Feb. 8, 1966 H. C. GRANT, JR., ETAL 3,234,536

ELECTRICAL CONTROL SYSTEM

Filed Feb. 20, 1963 4 Sheets-Sheet 1

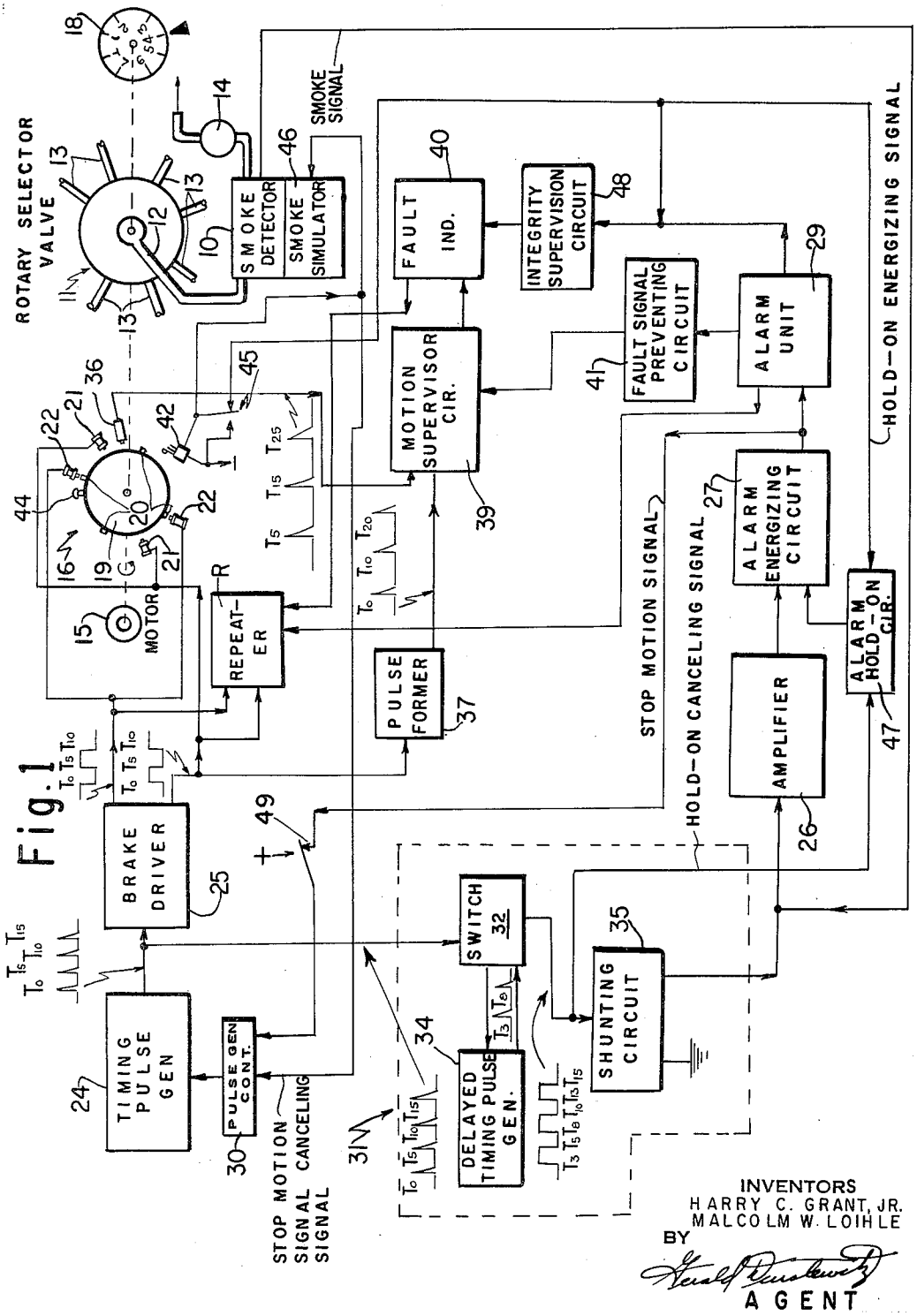


Fig. 1

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ELECTRICAL CONTROL SYSTEM

Filed Feb. 20, 1963 4 Sheets-Sheet 2

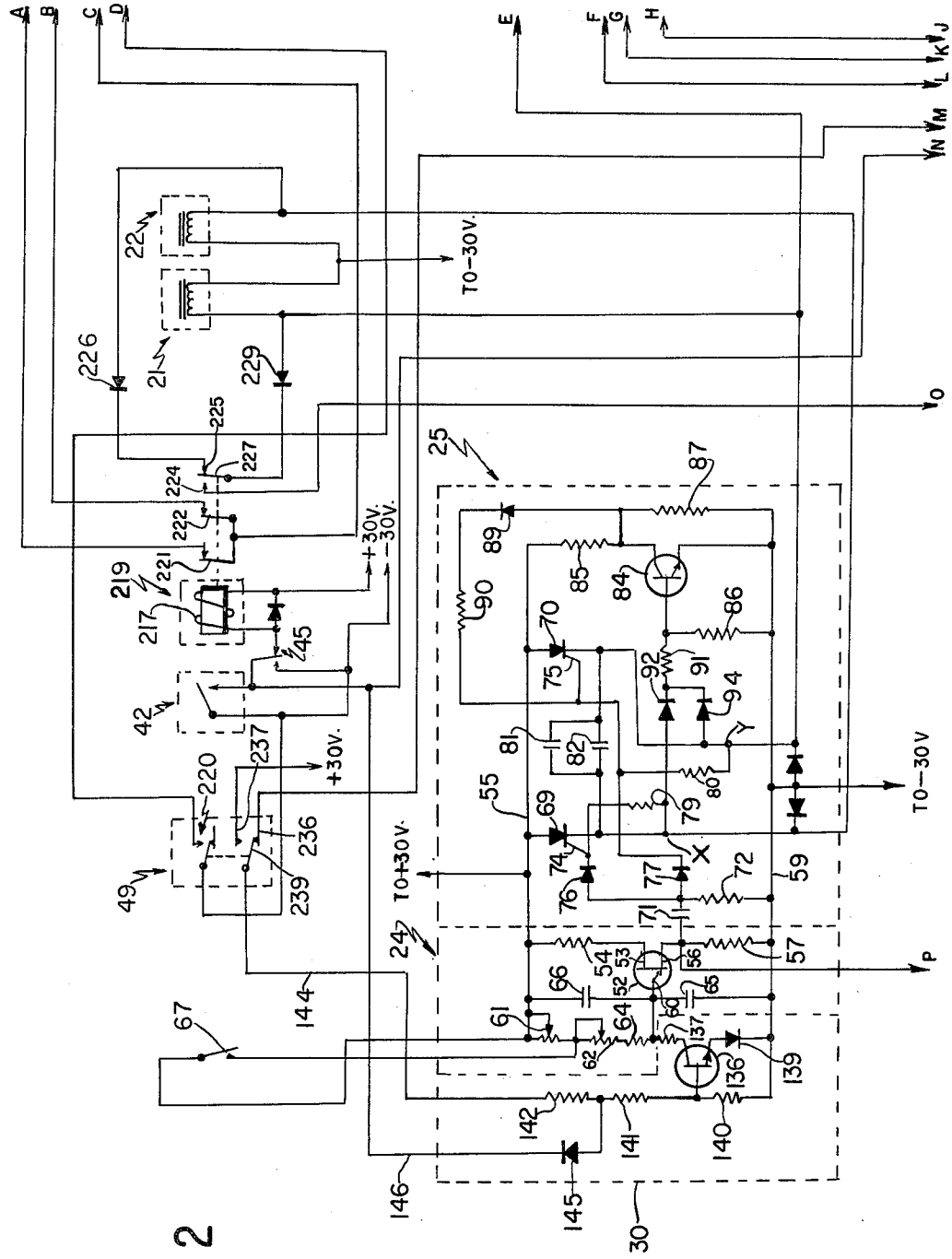


Fig. 2

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ELECTRICAL CONTROL SYSTEM

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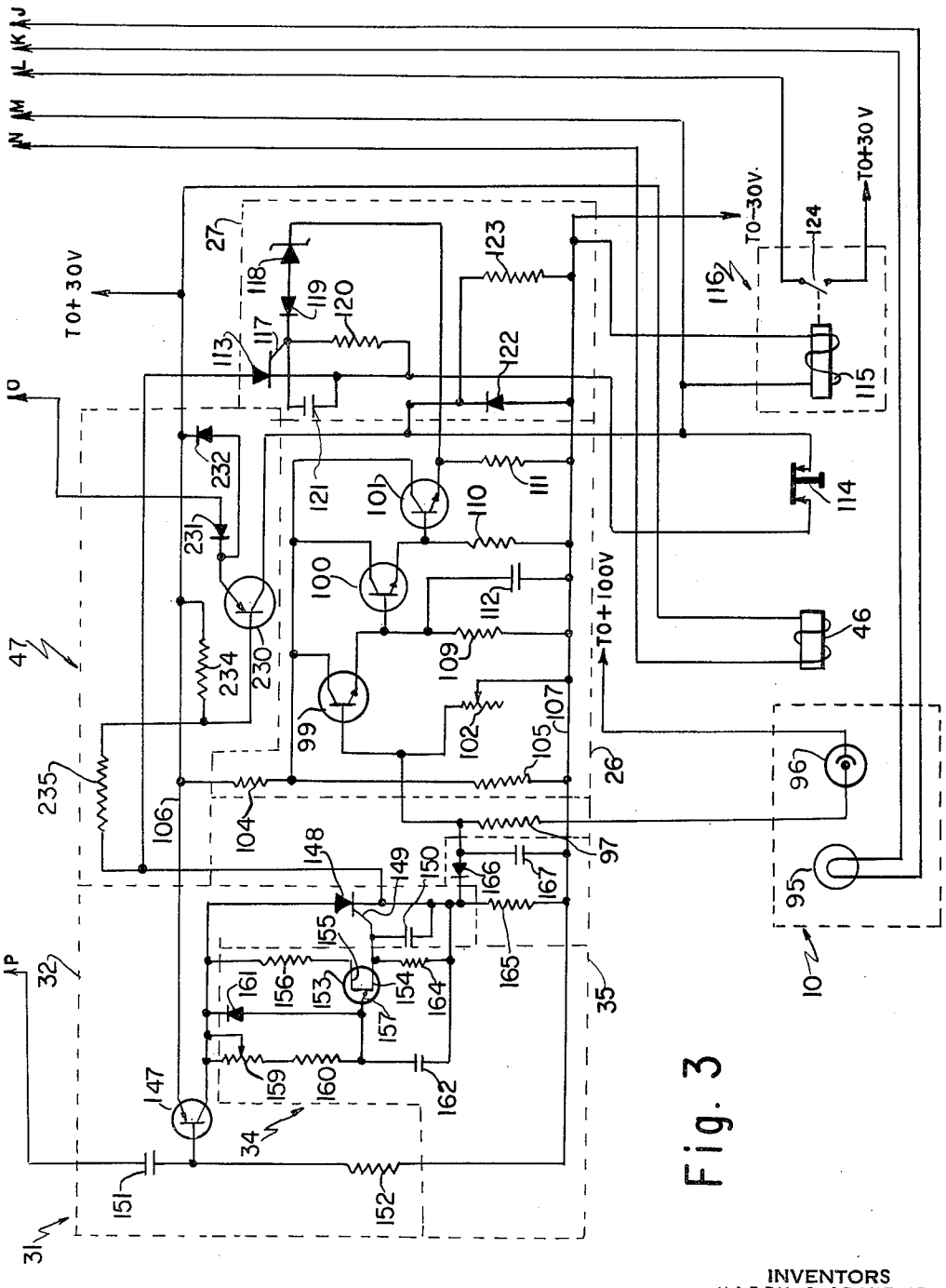


Fig. 3

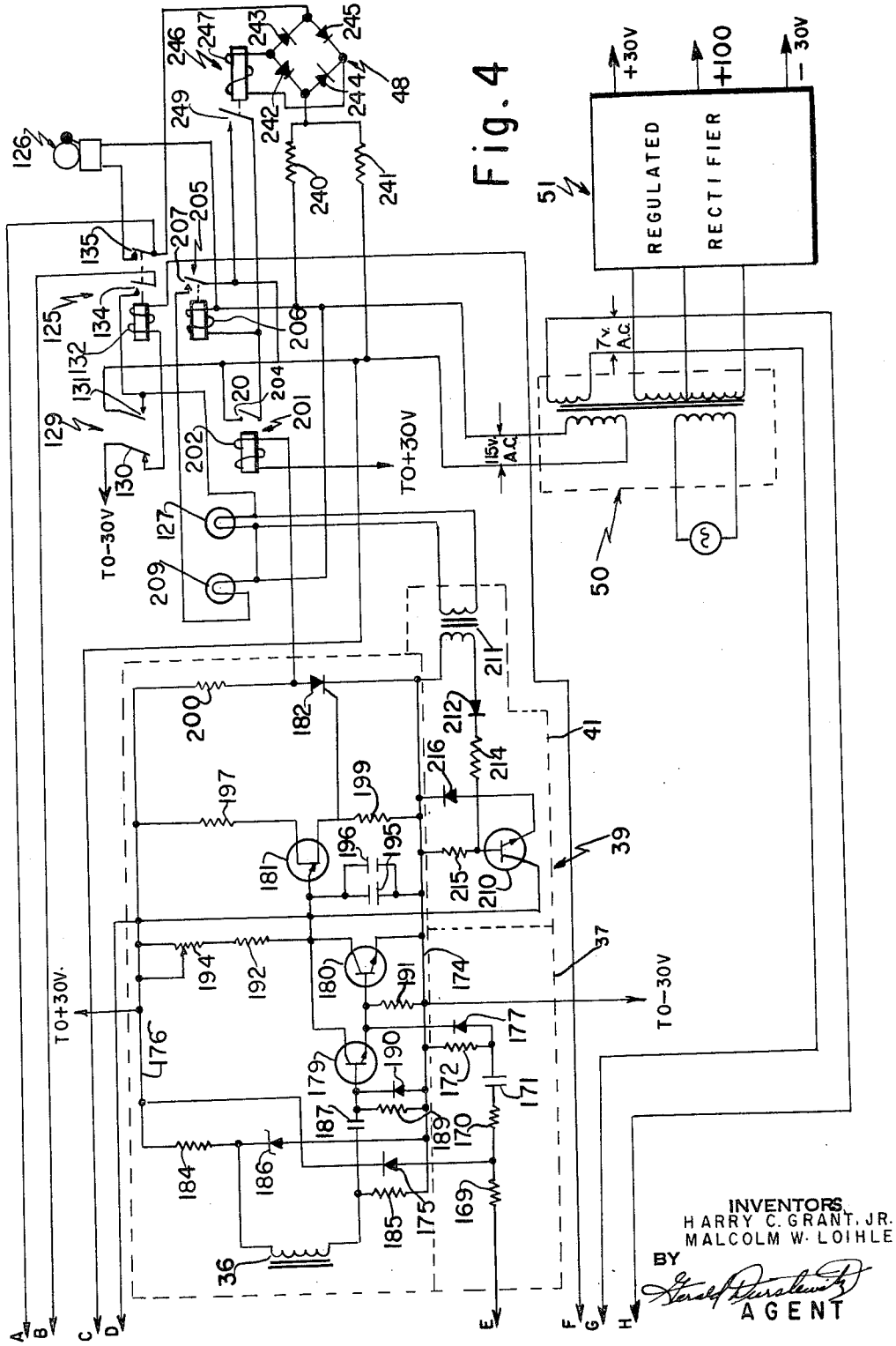
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ELECTRICAL CONTROL SYSTEM

Filed Feb. 20, 1963 4 Sheets-Sheet 4

Fig. 4



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United States Patent Office

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3,234,536

ELECTRICAL CONTROL SYSTEM

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Filed Feb. 20, 1963, Ser. No. 260,007
15 Claims. (Cl. 340—214)

The present invention relates to electrical control systems, and, more particularly, to such systems for controlling smoke detecting apparatus which automatically monitors a plurality of spaces in which smoke is to be detected.

The present invention, although useful for other purposes, is primarily concerned with an electrical control system for automatically operating, supervising and testing the smoke detecting apparatus, shown and described in co-pending application for Letters Patent Serial No. 229,807, filed October 11, 1962.

In smoke detecting apparatus of the type disclosed in the above identified co-pending application, a plurality of smoke conducting conduits extending from the spaces being monitored are connected through a selector valve device to a smoke detecting unit. The control system for such apparatus normally operates the selector valve device to sequentially connect each of the conduits to the detecting unit, and interrupts the operation of the valve device when the detecting unit responds to the presence of smoke. In previously known control systems, the smoke detecting unit could become inoperative or the selector valve device could cease to operate and such failures could be detected only by close scrutiny of the apparatus, if at all.

In smoke detecting apparatus of this type, a photoelectric cell is normally provided in a chamber where it is affected by the presence of smoke to produce a signal. The chamber is connected to the selector valve by a suitable length of pipe through which smoke laden air must move before it reaches the detector. Therefore, should smoke initially enter this connecting pipe just before the selector valve changes the line connected to the detector, an erroneous indication that smoke is present in the space associated with the subsequently connected line can result.

Accordingly, an object of the present invention is to provide an improved electrical control system for smoke detecting apparatus.

Another object is to provide such a system for automatically operating, and monitoring and testing the condition of the smoke detecting apparatus.

Another object is to provide such a system including an arrangement for preventing the smoke detecting apparatus from giving an erroneous indication as to the source of detected smoke.

Another object is to provide such a system including an arrangement for automatically and periodically testing the operativeness of the smoke detecting apparatus.

Another object is to provide such a system including an arrangement for monitoring the operation of the selector valve and automatically giving a false indication should the selector valve cease operating.

Another object is to provide such a system including an arrangement for stopping the selector valve and inerting the monitoring arrangement when smoke is detected.

Another object is to provide such a system wherein the operation of the detecting apparatus is tested once during each cycle of the selector valve without activating the arrangement for stopping the selector valve.

Another object is to provide such a system including improved means for operating the selector valve.

A further object is to provide such a system which is reliable, accurate, has long life, and requires a minimum of maintenance.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for purposes of illustration and description, and is shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a schematic block diagram of an electrical control system according to the present invention.

FIGS. 2, 3 and 4 are wiring diagrams which when arranged with FIG. 3 below FIG. 2 to align lines J to P and FIG. 4 to the right of FIG. 2 to align lines A to H provide an entire wiring diagram for the system shown in FIG. 1.

Referring to the drawings in detail and particularly to FIG. 1 thereof, there is shown a smoke detecting system including smoke detecting apparatus and an electrical system in accordance with the present invention for controlling the smoke detecting apparatus. The smoke detecting apparatus, which is disclosed in detail in the aforementioned co-pending application, generally comprises a photo-electric smoke detecting unit **10**, an eight position rotary selector valve **11** having an outlet conduit **12** connected to the air intake of the detecting unit **10**, seven input conduits **13** extending from the selector valve **11** to a plurality of spaces which are to be monitored by the detecting apparatus, an air blower **14** connected to the air outlet of the detecting unit **10**, and a motor arrangement for driving the selector valve including a continuously acting torque motor **15** and a stepping brake **16** mounted on a common shaft **17** with the selector valve **11**. A number wheel **18** is also provided on the shaft **17** to indicate which conduit **13** is connected to the detecting unit **10**.

The stepping brake **16** includes a disc **19** secured to the shaft **17** for rotation therewith, four armatures **20** on the disc **19** equally spaced about the circumference thereof, and two pairs of diametrically opposite electromagnets **21** and **22** positioned adjacent to the disc **19** to cooperate with the armatures **20** to provide a braking force on the shaft **17**. The pair of magnets **21** are positioned forty-five degrees in advance of the pair of magnets **22**.

The torque motor **15** constantly urges the shaft **17** to rotate, and the stepping brake **16** periodically interrupts the rotation of the shaft **17** so that the selector valve **11** moves in eight steps to connect each of the conduits **13** to the smoke detecting unit **10** for a predetermined period of time during each revolution of the valve. The blower **14** draws air from the spaces to be monitored through the conduits **13** and the selector valve **11** into the smoke detecting unit **10** which produces an electrical signal if smoke is present.

GENERAL DESCRIPTION OF CONTROL SYSTEM

The electrical control system for the apparatus just described generally comprises a timing pulse generator **24**, a brake driver **25** controlled by the pulse generator for alternately energizing the electro-magnets **21** and **22** to operate the stepping brake **16**, an amplifier **26** connected to the output of the detecting unit **10**, an alarm energizing circuit **27** connected to the output of the amplifier **26**, an alarm unit **29** under the control of the energizing circuit **27** for giving an indication when the detecting unit **10** responds to the presence of smoke, a pulse generator control circuit **30** for interrupting the operation of the pulse generator to stop the selector valve when an alarm is given, an alarm hold-off circuit **31** to insure that the valve **11** stops only on a conduit **13** delivering smoke, a motion supervising arrangement for giving an indication should

the selector valve fail to rotate, and a testing arrangement for testing the operativeness of the smoke detecting unit.

The alarm hold-off circuit **31** comprises a switching circuit **32**, a delayed timing pulse generator **34**, and a smoke detector shunting circuit **35**.

The motion supervising arrangement comprises a motion sensing unit **36** adjacent the disc **19**, a pulse former **37** connected to an output of the brake driver **25**, a motion supervisor circuit **39** responsive to the outputs of the motion sensor **36** and the pulse generator **37**, a fault indicator **40** controlled by the circuit **39**, and a fault signal preventing circuit **41** connected between the alarm unit **29** and the supervisor circuit **39**.

The testing arrangement comprises an automatic test switch **42** positioned adjacent the disc **19**, a test switch operator **44** mounted on the disc **19**, a manual test switch **45**, a smoke simulator **46** in the detector unit **10** under control of the test switches **42** and **45**, an alarm hold-on circuit **47** under the control of the automatic test switch and the alarm hold-off circuit **31**, and an integrity supervisor circuit **48**. The detecting unit **10** and the smoke simulator **46** may be of the type disclosed in co-pending application Serial No. 212,097, filed July 24, 1962.

To make the information provided by the system available at another location, a repeater R is connected to the alarm unit **29**, the fault indicator **40**, and the outputs of the brake driver **25** to provide duplicate alarm, fault and selector valve position indications. The duplicate alarm and fault indications are supplied by providing appropriate indicating equipment electrically connected with the equipment provided in the alarm unit **29** and the fault indicator **40**. The duplicate selector valve position indication is provided by a torque motor, indexing means, and a number wheel arrangement. Such a repeater is disclosed in co-pending application Serial No. 265,740, filed March 18, 1963.

GENERAL OPERATION OF THE CONTROL SYSTEM

The timing pulse generator **24** delivers a positive output pulse of short duration every five seconds to the brake driver **25**. The brake driver **25** has two outputs, and, as described hereinafter in detail, is constructed so that one or the other of these outputs is always energized. Each output pulse of the pulse generator acts on the brake driver to reverse the condition of the outputs, that is, the previously energized outputs is de-energized and the previously de-energized output is energized. The output signal of each of the driver outputs is therefore a series of square wave pulses of five second duration separated from each other by five second intervals, the pulses in one output occurring during the interval between the pulses in the other output.

The brake driver, therefore, energizes the electromagnets **21** for five seconds, then energizes the electromagnets **22** for five seconds and so forth. With reference to the waveforms shown in FIG. 1 for the output of the driver, during the interval T_0 to T_5 the electromagnets **21** are energized and co-act with a pair of the armatures **20** to hold the disc **19** stationary against the action of the torque motor **15**. At the time T_5 the electromagnets **21** are de-energized and the electromagnets **22** are energized. Since there are no armatures **20** adjacent the magnets **22** at this time, the motor **15** drives the disc **19** to move a pair of armatures **20** into alignment with the energized magnets **22**. The disc **19** is then held in this position until the time T_{10}.

Each time the disc **19** is stopped, the selector valve **11** stops in a position connecting a different one of the conduits **13** through the conduit **12** to the smoke detecting unit **10**. When smoke is present in the line **13** connected to the conduit **12**, the unit **10** produces an output which is amplified by the amplifier **26** and actuates the alarm energizing circuit **27** to deliver a signal to the alarm unit **29**. The output signal of the circuit **27** is also transmitted to the pulse generator control circuit **30**, which, in response to this signal interrupts the operation of the pulse generator **24**. Since the pulses to the brake driver **25** are interrupted, the output of the driver energized at that time remains energized to hold the selector valve stationary so that the smoke filled line **13** remains connected to the detecting unit **10**. The position of the number wheel **18** indicates the source of the smoke. The selector valve **11** may be stopped at any time by operation of a manual stop switch **49**.

When desired, for example after the source of smoke has been determined, the system is reset in a manner described hereinafter and the pulse generator **24** is placed in operation again.

A finite period of time is required to move air through the conduit **12** from the valve **11** to the detector **10**. Therefore, if smoke was introduced into the conduit **12** just prior to the time for movement of the valve **11** to its next position, the smoke would not reach the detecting unit until after the valve had moved to its next position. The detector therefore could give an alarm when the selector valve is actually connected to a smoke-free conduit following a smoke-bearing conduit. Such an alarm would stop the operation of the selector valve **11** and give an erroneous indication as to the location of the smoke source.

To prevent such erroneous indications, the alarm hold-off circuit **31** serves to render the detecting unit **10** ineffective during the first three seconds the selector is in a given position to allow the conduit **12** and the detecting unit **10** to be cleared of any smoke introduced from the preceding conduit. To provide this three second hold-off, the output of the timing pulse generator **24** is applied to the switching circuit **32**. The switching circuit **32** normally applies a direct current signal to the shunting circuit **35**. Each pulse produced by the timing pulse generator **24** actuates the switching circuit **32** to interrupt this direct current signal and simultaneously activates the delayed pulse generator **34**. After a three second delay, the delayed pulse generator **34** applies a pulse to the switching circuit **32** to re-establish the direct current signal to the shunting circuit **35**. The switching circuit **32** thus responds to the outputs of the delayed pulse generator **34** and the pulse generator **24**, and delivers a series of pulses of two second duration to the shunting circuit **35**.

The shunting circuit **35** normally prevents any output of the detecting unit **10** from being applied to the amplifier **26** and is rendered ineffective by the output of the switching circuit **32** during the last two seconds of the selector valve **11** is in each position. For example, at the time T_5 when the selector valve **11** moves to a new position, the output of the switching circuit **32** disappears. The shunting circuit **35** short circuits any output of the detecting unit **10** to prevent the amplifier **26** from receiving an input. Three seconds later the time T_8 the switching circuit **32** responds to the output of the delayed pulse generator **34** and produces an output which renders the shunting circuit **35** inoperative. From the time T_8 to the time T_{10} any output of the detecting unit **10** is applied to the amplifier **26**. At the time T_{10} the switching circuit **32** responds to the output pulse of the pulse generator **24** and the signal applied to the shunting circuit disappears as the selector valve moves to its next position.

Each time the electromagnets **22** are energized during the rotation of the selector valve, the armature **20** moves into alignment with one of the electromagnets **22**, passes the motion sensing unit **36** and causes this unit **36** to produce an output pulse. An armature **20** passes the motion sensing unit **36** once in every two steps, therefore, the output pulses of the unit are ten seconds apart. The output of the brake driver **25** for energizing the electromagnets **21** is passed through the pulse former **37** which transforms the leading edge of each square wave into a sharp pulse. These pulses are also ten seconds apart and occur in time between the output pulses of

the motion sensing unit 36. The motion supervisor circuit 39 therefore receives an input pulse every five seconds.

If motion of the disc 19 should stop for any reason, the motion sensing unit 36 produces no output and the motion supervisor circuit 39 then receives pulses only every 10 seconds from the pulse former 37. The motion supervisor circuit 39 is constructed and arranged, as described hereinafter in detail, to operate the fault indicator 40 in the event that no pulse is received for a predetermined period of time more than five seconds but less than ten seconds, for example, eight seconds.

When the alarm unit 29 is actuated in response to the detection of smoke, the fault signal preventing circuit 41 is actuated and produces an output signal which inerts the motion supervisor circuit 39 so that a fault indication is not given as a result of the stopping of the disc 19 through the operation of the control circuit 30.

During each revolution when the selector valve 11 moves through its eighth or test position wherein it is not connected to any of the seven conduits 14, the test switch operator 44 contacts and actuates the switch 42 to energize the smoke simulator 46 and send signals to both the control circuit 30 and the alarm hold-on circuit 47.

The smoke simulator 46 affects the photocell of the detecting unit 10 in a manner whereby, if the detecting unit 10 is in proper operating condition, an output signal is produced which is sufficient to cause the operation of the alarm 29. However, the hold-off circuit 31 temporarily prevents this signal from operating the alarm 29.

The hold-on circuit 47 responds to the signal from the test switch 42 and immediately energizes the alarm unit 29. The alarm unit 29, however, is prevented from giving an indication by other testing circuitry described in detail hereinafter. The alarm hold-on circuit 47 remains energized for the first three seconds that the selector valve 11 is in this position. At the end of the three second interval, the output of the switching circuit 32 appears and de-energizes the hold-on circuit, and the hold-off circuit is turned off to allow the output of the unit 10 to be fed through the amplifier 26.

If the detecting unit 10, the amplifier 26, the alarm energizing circuit 27, or the alarm unit 29 is not operating properly, the integrity supervisor circuit 48 operates at this time to give a fault indication during the final two seconds that the selector valve 11 is in this position.

The control circuit 30, in response to the signal from the test switch 42, is rendered insensitive to the stop motion signal transmitted thereto when the alarm energizing circuit 27 is activated by the operation of the hold-on circuit 47. Therefore, the timing pulse generator 24 continues to operate and the selector valve is moved without interruption to its next position at the end of the five second interval.

In addition to the above described automatic testing, the system may be tested at any time and in any position by operation of the manual test switch 45.

DETAILED DESCRIPTION OF THE CONTROL SYSTEM

Referring now to the detailed wiring diagram shown in FIGS. 2 to 4, the system is powered by a constant voltage transformer 50 providing constant 115 volt and 7 volt alternating current power, and by a regulated rectifier 51 providing 30 volt and 100 volt direct current power.

The timing pulse generator 24 (FIG. 2) includes a unijunction transistor 52 under the control of a RC timing network. The unijunction transistor 52 has a base 1 electrode 53 connected through a 330 ohm resistor 54 to a positive conductor 55, a base 2 electrode 56 connected through a 33 ohm resistor 57 to a negative conductor 59, and an emitter electrode 60 connected to the RC timing network. The timing network includes a 500,000 ohm variable resistor 61, a 250,000 ohm variable resistor 62, and a 100,000 ohm resistor 64 connected in series between the conductor 55 and the emitter 60; an 8 microfarad capacitor 65 connected between the emitter 60 and the conductor 59; and a 6 microfarad capacitor 66 connected in parallel with the resistors 61, 62, and 64, between the emitter 60 and the conductor 55. A fast step switch 67 is connected across the resistor 61 and the output of the timing pulse generator is taken across the resistor 57.

The brake driver 25 (FIG. 2) includes a controlled silicon rectifier 69 connected in series with the electromagnets 22 between the conductor 55 and the conductor 59, and a second controlled silicon rectifier 70 connected in series with the electromagnets 21 between the conductors 55 and 59. The output signal of the pulse generator 24 is coupled to the brake driver 25 by means of a .047 microfarad capacitor 71 and a 680 ohm resistor 72. This signal is applied to gate electrodes 74 and 75 of the controlled rectifiers 69 and 70 through diodes 76 and 77 respectively.

To complete the incoming signal circuits, the gate electrodes 74 and 75 are respectively connected through 2200 ohm resistors 79 and 80 to the points of junction X and Y of the controlled rectifiers 69, 70 with the brakes 22, 21 respectively. A pair of 18 microfarad capacitors 81, 82 are connected in parallel between these junction points.

The brake driver is provided with a starting circuit including a transistor 84, a 150 ohm resistor 85 connecting the collector of the transistor to the conductor 55, a 10,000 ohm resistor 86 connecting the base of the transistor to the conductor 59, a 360 ohm resistor 87 connected between the emitter and the collector of the transistor, a diode 89 and a 150 ohm resistor 90 connected in series between the collector of the transistor and the gate electrode 75 of the controlled rectifier 70, a 1,000 ohm resistor 91 having one end connected to the base of the transistor, and a pair of diodes 92, 94 respectively connected between the points X and Y and the other end of the resistor 91.

The smoke detecting unit 10 (FIG. 3) includes a lamp 95, and a photoelectric cell 96 connected through a 10,000 ohm resistor 97 to the input of the amplifier 26.

The amplifier 26 includes three transistors 99, 100, and 101 connected in a cascade emitter follower arrangement, a variable gain adjust resistor 102, and a voltage divider arrangement comprising a resistor 104 and a resistor 105 connected in series between a positive conductor 106 and a negative conductor 107. The collectors of each of the transistors 99, 100, 101 are connected to the junction of resistors 104 and 105, and the emitters thereof are respectively connected through resistors 109, 110 and 111 to the negative conductor 107. A capacitor 112 is connected in parallel with the resistor 109. The input resistor 102 is connected between the base of the transistor 99 and the negative conductor 107, and the output of the amplifier is taken across the resistor 111.

The alarm energizing circuit 27 includes a controlled silicon rectifier 113 connected in series with a reset switch 114 and the coil 115 of relay 116 between the output of the switching circuit 32 and the negative conductor 107. The output of the amplifier 26 is connected to the gate electrode 117 of the controlled rectifier 113 through a Zener diode 118 and a diode 119. A resistor 120 and a capacitor 121 are connected in parallel between the gate electrode 117 and the junction of the controlled rectifier and the reset switch 114. A diode 122 and a 1,000 ohm resistor 123 are connected in parallel with the coil 115 of the relay 116 and the contacts 124 are connected to the alarm unit 29.

The alarm unit 29 includes a fire alarm relay 125, a gong 126, a lamp 127, and a gong cut-off switch 129. The gong cut-off switch 129 has a pair of normally closed contacts 130 and a pair of normally open contacts 131. The relay 125 has a coil 132 and two pairs of normally open contacts 134, 135. The coil 132 is connected in

series with the contacts **130** of the switch **129**, and the contacts **124** of the relay **116** across the 30 volt D.C. source. The lamp **127** is connected across the 115 volt A.C. source, both in series with the contacts **131** of the switch **129** and in series with the contacts **134** of the reley **125**.

The pulse generator control circuit **30** includes a transistor **136**, a 220,000 ohm resistor **137** connected between the collector of the transistor **136** and the junction of resistor **64** and capacitor **65** in the pulse generator **24**, a diode **139** connected between the emitter of transistor **136** and the conductor **59**, a 220 ohm resistor **140** connected between the base of the transistor **136** and the conductor **59**, two 1,500 ohm resistors **141** and **142** connected in series between the transistor base and an input conductor **144**, and a diode **145** connected between a second input conductor **146** and the junction of the resistors **141** and **142**.

In the alarm hold-off circuit **31**, the switch circuit **32** includes a transistor **147** having its emitter connected to the positive conductor **106**, a controlled silicon rectifier **148** having its positive terminal connected to the collector of the transistor **147** and having a gate electrode **149**, a capacitor **150** connected between the gate electrode **149** and the negative terminal of the controlled rectifier **148**, a capacitor **151** connected between the base of the transistor **147** and the output of the pulse generator **24**, and a 1,000 ohm resistor **152** connected between the base of the transistor **147** and the negative conductor **107**.

The delayed timing pulse generator **34** includes a unijunction transistor **153** having a base **1** electrode **154** connected to the gate electrode **149** of the rectifier **148**, a base **2** electrode **155** connected to the collector of transistor **147** through a 300 ohm resistor **156**, and an emitter **157** connected to the collector of the transistor **147** through a 500,000 ohm variable resistor and a 150,000 ohm resistor **160** in series therewith and a diode **161** in parallel with the resistors **159** and **160**. The emitter **157** and the base **1** electrode **154** are respectively connected to the negative terminal of the controlled rectifier **148** through a 10 microfarad capacitor **162** and a 100 ohm resistor **164**.

The smoke detector shunting circuit **35** includes a 100 ohm resistor **165** connecting the negative terminal of the controlled rectifier **148** to the negative conductor **107**, a diode **166** connected between the input of the amplifier **26** and the negative terminal of the controlled rectifier **148**, and a .0005 microfarad capacitor **167** connected between the input of the amplifier **26** and the negative conductor **107**.

The pulse former **37** includes two 5,100 ohm resistors **169** and **170** connected in series with a 2 microfarad capacitor **171** and a 47,000 ohm resistor **172** between the negative conductor **174** and the point Y in the brake driver **25**, a diode **175** connected between a positive conductor **176** and the junction of the resistors **169** and **170**, and a diode **177** extending from the junction of the capacitor **171** and the resistor **172** to the motion supervisor circuit **39**.

The motion supervisor circuit **39** includes two transistors **179** and **180**, a unijunction transistor **181**, and a controlled silicon rectifier **182**. A 160 ohm resistor **184** and 910 ohm resistor **185** are connected in series with the motion sensing unit **36** between the positive conductor **176** and the negative conductor **174**. A Zener diode **186** is connected between the negative conductor **174** and one side of the unit **36**, and a 6 microfarad capacitor **187** is connected between the base of transistor **179** and the other side of the unit **36**. A 10,000 ohm resistor **189** and a diode **190** are connected in parallel between the negative conductor **174** and the base of the transistor **179**.

The emitter of transistor **179** is connected directly to the base of transistor **180**, a 10,000 ohm resistor **191** is connected between the base of transistor **180** and the negative conductor **174**, and the diode **177** of the pulse former **37** is connected to the base of transistor **180**. The collectors of the transistors **179** and **180** are interconnected and are connected to the positive conductor **176** through a 100,000 ohm resistor **192** and 500,000 ohm variable resistor **194**.

The emitter of the unijunction transistor **181** is connected directly to the collector of transistor **180** and is connected to the negative conductor **174** through an 18 microfarad capacitor **195** and a 10 microfarad capacitor **196** connected in parallel. The base **2** electrode is connected to the positive conductor **176** through a 300 ohm resistor **197** and the base **1** electrode is connected to the negative conductor **174** through a 100 ohm resistor **199**.

The controlled rectifier **182** is connected in series with a 2,700 ohm resistor **200** between the conductors **176** and **174**, and the gate electrode thereof is connected to the positive end of resistor **199**.

The fault indicator **40** includes a relay **201** having a coil **202** connected across the resistor **200** and having a pair of contacts **204**, a relay **205** having a coil **206** connected in series with the contacts **204** across the 115 volt A.C. supply and having a pair of contacts **207**, and a lamp **209** connected in series with the contacts **207** across the 115 volt A.C. supply.

The fault signal prevent circuit **41** includes a transistor **210** having its collector connected to the emitter of the unijunction transistor **181**, a transformer **211** having its primary winding connected across the fire indicating lamp **127**, a diode **212** and a 1,300 ohm resistor **214** connected in series with the secondary winding of the transformer **211** between the negative conductor **174** and the base of the transistor **210**, a 510 ohm resistor **215** also connected between the conductor **174** and the base of transistor **210**, and a diode **216** connected between the emitter of transistor **210** and the conductor **174**.

The automatic test switch **42** is connected in series with the manual test switch **45** and the coil **217** of a test relay **219** across the 30 volt D.C. supply, and is also connected in series with the smoke simulator **46** across the 30 volt D.C. supply. In addition, the test switch **42** is connected in series with a set of normally open contacts **220** in the stop switch **49** between the input conductor **146** of the control circuit **30** and the emitter of the unijunction transistor **181** in the motion supervisor circuit **39**.

The test relay **219** is provided with a pair of contacts **221** connected in series with the contacts **135** of fire alarm relay **125**, a pair of contacts **222** connected in series with the contacts **134** of the relay **125**, and a set of contacts including a stationary contact **224** connected to the alarm hold-on circuit **47**, a stationary contact **225** connected to the positive side of electromagnet **22** through a diode **226**, and a movable contact **227** connected to the positive side of the electromagnet **21** through a diode **229**.

The alarm hold-on circuit **47** includes a transistor **230** having its collector connected to the positive side of the relay coil **115**, a diode **231** connecting the emitter of the transistor **230** to the relay contact **224**, a diode **232** connecting the emitter of transistor **230** to the positive conductor **106**, a 10,000 ohm resistor **234** connected between the positive conductor **106** and the base of the transistor **230**, a 10,000 ohm resistor **235** connected between the negative terminal of the controlled rectifier **148** and the base of the transistor **230**.

The manual stop switch **49** has a second set of contacts including a stationary contact **236** connected to the positive side of the relay coil **115**, a second stationary contact **237** connected to the positive side of the 30 volt D.C. supply, and a movable contact **239** connected to the input conductor **144** of the control circuit **30**.

The integrity supervisor circuit **48** includes a 900 ohm resistor **240** and a 500 ohm resistor **241** connected across the 115 volt A.C. supply; four diodes **242** to **245** arranged in a rectifying bridge connected between the junction of the resistors **240**, **241** and junction of the contacts **135**, **221**; and a relay **246** having a normally ener-

gized coil 247 connected across the diode bridge 48, and a pair of normally open contacts 249 connected in series with the coil 206 of the fault relay 205 across the 115 volt A.C. supply. Such an integrity supervisor circuit is disclosed and claimed in co-pending application Serial No. 212,097, filed July 24, 1962.

DETAILED OPERATION OF THE CIRCUITS

The timing pulse generator 24

In operation, when the system is initially placed in operation, the transistor 84 in the brake driver 25 is in the non-conducting condition. As the voltage on the conductor 55 builds to +30 volts, current flows through the resistor 85, the diode 89, the resistor 90, and the resistor 80, and the electromagnet 21 to trigger the gate 75 of the controlled rectifier 70. The controlled rectifier 70 is thus turned on to provide a strong current flow through the electromagnet 21, and current also flows from the point Y through the diode 94 and the resistor 86 to turn on the transistor 84 thus placing the positive terminal of the diode 89 at a potential near that of the negative conductor 59 to render the diode 89 non-conductive.

The negative terminal of the controlled rectifier 70 is now at a high positive potential while the negative terminal of the controlled rectfier 69 is at ground potential, and the capacitors 81 and 82 charge to this potential difference.

The controlled rectifier 70 remains turned on for 5 seconds during which time the capacitors 65 and 66 in the timing pulse generator 24 charge to the voltage required to fire the unijunction transistor 52. At the end of the five second period, the unijunction 52 fires to discharge the capacitors 65 and 66 and produce a voltage pulse across the resistor 57. This voltage pulse is differentiated by the capacitor 71 and the resistor 72 and is applied to the gate electrodes 74 and 75 of the controlled rectifiers 69 and 70 through the diodes 76 and 77.

This applied pulse turns on the controlled rectifier 69 and has no effect on the controlled rectifier 70 which is already conducting. When the rectifier 69 conducts, its negative terminal moves quickly toward the potential of the positive conductor 55, therefore, the charge on the capacitors 81, 82 raises the negative terminal of the controlled rectifier 70 to a voltage more positive than the conductor 55 and the controlled rectifier 70 turns off. Now current flows through the controlled rectifier 69 to the electromagnet 22. The diode 92 provides a continuous current through the resistor 89 to maintain the transistor 84 in conduction.

During the 5 second period that the controlled rectifier 69 is conducting, the capacitors 81, 82 charge in the opposite direction so that the electromagnet 21 will become energized again in response to the next output pulse of the pulse generator 24.

Alarm hold-off, amplifier, and alarm energizing circuits; 31, 26, 27

When the system is initially placed in operation, the transistor 147 in the switching circuit 32 goes into conduction and the capacitor 162 begins charging through the emitter-collector circuit of the transistor 147 and the resistors 159 and 160. After 3 seconds, the capacitor 162 achieves a charge which causes the unijunction 153 to fire producing an output pulse which is impressed on the control electrode 149 and turns on the controlled rectifier 148. Current then flows from the positive conductor 106 through the emitter collector circuit of the transistor 147, the controlled rectifier 148, and the resistor 165 in the shunting circuit 35 to the negative conductor 107. During the period that the controlled rectifier 148 is conducting, the voltage across the delayed pulse generator 34 is held at nearly zero rendering the circuit inactive. When the first pulse is received from the pulse generator 24, the transistor 147 is cut off for the duration of the pulse and the controlled rectifier 148 turns off and the unijunction transistor 153 is reset. At the end of the pulse from the generator 24, the transistor 147 turns on again and the capacitor 162 charges for 3 seconds and fires the unijunction transistor 153 to turn on the rectifier 148 for the remaining 2 seconds before the next pulse from the generator 24 is received.

The photocell 96 in the detecting unit 10 is normally shielded from all light and has a very high resistance. When smoke is introduced into the unit 10 the light from the lamp 95 is reflected from the smoke and falls on the photocell causing it to drop in resistance to some lower value. Current then flows from the 100 volt supply through the photocell 96 and the resistor 97. During the first 3 seconds after each output pulse of the pulse generator 24, the controlled rectifier is not conducting therefore the negative side of the diode 166 is at ground potential and any current flowing through the resistor 97 is shunted to the conductor 107 through the diode 166 and the resistor 165. During the next 2 seconds, the rectifier 148 is conducting and the negative side of the diode 166 is at a high positive potential, therefore, the diode 166 is reverse biased and any current flowing through the resistor 97 produces a current flow in the base emitter circuit of the transistor 99 in the amplifier 26. This current flow is amplified by the transistors 99, 100, and 101 to provide sufficient power to turn on the controlled rectifier 113. The output of the transistor 101 is fed through the zener diode 118 and the diode 119 to the gate electrode 177 of the controlled rectifier 113. When the controlled rectifier 113 is turned on, current flows from the positive conductor 106 through the resistors 234 and 235, the rectifier 113, the reset switch 114, and the coil 115 of the relay 116 to the negative conductor 107. The coil 115 is thus energized and the contacts 124 are closed.

The zener diode 118 serves as a voltage reference to prevent unwanted low level signals from triggering the controlled rectifier 113 to give a false alarm. The diode 119 protects the controlled rectifier 113 against reverse voltages which may injure the rectifier 113 when it is turned on.

Alarm unit 29

When the contacts 124 close, current is permitted to flow from the 30 volt D.C. source through the coil 132 of the relay 125, and the contacts 130 of the gong cut-off switch 129, energizing the relay 125 to close the contacts 134 and 135. The closing of the contacts 134 and 135 permits current to flow from the 115 volt A.C. source through the lamp 127 and the gong 126. If it is desired to silence the gong 126, the switch 129 is thrown, opening the contacts 130 to de-energize the relay 125, and closing the contacts 131 to connect the lamp 127 across the 115 volt A.C. source.

At the time the relay 116 is energized, a portion of the current through the controlled rectifier 113 flows through the contacts 236 and 239 of the stop switch 220 to the conductor 144, and through the resistors 142, 141 and 140 of the control circuit 30 to turn on the transistor 136. The conducting transistor 136 then short circuits the capacitor 65 to render the pulse generator 24 inoperative so that the brake driver 25 holds the selector valve stationary with the detector 10 connected to the line 13 containing smoke.

After an alarm is given, the system is reset by operating the reset switch 114 to break the circuit through the controlled rectifier 113. The rectifier 113 is thereby turned off and the pulse generator 24 is re-activated to start the selector valve once again. If, at the time the reset switch 114 is operated, smoke is still present in the line 13 at which the selector valve was stopped, it is necessary to hold the reset switch open until the selector valve moves to the next line.

Motion supervisor 39

In the motion supervisor circuit 39, the unijunction

transistor 181 is controlled by the charge on the capacitors 195 and 196. These capacitors charge through the resistors 192 and 194 and require about 8 seconds to charge sufficiently to turn the unijunction transistor 181 on.

Each time one of the armatures 20 passes the motion sensing unit 36, the input 36 produces a pulse which passes through the capacitor 187 and momentarily turns on the transistors 179 and 180 to discharge the capacitors 195 and 196. Five seconds later, the output of the brake driver 25 to the electromagnet 21 is passed through the pulse former 37 and the resultant pulse is applied to the base of the transistor 180. The transistor 180 is thereby turned on momentarily to again discharge the capacitors 195 and 196. The alternate pulses from the unit 36 and the pulse former 37 discharge the capacitors 195 and 196 every 5 seconds when the selector valve is operating correctly whereby the unijunction transistor 181 is prevented from firing. Should the valve stop rotating due to some malfunction, the pulses from the motion sensing unit cease and there is sufficient time between the pulses from the pulse former 37 to allow the capacitors 195 and 196 to charge to the value required to cause the unijunction transistor 181 to fire. When the unijunction transistor 181 fires, it develops a positive pulse across resistor 99 of sufficient magnitude to trigger the gate electrode of controlled rectifier 182. The rectifier 182 turns on to complete a current path through the winding 206 of the fault relay 205. The contacts 207 of the relay 205 close placing the lamp 209 across the 115 volt A.C. supply.

Fault signal preventing circuit 41 (FIG. 4)

When the selector valve is stopped in response to the detection of smoke, the primary winding of the transformer 211 in the circuit 41 is energized and turns on the transistor 210 to short circuit the capacitors 195 and 196 and thus prevent the unijunction 181 from being fired to give fault indication.

Automatic test switch 42

Once during each revolution of the selector valve, the automatic test switch 42 is operated. The closing of the switch 42 connects the smoke simulator 46 across the 30 volt D.C. supply to direct light onto the photocell 96, connects the coil 217 of the relay 219 across the 30 volt D.C. supply, and connects the input conductor 146 of the control circuit 30 to ground potential to render ineffective the stop motion signal produced when the relay 116 is energized.

Alarm hold-on circuit 47

The operation of the relay 219 connects the emitter of the transistor 230 in the alarm hold on circuit 47 to the point Y in the brake driver 25 through the diode 231, the contacts 224 and 227, and the diode 229. The test switch operator 44 is positioned so that the test switch is closed when the controlled rectifier 70 is conducting to energize the electromagnet 21. The transistor 230 therefore conducts and immediately energizes the relay coil 115 to operate the relay 125, however the gong 126 and the lamp 127 will not operate because the relay contacts 221 and 222 are now open. When, at the end of the 3 second hold-off period, the controlled rectifier 148 is turned on, the base of the transistor 230 is driven positive turning the transistor off. If the system is operating properly, the output of the amplifier 26 will maintain the relay 125 energized with the contacts 134 and 135 closed. If the system is not working properly the integrity supervisor circuit will operate as described below to energize the fault relay 205 and light the lamp 209.

Integrity supervisor circuit 48

In the integrity supervisor circuit 48, the coil 247 remains energized holding the contacts 249 open as long as a connection exists between either side of the 115 volt A.C. supply and the junction of the diodes 243 and 245. When the selector valve is in the test position and the detecting unit 10, amplifier 26, and the alarm energizing circuit 27 are operated properly the contacts 135 of the relay 125 are closed and current can flow through the resistor 241, the diode 244, the coil 247, the diode 243 and the gong 126. This current flow is sufficient to energize the coil 247 and hold the contacts 249 open but is not sufficient to operate the gong 126. It will be seen that should the relay 125 fail to operate or should an open circuit exist in the gong 126 the current flow through the coil 247 will stop and the contacts 249 will close to energize the relay 205 and light the fault lamp 209.

Manual test switch 45

If at any time it is desired to test the operation of the gong 126 and the lamp 127, the manual test switch 45 is operated. This switch produces the same results as the automatic switch 42 with the exception that the relay 219 is not energized and therefore the gong 126 and the lamp 127 are energized when the relay 125 operates.

Manual stop switch 49

The manual stop switch 49 can be operated at any time to stop the movement of the selector valve. The operation of the switch 49 closes contacts 239 and 237 to produce a current flow through resistors 142, 141, and 140 to turn on the transistor 136 and short circuit the capacitor 65 to stop the operation of the pulse generator 24.

Fast step switch 67

If at any time it is desired to rapidly move the selector valve to any given position, the fast step switch 67 is closed to short out the resistor 61 thus increasing the rate at which the capacitor 65 is charged and decreasing the time interval between output pulses of the pulse generator 24. With the switch 67 closed, the pulse generator produces a pulse every two seconds whereby the selector valve is rapidly stepped through its positions and the hold-off circuit remains energized until after the switch 67 is released so that the detecting unit 10 will not produce a response during this period.

From the foregoing, it will be seen that the present invention provides an improved electrical control system for smoke detecting apparatus which automatically operates, and monitors and periodically tests the condition of the apparatus and prevents the apparatus from giving an erroneous indication.

Although the present invention is described herein in connection with the smoke detecting apparatus disclosed in the aforementioned co-pending application, it is to be understood that this invention is not limited to this use and can be employed in connection with other detecting apparatus.

As various changes may be made in the form, construction and arrangement of the parts herein, without departing from the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in any limiting sense.

We claim:

1. In an electrical control system for condition detecting apparatus including a plurality of lines for transmitting the condition from spaces in which the presence of the condition is to be detected, a detector for giving an indication in response to the presence of the condition, a rotary selecting device for connecting the detector to each of the lines, a motor for driving said rotary selecting device, and brake means for stopping said selecting device at predetermined positions to sequentially connect the detector to each of the lines, said brake means including circumferentially spaced armature means mounted on said selecting device for rotation therewith and a pair of stationary electromagnets positioned to cooperate with said armatures and being spaced differently

than the armatures so that only one electromagnet is aligned with an armature at a time; the combination of timing means for producing electrical impulses at a predetermined interval, and a brake driving circuit having two outputs for producing on said outputs alternate square wave pulses each having a duration equal to said predetermined interval, one of said outputs being connected to energize one of said electromagnets for one of said predetermined intervals of time and the other of said outputs being connected to energize the other of said electromagnets for the next said predetermined interval of time so that each of said armatures co-operates first with one of said electromagnets and subsequently with the other of said electromagnets to stop the selecting device in a number of positions greater than the number of armatures.

2. In an electrical control system for condition detecting apparatus including a plurality of lines for transmitting the condition from spaces in which the presence of the condition is to be detected, a detector for giving an indication in response to the presence of the condition, a rotary selecting device for connecting the detector to each of the lines, a motor for driving said selecting device, and brake means for stopping said selecting device at predetermined positions to sequentially connect the detector to each of the lines, said brake means including circumferentially spaced first elements mounted on said selecting device for rotation therewith and stationary second elements positioned to cooperate with said armatures to stop said selecting device; the combination of timing means for controlling said motor means to connect each of said lines to said detector for a predetermined interval of time, and means for monitoring the operation of said motor means to give an indication when said motor means ceases to operate including a pulse producing device mounted adjacent said selecting device for producing an electrical pulse in response to the passing of each of said first elements, and means connected to said pulse producing device for giving an indication when the time interval between pulses exceeds a predetermined value.

3. Apparatus according to claim 2 including means responsive to the output of said detector for stopping the operation of said timing means when said detector responds to the presence of the condition, and means responsive to the output of said detector for inerting said monitoring means when said detector responds to the presence of the condition.

4. In an electrical control system for conditioning detecting apparatus including a plurality of lines for transmitting the condition from spaces in which the condition is to be detected, a detector for giving an indication in response to the presence of the condition, a selector device for connecting the detector to each of the lines, and motor means for driving said device to sequentially connect the detector to each of the lines; the combination of timing means for controlling said motor means to connect each of said lines to said detector for a predetermined interval of time, means responsive to the output of said detector for stopping the operation of said timing means when said detector responds to the presence of the condition, means connected to said detector for simulating the presence of the condition to test the operation of said detector, and means for rendering said stopping means ineffective when said condition simulating means is energized.

5. In an electrical control system for smoke detecting apparatus including a plurality of conduits for supplying air samples from spaces in which smoke is to be detected, a detector for giving an indication in response to the presence of smoke, a selector valve for connecting the detector to each of the conduits, and motor means for driving said valve to sequentially connect the detector to each of the conduits; the combination of timing means for controlling said motor means to connect each of said lines to said detector for a predetermined interval of time, and indication hold-off means under the control of said timing means for rendering said detector ineffective during a predetermined initial portion of said interval of time whereby said detector is prevented from giving an indication after said detector is disconnected from a conduit transmitting smoke.

6. Apparatus according to claim 5 including means for simulating the presence of smoke at said detector for testing the operation of said detector, and means for rendering said indication hold-off means ineffective when said smoke simulating means is actuated.

7. Apparatus according to claim 5 including means responsive to the output of said detector for stopping the operation of said timing means when said detector responds to the presence of smoke.

8. Apparatus according to claim 7 including means connected to said detector for simulating the presence of smoke to test the operation of said detector, and means for rendering said stopping means ineffective when said smoke simulating means is energized.

9. Apparatus according to claim 8 including means for rendering said indication hold-off means ineffective when said smoke simulating means is actuated.

10. In an electrical control system for smoke detecting apparatus including a plurality of conduits for supplying air samples from spaces in which smoke is to be detected, a detector for giving an indication in response to the presence of smoke, a rotary selector valve having a plurality of positions for connecting the detector to each of the conduits, and motor means for moving said valve in steps through its various positions; the combination of motion detecting means associated with said motor means for producing an output pulse in response to the motion of said selector valve between positions thereof, an indicator, means for actuating said indicator, and time delay means actuated by the output pulse of said motion detecting means for preventing the actuation of said indicator for a predetermined time after the occurrence of each said output pulse.

11. In an electrical control system for smoke detecting apparatus including a plurality of conduits for supplying air samples from spaces in which smoke is to be detected, a detector for giving an indication in response to the presence of smoke, a rotary selector valve for connecting the detector to each of the conduits, motor means for placing a constant torque on said selector valve, a disc mounted for rotation with said selector valves having a plurality of armatures thereon, a braking member adapted to be energized to hold the armatures in predetermined rotational positions, and a second braking member adapted to be energized to hold the armatures in positions intermediate said predetermined positions; the combination of timing means for producing electrical impulses at a predetermined interval, brake driving means having one output for energizing said first braking member for one of said predetermined intervals of time and having another output for energizing said second braking member for the next said predetermined interval of time so that said valve is moved in steps and each of said lines is connected to said detector for said predetermined interval, motion detecting means associated with said stepping motor means for producing an output pulse in response to the passing of one of said armatures, an indicator, means for activating said indicator, and time delay means for preventing the actuation of said indicator when the selector valve moves in steps at said predetermined interval, said time delay means being connected to receive pulses alternately from said motion detecting means and one of said brake driver outputs.

12. In an electrical control system for smoke detecting apparatus including a plurality of conduits for supplying air samples from spaces in which smoke is to be detected, a detector for giving an indication in response to the presence of smoke, a selector valve for connecting the detector to each of the conduits, and motor means for driving said valve to sequentially connect the detector to each of the conduits; the combination of timing means for

controlling said motor means to connect each of said conduits to said detector for a predetermined interval of time, means for monitoring the operation of said motor means to give an indication when said motor means ceases to operate, means responsive to the output of said detector for stopping the operation of said timing means when said detector responds to the presence of smoke, means responsive to the output of said detector for inerting said monitoring means when said detector responds to the presence of smoke, indication hold-off means for rendering said detector ineffective during a predetermined initial portion of said interval of time whereby any delay in the response of said detector is prevented from causing said detector to give an indication after said detector is disconnected from a tube transmitting smoke, means connected to said detector for simulating the presence of smoke to test the operation of said detector, means for rendering said stopping means ineffective when said smoke simulating means is energized, and means for rendering said indication hold-off means ineffective when said smoke simulating means is actuated.

13. In an electrical control system for smoke detecting apparatus including a plurality of conduits for supplying air samples from spaces in which smoke is to be detected, a detector for giving an indication in response to the presence of smoke, a selector valve for connecting the detector to each of the conduits, and motor means having a plurality of electrically operable devices adapted to be alternately energized to move said valve in steps to sequentially connect the detector to each of the conduits; the combination of timing means for producing electrical impulses at a predetermined interval, driving means for energizing at least one of said devices for one of said intervals and at least one other of said devices for the next interval so that each of said conduits is connected to said detector for said predetermined interval of time, means for monitoring the operation of said motor means to give an indication when said motor means ceases to operate, means responsive to the output of said detector for stopping the operation of said timing means when said detector responds to the presence of smoke, means responsive to the output of said detector for inerting said monitoring means when said detector responds to the presence of smoke, indication hold-off means for rendering said detector ineffective during a predetermined initial portion of said interval of time whereby any delay in the response of said detector is prevented from causing said detector to give an indication after said detector is disconnected from a tube transmitting smoke, means connected to said detector for simulating the presence of smoke to test the operation of said detector, means for rendering said stopping means ineffective when said smoke simulating means is energized, and means for rendering said indication hold-off means ineffective when said smoke simulating means is actuated.

14. In an electrical control system for smoke detecting apparatus including a plurality of conduits for supplying air samples from spaces in which smoke is to be detected, a detector for giving an indication in response to the presence of smoke, a rotary selector valve for connecting the detector to each of the conduits, and a plurality of electrically operable motor means adapted to be alternately energized to move said valve in steps to sequentially connect said detector to each of said conduits; the combination of timing means for producing electrical impulses at a predetermined interval, motor means driving means having an input connected to said timing means and having a pair of outputs connected to different motor means, said driving means being constructed and arranged to provide an output signal to one or the other of said outputs at all times and to transfer the signal between said outputs in response to each input impulse, and means responsive to the output of said detector for interrupting the operation of said timing means whereby one of said outputs of said driver means is maintained in an energized condition to interrupt the movement of said selector valve.

15. Apparatus according to claim 14 including indication hold-off means under the control of said timing means for rendering said detector ineffective during a predetermined initial portion of said interval of time whereby said detector is prevented from giving an indication after said detector is disconnected from a conduit transmitting smoke.

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NEIL C. READ, *Primary Examiner.*