United States Patent

Hurrah

[15] **3,651,643**

[45] **Mar. 28, 1972**

[54] PNEUMATIC ANNUNCIATOR SYSTEM

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[22] Filed: **July 21, 1970**

[21] Appl. No.: **56,892**

[52] **U.S. Cl.** **60/105,** 92/1, 137/557, 60/1

[51] **Int. Cl.** **F01k 13/02**

[58] **Field of Search** 73/116–118; 60/105, 1; 137/557

[56] **References Cited**

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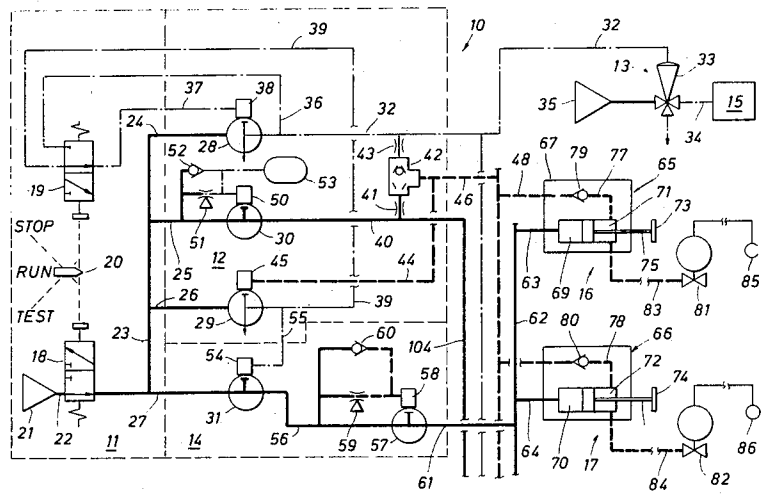
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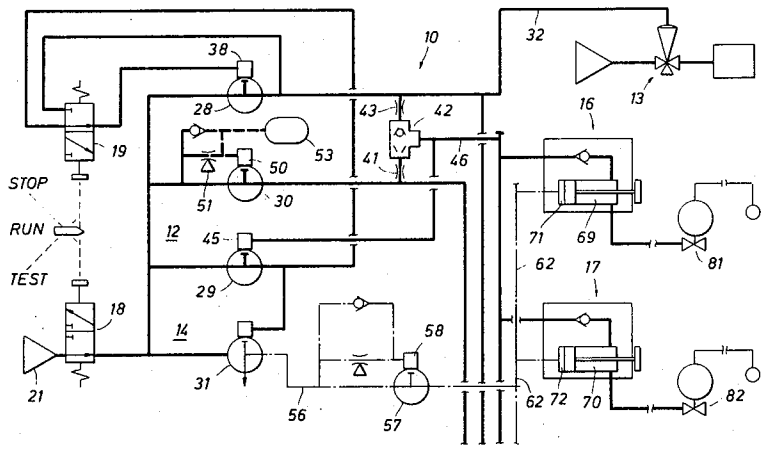
Primary Examiner—Edgar W. Geoghegan
Assistant Examiner—Allen M. Ostrager
Attorney—Donald Gunn

[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.

39 Claims, 15 Drawing Figures





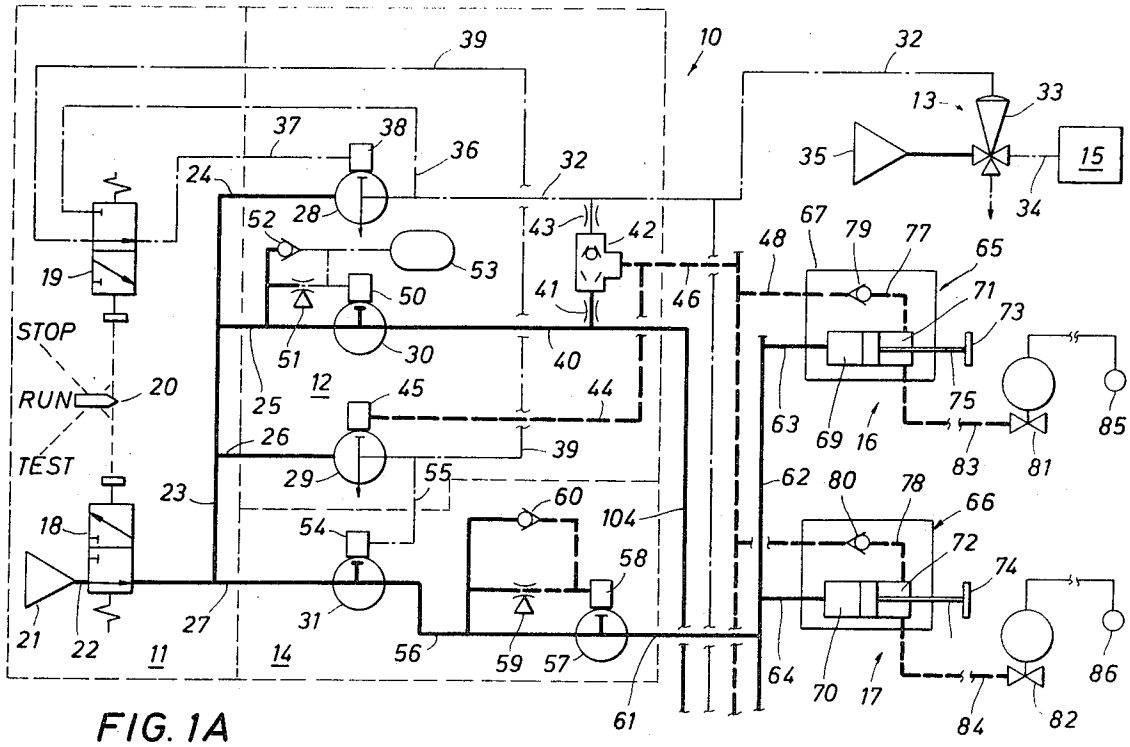


FIG. 1A

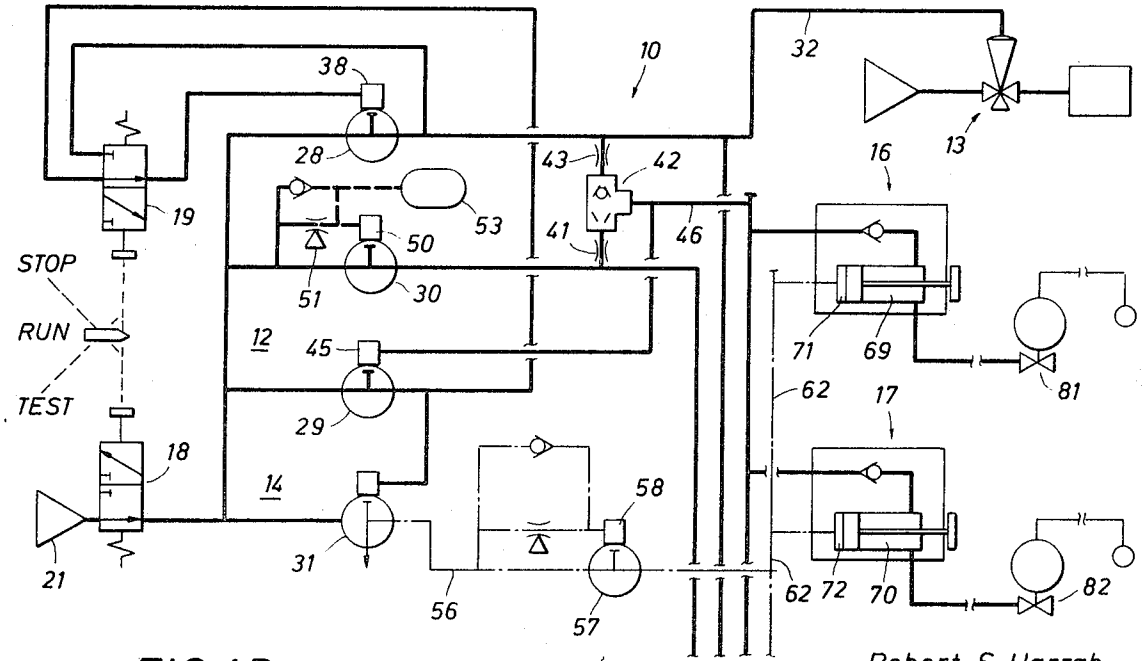


FIG. 1B

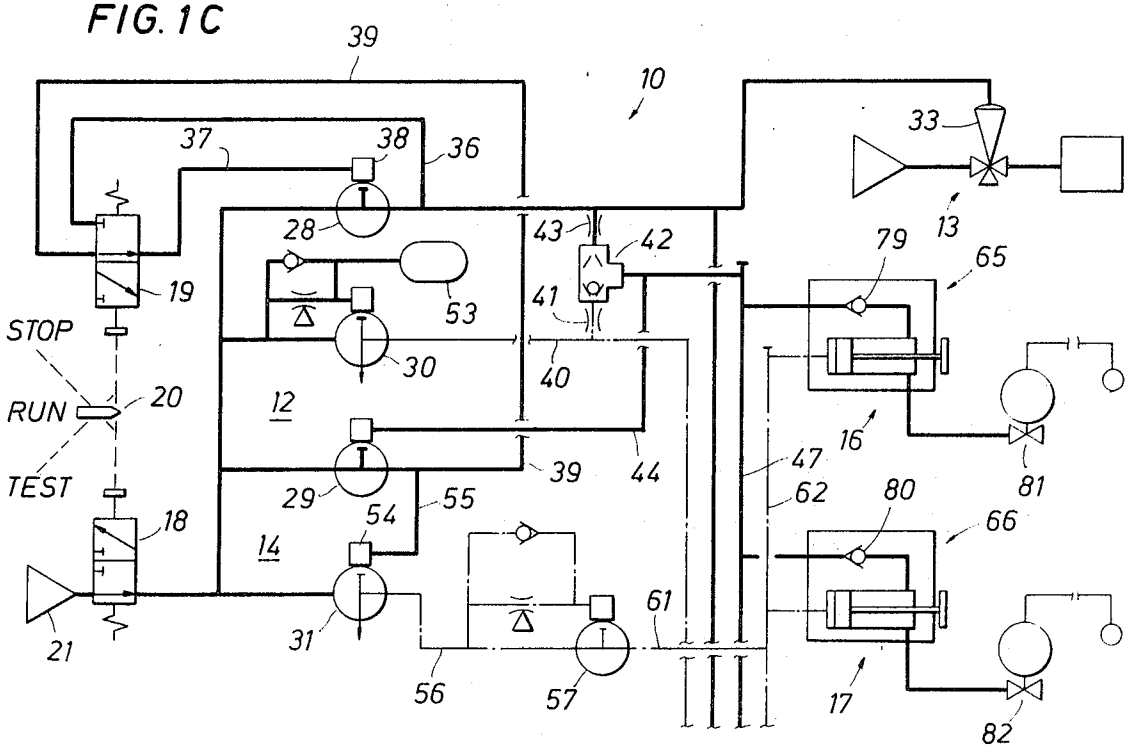
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FIG. 1C



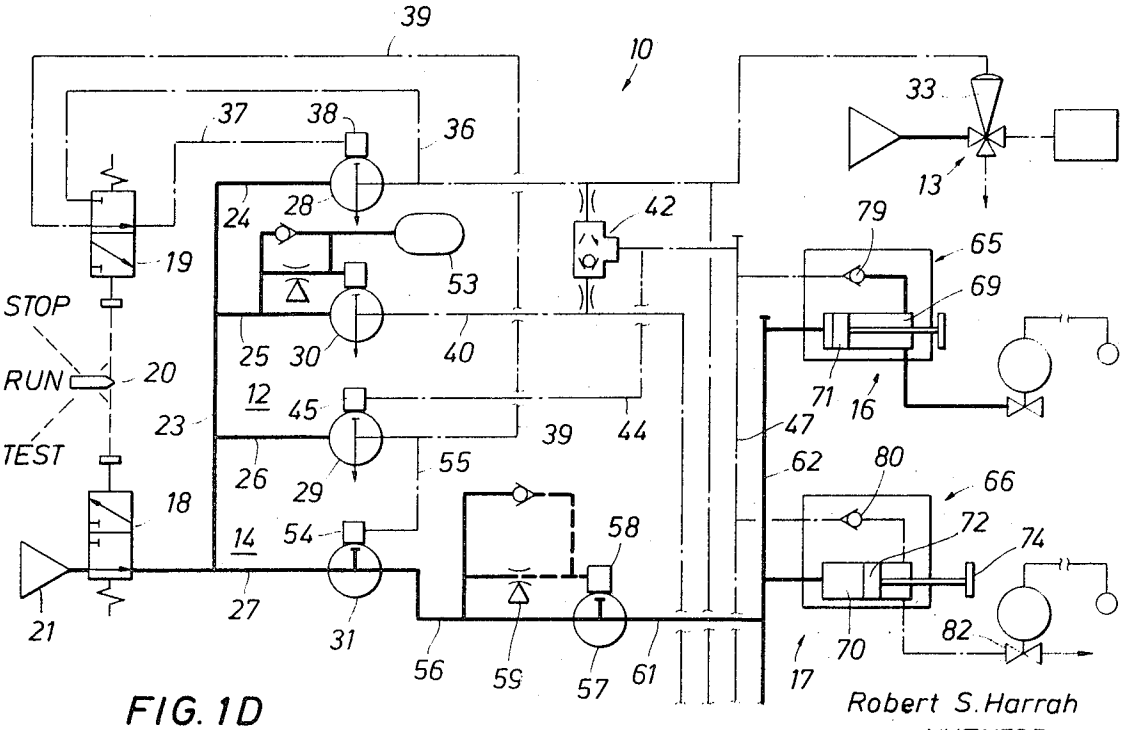


FIG. 1D

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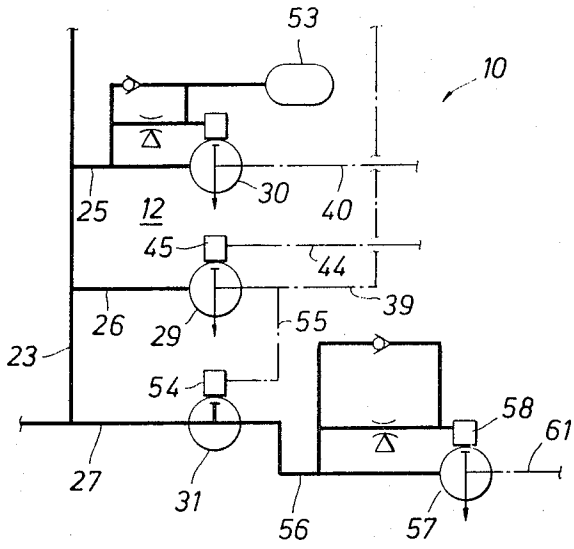


FIG. 1E

FIG. 2A

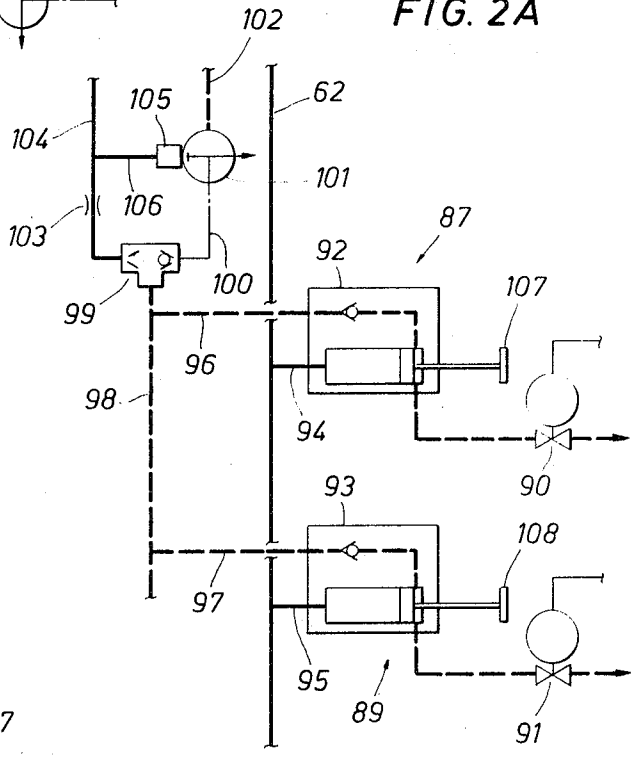
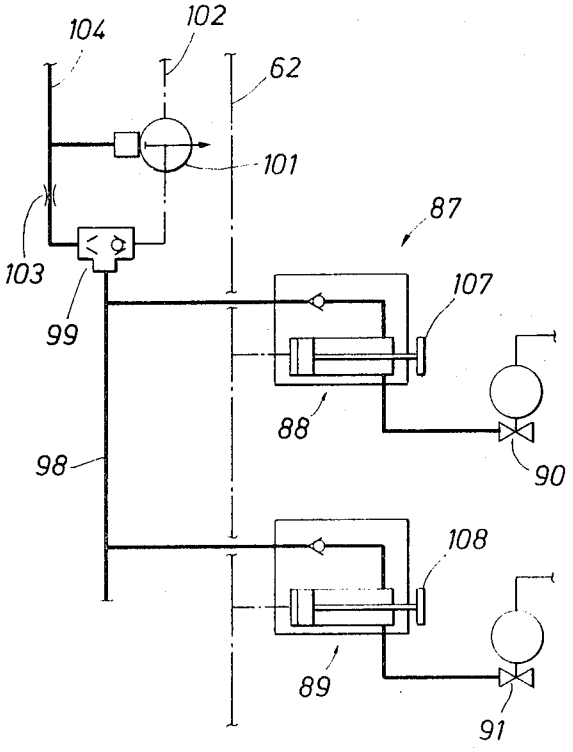


FIG. 2B

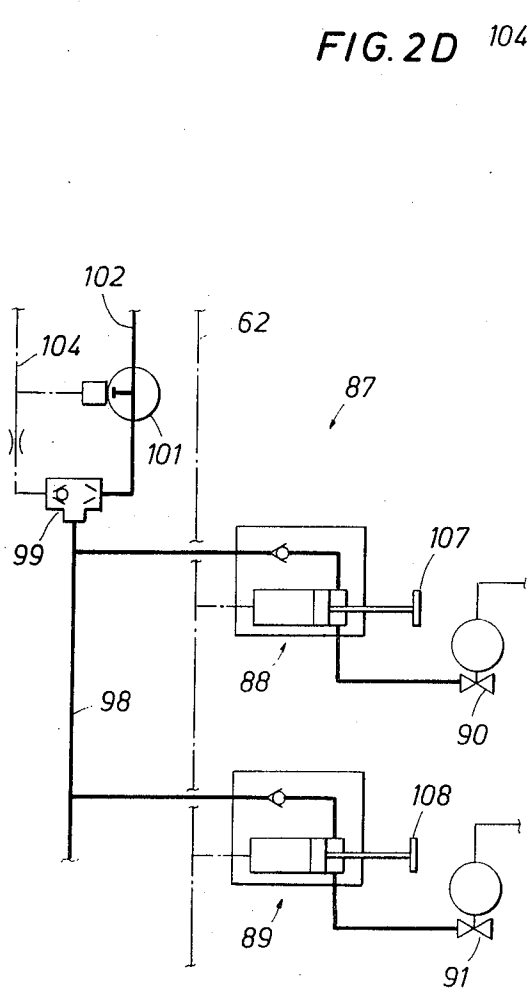


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FIG. 2D



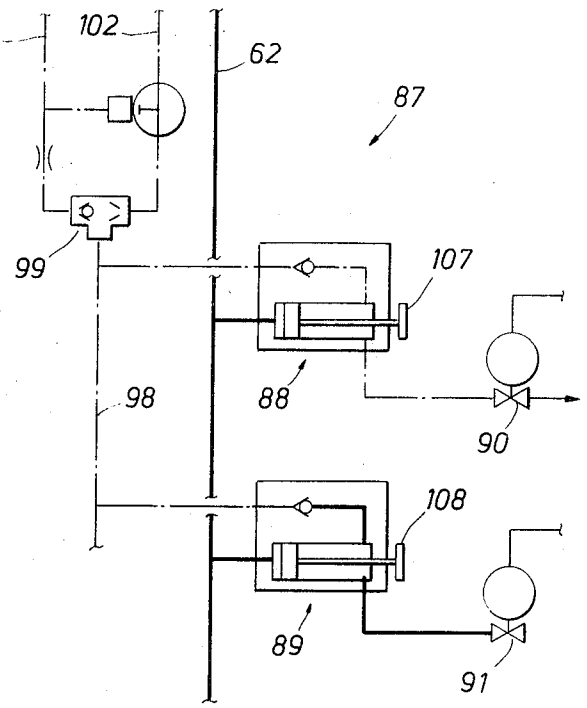


FIG. 2C

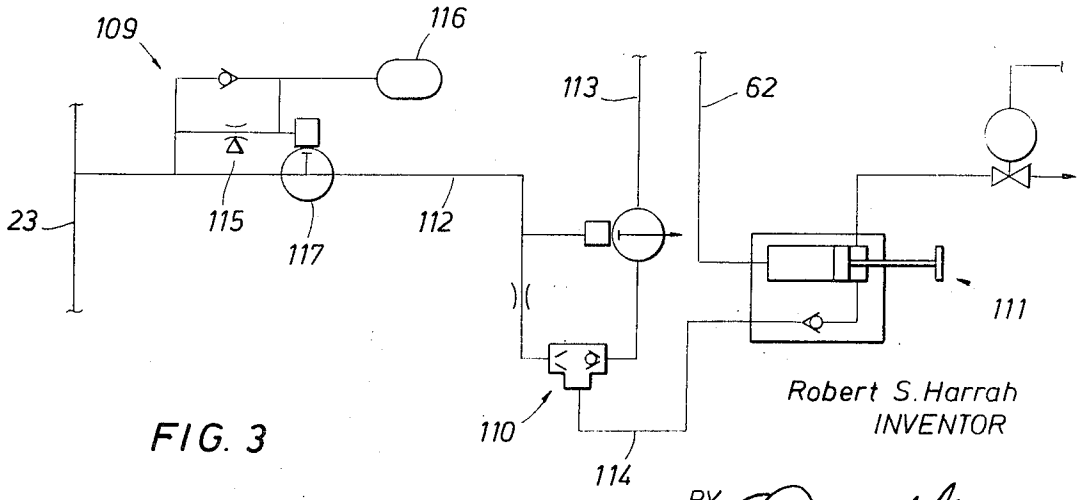


FIG. 3

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FIG. 4A

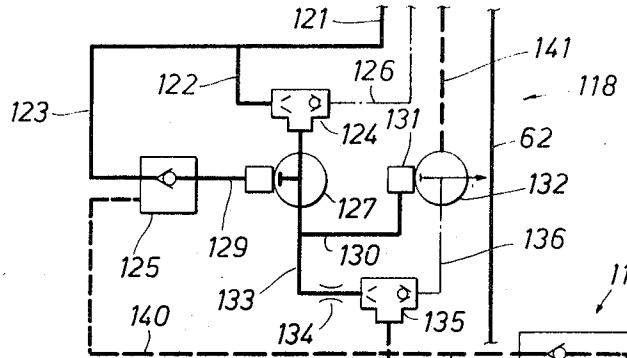
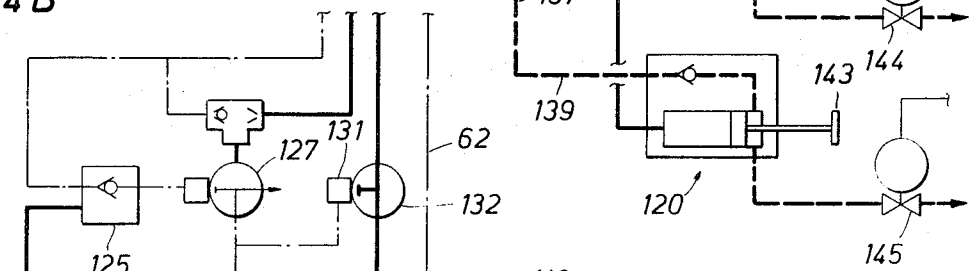


FIG. 4B



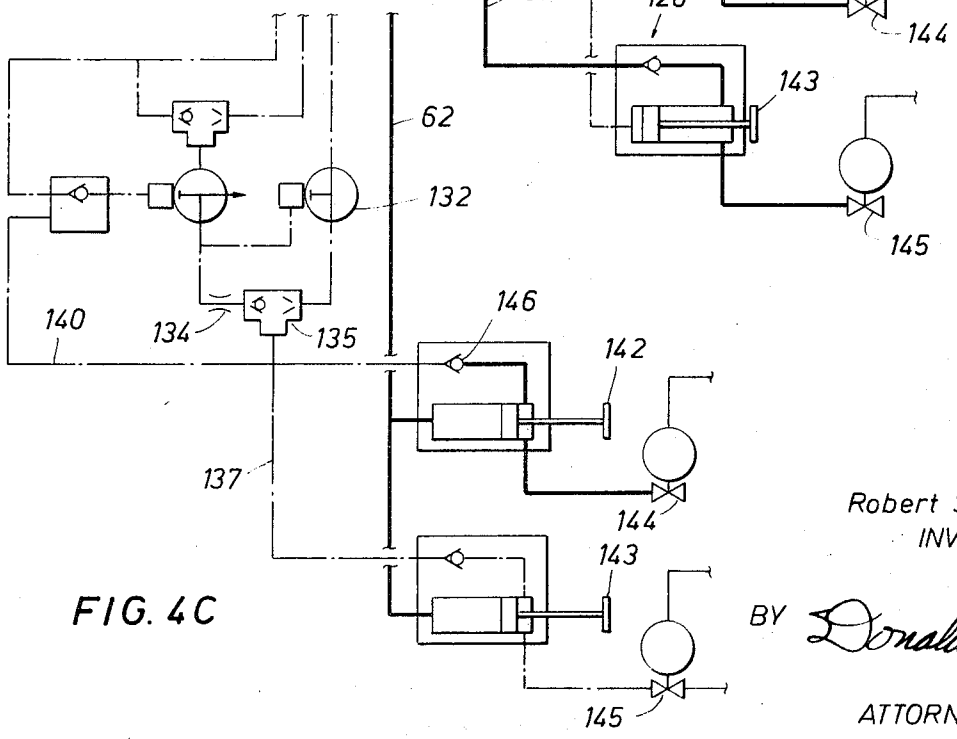


FIG. 4C

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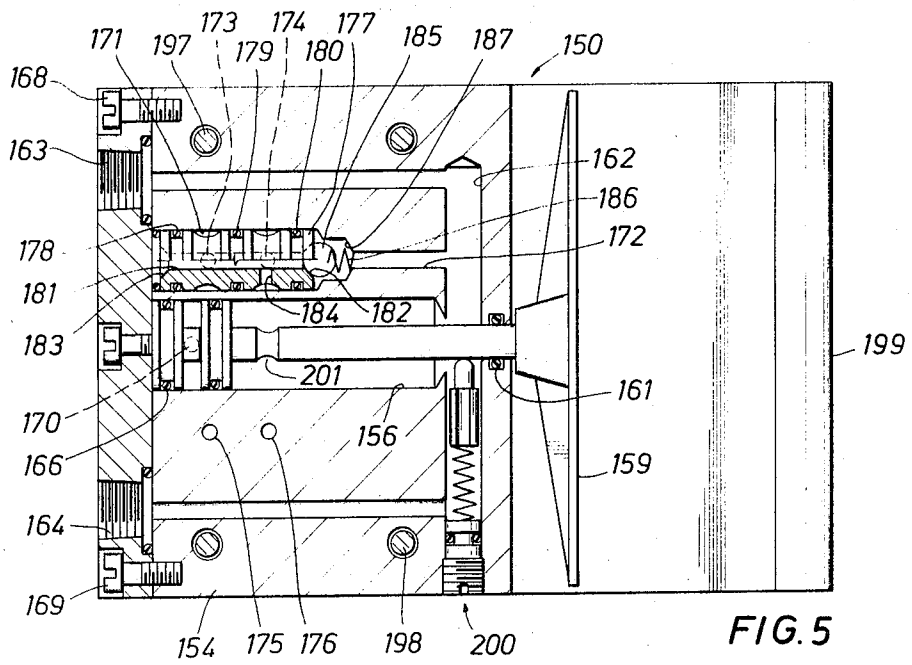


FIG. 5

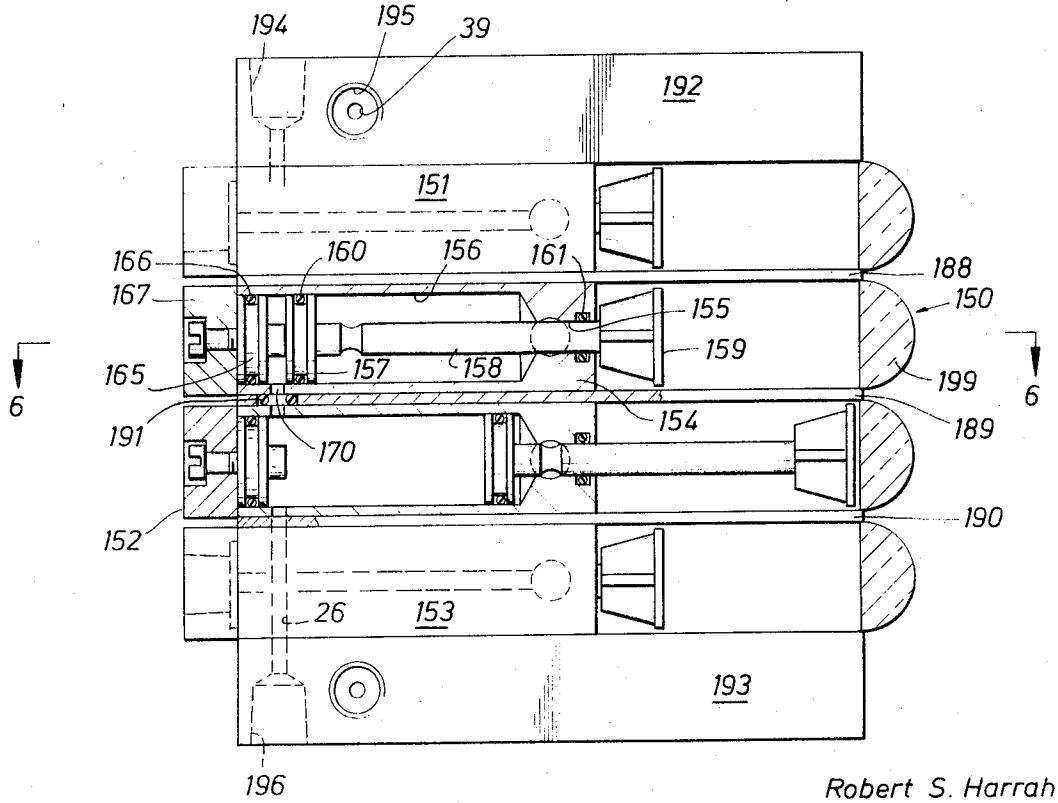


FIG. 6

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PNEUMATIC ANNUNCIATOR SYSTEM

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 which 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 cou-

pled 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 con-

trols. 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 annunciator 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 semispherical 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, of 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 por-

tion 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.

What is claimed is:

1. A pneumatic annunciator system adapted for monitoring a plurality of selected conditions respectively subject to change between at least two predetermined states and comprising: first and second pneumatic indicator means adapted for providing indications representative of first and second ones of such selected conditions and respectively including a member operable in response to a pulsed pneumatic signal to signify the occurrence of a selected one of such states; control means adapted for selectively enabling said indicator means for independent operation to their respective signifying condition and including first and second condition-responsive means respectively coupled to said first and second indicator means and independently operable in response to the occurrence of such selected states; and pneumatic signaling means coupled to said control means and said first and second indicator means and operatively arranged and adapted for producing a pulsed pneumatic signal in response to the operation of either of said first and second condition-responsive means for changing to its said signifying position only the one of said indicator means associated with the operated one of said condition-responsive means.

2. The pneumatic annunciator system of claim **1** further including first and second visual indicators operatively associated with said first and second members and adapted for respectively providing visual signals indicative of the movements of said movable members to their respective signifying positions.

3. The pneumatic annunciator system of claim **1** wherein such selected conditions are related to the operation of at least one machine and said control means further include: means operatively arranged and adapted for regulating the operation of such a machine in accordance with the states of such selected conditions; and means adapted for operating said regulating means in response to the operation of either of said first and second condition-responsive means to change the operation of such a machine accordingly.

4. The pneumatic annunciator system of claim **3** further including first and second visual indicators operatively associated with said first and second members which are movable and adapted for respectively providing visual signals indicative of the movements of said movable members to their respective signifying positions.

5. The pneumatic annunciator system of claim **1** wherein said control means further include: second pneumatic signaling means coupled to said first and second indicator means and operatively arranged and adapted for producing second pneumatic signals for independently restraining said members from their signifying positions before the operation of said first and second condition-responsive means, operation of said first and second condition-responsive means being operative for independently reducing said second pneumatic signal only on their respectively associated indicator means before production of said pulsed pneumatic signal.

6. The pneumatic annunciator system of claim **5** wherein said selected conditions are related to the operation of at least one machine and said control means further include: means operatively arranged and adapted for regulating the operation of such a machine in accordance with the states of such selected conditions; and means adapted for operating said regulating means in response to the operation of either of said first and second condition-responsive means to change the operation of such a machine accordingly.

7. The pneumatic annunciator system of claim **6** further including first and second visual indicators operatively associated with said first and second members and adapted for respectively providing visual signals indicative of the movements of said movable members to their respective signifying positions.

8. A pneumatic annunciator system adapted for monitoring a plurality of selected conditions related to the operation of at least one machine and respectively subject to change between desirable and undesirable states, and comprising: first and second pneumatic indicator means adapted for providing indications representative of the state of first and second ones of such selected conditions and respectively including a member operable in response to pneumatic signals between one condition signifying a desirable state and another condition signify-

ing an undesirable state; first and second condition-responsive means respectively coupled to said first and second indicator means and independently operable in response to the occurrence of such desirable states for enabling said members for operation to their said one condition and independently operable in response to the occurrence of such undesirable states for enabling said members for operation to their said other conditions; first control means including first pneumatic signaling means coupled to said first and second indicator means and operatively arranged and adapted for producing a first pneumatic signal for operating said first and second members to their said one condition only upon such first and second conditions achieving their respective desirable states; and second control means including second pneumatic signaling means coupled to said first control means to said first and second indicator means and operatively arranged and adapted for producing, in response to either of said first and second condition-responsive means responding to an undesirable state, a pulsed second pneumatic signal for operating to its said other condition only the one of said members associated with the responding one of said condition-responsive means.

9. The pneumatic annunciator system of claim 8 wherein said first pneumatic signaling means are operative for producing said first pneumatic signal for only a predetermined time interval; and further including third control means coupled to said first and second control means and operative for actuating said second pneumatic signaling means upon the termination of said first pneumatic signal whenever either of said first and second members are not in their respective one position at the end of said predetermined time interval.

10. The pneumatic annunciator system of claim 9 further including: means operatively arranged and adapted for regulating the operation of such a machine in accordance with the states of such selected conditions; and means operatively coupled to said regulating means and said third control means and adapted for discontinuing operation of such a machine upon operation of said third control means.

11. The pneumatic annunciator system of claim 10 further including: first and second visual indicators operatively associated with said first and second movable members and adapted for respectively providing visual signals indicative of the movements of said movable members to their respective signifying positions.

12. The pneumatic annunciator system of claim 9 wherein the first of such selected conditions is normally in its desirable state so that said first condition-responsive means are normally enabling said first movable member for movement to its said one position upon the commencement of said first pneumatic signal and the second of such selected conditions is normally in its undesirable state so that said second condition-responsive means are normally enabling said second movable member for movement to its said other position upon the commencement of said first pneumatic signal.

13. The pneumatic annunciator system of claim 8 wherein such selected conditions are normally in their respective desirable states so that said first and second condition-responsive means are normally enabling said movable members for movement to their said one positions upon the commencement of said first pneumatic signal and said first pneumatic signaling means are operative for producing said first pneumatic signal for only a predetermined time interval; and further including third control means coupled to said first and second control means and operative for actuating said second pneumatic signaling means upon the termination of said first pneumatic signal whenever either of said first and second movable members are not in their respective one position at the end of said predetermined time interval.

14. The pneumatic annunciator system of claim 8 wherein such selected conditions are normally in their respective undesirable states so that said first and second condition-responsive means are normally enabling said movable members for movement to their said other positions upon commencement of said first pneumatic signal and said first pneumatic signaling means are operative for producing said first pneumatic signals for only a predetermined time interval related to the time anticipated for such first and second conditions to reach their respective desired states; and further including third control means coupled to said first and second control means and operative for actuating said second pneumatic signaling means upon the termination of said first pneumatic signal whenever either of said first and second movable members have not moved to their respective one position by the end of said predetermined time interval.

15. The pneumatic indicator system of claim 8 wherein such selected conditions are normally in their respective undesirable states so that said first and second condition-responsive means are normally enabling said movable members for movement to their said other positions upon commencement of said first pneumatic signal and said first pneumatic signaling means are operative for producing said first pneumatic signals for only a predetermined time interval related to the time anticipated for such first and second conditions to reach their respective desired states; and further including third control means coupled to said first and second control means and operative in response to said first pneumatic signal for moving said movable members to their said one positions whenever said first and second condition-responsive means first operate in response to the occurrence of such desirable states.

16. A pneumatic annunciator system adapted for monitoring a plurality of selected conditions related to the operation of at least one machine and respectively subject to change between desirable and undesirable states, and comprising: a plurality of pneumatic indicator means adapted for providing individual indications representative of the state of such selected conditions and respectively including a member movable in response to pneumatic signals between one position signifying a desirable state and another position signifying an undesirable state; a plurality of condition-responsive means respectively coupled to each of said indicator means and independently operable in response to the occurrence of such desirable states for enabling said movable members for movement to their said one positions and independently operable in response to the occurrence of such undesirable states for enabling said movable members for movement to their said other positions; first control means including first pneumatic signaling means coupled to said indicator means and operatively arranged and adapted for producing a first pneumatic signal for moving said movable members to their said one positions only upon such first and second conditions achieving their respective desirable states; and second control means including second pneumatic signaling means coupled to said first control means to said first and second indicator means and operatively arranged and adapted for producing pulsed pneumatic signals, means operable in response to commencement of said first pneumatic signal for actuating said second pneumatic signaling means to produce a first pulsed pneumatic signal for temporarily moving said movable members to their respective said other positions, and means operable in response to any of said condition-responsive means responding to an undesirable state for moving to its said other position only those of said movable members associated with the responding condition-responsive means.

17. The pneumatic annunciator system of claim 16 wherein said means for moving said movable members to their said other positions include means operable in response to any of said condition-responsive means responding to an undesirable state for actuating said second pneumatic signaling means to produce a second pulsed pneumatic signal for moving to its said other position only those of said movable members associated with the responding condition-responsive means, and means operatively associated with said indicator means for retaining said first pneumatic signal to prevent movement of the others of said movable members from moving to their said other positions in response to said second pulsed pneumatic signal.

18. The pneumatic annunciator system of claim 17 further including: a plurality of visual indicators respectively associated with each of said movable members and adapted for respectively providing visual signals indicative of the positions of said movable members.

19. The pneumatic annunciator system of claim 17 further including: means operatively arranged and adapted for regulating the operation of such a machine in accordance with the states of such selected conditions; and means operatively coupled to said regulating means and said second control means and adapted for discontinuing operation of such a machine upon operation of said second pneumatic signaling means to produce said second pulsed pneumatic signal.

20. The pneumatic annunciator system of claim 19 further including: a plurality of visual indicators respectively associated with each of said movable members and adapted for respectively providing visual signals indicative of the positions of said movable members.

21. The pneumatic annunciator system of claim 17 wherein at least one of said condition-responsive means is adapted for monitoring a condition normally in a desired state upon starting of such a machine so that said one condition-responsive means will normally enable the movable member associated therewith for movement to its said one position upon commencement of said first pneumatic signal.

22. The pneumatic annunciator system of claim 17 wherein at least one of said condition-responsive means is adapted for monitoring a condition normally in an undesirable state upon starting of such a machine but which condition reaches a desirable state within a known time interval after starting of such a machine and said first pneumatic signaling means are operative for producing said first pneumatic signal for only a predetermined time interval somewhat greater than said known time interval so that said one condition-responsive means must enable the movable member associated therewith for movement to its said one position before the termination of said first pneumatic signal.

23. The pneumatic annunciator system of claim 22 wherein at least another one of said condition-responsive means is adapted for monitoring a condition normally in a desired state upon starting of such a machine so that said other condition-responsive means will normally enable the movable member associated therewith for movement to its said one position upon commencement of said first pneumatic signal.

24. The pneumatic annunciator system of claim 17 wherein at least one of said condition-responsive means is adapted for monitoring a condition normally in an undesirable state upon starting of such a machine but which condition reaches a desirable state within an undetermined time interval after starting of such a machine; and further including third control means coupled to said first and second control means and operative in response to said first pneumatic signal for moving the movable member associated with said one condition-responsive means to its said one position whenever said one condition-responsive means first operates in response to the occurrence of a desirable state in the condition monitored thereby.

25. The pneumatic annunciator system of claim 24 wherein at least another one of said condition-responsive means is adapted for monitoring a condition normally in a desired state upon starting of such a machine so that said other condition-responsive means will normally enable the movable member associated therewith for movement to its said one position upon commencement of said first pneumatic signal.

26. The pneumatic annunciator system of claim 24 wherein at least another one of said condition-responsive means is adapted for monitoring a condition normally in an undesirable state upon starting of such a machine but which condition reaches a desirable state within a known time interval after starting of such a machine and said first pneumatic signaling means are operative for producing said first pneumatic signal for only a predetermined time interval somewhat greater than said known time interval so that said other condition-responsive means must enable the movable member associated therewith for movement to its said one position before the termination of said first pneumatic signal.

27. The pneumatic annunciator system of claim 26 wherein at least a third one of said condition-responsive means is adapted for monitoring a condition normally in a desired state upon starting of such a machine so that said third condition-responsive means will normally enable the movable member associated therewith for movement to its said one position upon commencement of said first pneumatic signal.

28. A pneumatic annunciator system adapted for controlling the operation of at least one machine and monitoring a plurality of selected conditions related to its operation and which are subject to change between desirable and undesirable states, comprising a plurality of pneumatic indicator means adapted for providing individual indications representative of the state of such selected conditions and including a pressure-responsive member movable within an enclosed chamber between first and second positions which signify, as assigned, a desirable state and an undesirable state; control means connected to such one machine for controlling its continued operation, and for further terminating its operation, such machine being characterized in that a predetermined interval of time is required for said control means to terminate operation of such machine; a plurality of condition-responsive valves each adapted to be independently closed in response to the occurrence of a desirable state in its monitored condition and to be independently opened in response to the occurrence of an undesirable state in its monitored condition for venting to form a pneumatic signal indicative of the change thereof; connective means communicating said condition-responsive valves respectively to said pneumatic indicator means in a manner such that said pneumatic indicator means is enabled for subsequent operation; pneumatic pulse generator means for forming a pulsed pneumatic signal respectively applied to said pneumatic indicator means for moving said pressure-responsive members to either said first or second positions; each of said pneumatic indicator means being so constructed and arranged that its pressure-responsive member is enabled to be moved to a position indicative of an undesirable state only after operation of said respective condition-responsive valve associated therewith to form a pneumatic signal indicative of the change thereof; and said control means being at least partially dependent for initiation of its operation on operation of said condition-responsive valves for terminating operation of such machine.

29. The annunciator system of claim 28 wherein such machine is terminated in its operation over a predetermined interval of time, and said pulse generator means forms a pulsed pneumatic signal for said pneumatic indicator means, which signal is formed and completed prior to the end of the predetermined interval of time.

30. The annunciator system of claim 28 including a common manifold system connected to at least a pair of said pneumatic indicator means, and also in communication with said connective means, for communicating a pneumatic signal from said condition-responsive valve respectively associated with said pneumatic indicator means; and check valve means operatively incorporated in said connective means for communicating a pressure change from said condition-responsive valve to said respective pneumatic indicator means associated therewith for enabling its operation, said check valve means further preventing the communication of the pressure change through said common manifold system to the remaining one of said pair of pneumatic indicator means.

31. The annunciator system of claim 28 including a common manifold passage means connected between at least a pair of said pneumatic indicator means for applying a pressure level on said pressure-responsive members for maintaining said pressure-responsive members in positions indicative of their respective desirable states and tending to oppose the pneumatic signal applied thereto by said pulse generator means; check valve means isolating said pneumatic indicator

means from pressure drops communicated through said common manifold passage means; and wherein said pressure-responsive member is moved to a position indicating an undesirable state of such machine as sensed by said condition-responsive valves.

32. The annunciator system of claim 28 further including a manifold passage means connected to one of said pneumatic indicator means for applying a pressure level to said pressure-responsive member in said enclosed chamber tending to maintain said member in a position indicating a desirable state; said manifold passage means supplying its pressure level through a check valve means which is so connected as to maintain the pressure level acting on said pressure-responsive member from said manifold passage means; said connective means communicating said condition-responsive valve to said pressure-responsive member for venting the pressure level acting on said pressure-responsive member through said condition-responsive valve, and said check valve means venting said manifold passage means through said condition-responsive valve; an additional passage means communicated with said enclosed chamber for supplying the pulsed pneumatic signal from said pulse generator means, said additional passage means connected with said enclosed chamber such that said pulsed pneumatic signal tends to move said pressure-responsive member to the position indicative of an undesirable state, and said movement is accomplished when said condition-responsive valve has opened to vent and said movement is not accomplished when said condition-responsive valve has not opened to vent.

33. The annunciator system of claim 28 further including a manifold passage means connected to one of said pneumatic indicator means for applying a pressure level to said pressure-responsive member in said enclosed chamber tending to maintain said member in a position indicating a desirable state; said manifold passage means supplying its pressure level through a check valve means which is so connected as to maintain the pressure level acting on said pressure-responsive member from said manifold passage means; said control means being operatively connected to and controlled by the pressure level in said manifold passage means such that a drop in pressure created by the opening to vent of a selected condition-responsive valve coupled through a check valve means lowers the pressure in said manifold passage means and initiates termination of operation of such machine; and wherein such machine, during its termination of operation, changes the selected conditions monitored by said condition-responsive valves which changes attain an undesirable state monitored by their respective condition-responsive valves; said pulse generator means forming a pulsed pneumatic signal respectively applied to said pneumatic indicator means after the opening to vent of one selected condition-responsive valve but before the opening to vent of the remainder of said condition-responsive valves as such machine terminates operation and the selected conditions monitored by the remainder of said condition-responsive valves attain the undesired state.

34. The annunciator system of claim 28 further including a plurality of visual indicators respectively associated with each of said pressure-responsive members and is adapted for providing visual signals indicative of the positions of said pressure-responsive members.

35. The annunciator system of claim 28 wherein one or more of said condition-responsive valves is adapted to monitor a condition normally in an undesirable state upon starting of such a machine but which condition reaches a desirable state within a known time interval after starting such machine and such condition is monitored by one of said condition-responsive valves; and further including a manifold passage means connected to at least one of said pneumatic indicator means for deriving a pressure level from said means indicative of the open or closed condition-responsive valve associated therewith; said manifold passage means being operatively connected to said control means for terminating operation of such machine on opening of one of said condition-responsive valves as derived through said pneumatic indicator means; and enabling means interposed between said control means and said manifold passage means for enabling operation of said control means until after passage of the known time interval.

36. The annunciator system of claim 35 wherein the known time interval is determined by an event related to the operation of such machine.

37. The annunciator system of claim 35 further including a plurality of visual indicators respectively associated with each of said pressure-responsive members and is adapted for providing visual signals indicative of the positions of said pressure-responsive members.

38. The annunciator system of claim 35 wherein said enabling means includes a pressure source which supplies pneumatic pressure to said manifold passage means at a controlled rate, and so long as said one condition remains in an undesirable state said condition-responsive valve associated therewith opens to vent said manifold passage means; and further including means associated with said control means responsive to an increase in pressure in said manifold passage means which enables said control means to be responsive to a subsequent drop in pressure in said manifold passage means in terminating operation of such machine.

39. The annunciator system of claim 38 wherein said check valve associated with said condition-responsive valve which is closed after passage of a known time interval vents said manifold passage means through said condition-responsive valve continuously until said condition-responsive valve is closed.

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