United States Patent [19]

Harrah

[11] **3,720,182**

[45] **March 13, 1973**

[54] **PNEUMATIC ANNUNCIATOR SYSTEM**

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[22] Filed: **Nov. 18, 1971**

[21] Appl. No.: **199,894**

Related U.S. Application Data

[62] Division of Ser. No. 56,892, July 21, 1970, Pat. No. 3,651,643.

[52] **U.S. Cl.** **116/65,** 137/557

[51] **Int. Cl.** **G08b 1/04**

[58] **Field of Search** ...116/65, 117; 60/105; 137/455, 137/488, 551, 557; 251/289, 318

[56] **References Cited**

UNITED STATES PATENTS

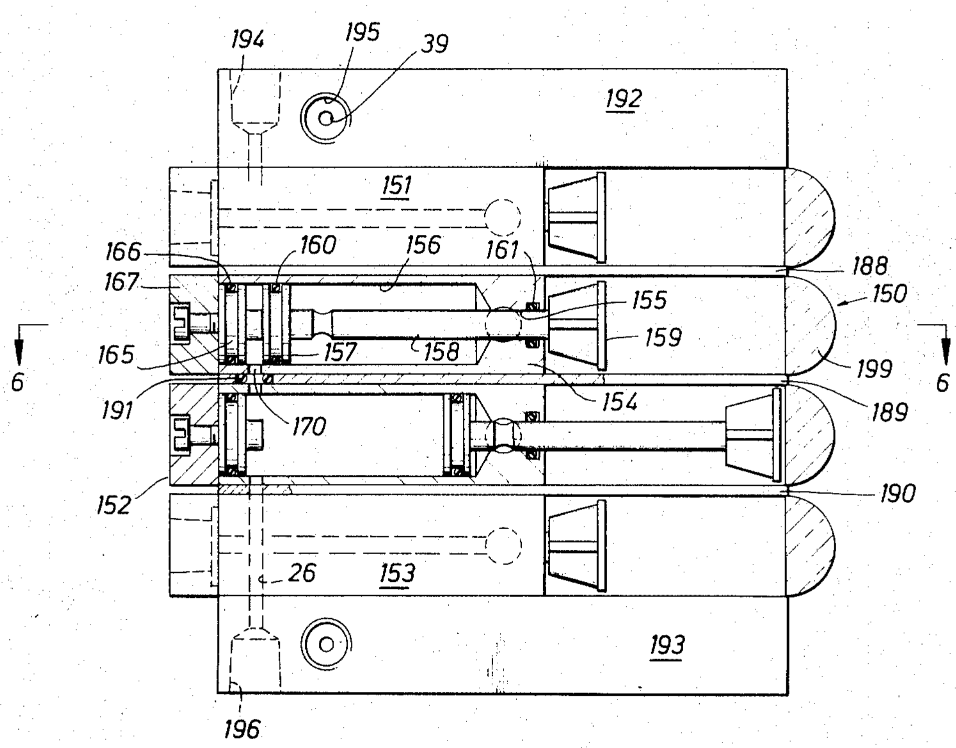
3,038,439	6/1962	Martin et al.	116/70 X
3,254,670	6/1966	Puster	137/557
3,651,643	3/1972	Hurrah	60/105
3,682,129	8/1972	Philbrick	116/65

Primary Examiner—Louis J. Capozi
Attorney—Donald Gunn

[57] **ABSTRACT**

As a representative embodiment of the present invention, pressure-responsive indicators are coupled to suitable transducers monitoring selected operating conditions of an industrial machine. Pneumatic controls are arranged for providing first pneumatic signals when these operating conditions reach a predetermined value and producing second pneumatic signals should any of the operating conditions vary from its selected range. Other pneumatic controls are uniquely arranged for responding to the second signals to produce a brief third pneumatic signal which is effective to operate only the associated indicator while the other unaffected indicators are positively retained in their safe indicating positions. The indicators of the present invention are adapted to be stacked together and respectively include a number of passages adapted to coincide with the matching passages in the other indicators. One set of these passages in each indicator can be isolated from the other set by orienting the indicator in one position in relation to the other indicators. A second set of these passages is coupled to an alternately-positionable spool in each indicator which is uniquely arranged to select which of the passages in this other set is to be coupled to the pressure-responsive element in that indicator.

18 Claims, 15 Drawing Figures



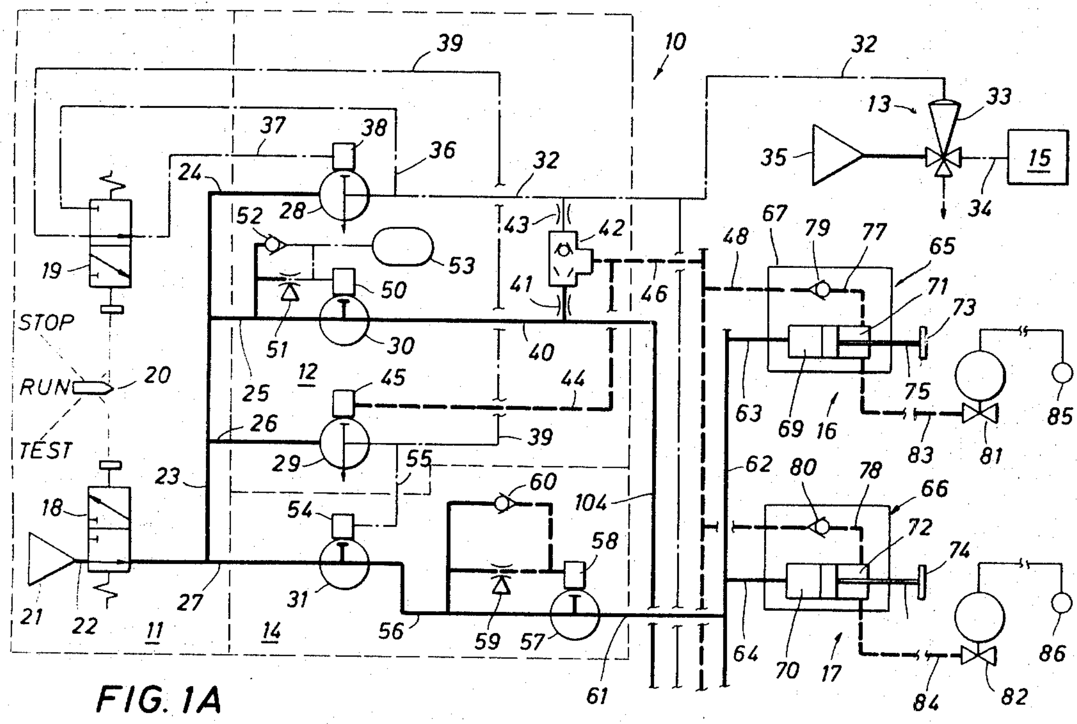


FIG. 1A

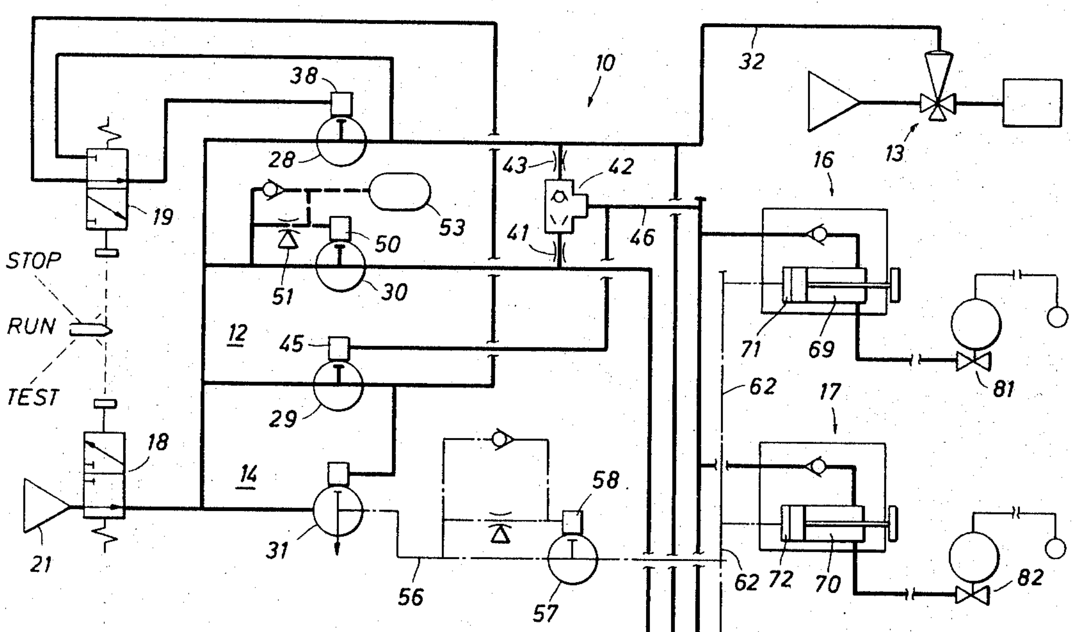
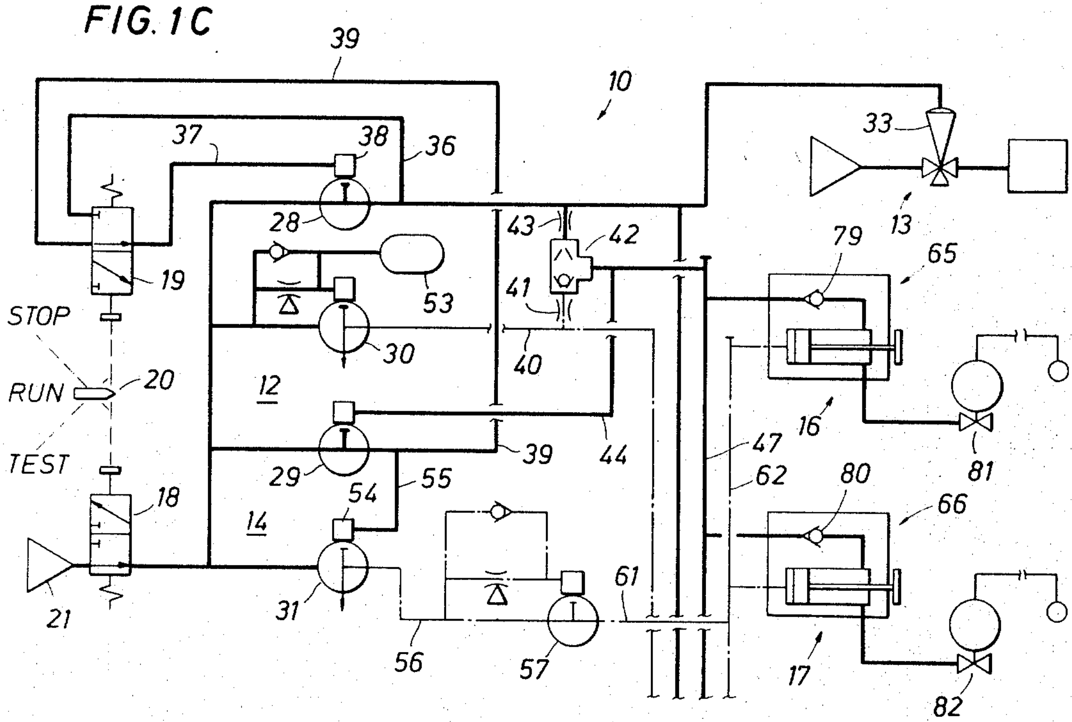


FIG. 1B

— · — VENT
——— SUPPLY
— — — TRANSIENT

FIG. 1C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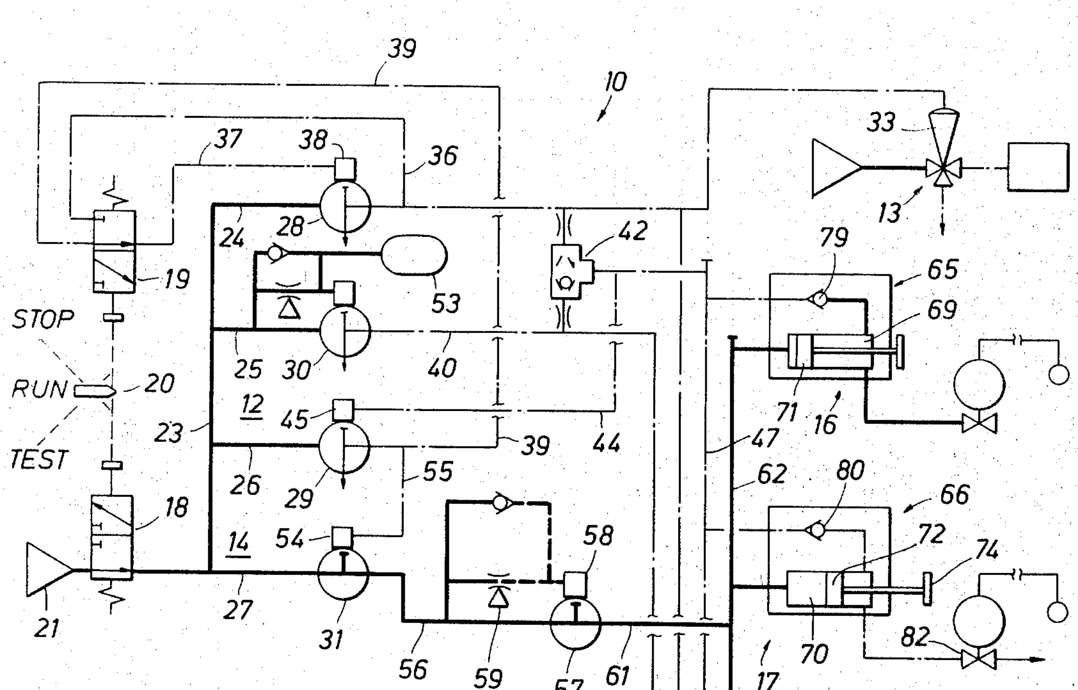
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FIG. 1D

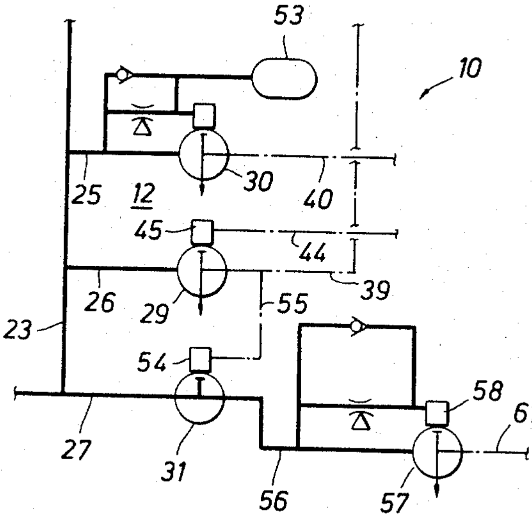


FIG. 1E

FIG. 2A

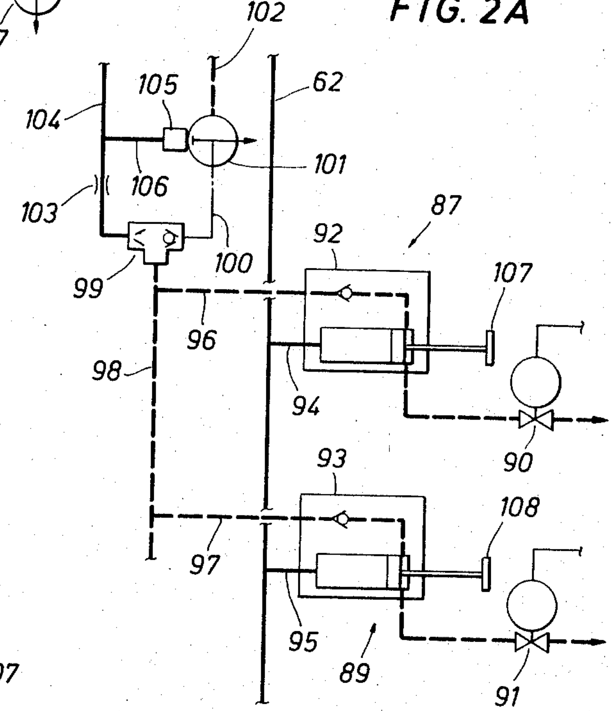


FIG. 2B

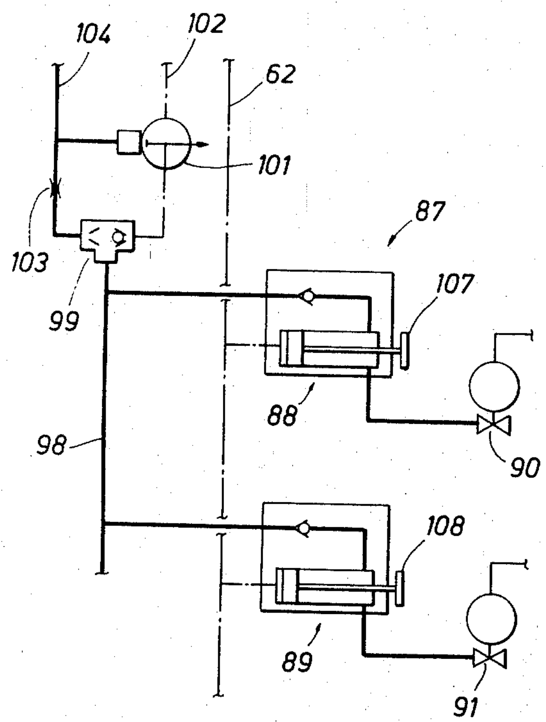
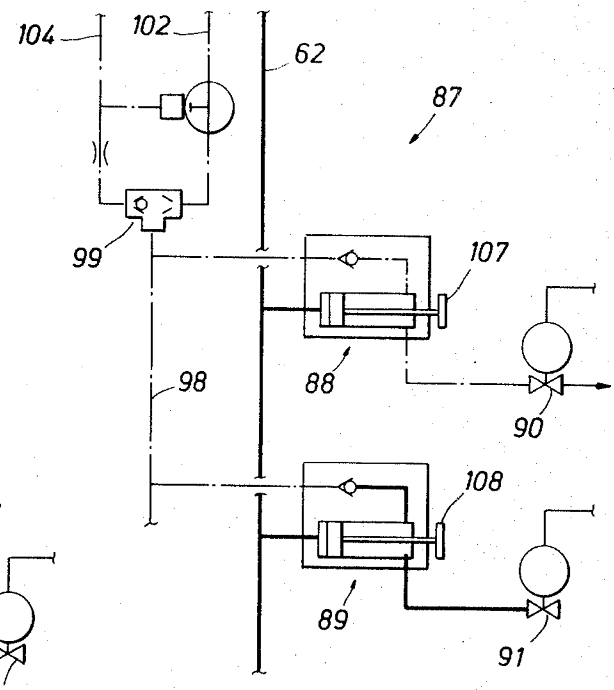


FIG. 2D



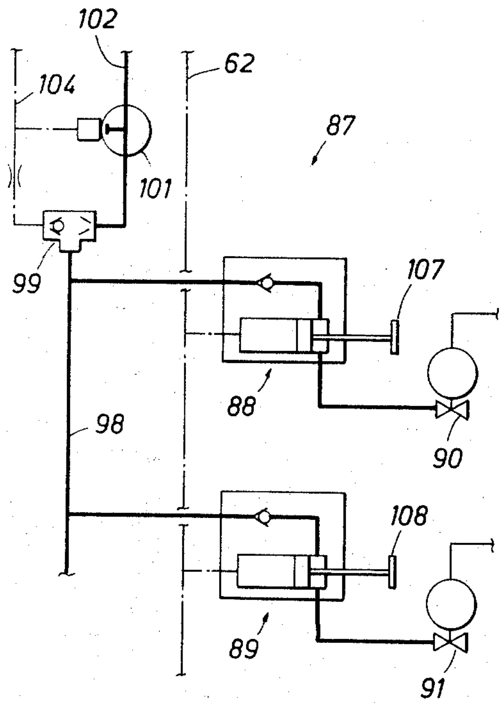


FIG. 2C

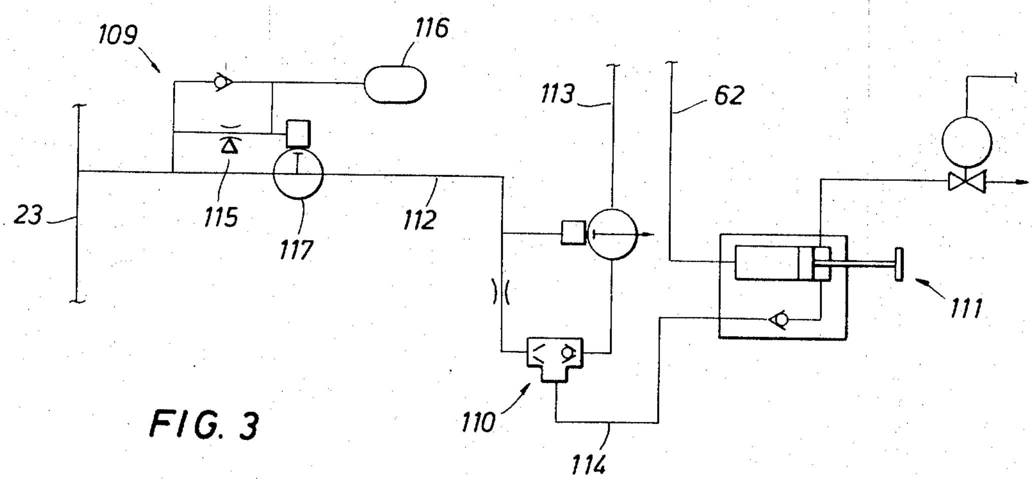


FIG. 3

FIG. 4A

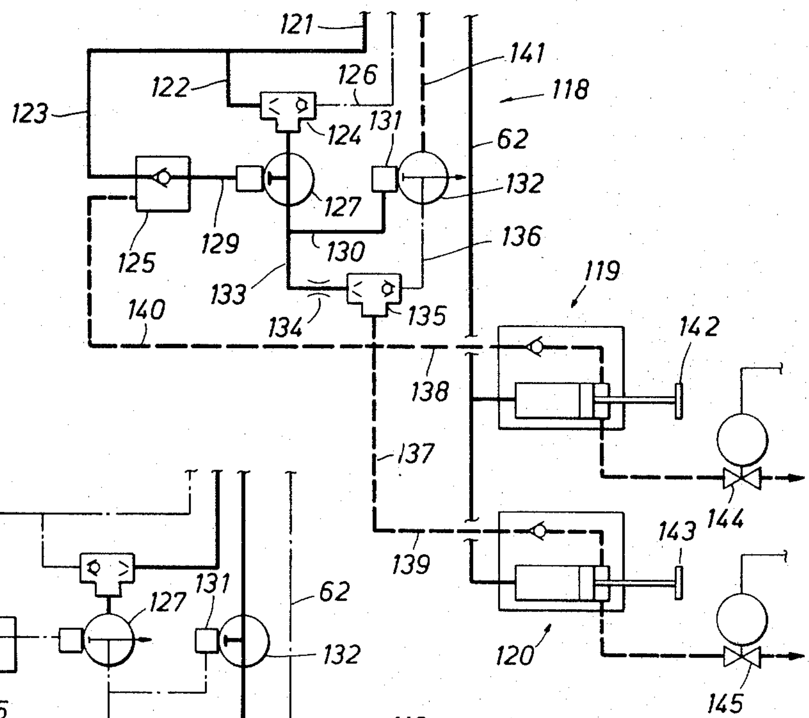
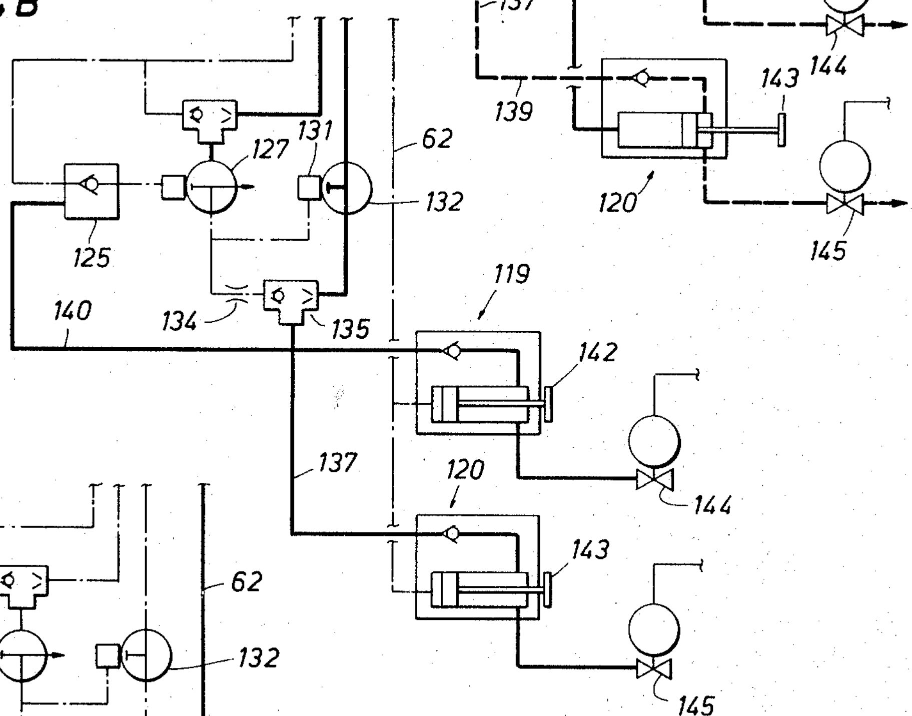


FIG. 4B



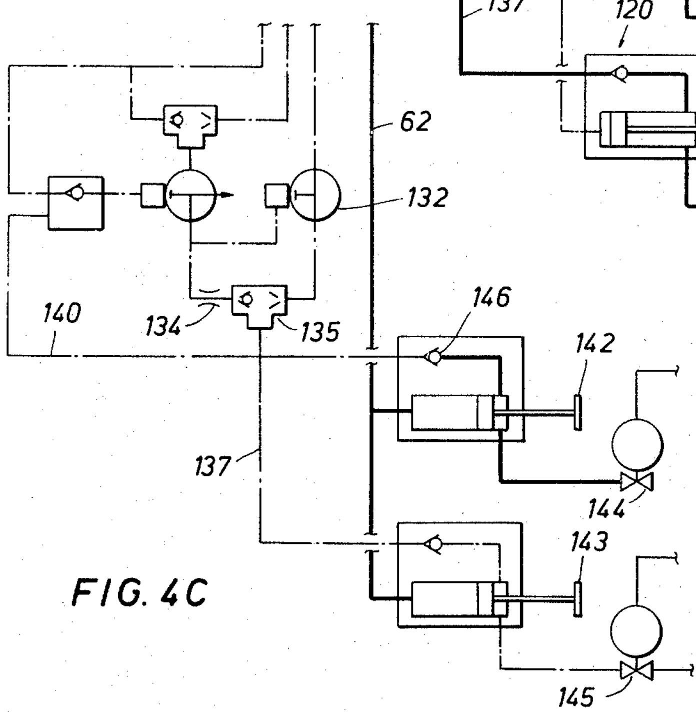


FIG. 4C

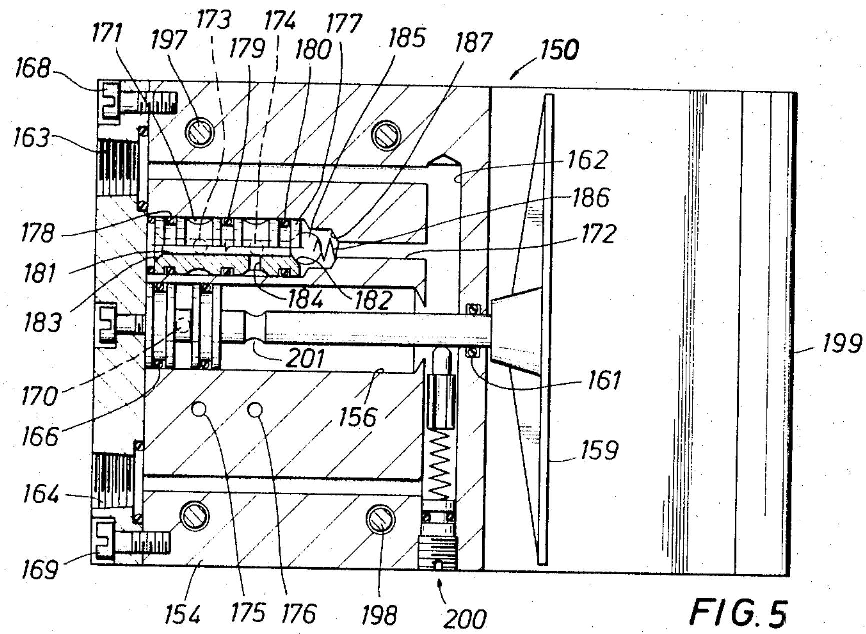

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FIG. 5

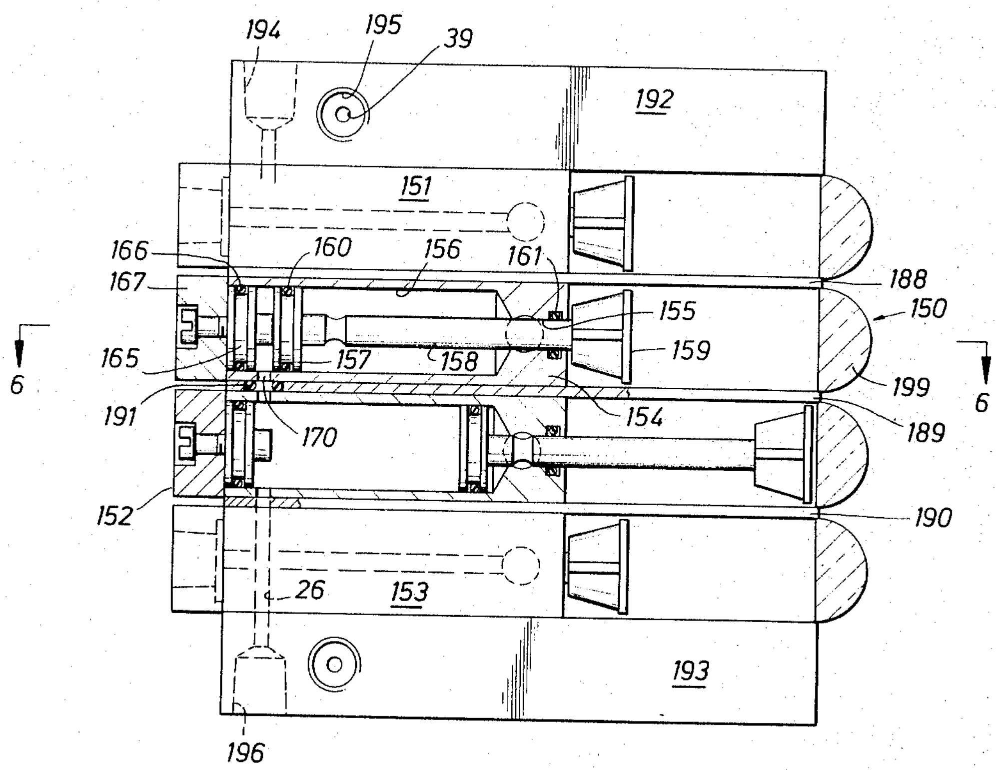
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FIG. 6

PNEUMATIC ANNUNCIATOR SYSTEM

This application is a divisional application of Ser. No. 56,892, filed July 21, 1970 now U.S. Pat. No. 3,651,643, entitled PNEUMATIC ANNUNCIATOR SYSTEM, by the same inventor.

Various pneumatic systems have, of course, been proposed heretofore for controlling the operation of unattended industrial machines such as compressors, engines, or the like. In general, these systems typically include a plurality of electro-pneumatic controls any one of which, upon sensing an unsafe or undesirable operating condition of the machine being monitored, will quickly halt the machine as well as provide a visible signal showing which of these several operating conditions caused the shutdown. To accomplish this, each of these selected operating conditions is monitored by an appropriate condition-responsive monitor or transducer which is adapted to open a normally-closed venting valve whenever that operating condition departs from a predetermined set point or operating range. Each venting valve is, in turn, connected by a normally-pressured conduit or tubing line to a pressure-responsive indicator relay which typically includes a movable member or so-called "flag" operatively arranged to present a first visual "safe" signal so long as the venting valve remains closed. An unsafe condition will, however, open the associated venting valve so that, once the pressure is reduced in the tubing line, the flag will move to present a second visual signal that this particular condition is no longer correct or safe. Typically, these indicator relays will also actuate a pneumatic control while halts the machine upon tripping of any one or more of the several relays.

Those skilled in the art will, of course, appreciate that the various indicator relays employed heretofore typically rely upon unbalanced pressure forces acting on a movable piston or diaphragm element to maintain the flags in their normal or "safe" operating positions as well as to shift the flags to their other positions for signaling a malfunction and actuating the shutdown controls. Generally speaking, these indicator relays employ one or the other of two basic techniques for controlling the position of the movable pressure-responsive member. In one common type of these indicator relays, the pressure-responsive element has equal pressure areas on each side of it. Thus, with this style, so long as the associated transducer-operated venting valve is closed, the visual indicator is maintained in its "safe" position by imposing the full supply pressure on one side of the pressure-responsive element and a lesser pressure on the opposite side. Then, when an alarm condition is sensed by the transducer and the control line is vented, the supply pressure is removed from one side of the pressure-responsive element and the lesser pressure, acting on the opposite side, causes the flag to signal the unsafe condition.

On the other hand, with the alternate style of these conventional indicator relays, the pressure-responsive element has unequal effective areas on its opposite sides. Normally, the supply pressure is imposed on both sides of the element; and opening of the venting valve will then function to vent the supply pressure from the larger side of the pressure-responsive element, allowing the supply pressure on the smaller side to shift the flag to its alternate position.

Regardless of which of these two styles are utilized in a multiple-control annunciator system, those skilled in the art will appreciate that although these indicator relays of the prior art will usually halt the monitored machine, it is not at all uncommon for the visual indicator or flag to fail to signal the origin of the malfunction responsible for the shutdown. This will, of course, require extensive and needless trouble-shooting just to determine the underlying cause for the shutdown of the machine. For example, in the typical annunciator systems employed heretofore, many of these prior indicator relays include one or more valves for controlling the pneumatic pressures involved in the shutdown system. As a result, should a venting valve which is opened by an improper operating condition be at the end of a particularly-long tubing line, there will be a significant lapse of time between the opening of this transducer-operated valve and the complete venting of the system. Accordingly, as the pressure begins to slowly drop in the control line, the system shutdown valves will function and vent the pneumatic supply before the control line has vented. Should this occur, the pressure still remaining in the long control line will unwittingly reset the indicator relay to again display a "-safe" signal and thereby remove any indication as to which operating condition caused the shutdown of the machine.

To avoid this undesirable resetting of the indicator relays, various arrangements have been typically employed heretofore for retarding the venting of the supply lines so that the longer control lines will hopefully be vented before the supply pressure is significantly diminished. This, however, requires that the entire pneumatic system be painstakingly balanced to prevent the loss of indication. This "balancing" must be done judiciously, however, or another equally undesirable result will be introduced. If the supply to the indicators is maintained for too long a time after the initial sensor has vented, then an indicator relay monitoring a condition dependent upon the continued operation or movement of the machine will trip without valid reason as the machine begins slowing and before the supply pressure has been removed from the system. As a result, when the machine finally comes to a halt, although the properly-tripped indicator will correctly signal that its associated condition was "unsafe," the incorrectly-tripped indicators will also falsely signal other unsafe conditions. This too is, of course, not at all desirable.

Accordingly, it is an object of the present invention to provide various new and improved pneumatic annunciator systems for reliably indicating only those malfunctioning operating conditions actually causing the shutdown of the machine being monitored without also falsely actuating other indicators monitoring different and unaffected operating conditions.

It is a further object of the present invention to provide new and improved pneumatic indicators which are especially adapted for use with the new and improved pneumatic annunciator systems of the present invention.

It is still another object of the present invention to provide new and improved pneumatic indicators which are uniquely arranged for compact mounting on control panels with only a minimum of piping connections being required to adapt the indicators in a given group for respectively monitoring selected conditions.

These and other objects of the present invention are attained by arranging a new and improved pneumatic annunciator system having pressure-responsive indicator means operatively coupled to transducer means adapted for monitoring one or more operating conditions of an industrial machine. To enable the system, first means are operatively coupled to the transducer means and adapted for providing first pneumatic signals in response to these operating conditions reaching a predetermined safe or desirable value. Second means are coupled to the transducer means and operatively arranged for providing second pneumatic signals in response to these operating conditions varying from these values. Means responsive to such second pneumatic signals are operatively arranged for imposing a brief, but positive, third pneumatic signal of limited duration for actuating only the indicator means monitoring the unsafe or undesirable operating conditions to provide a visual indication of a malfunction while the first signals reliably retain the other indicator means in positions indicating those operating conditions which are still within safe operating limits.

The indicators of the present invention are uniquely arranged for cooperative grouping with one or more like indicators. To accomplish this, each indicator has a body in which a pressure-indicator is arranged for movement between first and second indicating positions. A plurality of passages are uniquely arranged in each body so that when two or more indicators are stacked together, the passages will respectively be in communication with one another. By varying the orientation of the bodies in relation to one another as well as by means of a reversible spool member uniquely arranged in each body, any one of these several passages can be selectively coupled to the pressure-responsive indicator in a given body and the other passages isolated from the indicator.

The novel features of the present invention are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may be best understood by way of the following description of exemplary apparatus employing the principles of the invention as illustrated in the accompanying drawings, in which:

FIGS. 1A–1E schematically depict the sequential operations of a pneumatic system arranged in accordance with the principles of the present invention and including a first set of controls adapted for monitoring one or more similarly-characterized operating conditions of a typical internal combustion engine;

FIGS. 2A–2D schematically illustrate the sequential operations of a second set of controls for the pneumatic system shown in FIGS. 1A–1E while monitoring one or more of a second type of functionally-related operating conditions;

FIG. 3 schematically depicts an alternative control system for use with a group of controls such as shown in FIGS. 2A–2D;

FIGS. 4A–4C depict the sequential operations of a third set of controls for use with the pneumatic system shown in FIGS. 1A–1E when a third type of one or more operating conditions are to be monitored;

FIGS. 5 and 6 are cross-sectional views of a preferred pneumatic indicator relay for use with the several systems of the present invention.

Turning now to FIGS. 1A–1E, a preferred embodiment is depicted of a pneumatic annunciator system **10** arranged in accordance with the present invention, with the various elements thereof being shown in a schematic form for illustrating their various cooperative functions during a typical operating cycle. As best seen in FIGS. 1A, the new and improved annunciator system **10** is basically comprised of a first group **11** of controls for selecting the operational modes of the system, a second group **12** of system-initiating controls, one or more system-controlled elements as at **13**, and a third group **14** of controls adapted for initially resetting the various indicator relays employed with the system upon starting of the machine **15** being monitored as well as for actuating only those indicator relays sensing an unsafe condition. To simplify the explanation of the system **10**, only a first set of condition-responsive indicator relays, as at **16** and **17**, are depicted in FIGS. 1A–1E. It will be understood, however, that one or more indicator relays can be included with the system **10** either with or without the relays **16** and **17** for monitoring various types of conditions related to the operation of the machine **15** for which the relays **16** and **17** are not suited.

The first group **11** of controls are preferably comprised of a pair of similar or identical manually-actuated valves **18** and **19** respectively having a first normally-open position and a second position which, upon actuation of that valve, will close its inlet port and open its outlet port. An appropriate three-position manual actuator or selector, as at **20**, is operatively arranged between the valves **18** and **19** for alternately closing the valves in the two extreme positions of the actuator and opening both of the valves when the actuator is in its depicted neutral position. Accordingly, as seen in FIG. 1A, with the mode selector **20** in its neutral or "run" position, the valves **18** and **19** are in their normally-open positions. Movement of the actuator **20** to its so-called "test" position will move the valve **19** to its alternate position but leave the main control valve **18** in its normally-open position. Conversely, movement of the actuator **20** to its "stop" position will shift the main control valve **18** to its venting position without moving the valve **19** from its normally-open position.

A suitable pressure source, such as a typical supply **21** of instrument-quality air, is coupled by a conduit **22** to the inlet port of the main control valve **18**, with the common or outlet port of this valve being connected to a supply manifold **23** having four branch conduits **24–27** leading to the second and third groups **12** and **14** of the system controls. Two of these manifold conduits **24** and **26** are respectively coupled to the inlets of similar or identical normally-closed pressure-actuated three-way valves **28** and **29** adapted to vent their outlet ports so long as these valves are not actuated. On the other hand, the other two manifold conduits **25** and **27** are respectively coupled to the inlets of similar or identical normally-open pressure-actuated three-way valves **30** and **31** which, upon their actuation, are adapted to vent their outlet ports.

The outlet port of the normally-closed valve **28** is coupled by a conduit **32** to the pressure-responsive actuator 33 of the system-controlled element 13 which, if the machine 15 is an internal combustion engine, might be a valve controlling the flow of fuel through a conduit 34 to the machine. Accordingly, as is typical in such situations, the system-controlled element 13 is a normally-closed three-way valve adapted to normally vent the fuel line 34 of the engine 15 and to admit fuel thereto from a suitable source 35 only so long as air of a predetermined pressure is supplied to the pressure-responsive actuator 33.

For reasons that will subsequently be described, a branch conduit 36 is coupled between the outlet port of the normally-closed valve 28 in the second group 12 of system controls to that port of the manually-actuated valve 19 which is normally closed and is opened upon operation of the valve by movement of the manual mode-selector 20 to its "test" position. A conduit 37 is coupled between the pressure-responsive actuator 38 of the normally-closed control valve 28 and the outlet port of the manually-actuated valve 19; and another conduit 39 is coupled between the inlet port of the manual valve and the outlet port of the other normally-closed valve 29 in the second group 12 of system controls. It will be appreciated, therefore, that so long as the valve 19 is in its depicted position, opening and closing of the control valve 28 is selectively accomplished by correspondingly opening and closing the control valve 29. Similarly, the opening and closing of the system-controlled element 13 is also solely dependent upon the control valve 29.

The outlet of the normally-open valve 30 of the second group 12 of the system controls is coupled by a conduit 40 and an orifice 41 to one inlet port of a two-way check valve assembly 42 having its other inlet port connected by another orifice 43 to the conduit 32. The common outlet of the check valve assembly 42 is coupled by one conduit 44 to the pressure-responsive actuator 45 of the normally-closed valve 29 and by another conduit 46 to a first manifold 47 having one or more branch conduits, as at 48 and 49, which are respectively coupled to each of the several indicator relays 16 and 17. It will be appreciated, therefore, that by virtue of the orifice 41, the control valve 29 will remain closed until this orifice has passed a sufficient volume of air to the pressure-responsive actuator 45 for the pressure applied thereto to open this control valve. Thus, the delay provided by the orifice 41 will correspondingly delay the opening of the control valve 28 and the operation of the system-controlled element 13.

The pressure-responsive actuator 50 of the normally-open valve 30 is coupled to the inlet of that valve by means of a selectively-sized orifice, such as a manually-adjustable needle valve 51, in parallel with a one-way check valve 52 which blocks flow to the pressure-responsive actuator but is adapted to readily open for venting the actuator and a pressure accumulator 53 coupled thereto. It will be recognized, therefore, that admission of compressed air to the pressure-responsive actuator 50 is selectively regulated by the orifice or needle valve 51. Moreover, by virtue of the accumulator 53, the pressure imposed on the pressure-responsive actuator 50 will always be equal to the pressure maintained in the accumulator. Accordingly, since the orifice 51 regulates the rate at which compressed air is admitted to the accumulator 53 and the volume of the accumulator in turn further determines the rate at which the pressure imposed on the actuator 50 increases, the orifice and the accumulator cooperate to delay the closing of the normally-open valve 30 for a selected period of time after air is first supplied to the second group 12 of system controls. On the other hand, upon venting of the supply manifold 23, the check valve 52 will be effective for bypassing the orifice 51 to permit the accumulator 53 to be quickly vented.

The pressure-responsive actuator 54 of the normally-open valve 31 in the third group 14 of system controls is coupled by a conduit 55 to the outlet of the normally-closed valve 29 in the second group 12 of system controls. For reasons that will subsequently be explained, the outlet of the normally-open valve 31 is serially coupled by a conduit 56 to the inlet of another pressure-actuated normally-open valve 57. The pressure-responsive actuator 58 of this valve 57 is coupled to the conduit 56 by a selectively-sized orifice or needle valve 59 which is paralleled with a one-way check valve 60 adapted for venting the actuator upon reduction of pressure at the inlet of the pressure-actuated valve. The outlet of this normally-open valve 57 is coupled by a conduit 61 to a second manifold 62 having one or more branch conduits, as at 63 and 64, which are respectively coupled to each of the indicator relays 16 and 17. It will be appreciated, therefore, that this third group 14 of system controls is effective for supplying a short burst or pulse of compressed air to the manifold 62 which is terminated by the closing of either of the two normally-open valves 31 and 57. The significance of this function of the third group 14 of system controls will subsequently be explained.

As schematically illustrated in FIG. 1A, the first set of the indicator relays 16 and 17 include new and improved indicator units 65 and 66 respectively having separate bodies 67 and 68 with enclosed chambers 69 and 70 arranged therein in which a piston, as at 71 and 72, is slidably mounted for selective movement back and forth. A suitable visual indicator or flag, as at 73 and 74, is coupled to each of the pistons 71 and 72 as by a suitable connecting rod, such as at 75 and 76, and operatively arranged so that, upon movement of its associated piston from a retracted position to an extended position, a visual display will be provided to warn that a malfunction has occurred. As depicted, the second inlet conduits 63 and 64 are respectively communicated with the rear of the piston chambers 69 and 70; and the first inlet conduits 48 and 49 are respectively communicated to the forward portion of the piston chambers by conduits 77 and 78 in series with forwardly-opening check valves 79 and 80. The significance of this arrangement will subsequently be explained.

As is typical, the indicator relays 16 and 17 further include normally-closed, condition-responsive valves, as at 81 and 82, that are respectively coupled by conduits 83 and 84 to the forward portions of the chambers 69 and 70 of the indicator devices 65 and 66. To actuate these valves 81 and 82, each is associated with a suitable condition-sensing actuator, as at 85 and 86, that is operatively arranged to maintain its associated venting valve closed so long as the particular condition being monitored thereby is within a desired operating range. Thus, upon a change of the particular condition being monitored to what is considered to be an unsafe or undesirable status, the condition-sensing actuator **85** (or **86**) will respond and open its respectively-associated venting valve **81** (or **82**).

As one example of the utility of the new and improved annunciator system **10** of the present invention, it will be assumed that the indicator relays **16** and **17** are respectively monitoring different parameters functionally related to the operation of the machine **15** and which should not exceed a predetermined limit or range of conditions, but which can safely be either within or below the operating range. For example, where the machine **15** being monitored by the annunciator system **10** is an internal combustion engine or the like, such operating conditions might typically be the engine speed, cylinder-head temperatures, or cooling jacket temperatures. It will, therefore, be appreciated that to monitor conditions such as these, the condition-sensing actuators **85** and **86** are chosen for normally maintaining their respective valves **81** and **82** closed; and that these valves will be opened only in the event that sustained improper operation of the engine **15** causes any one or more of these various monitored conditions to exceed a safe limit.

To illustrate a typical application of the system **10**, assume that the manual selector **20** has just been moved from its "stop" position to the "run" position as depicted in FIG. 1A for initiating the operation of the annunciator system and, as a result, starting the engine **15** being controlled thereby. Accordingly, movement of the selector **20** to the "run" position will open the main control valve **18** for admitting compressed air from the pressure source **21** to the inlet manifold **23**. The other manual valve **19** will remain in the illustrated position. Since the control valves **28** and **29** in the second group of system controls are at this moment closed, compressed air will initially flow through only the conduits **25** and **27** respectively leading to the second and third groups **12** and **14** of system controls.

Accordingly, once compressed air is admitted to the inlet manifold **23**, the air will be simultaneously admitted by way of the normally-open valves **30**, **31** and **57** to the conduits **40** and **61**. However, even though the condition-responsive valves **81** and **82** are closed at this time, the rate at which air is admitted to the first inlet conduits **48** and **49** of the indicator relays **16** and **17** will be selectively regulated by the orifice **41**. Thus, for a finite period of time, the pressure imposed in the forward portions of the piston chambers **69** and **70** will slowly increase from atmospheric pressure to the operating pressure of the air source **21**.

On the other hand, since the serially-arranged control valves **31** and **57** in the third group **14** of system controls are both open at the time depicted in FIG. 1A and there is no undue flow restriction between the inlet manifold **23** and the second inlet conduits **63** and **64** of the indicator-relays **16** and **17**, the full operating pressure of the air source **21** will be quickly imposed in the rearward portions of the piston chambers **69** and **70**. Accordingly, since the pressure differential will be quickly developed across the two pistons **71** and **72**, the third group **14** of system controls will function to temporarily shift the visual indicator flags **73** and **74** forwardly to their extended positions as illustrated in FIG. 1A. It will be noted that at this point the second group **12** of system controls are still maintaining the fuel valve **13** closed to preclude the admission of fuel from the fuel supply **35** to the engine **15**.

The compressed air passing through the conduit **56** interconnecting the serially-arranged normally-open valves **31** and **57** will, however, gradually impose an increased pressure on the pressure-responsive actuator **58** of the latter valve at a selected rate determined by the orifice **59**. Once a sufficient pressure is applied to the actuator **58**, the normally-open valve **57** will be closed and the compressed air in the second manifold **62** will be vented as depicted in FIG. 1B. Similarly, once a sufficient volume of compressed air has passed the orifice **41** to significantly increase the pressure in the conduit **46** and the first manifold **47**, the normally-closed valve **29** will be opened by the increase of pressure on its actuator **45** and the pistons **71** and **72** will be shifted rearwardly in their respective piston chambers **69** and **70**. It will, therefore, be appreciated that the rearward movement of the pistons **71** and **72** will be positively assured since the pressure in the forward portions of the piston chambers **69** and **70** will be approaching that of the air source **21** and the pressure in the rearward portions of the chambers will be decreased to atmospheric pressure once the control valve **57** is closed.

It will also be noted in FIG. 1B that once the control valve **29** opens, the second group **12** of system controls functions to admit compressed air to the pressure-actuator **38** by way of the manual valve **19** to successively open the control valve **28** and the automatic fuel valve **13**. Although the engine **15** is now starting, the normally-open valve **30** of the second group **12** of system controls is still open and will not close until a sufficient quantity of air has passed the controllable orifice **51** to raise the pressure in the accumulator **53** to the actuating pressure of the pressure-responsive actuator **50**.

Particular note should be made that the valve **29** must open before the valve **30** closes in order for the fuel valve **13** to be opened and allow the engine **15** to start. Thus, should one of the transducer-actuated valves **81** and **82** be open by virtue of some malfunction, the valve **30** will close before the valve **29** opens and the engine **15** cannot be started. This interaction between the valves **29** and **30** is, therefore, provided by the cooperative relation of the orifice **51** and accumulator **53** which determines the delay between the opening of the valve **29** and the closing of the valve **30** if no malfunction occurs. Thus, by virtue of this timed delay, a brief flow or pulse of compressed air is provided to the first manifold **47** for a selected time interval which will ordinarily be sufficient to allow the engine **15** to start but which, if either of the valves **81** or **82** are open, will prevent the engine from being started. It will be realized, therefore, that the opening of the valve **29** provides a signal which is indicative that the operating conditions being monitored by the transducers **81** and **82** are each in a safe operating range.

Once, however, the valve **29** opens and the valve **30** closes as shown in FIG. 1C, the double-acting check valve **42** will function as an enabling device to condition the annunciator system **10** for subsequently responding to a malfunction in the engine **15** which will cause an excessive increase in any of the one or more operating conditions being monitored by the new and improved annunciator system of the present invention. The various elements of the annunciator system **10** will, of course, remain in their positions respectively illustrated in FIG. 1C so long as none of the operating conditions being monitored by the condition-responsive valves **81** and **82** do not exceed a predetermined level and cause one or more of these valves to open. Ordinarily, the various elements of the control system **10** will remain as illustrated until the engine **15** is to be halted routinely. To stop the engine **15**, the manual selector **20** is simply moved to its "stop" position which closes the main control valve **18** to block further communication between the air source **21** and the inlet manifold **23** and simultaneously vent the entire system to atmosphere.

Turning now to FIG. 1D, the annunciator system **10** is depicted at the moment when the operating condition being monitored by one of the condition-responsive valves, as for example the valve **82** controlling the indicator **66**, has exceeded its predetermined limits. When this occurs, the condition-responsive valve **82** will open as illustrated and rapidly vent the first manifold **47** and the conduit **44** coupled to the pressure-responsive actuator **45** of the valve **29** so as to rapidly close this latter control valve. Closing of the valve **29** can, of course, be considered as producing a second signal for indicating that one of the operating conditions being monitored has exceeded its selected range.

Reclosing of the control valve **29** will, therefore, simultaneously vent the conduit **55** coupled to the actuator **54** and the conduits **37** and **39** coupled to the actuator **38**. Venting of the actuator **38** will, in turn, close the control valve **28** which vents the conduit **32** coupled to the actuator **33** so that the fuel valve **13** is immediately closed. Simultaneously therewith, the control valve **31** is reopened and, as illustrated in FIG. 1D, compressed air is again admitted to the second manifold **62** by way of the still-open control valve **57**. As will be appreciated, therefore, with the forward portion of the piston chamber **70** now being at atmospheric or certainly near-atmospheric pressure, the piston **72** will be positively impelled forwardly to shift the visual indicator **74** to its forwardmost position to indicate that it is the operating condition being monitored by the indicator relay **17** which was responsible for the shutdown of the engine **15**.

It will be noted, however, by comparing FIG. 1D with FIG. 1E that the reapplication of pneumatic pressure in the conduit **56** occasioned by the opening of the valve **31** will soon close the control valve **57** downstream thereof once the orifice **59** has permitted the pressure applied to the pressure-responsive actuator **58** to rise to a sufficient level to operate the latter valve. Thus, the second manifold **62** will be exposed to only a brief surge of pressure upon opening of the valve **31**, with this pressure being quickly discontinued upon closing of the valve **57**. In other words, the third group **14** of system controls is operative for producing a momentary surge or pulse of compressed air which functions as a third signal for shifting the piston **72** and the visual indicator **74** forwardly. The other piston **71** will, of course, also be subjected to this momentary pressure pulse or signal and may very likely tend to begin moving forwardly. Yet, since fully-pressured air will still be trapped in the forward portion of the piston chamber **69** between the check valve **79** and the still-closed condition-responsive valve **81**, even should the piston **71** shift forwardly the trapped air will be further compressed so that the piston will be positively returned and retained in its normal rearward position once the control valve **31** closes and the manifold **62** is vented as shown in FIG. 1E. It will be recalled, of course, that the compressed air which is effective for retaining the piston **71** in position is provided by the initial signal previously produced.

It will, of course, be appreciated that there are other typical operating conditions which must also be monitored but which are incapable of providing a meaningful control signal until after the engine **15** has been started. For example, with a typical internal combustion engine, engine-driven oil pumps, water-circulation pumps, and the like, are often employed. Although it is important to monitor the discharge pressures of such pumps and guard against excessively-low pressures, these pumps cannot develop their expected operating pressures until the engine **15** is either approaching or has just reached full operating speed. A typical pressure-sensing transducer monitoring conditions such as these will, therefore, falsely signal that a malfunction is occurring until the engine **15** has been started. Thus, since the indicator relays **16** and **17** depicted in FIG. 1A are critically dependent upon their respective condition-responsive valves **81** and **82** being closed before the engine **15** is started, an alternative arrangement of pneumatic controls must be provided for those indicator relays which are to monitor those operating conditions which are not satisfied when the engine is first started but which will be satisfied once the engine is operating and is functioning properly.

Accordingly, as depicted in FIG. 2A, an alternative or additional set of controls **87** is provided for use with one or more indicator relays, as at **88** and **89**, respectively including typical condition-responsive valves **90** and **91** which will initially be open and then subsequently close either as the engine **15** is starting or once the particular operating conditions which they are monitoring respectively reach a predetermined value or range. It will be appreciated, of course, that the controls **87** are to be operatively associated with the annunciator system **10** whether or not the indicator relays **16** and **17** are included. For example, if the indicator relays **16** and **17** are not employed with the additional set of controls **87**, the first and second inlet conduits **48**, **49**, **63** and **64** would not be needed. On the other hand, if the indicator relays **16** and **17** are to be associated with the second set of controls **87**, the relays will function in the same manner as previously described. The operation of these additional controls **87** will, therefore, not be affected by either the inclusion or the omission of the indicator relays **16** and **17** in the annunciator system **10**.

As illustrated in FIG. 2A, the second set of indicator relays **88** and **89** include pneumatic indicator devices, as at **92** and **93**, operatively controlled by the condition-responsive valves **90** and **91** which have been appropriately selected for monitoring this second group of operating conditions. It will, of course, be noted that the second indicator devices **92** and **93** are otherwise identical or similar to those previously described and their second inlets are coupled in the same manner to branch conduits **94** and **95** of the second manifold **62**. The first inlets of the indicator devices **92** and **93** are, however, coupled by branch conduits **96** and **97** of a first manifold **98** connected to the outlet port of a two-way check valve **99** that is similar or identical to the first assembly **42** previously described. One inlet of the check valve assembly **99** is connected by a conduit **100** to the outlet of a normally-open control valve **101** having its inlet connected to a branch conduit **102** of the first manifold **47**. The other inlet of the check valve assembly **99** is connected by way of a selected orifice **103** and a branch conduit **104** that is coupled to the conduit **40** upstream of the delay orifice **41** (FIG. 1A). The pressure-responsive actuator **105** of the control valve **101** is coupled by a branch conduit **106** to the conduit **104**.

It will be appreciated, therefore, that this additional set of controls **87** will be immediately responsive to the controlled pulses of compressed air supplied to the second manifold **62** by the third group **14** of system controls. On the other hand, as will subsequently be explained, unless the condition-responsive valves **90** and **91** are closed before the cessation of the timed pulse of compressed air supplied to the conduit **104** by the second group **12** of system controls, the annunciator system **10** will halt further operation of the machine **15**.

Accordingly, the additional controls **87** are depicted in FIG. 2A at the same point in time illustrated in FIG. 1A. The control valves **31** and **57** in the third group **14** of system controls have just functioned as previously described for delivering the brief burst of compressed air to the second manifold **62** to simultaneously move the first and second visual indicators **73**, **74**, **107** and **108** momentarily outwardly. It will be noted, however, that the pneumatic pressure in the conduit **104** is functioning to temporarily hold the control valve **101** closed so that the pressure in the first manifold **47** can increase at its usual rate for retracting the first indicators **73** and **74** if, of course, the first condition-responsive valves **81** and **82** are closed. On the other hand, as shown in FIG. 2A, so long as either of the second condition-responsive valves **90** and **91** remain open, the pressure in the other first manifold **98** cannot increase to any significant level. The second visual indicators **107** and **108** will, of course, remain in their extended positions as depicted in FIG. 2A until the second condition-responsive valves **90** and **91** are closed. The initial open positions of the second condition-responsive valves **90** and **91** will, therefore, not prevent the initial starting of the engine **15** so long as the valve **101** remains closed for isolating the first manifolds **47** and **98** from one another.

As previously defined, the additional controls **87** are operatively arranged to permit the engine **15** to be started and continue operating if the several conditions being monitored by the second set of indicator relays **88** and **89** reach their respective operating ranges no later than a short time after the engine has been started. It will be recalled that pressure is immediately introduced to the conduit **104** when the engine **15** is started (FIG. 1A) and that this pressure will be maintained only until the valve **30** is closed. Thus, as previously described, this desired timing function is accomplished by selectively arranging the orifice **51** and the accumulator **53** to close the valve **30** at the end of a predetermined time interval so that cessation of the pressure in the conduit **104** will provide a positive signal for enabling further operation of the engine **15** only if the second set of operating conditions have then reached a satisfactory level. This predetermined time interval is, of course, related to what should be the normal time required for these operating conditions to respectively reach a proper level after the engine **15** starts.

Accordingly, as illustrated in FIG. 2B, if the condition-responsive valves **90** and **91** close while the second group **12** of system controls are still supplying compressed air to the to the conduit **104**, the orifice **103** will enable the pressure in the first manifold **98** to rapidly build up for retracting the second indicators **107** and **108** in the same manner as the first indicators **73** and **74**. It will be appreciated, of course, that the orifice **103** will prevent excessive loss of compressed air from the conduits **40** and **104** so long as the condition-responsive valves **90** and **91** are open and the second group **12** of system controls is supplying the timed flow of compressed air to these conduits.

On the other hand, should an operational malfunction hold either of the condition-responsive valves **90** and **91** open longer than anticipated, once the valve **30** closes the pressure in the conduit **104** will be relieved to quickly open the valve **101** and couple the pressured first manifold **47** to the still-vented first manifold **98**. It will be appreciated, therefore, from the preceding description as well as from FIG. 1D that venting of the pressured first manifold **47** will immediately initiate the shutdown of the engine **15**. Thus, depending on the positions of the condition-responsive valves **90** and **91** at the end of this selected time interval governed by the second group **12** of system controls, the signal provided thereby upon the resulting cessation of pneumatic pressure in the conduit **104** will in one instance permit continued operation of the engine **15** and in the other instance immediately terminate the operation of the engine.

When the condition-responsive valves **90** and **91** are safely closed before the valve **30** closes to discontinue the signal in the conduit **104**, the visual indicators **107** and **108** will be retracted; and, once the valve **101** opens as shown in FIG. 2C, the first manifolds **47** and **98** will be coupled to one another by way of the check valve assembly **99**. The additional controls **87** will, of course, remain in their depicted respective positions so long as the operating conditions being monitored by the second indicator relays **88** and **89** are within their specified limits.

It will, of course, be appreciated that opening of one or more of the first set of condition-responsive valves **81** and **82** as depicted in FIGS. 1D and 1E will initiate operation of the control system **10** to cause shutdown of the engine **15** in the same manner as already described, When this occurs, so long as the second condition-responsive valves **90** and **91** were closed, the visual indicators **107** and **108** will be retained in their "-safe" positions. Similarly, opening of either of the second set of condition-responsive valves **90** and **91** will also cause the interconnected manifolds **47** and **98** to be vented to atmosphere as depicted in FIG. 2D. Venting of the first manifolds **47** and **98** will, therefore, immediately cause shutdown of the engine **15** in the same manner as depicted in FIG. **1E**. Although it is not necessary to illustrate the actions of the additional set of controls **87** when the annunciator system **10** is functioning as illustrated in FIG. **1E**, it should be noted that the visual indicator **108** (as well as the indicators **73** and **74**) will be retained in its "safe" position and the momentary burst of compressed air supplied by the third group **14** of system controls to the second manifold **62** will move only the other visual indicator **107** forwardly to indicate the source of the malfunction causing the shutdown of the engine **15**.

The operating conditions which are to be monitored by the additional set of pneumatic controls **87** must, of course, all reach satisfactory levels within the time interval provided by the orifice **51** and the accumulator **53** of the second group **12** of system controls. It will be appreciated, however, that there may be situations where one or more of such operating conditions may not necessarily reach a satisfactory level by the time that the valve **30** closes.

Accordingly, to permit one or more of such different operating conditions to be reliably monitored by the annunciator system **10**, an alternate group **109** of system controls is depicted in FIG. **3** which can be employed for controlling a set of pneumatic controls **110** similar or identical to those depicted in FIGS. **2A-2D** and operatively arranged for controlling one or more indicator relays as at **111**. Since the respective functions of the alternate group **109** of system controls and the set of controls **110** and **111** are identical to their respective counterparts previously described, it is necessary to point out only that the interval before the cessation of the timed pulse of compressed air supplied to the conduit **112** will be selected in accordance with the particular condition being monitored. This time interval may, of course, be either longer or shorter than that provided by the second group **12** of system controls. Thus, if the branch conduit **113** from the first manifold **47** is not to be communicated with the first manifold **114** until some later time, the controllable orifice **115** as well as the size of the accumulator **116** can be appropriately selected for closing the valve **117** as determined by the particular situation. More than one system of controls, as at **109–111**, can, of course, be included in the system **10**.

In addition to the first and second types of conditions previously described with reference to FIGS. **1A–1E** and FIGS. **2A–2D**, a third type of operating condition is often experienced while operating typical industrial machines. These third conditions are those which may not be satisfied until some undetermined time after the machine is started but which will also be temporarily deficient as that machine is first being started. For example, in a typical installation, there will be instances where a low temperature, a low liquid level, or a low pressure will normally be experienced until sometime after the machine being monitored is started; but, once this condition is satisfied, a subsequent reduction will then endanger the machine. Thus, in distinction to the second type of conditions previously described, these third conditions may either remain unsatisfied for long periods of time or else they will become satisfied at some unpredictable time after the machine has started.

Accordingly, a third set of pneumatic controls **118** is depicted in FIG. **4A** for monitoring such conditions. Hereagain, this third set of controls **118** is to be used in conjunction with the control system **10** irrespective of whether or not the indicators **16** and **17** are utilized. Similarly, the third set of controls **118** is wholly independent of the second set of controls **87** and can be used either with or without either this latter system or the pneumatic controls **109–111**.

As illustrated in FIG. **4A**, the second manifold **62** is also coupled directly to the second inlets of each of one or more indicator relays, as at **119** and **120**, such as those previously described. A branch conduit **121** (which will be either coupled to or paralleled with the branch conduit **104** if the second set of controls **87** is being used) is coupled to the conduit **40** between the delay orifice **41** and the control valve **30** (FIG. **1A**). It will, of course, be appreciated that the conduit **121** could be alternatively coupled to the conduit **112** (FIG. **3**) if the timed interval of the pulse developed by the group **109** of system controls was to be employed. In any event, this branch conduit **121** is, in turn, divided into two other conduits **122** and **123** which are respectively coupled to the inlet of a two-way check valve **124** (similar or identical to those previously described at **42** and **99**) as well as to the inlet port of a typical pilot-operated check valve **125**. The other inlet of the two-way check valve **124** is coupled by a conduit **126** to the inlet of the control valve **28** controlling the system-controlled element **13** (FIG. **1A**).

The outlet of the two-way check valve **124** is coupled to the inlet of a normally-closed control valve **127** having its pressure-responsive actuator **128** coupled by a conduit **129** to the outlet port of the pilot-operated check valve **125**. The outlet of the normally-closed control valve **127** is coupled by one conduit **130** to the pressure-responsive actuator **131** of a normally-open control valve **132** and by another conduit **133** and an orifice **134** to one inlet of another two-way check valve **135**. The other inlet of this latter check valve assembly **135** is coupled by a conduit **136** to the outlet of the normally-open control valve **132**; and the outlet of this check valve assembly is coupled by a first manifold **137** having branch conduits **138** and **139** which are respectively connected to the first inlets of the indicator-relays **119** and **120**. For reasons that will subsequently be explained, a conduit **140** is coupled between the first manifold **137** and the reset or pilot port of the pilot-operated check valve **125**. The inlet of the normally-open valve **132** is coupled to a branch conduit **141** of the first manifold **47**.

Accordingly, the third set of controls **118** is depicted in FIG. **4A** as it will appear at the same moments respectively illustrated in FIGS. **1A** and **2A**. Since the second manifold **62** is coupled directly thereto, the brief pulse of compressed air applied thereto will also be effective for initially moving the visual indicators **142** and **143** forwardly. Hereagain, as was the case with the second set of controls **87**, since the third condition-responsive valves **144** and **145** will not be closed for at least a short time interval, the pressure in the first manifold **137** will remain at, or very near to, atmospheric pressure until such time that all of the third condition-responsive valves have closed when their respective operating conditions have reached their selected operational ranges for the first time. Similarly, since the control valve **132** is temporarily closed, the pressure in the first manifold **47** of the first set of indicator relays **16** and **17** can reach full pressure irrespective of what is happening in either the second or third sets of controls **87** and **118**.

Pressure will, however, be applied by way of the conduits **40**, **121** and **122** to the left-hand inlet of the two-way check valve **124** and to the inlet of the pilot-operated check valve **125** to retain the control valve **127** open and supply compressed air by way of the orifice **134** to the other two-way check valve **135**. This same pneumatic pressure will also function to maintain the control valve **132** closed. The various elements depicted in FIG. 4A will retain their same positions whenever the system **10** is at the point illustrated in FIG. 1B. Similarly, even after the system **10** is functioning as illustrated in FIG. 1C, should the third condition-responsive valves **144** and **145** still be open as shown in FIG. 4A, the various elements of the third set of controls **118** will remain in the same positions. These intermediate situations are, therefore, not illustrated. It should be noted, however, that the pilot-operated check valve **125** will initially trap pressure in the conduit **129** to retain the valve **127** open even after the conduit **123** is vented by closing of the valve **30**. In this manner, the pressure in the conduit **129** will then be effective for temporarily retaining the valve **127** closed for an indeterminate period of time.

Once, however, the condition-responsive valves **144** and **145** are closed as seen in FIG. 4B, the pressure will rapidly increase in the first manifold **137** to shift the visual indicators **142** and **143** to their "safe" positions and simultaneously supply a reset signal or pressure pulse to the pilot-operated check valve **125** by way of the conduit **140**. It will be appreciated that once the reset signal is applied to the pilot-operated check valve **125**, it will open to vent the pressure trapped in the conduit **129** which closes the control valve **127**. In this manner, the reset signal to the pilot-operated check valve **125** will be effective for venting the control actuator **131** which, in turn, opens the control valve **132**.

As previously described, the shutdown operations of the annunciator system **10** as shown in FIG. 1A and the several sets of controls **87**, **110** and **118** are wholly independent of one another. Thus, opening of one or the other of the first or second condition-responsive valves, as at **82** and **90**, will cause the annunciator system **10** to halt the engine **15** without affecting the positions of the indicators **142** and **143**. Conversely, as illustrated in FIG. 4C, upon opening of either of the condition-responsive valves **144** and **145**, the third set of controls **118** will halt the engine **15** in the same manner as already described. Thus, as shown in FIG. 4C, should the condition-responsive valve **145** be opened, venting of the first manifold **137** will simultaneously cause venting of the first manifold **47** as depicted in FIG. 1D. This, in turn, will produce the momentary pulse of compressed air through the second manifold **62** to move the appropriate visual indicator **143** outwardly while the check valve **146** and the still-closed condition-responsive valve **144** cooperate to retain the visual indicator **142** properly positioned. Once the first manifold **47** is vented, the annunicator system **10** will again function as previously described in FIGS. 1D and 1E to shutdown the entire system and halt the engine **15**.

Referring again to FIG. 1A, it will be appreciated that a test can be made of the annunciator system **10** (as well as the second and third sets of controls **87**, **110**, **111** and **118**) by momentarily positioning the manual selector **20** in its "test" position. This will simply supply compressed air through the valve **19** from the conduit **32** (valve **28** initially being open) back to the actuator **38** to retain the valve **28** in its open position so as to keep the fuel valve **13** open irrespective of the subsequent closing of the valve **29** to test the system. Once the valve **19** is in its "test" position, any of the condition-responsive valves, such as **81**, can be manually opened to simulate a malfunction condition. This will cause the appropriate visual indicator, such as **73**, to be extended without closing the fuel valve **13**. In this manner, a simulated test can be made of the system **10** without halting the engine **15**. It will be noted, however, that moving of the manual actuator **20** to the "-test" position will be ineffective until the valve **28** has been opened for the first time.

Turning now to FIGS. **5** and **6**, cross-sectional elevation and plan views are shown of a preferred embodiment of a new and improved pneumatic indicating device **150** especially adapted for use with the annunciator system **10** of the present invention and arranged in accordance with the principles of the present invention. The indicating device **150** is uniquely arranged for cooperative grouping with one or more similar or identical devices, as at **151–153**, which can be conveniently mounted as a unitary assemblage on a control panel (not shown) with a minimum number of interconnections.

As best seen in FIG. **6**, the new and improved indicating device **150** includes a generally-rectangular body **154** of uniform thickness and having opposed upper and lower planar faces to facilitate stacking of the device with the other devices **151–153** in the assemblage. A first elongated bore formed lengthwise through about the middle of the body **154** includes a short reduced forward portion **155** coincidentally aligned with a longer enlarged-diameter rearward portion **156** in which a longitudinally movable piston member **157** is slidably disposed. To provide an indication of the relative positions of the movable piston member **157**, a reduced diameter rod **158** coaxially mounted on the piston and extended through the forward bore **155** is operatively coupled to a suitable visual indicator or flag **159**.

Sealing members, such as O-rings **160** and **161**, are respectively arranged around the piston **157** and the internal wall of the forward bore **155** for defining a first pressure chamber in the enlarged bore **156** ahead of the piston member. To provide communication with this first pressure chamber, a transverse passage **162** is extended across the body **154** through the forward end of the enlarged bore **156** and preferably terminated by threaded counterbores or ports **163** and **164** formed on the rear face of the device. To close the rear of the enlarged bore **156**, a closure member **165** carrying a sealing member **166** is complementally fitted into the rearward end of the bore and retained therein by a cover plate **167** mounted across the rear of the body **154** and secured thereto as by bolts **168** and **169**. To provide communication with the second pressure chamber defined between the sealing members **160** and **166**, a vertical passage **170** is formed through the body **154** between its upper and lower faces to intersect the enlarged bore **156** just ahead of the closure member **165**.

A second elongated bore **171** is formed in the body **154** adjacent to one side of the first elongate bore and intersects it through a smaller coincidentally aligned passage **172** that intersects the transverse passage **162** about midway between the port **163** and the enlarged bore **156**. As best seen in FIG. **5**, a first pair of vertical passages **173** and **174** are formed through the body **154** between its upper and lower faces and intersect the second bore **171** at longitudinally-spaced intervals. Similarly, a second pair of vertical passages **175** and **176** are formed in the opposite side of the body **154** between its upper and lower faces. For reasons that will subsequently be explained, it will be noted that the passages **173-176** are symmetrically disposed on opposite sides of the enlarged bore **156** and are selectively positioned so that the lateral spacing between each of the four passages and the first bore is equal and the longitudinal spacing between the forward and rearward passages of each pair is equal.

An elongated tubular spool **177** is disposed in the second bore **171** and carries three longitudinally-spaced sealing members or O-rings **178-180** cooperatively arranged thereon for dividing the elongated bore into forward and rearward enclosed spaces that are isolated from one another and are respectively intersected by the vertical passages **173** and **174**. The longitudinal bore **181** through the spool **177** is terminated at its opposite ends by semi-spherical counterbores **182** and **183** respectively formed in the forward and rearward end surfaces of the spool. For reasons that will subsequently be explained, a single transverse passage **184** is formed through the spool **177** between the O-rings **179** and **180** and intersects the longitudinal bore **181** through the spool. It will be appreciated from FIG. **5** that with the spool **177** in the position illustrated and retained in the second bore **171** by the cover plate **167**, the rearward enclosed space will be in communication with the vertical passage **173** but will be isolated from the longitudinal bore **181** through the spool by the O-rings **178** and **179**. Conversely, by virtue of the transverse passage **184**, the forward enclosed space between the O-rings **179** and **180** will be in communication with the vertical passage **174** as well as the longitudinal bore **181** through the spool **177**.

With the spool **177** in this position, the vertical passage **173** and its associated rearward enclosed space will be isolated from the longitudinal passage **172** and the transverse passage **162** but the longitudinal bore **181** and the transverse passage **184** in the spool will communicate the vertical passage **174** with the passages **162** and **172** and the enlarged bore **156**. To permit flow from the vertical passage **174** to the enlarged bore **156**, a typical valve member, such as a ball **185**, is operatively disposed in the forward end of the second bore **171** and yieldably biased into seating engagement with the counterbore **183** in the forward end of the spool **177** by a spring **186** that is abutted against a shoulder **187** formed by the junction of the bore **171** and passage **172**. In this manner, compressed air can readily flow between the vertical passage **174** and the enlarged bore **156** but the spring-biased ball **185** will prevent flow in the opposite direction.

It will be appreciated from FIG. **6** that the several indicating devices **150–153** are well suited for being stacked together to form a unitary assemblage of any number of the devices. To facilitate their stacking, thin rectangular plates, as at **188–190**, each having five holes therein corresponding to the vertical passages **170** and **173–176** and respectively carrying a sealing member, as at **191**, are placed between the opposed faces of each indicating device. To provide a convenient connection with the vertical passages **170** and **173–176**, generally-rectangular bodies, as at **192** and **193**, are mounted on the top and bottom of the stacked indicating devices **150–153** and provided with appropriate ports, as at **194–196**, for communicating with the passages **170** and **173–176**. The complete assemblage of indicating devices **150–153**, the plates **188–190**, and the upper and lower manifold blocks **192** and **193** are secured together by vertical bolts as at **197** and **198**. As best described in a copending application, Ser. No. 777,670, by the present inventor, optical members or lenses, as at **199**, are respectively arranged between the forward ends of the spacer plates, as at **188** and **189**, for providing a positive visual indication only when the flag **159** is in its forward position immediately to the rear of the lens. To further assure that the flag **159** will remain in its warning position when urged forwardly by the pressure pulse produced upon the occurrence of a malfunction, a spring-biased detent **200** is arranged in the body **154** for cooperation with a reduced portion **201** arranged on the rod **158**.

Accordingly, it will be appreciated from the preceding description that when the indicating device **150** is to be used in the annunciator system **10**, the first manifold (as at **47** in FIG. 1A) will be coupled to the vertical passage **174** and the second manifold (as at **62** in FIG. 1A) will be coupled to the vertical passage **170**. The port **163** can be plugged and the port **164** coupled to the condition-responsive valve (as at **81** in FIG. 1A). The vertical passages **173**, **175** and **176** will, or course, be ineffective for purposes of operating the indicator device **150**.

As previously explained with reference to FIGS. 1A–1C, the brief pressure pulse initially delivered by way of the manifold **62** to the vertical passage **170** will be effective for temporarily shifting the piston **157** and its associated flag **159** forwardly. Then, once sufficient pressure has built up in the forward portion of the enlarged bore **156**, the piston **157** will be returned to the position illustrated in FIG. **6** to bring the flag **159** to a position indicating a safe operating condition. As previously described with reference to FIGS. 1D–1E, venting of the transverse passage **162** will, of course, be effective for initiating the momentary pressure pulse which is delivered by way of the vertical passage **170** to the rear of the piston **157** for driving the piston forwardly. Similarly, if the transverse passage in the indicating device **162** is not vented, the momentary pulse delivered to the vertical passage **170** will not be effective for moving the piston **157** a sufficient distance forwardly to indicate a malfunction.

It will be recognized, therefore, that by stacking the several indicators **150–153** as shown in FIG. **6**, their respective passages **170** will be in alignment with one another to provide an uninterrupted passage from top to bottom of the assemblage which will serve as the common second manifolds, as at **62**, with a common port as at **194** and **196**. On the other hand, by reversing the elongated spool **177**, the longitudinal bore **181** can be selectively placed in communication with either of the vertical passages **173** and **174**. The ball member **185** will, of course, be left in its depicted position for seating with either the seat **182** or **183**. Moreover, by turning the body **154** over, the passages **173** and **174** will then be placed into communication with the passages **175** and **176** in the adjacent devices **151** and **152**. Thus, by reversing the valve spool **177**, two additional combinations of interconnection can be readily obtained.

It will be seen, therefore, that by virtue of the alternate positions of the spool **177** as well as the alternate positions of the body **154**, any one of the four vertical passages **173–176** can be employed as the first manifold to the indicator device **150** irrespective of the arrangements of the other devices **151–153**. Thus, with only the four indicator devices **150–153** in a given stack, each device can be arranged for individual actuation. Similarly, with more than four indicator devices, as at **150**, in a given stack, those units sharing a common first manifold (as at **47** in FIG. **1A**) will be arranged identically to one another. The remaining units will, of course, be arranged as required to be coupled to the proper first manifold.

Accordingly, it will be appreciated that the new and improved pneumatic annunciator systems of the present invention are uniquely arranged for reliably providing indications of the occurrence of a malfunction of an industrial machine. Moreover by virtue of the cooperative relations of the several signal-producing controls of these annunciator systems, only those indicator relays individually associated with a transducer that actually senses an undesirable operating condition will be tripped so as to accurately designate the source of the malfunction causing the shutdown of the machine being monitored by the new and improved annunciator system. In this manner, false indications will not be presented and there will be no unwarranted resetting of an indicator relay as has been typical heretofore with annunciator systems of the prior art.

Furthermore, by virtue of the unique arrangement of the indicator units of the present invention, a number of these units can be conveniently stacked into a compact group and various connections made thereto. As described, the orientation of each unit with respect to the other units in the stack will provide one set of alternate connection combinations. Moreover, depending upon the position of the selector valve in each unit, another set of alternate connection combinations is provided.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. A pneumatic indicator adapted to be joined to another like indicator and comprising: a body having a chamber arranged therein; pressure-responsive indicator means operatively arranged in said chamber and adapted for movement therein between first and second indicating positions in response to pressure signals respectively applied to first and second portions of said chamber; a first passage in said body and communicating with said first portion of said chamber for conducting pressure signals thereto; second and third passages in said body and respectively terminating at an outer surface thereof adapted for placement adjacent to a matching outer surface of the body of a like pneumatic indicator; a fourth passage in said body intersecting said second and third passages and communicating with said second portion of said chamber for conducting pressure signals thereto; and means adapted for selecting which of said second and third passages is to be in communication with said second portion of said chamber and including a spool member adapted for positioning in said fourth passage between said second and third passages in either of two alternate positions therein, seal means adapted for sealing said spool member in relation to said body for isolating said second and third passages from one another and dividing said spool into spaced portions, and passage means in said spool member and adapted for communicating said fourth passage with the exterior of only one of said spaced spool portions to conduct pressure signals to said second portion of said chamber from only that one of said second and third passages then adjacent to said one spaced spool portion.

2. The pneumatic indicator of claim **1** wherein said spool member is adapted to be reversed end for end for selecting which of its said alternate positions it will occupy when said spool member is positioned in said fourth passage.

3. The pneumatic indicator of claim **1** further including check valve means in said passage means adapted for passing pressure signals only from that one of said second and third passages then adjacent to said one spaced spool portion to said second portion of said chamber.

4. The pneumatic indicator of claim **1** wherein said passage means include a bore extending the length of said spool member and terminating at the opposite ends thereof, and a branch bore between said bore and said one spaced spool portion; and further including check valve means adapted for selective cooperation with either of said ends of said spool member for passing pressure signals only from that one of said second and third passages then adjacent to said one spaced spool portion to said second portion of said chamber; and wherein said spool member is adapted to be reversed end for end for selecting which of its said positions it will occupy when said spool member is positioned in said fourth passage.

5. The pneumatic indicator of claim **1** wherein said indicator means include a visual indicator adapted for signifying at least one of said indicating positions of said indicator means.

6. The pneumatic indicator of claim **5** wherein said visual indicator is exterior of said chamber.

7. The pneumatic indicator of claim **5** further including detent means on said body and operatively arranged for retaining said indicator means in said one indicating position upon movement thereto.

8. A pneumatic indicator adapted to be joined to another like indicator and comprising: a body having a chamber arranged therein along a selected axis of said body; pressure;responsive indicator means operatively arranged in said chamber and adapted for movement therein between first and second indicating positions in response to pressure signals respectively applied to first and second portions of said chamber; a first passage in said body and communicating with said first portion of said chamber for conducting pressure signals thereto; a pair of second passages and a pair of third passages in said body respectively located on opposite sides of said chamber and equally spaced from said axis, said second and third passages respectively terminating at an outer surface of said body adapted for placement adjacent to a matching outer surface of the body of a like pneumatic indicator; a fourth passage in said body intersecting said second passages and communicating with said second portion of said chamber for conducting pressure signals thereto; and means adapted for selecting which one of said second passages is to be in communication with said second portion of said chamber and including a spool member adapted for positioning in said fourth passage between said second passages in either of two alternate positions therein, seal means adapted for sealing said spool member in relation to said body for isolating said second passages from one another and dividing said spool into spaced portions, and passage means in said spool member and adapted for communicating said fourth passage with the exterior of only one of said spaced spool portions to conduct pressure signals to said second portion of said chamber from only that one of said second passages then adjacent to said one spaced spool portion.

9. The pneumatic indicator of claim **8** wherein the spacing between said pair of second passages is equal to the spacing between said pair of third passages so that either of said pairs will coincide with either of such pairs of passages in a like pneumatic indicator.

10. The pneumatic indicator of claim **9** wherein said second and third passages extend through said body to opposed outer surfaces thereof so that the matching outer surfaces of like pneumatic indicators can be placed adjacent to said opposed outer surfaces and the matching pairs of such passages will coincide with said second and third passages.

11. An assembly of a plurality of pneumatic indicators comprising at least a pair of indicators, each of which is adapted to be connected to a transducer and operated thereby and each of said indicators being comprised of a body having sides thereto; at least two passage means cooperative with said assembly of indicators, said passage means extending through a first body and a second body wherein integrity of communication is achieved by placing said bodies in a side by side relationship; said first indicator being operatively communicated with either one or the other of said passage means; and said second indicator being operatively communicated with either of said passage means.

12. The assembly of pneumatic indicators of claim **11** wherein said first body is constructed and arranged with respect to said second body to permit said bodies to assume a first and a different and second side by side relationship characterized by the fact that said first and second passage means maintain integrity of communications in both side by side relationships.

13. The assembly of claim **12** wherein said first body incorporates a flag means movable between a tripped and an untripped position in response to pressure signals operatively applied thereto; internal passage means within said first body communicating either with said first or second passage means for obtaining therefrom pressure signals for operation of said flag means; and means for selectively limiting communications through said internal passage means to one of said first and second passage means.

14. The assembly of claim **11** wherein said first and second bodies each have opposing faces with openings therein communicating said first and second passage means therethrough, said opening in said first body and in said second body matching one another or juxtapositioning said bodies; and further including sealing gasket means positioned between said opposing faces.

15. The pneumatic indicator assembly of claim **11** further including movable indicator flag means forming a visual signal of the tripped and untripped positions of said indicator; pneumatic responsive means responsive to pressure signals and operably connected with said flag means for moving it to the tripped position; a first manifold pressure source means, connected with said first passage means; a connective means permitting connection of said indicator to a transducer which vents said connective means to a reduced pressure; a source of pneumatic pressure controllably supplied to said pneumatic responsive means for selectively moving said flag means to the tripped position; valve means communicating said connective means to said first passage means and to said pneumatic responsive means for applying a pressure signal tending to operate said pneumatic responsive means; said valve means, on reduction of pressure from a transducer through said connective means, reducing pressure in said first passage means, and further removing the tendency to operate said pressure responsive means, however said reduction in pressure in said first passage means occurring without regard to operation of said flag means.

16. The invention of claim **15** wherein said source of pneumatic pressure controllably supplied to said pneumatic responsive means forms a pressure pulse after the drop of pressure in said first manifold means, and said pressure pulse is supplied to said pneumatic responsive means to move said flag means to the tripped condition.

17. The invention of claim **15** wherein said valve means includes a check valve isolating said first passage means from said connective means and a transducer connected thereto and also from said pneumatic responsive means.

18. The assembly of indicators of claim **11** including a connective block means adapted to permit connection of the transducer thereto, said connective block means permitting connection of the transducer to at least a pair of alternative points on said connective block means and said connective block means operatively communicating the transducer to said body of said indicator.

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