

[54] **SEQUENCE CONTROL OF COLOR CHANGE**

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222/144.5; 137/238, 240, 244

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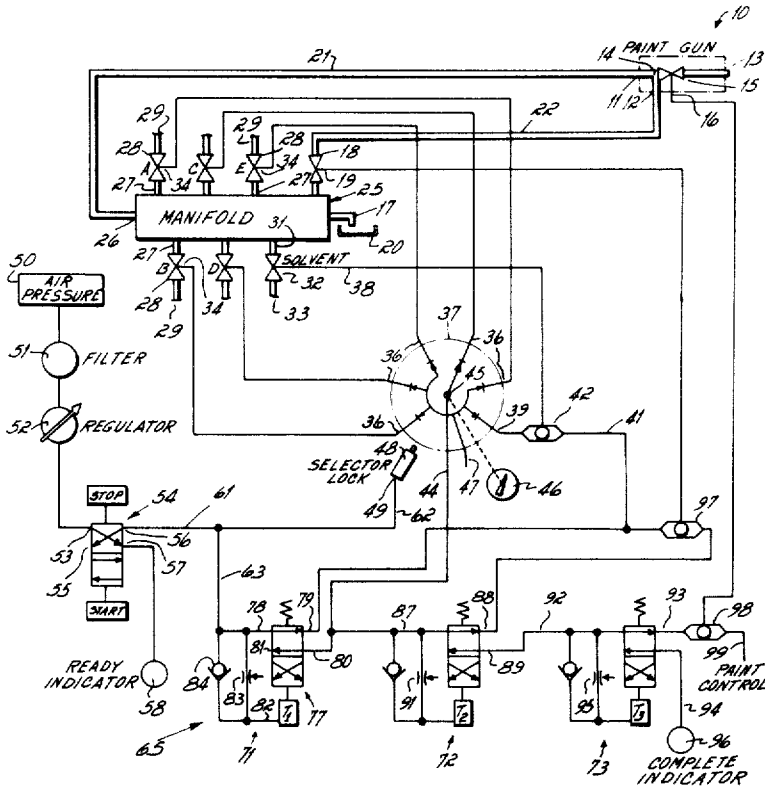
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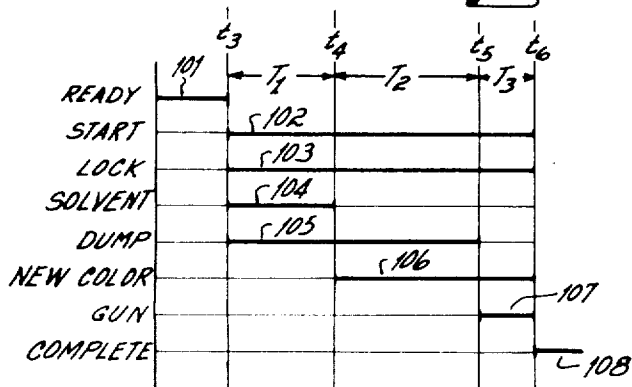
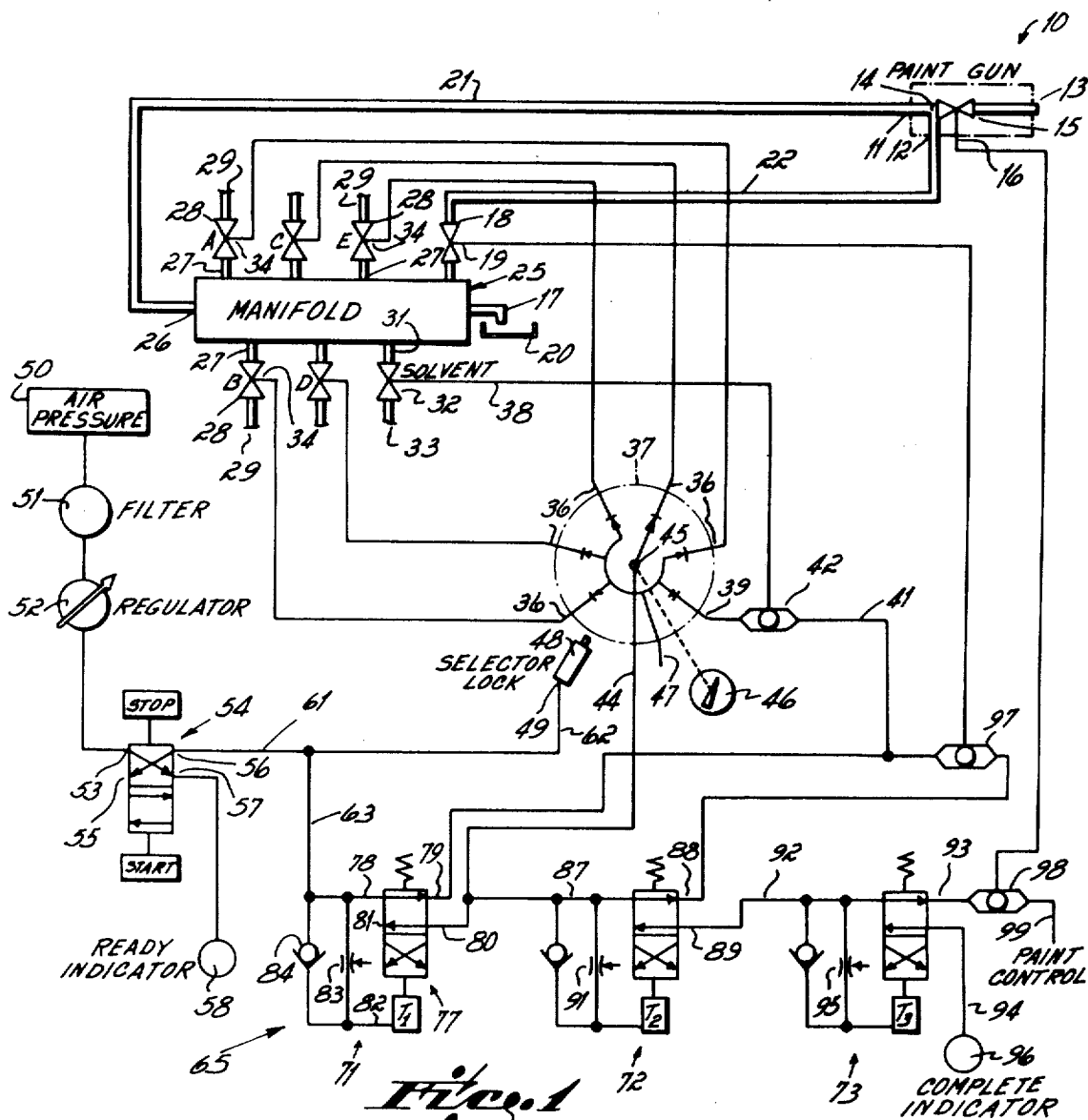
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[57] **ABSTRACT**

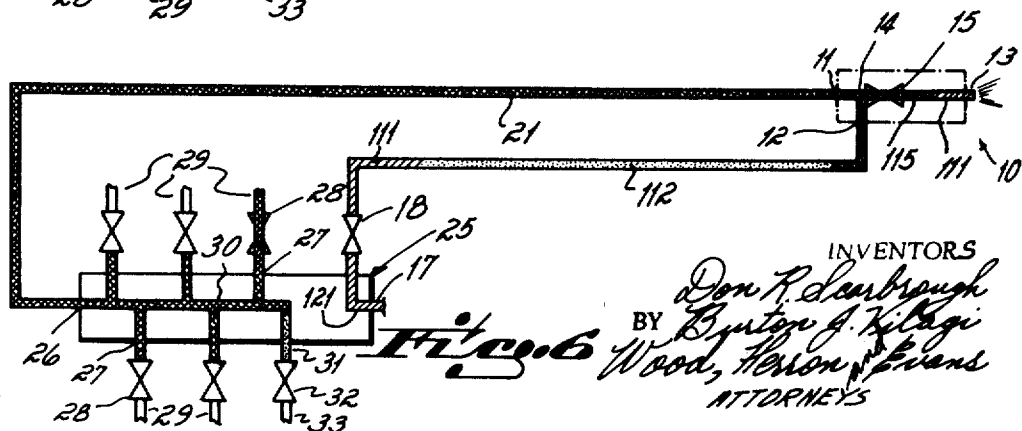
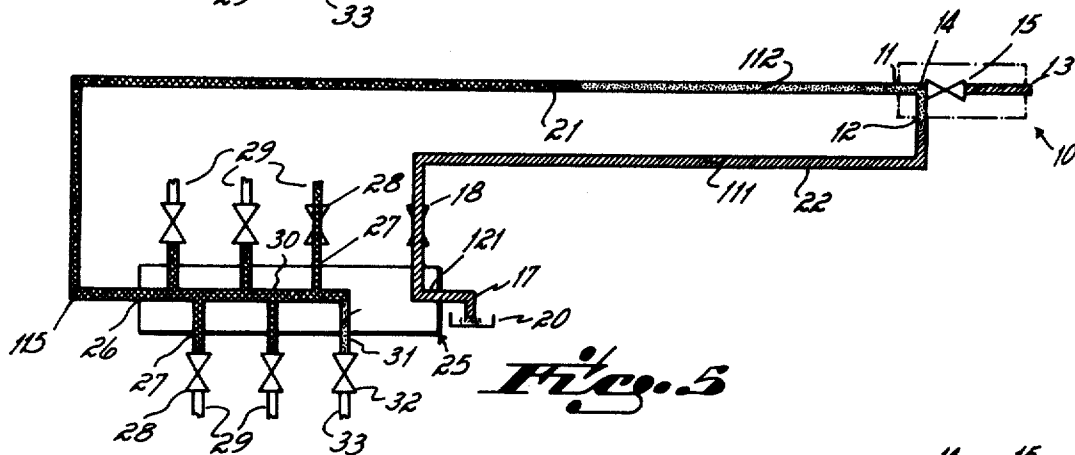
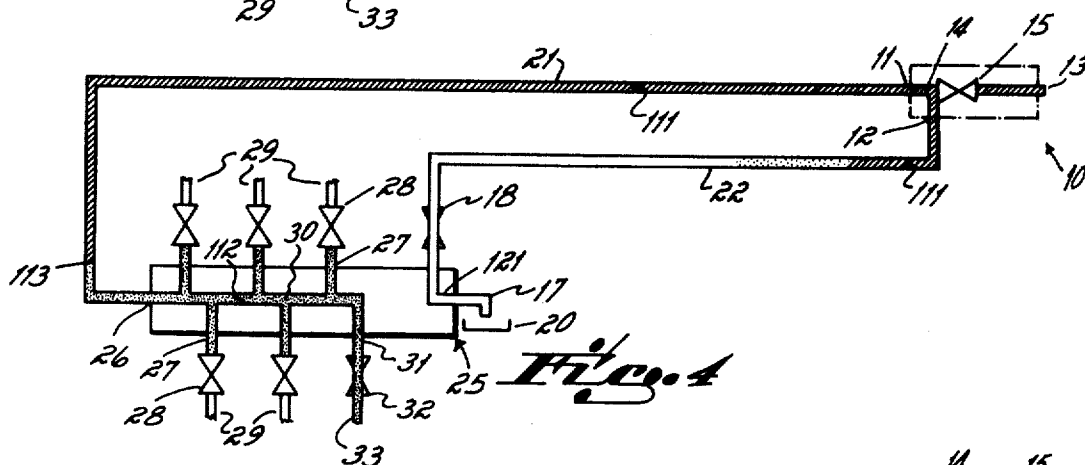
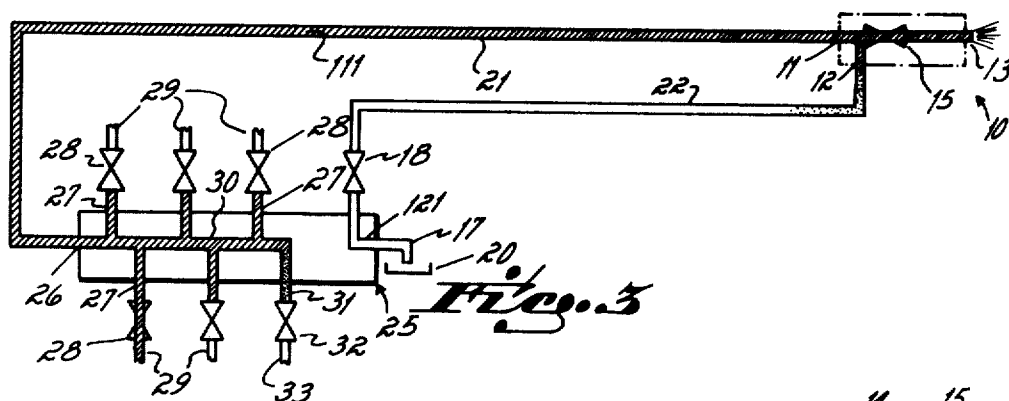
A pneumatically controlled color change system for use with automatic multi-color paint spray apparatus and the like wherein an entirely pneumatically controlled system employing a pneumatic timer including pneumatic sequence valves controls a quick-color change system in which a plurality of colors of paint are connected to various inputs of a manifold, each through a check valve which isolates each of the manifold ports from each other and in which a source of solvent is connected to another input of the manifold. An exceedingly high-speed system is provided in which a metered charge of solvent only partially filling the system is injected through the manifold and forced through the system with the new color to be selected, thereby purging the system of the old color. High-speed valve timing is provided in the order of magnitude of 1 second per valve of the sequence.

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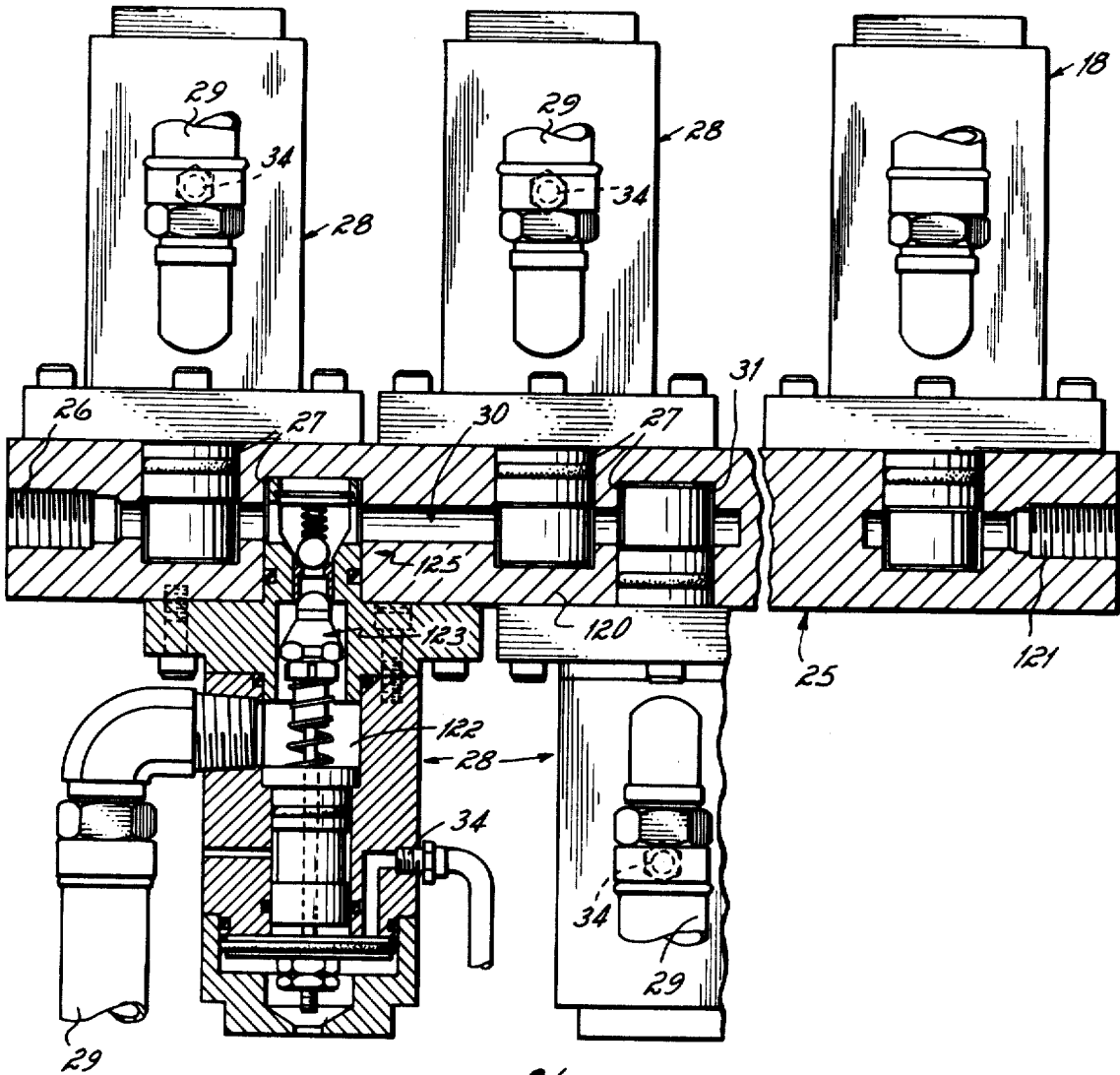


Fig. 7

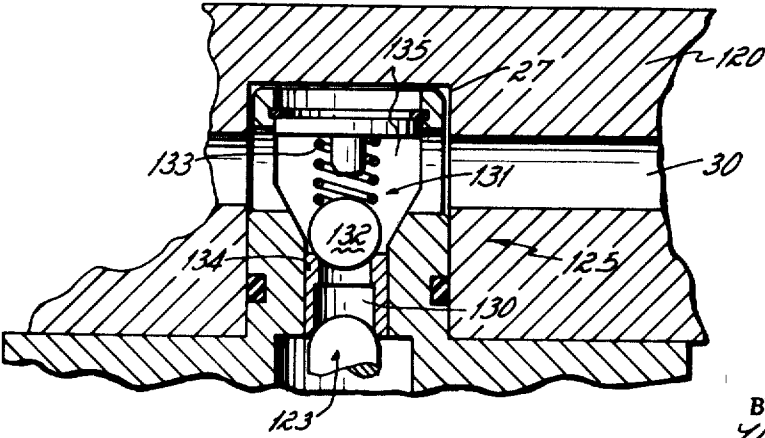


Fig. 8

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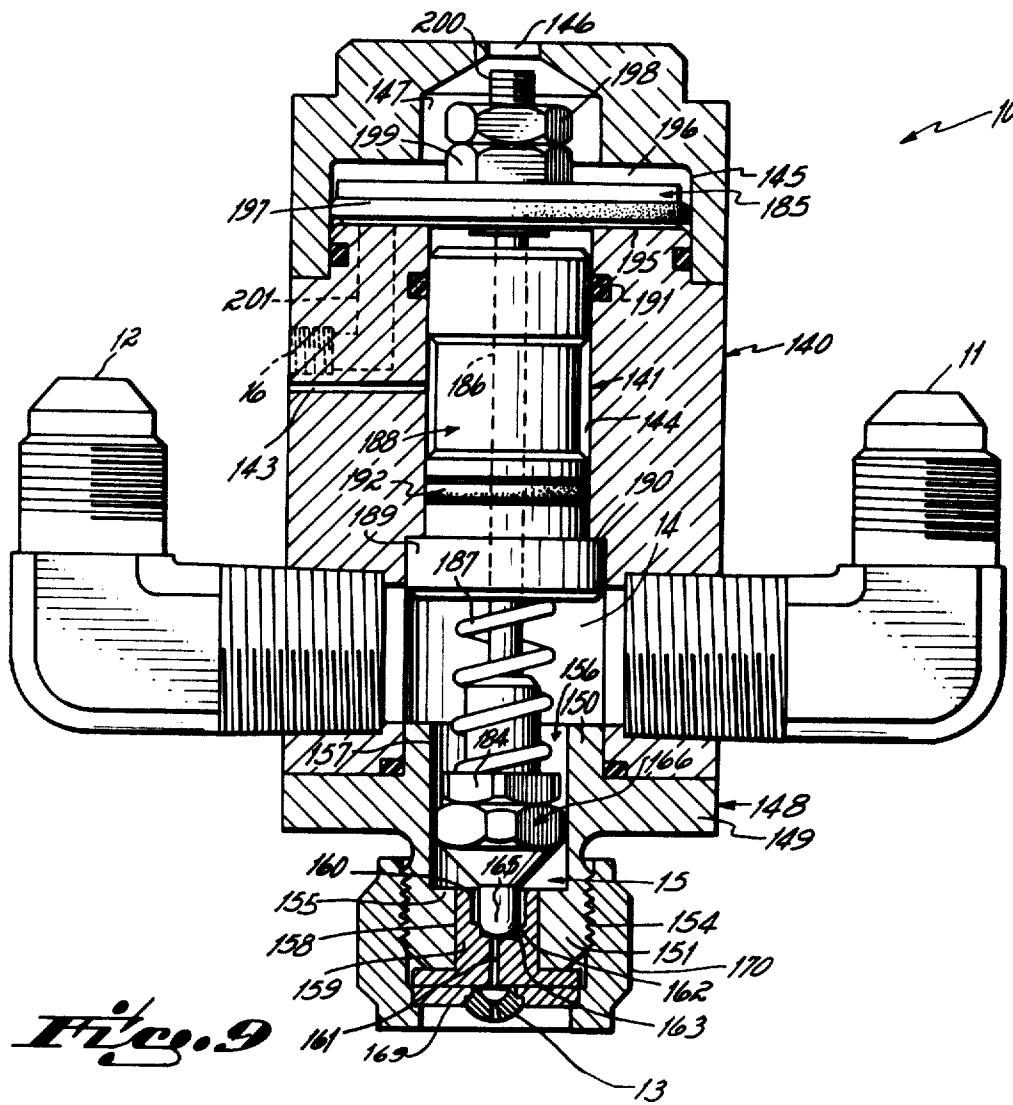


Fig. 9

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SEQUENCE CONTROL OF COLOR CHANGE

The present invention relates to a quick-change system for use with a single gun operable to selectively discharge different coating liquids, such as paints of different color, or varnishes, waxes, protective coating materials or other surface treating liquids upon a substrate. More particularly, the present invention relates to a quick-color change system in which the paint is sprayed or discharged from the nozzle, and deposited upon a substrate or object to be painted. The present invention is specifically directed to such a quick-change spray system for changing from one liquid to another without the previously used old liquid contaminating the new liquid when it is sprayed.

The increased use of automated painting and coating apparatus such as in assembly lines on automobile plants, or a series of objects to be painted or otherwise coated pass a paint station, and in which these objects typically require the applications of different coatings and colors, have resulted in an increased demand for multiple color paint spray systems. While systems have been proposed utilizing a separate apparatus having a separate nozzle for each of the colors or coating liquids to be sprayed, such systems are cumbersome and unduly expensive. The utility of systems wherein a single apparatus having a single discharge nozzle, or single set of nozzles as the requirement may be, for spraying the plurality of coating liquids one at a time, has resided in the ability of the color change system to change from one color to another quickly with a minimum waste of paint and solvent. Typically, these systems employ a manifold to which the plurality of coating liquids is connected and through which one of the plurality of coating liquids is selectively connected to the coating apparatus. When changing from one coating liquid to another, it is necessary to purge the manifold, the feed line connecting the manifold to the apparatus, and the apparatus itself of the old coating liquid prior to the injection of a new coating liquid. Commonly, the solvent material is injected into the system to force the old liquid out of the system through a dump valve and to flush the system of the old coating liquid. A common method employed by the prior art systems have been to manually cause the solvent to be injected into the system and to visually observe a clean solvent being exhausted through the dump valve. Then, either air is injected into the system to purge the system of the solvent, or the new coating liquid is injected to push ahead of it the solvent from the system. These systems of the prior art have consumed much valuable time and wasted a great deal of paint and solvent in changing color in this manner. Indeed, in automotive paint lines, where each of the objects is to be painted a different color, the waste of time and paint can be a major cost factor.

Furthermore, automated systems of the prior art rely principally upon valves controlled by electrical solenoids to automatically sequence a change cycle. Since such systems are almost always used in a highly explosive atmosphere, these electrical control systems have been encased in sealed, armored explosion-proof cabinets. In many cases, the cabinets have been installed at greater cost than the systems themselves. Another disadvantage of such explosion-proofing has been the requirement that the entire system be shut down whenever any maintenance is required upon the system, even minor maintenance, for the explosion-proof cabinet had to be opened to allow such maintenance to proceed.

Accordingly, it has been the principal object of the present invention to provide an explosion-hazard-free control system which uses entirely fluid-controlled valves and fluid-controlled timing circuits to operate the valves. Another object of the present invention has been to provide a change system which operates faster than comparable systems of the prior art, typically in the order of 1 to 5 seconds in situations where prior art systems have required 25 seconds and above; and generally not more than 20 seconds for a complete change cycle in some of the more special application systems which utilize high viscosity liquids, very long lines or lower pressure, in which systems the prior art devices have typically required a minute or longer for such a change.

Accordingly, the present invention is predicated in part upon the concept of providing an all-fluid-controlled valve system which is controlled entirely through the use of a fluid control circuit which includes a fluid-operated timing circuit for controlling the sequencing of the valves during a liquid change cycle. More particularly, the present invention provides a fluid control system employing variable time delay pneumatic sequence valves which deliver control pressure from a variable control pressure source to operate the liquid flow control valves in a programmed color change sequence.

The present invention is also predicated in part upon the concept of injecting a metered slug of solvent into the lines of the system, the slug being only long enough to purge the system of the old color, and then forcing the slug through the system with the new coating liquid to be applied. Furthermore, the present invention employs valve opening times in order of magnitude of 1 second each.

Furthermore, the present invention employs a novel manifold arrangement wherein each of the input ports of the manifold includes a double-check valve arrangement. More particularly, one of the check valves of this double-check valve arrangement is the remote control valve which connects the particular liquid to the system, and the other is a check valve which isolates from the manifold all but a small region in the path of the solvent passing through the manifold and thereby presents an area easily flushed of the solvent. The advantage of this manifold arrangement is that it is easily and quickly cleaned or flushed of one liquid preparatory to the introduction of another.

The primary advantages of the present invention reside in the provision for an automatic, quick-change system which is completely safe for use in an explosive environment without the need for expensive explosion-proof cabinets and the impairment for servicing during operation which they entail. An additional important advantage is in the provision for high-speed paint change system, wherein the complete change from one coating liquid to another in an airless system takes the time of typically 4 to 10 seconds. A further advantage resides in the variable timer of such a system so that the times of the various steps of the cycle can be varied either independently or collectively to account for different types and viscosities of coating liquids. Another advantage is that it substantially reduces any wasted paint and solvent which results from the use of this liquid change apparatus.

Other advantages of the present invention which will be more readily apparent from the detailed description of the present invention reside in the provisions for positive interlocking sequencing of the quick-change system, manual emergency shut-off of the system, a system which is essentially the same regardless of the number of colors or different coating liquids to be used, and a system which can be constructed virtually from standard components.

Other objects and advantages of the present invention will be more readily apparent from the following detailed description of the drawings illustrating one preferred form of a quick change system according to the present invention in which:

FIG. 1 is a fluid control diagram of a quick change system according to the present invention;

FIG. 2 is a timing diagram of the operation of the system of FIG. 1;

FIGS. 3-6 are diagrams of the system of FIG. 1 illustrating the states of the different coating liquids and solvent at the different times illustrated at t_1 - t_6 in FIG. 2;

FIG. 7 is a partial cut-away view of the coating liquid and solvent distribution manifold;

FIG. 8 is an enlarged cross-sectional view of the double check valve at an input port of the manifold of FIG. 7; and,

FIG. 9 is a cross-sectional view of a coating liquid discharge gun.

Referring to the system diagram of FIG. 1, a quick change system according to one of the principles of the present invention includes a paint discharge gun 10 which is of the circulating type, that is, it includes three ports, including an input port 11 through which paint enters the gun, and outlet port 12

through which paint exits that particular gun, and a nozzle 13 through which paint or other coating material is sprayed upon a substrate to be coated.

The gun includes an internal passage 14 which communicates with the input and exhaust ports directly, and also communicates with the nozzle 13 through a trigger valve 15. The trigger valve 15 is typically lever-operated when the gun is a hand-held type. In the embodiment shown, however, the gun 15 is remotely controlled through the application of control pressure to the pilot port 16. This form is preferred when the gun is either fixedly or movably mounted upon a support such as might be found adjacent a paint line in an automobile assembly plant. An outlet line 17 is connected through a dump valve 18 to a return line 22 which communicates with the exhaust port 12 of the gun 10. The dump valve operates in response to control pressure at the pilot port 19 to open the exhaust line 17 to allow paint to be purged from the gun 10 and drained into a scrap drum 20. The dump valve 18 is normally closed to block the exhaust line 17 in the absence of control pressure at the pilot port 19.

Paint is supplied to the gun 10 through a feed line 21 which is connected to the input port 11 of the gun 10. Whereas the gun 10 is preferably of the circulating type as herein described in order that the maximum amount of trapped old paint can be purged from the system through the outlet port rather than the nozzle, it is within certain of the broader concepts of the present invention to operate without such a circulating gun. In such cases, it is preferable that a T be incorporated and connected to the feed line at some point prior to the input 11 of the gun 10 and preferably as close thereto as possible. A return line, external of the gun, is then connected between the T and the dump valve.

The selected color of paint or coating liquid is supplied to the gun through a manifold 25. The manifold has an output port 26 which connects to the feed line 21, and a plurality of input ports 27 each connecting through a shut-off valve 28 to any one of a plurality of lines 29 which are connected to various sources of coating liquid.

The manifold 25 has therein an elongated passage or through-port 30 (FIGS. 3-7) which communicates each input port 27 with the output port 26. The manifold also includes an input port 31 which is connected through a cut-off valve 32 to line 33 which is connected to a source of pressurized solvent. The input port 31 communicates with the passage 30 at a point which is the most remote from the output 26 of the manifold. Thus the input ports 27 communicate with the passage 30 at points intermediate the solvent input port 31 and the output port 26 so that the solvent when passed by valve 32, can most effectively flush the manifold 30 clear of the old coating liquid of the previous application prior to subsequent application of a different coating liquid.

The pressure of the sources of coating liquid connected to the source lines 29 is typically 200 to 1,000 psi for spray systems of the airless type, and is typically 3-75 psi for systems of the air spray type. An airless system is one in which paint is sprayed at high pressure and atomized solely by forcing the high pressure liquid through the nozzle of a paint spray gun. In an air system, the liquid is injected as an extruded stream at low pressure into a stream of high pressure air which causes it to atomize. The present invention can operate with either system, but in the preferred embodiment shown, the airless system is employed with source pressures of approximately 500 psi.

Each of the coating liquid valve 28 and the solvent valve 32 are normally closed. The coating liquid valves 28 are opened in response to control pressure at their pilot ports 34, and the solvent valve 32 is opened in response to control pressure at its pilot port 38. Each of the pilot ports 34 of the liquid coating valves 28 connect to the output ports 36 of a rotary selector valve 37. The pilot port 38 of solvent valve 32 is connected to an output 39 of the selector switch 37 to allow for selection of the solvent as one of the coating liquids. As is described in more detail below, the solvent valve 32, is however, also

operated under the control of a timing circuit which applies control pressure through a control line 41. The selector switch output 39 and the line 41 are alternately connected to the pilot port 38 of the solvent valve 32 through the shuttle valve 42.

The selector 37 also has an input port 44 which is selectively connectable to any one of the output ports 36 or 39 through the manually movable spool 45 which is controlled either by the dial 46 or automatically through a programmer (not shown) to select new coating materials. The ports 36 which are not connected to the input port 44 are normally connected to an exhaust port 47 at atmospheric pressure. A fluid pressure responsive selector lock 48 is provided to lock the spool 45 of the selector valve 37 and thereby prevent a change in selection while an automatic change cycle is in progress.

The automatic control and timing circuit is entirely a pneumatically-controlled system in which the source of control pressure is supplied from an air pressure source 50. The control pressure is normally maintained at approximately 40-70 psi. The air pressure source 50 connects through a filter 51 and a variable air pressure regulator 52 to the input port 53 of a manually actuatable four-way valve 54. The valve 54 is the main control valve which provides for the manual starting and stopping of the color change cycle. The valve 54, however, could also be automatically controlled by a programmer, for example, if the present invention were used as part of a completely automated painting process. The valve 54 has an exhaust or drain port 55 and a pair of output ports 56 and 57. When the valve is in its de-actuated condition, the port 57 is normally connected to the pressure input port 53 to communicate a ready signal to a pressure responsive indicator 58, while the output port 56 is connected to exhaust port 55. This removes pressure from the control circuit, and, because all valves are normally closed, the change system is at this time disabled. The valve 54 has a manual override to utilize this feature for emergency cut off of the system. When the valve 53 is actuated the output port 56 communicates with the input port 53 thereby opening the pressure path through the valve 54 to a line 61 connected to the output port 56 to initiate the change cycle. Line 61 is connected through a line 62 to the pilot port 49 of the pneumatically controlled selector lock 48 to energize the lock 48 and lock the selector switch 37. The line 61 is also connected through line 63 to the pneumatic timing circuit illustrated generally at 65.

The timing circuit 65 is an entirely pneumatically controlled timing circuit for generating a series of timed-delayed control signals. The timing circuit 65 employs sequence valves or series-connected timed-delay valves which actuate at some delayed time after pressure is applied to their input terminals. The specific circuit illustrated employs three such valves, 71, 72, and 73, however, more or less than three could be employed as will be explained more fully below. Each of the valves 71 and 73 are substantially identical and will be explained here by reference to valve 71.

The first timing valve 71 includes a four-way valve 77, having an input port 78 and a pair of ports 79 and 80. The output port 79 is a normal through-port of the valve while the second output port 80 is normally connected to an exhaust port 81. When the valve is actuated, the output ports are reverse connected and the first output 79 is connected to the exhaust port 81 while the second output port 80 is connected to the input port 78. The valve 77 actuates in response to control pressure of a certain predetermined level at a pilot port 82. The pilot port 82 is connected through a variable restriction valve 83 to the input ports 78. The restriction valve 83 serves to impede the flow to the pilot port 82 thereby delaying the time at which the predetermined pressure required to actuate the valve is attained at the pilot port 82. This time delay can be variably controlled by the setting of the valve 83. It should also be noted, that the actual time delay is also dependent upon the setting of the pressure regulator 52. Setting the valve 83 varies the delay time of valve 81 independently of other valves in the circuit, while setting the regulator 52 varies the response of all

valves of the circuit by approximately the same factor. A check valve 84 is provided to quickly release the pressure on the pilot port 82 when the pressure on the input port 78 is removed. Thus, when pressure is applied to the input port 78 by the opening of the main valve 54, a control pressure signal is present at the output 79. After a certain time delay determined by the setting of the restriction valve 83, the four-way valve 77 is actuated and pressure on line 79 is removed and applied to port 80.

In like manner valve 72 has an input port 87, first output port 88 and a second output port 89. The input 87 is connected to the output port 80 of the valve 71. The valve 72 includes a variable restriction valve 91, which determines the time delay constant of the valve 72. Thus, when the valve 71 is actuated, a control pressure signal appears at port 88, and after a predetermined time delay determined by the setting of the valve 91, the signal is removed from the port 88 and transferred to the port 89.

Similarly, the valve 73 includes an input port 92 connected to the second output port 89 of the valve 72, and a first output port 93 and the second output port 94. The valve 73 includes a variable restriction valve 95 which determines the time delay constant to the valve 73. Thus, after valve 72 is actuated, a control signal appears at port 93, and after a time delay determined by the setting of the valve 95, the signal is removed from the port 93 and transferred to port 94. Connected to port 94 is a pressure response indicator 96 which signals the completion of a change cycle.

The output port 79 of the valve 71 is connected to line 41 and through the shuttle valve 42 to the pilot port 38 of the solvent valve 32, and also through a shuttle valve 97 to the pilot port 19 of the dump valve 18. The output 80 of the valve 71 is connected to the input 44 of the selector valve 37. (This is equivalent to connecting the selector input 44 through a shuttle valve to ports 89 and 93 of the timer and this latter method would be preferred if an additional step were added to the system.) The output 88 of the valve 72 is connected through another port of the shuttle valve 97 to the pilot port 19 of the dump valve 18. The output 93 of the valve 73 is connected to a shuttle valve 98 to the pilot port 16 of the trigger valve 15 of the gun 10. Also connected through the shuttle valve 98 to the pilot port 16 of the trigger valve 15 is a control line 99 through which a signal is provided to operate the paint spray gun 10 during painting operations between change-cycles.

Briefly, the timing operation can be understood by reference to the timing diagram of FIG. 2. Prior to a change cycle, the main valve 54 is in the closed condition and the ready indicator is "ON" as illustrated by the curve 101 on the diagram. At some time t_0 the main valve is opened, as illustrated by curve 102. At this time control pressure is applied to energize the selector lock as illustrated by curve 103 and to open the solvent and dump valves as illustrated by curves 104 and 105. This initiates the time delay T_1 of the first of the sequence valves 71 at the end of which valve 71 is actuated at a time represented by t_1 in FIG. 2. At time t_1 the solvent valve is closed and the new color valve as selected by the setting of the selector valve 37 is opened as illustrated by curve 106.

At time t_1 control pressure is also removed from the pilot input 19 of the dump valve 18, however, this pressure is reapplied through the valve 72 and in practice this time is too short to result in a closing of the dump valve 18. After a time delay T_2 the valve 72 closes, and causes the dump valve 18 to close as shown by curve 105. This is illustrated at time t_2 in FIG. 2. At t_2 pressure is applied through the third of the timing valves 73 to momentarily open the trigger valve 15 for a period of time T_3 after which valve 73 closes, and time t_3 closing the new color valve, and the trigger valve, of the gun as shown by curve 106 and 107. Also at time t_3 the complete indicator is turned on as illustrated by curve 108 in FIG. 2 and the selector lock 48 is de-energized as illustrated by curve 103. At this point the main valve 54 can either be manually or automatically disengaged as the color change-cycle is complete.

The change-cycle can best be understood by reference to FIGS. 3 through 6 which illustrate the highly efficient manner in which the lines are only partially purged by the injection of solvent, and then finally purged of the old coating liquid 111 through the injection of the new coating 115 which pushes ahead of it a metered slug of solvent which clears the lines of the old material. With reference back to the timing diagram of FIG. 2, FIG. 3 illustrates the system prior to a change-cycle at time t_0 . It will be seen that the passage 30 of the manifold 25, the feed line 21, the passage 14 of the gun 10 and the nozzle 13 are filled with the old coating material 111 being supplied through valve 34-B.

Prior to the color change, the selector dial 46 of the selector valve 37 is set to the new paint color or coating liquid and the main valve 54 is actuated.

During this first step (FIG. 4) of the cycle, the solvent valve 32 and the dump valve 18 are opened, and the trigger valve 15 of the gun 10 is closed. This allows solvent to enter into the manifold passage 30 and to force the old paint through the dump valve 18 into the scrap drum 20. At time t_1 a slug of solvent 112 has entered the manifold passage 30 and proceeded partially down the length of the feed line 21 to point 113. The solvent slug 112 is not allowed to completely extend through the entire feed line 21 to purge the entire system since this is not necessary. Instead, only a slug of sufficient length to clear the passage 30 is employed. Typically about 2-5 feet of manifold passage and feed line would be filled with solvent. At this point and as shown in FIG. 5, the solvent valve 32 is closed and the new liquid valve 34-E is opened. The new liquid 115 is introduced into the manifold passage 30 and along the feed line 21 to advance the slug of solvent 112 as far as the juncture of the trigger valve 15 with the passage 14 of the gun 10. At this point it is still not necessary to completely purge the old liquid 111 from the exhaust line 17. The length of the slug 112 is sufficient to completely wash the line 21 of the old liquid. FIG. 5 illustrates the state of this system at time t_2 .

Referring to FIG. 6, the dump valve 18 is closed but the source valve 34-E remains open communicating the pressurized new color with the paint lines 21. At this time the trigger valve is opened and preferably the new paint color is fed through the nozzle, thereby discharging the old paint 111 which remains in the nozzle. In some applications, however, it may be desirable to eject a small amount of solvent through the nozzle to purge it of old paint. At time t_3 the trigger valve 15 closes and the system is ready for operation with the new color 115.

Referring back to FIG. 5, it will be noted that it is possible for a small amount of solvent to remain trapped in the manifold in the region 117. This solvent, however, is normally selected such that it is compatible with the coating and will diffuse and dissipate into the new liquid mixture without affecting the quality of the coating. As will be explained below, the manifold of this system has the particular advantage of minimizing the amount of this trapped solvent.

As mentioned above it is possible to operate this system with fewer or more timing valves than the three illustrated in FIG. 1. For example, where the hand-held gun is employed, the valve 73 is not required, in this case, the operator, merely by aiming the gun into the scrap drum and momentarily depressing a manual trigger can thereby expel the old liquid 111 from the nozzle into the drum. In other cases, it is sometimes desirable to employ more valves than three in situations where more steps are required. For example, when incompatible coating liquids are to be employed in consecutive steps, it may be desirable to produce a charge of air to purge the old paint from the system and through the exhaust line 17. It also may be required in such situations to employ different solvents and to separate the solvents by a charge of air. Occasionally, a strong solvent might be used which is incompatible with the coating liquid. This solvent would be injected in the same manner through the sequences illustrated of the FIG. 4, but then followed by a charge of air to expel the solvent through the exhaust line 17, which is then followed by the new coating liquid.

Referring more particularly to the details of the manifold 25, this is best illustrated by reference to FIG. 7. The manifold 25 includes a housing 120 having the through port or central passage 30 extending substantially therethrough. The output port 26 is provided in one end of the passage 30 and the solvent input port 31 is provided adjacent the innermost end. Intermediate these extreme ends the plurality of input ports 27 are connected to passage 30, each connecting through one of the coating liquid valves 28 through lines 29 to corresponding coating liquid sources. The solvent input port 31 connects through the solvent input valve 32 to the solvent source line 33 which is connected to a solvent source. The dump valve 18 is also physically mounted on the manifold housing 120 and connects through a passage 121 therein to the exhaust line 17. The passage 121 is, however, completely isolated hydraulically from the passage 30.

In one embodiment, each of the valves 18, 28 and the valve 32 may be identical and hence only one valve 28 is illustrated in the cut-away portion of the drawing (FIG. 7). However, in a preferred embodiment for many applications, the valves 28 are of the circulating type and each will be identical to that illustrated for the trigger valve 15 of the gun 10 in FIG. 9. The dump valve 18, however, and the solvent valve 32, are usually non-circulating even in this preferred embodiment. An example of such a circulating type system is completely illustrated and disclosed in U.S. Pat. No. 2,754,228 of Bede, issued July 10, 1966. As noted above, the valve includes the input line 29 which communicates with an internal passage 122. The passage 122 communicates through a pneumatically controlled check valve 123 to the input 27 of the manifold. Control pressure for opening the check valve 123 is supplied through the pilot port 34. The details of the source valves 28 and 32 are identical to the details of the operating mechanism of the trigger valve 15 of the gun 10 and will be explained in more detail in conjunction with the description of the trigger valve of the FIG. 9.

The check valve 123 forms one of the check valves of a double-check valve assembly 125. This check valve arrangement prevents back flow of the coating liquid or solvent and thereby prevents contamination of one liquid coating with another. The valve also presents a minimum washing area for the solvent to purge of coating material. The valve 125 is more clearly illustrated in the cross-section view of FIG. 8. The valve 125 comprises a narrow throat 130 adjacent the check valve 123. A check valve 131 is provided in a close relation to the check valve 123 and also adjacent the throat 130 opposite the check valve 123. The check valve 131 is a passive check valve operating entirely by the pressure of the paint from the source through the valve 123. The valve 131 includes a ball or check 132 urged by a spring 133 against the rim of the walls 134 of the throat section 130. The check valve 131 presents only a small surface area 135 which lies directly in the path of the passage 30 and is easily washed by the solvent as it passes through the passage 30.

Referring to FIG. 9, a paint spray gun is illustrated. The gun is generally a recirculating airless-type having an input port 11, and outlet port 12 and a nozzle 13. The nozzle is operated by a trigger valve 15 in response to control pressure at the pilot port 16 to connect the nozzle with the internal passage 14 of the gun 10. While an airless spray nozzle 13 is illustrated, a typical use of the system of the present invention is contemplated to be in conjunction with an electrostatic spray gun having a nozzle extension which will typically project several times a length of the nozzle 13 as illustrated.

As it will be seen from FIG. 9, the gun 10 generally comprises a two-piece square body 140 within which there is an axial or central bore 141. This bore comprises the internal passage or fluid chamber 14 adjacent the front end of the body, a smaller diameter connecting chamber 144 and a large diameter piston chamber 145. The chamber 144 is connected to atmosphere through a bleed port 143. The rear side of the piston chamber 145 is opened to the atmosphere through a small diameter section 146 of the bore 141 which is connected to the piston chamber 145 via an intermediate diameter

chamber 147. An end cap 148 is secured to the body by bolts (not shown) and closes the fluid chamber 14. The cap 148 comprises a central plate 149 from which hub sections 150, 151 extend rearwardly and forwardly, respectively. The rearward hub 150 fits within, and with an O-ring, seals the fluid chamber 14. The forwardly extending hub section 151 is threaded on its exterior as indicated at 154 and has an inwardly extending flange 155. An axial bore 156 extends through the cap 148. It comprises a large diameter rear section 157 and a smaller diameter front section 158.

A cylindrical metal insert 159 made from a hard material, as for example, tungsten carbide, is inserted within the small diameter section 158 of the cap. This insert defines the seat of the check valve 15. It has a stepped axial bore which comprises a large diameter rearward section 160 and a small diameter passage 161 interconnected by a shoulder 162. An arcuate seat 163 is machined into the shoulder at the point where the shoulder 162 joins the small bore 161. The seat is configured as an annular taper so as to cooperate with a generally semi-spherical end 165 of the check valve head 166 to form a seal.

The nozzle 13 is made of a hard material and is welded to a nozzle mounting disc 169. A retaining nut 170 is threaded onto the externally threaded section 154 of the hub 151. This retaining nut secures the disc 169, which carries the spray nozzle 13, against the hub 151 of cap 148.

It will be seen that the check valve head 166 is controlled in its movement into and out of engagement with the check valve seat 163 by the pneumatic piston 185. This piston 185 is connected to the head end of the check valve by a connecting rod 186. A conventional threaded coupling and lock nut 184 enable the rod 186 to be adjusted in length relative to the head 166. A compression spring 187 normally biases the head and connected piston rod 186 toward the nozzle to a position in which the check valve 15 is seated or closed. This spring 187 bears at one end against the nut 184 and at the opposite end against a collar 188 which is fixedly seated in the chamber 144 of bore 141 and has a shoulder or flange 189 seated against a shoulder 190 of the bore 141. O-rings 191 and 192 seal the liquid chamber 14 from the pneumatic chamber 145, and vice versa. The forward end 195 of the piston chamber 145 is also sealed from the rear portion 196 by a pneumatic seal 197 located around the periphery of the piston 185. The piston is secured onto the end of the rod 186 by a pair of lock nuts 198 and 199 threaded onto the threaded innermost end 200 of the rod 186. Air under regulated pressure, e.g., approximately 60 psi is supplied to the inner chamber 195 of the piston chamber 145 from the pilot port 16 via a connecting passage 210 in the body 140 of the gun 10.

The primary advantage of this invention over quick-change color spray systems now being used commercially is that it eliminates all use of electrical solenoid-controlled valves and control circuits and thereby avoids the hazard of an electrically initiated explosion. By eliminating all electronic sequencing and control there is no longer any need to explosion-proof the area in which the paint is sprayed and the gun is utilized.

Another advantage of this invention is the positive sequencing which results from the pneumatic sequencing control valves. In the event that one valve stops or jams, it automatically stops the complete cycle, thereby insuring a properly sequenced cycle or none at all.

Another advantage of this invention resides in its quick cycle time and the fact that it operates in approximately one-fourth to one-tenth the cycle time of quick-change color systems now in commercial use. Because it is so much faster than systems in present use, it results in less wasted paint being dumped to scrap and less solvent being utilized to purge the system during color changes.

While only a single preferred embodiment of the invention is described, those persons skilled in the art to which this invention pertains will readily appreciate numerous changes and modifications which may be made without departing from the

spirit of the invention. For example, it will sometimes be desired to incorporate certain of the features and advantages derived from the fluid operated control aspects of the present invention while omitting the automatic sequencing feature. In such a case, the flow control valves can be provided with independently actuatable fluid control valves which may be, for example, manually actuatable pneumatic remote control valves connected through control lines to the pilot ports of the flow control valves mounted on the manifold or to the trigger-check valves of the gun. Therefore, the present application is not intended to be limited except by the scope of the appended claims.

What is claimed is:

1. An automatic quick-change system for replacing an old coating liquid with a new coating liquid in an apparatus for selectively depositing a coating liquid on a sub-strate, said system comprising:

a. a discharge gun having an input port, an exhaust port, a passage therein communicating with said input and exhaust ports, a nozzle, a check valve connected between said passage and said nozzle for connecting said nozzle to said passage when said check valve is opened;

b. an exhaust line;

c. a fluid-controlled dump valve having a pilot port and connected between said gun exhaust port and said exhaust line for connecting said gun exhaust port to said exhaust line in response to control pressure at said dump valve pilot port;

d. a manifold having an output port, a solvent input port, an elongated passage therein communicating with said output port and said solvent port, and a plurality of coating liquid input ports communicating with said manifold passage intermediate said output and said solvent input ports;

e. a feed line connected between said manifold output port and said gun input port;

f. a source of pressurized solvent;

g. a fluid-controlled solvent valve having a pilot port and connected between said solvent source and said solvent input port of said manifold for connecting said solvent source to said manifold input port in response to control pressure at said solvent valve pilot port;

h. a plurality of sources of different pressurized coating liquids;

i. a plurality of fluid-controlled coating liquid valves each having a pilot port and each connected to a different one of said coating liquid sources and a different one at said one of said sources with said one of said ports in response to control pressure at said coating liquid valve pilot port;

j. a fluid control circuit including:

1. a source of pressurized control fluid,

2. a fluid timing circuit,

3. a variable pressure regulator connected between said control pressure source and said timing circuit,

4. a main valve connected between said regulator and said timing circuit for opening and closing a path therebetween,

5. a selector valve having a plurality of output ports each connected to the pilot port of a different one of said coating liquid valves, an input port selectively connectable to any one of said output ports for selecting said new coating liquid,

6. said timer comprising a plurality of fluid-actuated timing valves connected in sequence, each of said valves having

a. a first output port, a second output port, a pilot port, and an input port normally connected to said first output port and alternatively connectable to said second output port in response to control pressure at said pilot port,

b. a variable restriction valve connected between said timing valve input port and said pilot port for com-

municating control pressure to said pilot port at some delayed time after pressure is applied to said input port, said delay time being variable by the combined settings of said restriction valve and said regulator,

c. said plurality of timing valves including:

1. first fluid-controlled timing valve having its input port communicating with the output port of said main valve, its first output port communicating with the pilot port of said solvent valve and with the pilot port of said dump valve, and its second output port communicating with the input port of said selector valve for communicating control pressure to said pilot ports in accordance with the positions of said first timing valve and said main valve,

2. a second fluid-controlled timing valve having its input port communicating with the second output port of said first valve, its first output port communicating with the pilot port of said dump valve for communicating control pressure to said pilot port in accordance with the positions of said first and second timing valves and said main valve.

2. A pneumatically controlled system according to claim 1 wherein:

said fluid control circuit is a pneumatic control circuit, said source of pressurized control fluid being a source of pressurized air, and said fluid timing circuit being a pneumatic timing circuit.

3. A system according to claim 1 wherein said manifold further comprises:

a plurality of double-check valves, one connected in each of the input ports of said manifold, each including a pair of opposed check valves, one of the valves of said pair being said source control valve.

4. A system according to claim 1 wherein said selector valve further comprises:

a pneumatically controlled selector lock having a pilot port connected to the output of said main valve to lock said selector when said valve is open.

5. A system according to claim 1 wherein:

said first timing valve has a time delay of T_1 , T_1 being sufficiently long to allow solvent to flow into said manifold but shorter than the time required for solvent to flow to said gun, for introducing a slug of solvent into said line; and said second timing valve has a time delay of T_2 , (T_1 plus T_2) being sufficiently long to allow the new coating liquid to flow into said manifold to force some of said solvent into said gun passage, but shorter than the time required to force all of said solvent out of said exhaust line.

6. An automatic quick-change system for replacing an old coating liquid with a new coating liquid in an apparatus for depositing a coating liquid on a sub-stratum, said system comprising:

a. a discharge gun having an input port, an exhaust port, a passage therein communicating with said input and exhaust ports, a nozzle, a fluid-controlled check valve having a pilot port and connected between said passage and said nozzle for connecting said nozzle to said passage in response to control pressure at said check valve pilot port;

b. an exhaust line;

c. a fluid-controlled dump valve having a pilot port and connected between said gun exhaust port and said exhaust line for connecting said gun exhaust port to said exhaust line in response to control pressure at said dump valve pilot port;

d. a manifold having an output port, a solvent input port, an elongated passage therein communicating with said output port and said solvent port, and a plurality of coating liquid input ports communicating with said manifold passage intermediate said output and said solvent input ports;

- e. a feed line connected between said manifold output port and said gun input port;
- f. a source of pressurized solvent;
- g. a fluid-controlled solvent valve having a pilot port and connected between said solvent source and said solvent input port of said manifold for connecting said solvent source to said manifold input port in response to control pressure at said solvent valve pilot port;
- h. a plurality of sources of different pressurized coating liquids;
- i. a plurality of fluid-controlled coating liquid valves each having a pilot port and each connected to a different one of said coating liquid sources and a different one at said coating liquid input ports of said manifold for connecting said one of said sources with said one of said ports in response to control pressure at said coating liquid valve pilot port;
- j. a fluid control circuit including:
 - 1. a source of pressurized control fluid,
 - 2. a fluid timing circuit,
 - 3. a variable pressure regulator connected between said control pressure source and said timing circuit,
 - 4. a main valve connected between said regulator and said timing circuit for opening and closing a path therebetween,
 - 5. a selector valve having a plurality of output ports each connected to the pilot port of a different one of said coating liquid valves, an input port selectively connectable to any one of said output ports for selecting said new coating liquid;
 - 6. said timer comprising a plurality of fluid-actuated timing valves connected in sequence, each of said valves having
 - a. a first output port, a second output port, a pilot port, and an input port normally connected to said first output port and alternatively connectable to said second output port in response to control pressure at said pilot port,
 - b. a variable restriction valve connected between said timing valve input port and said pilot port for communicating control pressure to said pilot port at some delayed time after pressure is applied to said input port, said delay time being variable by the combined settings of said restriction valve and said regulator,
 - c. said plurality of timing valves including:
 - 1. first fluid-controlled timing valve having its input port communicating with the output port of said main valve, its first output port communicating with the pilot port of said solvent valve and with the pilot port of said dump valve, and its second output port communicating with the input port of said selector valve for communicating control pressure to said pilot ports in accordance with the positions of said first timing valve and said main valve,
 - 2. a second fluid-controlled timing valve having its input port communicating with the second output port of said first valve, its first output port communicating with the pilot port of said dump valve for communicating control pressure to said pilot port in accordance with the positions of said first and second timing valves and said main valve,
 - 3. a third fluid-controlled valve having its input port communicating with the second output port of said second valve and its first output port communicating with the pilot of the check valve of said gun for communicating pressure to said pilot port in accordance with the positions of said first, second and third timing valves and said main valve, and having a delay time T_3 .
- 7. A pneumatically controlled system according to claim 6 wherein:

- said fluid control circuit is a pneumatic control circuit, said source of pressurized control fluid being a source of pressurized air, and said fluid timing circuit being a pneumatic timing circuit.
- 8. A system according to claim 6 wherein said manifold further comprises:
 - a plurality of double-check valves, one connected in each of the input ports of said manifold, each including a pair of opposed check valves, one of the valves of said pair being said source control valve.
- 9. A system according to claim 6 wherein said selector valve further comprises:
 - a pneumatically controlled selector lock having a pilot port connected to the output of said main valve to lock said selector when said valve is open.
- 10. A system according to claim 6 wherein:
 - said first timing circuit has a time delay of T_1 , T_1 being sufficiently long to allow solvent to flow into said manifold but shorter than the time required for solvent to flow to said gun, for introducing a slug of solvent into said line,
 - said second timing circuit has a time delay of T_2 , (T_1 plus T_2) being sufficiently long to allow the new coating liquid to flow into said manifold to force some of said solvent into said gun passage, but shorter than the time required to force all of said solvent out of said exhaust line; and
 - said third timing circuit has a time delay of T_3 , T_3 being sufficiently long to purge said old liquid from said nozzle.
- 11. A system according to claim 10 wherein T_1 and T_2 are in the range of from 0.1 to 10 seconds and T_3 is in the range of from 0.1 to 3 seconds.
- 12. A quick-change system for replacing any one liquid from a multiplicity of liquids with a new one of said multiplicity in a discharge apparatus operable to selectively discharge said liquids, said system comprising:
 - a discharge nozzle;
 - an exhaust line;
 - a feed line;
 - a nozzle control valve for selectively connecting said nozzle to said feed line;
 - an exhaust control valve for selectively connecting said exhaust line to said feed line;
 - a source of liquid solvent;
 - a solvent control valve for selectively connecting said solvent source to said feed line;
 - a source of each of said multiplicity of liquids;
 - a multiplicity of liquid control valves for selectively connecting each of said sources of liquids to said feed line; and
 - a source of pressurized control fluid;
- an all fluid operated control circuit, said circuit including a fluid timing circuit which is operative upon connection of said source of pressurized control fluid into said circuit to automatically control the sequencing of said exhaust control valve, said solvent control valve and said liquid control valves so as to purge said feed line of one liquid by means of solvent flow through said feed line, and to then fill said feed line with a second liquid.
- 13. A quick-change system according to claim 12 wherein:
 - said fluid control circuit is a pneumatic control circuit and said source of pressurized control fluid is a source of pressurized air.
- 14. A quick-change system according to claim 12 wherein said control circuit further comprises:
 - fluid valve means for selecting said second liquid from said multiplicity.
- 15. A quick-change system according to claim 12 wherein:
 - said fluid control circuit includes a first control output connected to apply control fluid to said solvent and exhaust control valves to open said valves to purge said feed line, and a second control output connected to apply control fluid to said exhaust and second liquid control valves to open said valves to fill said feed line.

16. A system according to claim 12 wherein said timing circuit includes fluid means for varying the time of operation thereof.

17. A system according to claim 12 wherein:
said control circuit includes fluid means for operating said nozzle control valve under control of said fluid timing circuit to cause solvent to flow through said nozzle to purge said nozzle.

18. A system according to claim 12 wherein:
said fluid timing circuit comprises a plurality of fluid-actuated timing valves each of said valves having

a. a first output port, a second output port, a pilot port, and an input port normally connected to said first output port and alternatively connectable to said second output port in response to control pressure at said pilot port,

b. a variable restriction valve connected between said timing valve input port and said pilot port for communicating control pressure to said pilot port at a delayed time after pressure is applied to said input port.

19. An automatic, quick-change system for replacing an old liquid with a new liquid in a discharge apparatus for selectively discharging a coating liquid, said system comprising:

a discharge nozzle;

an exhaust line;

a feed line;

a check valve for selectively connecting said nozzle to said feed line;

a dump valve for selectively connecting said exhaust line to said feed line;

a source of solvent;

a solvent valve for selectively connecting said solvent source to said feed line;

a source of said new liquid;

a source valve for selectively connecting said new liquid source to said feed line;

controls for operating said dump, solvent, and source valves to cause the presence in said feed line, at some time during a liquid replacing operation, of said old liquid followed by said new liquid with a slug of solvent immediately therebetween.

20. The system of claim 19 wherein:

said controls are operable to open said dump and solvent valves for a time T_1 and thereafter to open said dump and new liquid valves for a time T_2 ;

time T_1 being sufficiently long to allow solvent to flow into

said feed line but shorter than the time required for solvent to flow to said nozzle, so that a slug of solvent is introduced into said line during said time T_1 ; and

the sum of the times T_1 and T_2 being sufficiently long to allow the new liquid to flow into said feed line to force at least some of said solvent past said check valve, but shorter than the time required to force all of said solvent out of said exhaust line.

21. A system according to claim 19 wherein:

said controls further operate to open said new source and check valves for a time T_3 , time T_3 being sufficiently long to allow some of said slug of solvent to pass through said nozzle.

22. A system according to claim 20 wherein:

the time T_1 is in the range of from 0.5 to 5 seconds, and the time T_2 is in the range of from 1 to 10 seconds.

23. A system according to claim 22 wherein:

said timing circuit opens said check and new source valves for a time T_3 in the range of from 0.1 to 1 second.

24. An automatic, quick-change system for replacing an old liquid with a new liquid in a discharge gun for selectively discharging said liquids, said system comprising:

a discharge nozzle;

an exhaust line;

a feed line;

a check valve for selectively connecting said nozzle to said feed line;

a dump valve for selectively connecting said exhaust line to said feed line;

a manifold having an output port, connected to said feed line, a solvent input port, an elongated passage therein communicating with said output port and said solvent port, and a plurality of liquid input ports communicating with said manifold passage intermediate said output and said solvent input ports;

a plurality of double-check valves, one connected in each of the input ports of said manifold, each including a pair of opposed check valves, one of the valves of said pair being said source control valve;

a pressurized source of solvent;

a solvent valve for selectively connecting said solvent to said solvent input port of said manifold;

a plurality of pressurized sources of liquids;

a plurality of source valves each for selectively connecting a different one of said liquid sources to a different one of said liquid input ports of said manifold.

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