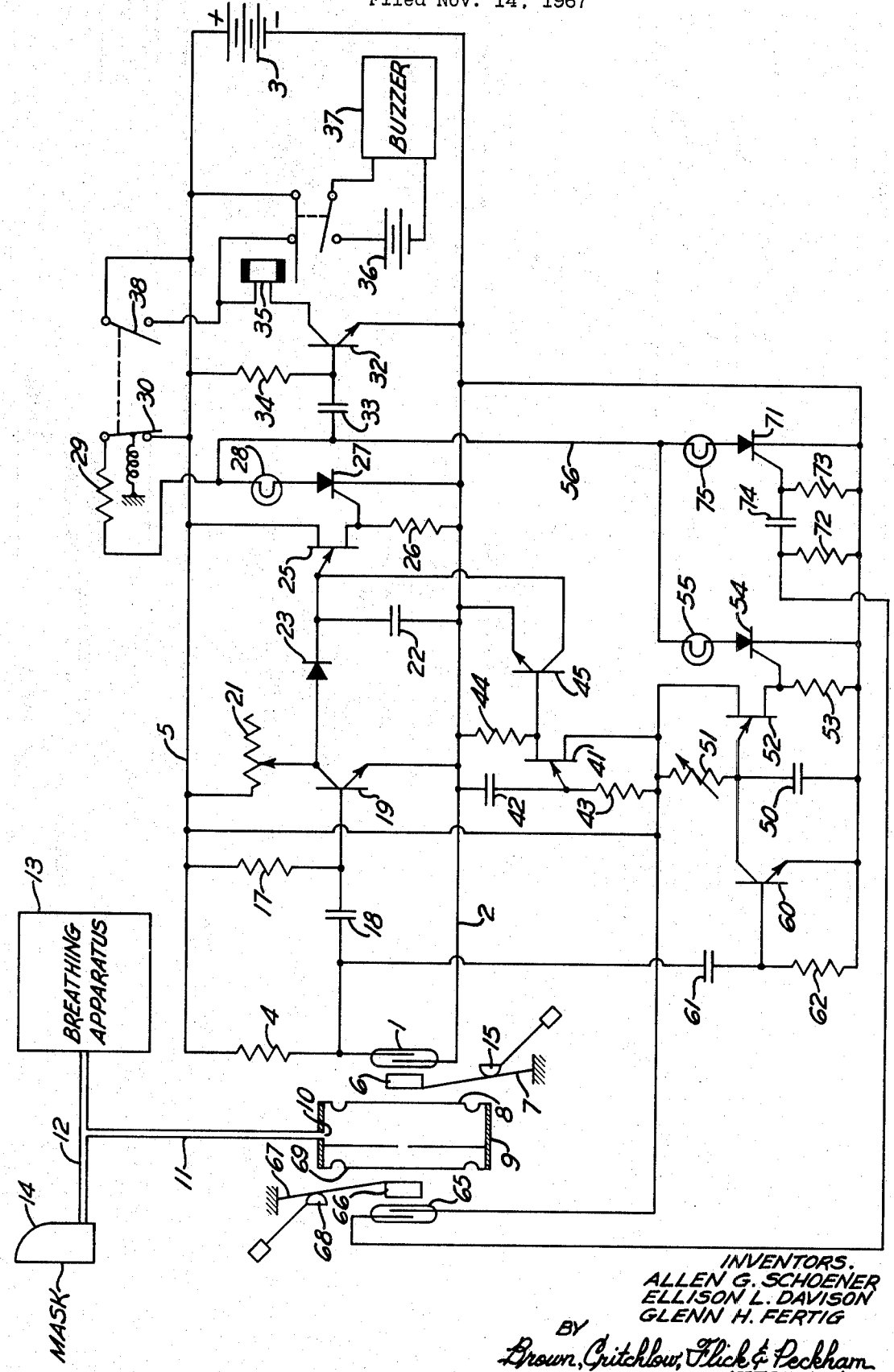
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MONITORING DEVICE FOR POSITIVE PRESSURE BREATHING APPARATUS

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MONITORING DEVICE FOR POSITIVE PRESSURE BREATHING APPARATUS

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ABSTRACT OF THE DISCLOSURE

The respiration pressure of a patient being treated with positive pressure breathing apparatus is used for closing an electric switch during each inhalation cycle. Every time the switch is closed an electric charge is delivered to a first condenser, which is discharged at regular intervals, but a first electric signal indicator for excessive breathing rate will be actuated by the charge built up on the condenser if it reaches a predetermined value before the condenser is discharged. There also is a second condenser and means for charging the condenser continuously, as well as means for discharging it every time the switch is opened. A second electric signal indicator for inadequate breathing rate will be actuated by the charge built up on the second condenser if it reaches a predetermined value before that condenser is discharged.

It is among the objects of this invention to provide a device that monitors the respiratory pattern being delivered by intermittent positive pressure breathing apparatus to a patient and signals any significant deviation from that pattern. More specifically, the device is designed to signal if the patient respiration pressure fails to attain a preset minimum or exceeds a preset maximum, and also to signal if the respiration rate falls below a preset minimum or exceeds a preset maximum.

The invention is illustrated in the accompanying drawing, in which the single figure is a circuit diagram for our monitoring device.

Referring to the drawing, a normally open electric switch **1** has one contact connected by a conductor **2** with one terminal of a battery **3** and the other contact connected through a resistor **4** and a conductor **5** with the other terminal of the battery. The switch may be a magnetic switch that is closed when a magnet **6** is moved close enough to it. The magnet may be supported by a leaf spring **7** between the switch and a movable wall, preferably in the form of a flexible diaphragm **8**, that forms one wall of a housing **9**. The side of the housing is provided with an inlet **10** that is connected by a tube **11** with the breathing hose **12** that connects any intermittent positive breathing apparatus **13** with a mask **14** worn by a patient, whereby the inside of the housing is subjected to the air or oxygen pressure in the breathing hose. During the pressure or inhalation cycle of the breathing apparatus, the gas pressure in the housing becomes great enough to cause the diaphragm to move the magnet toward the switch so that the switch will be closed. The pressure that is required for this purpose may be determined by an adjustable cam **15** that is used for pre-loading the magnet spring. Thus, the switch is closed at a preset pressure periodically at the respiration rate of the patient.

Each time the switch is actuated to a predetermined position, which is the closed position in the circuit described, a differentiator circuit, consisting of resistors **4** and **17** in parallel and a capacitor **18** in series with resistor **17**, produces a negative pulse that causes a transistor **19** to become nonconductive for the duration of the pulse. While the transistor is nonconductive, the voltage at its collector rises at a rate determined by the time constant of a variable resistor **21** and a condenser **22** which are connected by a diode **23**. Those last three elements are connected in series across conductors **2** and **5**. Due to the unidirectional effect of the diode, the voltage just mentioned is stored on the condenser. If the charge is allowed to build up without interruption, it will increase to the "firing point" of a unijunction transistor **25**, whereupon a positive pulse is produced across a resistor **26** connecting this transistor with conductor **2**. This causes a silicon control rectifier **27** to conduct. The rectifier connects to conductor **2** a signal indicator, such as a lamp **28**, that also is connected through a resistor **29** and a normally closed reset switch **30** with conductor **5**. When the lamp is lit, electric current flows through resistor **29**, thus creating a voltage drop that causes a transistor **32** to enter a nonconductive state by way of a capacitor **33** and a resistor **34** that are connected in parallel with each other between conductor **5** and the transistor. When transistor **32** becomes nonconductive, a relay **35** in series with it is released, which opens the power circuit to the transistor and closes a separate circuit containing a battery **36** and an audible alarm, such as a buzzer **37**. The buzzer and lamp will continue to function until a normally open reset switch **38** is closed momentarily. The two reset switches are mechanically connected so that closing switch **38** opens reset switch **30** momentarily. Switch **38** connects the relay back in circuit and reverses it to open the buzzer circuit, and opening switch **30** extinguishes the lamp and renders rectifier **27** nonconductive again. It will also be seen that if there is a power failure in the main circuit, relay **35** will be released and the buzzer will sound the alarm.

The system described thus far shows that a signal or alarm is actuated whenever sufficient voltage is built up on condenser **22** to fire unijunction transistor **25**. However, this build-up does not occur if the respiration rate of the patient does not exceed the desired rate for which the device is set. Prevention of voltage build-up is accomplished by timing means that discharge the condenser at regular intervals short enough to normally not leave enough time for the condenser to be charged to the value necessary for firing the unijunction transistor. For example, timing means may be used that will discharge the condenser every 30 seconds, in which case variable resistor **21** is set to require more than the expected number of closings of switch **1** in 30 seconds to charge the condenser to the alarm point. Therefore, as long as the patient does not breathe faster than intended, the switch will not close enough times in 30 seconds to charge condenser **22** to the point where it will fire transistor **25**. However, if the respiration rate increases so that the switch is closed more frequently in the same selected period of time, a signaling voltage will be built up on the condenser.

The timer may take the form of a unijunction transistor **41** in conjunction with a capacitor **42** and a resistor **43**. The last two elements are connected across conductors **2** and **5**. The three elements generate a positive pulse which is distributed across a resistor **44** at regular intervals, such as every 30 seconds, for example. When this happens a transistor **45** is made conductive momentarily and discharges condenser **22**, with which it is connected in parallel. Consequently, under normal conditions the condenser is discharged every 30 seconds before it can acquire a large enough charge to cause the lamp to light and the buzzer to sound, but if the respiration rate rises above the desired value, the alarm will be actuated.

Another feature of this invention is that the device will signal in case the respiration rate of a patient falls below the minimum rate it is desired to maintain. To accomplish this, a condenser **50** is connected in series

with a variable resistor 51 across conductors 2 and 5, so that the condenser is charged continuously at a rate controlled by variable resistor 51. If sufficient voltage is stored on this condenser, it will fire a unijunction transistor 52, thereby producing a pulse across a resistor 53 which causes a silicon control rectifier 54 to conduct and permit a second signal lamp 55 to light. The rectifier connects one side of the lamp with conductor 2 and the other side is connected by a conductor 56 to a point between lamp 28 and resistor 29. When lamp 55 is lit, a current flow is created through resistor 29 and produces a voltage drop that causes transistor 32 to enter a nonconductive state and thereby release relay 35 so that the buzzer will sound until reset switch 38 is closed again and reset switch 30 is opened simultaneously as previously explained.

To prevent lamp 55 from lighting while the minimum respiration rate is satisfactory, which means that there are not too few respirations per minute, condenser 50 is discharged periodically before sufficient voltage is stored on it to fire transistor 52. This discharging of the condenser is accomplished by a transistor 60 in parallel with it. The transistor normally does not conduct, but every time the pressure switch 1 is actuated to a predetermined position, the open position as shown, a positive pulse is injected into the base of the transistor to make it conduct and discharge condenser 50. The time that it takes for a signaling voltage to build up on condenser 50 can be adjusted by variable resistor 51. A time period is selected that is slightly greater than the period between successive openings of the switch while the breathing rate is above the minimum desired, so that under normal operating conditions condenser 50 will be discharged before it can store a firing voltage.

Due to a capacitor 61 connected between conductor 5 and the base of the transistor, and a resistor 62 connected between the base of the transistor and conductor 2, transistor 60 conducts only momentarily and immediately becomes nonconductive again so that charging of condenser 50 can begin again. Therefore, if the respiration pressure is not sufficient to close the switch, enough voltage will build up on condenser 50 to cause lamp 55 to light. A drop in the respiration pressure may be due to a leak in the air stream of the breathing apparatus, or to loosening or loss by the patient of the mouthpiece, face mask or tracheotomy adapter. Lighting of the lamp 55 can mean that either the respiration rate or the respiration pressure is too low.

By the addition of further transistors to the circuits in a known manner, transistor 19 could be made nonconductive every time switch 1 is opened instead of closed, and transistor 60 could be made conductive every time the switch is closed instead of opened.

A further feature is that this system can also be used for giving an alarm in case the respiration pressure becomes too great. This might occur if the patient suffers a severe airway obstruction or a mucous block. To give such an alarm a second pressure operated switch 65 is provided that likewise may be magnetic and closed by a magnet 66 mounted on the end of a leaf spring 67 that can be pre-loaded by a cam 68. To move the magnet toward the switch, the side of housing 9 opposite switch 1 likewise is provided with a movable wall, such as a flexible diaphragm 69, that will be moved outwardly to close switch 65 if the pressure in the housing rises above a predetermined maximum determined by the setting of cam 68. Closing of switch 65 creates a positive pulse, which is delivered to the gate of a silicon control rectifier 71 by way of a pair of resistors 72 and 73 and a capacitor 74. The pulse causes the rectifier to conduct and that connects a third signal lamp 75 into the circuit between wire 56 and conductor 2. When the lamp is lit, current flows through resistor 29 and creates a voltage drop to cause transistor 32 to become nonconductive. The result is that relay 35 is released and the alarm buzzer sounded. The lamp remains lit and the buzzer continues to buzz until the reset switches are operated.

To prevent a sudden but transistory increase in pressure from closing switch 65, a partition 77 is disposed inside housing 9 between inlet 10 and diaphragm 69. This partition divides the inside of the housing into two chambers that are connected by an aperture 78 in the partition. If the patient happens to cough and thereby suddenly increase the pressure in the larger chamber, this pressure will be prevented by the partition from reaching the other chamber and closing switch 65. That is, before the momentary increased pressure in the large chamber can be transmitted through the small hole in the partition to the other chamber, the breathing apparatus will have switched to the exhalation cycle and the pressure in the housing will be reduced.

According to the provisions of the patent statutes, we have explained the principle of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. A monitoring device for breating apparatus comprising an electric switch movable between open and closed positions and normally in one of said positions, means actuated by patient respiration pressure above a predetermined minimum for periodically moving the switch to the other of said positions, a first condenser, means for charging the condenser every time the switch is actuated to said other position, means for discharging the condenser at regular intervals, a first electric signal indicator for excessive breathing rate adapted to be actuated in response to the charge built up on the condenser if it reaches a predetermined value before the condenser is discharged, a second condenser, means for charging the second condenser continuously, means for discharging the second condenser every time said switch returns to said normal position, and a second electric signal indicator for inadequate breathing rate adapted to be actuated in response to the charge built up on the second condenser if it reaches a predetermined value before that condenser is discharged.

2. A monitoring device according to claim 1, in which said normal position of the switch is its open position.

3. A monitoring device according to claim 1, in which said normal position of the switch is its open position, and said second condenser discharging means are effective only momentarily, whereby a charge will be built up on the second condenser to said last-mentioned predetermined value if said respiration pressure becomes insufficient to close said switch.

4. A monitoring device according to claim 1, in which said signal indicators are electric lamps, said device including an electric audible alarm, an electric circuit for energizing the alarm, a normally open switch in said circuit, and means causing that switch to close whenever either of said lamps is lit.

5. A monitoring device according to claim 1, in which each of said discharging means includes a normally nonconductive transistor in parallel with one of said condensers, and means for rendering the transistors conductive periodically.

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