May 8, 1951 S. E. MILLER ET AL 2,552,107

AIR HEATER CONTROL

Filed Sept. 11, 1943 5 Sheets-Sheet 1

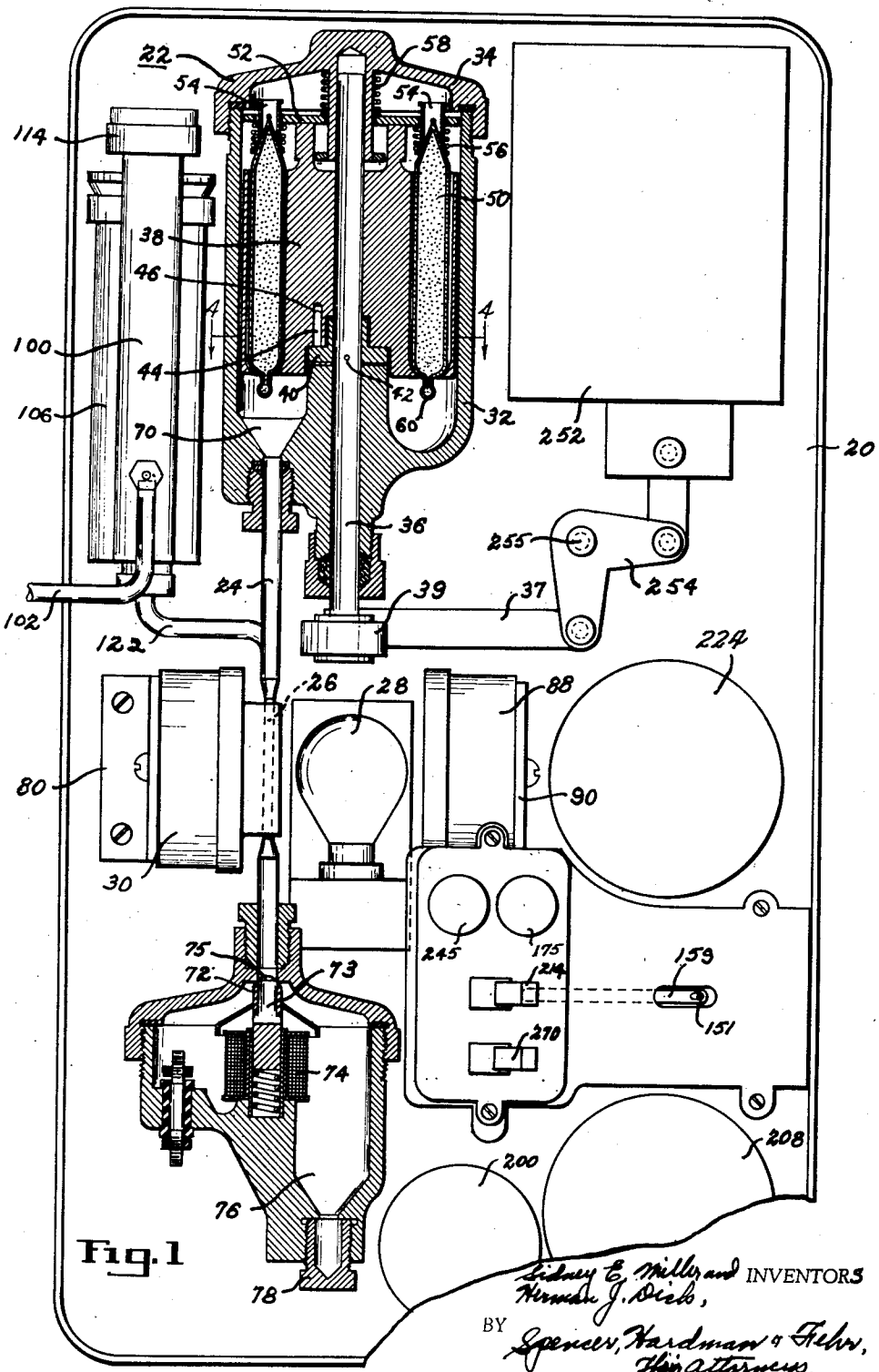


Fig. 1

Sidney E. Miller and Herman J. Dieb, INVENTORS

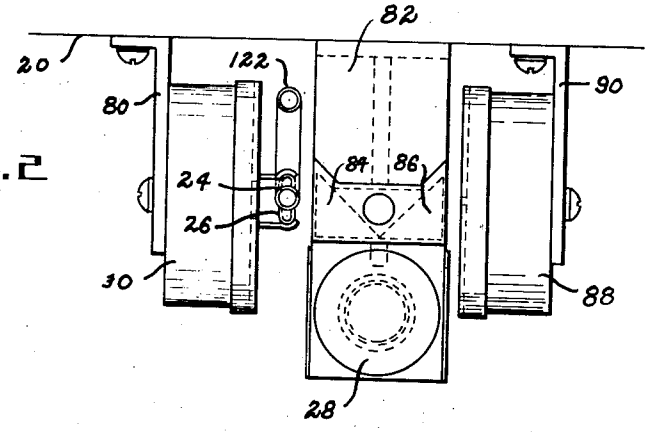
BY Spencer, Hardman & Fehr, their attorneys.

May 8, 1951 S. E. MILLER ET AL 2,552,107

AIR HEATER CONTROL

Filed Sept. 11, 1943 5 Sheets-Sheet 2

Fig. 2



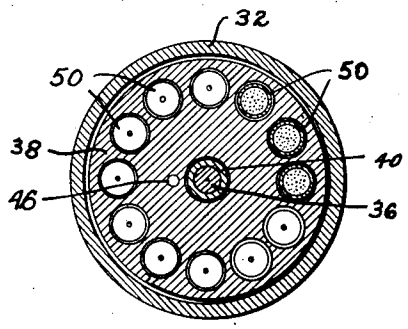
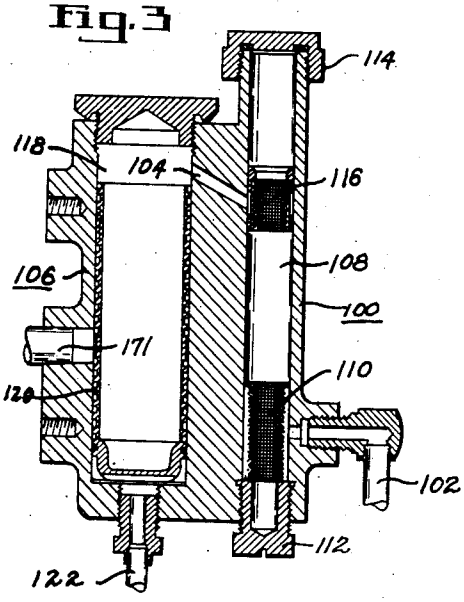


Fig. 4

Fig. 3



Sidney E. Miller and
Herman J. Dicks, INVENTORS.

BY
Spencer, Hardman & Fuchs,
their attorneys.

May 8, 1951 S. E. MILLER ET AL 2,552,107

AIR HEATER CONTROL

Filed Sept. 11, 1943 5 Sheets-Sheet 3

Fig. 5

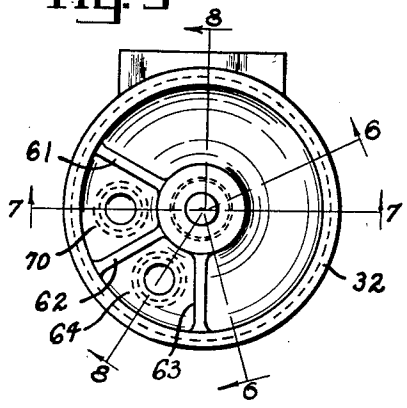


Fig. 6

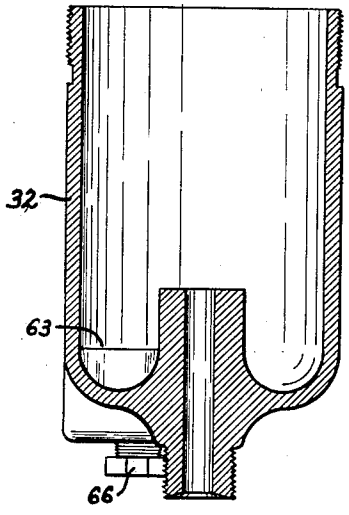


Fig. 7

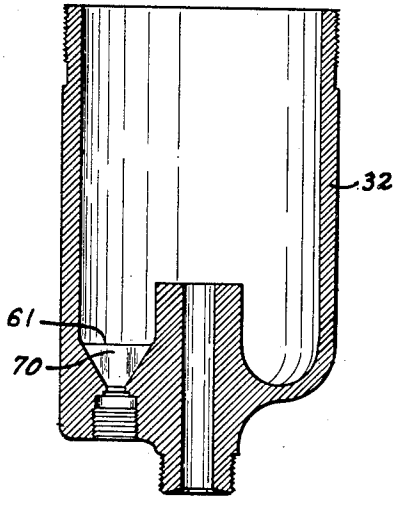
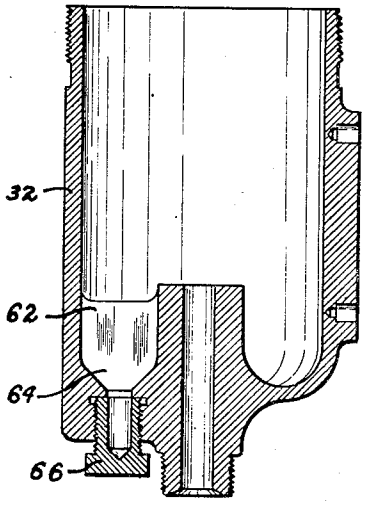


Fig. 8



Sidney E. Miller and
Herman J. Dicks, INVENTORS.
BY Spencer, Hardman & Fehr,
their Attorneys.

May 8, 1951 S. E. MILLER ET AL 2,552,107

AIR HEATER CONTROL

Filed Sept. 11, 1943

5 Sheets-Sheet 4

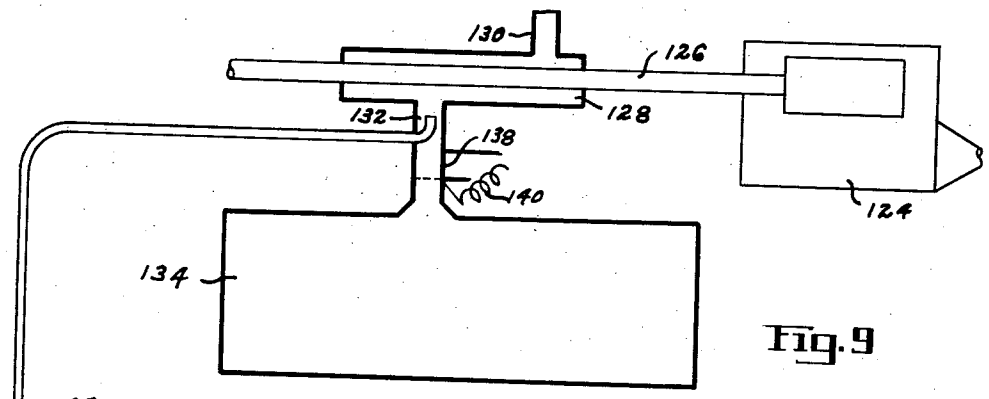


Fig. 9

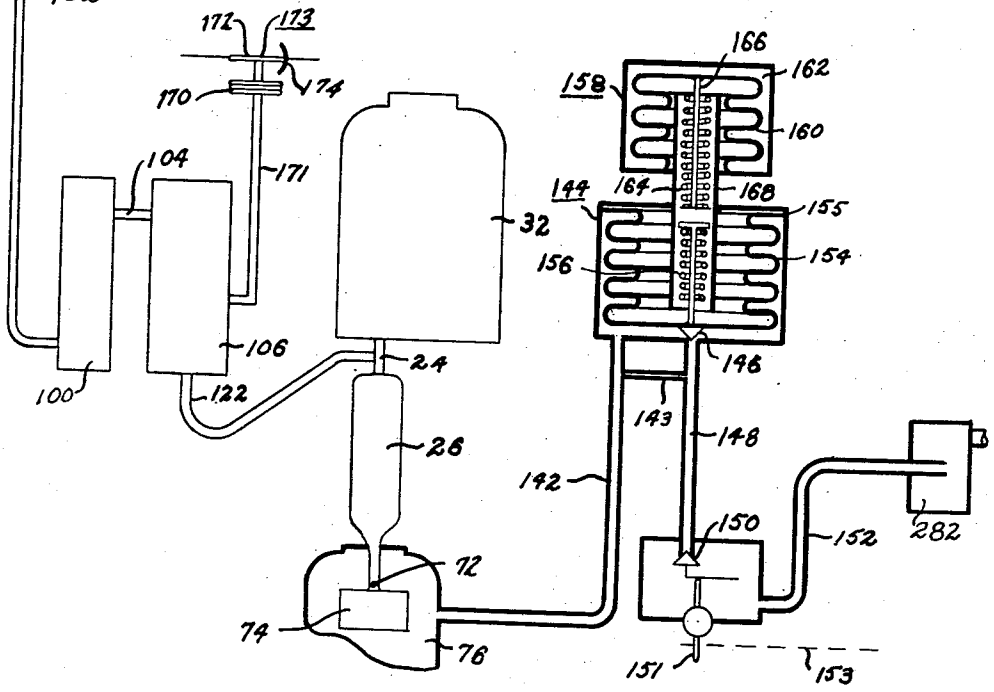
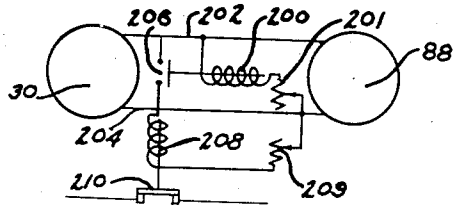


Fig. 11



Sidney E. Miller and
Herman J. Dicks, INVENTORS.

BY

Spencer, Hardman & Fehr,
Their Attorneys.

May 8, 1951 S. E. MILLER ET AL 2,552,107

AIR HEATER CONTROL

Filed Sept. 11, 1943 5 Sheets-Sheet 5

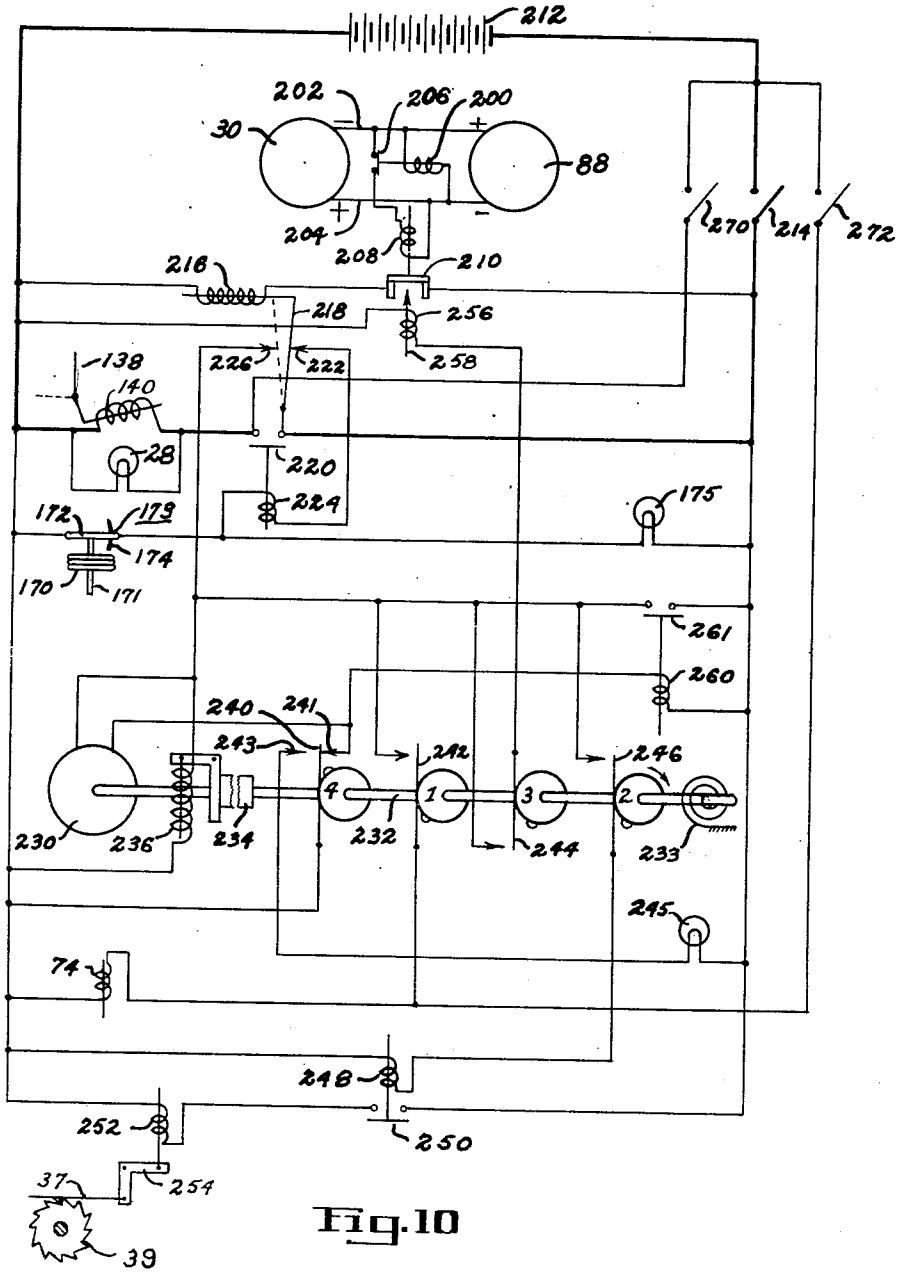


Fig. 10

Sidney E. Miller and
Herman J. Dick, INVENTORS

BY
Spencer, Hardman & Fisher,
Their Attorneys.

Patented May 8, 1951

2,552,107

UNITED STATES PATENT OFFICE

2,552,107

AIR HEATER CONTROL

Sidney E. Miller, Dayton, and Herman J. Dick, Shelby, Ohio, assignors to General Motors Corporation, Dayton, Ohio, a corporation of Delaware

Application September 11, 1943, Serial No. 501,970

14 Claims. (Cl. 23—255)

1

This invention relates to an air heater control and more particularly to an improved apparatus for shutting off the supply of heated air coming from a manifold heater in the event that the heated air contains an excessive amount of carbon monoxide.

One of the objects of this invention is to provide a compact reliable apparatus capable of indicating the presence of very slight amounts of a foreign substance in a fluid.

Another object of this invention is to provide an apparatus capable of distinguishing between a long exposure to a small amount of carbon monoxide and a short exposure to a larger amount of carbon monoxide.

A further object of this invention is to provide a simple means for storing and discharging measured quantities of a chemical substance.

Another object of this invention is to provide an apparatus which is unaffected by changes in the fluid density whereby the apparatus gives a true indication even at high altitudes.

A still further object of this invention is to provide an apparatus which is unaffected by changes in the voltage supplied to the electrical controls forming a part of the apparatus.

Another object of this invention is to provide a light sensitive means which responds to either an excess or a deficiency in the amount of light striking the light sensitive means.

A further object of this invention is to provide means for giving a warning in case the control apparatus fails due to a break in the air lines or the like.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, where a preferred form of the present invention is clearly shown.

In the drawings:

Fig. 1 is an elevational view of the heater control panel showing certain of the parts in section;

Fig. 2 is a fragmentary plan view showing the arrangement of the light sensitive cells and the light source;

Fig. 3 is a sectional view through the dryer and the restrictor;

Fig. 4 is a sectional view taken substantially on line 4—4 of Fig. 1;

Fig. 5 is a plan view of the chemical storing and dispensing casing;

Fig. 6 is a vertical sectional view taken on line 6—6 of Fig. 5;

Fig. 7 is a vertical sectional view taken on line 7—7 of Fig. 5;

2

Fig. 8 is a vertical sectional view taken on line 8—8 of Fig. 5;

Fig. 9 is a diagrammatic view showing the air flow circuit;

Fig. 10 is a diagrammatic view showing the electrical circuit used in the apparatus; and

Fig. 11 shows a modified circuit arrangement for the photo-electric cells.

Referring now to the drawings, reference numeral 20 designates the main support for the various elements of the apparatus, some of which are mounted on the front of the support and are visible in Fig. 1, and others of which are mounted on the back of the support. A substantially light proof cover (not shown) encloses the apparatus on the front of the support 20. Reference numeral 22 designates generally a chemical storing and dispensing unit which supplies a fresh charge of carbon monoxide detecting chemical to the glass tube 24 when and as required. The tube 24 is provided with a flattened carbon monoxide detecting chamber 26 arranged in the path of the light passing from the scanning light 28 to the light sensitive cell 30.

The chemical storing and dispensing unit 22 comprises a main cylindrical casing 32 provided with a removable end cap 34. A rotatable shaft 36 is journaled in the casing 32 and the end cap 34 as shown in Fig. 1. A plurality of sealed, chemical holding capsules 50 are supported in the casing 32 by the revolving holder 38. The holder 38 is slidably mounted on the shaft 36 and is arranged to be rotated by the shaft 36. A pawl 37 and ratchet 39 are used to rotate the shaft 36 and holder 38 as desired. A collar 40 is keyed to the shaft 36 by means of the key 42 as best shown in Fig. 1. The collar 40 is provided with an upstanding pin 44 which engages in a recess 46 provided in the rotatable element 38. By virtue of this arrangement the element 38 is caused to rotate with the shaft 36 and the element 38 cannot be lowered fully on the shaft 36 unless the pin 44 and recess 46 are properly aligned.

As best shown in Fig. 4 the rotatable element 38 is provided with 12 circumferentially arranged capsule holding recesses which are adapted to receive a corresponding number of sealed glass capsules 50. In Fig. 4 of the drawing, 3 of the capsules are shown in section whereas the remaining capsules are shown in elevation. As shown in Fig. 1, the capsules 50 are resiliently held in place. Thus a plate 52 resting against the upper end of the rotatable element 38 is provided with a plurality of capsule engaging ele-

ments 54 which are biased downwardly into engagement with the capsules by means of springs 56 as shown. The plate 52 is biased downwardly by means of the spring 58 which has its upper end in contact with the cap 34 as shown. The lower ends of the capsules 50 are provided with tips 60 which project beyond the lower face of the rotatable element 38.

The capsules 50 are initially charged with a chemical of the type which is very sensitive to the presence of carbon monoxide so that the presence of carbon monoxide changes the color of the chemical. There are several well known chemical compositions which may be used for this purpose. One material for this purpose comprises palladium chloride absorbed on highly purified silica gel. Another chemical which may be used for this purpose comprises palladium sulphate absorbed on highly purified silica gel. Both of these materials are normally light in color, are granular in form and freely flow out of the capsules upon breakage of the tips 60. The bottom wall of the casing 32, as best shown in Figs. 5–8, is provided with a high barrier 62 which extends high enough so as to break off the tips 60 as the tubes are rotated past the barrier 62 and two lower barriers 61 and 63 disposed on opposite sides of the high barrier as shown. The broken-off tips collect in the hopper 64 and the contents of the capsules discharge into the substantially funnel shaped hopper 70 disposed next to the barrier 62 as best shown in Figs. 5 and 7. The hopper 70 guides the granular chemical into the glass tube 24 which is provided with a flattened detector section 26 as described hereinabove. The broken tips may be removed by removing the plug 66 at the bottom of the hopper 64.

Upon discoloration of the chemical in the detector 26 it is drained out to make room for a fresh supply. A solenoid operated plunger 72 controls the flow of the chemical from the lower end of the tube 24. Energization of the solenoid 74 causes the plunger 72 to move downwardly thereby allowing the granular material in the tube 24 to drain into the hopper 76. The hopper 76 has a sufficient storage capacity to store all of the chemical from at least 12 of the cartridges. A drain plug 78 has been provided for draining the used chemical from the hopper 76. The plunger 72 is provided with an air passage 73 having a screen 75 at its upper end whereby air only may flow through the passage 73.

A current generating photo-electric element of the barrier layer type 30 is arranged adjacent the detector portion 26 of the tube 24 as best shown in Fig. 2. The element 30 is supported on the base 20 by means of a bracket 80. The scanning light 28 is also supported on the base 20 by means of suitable bracket means 82. The bracket 82 supports a pair of prisms 84 and 86 arranged as shown in Fig. 2. A second photo-electric element 88 is also supported on the base 20 by means of a bracket 90. By virtue of the arrangement of the prisms shown in Fig. 2, a part of the light from the source 28 is directed onto the cell 30 through the detector portion 26 of the tube 24 and some of the light is directed onto the cell 88 without passing through any of the chemical.

As will be pointed out more fully hereinafter, the photo-electric cells 30 and 88 are so connected into an electric circuit that a predetermined change in the amount of light passing from the source 28 to the cell 30 will cause a suitable warning to be given and will also discontinue the supply of heated air.

Inasmuch as the chemical used for detecting the carbon monoxide becomes discolored when subjected to moisture, and inasmuch as moisture interferes with the operation of the pressure regulating apparatus, means has been provided for removing the moisture from the air to be tested before the air comes in contact with the chemical. This means comprises a drier 100 through which the air is caused to flow. The air enters the drier 100 through the line 102 and leaves the drier through the passage 104 which conveys the air to a restrictor designated generally by the reference numeral 106. The drier includes a chamber 108 in which a suitable drying medium such as silica gel is placed. A screen element 110 is provided at the bottom of the chamber 108 for preventing silica gel from running out through the air inlet 102. The screen 110 also serves to filter the incoming air. The screen 110 is carried directly by a removable plug 112 which may be removed so as to clean the screen and empty out the silica gel when it has lost its effectiveness. A new charge of silica gel may be added by removing the filler cap 114. A second screen element 116 is provided adjacent the outlet passage 104 so as to prevent any of the silica gel or other solids from entering the restrictor 106.

The restrictor 106 is provided with a main bore 118 within which is disposed an externally threaded cylindrical element 120 which closely fits within the bore 118 as shown in Fig. 3 so as to provide a long tortuous path between the element 120 and the wall of the bore 118. The incoming air entering the chamber 118 through the passage 104 is required to follow the threads provided on the outer surface of the element 120 for the full length of the threads before leaving through the outlet line 122 which leads to the upper portion of the glass tube 24 as best illustrated in the diagrammatic showing in Fig. 9. The passage formed by the threads within the restrictor is an elongated orifice which limits or restricts the amount of air passing through the detecting apparatus.

Referring now to the diagrammatic showing in Fig. 9, reference numeral 124 designates a conventional internal combustion engine provided with an exhaust pipe 126. A heat interchanger 128 surrounds the exhaust pipe whereby fresh outside air coming in through the passage 130 is heated before leaving through the passage 132 which leads to the space 134 which is to be heated. The space 134 is intended to diagrammatically represent the cabin of an aeroplane or the like. A damper 138 is provided for controlling the supply of heated air to the space to be conditioned 134. The damper 138 is controlled by means of a solenoid 140 which, in turn, is controlled by the photo-electric cells 30 and 88. The arrangement is such that the damper 138 is moved from its full-line position, as shown in Fig. 9, to its dotted-line position whenever the light-sensitive means indicates the presence of carbon monoxide in the air sample flowing through the tube 24 as will be explained more fully hereinafter.

In order to test for the presence of carbon monoxide in the air coming from the heater, a small portion of the air flowing through the passage 132 is withdrawn into the line 102 which leads to the drier 100. The dried air flows from the drier 100 into the restrictor 106 via the pas-

sage 104. The air leaves the restrictor 106 through the line 122 which leads to the detector 26. The air leaves the detector 26 through the lower end thereof which leads to the interior of the hopper 76. The air leaves the hopper 76 through the line 142 which leads to a pressure regulating unit generally designated by the reference numeral 144. The flow of air through the unit 144 is controlled by the valve 146 arranged adjacent the outlet line 148. A valve 150 is provided adjacent the outlet of the line 148. The valve 150 is provided with an operator 151 which is connected to the main control switch 214 (described hereinafter) by means of a link 153 so that closing of the main switch opens the valve 150. A suction line 152 is provided which may be connected to any suitable vacuum pump 282 or to the intake manifold of the engine so as to pull air through the air circuit described hereinabove.

The pressure-regulating apparatus 144 is of the well known type which maintains a constant pressure at the inlet thereof and comprises the usual form of bellows 154 which is subjected to atmospheric pressure on the inside and is subjected to a pressure corresponding to the pressure in the line 142 on the outside. The upper end of the bellows 154 is anchored at 155. A spring 156 biases the valve 146 to valve opening position. The tension on the spring 156 is automatically adjusted by means of the compensating unit 158 which varies the loading on the spring 156 in accordance with changes in the atmospheric pressure. Thus, as the aeroplane on which the apparatus is mounted ascends or descends, an adjustment is made for changes in the outside air pressure whereby the rate of flow by weight through the analyzing apparatus is not varied.

The compensating unit 158 comprises a bellows 160 which is subjected to atmospheric pressure on the inside thereof and is subjected to a vacuum or a substantial vacuum on its other side. Thus, the chamber 162 is substantially fully evacuated so that any changes in pressure on the inside of the bellows 160 will tend to adjust the tension on the spring 164 as shown in Fig. 9 of the drawing. The upper end of the bellows 160 is secured to the stationary rod 166 carried by the upper wall of the assembly 144. Inasmuch as the upper end of the bellows 160 is held stationary by the rod 166, it is apparent that the lower end only is free to move and that the movement of the lower end causes movement of the element 168, which is carried by the lowered end of the bellows 160. It is also apparent that movement of the element 168 varies the spring pressure on the spring 156. Thus as the surrounding air pressure increases, the lower end of the bellows 160 and the element 168 will tend to move downwardly so as to decrease the valve opening force exerted by the spring 156. By virtue of the above described arrangement the valve 146 tends to open upon an increase in the inlet air pressure and to close upon a decrease in the inlet pressure so as to compensate for changes in the pressure at the inlet of the air circuit whereby the flow of air to be analyzed is maintained substantially constant irrespective of changes in surrounding air pressures.

A pressure responsive bellows 170 is connected to the restrictor 106 substantially at the midpoint thereof by means of a tube 171. The pressure responsive bellows 170 operates a switch 173 having a movable contact element 172 which cooperates with a stationary contact element 174 as shown in Fig. 10. The arrangement of the contacts 172 and 174 is such that the circuit is opened either by an excessive pressure in the bellows 170 or by an abnormally low pressure in the bellows 170. By virtue of this arrangement it is obvious that a break in the air line anywhere between the suction line 152 and the restrictor 106 would open the electrical circuit leading to a pilot light 175 and to the heater control, as will be explained hereinafter. Likewise, any restriction in either the line 102, the drier 100, or the restrictor 106 would open the electrical circuit to the pilot light 175 so as to give a warning. A capillary bypass 143 is provided around the valve 146 so as to allow a very small flow of fluid around the valve even though the valve 146 may be tightly closed so that if the lines ahead of the valve 146 clog, the vacuum source 152 will reduce the pressure in the line ahead of the valve 146 beyond the pressure at which the valve 146 is set to close so as to operate the switch 173.

Referring now to Fig. 10 wherein we have diagrammatically shown the control circuit it will be observed that the photo-electric cells 30 and 88 are connected in circuit in opposition to one another with the positive terminal of the one cell connected to the negative terminal of the other cell. The cell 30 has a larger light aperture than the cell 88 and under normal conditions generates more current than the cell 88 whereby the pair of solenoids 200 and 208 connected across the lines 202 and 204 are both normally energized. The current through the solenoids 200 and 208 is the differential of the currents from the cells 30 and 88. The circuit arrangement shown serves to minimize the effect of changes in light intensity at 28 due to voltage changes in the circuit since a decrease in light intensity affects both light cells at the same time. Thus changes in light intensity striking cell 30 which are caused by ordinary changes in light intensity at the source of light will not give a false indication but the complete failure of light, the absence of chemical in chamber 26 or the discoloration of the chemical in chamber 26 will cause operation of the switch 210. The circuit used also makes it possible to use low cost, trouble-free, standard parts. Other advantages of the circuit arrangement using two cells in the manner shown will be apparent from the following description which is self-explanatory. The solenoid 200 operates a switch 206 arranged in series with the solenoid 208 when an excessive amount of light strikes cell 30 only, as when there is no chemical in the detector 26 whereby an abnormal amount of current flows through the solenoid 200. In other words the normal amount of current flowing through the solenoid 200 is too small to be able to open the switch 206 and it is only when there is no chemical in the detector whereby an unrestricted amount of light strikes the cell 30 that the switch 206 opens. The solenoid 208 is arranged in parallel with solenoid 200 and under normal conditions has enough current flowing therethrough to hold the switch 210 open and it is only when the chemical in the detector becomes discolored that the current flow is too little to hold the switch open. The switch 210 has magnetized contacts whereby the switch 210 cannot be opened by the solenoid 208 when once closed. The solenoid 208, however, is strong enough to hold the switch 210 in the open position when once opened when the amount of light flowing to the cells 30 and 88 is at the proper intensity. Reference numeral 212 designates a source of

electricity for the heater controls such as a battery. While we have shown a battery for supplying current it is obvious that any other source of current such as a generator may be used. A manual switch 214 has been provided which turns on and off the current to the main electrical controls. Operation of the switch 214 also operates the valve 150 through the lever mechanism 151, 153 (Figs. 1 and 9) so as to control the flow of air through the apparatus. The switch 210 controls the flow of current through the solenoid 216 which in turn controls the single pole, double throw switch 218. The heater control solenoid 140 which controls the heater damper 138 is controlled by the switch 220 which in turn is controlled by the solenoid 224 arranged in series with the switch 222. Assuming that the switch 220 is closed, energization of the solenoid 216 by closing of the switch 210 will cause the switch 218 to open the circuit to the contact 222 thereby deenergizing the solenoid 224 and consequently opening the circuit to the heater control solenoid 140 and the scanning light 28. The solenoid 224 is also controlled by the switch 173 which is arranged in series with the solenoid 224. As explained hereinabove the switch 173 will remain closed under all normal operating conditions and will open only in the event of breakage or clogging of the air lines. Discoloration of the chemical in the detector 26 or the lack of any chemical in 26 will cause closing of the switch 210 and consequent energization of the solenoid 216 which will cause the movable switch element 218 to open the circuit to contact 222 and close the circuit to the contact 226. Closing of the circuit to the contact 226 initiates operation of the timing motor 230 and the clutch operating solenoid 236 and also energizes solenoid 260 as will be explained hereinafter.

The motor 230 is a timing motor which preferably drives the cam shaft 232 at a rate of approximately one revolution in three minutes' time. Cam segments 1, 2, 3 and 4 are secured to the shaft so as to rotate therewith. A spring 233 having one end fixed and the other end secured to the shaft 232 returns the shaft and the cams secured thereto to the position in which it is shown upon disengagement of the clutch 234. The clutch 234 is controlled by the solenoid 236 which in turn is controlled either by the switch contact 226 or the switch 261. The motor 230 is controlled by either the switch 226, 261 or 241. The switch 241 must be closed before the motor 230 can be operated. Energization of the solenoid 236 causes engagement of the clutch 234 whereby the motor drives the cams which operate the switches 240, 242, 244 and 246. Cam number 1 which is the first cam to come into operation at the beginning of each complete test cycle operates switch 242 which is arranged in series with the solenoid 74. The solenoid 74 controls the release valve 72 which dumps the chemical from the detector tube 26 as explained hereinabove. Cam number 2 controls the switch 246 which controls the solenoid 248 which in turn operates the switch 250. The switch 250 is arranged in series with the solenoid 252 which operates the pawl and ratchet mechanism 37 and 39 to deliver a new sample of chemical to the detector tube 26. As shown in Fig. 1, a bell crank 254 pivoted at 255 is provided between the solenoid 252 and the pawl 37. Cam number 3 energizes the reset solenoid 256 which resets the main switch 210 in its open position. Opening switch 210 deenergizes relay 216 whereby the motor switch 226 is opened and the switch 222 is closed so as to energize the scanning light and turn on the heat. The motor is still energized through the switch 261. The reset solenoid 256 when energized lifts the plunger 258 which lifts the contact 210. When once lifted the contact 210 remains in the open position so long as everything is satisfactory whereby the light 28 is energized and the heat is on. Any change in the light resulting from either the presence of carbon monoxide, the failure of any chemical to be fed into the detector or the failure of light 28 will cause closing of the switch 210. The cam number 4 controls the switches 241 and 243 which control the solenoid 260 and the hazard light 245 respectively.

Opening switch 210 deenergizes solenoid 216 whereby the motor circuit and the clutch circuit is opened at 226 and the heat is turned on through the switch contact 222 which energizes the solenoid 224. The clutch does not disengage nor does the motor stop upon opening the switch at 226 since the switch 261 arranged in an alternate circuit is still closed. In the absence of carbon monoxide indication the switch 261 remains closed for approximately two minutes until the cam 4 opens the circuit at 241 at which time the solenoid 260 is deenergized and the switch 261 opens the alternate circuit to the motor 230 and the clutch 234 whereby the spring 233 returns the cams to their initial starting position where they remain until the relay 208 allows switch 210 to close in response to either the presence of carbon monoxide, the burning out of the light bulb 28, or the opening of switch 173.

Closing of switch 210 thereafter may, for example, be caused by a long exposure of the detecting chemical to a negligible amount of carbon monoxide or to a short exposure to a larger amount of carbon monoxide and in order to determine which it is, the apparatus automatically begins to repeat the test cycle.

The discoloration of the chemical in 26 reduces the amount of light striking the cell 30 whereby the current generated thereby approaches in value the current generated by cell 88 whereby the solenoid 208 is too weak to hold the contacts 210 open. This results in relay 216 being energized whereby the motor and clutch circuit is closed at 226 and the circuit to heater solenoid 140 and scanning light 28 is opened at 222 while the motor operated cam switches are instrumental in renewing the charge of chemical so as to make a new test. When the motor 230 is first energized along with the solenoid 260 it causes cam 1 to energize the solenoid 74 which dumps the old charge of chemical and then causes cam 2 to close switch 246 which is instrumental in operating the pawl and ratchet mechanism so as to renew the charge of chemical. Cam 3 is then instrumental in resetting the switch 210 in its open position whereby relay 216 is deenergized whereby the contact 218 moves away from contact 226 and into contact with 222. Solenoid 224 is then energized whereby the switch 220 turns on the scanning light 28 and also turns on the heat. If a dangerous amount of carbon monoxide is present in the air the chemical will become discolored within the two minute period whereby switch 210 will close. Closing of switch 210 at this point in the sequence of operations moves the contact 218 away from 222 and in contact with 226 whereby the heat is turned off and both the clutch solenoid

236 and the motor 230 are energized through the contacts 218 and 226 as well as through switch 261. As a consequence of these contacts being closed the clutch solenoid 236 will continue to hold the clutch in engagement even after the cam 4 opens the motor circuit and the circuit through switch 261 whereby the cams will not be returned to their starting position by the spring 233, but will remain in the position in which cam 4 holds the switch 241 open and holds the switch 243 closed. When switch 243 is closed the hazard light 245 indicates either the presence of carbon monoxide in the air, failure of vacuum supply, clogging of sampling tube or failure of scan light 26. Normally, however, the hazard light would indicate the presence of carbon monoxide. In order to restart the testing apparatus, the main switch 214 must then be opened and reclosed, in this manner deenergizing the clutch solenoid 236 which allows the cams to return to their initial position through the action of spring 233.

There may be times when it will be desirable to supply heat to the cabin even though carbon monoxide is present in the heated air. Thus a switch 270 has been provided which may be used for turning on the heat even though the automatic control apparatus indicates the presence of carbon monoxide. A manual switch 272 has also been provided for manually operating the chemical release valve solenoid 74 whenever desired. Another pilot light 245 is controlled by the switch 243 and serves as a warning light to indicate that carbon monoxide has been detected or that something else is wrong.

It is apparent that the automatic timing apparatus does not distinguish between a break in the air line, a clogged air line, failure of the light bulb 28, failure of the palladium chloride feeding mechanism, or the presence of carbon monoxide in the air. Any failure of the air circuit, however, will be indicated by the light bulb 75 and failure of the light 28 would be readily apparent as would be failure of the feeding mechanism by mere visual inspection of the apparatus. In the event that a dangerous amount of carbon monoxide is present in the air, the light 28 and the heater will immediately be turned off and the hazard light 245 will be turned on at the end of the analyzing cycle indicating that the carbon monoxide leak must be repaired or oxygen masks must be used. The emergency heat switch 270 may be closed so as to turn on the heat even though there is carbon monoxide present in the air.

In Fig. 11 of the drawing we have shown an alternative circuit arrangement for the light sensitive cells which may be substituted for the corresponding circuit arrangement shown in Fig. 10. In the modification shown in Fig. 11 a first rheostat 201 is arranged in series with the solenoid 200 and a second rheostat 209 is arranged in series with the solenoid 208. By virtue of this circuit arrangement the response curves of the two cells may be brought in exact parallelism for the particular color wave length dealt with. These rheostats may be dispensed with where the cells 30 and 88 are properly matched and the solenoids 200 and 208 are properly designed.

While the apparatus disclosed herein is primarily designed for use on an aeroplane for detecting carbon monoxide it is apparent that many features of this invention have wider application.

While the form of embodiment of the invention

as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adapted, as may come within the scope of the claims which follow.

What is claimed is as follows:

1. In combination, a first current generating photo-electric element of the barrier layer type having a positive connection and a negative connection, a second current generating photo-electric element of the barrier layer type having a positive connection and a negative connection, means for connecting the positive connection of said first element to the negative connection of said second element, means for connecting the negative connection of said first element to the positive connection of said second element, a first solenoid connected between said connecting means, a second solenoid connected between said connecting means, a normally closed switch in series with the said second solenoid, means whereby the flow of a predetermined current through said first named solenoid opens said normally closed switch, and a control element operated by said second named solenoid.

2. In combination, a first light sensitive means, a second light sensitive means, means for directing light unto said light sensitive means, means energized in response to either an excess or deficiency in the amount of said light striking one of said light sensitive means, said last named means comprising a pair of electrical conductors for connecting said first and second light sensitive means in electrical opposition, a first relay connected across said conductors, a second relay connected across said conductors including control means in series with the first relay and operated by the second relay for reducing the flow of current through said first relay upon an increase in current flowing through said second relay, and a second control means operated by said first relay in response to a decrease in current through said first relay.

3. In a vehicle having a passenger compartment heated by an exhaust manifold heater, valve means for controlling the flow of air from the heater into the passenger compartment, means including a gas analysis unit for controlling said valve means so as to discontinue the supply of heated air in response to the presence of a given percentage of carbon monoxide gas in said air, and electrical means electrically responsive to a failure of said gas analysis unit for operating said valve so as to shut off the flow of air from said heater into the passenger compartment.

4. In combination, photoelectric means capable of generating a voltage, a first relay having its operating element connected across the terminals of said photoelectric means, a second circuit connected across the terminals of said photoelectric means, said first relay having contacts connected in and controlling said second circuit, a second relay having its operating element connected in said second circuit, said relays being calibrated to operate at different current flows.

5. In a storing and dispensing means, the combination, a movable holder having means for supporting and moving in a predetermined path a plurality of sealed containers each having a fragile portion and each adapted to contain a substance, a support for said holder, said support having a barrier arranged in the path of a portion of each of said sealed containers for breaking said containers one by one, means for moving said holder relative to said support so as to

cause said barrier to break said containers one by one, said support including wall means forming a substance receiving chamber directly adjacent and on one side of said barrier for receiving the substance which discharges from the broken containers, said support also including a wall means forming a second chamber directly adjacent said barrier on the side of the barrier opposite said first named chamber for receiving broken portions of said containers, said barrier being in substantially the same plane as the wall portion dividing said two chambers.

6. In a storing and dispensing means, the combination, a movable holder having means for supporting and moving in a predetermined path a plurality of sealed containers each having a fragile portion and each adapted to contain a substance, a support for said holder, said support having a barrier arranged in the path of a portion of each of said sealed containers for breaking said containers one by one, means for progressively moving said holder relative to said support so as to cause said barrier to break said containers one by one, said support including a receiving chamber directly adjacent and on one side of said barrier for receiving the substance which discharges from the broken containers, said support also including a chamber directly adjacent said barrier on the side of said barrier opposite said first named chamber for receiving broken portions of said containers, valve means for controlling the flow of the substance leaving said first named chamber, interlocking means for operating said valve means in synchronism with said means for progressively moving said holder relative to said support whereby the contents of one container is discharged from said first named chamber before the contents of another container is dispensed thereinto.

7. In a gas analysis apparatus, in combination, a movable holder having means to support a plurality of sealed containers each adapted to contain a chemical reagent, tube means including a test chamber located below said holder, means mounting for movement said holder to successively bring the containers into registration with said tube means, means located in the path of the moving containers and adjacent the tube means operable upon movement of said holder to break the lower end of the container approaching registration with the tube means to permit the contents thereof to flow to the test chamber, and conduit means connecting with said tube means for conducting gas to be analyzed to said test chamber adapted to contain the reagent whereby the presence of a tested-for constituent in the gas to be analyzed may be observed by change of visual appearance of the material in the test chamber.

8. In a gas analysis apparatus, in combination, a movable holder having a plurality of individual means for receiving and supporting a plurality of sealed containers containing a chemical reagent in a position for gravity discharge of the contents thereof, means arranged to intermittently move said holder and to successively present said individual supporting means and said containers to a fixed station, fixed hopper receiving means at said station, a test chamber located below said holder and said hopper means, conduit means connecting said hopper means and said test chamber, means located in the movement path of said holder and said supporting means and immediately adjacent said fixed station and hopper means constructed and arranged to break the lower end of said containers upon continued movement of an individual container supporting means into said fixed station in registration with said hopper receiving means, conduit means connecting with the lower portion of said first mentioned conduit means for conducting gas to be tested to said testing chamber, and said testing chamber including a transparent wall section for visual observance of change in appearance of the material in said chamber, and being constructed for reception and discharge of said chemical reagent.

9. The apparatus set forth in claim 8, in combination with photoelectric means positioned adjacent said test chamber, a control system for said gas analysis apparatus, said control system including means responsive to changes in the operation of said photoelectric means for conditioning said control system for operation, means for initiating the discharge of said chemical reagent from said test chamber, and means operatively associated with said holder moving means for initiating the operating of the latter.

10. The apparatus set forth in claim 8, in combination with means for discharging the chemical reagent from said test chamber, a timing device for controlling the operation of said chemical discharge means and said holder moving means, and a detecting apparatus responsive to the change in appearance of the material in said test chamber for controlling the operation of said timing device.

11. The apparatus set forth in claim 8, in combination with means for discharging said chemical reagent from said test chamber, damper means for controlling the flow of said gas to said test chamber, a timing device, a plurality of means actuated by said timing device for first initiating operation of said discharge device, then initiating operation of said holder moving means to cause a new charge of the reagent to be deposited in said test chamber and then initiating operation of said damper means to shut off the flow of said gas, and detecting apparatus positioned adjacent said testing chamber for initiating operation of said timing device upon a change in the appearance of the material in said chamber.

12. The apparatus set forth in claim 8, in combination with discharge means for the chemical reagent in said test chamber, photoelectric means positioned adjacent said chamber and being responsive to colorometric changes in said reagent, an electrical control circuit comprising switch means for controlling the operation of said reagent discharging means, second switch means for controlling the operation of said holder moving means, a control switch for said electric circuit, and means operably associated with said photoelectric means for actuating said control switch when a colorometric change of the reagent in said test chamber takes place.

13. The apparatus set forth in claim 8, in combination with discharge means for discharging the chemical reagent in said test chamber, an electrical control circuit including first switch means for initiating operation of said reagent discharging means, second switch means for then initiating operation of said holder moving means to cause a fresh supply of reagent to be deposited in said test chamber, a timing mechanism for successively actuating said first and second switch means, a control switch for said electric circuit, and photoelectric means responsive to a colorometric change of the reagent in said test

chamber for controlling the operation of said control switch.

14. The apparatus as specified in claim 13, in combination with damper means for controlling the flow of gas to said test chamber, and means controlled by said timing mechanism and photoelectric means for controlling the operation of said damper means.

SIDNEY E. MILLER.
HERMAN J. DICK.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
385,661	Cummings	July 3, 1888
893,153	Eggleston	July 14, 1908
921,897	Schmidt	May 18, 1909
1,303,514	Spindler	May 13, 1919
1,338,828	Groof	May 4, 1920
1,364,035	Carter	Dec. 28, 1920
1,383,270	Henning	June 28, 1921
1,485,757	Alsberg	Mar. 4, 1924
1,526,170	Milligan	Feb. 10, 1925
1,695,031	Schmick	Dec. 11, 1928
1,700,852	Packard	Feb. 5, 1929
1,779,569	Thompson	Oct. 28, 1930
1,919,858	Pettingill	July 25, 1933
1,940,346	Edward	Dec. 19, 1933
1,977,359	Styer	Oct. 16, 1934
2,005,036	Howe	June 18, 1935
2,019,871	Pettingill et al.	Nov. 5, 1935
2,042,109	Lamb	May 26, 1936
2,082,915	Sontag	June 8, 1937
2,096,902	Lamb	Aug. 23, 1938
2,127,414	Lohsse	Aug. 16, 1938
2,127,977	Lamb	Aug. 23, 1938
2,141,646	Ferguson	Dec. 27, 1938
2,160,383	Kannenberg	May 30, 1939
2,176,042	Pittenger	Oct. 10, 1939
2,183,606	Day	Dec. 19, 1939
2,184,152	Saffir	Dec. 19, 1939
2,232,622	Moses et al.	Feb. 18, 1941
2,233,616	Lamb	Mar. 4, 1941
2,234,499	McAllister	Mar. 11, 1941
2,237,558	Hutton	Apr. 8, 1941
2,251,751	Minter	Aug. 5, 1941
2,260,821	Bendy	Oct. 28, 1941
2,329,459	Dickey	Sept. 14, 1943
2,330,387	Ruttiman	Sept. 28, 1943

FOREIGN PATENTS

Number	Country	Date
407,309	Great Britain	printed 1934
457,910	Great Britain	Dec. 8, 1936
509,288	Great Britain	July 13, 1939

OTHER REFERENCES

"Heating, Piping and Air Conditioning," March 1939, pages 168–170.