the high voltage limit as established by V_{RH} and the low voltage limit as established by V_{RL} the conditioned sensor voltage output is unchanged. Thus, this limiting circuitry limits the condition sensor outputs between fixed levels. The circuitry in blocks **24** and **25** is identical to the circuitry shown in for limiting circuitry **23** and is not described in detail. The outputs of the limiting circuitry is coupled through resistors **30, 31** and **32,** respectively, to an averaging amplifier **33** which averages the voltage output of limiting circuitry **23, 24** and **25** so that the output of amplifier **33** is a voltage which represents the average voltage of oxygen sensors **10, 11** and **12.**

The average voltage as appearing at the output of amplifier **33** is sampled periodically. This is done by a free running multivibrator **35** which supplies sampling pulses to sampling circuit which comprises diodes D_5, D_6 and D_7 and resistors **36** and **37** which have applied thereto the relative potentials illustrated in FIG. 1. Functionally the sampler circuit is a gate circuit which is gated on by an output pulse from free running multivibrator **35** and in the absence of a pulse from free running multivibrator **35** the averaged voltage of the PO_2 sensors appearing at the output of amplifier **33** is

blocked. Free running multivibrator **35** may be adjusted to have a rate of one gate pulse output every selected time interval and in the present case, the sampler applies or passes the averaged sensor voltage at the output of amplifier **33** to comparator amplifier **40** every five seconds. It will be appreciated that this time interval may be increased or decreased according to the desired discipline of the oxygen supply system to the breather. In addition, a reference voltage is applied via line **41** to comparator amplifier **40** and constitutes the control point. In the event the average voltage from amplifier **33** is greater than this reference voltage, there is an output voltage from comparator amplifier **40** which is coupled through zener diode **42** and current limiting resistor **43** to driver amplifier **44** which turns on or energizes solenoid **46** which in turn controls solenoid valve **16.** The solenoid is designed to remain energized for about one-half a second which admits one-half a liter slug of oxygen into the breathing mixture in breathing gas circuit **13.** The sampling circuitry then turns off a solenoid driver **44,** waits another five seconds and then repeats the comparing process. Thus, oxygen is admitted to the breathing gas circuit only if the level of oxygen as measured by sensors **10, 11** and **12** is below a selected level. Moreover, fluctuations in oxygen partial pressure are minimized by use of sample data control e.g., the periodic sampling and introduction of fixed pulses of oxygen when necessary reduces fluctuations by reducing mixing and transportation time relays in the small volume (the pipe **14** being diagrammatic). In addition to providing closer control of oxygen, battery power consumption is greatly reduced.

DIGITIZER AND DISPLAY

As shown in FIG. **1,** the output from averaging amplifier **33** is applied by lead **50** to selector switch **51** which may be used to select any one of the voltages from the sensor **10, 11,** or **12,** respectively or the averaged voltage from averaging amplifier **33.** Normally, as shown in FIG. **1,** the switch **51** is in the position to select the averaged voltage from averaging amplifier **33** which voltage is applied over line **52** as one of the inputs to a plurality of operational or comparator amplifiers **53, 54, 55** and **56.** The second input to amplifier **53, . . . 56** is derived from a voltage divider **60.** To the top or upper end **60T** of voltage divider **60,** is applied a calibrated or reference voltage from precision reference voltage source **70** which, as shown, is conventional using a zener diode as a precision reference device. (The reference voltage V_{RH} is obtained from this source as well as the reference voltage V_{RL} .)

It will be noted that the precision or calibrated voltage from source **70** that is applied to voltage divider **60** is also applied as one input or one comparison input to comparator **56.** Similarly, the voltage from the lower level **60L** of the voltage divider **60** is applied through a resistor **61** as a second input to comparator amplifier **53.** Similarly, the next highest level **60T–2** on voltage divider **60** is applied as an input to comparator amplifier **55** whereas the intermediate point **65** on the voltage divider is applied on line **41** as an input to comparator amplifier **40** which is used to establish the set point or control point for the admission of oxygen into the breathing gas circuit **13.** Finally, the second level from the bottom **60L–2** on voltage divider **60** is applied as a second input to comparator amplifier **54.**

If the applied signal voltage from averaging amplifier **33** is lower than the step voltage applied to comparator amplifier **53,** the output of comparator amplifier **53** is positive. The output of each of the comparator amplifiers is applied via series resistors **71–78** to AND logic circuits which are comprised of alternate NPN, PNP transistor units, with the alternate PNP or NPN transistor driving output indicator lamps **100, 101, 102, 103, 104,** respectively.

If the applied signal voltage from averaging circuit **33,** for example, or from any one of sensors **10, 11** and **12** as determined by the position of switch **51,** is lower than the step voltage level applied to comparator amplifier **53,** the output of this amplifier is positive so that the NPN transistor **80** is turned on or rendered conductive and the PNP transistor **81** is turned off. Thus, the "low" light is **100** is turned on or illuminated. The "AND" circuits formed by transistors **81, 82, 83, 84, 85, 86** and **87,** in the examples shown, keep the remaining lights **101–104** off.

When the signal level just exceeds this low step value, the output of comparator amplifier **53** becomes negative which turns off transistor **80** and turns on transistor **81.** Since the output of comparator amplifier **54** is also negative, the transistors **81** and **82** (both of which are PNP) are "on" so that lamp **101** (intermediate low) is on and the remaining lights **100, 102–104** are off. When the signal level reaches the step value applied to comparator **54** (the voltage at point **60–L–2**), the output thereof becomes positive and transistor **81** and transistor **82** turn off and transistor **83** then turns on because of the positive potential on its base, to energize or illuminate the lamp **102** (the desired level) turns on tand transistor **82** turns off thus extinguishing the lamp **101.** In between this value of set voltage and the next highest level is the control point voltage as applied to comparator **40.** Thus, the control point is exactly in the middle of the desired level band.

The meter-light electronics continues to sequence the lights as the signal voltage increases with the same control as exercised by the AND logic circuitry as described above. Electrical energy to operate the circuitry may derive from battery packs, not shown, which may constitute both positive and negative powers supplies.

ALARM CIRCUITS

The sixth lamp **107** illustrated in FIG. **1** is an alarm lamp. As illustrated, the output voltages from the PO_2 sensors **10, 11,** and **12** are coupled through coupling diode set **112** and coupling diode set **113** (connected in opposite polarity to diode set **112**) to limit selection circuitry **114** and **116** which, in turn, select the highest and lowest oxygen sensor readings and applies same to comparators **118** and **119,** respectively, and which, in turn, operate driver amplifiers **120** and **121** respectively. These amplifiers **120** and **121** are simply switches which operate or energize alarm lamp **107** and alarm buzzer **160** as illustrated. The circuitry comparator consisting of diodes **113** and limiting low level selecting diode circuitry **116** operate in a similar manner, it being noted that the high level comparison voltage is selected from the upper end **60T** of voltage divider **60** whereas the low level is selected from the lower end **60L** of the voltage divider **60.**

As illustrated, a plurality of additional sensors **130, 140** and **150** are connected to driver amplifiers **131,**

141, 142, respectively to sense various other conditions, as for example the battery voltage, to provide an alarm whenever the battery voltage is low, and/or sense the oxygen pressure at an oxygen bottle 17 and operate the alarm when the contents or pressure of the oxygen in oxygen bottle 7 is low or, to sense the pressure of the diluent gas and provide an alarm when the diluent pressure becomes low. These and other conditions may be sensed to provide an alarm at low level or high level conditions whenever it is necessary to warn the user of a dangerous or impending dangerous situation. At the same time that the alarm light is 107 is illuminated or energized, an audible alarm or buzzer 160 may be energized to provide both simultaneous visual alarm by the illumination of lamp 107 audible alarm by buzzer 160.

DIGITAL WRIST DISPLAY ASSEMBLY

The digital wrist display assembly (FIGS. 3–5) includes a main elongated body or housing member 170, one or more wrist straps or fastening assemblies 171, 172 (which may be velcro. snap fasteners, buckles, etc.) secured to the base by plate 173. Body member 170 is preferably made of a transparent plastic material (Lexan, for example) and has a transparent elongated viewing window, 174 which may be separate, but is preferably formed integral with body member 170 so as to avoid the necessity of forming a water tight seal for the window. An elongated chamber 176 is formed in body member 170 and chamber 176 is sized so as to snugly receive miniature lamp carrier member 177.

Lamp carrier member 177 has a plurality of spaced transverse bores 178, each bore 178 ending in a conically or parabollically shaped opening or bore 179, the bores 178 being adapted to receive the base of miniature lamps 100, 101 . . . . 104, 107, with the filament portion of the lamp bulbs being in the conically enlarged bore portion 179 and opposite the viewing window 174. The individual lamps may be frictionally secured in the bores 178 and wired by means of wires seated in longitudinal grooves 181 to a connector member 182 at the end of flexible conductor cabling 184 which is supplied with operating current by digitizer and alarm circuitry as described above.

Connector 182 is provided with a threaded portion 186 for threadably engaging internal threads 187 on the interior of housing member 170. Sealing washers or 0-rings (not shown) provide a water tight seal for the chamber. After assembling the lamp carrier 177 and connector 182 with body member 170, the chamber is filled with a non-conductive liquid, such as mineral oil, through a filing port 190 which is sealed by a sealing screw 191.

Various modifications may be made to the invention as disclosed herein and still be within the scope of the claims appended hereto.

What is claimed is:

1. An underwater display unit for displaying breathing gas condition in underwater diving apparatus, comprising;

an elongated rigid, fluid-tight housing having an elongated viewing window in a side wall thereof and an elongated chamber in said housing;

a miniature indicator lamp carrying member, said lamp carrying member having a length corresponding to the length of said elongated chamber and received therein;

means on said lamp carrying member for mounting a plurality of miniature color coded electrical indicator lamps spaced along the length of said chamber and along said side wall viewing window;

connector means for electrically connecting said lamps to an external source of operating current, and for sealing said elongated chamber;

and means for releasably securing said housing on the body of a user.

2. The invention defined in claim 1 wherein there are at least five of said miniature indicator lamps, in said row, the center lamp of which indicates a normal condition with the lamps to each side thereof indicating unsafe condition with the greatest degree of unsafety being indicated by lamps most remote from the lamp indicating said normal condition.

3. The invention defined in claim 1, including a light-transmissive non-conductive liquid filling the voids in said elongated housing.

4. The invention defined in claim 1, wherein said means for securing said unit on the body of a user comprises a wrist strap means securing said unit in position wherein said viewing window is in a plane parallel to the back of the user's wrist.

5. An underwater display unit for displaying breathing gas conditions in underwater diving apparatus, comprising, an elongated housing having an elongated viewing window in a side wall thereof and an elongated chamber in said housing, a miniature indicator length carrying member, said length carrying member having a length corresponding to the length of said elongated chamber and received therein, said lamp carrying member having a plurality of spaced bores in a single row and extending normal to the longitudinal axis thereof and to said elongated side wall viewing window, each said bore having a lamp base securing portion and a conically shaped lamp bulb receiving portion, said conically shaped bulb portion being adjacent said viewing window, a plurality of miniature electrical indicator lamps mounted in said bores, and connector means for electrically connecting said lamps to a source of operating current and for sealing said elongated chamber, and means for releasably securing said housing on the body of a user.

6. The invention defined in claim 1 including at least one further lamp in said row and at an end thereof for providing an alarm indication in addition to and independent of any indication by the other of said lamps.

7. Apparatus for digitally displaying breathing gas condition in a breathing gas system comprising,

an elongated housing having an elongated substantially transparent viewing window portion in a side wall thereof and an elongated chamber in said housing aligned with said viewing window,

an indicator lamp carrying member having a length corresponding to the length of said elongated viewing window and received in said elongated chamber in said housing,

a plurality of electric lamps carried by said lamp carrying member and spaced therealong and in contiguous relation with said elongated viewing window,

connector means for electrically connecting said lamps to their source of operating current and for sealing said chamber, and

means for selectively electrically energizing said lamps in accordance to digital signals applied thereto.

8. A method of unambiguously displaying vital breathing gas system conditions to a diver underwater, wherein said system includes means for sensing the oxygen levels and supply therein and producing a control signal for each range of conditions, said method of display comprising,

establishing a viewing line for said range of conditions,

projecting green light from the center of said display for a normal condition,

projecting red light from the spaces at the extreme opposite sides of the center of said display indicating dangerous conditions, and

projecting amber light from the side spaces adjacent said center of said display and said extreme opposite sides of the center to indicate a degree of unsafe conditions intermediate said dangerous condition and said normal condition.

* * * * *