May 14, 1957 R. M. HOWARD 2,792,012

AUTOMATIC TANK SWITCHER

Filed March 9, 1953 3 Sheets-Sheet 1

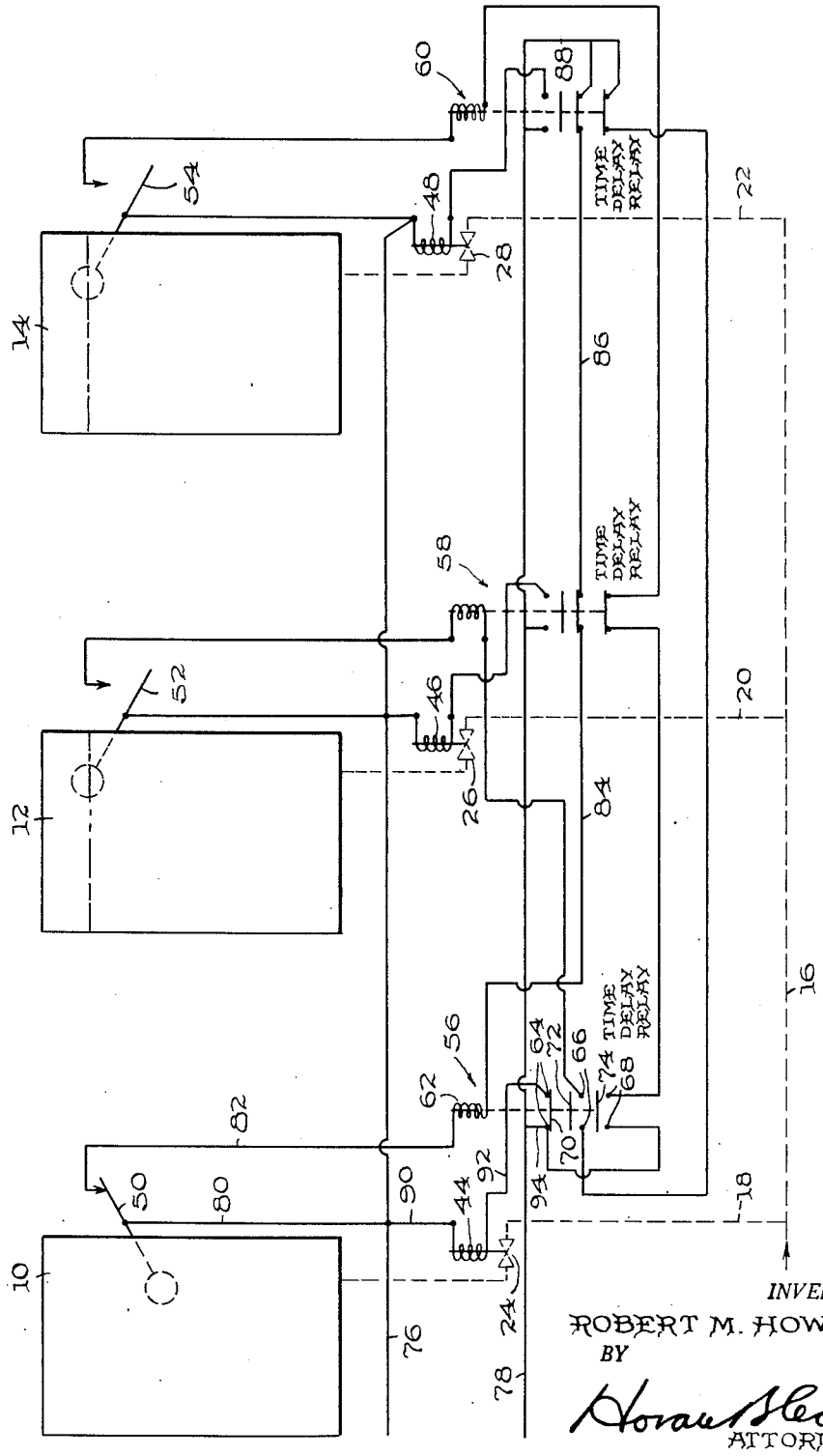

FIG. 1.

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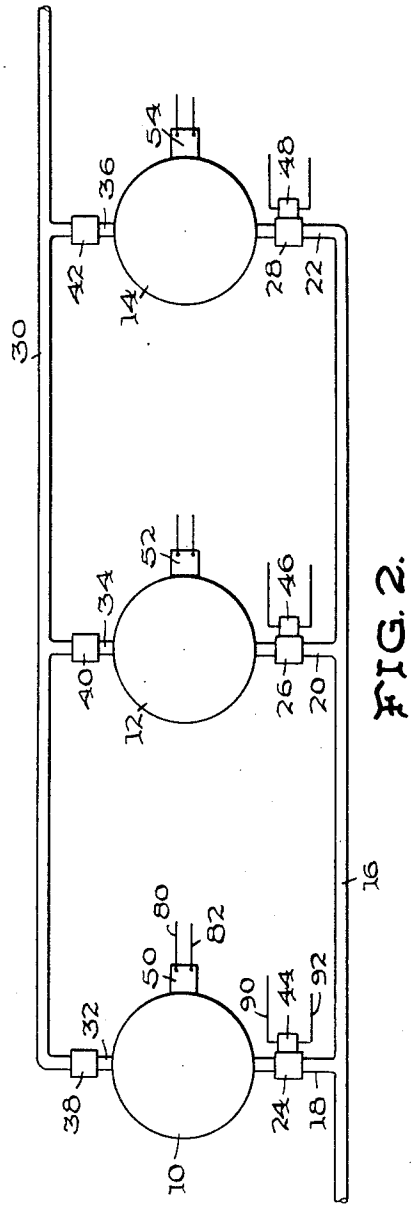

FIG. 2.

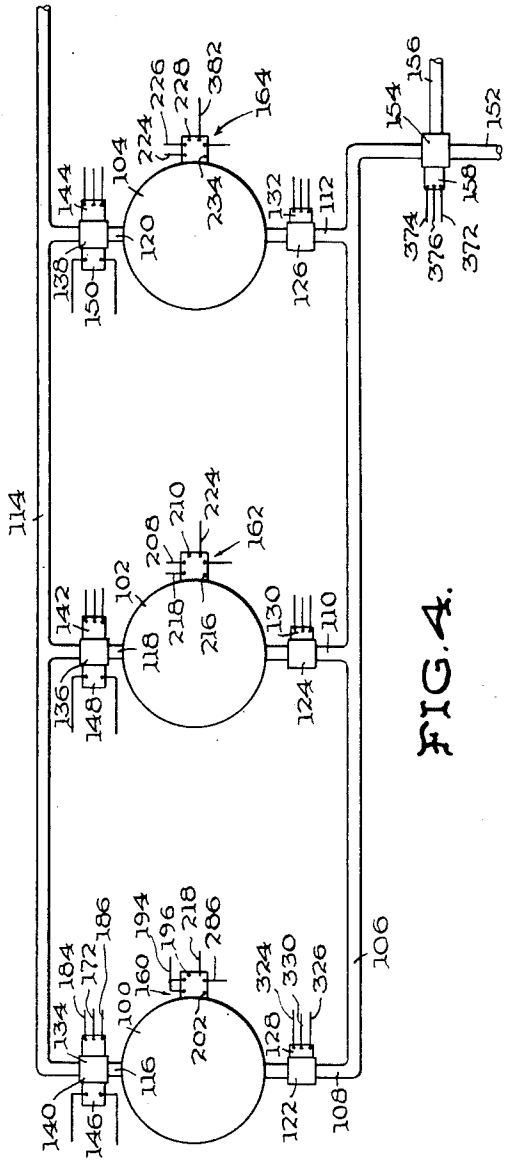

FIG. 4.

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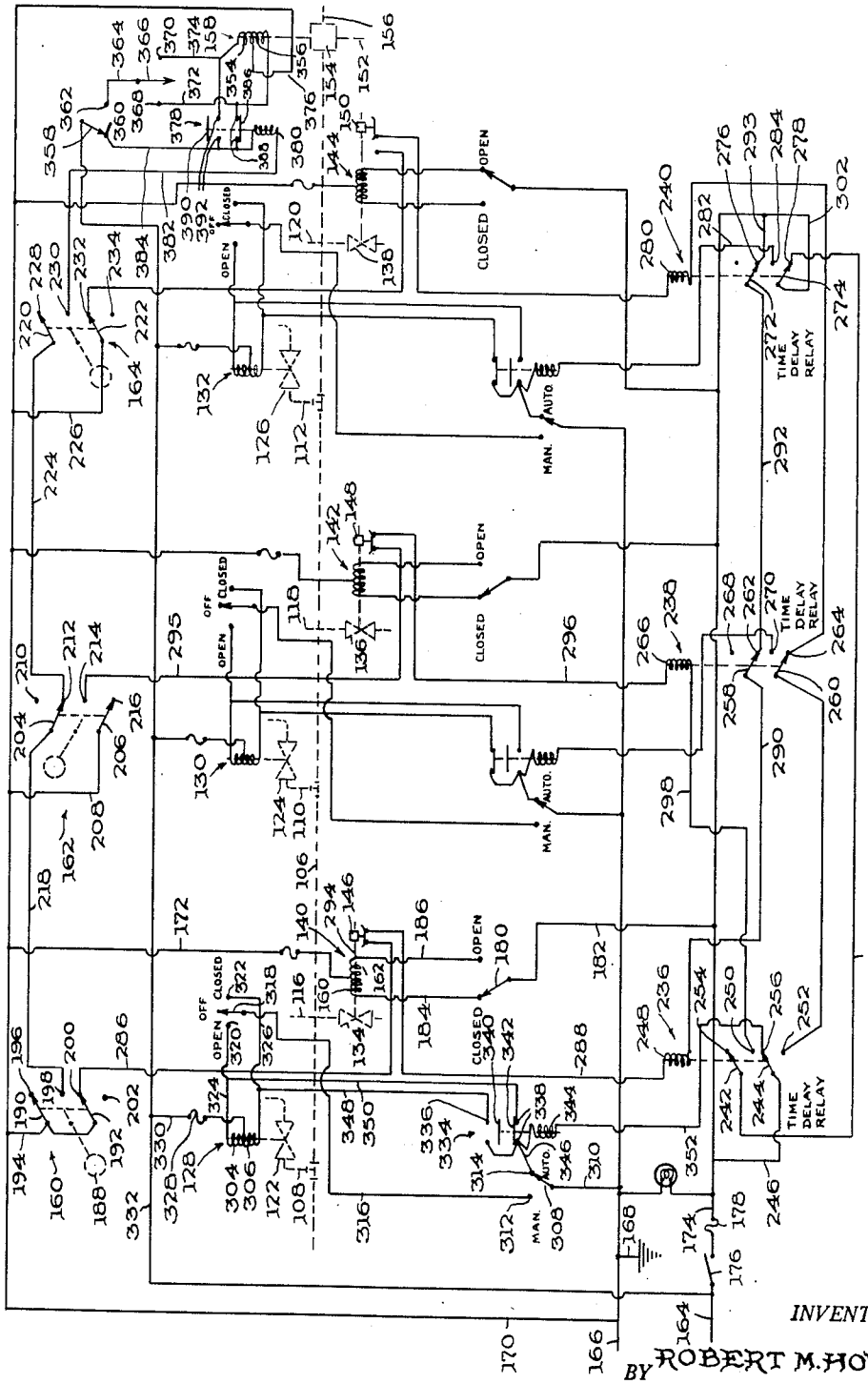

FIG. 3.

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2,792,012

AUTOMATIC TANK SWITCHER

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Application March 9, 1953, Serial No. 341,115

21 Claims. (Cl. 137—122)

This invention relates to new and useful improvements in electrical control apparatus, particularly to such apparatus that is adapted to control the sequential filling of units of a multiple-unit storage facility, and has the same general purposes as the apparatus disclosed in the Melborne L. Robertson application Serial No. 320,262, entitled Fluid Production and Storage Control Apparatus, and filed November 13, 1952.

Various industrial procedures involve the handling and storage of substantial quantities of fluids and necessitate the use of multiple-unit storage facilities. The necessity for multiple-unit storage facilities rather than a single large storage vessel may be indicated by economics, but usually stems from considerations such as a multiple-unit storage facility enables over-all steady flow operation to be realized as may be obtained by the filling of one storage unit while another previously filled and gauged unit is being emptied, the ease with which the number of storage units may be varied to satisfy individual storage requirements, and in some instances by the fact that placement of a fluid in separate units permits the same to be used in batch treating processes.

Irrespective of the particular fluid-handling process involved, it is generally desired that the fluid stream introduced into a multiple-unit storage facility be so directed that the entire stream sequentially fills empty units of the storage facility. Furthermore, it is also generally desired that the fluid stream be directed to only such empty units that have their outlets closed.

In order to achieve automatically the desired manner of handling fluid set forth in the preceding paragraph and thus avoid substantially continuous supervision and manual control, various proposals have been made; however, such proposals generally have involved the use of a rotary, motor-driven device for sequentially and cyclically selecting an empty unit next to be filled.

It is a principal aim of this invention to provide electrical control apparatus of the general character described above which will be largely free of moving parts and which will not require the use of a rotary, motor-driven device for selecting units to be filled.

Another important aim of this invention is to provide apparatus of the character described which will enable selected units to be by-passed insofar as the automatic filling operation is concerned, and which will permit introduction of fluid into such selected units at the option of the operator.

Still another aim of this invention is to provide apparatus which, instead of cyclically filling empty units, will make its selection of an empty unit for filling in accordance with a predetermined order of preference among the various units of the storage facility.

A further aim of this invention is to provide apparatus which, in automatic operation, will introduce fluid into only such units having their outlets closed.

Yet another purpose of the invention is to provide apparatus of the character described which, upon all of the units becoming full, will curtail the supply of fluid thereto,

or, if desired, divert the supplied fluid to a further multiple-unit storage facility that, in turn, may likewise be provided with similar automatic control apparatus.

A further purpose of the invention is to provide apparatus of the described character, which may include electrically actuated valves for both the inlet and outlet valves of each unit, and which valves may be energized to both the open and the closed positions.

Inasmuch as it is thought that one of the principal fields of use of the invention will be in the handling of liquids, such as the customary storage of petroleum in multiple-tank batteries near a petroleum producing area, the invention is illustrated and described in such a utilization environment.

In the drawings:

Figure 1 is a schematic diagram of a simplified version of the invention with the fluid conduits, valves, and switch-actuating floats being shown in dashed lines;

Figure 2 is a diagrammatic representation of storage tanks, fluid conduits, and valves of a storage facility, and illustrates the manner in which the control apparatus shown in Figure 1 is applied thereto;

Figure 3 is a schematic diagram of a modified and more elaborate version of the invention, wherein valves and portions of the fluid conduits and the switch-actuating floats being illustrated in dashed lines; and

Figure 4 is a diagrammatic representation of storage tanks, fluid conduits, and valves of a storage facility, and illustrates the manner in which the control apparatus of Figure 3 is applied thereto.

Attention is first directed to the form of the invention disclosed in Figures 1 and 2. The fluid system to which the electrical control system is applied is shown diagrammatically in Figure 2, and comprises a battery of tanks shown as being formed of tanks **10**, **12** and **14**.

The tanks **10**, **12** and **14** are supplied oil from a header **16** through inlet pipes **18**, **20** and **22**, respectively, with such inlet pipes being provided with inlet valves **24**, **26** and **28**, respectively.

In addition, the tanks **10**, **12** and **14** are arranged to discharge into a common discharge pipe **30** through outlet pipes **32**, **34** and **36**, respectively, such outlet pipes being provided with outlet valves **38**, **40** and **42**, respectively.

Although the outlet valves **38**, **40** and **42** may be simply manually operated valves, the inlet valves **24**, **26** and **28** are provided with electrical actuating means **44**, **46** and **48**, respectively, with each of such inlet valves and its actuating means being of such character that the inlet valve is normally biased closed, but opens and remains open during electrical energization of the actuating means so as to close automatically upon de-energization of the actuating means. The inlet valves **24**, **26** and **28** and their respective actuating means **44**, **46** and **48** may be of any conventional type of assembly operable with either A.-C. or D.-C. for the purpose desired, and may conveniently be of a known type utilizing an electric motor and hydraulic valve-moving means, or the common solenoid-actuated valve.

The tanks **10**, **12** and **14** are also respectively provided with liquid-level-sensitive electric switches **50**, **52** and **54**. Each of the switches **50**, **52** and **54** is shown in block diagram in Figure 2, and is of a known type that is open whenever the liquid level in its associated tank is above a predetermined level, and is closed whenever the liquid level is below such predetermined level. Various known types of liquid-level-sensitive switches are suitable for this purpose, such as liquid-head or pressure-operated switches, or float-operated switches such as shown diagrammatically in Figure 1. Irrespective of the nature of the liquid-level detector and switch-actuating means, snap-action switches are preferred.

While the basic principles of this invention are herein disclosed in conjunction with vessel-filling apparatus, it will be evident that such electrical control apparatus may be utilized in other environments wherein the detectors for operating the switches 50, 52 and 54 may be responsive to other than the above-mentioned conditions for switch actuation, such as pressure, temperature, etc.

The electrical system, which includes the switches 50, 52 and 54, for energizing the valve-actuating means 44, 46 and 48 is shown in Figure 1, to which attention is now directed.

The tanks 10, 12 and 14 have associated therewith, respectively, time-delay relays designated generally at 56, 58 and 60. These time-delay relays 56, 58 and 60 may be of any conventional type of time-delay relays, either A.-C. or D.-C. operated and differ from each other only in the fact that they have different time-delay values, that is, relay 58 has a greater time-delay value than relay 56, while relay 60 has a greater time-delay value than relay 58. It will be evident that relay 56 may be either of the substantially instantaneous type or have a time-delay feature and still satisfy the necessary condition that the relays 56, 58 and 60 require different periods of solenoid energization before the switch components thereof are actuated.

The relays 56, 58 and 60 are identical except for the different time delays thereof noted in the preceding paragraph, and it is therefore believed that a description of one of such relays will suffice for all. Accordingly, it will be seen that relay 56 comprises a solenoid 62 and integral pairs of contacts 64, 66 and 68. For a reason to become subsequently apparent, it will be noted that the relay 56 includes three pairs of contacts 64, 66 and 68 which correspond in number to the number of tanks 10, 12 and 14. Relay 56 also includes three movable contactors 70, 72 and 74 for the pairs of contacts 64, 66 and 68, respectively.

When the solenoid 62 is de-energized, the contactors 72 and 74 bridge the pairs of contacts 66 and 68, respectively, while the contactor 70 is positioned so as not to bridge the pair of contacts 64. However, upon energization of the solenoid 62, the contactors 70, 72 and 74 move under the influence of the solenoid 62 into such positions that the contactor 70 bridges the pair of contacts 64, and the contactors 72 and 74 are spaced from their normal positions bridging the respective pairs of contacts 66 and 68. It will be noted that the contactors 70, 72 and 74 of relay 56 are shown in the positions occupied thereby during energization of the solenoid 62 of the relay 56, while the contactors of the relays 58 and 60 are shown in the positions they occupy during the time that the solenoids of relays 58 and 60 are de-energized.

The solenoids of the relays 56, 58 and 60 are so arranged electrically that any one of them can only be energized during the time that the liquid-level sensitive switch of the tank associated therewith is closed as well as the contactors of the other relays being in their normal positions as hereinbefore described. Such electrical arrangement is essentially identical for the solenoids of each of the relays 56, 58 and 60 and it is thought that a detailed description of such electrical arrangement for the solenoid 62 of relay 56 alone will suffice for all. Such electrical arrangement for the solenoid 62 comprises electrical power leads 76 and 78, with the solenoid 62 being connected in series with the liquid-level sensitive switch 50 and the pairs of contacts of relays 58 and 60 which correspond to the pair of contacts 66 of relay 58 between the power leads 76 and 78 by means of leads 80, 82, 84, 86 and 88, as shown.

It will thus be seen that the energization of the solenoid 62 is interlocked with the relays 58 and 60. The energization of the solenoid of the relay 58 is similarly interlocked with the relays 56 and 60, and in an analogous fashion the energization of the relay 60 is interlocked with the relays 56 and 58.

The electrical arrangement of the solenoids of the relays 56, 58 and 60 may be summarized by stating that each of such solenoids is connected between the power leads 76 and 78 in series with the liquid-level-sensitive switch of the tank associated therewith and the pairs of contacts of the other relays that are normally bridged. Accordingly, it is evident that the contactors of only one of the relays 56, 58 and 60 may be displaced from their normal positions at any one time inasmuch as such displacement of such contactors is necessarily dependent on the contactors of all of the other relays being in their normal positions.

As previously described, each of the electrically-interlocked relays 56, 58 and 60 includes a pair of contacts that correspond to the pair of contacts 64 of relay 56 that is bridged whenever the contactors of such relay are displaced from their normal positions by its respective solenoid. Whenever the pair of contacts of any one of the relays 56, 58 and 60 that correspond to the pair of contacts 64 of relay 56 are bridged, means is provided to energize the inlet-valve-actuating means of the tank associated therewith. Since such means are identical for each of the relays 56, 58 and 60, it will suffice to describe in detail only such means provided for relay 56, wherein it will be seen that the inlet-valve-actuating means 44 of tank 10 is connected between the power leads 76 and 78 in series with the pair of contacts 64 by leads 90, 92 and 94.

The operation of the form of the invention shown in Figures 1 and 2 will now be described. Let it first be assumed that all three of the tanks 10, 12 and 14 are empty, and, in addition, that the power to the power leads 76 and 78 is cut off. Since the contactors of all the relays 56, 58 and 60 are in their normal positions, it will be evident that turning the power on to the power leads 76 and 78 will simultaneously energize the solenoids of all of such relays, since the liquid-level-sensitive switches are all closed. Furthermore, since all the contactors are in their normal positions, all the pairs of contacts corresponding to the pair of contacts 64 of relay 56 are not bridged so that the inlet-valve-actuating means 44, 46 and 48 of all the tanks are de-energized.

Since the time-delay value of the relay 56 is less than the time-delay values of the relays 58 and 60, it will be evident that the contactors of the relay 56 will be moved to the position shown thereof in Figure 1 before sufficient time has elapsed for the contactors of the relays 58 and 60 to be displaced from their normal positions. As soon as the contactors of the relay 56 have moved to the position shown thereof in Figure 1, the circuits through the solenoids of the relays 58 and 60 are broken so that the contactors of the time-delay relays 58 and 60 will remain in their normal positions, and, in addition, the contactor 70 will complete the circuit through the inlet-valve-actuating means 44 of tank 10, whereupon liquid enters tank 10 from the header 16 through the inlet pipe 18.

The solenoid 62 of the relay 56, as well as the inlet-valve-actuating means 44 will remain continuously energized until such time as liquid within the tank 10 rises to a sufficient level to cause the liquid-level-sensitive switch 50 to open, whereupon the circuit through the solenoid 62 of the relay 56 is broken.

Breaking of the circuit through the solenoid 62 of the relay 56 results in the contactors of the relay 56 returning to their normal positions, thereby again completing the circuits through the solenoids of the relays 58 and 60, while opening the circuit through the inlet-valve-actuating means 44.

Upon de-energization of the solenoid 62 and the return of the contactors 70, 72 and 74 to their normal positions with the consequent energization of the solenoids 58 and 60, it will be apparent that the contactors

of the relay 58 will be displaced from their normal positions prior to sufficient time having elapsed for such displacement of the contactors of the relay 60. Displacement of the contacts of the relay 58 from their normal positions results in the de-energization of the solenoid of the relay 60, the energization of the inlet-valve-actuating means 46, and, in addition, prevents energization of the solenoid 62 of the relay 56 in the event that the liquid-level-sensitive switch 50 should open as long as the liquid-level-sensitive switch 52 remains closed.

Eventually, the liquid level in the tank 12 will rise to a level sufficient to cause the opening of the switch 52, whereupon the solenoids of all the relays associated with tanks having closed liquid-level-sensitive switches will be energized. Of all the solenoids energized under such circumstances, it will be evident that the relay requiring the least time for displacement of its contactors will operate to de-energize the solenoids of the remaining relays and to open the inlet valve of the tank associated therewith.

Although the form of the invention shown in Figures 1 and 2 has been illustrated and described only in connection with controlling the introduction of liquid into three tanks, it will be evident to those skilled in the art that the principle of the invention may be extended for use in conjunction with either more or less tanks. For example, extension of the principle of the form of the invention shown in Figure 1 to a number of tanks exceeding three would require only that each of the additional tanks be provided with an associated liquid-level-sensitive switch, electrical inlet-valve-actuating means, and a relay, with the relays of all the tanks so modified as to include pairs of contacts corresponding in number to the total number of tanks, with all the pairs of contacts, except one, of each of the relays being normally closed. Each relay would have the solenoid thereof connected in series with the liquid-level-sensitive switch of its respective tank and a normally-closed pair of contacts of each of the remaining relays. Further amplification of the manner in which the principles of the form of the invention shown in Figures 1 and 2 may be extended to tank batteries of more than three tanks is thought to be unnecessary.

Summarizing, the operation of the form of the invention illustrated in Figures 1 and 2 is such that upon one tank becoming full, the inlet valve of such tank is closed and the inlet valve of the tank next to be filled is opened, with the particular tank next to be filled being determined by the fact that the relay associated therewith has a lesser time value than the relays associated with any of the other tanks that may be empty. Whenever all the tanks are full, all the solenoids of the time-delay relays are de-energized as well as the inlet-valve-actuating means associated therewith, and the apparatus will remain in such condition until such time as one of the liquid-level-sensitive switches is opened, with such occurrence causing the solenoid of the time-delay relay associated with such liquid-level-sensitive switch to become energized with the consequent opening of the inlet valve of the tank involved.

The form of the invention shown in Figures 1 and 2 is well adapted for the application of indicator lights thereto, such as for indicating whenever a tank is not full, or when the inlet-valve-actuating means thereof is energized to admit liquid thereto. Such provision of indicator lights may conveniently take the form of an indicator light, not shown, connected between the lead 82 and the power lead 78 that will be on whenever tank 10 is not full. For the purpose of indicating whenever the inlet-valve-actuating means of a tank is energized, an indicator light, not shown, may be connected between leads 90 and 92 that will be turned on whenever the inlet-valve-actuating means 44 of tank 10 is energized to open the inlet valve thereof.

Attention is now invited to the modified and somewhat more elaborate form of the invention illustrated in Figures 3 and 4. The fluid circuit is shown in Figure 4 and it comprises tanks 100, 102 and 104 which are supplied liquid from a header 106 through inlet pipes 108, 110 and 112, respectively. The tanks 100, 102 and 104 are arranged to discharge to a common discharge pipe 114 through outlet pipes 116, 118 and 120, respectively.

The inlet pipes 108, 110 and 112 are provided with inlet valves 122, 124 and 126 which are respectively provided with electrical inlet-valve-actuating means 128, 130 and 132. The inlet valves 122, 124 and 126 are of the two-position type, that is, either open or closed, and may be operated by either A.-C. or D.-C. The electrical valve-actuating means 128, 130 and 132 are of conventional character and are of the type that may be selectively energized to drive the inlet valve associated therewith to the closed and open positions. It is preferred that the valve-actuating means 128, 130 and 132 be of the "fail-safe" type that will automatically close the valve in the event of a power failure.

The outlet pipes 116, 118 and 120 are provided respectively with outlet valves 134, 136 and 138, such outlet valves being provided respectively with outlet-valve-actuating means therefor 140, 142 and 144. The outlet valves 134, 136 and 138 are of the same character as the previously-described inlet valves 122, 124 and 126 and the outlet-valve-actuating means 134, 136 and 138 are of the same character as the above-described inlet-valve-actuating means 128, 130 and 132.

In addition, the outlet valves 134, 136 and 138 are provided with and mechanically coupled to electric switches 146, 148 and 150, respectively. The switches 146, 148 and 150 may be conveniently termed outlet-valve switches and the same are mechanically coupled with their respective outlet valves in a conventional manner, the arrangement being such that whenever the outlet valve associated with one of the switches is closed, the outlet-valve switch will also be closed, and conversely, whenever the associated outlet valve is open, the outlet-valve switch is also open.

The header 106 is supplied liquid from a main supply conduit 152 through a two-position, 3-way valve 154 which in its normal position opens the conduit 152 into the header 106. The 3-way valve 154 is also connected to a further conduit 156, and may be actuated to its second position closing of the header 106 from the supply conduit 156 while cutting off the flow of liquid while opening the conduit 156 thereto. Electrical valve-actuating means 158 is provided for the 3-way valve 154, such means 158 being similar to the above-described valve-actuating means 128, 130 and 132. The valve-actuating means 158 is of conventional design and is arranged to be selectively energized for driving the valve 154 to its normal and its second position. The valve-actuating means 158 preferably also includes means to drive the valve 154 to its normal position in the event of a power failure.

Alternatively, the valve 154 may simply be a two-position valve such as the inlet valve 122, in which case the conduit 156 would, of course, be dispensed with and the electrical valve-actuating means would be of the same type as the inlet-valve-actuating means 128. The purpose of the valve 154 will be described hereinafter.

The tanks 100, 102 and 104 are provided respectively with liquid-level-sensitive switch means 160, 162 and 164. Each of the electrical switch means 160, 162 and 164 is of the snap action type and includes a double-pole-double-throw switch together with detector means for throwing the double-pole-double-throw switch into one position whenever the liquid level in the tank associated therewith is above a predetermined level, and for throwing the double-pole-double-throw switch into the other position whenever the liquid level falls below such predetermined level. The means for actuating the double-

pole-double-throw switch in response to such changes in the liquid level may be of conventional float type as indicated diagrammatically in Figure 4, or may be of the fluid-pressure-actuated type.

The electrical system for use in association with the apparatus shown in Figure 4 is illustrated in Figure 3.

Referring now to Figure 3, it will be seen that the outlet-valve-actuating means 140, 142 and 144 are illustrated diagrammatically and inasmuch as each of such means and the arrangement for controlling the same are identical, only the valve-actuating means 140 will be described in detail. As previously explained, the outlet-valve-actuating means 140 is of the type that may be selectively energized to close and open the valve 134. In the schematic representation of such means 140 shown in Figure 3, the same is shown as including a circuit element 160 which, when energized, will serve to close the outlet valve 134, and a further circuit element 162 which, when energized, will serve to open the valve 134.

The power supply comprises a pair of power leads 164 and 166, the latter of which is grounded at 168 and is provided with a branch power lead 170 that has connection to a common junction of the circuit elements 160 and 162 by means of a lead 172. It will be noted that the branch power lead 170 is similarly connected to the other outlet-valve-actuating means 142 and 144.

The power lead 164 is connected to a further power lead 174 through a normally-closed on-off power switch 176, with the power lead 174 being provided with an overload fuse 178. The power lead 174 is connected to the circuit elements 160 and 162 of the outlet-valve-actuating means 140 by means of a single-pole-double-throw switch 180 that is connected to the power lead 174 by a lead 182 and which switch 180 is connected to the circuit elements 160 and 162, respectively, by leads 184 and 186, whereby such circuit elements 160 and 162 may be selectively energized. It will be noted that the outlet-valve-actuating means 142 and 144 are provided with corresponding power connections.

Thus, whenever the switch 180 is in the position shown in Figure 3, the positions of the switch being appropriately labeled, the circuit element 160 is energized through the lead 184. However, when the switch 180 is in its alternative position, that is, the position labeled "open," the circuit element 162 is energized through the lead 186.

The liquid-level-sensitive switches 160, 162 and 164 are illustrated diagrammatically in Figure 4 together with diagrammatic representations in dashed outline of floats for actuating the same, such as the float shown in dashed outline at 188 in conjunction with the switch 160. It will be evident upon comparing the position of the floats shown in association with the switches 160 and 162 that the switch 160 is in the the position thereof when the tank 100 is empty and that the switch 160 would be in the position in which the switch 162 is illustrated when the tank 100 is filled.

The double-pole-double-throw switch 160 comprises upper and lower movable blades 190 and 192 that are connected to the branch power lead 170 by a lead 194. The blades 190 and 192 are arranged to move in unison with the upper blade 190 selectively engaging contacts 196 and 198, with the blade 192 selectively engaging contacts 200 and 202.

The double-pole-double-throw switch 162 comprises a pair of movable blades 204 and 206, the latter blade being connected to the branch power lead 170 by a lead 208. The blade 204 is movable for selectively contacting contacts 210 and 212, with the blade 206 being movable to selectively engage contacts 214 and 216. The blade 204 is connected to the contact 198 of the switch 160 by a lead 218.

The double-pole-double-throw switch 164 comprises a pair of blades 220 and 222 which are connected respectively to the contact 212 of switch 162 and branch power lead 170 by leads 224 and 226. The blade 220 is movable to contact selectively contactors 228 and 230 and the blade 222 is movable to contact selectively contacts 232 and 234.

The tanks 100, 102 and 104 have associated therewith respectively time-delay relays 236, 238 and 240 that may be either of the A.-C. or D.-C. type. The time-delay relays 236, 238 and 240 are analogous to the previously-described time-delay relays 56, 58 and 60 shown in Figure 1 in that the time-delay values thereof are different. The time-delay relay 236, like the previously-described time-delay relay 56, may either be substantially instantaneous or have a short time-delay value, while the time-delay relays 238 and 240 have progressively greater time delays. For example, the time-delay relay 236 may be substantially instantaneous, while the time-delay relays 238 and 240 require 5 and 10 seconds, respectively, for operation. The time-delay relay 236 incorporates switch means of the double-pole-double-throw type which comprises a pair of blades 242 and 244, the latter of which is connected to the power lead 174 by a lead 246. The blades 242 and 244 are movable in unison under the influence of a solenoid 248 from normally-biased positions contacting contacts 250 and 252, respectively, to positions contacting contacts 254 and 256, respectively, the latter-described alternative position of the blades 242 and 244 being illustrated.

The time-delay relay 238 also includes switch means of the double-pole-double-throw type which comprises a pair of blades 258 and 260 which are normally in contact with contactors 262 and 264, respectively, but which blades 258 and 260 are arranged to move under the influence of a solenoid 266 into engagement with contacts 268 and 270, respectively.

Time-delay relay 240 is similar to the relays 236 and 238 in that the same includes a double-pole-double-throw switch which comprises blades 272 and 274 which are normally in contact with contacts 276 and 278, respectively, which blades 272 and 274 will move under the influence of the solenoid 280 into engagement with contacts 282 and 284, respectively.

Electrical means is provided to make the energization of the solenoid 248 of the relay 236 dependent upon the simultaneous occurrence of three conditions, namely, that the liquid level in the tank 100 be at a sufficiently low level that the switch 160 will be in the position shown thereof in Figure 3, that the switch 146 associated with the valve 134 must be closed as a consequence of the valve 134 being closed, and that the blades of the relays 238 and 240 must be in their normal positions as they are shown in Figure 3. Such electrical means comprises leads 286 and 288 connecting the solenoid 248 to the contact 200 of the switch 160 through the switch 146, and leads 290, 292 and 294 connecting the solenoid 248 to the power lead 174 through the relays 238 and 240. The circuit through the solenoid 248 may be traced from the power lead 166 to the power lead 164 as follows: lead 170, lead 194, switch blade 192, contact 200, lead 286, switch 146, lead 288, solenoid 248, lead 290, switch blade 258, lead 292, switch blade 272, lead 293, power lead 174, fuse 178 and switch 176. It follows therefore that movement of any of the switch blades 192, 258 and 272 from the positions shown thereof in Figure 4 will open the circuit through the solenoid 248. Furthermore, opening of the outlet valve 134 will also open the circuit through the solenoid 248 through the action of the switch 146 that is mechanically coupled to the valve 134, as indicated at 294, so as to open therewith.

The electrical circuitry associated with the solenoid 266 of the relay 238 is analogous to that associated with the solenoid 248, and comprises a lead 295 connecting the contact 214 and the switch 148, a lead 296 connecting the switch 148 and the solenoid 266, a lead 298 connecting the solenoid 266 and the contact 250, a lead

300 connecting the blade 242 and the contact 278, and a lead 302 connecting the blade 274 and the power lead 174. The requisites for energization of the solenoid 266 are analogous to the requisites for energization of the solenoid 248 in that the blade 206 of the switch 162 must be in contact with the contact 214, the switch 148 must be closed to connect electrically the leads 295 and 296, as well as the switch of the relays 236 and 240 being in their normal positions in which the blades 242 and 274 are in engagement with the contacts 250 and 278, respectively.

Since the circuits of the solenoids 248 and 266 have been described in detail, and since the circuit of the solenoid 280 is closely analogous thereto, it is thought sufficient for the purpose at hand simply to point out that the same is in electrical series with the contact 232 of the switch 164, the switch 150 and contacts 264 and 252 of the relays 238 and 236, respectively. In connection with the circuit of the solenoid 280, it will be noted that as contrasted to the illustrated positions of the switches 146 and 148, the switch 150 is shown in the open position, as of course is the case when the outlet valve 133 is open as a consequence of the single-pole-double-throw switch associated with the outlet-valve-actuating means 144 being in the position shown thereof.

The electrical means provided in association with the inlet-valve-actuating means 128, 130 and 132 of each of the tanks 100, 102 and 104 are identical and accordingly only such means provided in association with the inlet-valve-actuating means 128 of the tank 100 will be described in detail. As previously described, the inlet-valve-actuating means 128 is of the type that may be selectively energized to close and open the valve 122, and in the schematic representation thereof shown in Figure 3, the elements 304 and 306 upon energization will open and close the valve 122, respectively.

The selective energization of the circuit elements 304 and 306 may be controlled either manually or automatically. The means whereby the selective energization of the circuit elements 304 and 306 may be controlled manually will be first described, such means comprising a single-pole-double-throw switch having the blade 308 thereof connected by lead 310 to the power lead 166. The blade 308 may be placed in selective engagement with contacts 312 and 314 which are appropriately labeled with respect to manual and automatic operation. The contact 312 is connected by a lead 316 to the blade 318 of a further single-pole-double-throw switch, which blade 318 may be selectively placed in engagement with contacts 320 and 322 or placed in a position intermediate the contacts 320 and 322, as shown, appropriately labeled the "off" position. The contacts 320 and 322 are connected respectively to the circuit elements 304 and 306 by leads 324 and 326, while the common junction of the circuit elements 304 and 306 is connected through a fuse 328 and lead 330 to a branch power lead 332 of the power lead 164.

It will thus be seen that when the switch blade 308 is placed in engagement with the contact 312 and the switch blade 318 is placed in engagement with the contact 320, the circuit element 304 is energized to open the valve 122, or alternatively, if the switch blade 318 is placed in contact with the contact 322 the circuit element 306 is energized to close the valve 122. It is to be noted that the described manual control for the inlet-valve-actuating means 128 will function in the described manner independently of the state of the liquid-level-sensitive switch 160 and the relays 236, 238 and 240.

The electrical means for automatically controlling the operation of the inlet-valve-actuating means 128 comprises a relay 334 which includes integral pairs of contacts 336 and 338 and contactors 340 and 342. The contactors 340 and 342 are biased so that the contactor 340 normally bridges the pair of contacts 336 with the contactor 342 spaced from the pair of contacts 338. The relay 334 also includes an actuating solenoid 344, which when energized will urge the contactors 340 and 342 from their described normal positions into the positions shown thereof wherein the contactor 342 bridges the pair of contacts 338 and the contactor 340 is spaced from the pair of contacts 336.

The solenoid 344 as well as one contact each of the pairs of contacts 336 and 338 are connected by a lead 346 to the contact 314 while the other contacts of the pairs of contacts 336 and 338 are connected by leads 348 and 350 to the leads 326 and 324, respectively. When automatic operation of the inlet-valve-actuating means 128 is desired, the switch blade 308 is placed in contact with the contact 314, the arrangement being such that when the switch blade 244 of the time-delay relay 236 is in the position shown thereof, a circuit through the solenoid 344 is completed between the power leads 174 and 166. Such circuit may be traced as follows: lead 246, switch blade 244, contact 256, a lead 352 connecting the contact 256 to the solenoid 344, solenoid 344, lead 346, switch blade 308 and lead 310. When the circuit just described is completed, the contactor 342 bridges the pair of contacts 338 so that a circuit is completed through the circuit element 304 of the inlet-valve-actuating means 128 in the following manner: lead 310, switch blade 308, lead 346, a pair of contacts 338 bridged by the contactor 342, lead 350, lead 324, circuit element 304 and leads 330 and 332. It will thus be apparent that energization of the solenoid 344 results in the circuit element 304 being energized so as to open the inlet valve 122. It will also be appreciated that when the switch blade 308 is in the position shown thereof in Figure 3 and the solenoid 344 is de-energized, a circuit is completed through the circuit element 306 so as to close the inlet valve 122, such circuit comprising the lead 310, switch blade 308, lead 346, the pair of contacts 336 that are bridged by the contactor 340, the lead 348, lead 326, circuit element 306, and leads 330 and 332.

In connection with the described operation of the relay 334, it should be pointed out that the energization of the solenoid 344 thereof is necessarily dependent upon the switch blade 244 of the time-delay relay 236 being in the position shown thereof which can only occur during the time that the solenoid 248 is energized. Furthermore, it should be pointed out that such dependence of the automatic opening of the inlet valve 122 upon the state of the time-delay relay 238 also applies to the automatic control means for opening the other inlet valves 124 and 126. Consequently, only one of the inlet valves 122, 124 and 126 may be open at any one time by virtue of the automatic controls provided for the opening thereof, since the time-delay relays 236, 238 and 240 are so interlocked that the switch elements of only one of such time-delay relays can ever at any one time be in such position as to cause the automatic opening of the inlet valve associated therewith.

Such interlocking of the time-delay relays 236, 238 and 240 is analogous to the previously-described interlocking of the time-delay relays 56, 58 and 60 of the embodiment of the invention shown in Figure 1, and stems from the fact that the energization of the solenoid of any one of the time-delay relays 236, 238 and 240 is dependent upon switch elements of the remaining time-delay relays being in their described normal positions.

Attention is now directed to the electrical means provided in association with the valve-actuating means 158 of the 3-way valve 154, whereby the position of the valve 154 may be controlled automatically, or manually if desired, so that fluid is normally directed from the conduit 152 into the header 106 when any one of the tanks 100, 102 and 104 is less than full, but which will serve to divert fluid from the conduit 152 to the conduit 156 upon all of the tanks 100, 102 and 104 being full. The manual means for controlling the valve-actuating means 158 will first be described.

As previously explained, the valve-actuating means 158 includes a circuit element schematically illustrated at 354

which when energized will operate the valve 154 to divert fluid into the conduit 156, and also includes a further circuit element schematically illustrated at 356 which when energized will drive the valve 154 into such position as to direct liquid from the conduit 152 into the header 106.

Electrical circuitry affording manual control of the operation of the valve-actuating means 158 comprises a single-pole-double-throw switch, the blade 358 of which is connected to the branch power lead 332 and which is movable for selective engagement with contacts 360 and 362. The contact 362 is connected by a lead 364 to the blade 366 of a further single-pole-double-throw switch.

The blade 366 is movable for selectively engaging contacts 368 and 370, such contacts being respectively connected to the circuit elements 356 and 354, respectively, by leads 372 and 374. The common junction of the circuit elements 354 and 356 is connected to the branch power lead 370 by a lead 376. It will thus be seen that with the switch blade 358 in engagement with the contact 362, the switch blade 366 may be placed in engagement with either the control 368 or the contact 370 to selectively energize the circuit elements 356 and 354, respectively.

Circuit means affording automatic control of the valve-actuating means 158 comprises a relay 378 which includes a solenoid 380 connected between the contact 230 of the liquid-level-sensitive switch 164 and the contact 360 by leads 382 and 384, respectively. The arrangement is such that when the switch blades 190, 204, 220 and 358 are in engagement with the contacts 198, 212, 230 and 360, respectively, a circuit is completed through the solenoid 380 between the branch power leads 170 and 332, whereby the solenoid 380 is energized. It will be appreciated that completion of such circuit is necessarily dependent upon each of the liquid-level-sensitive switches 160, 162 and 164 being in the state brought about by the respective tanks being full as well as the switch blade 358 being in contact with the contact 360. The circuit through the solenoid 380 may be traced from the branch power lead 170 to the branch power lead 332 as follows: lead 194, switch blade 190, lead 218, switch blade 204, lead 224, switch blade 220, lead 232, solenoid 380, lead 384, and switch blade 358. The contactors of the relay 378 are normally biased into the position shown thereof in Figure 3 and in such position the lowermost contactor 386 bridges a pair of contacts 388 that are connected respectively to leads 384 and 372 so that a circuit is completed through the circuit element 356 of the valve-actuating means 158 as follows: branch power lead 332, switch blade 358, lead 384, the pair of contacts 388, lead 372, circuit element 356 and lead 376. When the solenoid 380 is energized, the uppermost contactor 390 is moved into a position bridging a pair of contacts 392 that are connected respectively to the leads 384 and 374 so that when the contactor 390 so bridges the pair of contacts 392 a circuit is completed through the circuit element 354 of the valve-actuating means 158 which may be traced as follows: branch power lead 332, switch blade 358, lead 384, the pair of contacts 392, lead 374, circuit element 354 and lead 376.

Therefore, during automatic operation, the switch blade 358 is in contact with the contact 360, and so long as any one of the tanks 100, 102 and 104 is less than full, the solenoid 380 is de-energized and the circuit element 356 of the valve-actuating means 158 is energized so that the valve 154 is driven to the position cutting off the conduit 156 while permitting fluid to flow from the conduit 152 into the header 106. However, upon all the tanks becoming full, a circuit is completed through the solenoid 380 to cause energization thereof with the consequent de-energization of the circuit element 356 and the energization of the circuit element 354 of the valve-actuating means 158; whereupon the valve 154 is driven to a position cutting off further flow of liquid from the conduit 152 into the header 156 and diverting the flow of liquid from conduits 152 into the header 156.

It will be obvious that the conduit 156 may constitute a header for a further battery of storage tanks, not shown, which could similarly be provided with automatic control apparatus. On the other hand, the valve 154 may be simply a two-position valve, in which event the same would be closed upon the occasion of all the tanks 100, 102 and 104 becoming full. When employing the latter arrangement, well production should be curtailed when the valve 154 is closed. The apparatus of the instant invention may be readily modified to accomplish such production-curtailing function. An example of one of the various ways in which such additional function may be realized is to make the pumping of a well, or the opening of the valve at the head thereof, dependent in some manner upon the existence of an electrical potential between the leads 372 and 376, such as by connecting an electrically opened, normally closed, well-head valve between the leads 372 and 376. Similarly, a suitable relay system for controlling pumping equipment may be connected to the leads 372 and 376.

Each of the forms of the invention shown in Figures 1 and 3 with only slight modification are applicable to the storage of gases as well as liquids. For use in the storage of gases, the liquid-level-sensitive switches would be of the pressure-sensitive type, as will be readily understood by those familiar with the art.

In using the invention for the storage of inflammable fluids, the switches and indicator lights that may be applied thereto should be of the explosion-proof types. For example, in lieu of the type of liquid-level-sensitive switches shown in the drawings to illustrate the principles of the invention, equivalent mercury switches may be used.

The illustrated forms of the invention are readily subject to numerous other modifications without departing from the spirit thereof. Exemplary of such modifications, mention should be made of the fact that the inlet-valve-actuating means shown in Figure 3 may be replaced by the type of inlet-valve-actuating means shown in Figure 1. Such replacement of the inlet-valve-actuating means 128 of Figure 3 by the corresponding means 44 of Figure 1 would only require connecting the means 44 between the power lead 166 and the contact 256 and preferably in series with single-pole-single-throw switch. Of course, such a replacement would obviate the necessity for the relay 334, etc.

The form of the invention shown in Figure 3 is particularly well adapted for the application of indicator lights thereto. Such lights have not been shown in the drawings for the reason that such provision does not constitute the subject matter of the invention and would simply obscure the actual invention. However, it is thought appropriate that the manner in which indicator lights may be applied be mentioned. For example, visual indication of whether tank 100 is full may be obtained by connecting an indicator light between the contact 202 of switch 160 and the power lead 332. Visual indication of whether tank 100 is in condition to be filled, that is empty and with its outlet closed, may be obtained by connecting an indicator light between the lead 288 and the power lead 174.

In addition, visual indication of when tank 100 is being filled may be obtained indirectly by connecting an indicator light between the lead 350 and the power lead 332. Of course, direct indication of when the inlet valve 122 is open may be had by mechanically coupling an electric switch with the valve 122 and placing such switch in series with an indicator light between power leads. Indirect indication of the position of the valve 154 may be had upon connecting an indicator light between the leads 170 and 372.

The invention has been described in considerable detail in the interest of conveying a speedy and complete

understanding thereof, rather than to imply a narrow scope of invention. The actual scope of the invention should be ascertained by inspection of the appended claims.

I claim as my invention:

1. In electrical control apparatus, a plurality of electromagnetic relays each including an actuating solenoid and a control switch actuated thereby, means electrically interlocking said relays for preventing energization of the solenoids of the other relays upon actuation of any one of such relays, at least all but one of said relays being provided with time-delay means for delaying relay actuation after energization of the solenoid thereof, each of said time-delay means having a different time-delay value, and each of said solenoids having in electrical series therewith an electric switch that is adapted to be operated by a detector.

2. In electrical control apparatus, a plurality of electric switches adapted to be operated by detectors, and a corresponding number of electromagnetic relays, each of said relays comprising an actuating solenoid and a control switch actuated thereby, at least all but one of said relays being provided with time-delay means for delaying relay actuation after energization of the solenoids thereof, each of said time-delay means having a different time-delay value; each of said relays being provided with a solenoid circuit that includes in series with the actuating solenoid one of said electric switches, and means for opening such solenoid circuit in response to actuation of any of the other relays.

3. In electrical control apparatus, a plurality of independent electric switches each adapted to be independently operated by a detector, a corresponding number of electromagnetic relays; each of said relays including as many normally-closed solenoid-actuated switches as there are other relays, a solenoid-actuated control switch, and an actuating solenoid; and each of said relays being provided with a solenoid circuit that includes in series the actuating solenoid of such relay, one of the first-mentioned electric switches, and one of the normally-closed solenoid-actuated switches of each of the other relays.

4. In electrical control apparatus, a plurality of independent electric switches each adapted to be independently operated by a detector, a corresponding number of electromagnetic relays; each of said relays including as many normally-closed solenoid-actuated switches as there are other relays, a solenoid-actuated control switch, and an actuating solenoid; at least all but one of said relays being provided with time-delay means for delaying actuation after energization of the solenoids thereof, each of said time-delay means having a different time-delay value; and each of said relays being provided with a solenoid circuit that includes in series the actuating solenoid of such relay, one of the first-mentioned electric switches, and one of the normally-closed solenoid-actuated switches of each of the other relays.

5. In electrical apparatus for controlling the storage of fluids in a multiple tank battery, a plurality of relays each including an actuating solenoid and a control switch actuated thereby, means electrically interlocking said relays for preventing energization of the solenoids of the other relays upon actuation of any one of such relays, at least all but one of said relays being provided with time-delay means for delaying relay actuation after energization of the solenoid thereof, each of said time-delay means having a different time-delay value, electrical valve-actuating means connected to each of said control switches, and a detector-actuated switch in series with each actuating solenoid.

6. In fluid storage control apparatus, a plurality of storage vessels; each vessel having associated therewith a detector-operated electric switch, an electrical valve-actuating means and an electromagnetic relay; each of said relays comprising an actuating solenoid and a control switch actuated thereby, the control switch of each relay having electrical means associated therewith for controlling operation of the electrical valve-actuating means associated with the same vessel as the relay; each of said relays being provided with a solenoid circuit that includes in series the detector-operated electric switch associated with the same vessel as the relay and the actuating solenoid of such relay; and means electrically interlocking the relays for preventing closure of such solenoid circuit in response to any of the other relays being actuated by their respective solenoids.

7. In fluid storage control apparatus, an equal number of detector-operated electric switches, electrical valve-actuating means and electromagnetic relays, at least all but one of said relays being provided with time-delay means, each of said relays comprising an actuating solenoid and a control switch actuated thereby, each of said control switches having electrical means associated therewith for controlling operation of one of the electrical valve-actuating means; each of said relays being provided with a solenoid circuit that includes in series one of the detector-operated electric switches, the actuating solenoid of such relay, and means for preventing closure of such solenoid circuit in response to any of the other relays being actuated by their respective solenoids.

8. In fluid storage control apparatus, an equal number of detector-operated electric switches, electrical valve-actuating means, and electromagnetic relays, each of said relays comprising an actuating solenoid, a solenoid-actuated control switch and said number less one of normally-closed solenoid circuit switches; each of said relays being provided with a solenoid circuit that includes in series one of the detector-operated electric switches, the actuating solenoid of such relay, and one of the solenoid circuit switches of each of the other relays; and each of said control switches having electrical means associated therewith for controlling the operation of one of the electrical valve-actuating means.

9. The combination of claim 6, wherein said electrical valve-actuating means is of the type that on energization will change a two-position valve from its normal position, said electrical means comprising a circuit including in series the detector-operated switch, the control switch and the electrical valve-actuating means.

10. The combination of claim 6, wherein said electrical valve-actuating means is of the type selectively energized for opening and closing a valve, said electrical means comprising an auxiliary relay which includes switch means for selectively energizing the electrical valve-actuating means for opening and closing a valve, and said auxiliary relay also including a solenoid connected in series with the control switch.

11. The combination of claim 6, wherein said electrical valve-actuating means is of the type selectively energized for opening and closing a valve, said electrical means comprising an auxiliary relay which includes switch means for selectively energizing the electrical valve-actuating means for opening and closing a valve, said auxiliary relay also including a solenoid in a series circuit with the control switch, and manually operable switch means for opening the circuit of the last-mentioned solenoid and also for selectively energizing the electrical valve-actuating means for opening and closing a valve.

12. In electrical apparatus for controlling the storage of fluid in a multiple tank battery, a plurality of electromagnetic relays each including an actuating solenoid and a control switch actuated thereby, means electrically interlocking said relays for preventing energization of the solenoids of the other relays upon actuation of any one of such relays, a tank-content-detector-actuated switch associated with each of said relays, a valve-position-detector-actuated switch associated with each of said relays; a solenoid circuit associated with each of said relays in-

cluding in series the solenoid of such relay, one of the tank-content-detector-actuated switches, and one of the valve-position-detector-actuated switches; electrical valve-actuating means associated with each of the relays, and electrical means associated with each of said control switches for controlling the operation of one of the last-mentioned means in response to the position of such control switch.

13. In electrical apparatus for controlling the storage of fluid in a multiple tank battery, a plurality of electromagnetic relays each including an actuating solenoid and a control switch actuated thereby, means electrically interlocking said relays for preventing energization of any of the solenoids of the other relays upon actuation of any one of such relays, at least all but one of said relays being provided with time-delay means, each of said time-delay means having a different time-delay value, a tank-content-detector-actuated switch associated with each of said relays, a valve-position-detector-actuated switch associated with each of said relays; a solenoid circuit associated with each of said relays including in series the solenoid of such relay, one of the tank-content-detector-actuated switches, and one of the valve-position-detector-actuated switches; electrical valve-actuating means associated with each of the relays, and electrical means associated with each of said control switches for controlling the operation of one of the last-mentioned means in response to the position of such control switch.

14. In fluid storage control apparatus, an equal number of detector-operated electric switches, electrical valve-actuating means, and electromagnetic relays, each of said relays comprising an actuating solenoid and a control switch actuated thereby, each of said control switches having electrical means associated therewith for controlling operation of one of the electrical valve-actuating means; each of said relays being provided with a solenoid circuit that includes in series one of the detector-operated electric switches, the actuating solenoid of such relay, and means for preventing closure of such solenoid circuit in response to any of the other relays being actuated by their respective solenoids; a further electrical valve-actuating means, and means for controlling the last-mentioned means upon all of said detector-operated electric switches being open.

15. In fluid storage control apparatus, an equal number of detector-operated electric switches, electrical valve-actuating means, and electromagnetic relays, each of said relays comprising an actuating solenoid and a control switch actuated thereby, each of said control switches having electrical means associated therewith for controlling operation of one of the electrical valve-actuating means; each of said relays being provided with a solenoid circuit that includes in series one of the detector-operated electric switches, the actuating solenoid of such relay, and means for preventing closure of such solenoid circuit in response to any of the other relays being actuated by their respective solenoids; at least all but one of said relays being provided with time-delay means, each of said time-delay means having a different time-delay value, a further electrical valve-actuating means, and means for controlling the last-mentioned means upon all of said detector-operated electric switches being open.

16. In a fluid storage system, a plurality of storage vessels, each of said vessels being provided with an inlet valve and electrical means for controlling such valve, an electric switch and means for opening such switch upon the vessel being filled to a predetermined extent, and an electromagnetic relay including an actuating solenoid in series with the electric switch and a control switch operatively associated with said electrical means, and each of said relays including means effective upon actuation thereof for preventing energization of the other relays.

17. In a fluid storage system, a plurality of storage vessels, each of said vessels being provided with an inlet valve and electrical means for controlling such valve, each of said vessels also being provided with an electric switch and means for opening such switch upon the vessel being filled to a predetermined extent, each of said vessels also being provided with an outlet valve and a further electric switch arranged to open and close with such outlet valve, an electromagnetic relay associated with each of said vessels, said relays each including an actuating solenoid and a control switch operatively associated with one of said electrical means, and the solenoid of each of said relays being in electrical series with one of said electric switches and one of said further electric switches.

18. In a fluid storage system, a plurality of storage vessels, each of said vessels being provided with an inlet valve and electrical means for controlling such valve, each of said vessels also being provided with an electric switch and means for opening such switch upon the vessel being filled to a predetermined extent, an electromagnetic relay associated with each of said vessels, said relays each including an actuating solenoid and a control switch, each of said relays including means effective upon actuation thereof for preventing energization of the other relays, said control switch of each of said relays being in electrical series with one of said electrical means, and said solenoid of each of the relays being in electrical series with one of said electric switches.

19. In a fluid storage system, a plurality of storage vessels, each of said vessels being provided with an inlet valve and electrical means for controlling such valve, each of said vessels also being provided with an electric switch and means for opening such switch upon the vessel being filled to a predetermined extent, an electromagnetic relay associated with each of said vessels, said relays being electrically-interlocked and each including an actuating solenoid that is in series with one of the electric switches, each of said relays also including a control switch actuated by the solenoid thereof, and means including an electromagnetic relay operatively connecting each of said control switches to one of said electrical means.

20. In a fluid storage system, a plurality of storage vessels, each of said vessels being provided with an inlet valve and electrical means for controlling such valve, each of said vessels also being provided with an electric switch and means for opening such switch upon the vessel being filled to a predetermined extent, an electromagnetic relay associated with each of said vessels, said relays each including an actuating solenoid and a control switch operatively associated with one of said electrical means, means effective upon actuation of any one relay to prevent energization of the other relays, at least all but one of said relays being provided with time-delay means, each of said time-delay means having a different time-delay value, and the solenoid of each of said relays being in electrical series with one of said electric switches.

21. In a fluid storage system, a plurality of storage vessels, each of said vessels being provided with an inlet valve and electrical means for controlling such valve, a further valve for controlling the supply of fluid to said inlet valves, further electrical means for controlling said further valve, each of said vessels also being provided with an electric switch and means for opening such switch upon the vessel being filled to a predetermined extent, an electromagnetic relay associated with each of said vessels, said relays being electrically-interlocked for preventing concurrent actuation of two relays and each including an actuating solenoid and a control switch operatively associated with one of said electrical means, the solenoid of each of said relays being in electrical series with one of said electric switches,

and means for actuating said further electrical means upon all of said electric switches being open.

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