United States Patent

Zehr et al.

[15] **3,665,399**

[45] **May 23, 1972**

[54] MONITORING AND DISPLAY SYSTEM FOR MULTI-STAGE COMPRESSOR

[72] Inventors: **Richard M. Zehr,** Tonawanda; **James Mott,** Buffalo; **Lawrence Schlimgen,** Tonawanda, all of N.Y.

[73] Assignee: **Worthington Corporation,** Harrison, N.J.

[22] Filed: **Sept. 24, 1969**

[21] Appl. No.: **860,768**

[52] **U.S. Cl.** .....**340/152 R,** 235/151, 340/413

[51] **Int. Cl.** **H04q 9/00,** G06f 11/00

[58] **Field of Search** 340/413, 415, 152, 151; 235/153, 151, 151.1; 417/12, 18, 32, 282, 292

[56] **References Cited**

UNITED STATES PATENTS

3,260,998	7/1966	Fluegel	235/151
3,147,469	9/1964	Buchsbaum	340/336
3,130,348	4/1964	Lieb	340/336
3,232,519	2/1966	Long	417/32
3,142,820	7/1964	Daniels	235/151
3,202,804	8/1965	Schlein	235/151
3,260,998	7/1966	Fluegel	235/151
3,519,807	7/1970	Jacques et al	235/151.1

Primary Examiner—Donald J. Yusko

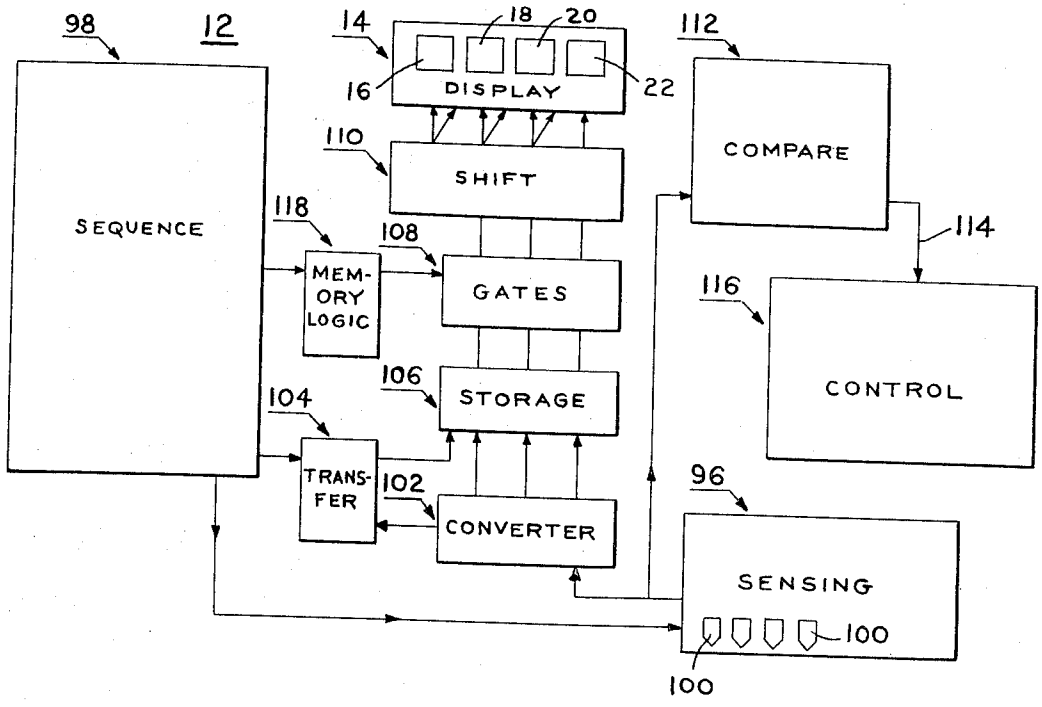
Attorney—Lerner, David & Littenberg

[57] **ABSTRACT**

A system is disclosed for sequentially monitoring and displaying the instantaneous value of a plurality of parameters associated with a motor driven device such as a multi-stage compressor. In addition to the basic functions of monitoring and displaying these values, the system performs a multitude of other functions such as: continuously comparing preselected ones of these parameters with pre-established reference signals to determine if these various parameters exceed predetermined safe limits; activating alarm devices should the particular parameters chosen exceed their pre-established limits; shutting down or otherwise controlling the device being monitored should the selected parameters exceed their predetermined levels so as to generate alarm signals; and storing the values of other preselected parameters such that these values can be subsequently displayed after the occurrence of an alarm situation. The system can be operated in a "scan" mode whereby the parameters are sequentially monitored, checked, and stored values updated at a preselected rate.

Alternatively, an operator can select a particular station to be monitored in which case the instantaneous value of that particular parameter will continuously be displayed by the system. Regardless of whether the system is operated in the "scan" or "hold" mode, the occurrence of an alarm condition in any of the pre-established parameters will generate appropriate command signals to shut down or otherwise control the device being monitored; while at the same time, the value of the parameter which generated the alarm signal will be displayed on the apparatus.

53 Claims, 17 Drawing Figures



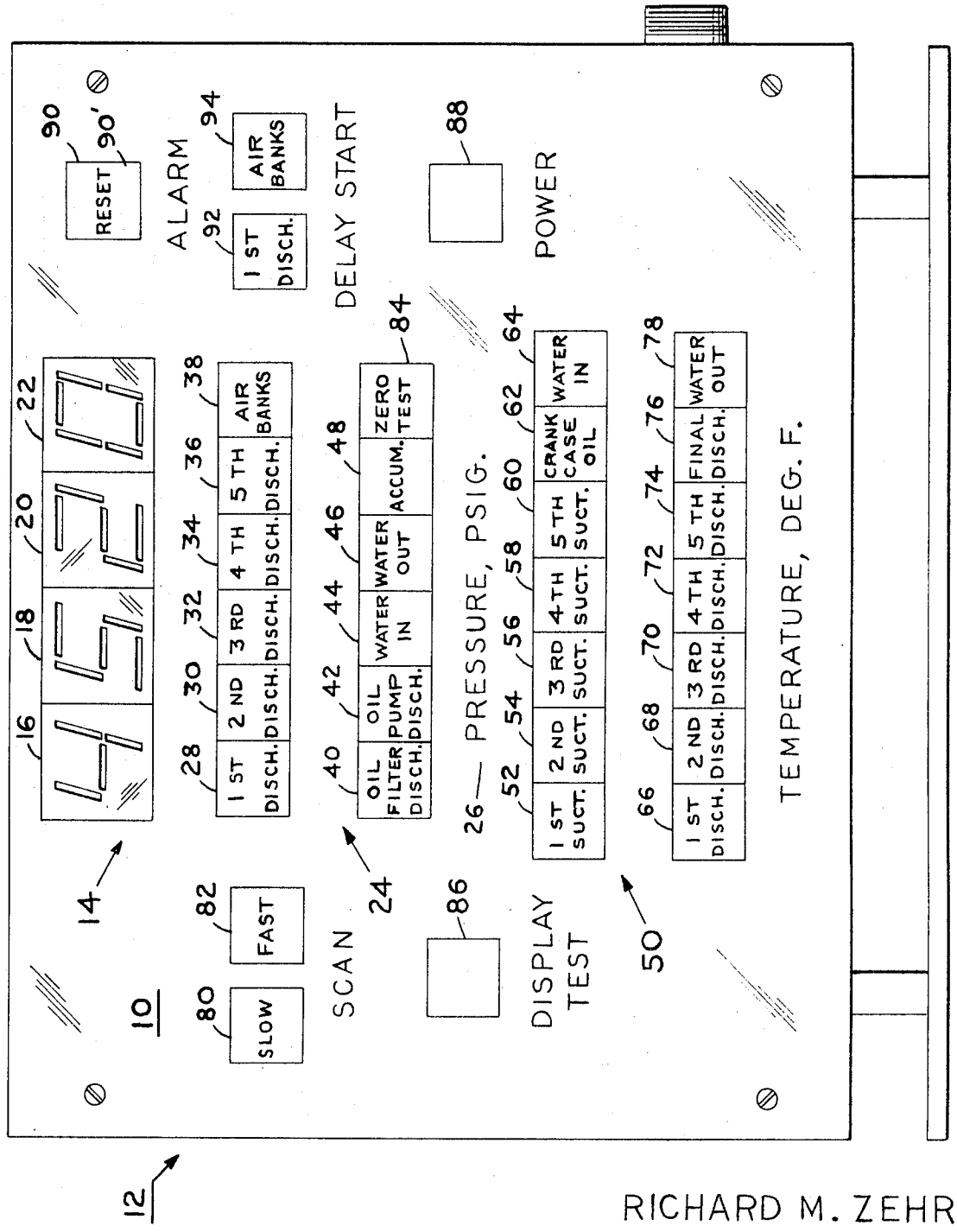


FIG. 1

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

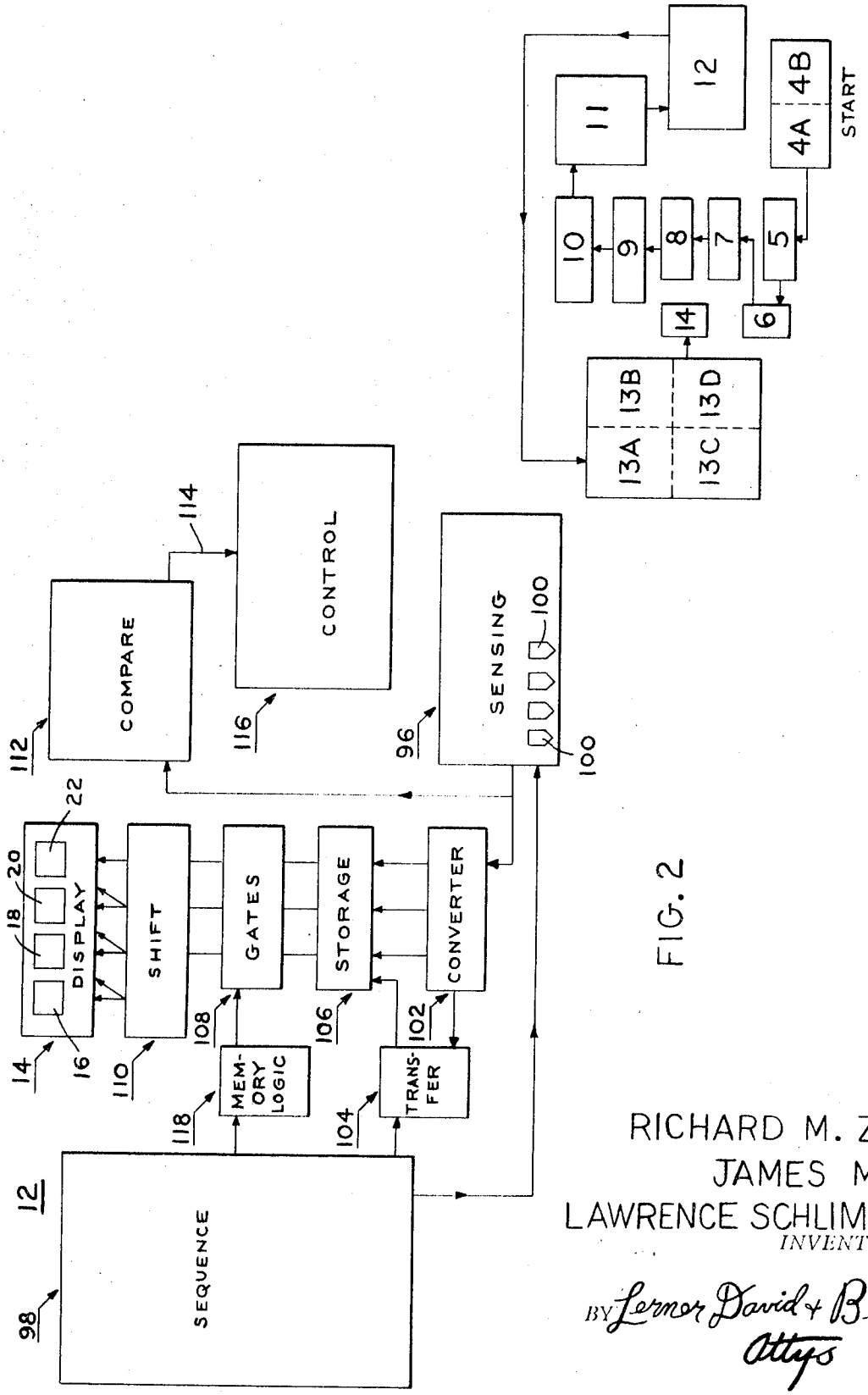


FIG. 3

FIG. 2

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

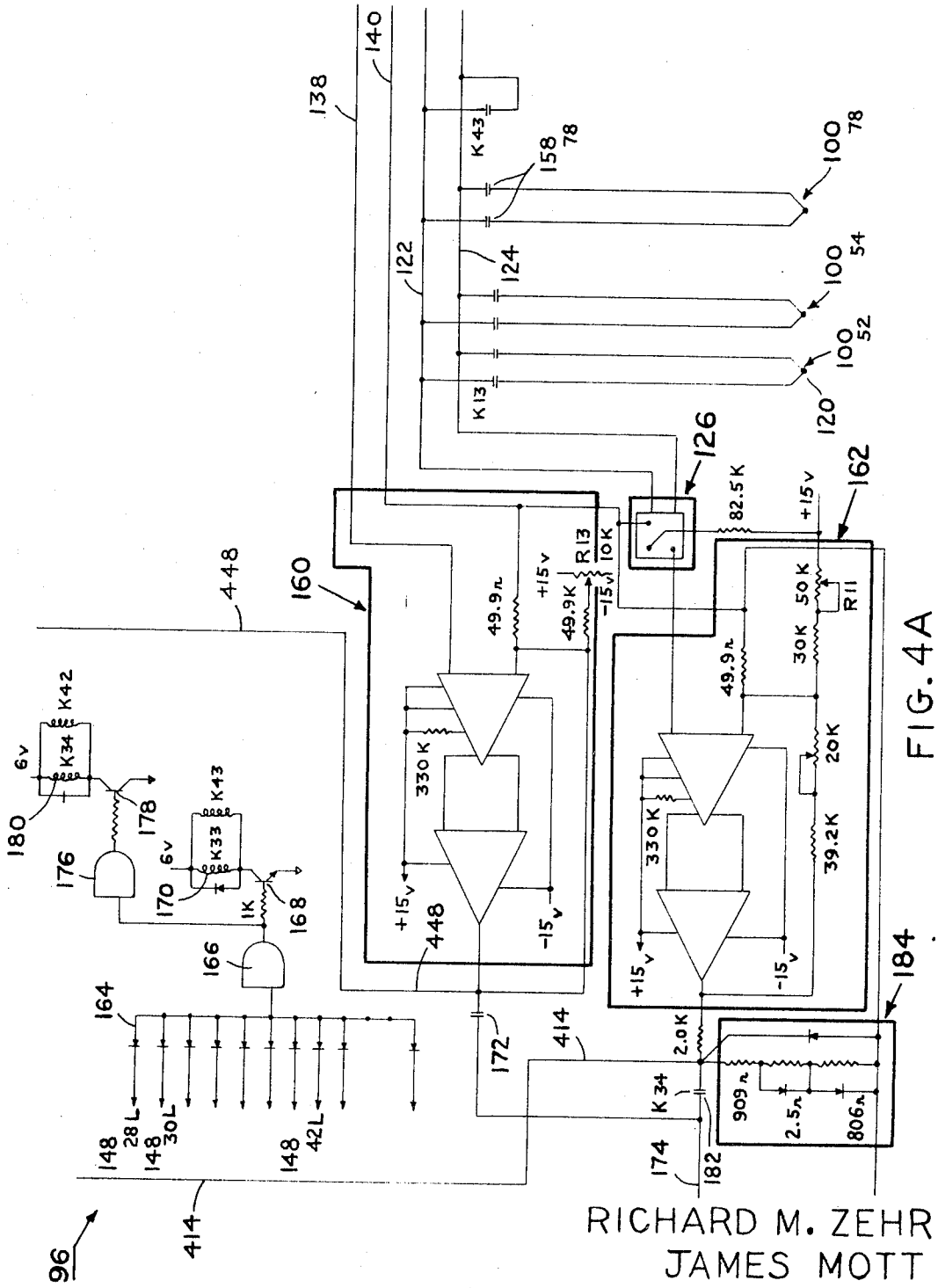


FIG. 4A

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

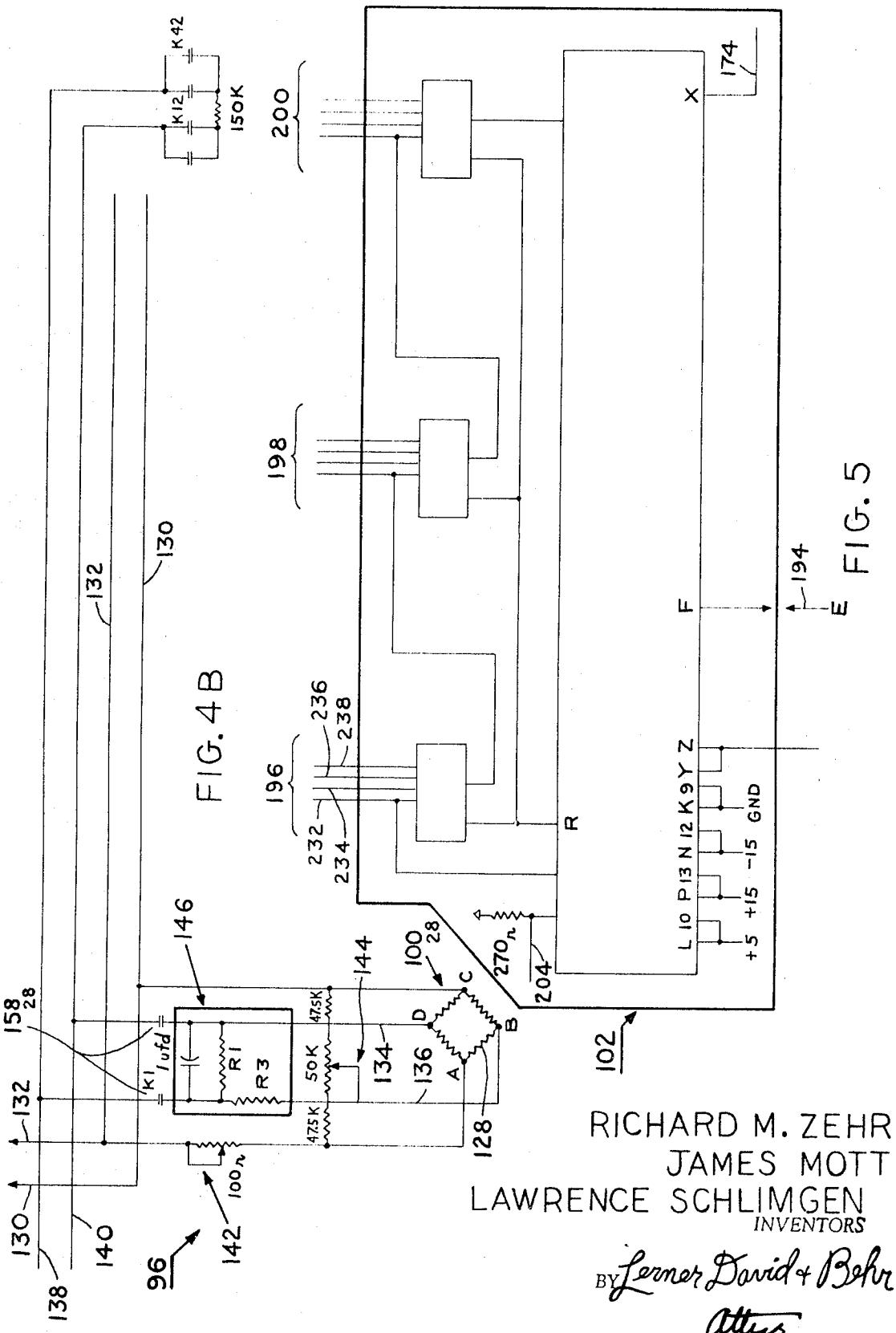


FIG. 4B

FIG. 5

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

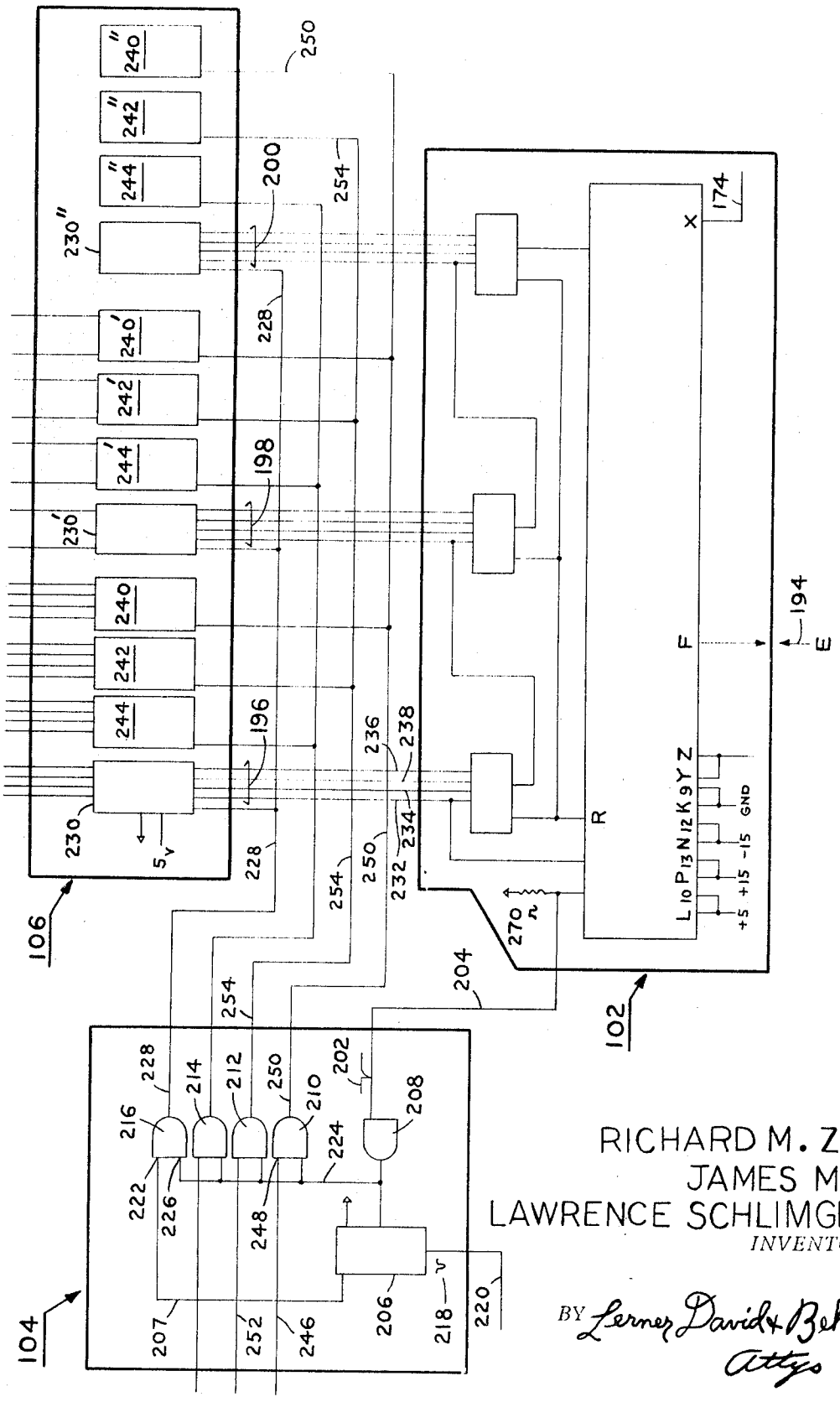
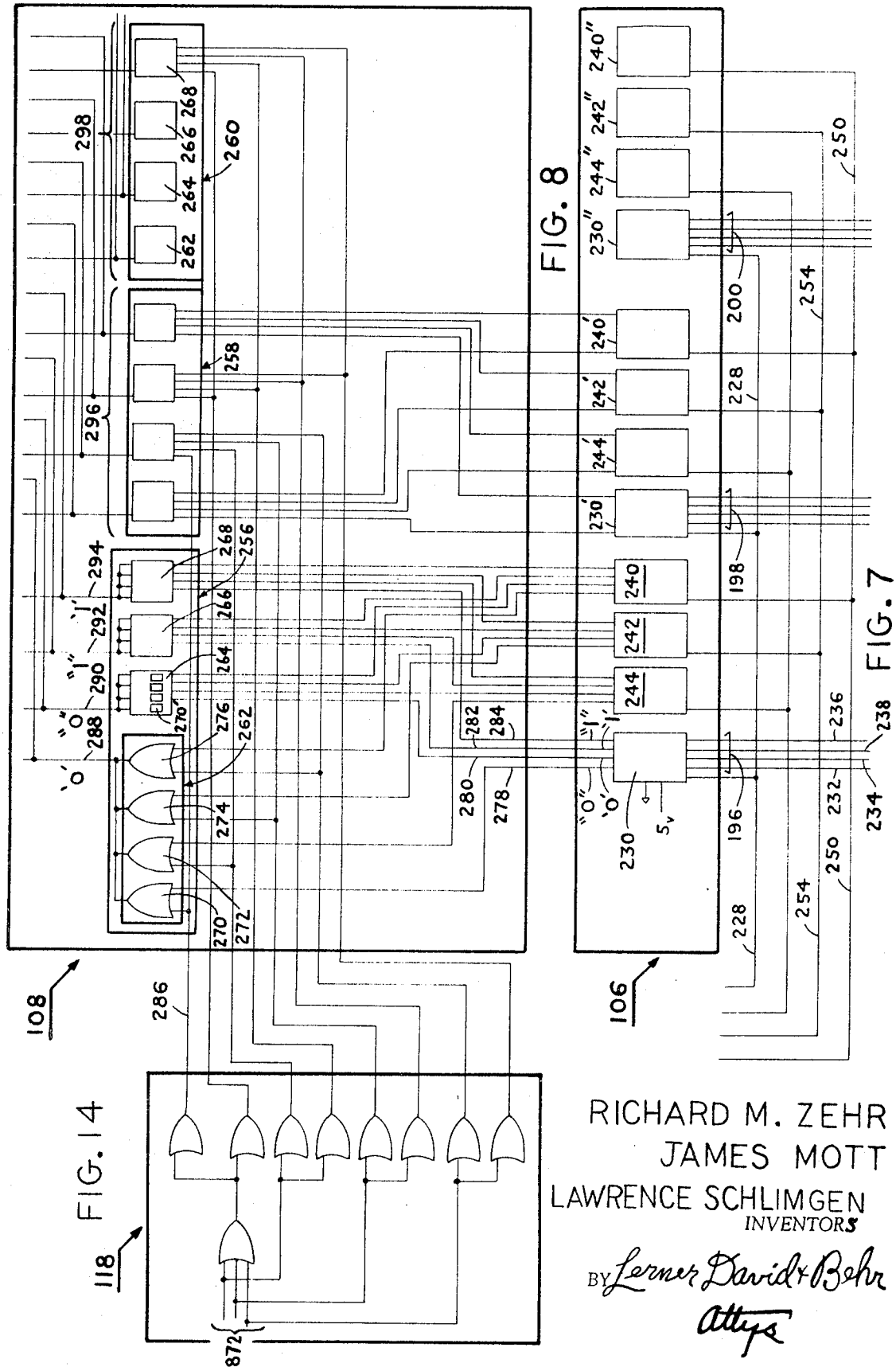


FIG. 6

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner, David & Behr
Attys



RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS
BY Lerner David & Behr
Attys

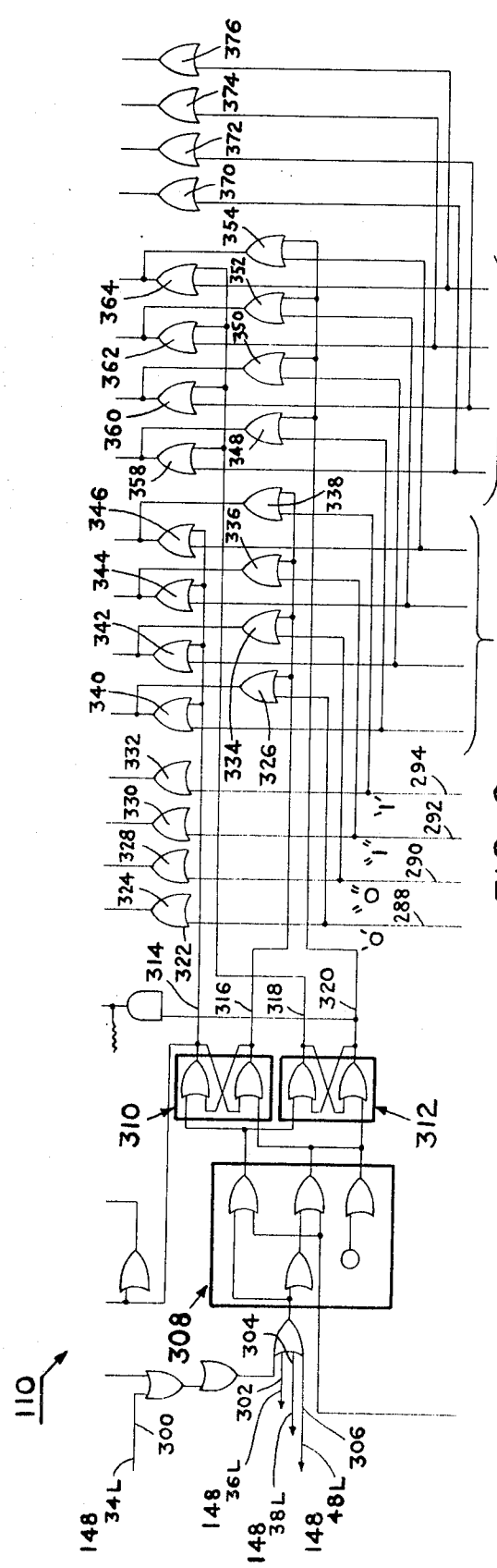


FIG. 9

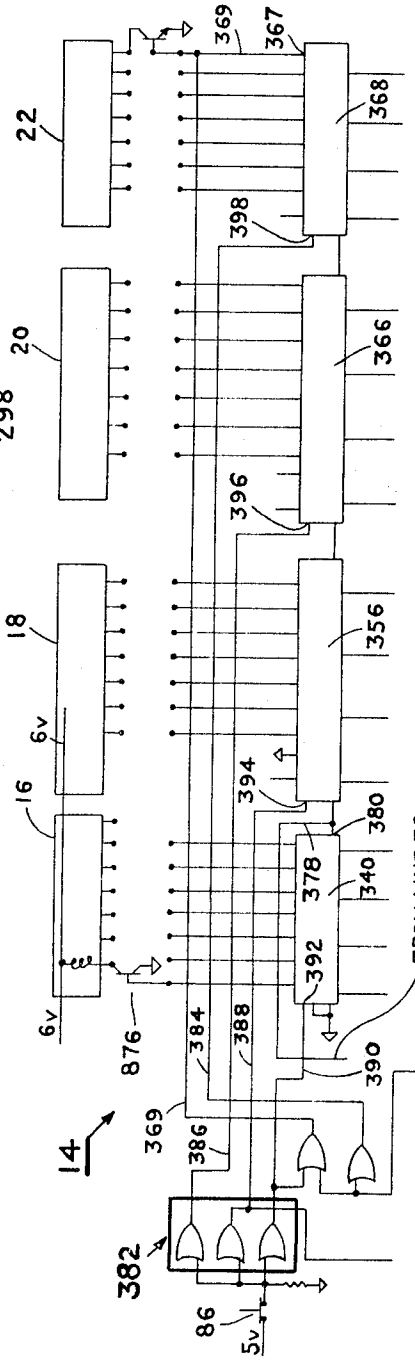


FIG. 10

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Baker
Attys

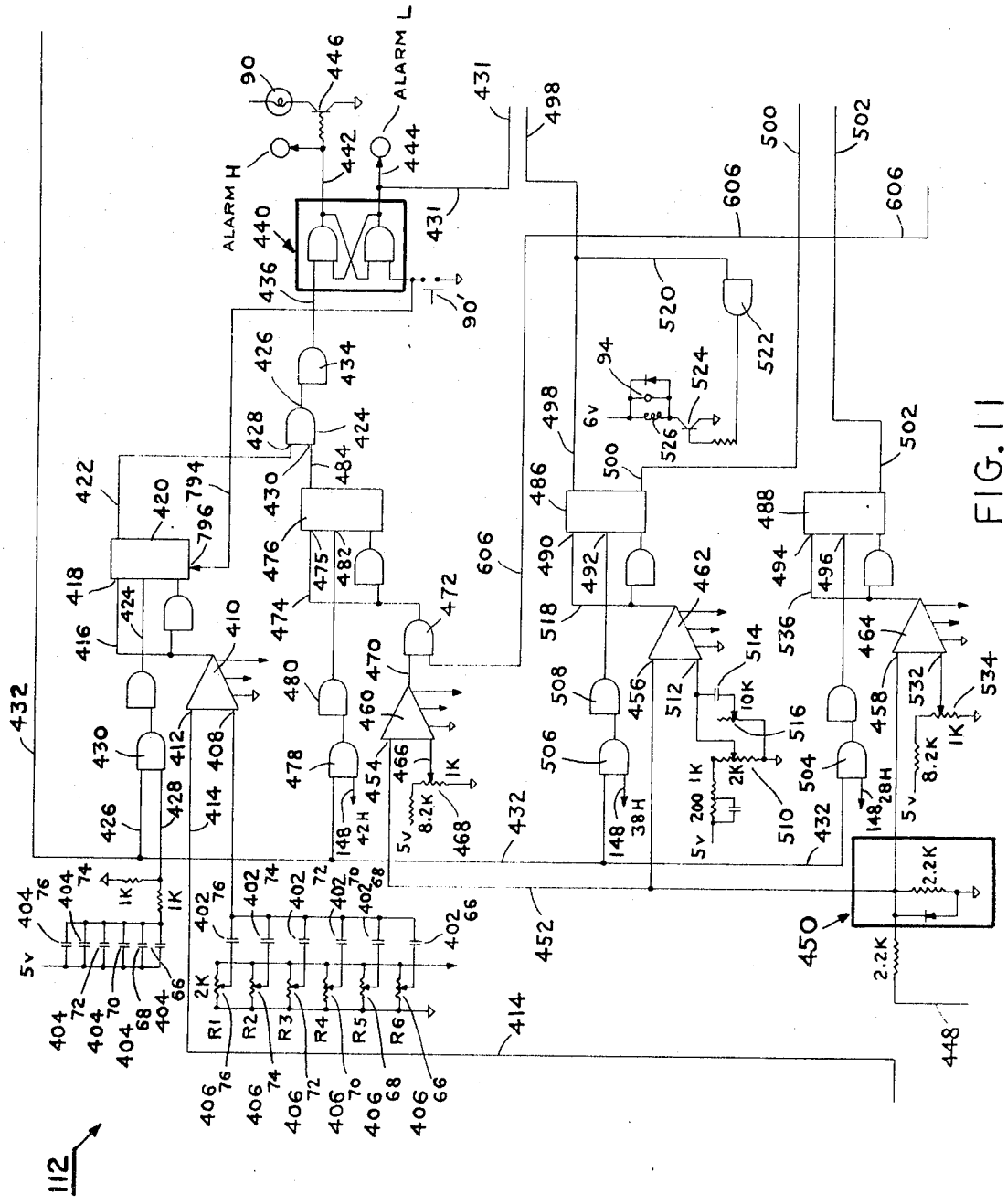


FIG. 11

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

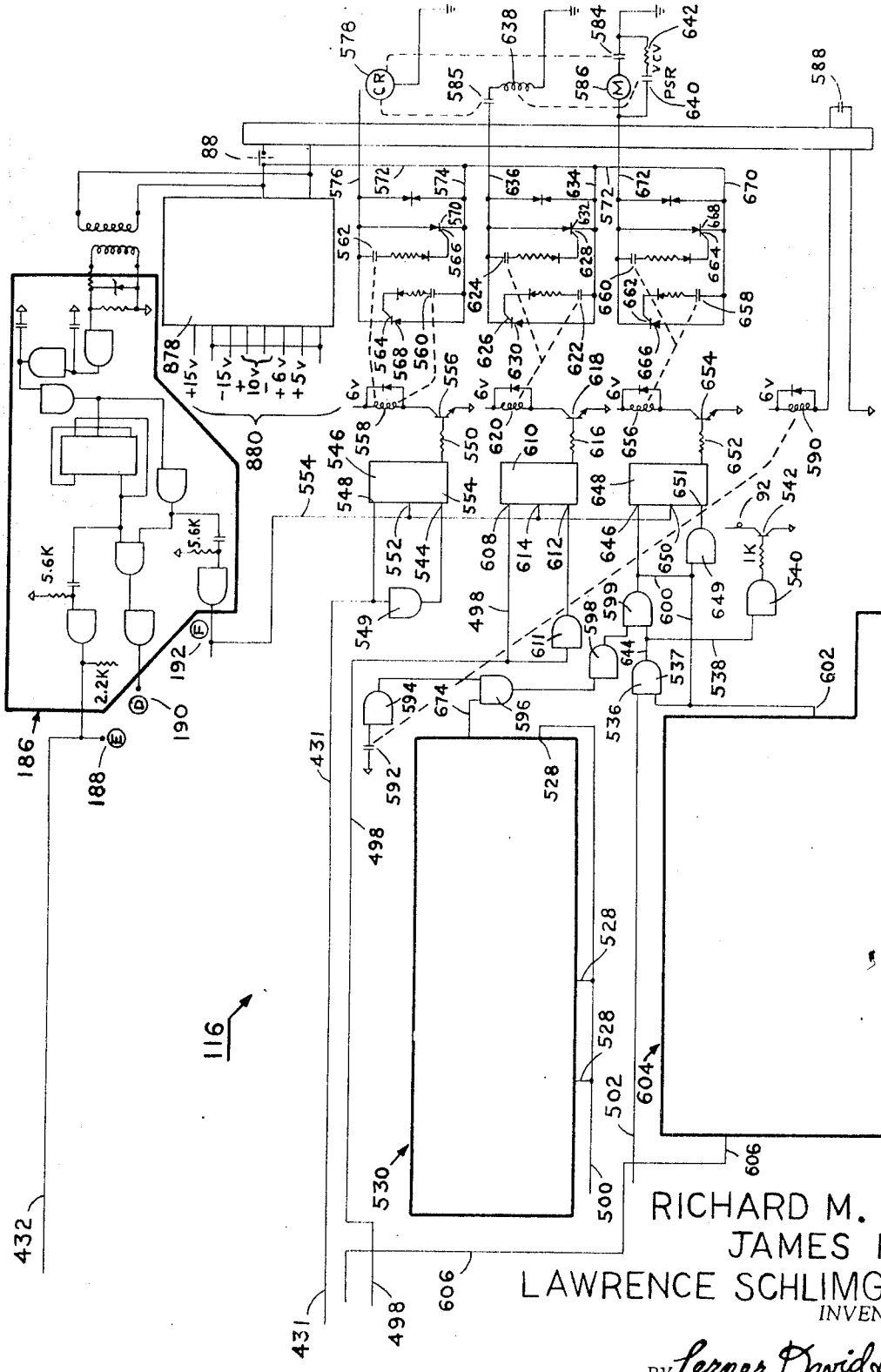


FIG. 12

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

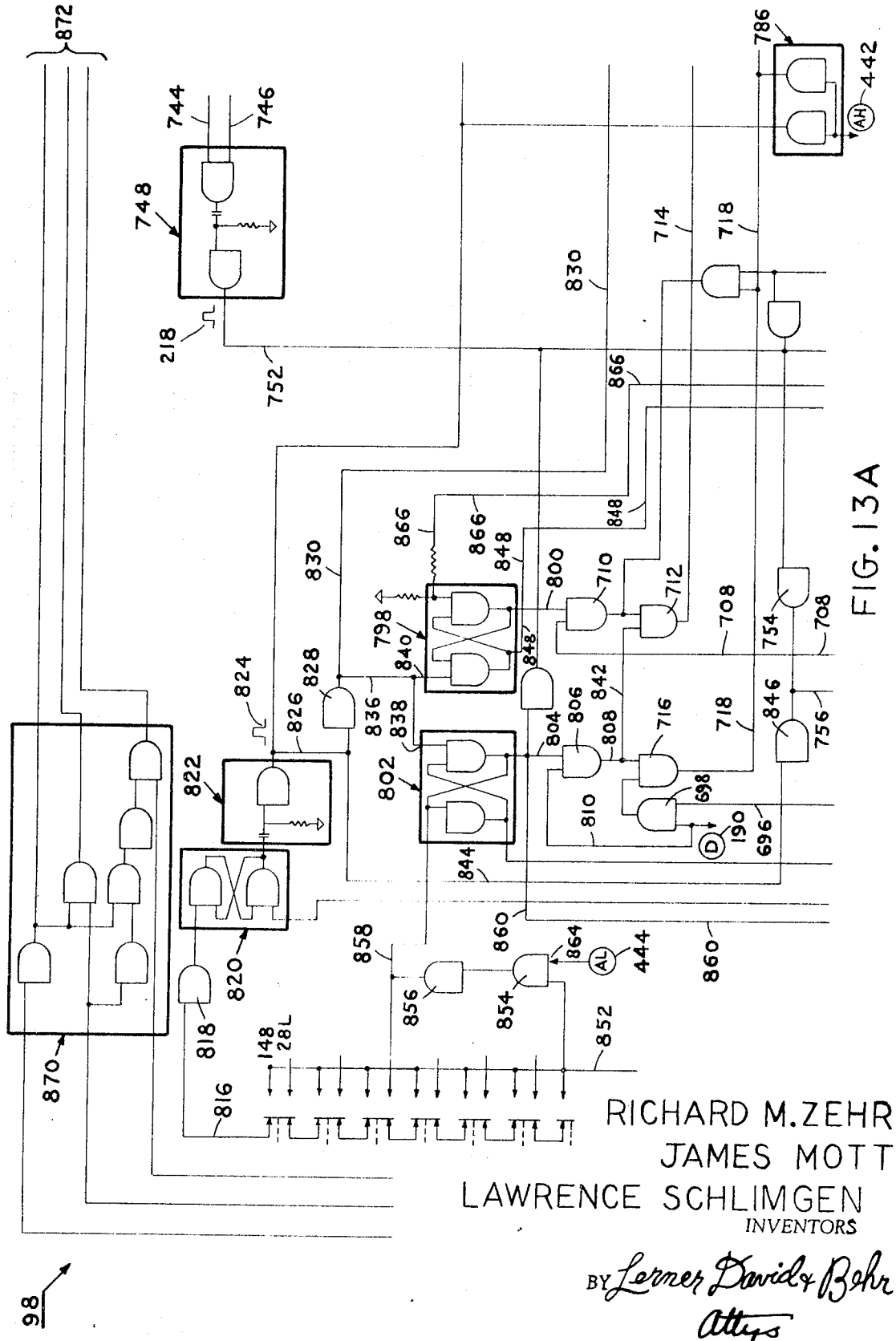


FIG. 13A

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

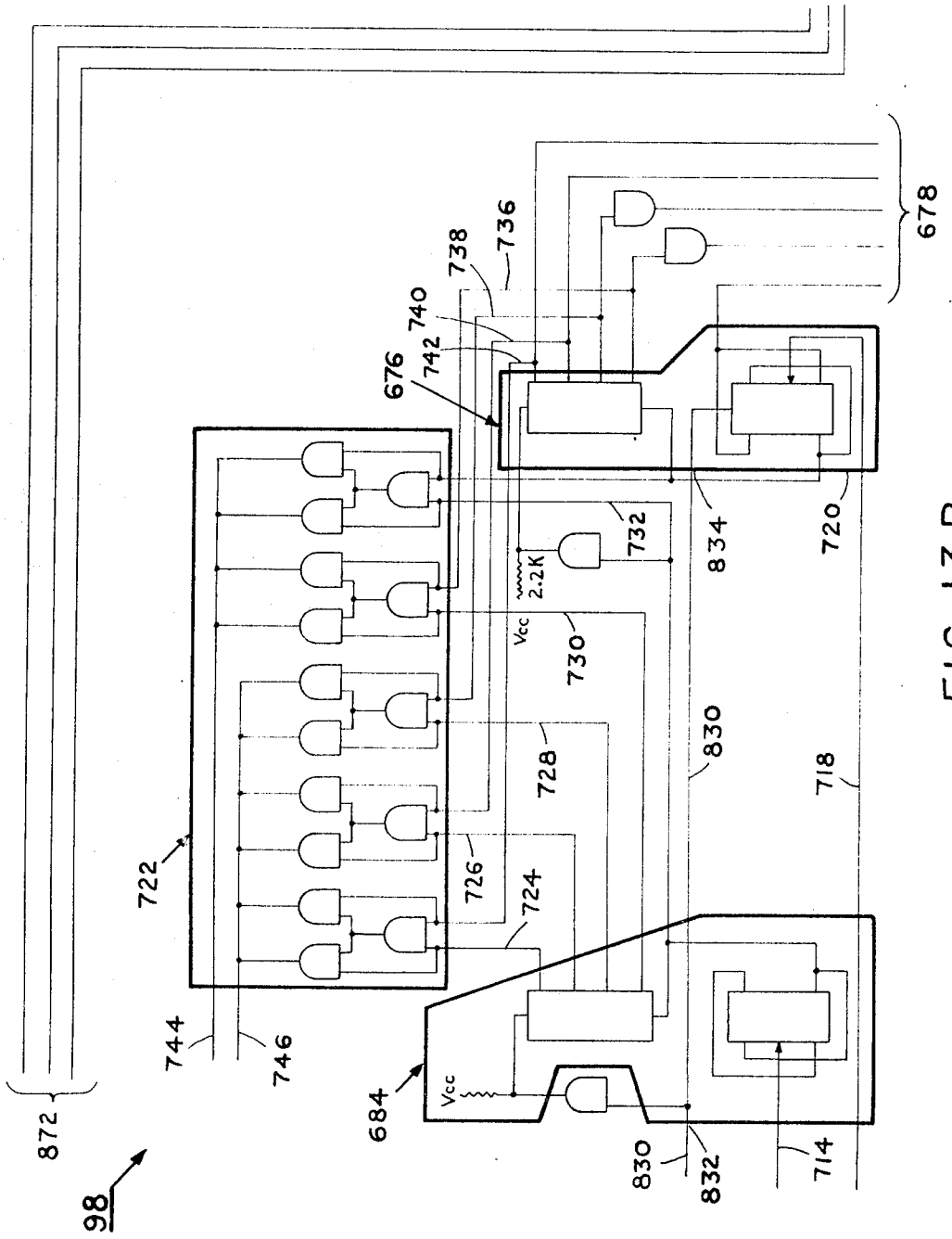


FIG. 13B

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

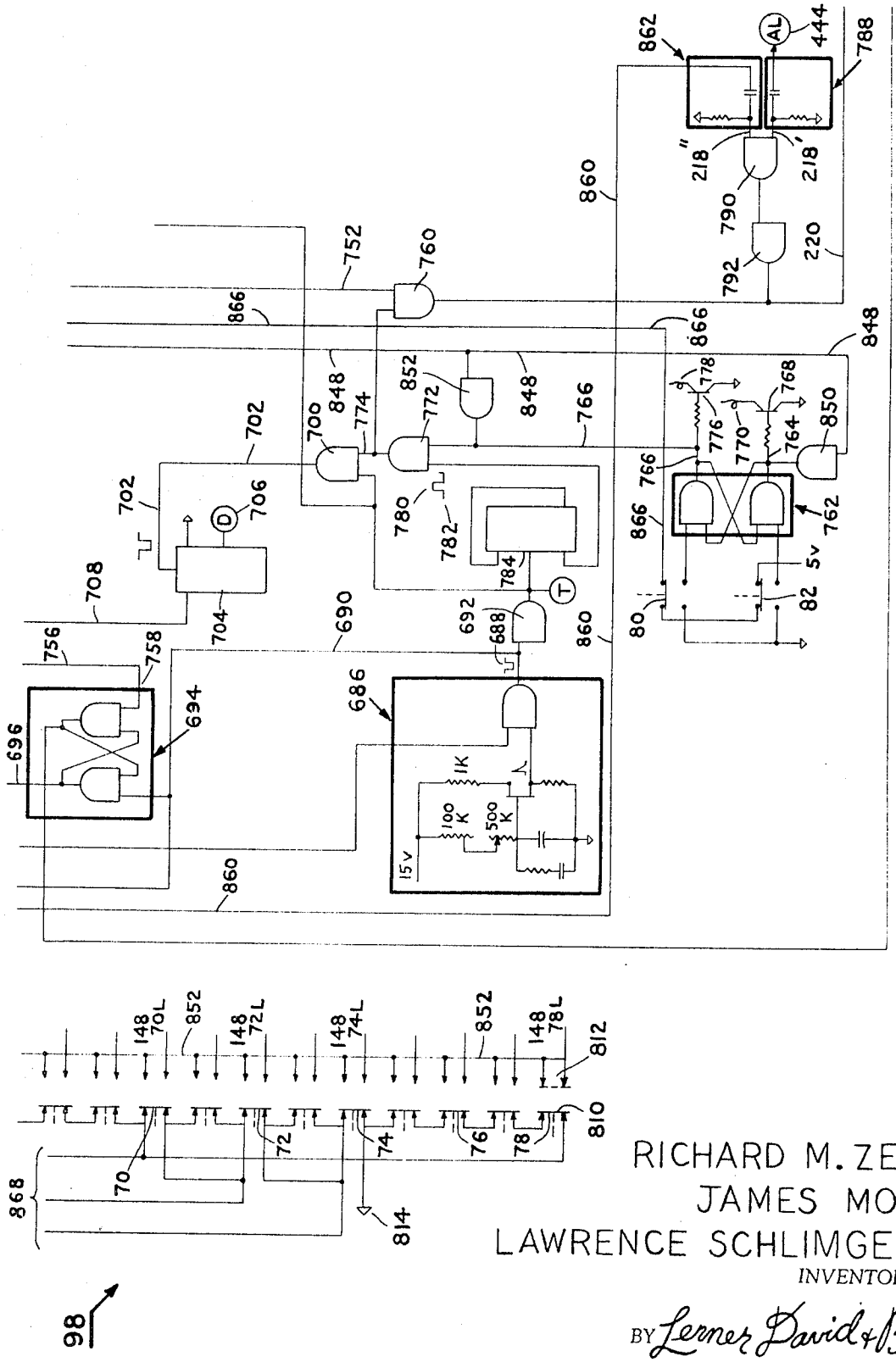


FIG. 13C

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

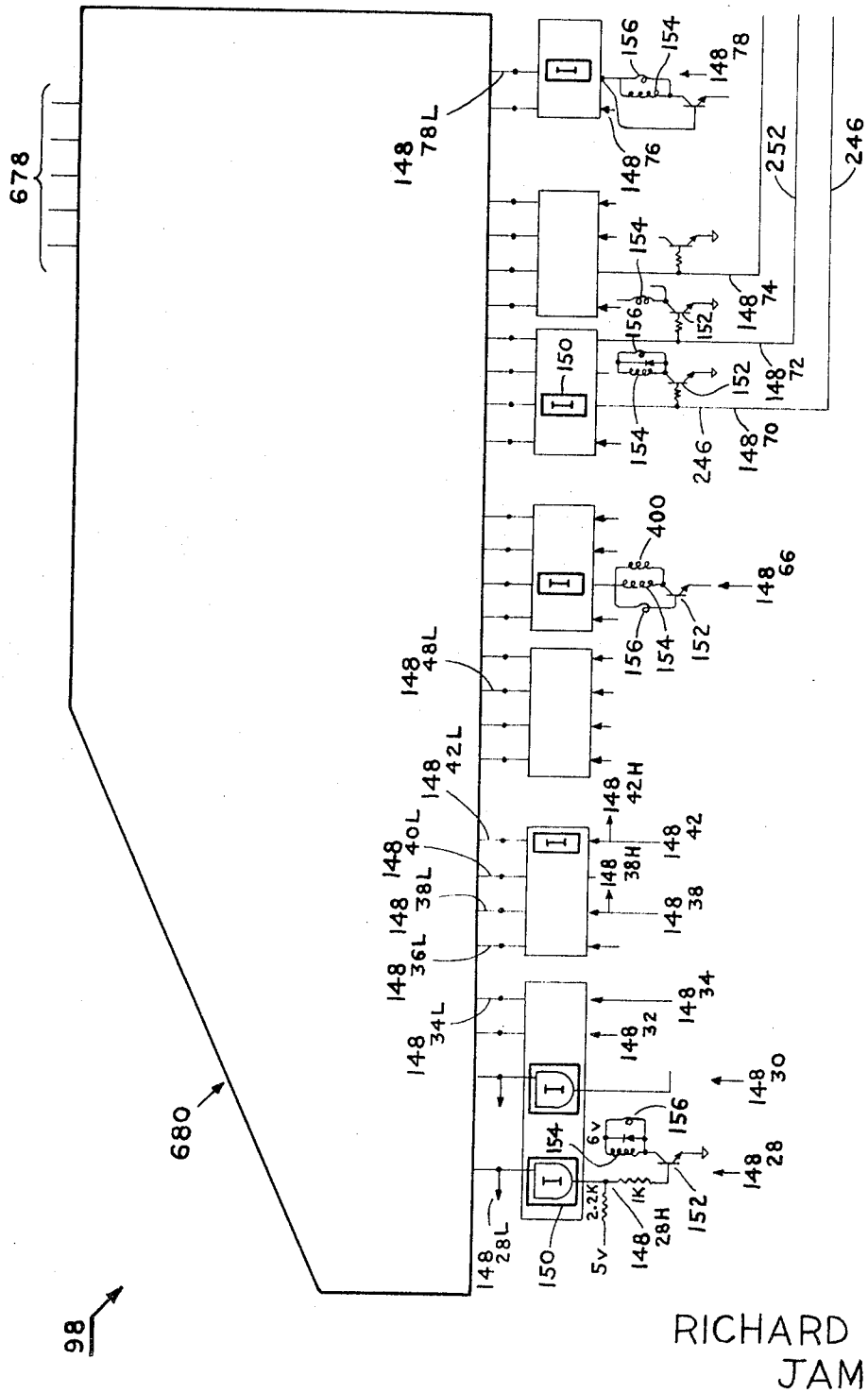


FIG. 13D

RICHARD M. ZEHR
JAMES MOTT
LAWRENCE SCHLIMGEN
INVENTORS

BY Lerner David & Behr
Attys

MONITORING AND DISPLAY SYSTEM FOR MULTI-STAGE COMPRESSOR

BACKGROUND OF THE INVENTION

This invention relates to monitoring and display apparatus and more particularly to a system which not only monitors and displays the value of a plurality of parameters associated with a particular device, but also relates to such a system which can perform a multitude of other functions related to the satisfactory performance of the particular device being monitored.

Monitoring and display problems are becoming increasingly more complex as the speed of operation and complexity of the device being monitored increases. For instance, in a multi-stage compressor for which the system of the instant invention was specifically designed, there are some **25** check points which must be continuously monitored to determine if the compressor is functioning properly. Should the parameters being monitored at preselected ones of these check points exceed predetermined safe limits, specific steps must be taken to either relieve the condition which caused the "alarm" situation or shut down the compressor completely.

One display system in common usage on such multi-stage compressors comprises nothing more than a plurality of dials responsive to appropriate transducers which sense temperature and pressure. This system requires the presence of one or more operators to continuously read these dials; compare their instantaneous indication with preestablished limits; and take necessary corrective steps should any one of the various temperatures or pressures exceed pre-established safe limits therefore. Obviously, such a system is highly unsatisfactory since there is room for human error in taking the readings, making the necessary comparisons and taking appropriate corrective measures in response thereto. Furthermore, such a system, which depends on human response, is dangerously slow in view of the tremendously high temperatures and pressures which can quickly build up within a device such as a multi-stage compressor.

Accordingly, in recent years there has been great emphasis on the development of multi-function systems which can quickly and accurately display the instantaneous magnitude of a plurality of parameters associated with a particular device being monitored and which system can automatically take necessary corrective steps in the event preselected ones of such parameters exceed predetermined safe limits.

SUMMARY OF THE INVENTION

The instant invention is in fact the result of a concentrated effort to improve monitoring and display systems utilized in conjunction with multi-stage compressors. To that end, the monitoring and display system of the instant invention was specifically designed to display **25** pressure and temperature check points which are crucial to the continuous operation of such a compressor. Additionally, various control functions built into the system of the instant invention are particularly tailored to shut down a compressor; relieve the air bank thereof etc., in response to predetermined alarm situations. Similarly, other functions built into the monitoring and display system of the instant invention were designed with a multi-stage compressor in mind and accordingly will be described in that context. However, it is to be understood that the instant invention is, in its broadest sense, directed to a system which can monitor and display the instantaneous value of a plurality of parameters associated with the operation of any desired device and additionally, is directed to such a system which has multi-function capabilities useful in conjunction with whatever particular device is being monitored. In a narrower sense, the instant invention relates to a monitoring and display system which has particularly advantageous characteristics when considered in conjunction with, and in the context of, the multi-stage compressor for which it was designed.

Broadly speaking, the monitoring and display system of the instant invention comprises a number of sub-systems which co-act with one another to perform a multitude of functions.

For example, there is a sensing sub-system which includes a plurality of transducers each of which produces a signal representative of the magnitude of the parameter being monitored by that transducer. There is a display sub-system responsive to the signals produced by the sensing sub-system which display system produces an accurate decimal readout of the magnitude of the various parameters monitored by the transducers. Additionally, there is a sequencing sub-system for sequentially selecting each of the transducers of the sensing sub-system whereby the display sub-system will sequentially display the magnitude of each of the parameters as corresponding transducers are sequentially energized. Thus, in accordance with a first aspect of the instant invention, a plurality of parameters are continuously and sequentially monitored with the magnitude of each of these parameters being accurately displayed in sequence at one central readout location.

As a further feature of the instant invention, the aforementioned sequencing sub-system may be operated in either a "-scan" mode (in which each of the aforementioned transducers are sequentially selected) or in a "hold mode" in which a particular one of the stations being monitored remains selected such that the magnitude of its respective parameter is continuously displayed. Additionally, means are provided to operate in the scan mode at either a "slow" or "fast" scan. Finally, the sequencing sub-system includes a plurality of energizable light indicators each of which carries appropriate indicia and corresponds to one of the stations being monitored. In this manner, when a particular station is being monitored, such that the magnitude of the parameter detected is displayed on the readout section of the system, the appropriate indicator will be energized to provide a visual indication of which station is being monitored and displayed at that particular instant.

As a further feature of the invention, there is provided a "-compare" sub-system in which the magnitude of preselected ones of the monitored parameters are continuously compared to pre-established "safe" reference values. Should a monitored parameter exceed its predetermined level, an alarm signal is produced to energize an alarm indicator on the monitor and display panel and/or to simultaneously initiate corrective steps which take place in the control sub-system about to be described.

The control system is, as noted above, responsive to the generation of alarm signals and has as its function the responsibility for quickly and automatically taking appropriate corrective or "shut down" measures when such alarm signals have been generated.

Thus, in the monitoring and display system of the instant invention which was designed in accordance with the requirements of a multi-stage compressor, the comparator sub-system generates alarm signals in three special circumstances. First, should a particular group of temperature check points exceed pre-established magnitudes or should the oil pressure of the system fall below a predetermined safe magnitude; a first alarm signal is generated and the control system, responsive thereto, will permanently shut down the motor of the system which can not be reactivated again without manual assistance. The comparator sub-system will generate a second alarm signal should the air banks pressure of the compressor exceed a predetermined maximum level. Should the second alarm signal be generated, the control sub-system will de-energize the compressor's unloader control valve thereby allowing the compressor to operate in the unload condition. Furthermore, should the air banks pressure fail to fall below the pre-established maximum level within **10** minutes, the control system will then shut down the compressor motor until the air banks pressure returns to an acceptable value. Should the air banks pressure fall below a pre-established minimum level, the unloader control valve will be energized to allow the compressor to operate in the loaded mode to build up pressure. The end result is that the air banks pressure will oscillate within a given range established by the pre-established maximum and

minimum values. Finally, should an especially critical "first stage discharge pressure" exceed a predetermined limit during any start up operation, a third alarm signal is generated in the comparator circuit, and in response thereto, the control sub system will prevent the compressor's motor from starting and prevent the unloader control valve from closing.

Thus, in another aspect of the instant invention, the comparator and control sub systems cooperate to (1) indicate the occurrence of pre-established alarm situations and to (2) take necessary corrective steps to alleviate the condition which caused the alarm.

As a further feature of the instant invention, appropriate sub systems and circuits are provided to instantaneously display the value of the particular parameter which generated an alarm condition even if another station is being displayed when the alarm occurs. Thus, regardless of whether the system is operating in a "scan" mode or is holding at a particular channel, when an alarm occurs, the readout system will automatically shift and display the magnitude of the parameter which caused the alarm situation and simultaneously the indicator for that particular channel will be energized to indicate which channel caused the alarm and is being displayed at that moment.

As a further feature of the instant invention, a memory sub system is provided which will continually update and retain the value of preselected ones of the parameters being monitored. Thus hours, days, or even months after a particular alarm has caused the shut down of the compressor (or any other device being monitored), an operator can return, depress the switches corresponding to the pre-established memory channels, and visually observe on the display the value of those particular parameters immediately prior to the instant of alarm. It will be appreciated that such after-gathered information frequently provides insight into the reason for the failure.

From the above, it will be seen that it is an object of the instant invention to provide a system for monitoring and displaying the instantaneous magnitude of a plurality of parameters associated with the continuous safe operation of a particular device.

Another object of the instant invention is to provide such a system which can sequencially monitor and display the value of the aforementioned parameters.

Another object of the instant invention is to provide such a system which includes means for continuously monitoring and displaying the magnitude of a selected parameter associated with a monitored device.

Yet another object of the instant invention is to provide such a system which, in addition to monitoring and displaying a plurality of parameters, also performs a plurality of other useful functions.

Another object of the instant invention is to provide such a monitoring-display system which continuously compares a plurality of monitored parameters with pre-established magnitudes and generates alarm signals should safe limits be exceeded.

Yet another object of the instant invention is to provide such a monitoring and display system which includes a control system responsive to the generation of such alarm signals corrective actions to alleviate situations which have caused alarm situations.

Another object of the instant invention is to provide such a monitoring display system which will immediately display the magnitude of a parameter which has caused an alarm situation.

Yet another object of the instant invention is to provide such a system which includes a memory sub system for retaining the value of preselected parameters for subsequent display after an alarm situation.

Another object of the instant invention is to provide such a monitoring and display system which has especially advantageous characteristics when operating in conjunction with and in a context of a multi-stage compressor.

These and other objects of the instant invention will be had by referring to the following description and drawings in which:

FIG. **1** is a front view of a display panel of a monitoring system constructed in accordance with the teachings of the instant invention;

FIG. **2** is a schematic block diagram of the monitoring and display apparatus of the instant invention;

FIG. **3** is a layout illustrating the manner in which the remaining FIGS. **4A** through **13D** may be positioned to correspond to the block diagram of FIG. **2**; and

FIGS. **4A** through **13D** are schematic circuit diagrams illustrating in detail, the apparatus of the instant invention.

DISPLAY PANEL

Turning to FIG. **1**, there is shown the front face **10** of a monitoring and display system **12** constructed in accordance with the instant invention. As mentioned previously, the system of the instant invention was specifically designed in conjunction with a five-stage motor driven compressor and therefore, the following description will present the operation of the invention in the specific environment of such a compressor. However, it is to be understood that the instant invention is not to be limited to such environment, but insteat has application in any system where it is desired to monitor, display, and/or control a particular device.

For the purpose of understanding the invention, it is sufficient to describe a motor driven multi-stage compressor as comprising two or more compression cylinders acting in series, with the first stage taking its suction from the atmosphere or other source and discharging at a higher pressure; the second stage taking its suction from the discharge of a first stage and compressing to a still higher pressure; and so on. It is the compressed air which is exhausted from the last stage which is received and stored by the air banks of the compressor system. Conventionally water cooling is used in the compressor (around the compression cylinder head and also between compression stages) to maintain the temperatures involved as low as possible.

With this background in compressors, it will be seen that the front surface **10** of the monitoring display apparatus **12** includes at its upper extremity a display readout section **14** comprising four conventional seven bar display bulbs, **16**, **18**, **20** and **22** respectively. As will be explained in greater detail, this display section **14** presents an accurate, visual readout of the magnitude of a particular parameter being monitored by the system **12**.

Located substantially in the middle of the face **10** is a first group of push-button **26**, **24** (with individual lights therebeneath) which as indicated at **25**, correspond to a plurality of pressure locations around the compressor which are being monitored. The second push-button **30** corresponds to a station wherein the discharge pressure at the second stage of the multi-stage compressor is being monitored. Similarly, the push buttons **32** through **48** bear identifying indicia and correspond to other stations in the multi-stage compressor where it is desirable to take a measurement of pressure.

Beneath the first group of push-button **24** is a second group **50** of push-button switches (with individual lights therebeneath) each one of which corresponds to a particular location around the multi-stage compressor at which a temperature reading is to be taken. Thus, the push-button **52** corresponds to the suction or input station of the first stage of the multi-stage compressor at which a temperature reading is desirable. Similarly, the push-button **54** corresponds to the suction or input station to the second stage of the multi-stage compressor where a temperature reading is desirable. In kile manner, the push-buttons **56** through **78** correspond to various stations throughout the multi-stage compressor at which it is desirable to sense temperature.

To the left of the first group of push-buttons **24** are slow and fast "scan" push-buttons **80** and **82** (with lights

therebeneath), the functions of which may best be understood by considering at this time the interrelationship of the push buttons of groups **24** and **50** and the display **14**.

Assuming it is desirable to sequentially monitor and display the pressures and temperatures at the various stations which have been identified by the push-button numerals **28** through **48** and **52** through **78**, the operator depresses either the slow scan push-button **80** or the fast scan push-button **82** (depending upon the speed at which he wishes to scan the stations). If he depresses the fast scan button **82**, this button will light up to indicate rapid scan and the following events occur. First the push button **28** will light up to indicate that the pressure at the first stage discharge port of the compressor was being monitored, while simultaneously the magnitude of the pressure at the first stage discharge port would appear on the display bulbs **16–22**. Four seconds later, the light in the first push button **28** will extinguish, and the light in the second push-button **30** would become energized indicating that the pressure at the second stage discharge port was now being monitored. Simultaneously, the readout on the display **14** would change to the magnitude of the pressure at second stage discharge port. This process continues with each of the **25** stations being sequentially monitored (at 4 second intervals) with the appropriate push-button being lit to indicate the channel being displayed. Furthermore, unless stopped, the cycling will continue indefinitely. If the oeprator wishes to slow down the scan, he would depress the slow scan button **80** which changes the scan interval to every 8 seconds rather then every 4 seconds.

Rather than operating in the scan mode, the operator can depress any one of the station push buttons, such that the system will switch from the scan mode to the "Hold mode" with the station corresponding to the depressed push button being continuously monitored and displayed on the bulbs.

As additional zero test push button **84** is provided in the first group of buttons **24** and, as will be further described, should produce a zero reading on the display bulbs whenever that zero test push button **84** is lit. Therefore, so long as a 0 continues to reappear each time the push button **84** is lit in the scan cycle, the operator knows that the system is functioning properly.

A "display test" push button **86** is provided beneath the scan push buttons **80** and **82**. When this button is depressed, it has the affect of causing the display **14** to display 8888 which is the maximum utilization of all seven bars in the display bulbs **16, 18, 20** and **22**. Thus at any time, the operator can assure himself that the bulbs of his display **14** are functioning properly.

On the right side of the display panel **10** is provided an "off/on power" push button **88**; an alarm reset push button **90**; and first discharge and air banks alarm push buttons **92** and **94** respectively, the functions of which will be presented in greater detail. It is sufficient at this point to note that the buttons **90, 92** and **94**, and the lights located therein, provide alarm capability in the instant invention and indicate that preselected parameters have exceeded pre-established limits.

OVERALL SYSTEM OPERATION

Turning to FIG. **2**, there is shown in schematic block diagram form the monitoring and display apparatus which was broadly designated **12** in FIG. **1**. The system includes a sensing system **96** which, broadly speaking, and as will be further described, includes a plurality of transducers **100** each of which produces an electrical analog signal representative of the particular parameter being sensed by that transducer. As was suggested previously, these transducers are located at the various points throughout the multi-stage compressor at which it is desirable to monitor and display parameters such as pressure and temperature.

A sequencing system **98** sequentially selects or enables the individual transducers **100** such that every 4 or 8 seconds (assuming operation in the scan mode) a different transducer will pass its analog signal to an analog to digital converter **102**. Should it be desirable to operate in the "hold" mode, depression of the desired push button on the panel **10** of FIG. **1** will direct the sequencing system **98** to seek out the appropriate transducer **100** in a sensing system **96** and continuously enable it to pass its signal to the converter **102**.

At appropriate intervals, transfer logic **104** transfers the digital signals from the output of the A-to-D converter **102** to storage system **106** from which the signals pass through gating logic **108** to shifting logic **110** which directs the information to the appropriate display bulbs in the display system **14**. As will be further described, the function of the shifting system **110** is to direct the digital information into the bulbs **18, 20**, and **22** should a three place parameter be displayed (and blank out the first bulb **16**) or alternatively to direct the information to the three most mathematically significant bulbs **16, 18** and **20** (and add a 0 to the fourth bulb **22**) should a four place parameter have to be displayed.

At the same time that the output of a particular transducer was being passed to the A-to-D converter **102**, it might also be on its way to a comparator system **112** where preselected signals from the sensing system **96** (representative of preselected stations in the compressor) are compared with predetermined safe limits. If these safe limits are exceeded, alarm signals are generated on the output lines broadly designated **14** of the comparator **112**. These alarm signals perform a number of functions such as energizing the lights in the alarm buttons **90, 92** or **94** on the panel **10** of FIG. **1** to indicate to an operator that an unsafe alarm condition exist. Additionally, such alarm signals are passed on to a control system **116** which broadly speaking takes steps to shut down the compressor and/or obviate the particular condition which caused the alarm.

Finally, as mentioned previously, the instant invention has memory capabilities in that it will continuously store updated values of preselected parameters which it might be useful to display at some subsequent point after an alarm situation. Thus memory logic **118** of FIG. **2** is provided to permit the information stored in auxiliary buffer devices of storage system **106** to be transferred to the display system when it is desired to display the retained information.

SENSING SUB SYSTEM

As noted, the sensing system **96** includes a plurality of transducers **100** each of which produces an electrical analog signal representative of the magnitude of the parameter being sensed by the respective transducer. For the sake of clarity in the drawings, only four such transducers have been illustrated in FIGS. **4A** and **4B**: namely, the temperature transducers 100_{52}, 100_{54} and 100_{78}; and the pressure transducer 100_{28}. The sub scripts **52, 54, 78** and **28** are intended to indicate that the particular transducers identified in FIGS. **4A** and **4B** are located about the multi-stage compressor at the various stations which have been previously identified in FIG. **1** by a like numbered push button. For example, the temperature transducer 100_{52} would be located, according to the indicia on push button **52** of FIG. **1**, at the entrance or suction port of the first stage of the multi-stage compressor to sense the temperature developed at that point. Although not completely shown in FIGS. **4A** and **4B**, it will be appreciated that the sensing system **96** utilized in the instant invention would actually comprise 14 temperature transducers corresponding in number 100_{52} through 100_{78} and **11** pressure transducers corresponding in number to 100_{28} through 100_{48}. Furthermore, it should be apparent that a greater number of transducers can be provided should it be desirable to monitor more than the **25** stations considered critical in the multi-stage compressor under consideration. Similarly, a less sophisticated piece of equipment might require fewer transducers to provide adequate monitoring functions. Also, parameters other than temperature and pressure can be monitored using different types of transducers available in the art.

Each of the temperature transducers 100_{52} through 100_{78} comprises a thermocouple preferably of the copper-constantan type, and as such includes a hot junction **120** of these two metals. By virtue of the common lines **122** and **124**, all of the temperature responsive thermocouples share a common reference junction **126** which is provided with conventional temperature compensation means for correcting for changes in ambient temperature conditions. From the point of view of operation of these transducers, it is sufficient to note that each will produce an analog voltage the magnitude of which will represent the particular temperature being sensed at the hot junction **120** thereof.

Each of the pressure transducers 100_{28} through 100_{48} is preferably of the strain gage type and as such includes a resistive bridge **128** excited by the common 10-volt lines **130** and **132**. As well known in the art, the bridge **128** of such units will become unbalanced to the extent of the pressure applied to one pressure responsive resistor thereof and will generate an analog voltage signal on the lines **134** and **136** which is representative of the pressure sensed. The output lines **134** and **136** from each pressure transducer are connected through normally open contacts such as 158_{28} to common lines **138** and **140**.

In their preferred embodiment, each of the pressure transducers 100_{28} through 100_{48} includes an individual gain adjustment means **142** in the form of a multi-turn minature potentiometer provided with a selectively positionable tap whereby the gain of the individual pressure transducers can be individually adjusted. Similarly, each pressure transducer includes a zero adjustment means **144** similarly in the form of a minature multi-turn potentiometer provided with a positionable tap. The zero adjustment means **144** is customarily used in the initial set up procedure by applying zero pressure to the transducers **134** and **136** to generate a zero signal on lines **134** and **136** which by definition represents a zero pressure (atmospheric pressure). When this zero pressure is applied, the tap of the multi-turn potentiometer **144** is then varied until the display system **14** visually presents 0 on its bulbs.

Finally, each of the pressure transducers includes a filter network **146** the components of which are selected to filter variations approximately 15 cycles per second and above which also happens to be the normal frequency variation in the pressure responsive system. Thus, the selection of 15 cycles per second eliminates all noise in that frequency range while at the same time eliminates undesirable frequency variations in the transducer output.

TRANSFER FROM THE SENSING SYSTEM TO THE ANALOG-TO-DIGITAL CONVERTOR

As will be described in greater detail, the sequencying system **98** of FIGS. **13A–13D** includes a plurality of output channels **148** which for the sake of uniformity of numbering, are designated 148_{28} through 148_{78} to suggest the fact that each of the output channels corresponds to one of the transducers in the sensing system **96**. Taking output channel 148_{28} for example, it is sufficient to point out at this time that as each channel is energized, there will be a low signal, such as illustrated at the take off point 148_{28L} and by virtue of an inverter **150**, there will be high signal (148_{28H}) utilized to turn on a transistor **152** which permits the energization of a coil **154** and simultaneously the energization of an indicating light bulb **156** which are in fact the indicating lights positioned beneath the push buttons **28** through **78** of FIG. **1**.

The coil **154** of each channel **148** controls a respective pair of normally open contacts such as 158_{28} in the sensing system **96** of FIG. **4B**. It is to be understood that each coil **154** of the respective output channels **148** controls a similar pair of normally open contacts in the particular transducer circuit which corresponds to that particular channel.

Also to be described further is the fact that the sequencing system **98** includes means for sequentially selecting each of the channels 148_{28} through 148_{78}. Therefore, as each channel is energized the following events take place. Considering channel 148_{28} of FIG. **13D** as illustrative, high signal 148_{28H} turns on transistor **152** and permits the energization of the coil **154** and the indicating light **156**. When coil **154** is energized, the contacts 158_{28} in sensing system **96** controlled thereby, close to enable the pressure transducer 100_{28} to pass the pressure representing voltage signal along the common lines **138**, **140** to a pressure amplifier **160** (FIG. **4A**). Thus the signal representative of the pressure at the discharge port of the first stage of the multi-stage compressor is on its way to be displayed by the display system. Simultaneously, the energization of the light **156** positioned beneath the push button **28** on the panel **10** reading on the display **14** corresponds to the pressure at the first stage discharge port.

Thus, with the system operating in the scan mode, every 4 or 8 seconds one of the channels will be sensed and displayed.

In the event a temperature channel such as 148_{78} happens to be energized, its respective coil **154** will be energized to close contacts 158_{78} in sensing system **96**, to pass the analog signal representative of temperature along common lines **122** and **124** through the common reference junction **126** and on to a temperature amplifier **162**.

The amplifiers **160** and **162** are preferably conventional DC operational amplifiers of the integrated circuit type and as suggested in FIG. **4A** are gain controlled by feedback resistors which are externally connected. The amplifiers raise the millivolt output of the respective transducers to approximately a 5 volt level which signals are then passed by the following described circuitry, to the analog-to-digital convertor **102**.

Specifically, whenever a pressure channel (such as 148_{28} - 148_{48}) of the sequencing system **98** is energized; the low signal produced therein (for example 148_{28L} of FIG. **13D**) is applied to a line such as **164** in the sensing sub system **96** of FIG. **4A** which, through the inverter **166**, applies a high to a transistor **168** to energize a coil **170** the normally open contacts **172** of which will close to pass the output of the pressure amplifier **160** along the line **174** to the analog-to-digital converter **102** of FIG. **5**. Should a temperature channel such as 148_{78} be energized, it will be appreciated that no signal will be applied to the inverter **166** of FIG. **4A** and therefore a low signal will appear at its output. However, this low signal is inverted by inverter **176** to turn on transistor **178** which in turn brings about the energization of the coil **180** whose normally open contact pair **182** will close to pass the signal developed at the output of the temperature amplifier **162** on to the line **174** and to the analog-to-digital converter **102**. It may be pointed out that at the output of temperature amplifier **162** there is provided a shaping network **184** to linearize the signal representing temperature.

ANALOG DIGITAL CONVERSION

Although not specifically illustrated in the block diagram of FIG. **2**, the system of the instant invention employs a pulse generator **186** (see FIG. **12**) which produces at output terminals **188**, **190**, and **192** pulses which are designated "E" pulses, "D" pulses, and "F" pulses respectively. The purpose of each of these pulses will become further apparent as the description of the system unfolds.

Considering the analog-to-digital converter and with reference to FIG. **5**, 30 times per second an "E" pulse is applied to the terminal **194** of the A-to-D converter to initiate a conversion process. The A-to-D converter is a conventional device responsive to analog signals and produces as an output three groups of digital signals **196**, **198** and **200** each of which, in four line binary form, represents one decimal digit of a three digit number.

Each time the conversion process is complete, an end of conversion pulse **202** is produced on an output line **204** (see also FIG. **6**). The manner in which the numbers represented by the three, four line groups **196**, **198**, and **200** are transferred to the storage system **106** is controlled by the transfer logic **104** in the following manner.

TRANSFER LOGIC

The transfer logic **104** of FIG. **6** includes a flip-flop **206** and gates **208**, **210**, **212**, **214**, and **216** which operates as follows: With the generation of a coincidence pulse **220** (to be described) flip flop **206** is enabled (to apply one signal via line **207** to pin **222** of gate **216**) such that an end of conversion pulse **202** developed on the line **204** passes through gate **208** and is applied by line **224** as the second enabling signal to gate **216**. Thus, the output line **228** of the gate **216** will go low and enable main buffer storage devices **230**, **230'** and **230''** of the storage system **106** of FIG. **7** to receive the respective groups of signals **196**, **198** and **200**. In this manner, each of the main buffer storage devices will receive and retain a four bit binary signal representing one mathematical place of a three place number which, as previously described, corresponds to the particular parameter which happens to be monitored at the particular instant of time when the end of conversion pulse **202** was applied to gate **216**. In addition the end of conversion pulse **202** resets flip flop **206** which then awaits the next coincidence pulse **218**.

It will be appreciated that for the sake of drawing clarity, only the four lines **232**, **234**, **126** and **238** of the signal group **196** of FIGS. **5** and **6** have been fully shown as directly passing to the main buffer storage device **230**. Similar connections are suggested in FIG. **6** and do, in fact, exist between the signal groups **198** and **200** of FIG. **5** and the respective main buffer storage devices **230'** and **230''** of FIG. **7**.

MEMORY FUNCTION

As noted previously, it is a feature of the instant invention that the last value of preselected ones of the parameters being monitored can be stored and subsequently displayed after an alarm situation. To that end the storage system **106** of FIG. **7** includes auxiliary buffer storage devices **240**, **240'**, **240''**; **242**, **242'** and **242''**; and **244**, **244'** and **244''**. Before going into detail, it might be pointed out that in the instant system, by design, the auxiliary buffer storage devices **240**, **240'** and **240''** will store the third stage discharge temperature of the compressor; auxiliary buffer storage devices **242**, **242'** and **242''** will store the fourth stage discharge temperature; and auxiliary buffer storage devices **244**, **244'** and **244''** will store the fifth stage discharge temperature.

Returning to the sequencing system **98** of FIG. **13D**, let it be assumed that the system is operating in the scan mode in which each of the output channels **148** will be sequentially energized to perform the functions previously described. When the scanning gets up to output channel 148_{70} for example, in addition to the respective coil **154** and indicator **156** becoming energized, an additional line such as **246** will go high to apply a signal to pin **248** of the gate **210** of transfer logic **104** of FIG. **6**. Therefore, upon the generation of the next end of conversion pulse **202** (signifying that the analog voltage representative of the 3rd stage discharge temperature developed at transducer 100_{70} has passed through respective contacts such as 158_{70} and has been converted to digital form) line **224** will go high, so as to apply an enabling pulse not only to the gate **216** of FIG. **6** but also to the gate **210**. Therefore, with the gate **216** enabled (by the application of pulses on pins **222** and **226**) and gate **210** enabled (by the application of signals on lines **246** and **224**); the net result is that enabling signals appear not only on the output line **228** to enable the main buffer storage devices, but also on a line **250** to enable the third stage discharge auxiliary buffer storage devices **240**, **240'** and **240''**.

Thus each time the output channel 148_{70} of the sequencing system **78** is energized, the magnitude of the 3rd stage discharge temperature will pass to the main buffer devices **230**, **230'** and **230''** and simultaneously to the auxiliary buffer storage devices **240**, **240'** and **240''**. To be described subsequently in the manner in which this additionally stored information can be displayed after an alarm situation has occurred.

A similar operation takes place when channel 148_{72} of FIG. **13D** energized during a scan cycle (with the magnitude of the fourth stage discharge temperature being transmitted from the respective transducer 100_{72}; through the respective contacts 158_{72}; through the temperature amplifier **162** and to the analog-to-digital converter **102**). Thus, in addition to energizing the coil **154** and indicator light **156** of the output channel 148_{72}, an additional line **252** goes high to apply a signal to the gate **212** of FIG. **6**. Thus, on the next end of conversion pulse **202**, line **224** goes high to enable gate **212** which drives line **254** high to enable the auxiliary storage buffer devices **242**, **242'**, and **242''** to receive and store the signals representative of the fourth stage discharge temperature. At the same time, the main buffer storage devices **230**, **230'**, and **230''** are enabled by the high signal on the line **228** as previously described. Again the net result is to transfer the three groups of binary signals representing the fourth stage discharge temperature to the auxiliary buffer storage devices as well as to the main buffer storage devices.

Finally, whenever the output channel 148_{74} of the scanning system **98** is energized, so as to sense the 5th stage discharge temperature; similar circuitry enables the gate **214** (as well as **216**) such that the magnitude of the fifth stage discharge temperature will be passed not only to the main buffers **230**, **230'** and **230''** but also to the fifth stage auxiliary storage buffer devices **244**, **244'** and **244''**.

Summarizing, as the various output channels 148_{28} through 148_{78} of FIG. **13D** are sequentially energized, the magnitude of the parameters sensed by the corresponding transducers are sequentially placed in the main storage buffer devices **230**, **230'** and **230''**, each device receiving four bits of binary information representative of one decimal number. If the particular channel energized happens to be one such as 148_{70}, 148_{72} or 148_{74} wherein it has been predecided to store the value of such corresponding parameter, the parameter will be additionally stored in one of the respective auxiliary buffer storage devices such as **240**, **242**, **244** and their respective primed devices.

TRANSFER FROM STORAGE TO DISPLAY

Assuming there is no alarm situation generated in the comparator system **112** of FIG. **11**, gating circuitry broadly designated **108** (FIG. **8**) is utilized to transfer the information from the main buffer storage devices **230**, **230'** and **230''** to the shifting circuitry **110** (FIG. **9**) which in turn applies such information to the display section **14** of FIG. **10**.

The gating circuitry **108** includes **3** banks of gates **256**, **258**, and **260**, one for each of the three decimal numbers. Each bank (for example, **260**) includes four smaller banks of gates such as **262**, **264**, **266** and **268**. Each smaller bank such as **262** includes four individual gates such as **270**, **272**, **274** and **276**. It should be noted that in the interest of simplifying the Figures, only one such sub-bank **262** has been illustrated in detail, it being understood however, that the following description would be applicable to each of the sub-banks **264**, **266**, and **268** within a larger group of banks **256**, **258** and **260**.

For the sake of explanation, let it be assumed that the main buffer storage devices **230**, **230'** and **230''** presently store the magnitude **367** which is representative of the particular parameter being sensed. Thus, and considering the main buffer storage device **230** which would be storing the decimal number **3**, output lines **278**, **280**, **282**, and **284** thereof would be presented with the bits of information 0011. Thus, the voltage representing "0" on line **278** is passed to one input of the gate **270**, the other input of which is maintained high by a signal appearing, in a manner to be further described, on output line **286** of memory logic circuitry **118**. With gate **270** enabled, the "0" signal appears on line **288**.

Similarly, the voltage representing the "0" on line **280** of buffer device **230**, passes through corresponding gate **270'** of bank **264** such that a "0" voltage appears on the output line **290**. In like manner, the "1's" appearing on lines **282** and **284** are transferred through the corresponding gates **270** (not

shown) of banks **266** and **268** such that the respective "1" signals appear on the lines **292** and **294** of bank **256**. In this manner the four bit binary representation of the decimal numberal "3" has been transferred from the main storage buffer device **230** through the gating logic **108**.

Similar events take place with respect to the main buffer storage devices **230'** and **23''** such that the second and third decimal numbers will appear on the four line groups **296** and **298** at the output of the banks **258** and **260**.

SHIFTING LOGIC

As may be appreciated from the description thus far, the instant invention produces at the output of the gating circuitry **108**, a three digit number (represented in binary form). However, some of the parameters being monitored require four mathematical places to represent them (i.e., their magnitude is greater than **999**), while others of the parameters require only three mathematical places to represent their magnitude (i.e., less than 999 in magnitude). Thus, means must be provided to properly direct these signals to the proper display bulb: namely bulbs **16**, **18**, and **20** (and force a "0" on bulb **22**) if a four placed parameter is to be displayed; or bulbs **18**, **20** and **22** (and blank the display bulb **16**) if a three placed parameter is to be displayed.

In the instant system, it is known that the fourth stage discharge pressure, the fifth stage discharge pressure, the air banks pressure, and the accumulated pressure may all have a magnitude of 1,000 or greater psi. Therefore, whenever one of these stations is being monitored, the shifting logic **110** of FIG. **9** must provide that the three decimal numbers (represented in binary form) appearing at the output of the gating circuitry **108** be shifted directly to the bulbs **16**, **18** and **20** and means must be provided for causing the least mathematical significant bulb **22** to display a "0". Should any other station be monitored, the shifting circuitry must be such as to direct the three place quantity to the bulbs **18**, **20**, and **22** and appropriate means must be provided to blank out the most mathematically significant display bulb **16**.

As discussed previously, whenever one of these four stations are being monitored, the corresponding output channel of the sequencing system **98** of FIG. **13D** (i.e., output channels 148_{34}; 148_{36}; 148_{38}; 148_{48}) will be energized so as to apply the corresponding low signal (148_{34L}, 148_{36L}, 148_{38L}, 148_{48L}) to the line **300**, **302**, **304**, or **306** respectively of the shifting logic **110** of FIG. **9**. In response to the application of such a low signal, gating circuitry designated **308** influences a pair of flip flops **310** and **312** to produce high and low signals respectively on the lines **314**, **316**; **318**, **320** to perform the following functions.

Assuming that a four place parameter is to be displayed, a high appears on the line **314** to enable gates **340**, **342**, **344**, **346**; and a high on line **318** enables gates **358**, **360**, **362** and **364**. Similarly, a low will appear on the line **316** to disable gates **326**, **334**, **336**, **338** and a low on line **320** disables gates **348**, **350**, **352**, and **354**. Gates **324**, **328**, **330** and **332** are always enabled and, accordingly the signal 0011 representing the decimal number 3 will be shifted directly through the gates **324**, **328**, **330** and **332** to a four bit-to-seven line converter **340** (FIG. **10**) which converts the four bit information into corresponding seven line information which in turn is applied to the seven bar display bulb **16** which will thereby display the decimal number 3 on the bulb **16**.

With the gates **340**, **342**, **344** and **346** enabled by the high on line **314**, the signals appearing on the group of lines broadly designated **296** will pass directly to a second four bit-to-seven converter **356** of FIG. **10** which in turn will apply appropriate signals to the second display bulb **18** which will display the decimal number represented by the group of **296**.

Finally, the high signal on line **318** will enable gates **358**, **360**, **362** and **364** such that the signals on the group of lines broadly designated **298** will pass directly to a four bit-to-seven bit converter **366** which will produce the necessary signals to energive the seven bar display bulb **20** in accordance with the magnitude of the decimal number represented by the group of signals on the lines **298**.

Since it has been assumed that the display system **14** is presenting a four place mathematical figure, means must be provided to cause the fourth display bulb **22** of FIG. **10** to display a 0. This is accomplished by applying on overriding "0" signal at the input terminal **367** of the fourth four bit-to-seven converter **368** which signal is derived from a line **369** which is high whenever the line **314** of flip-flop **310** of FIG. **9** is high, indicating, as noted previously, that a four place number is to be displayed. This "0" regardless of the fact that the group of signals broadly designated **298** are simultaneously being applied to the gates **370**, **372**, **374**, and **376** of FIG. **9**. In effect, the "0" signal on the line **369** over powers the signals which are being applied to these gates **370** through **376**.

In the event that any other station is being monitored, such that a three place figure is to be displayed, the channel signals such as 148_{34L} through 148_{48L} will not be applied on the lines **300** through **306** of the shifting logic **110** of FIG. **9** such that the flip flops **310** and **312** will be switched and the respective pairs of lines **314**, **316**; **318**, **320** will reverse their high and low condition respectively. Thus, dealing with the group of signals broadly designated **296**, it will be seen that when line **314** goes low, gates **340**, **342**, **344**, and **346** will be disabled, while (because line **320** has gone high) gates **348**, **350**, **352** will be enabled. Therefore, the signal represented by group of lines **296** will be shifted one place and be passed through the last mentioned gates to the four bit-seven bit converter **366** of FIG. **10** whereby appropriate signals will then be applied to the seven bar display bulb **20**.

Similarly, when line **318** of flip flop **312** goes low, gates **358**, **360**, **362** and **364** will be disabled; and the information represented by the group of lines **298** will only pass through the gates **370**, **372**, **374** and **376** to the four bit-to-seven bit converter **368** of FIG. **10** and then to the seven bar display bulb **22**. (Of course the high line **369** of FIG. **10** now goes low because line **314** of flip flop **310** has gone low).

With respect to the 0011 signal appearing on lines **288** through **294**, these signals will be applied through the gates **322**, **328**, **330** and **322** to the four bit-to-seven bit converter **340** of FIG. **10**, and also to the converter **356** through the gates **326**, **334**, **336** and **338** which are enabled by the high now appearing on line **316**. However, a blanking signal carried by the line **378** of FIG. **10** will be applied to the converter **340** to override the signals being applied by gates **324**, **328**, **330** and **332**. It may be appreciated that the high appearing on line **378** of FIG. **10** and being applied to the converter **340** at an input terminal **380** thereof, is derived from the high which now appears on the line **320** of the flip flop **312** by virtue of the fact that a three place number, and not a four place number, is being sensed.

It will be appreciated that by virtue of the "blank" and "zero" signals utilized on the lines **378** and **369** respectively, it is possible to eliminate the duplicate set of gates which were required for the middle two mathematical places. Furthermore, such arrangement compensates for the fact that certain of the transducers (monitoring pressures over 1,000 psi) have a different output sensitivity. Thus the output of these transducers differs from those monitoring less than 1,000 psi by a factor of 10 for which the shifting logic inherently compensates.

Finally, with respect to the display, it was noted previously that there is a display test push button provided on the panel **10** of FIG. **1**. This push button **86** shows diagramatically in FIG. **10** and when depressed, influences gating broadly designated **382** to develop high signals on the lines **384**, **386**, **388** and **390**. These high signals are applied to the respective input terminals **392**, **394**, **396** and **398** respectively to cause the converters to apply high signals to each of the seven inputs of each of the bulbs **16**, **18**, **20**, and **22**. The net result is that the display will read **8888** whenever the display push button **86** is depressed. Should any bar lights be out when that button is depressed, it will become immediately apparent.

Thus far it will be appreciated that when the sequencing means **96** of FIG. **13D** sequentially selected the output channels 148_{28} through 148_{78}, the respective contacts in the sensing system of FIGS. **4A** and **4B** will close to enable the corresponding transducer to pass its signal representative of a particular parameter to the analog-to-digital converter **102** the digital output of which is eventually transferred to the display system **14** in the manner described.

"COMPARE SYSTEM"

As noted previously, the instant invention includes means to compare preselected ones of the monitored parameters with pre-established "safe" levels to generate alarm signals should these pre-established safe levels be exceeded. In this respect, for the multi-stage compressor for which the instant system was designed, it is desirable to generate a first alarm signal should the first stage, second stage, third stage, fourth stage, fifth stage or final discharge temperature exceed a predetermined safe limit. These stations, according to the push button indicia of FIG. **1**, correspond to the push buttons **66**, **68**, **70**, **72**, **74** and **76** and would be monitored whenever the output channels 148_{66} through 148_{76} of scanning system **98** of FIG. **13D** were energized.

TEMPERATURE COMPARISON

To illustrate the manner in which the temperature sensed at these six particular stations are compared to pre-established levels, the first stage discharge temperature will be used as an example. Thus, assuming that the output channel 148_{66} of FIG. **13D** becomes energized, the previously noted primary enabling coil **154** will be energized to close the appropriate contacts 158_{66} in the sensing system of FIG. **4A** and **4B**. However, in parallel with the coil **154** is an additional coil **400** which controls two pairs of normally open contacts 402_{66} and 404_{66} located in the comparative system **112** of FIG. **11**. In series with the contact pair 402_{66} is an adjustable potentiometer 406_{66} by which one may establish a voltage signal representative of the pre-selected safe limit for the temperature at the first stage discharge port. Thus, it will be appreciated that when the output channel 148_{66} of FIG. **13D** is energized, the auxiliary coil **400** of the sequencing system **98** will be energized to close contact pair 402_{66} (and 404_{66}) to pass the voltage on the potentiometer 406_{66} to one input **408** of a voltage comparator **410**.

To establish a comparison at the voltage comparator **410**, it is, of course, necessary that the voltage signal representing the first stage discharge temperature be passed to the other input **412** of the comparator **410** of FIG. **11**. This is accomplished in the following manner.

It will be recalled that when the output channel 148_{66} of the scanning system **98** (FIG. **13D**) is energized, the primary coil **154** thereof is energized to close the appropriate contact 158_{66} of the sensing system **96** of FIGS. **4A** and **4B**. In this manner, the signal representing first stage discharge temperature is passed from the transducer 100_{66}, through the common lines **122**, **124** and on the temperature amplifier **162** of FIG. **4A** by which it can be passed via line **174** to the analog-to-digital converter **102** of FIG. **5** and from there on to the display **14**.

Additionally, a branch line **414** taken at the output of temperature amplifier **162** will apply that signal representative of first stage discharge temperature to the second input terminal **412** of the comparator **410** of FIG. **11**. Thus, if the instantaneous temperature sensed at the first discharge port of the compressor exceeds the voltage which was pre-set on the pot 406_{66} of the compare system of FIG. **11**, the output line **416** of the voltage comparator **410** will go high and be applied to one input **418** of a flip flop **420**.

It may be pointed out that the output line **422** of the flip flop **420** will only be driven high if there is a simultaneous application of signals on lines **416** and **424**. However, there will only be a signal on line **424** if there is a simultaneous application of signals on lines **426** and **428** which are inputs to an "and" gate **430**. The signal on line **426** is derived from a synchronizing "E" pulse appearing at terminal **188** of the previously mentioned pulse generator **186** (FIG. **12**) and applied by way of common line **432** to the input line **426** of the gate **430**. The second input to the gate **430** will appear on line **428** only when the appropriate contact such as 404_{66} closes in response to the energization of the auxiliary coil **400** in the output channel 148_{66} of FIG. **13D**. It will be appreciated that the use of the contacts 402_{66} guarantees that the signal on line **414** (representative of the first stage discharge temperature) will in fact be compared to the correct reference voltage, namely that previously established on the variable pot 406_{66}. Similarly, the use of auxiliary contacts 404_{66} in conjunction with the "E" pulses from the pulse generator **186**, synchronize the comparing operation and, in addition, acts as a double check in allowing the flip flop **420** to pass an alarm signal only if a proper comparison has been made.

Returning to a comparison and assuming that the temperature at the first stage discharge port **66** has exceeded the predetermined value set on the pot 406_{66} then by the previously described circuitry a low will appear on the output line **422** of flip flop **420**, which line **422** is applied to one input **428** of an "and" gate **424**. The "and" gate, **424** is such that its output **426** is high if one of its inputs **428** or **430** is low. Therefore, when the low from the line **422** is applied to the input **428**, the output **426** of the "and" gate **424** is driven high. An inverting gate **434** takes the high output of gate **424** and applies a low on the line **436** with the low on line **436** being applied to flip flop **440** to produce a high on its output line **442** and low on its output line **444**. This high signal on line **442** is applied to the base of a transistor **446** (to switch it on) which in turn energizes the alarm indicator light **90** which has been previously identified on the panel **10** of FIG. **1**. It should be pointed out that the alarm light **90** is physically positioned beneath a reset push button **90'** which is also identified in FIG. **1**. As will be further described, the purpose of the reset button **90'** is to de-energize the alarm light **90** and take other steps when the situation which caused the alarm, subsides.

Without going into further detail, it will be appreciated that a similar comparison takes place whenever the output channels 148_{68}–148_{76} of the scanning system **98** are energized. In each of these situations, an appropriate auxiliary coil such as **400** is energized to close respective ones of the contact pairs 402_{68} – 402_{76} and contact pairs 404_{68} – 404_{76}. When the respective contact pairs close, then the appropriate pre-established reference voltages on the appropriate potentiometer 406_{68} – 406_{76} will be applied through the appropriate contact pair to the input terminal **408** of the voltage comparator **410**. Likewise, the second input **412** to the voltage comparator **410** will be the particular temperature being sensed at the corresponding station **68** through **76** in accordance with the condition of the respective contact switches 158_{66} through 158_{76} in the sensing sub system **96** of FIGS. **4A** and **4B** as established by the respective coil **154** in the respective energized output channel of the scanning system **98**.

OIL PRESSURE

The next function to be compared to a pre-established level is oil pressure, an especially critical parameter in the multi-stage compressor for which the instant invention was designed, and probably equally as important in any machine employing many moving parts. As indicated in FIG. **1**, the oil pressure is sensed at a channel which has been designated **42**. Accordingly, whenever output channel 148_{42} of FIG. **13D** is energized, it is required to compare the magnitude of the parameter sensed by the transducer 100_{42} with a pre-established minimum value and to generate an alarm signal should the oil pressure fall below this minimum safe value. This is accomplished in the following manner.

When channel 148_{42} of the scanning system **98** is energized, the appropriate contacts 158_{42} in the sensing system **96** of FIGS. **4A** and **4B** will close, and the voltage representative of

oil pressure will pass through the common lines **138, 140**; to the pressure amplifier **160**; through the contacts **172**; and on through the line **174** to the analog-to-digital converter **102** of FIG. **5** for subsequent display at **14**. Simultaneously, by way of branch line **448** (FIGS. 4A), the signal will be applied from the output of pressure amplifier **160** and passed by an attenuator **450** (FIG. **11**) to a line **452** (in the compare system **116** of FIG. **11**) and to the input terminals **454, 456** and **458** of three voltage comparators **460, 462** and **464** respectively.

A second input to the comparator **460** is established on the line **466** by a variable potentiometer **468** which may be set to produce a voltage corresponding to the desired minimum oil pressure. Should the pressure appearing on the input **454** fall below the voltage established by the pot **468**, comparator **460** will produce an output signal on the line **470** which in turn is applied to a gate **472**. As will be further described, gate **472** will normally allow a signal to pass from line **470** to line **474**, and will only inhibit such a signal in one special circumstance. The signal appearing on line **474** is applied to one input pin **475** of the oil flip flop **476**.

Thus far, in the description of the oil pressure comparison, it is apparent that the oil pressure signal appearing on the common line **452** will be applied to each of the comparators **460, 462** and **464**. However, since comparator **462** and **464** are used for other comparisons, to be described, it is imperative that only the output of the oil pressure comparator **460** have any influence when in fact, an oil pressure signal is appearing on the line **452**. To that end, when the output channel 148_{42} of the scanning system **98** of FIG. 13D is energized, a high signal of that channel namely the high signal 148_{42H} is applied to one input pin of a gate **478** in the compare system **112** of FIG. **11**. The second input to gate **478** is an "E" pulse generated by the pulse generator **186** of FIG. **12** and carried to gate **478** on the previously mentioned line **432**. Thus upon the simultaneous application of the high signal 148_{42H} and an E pulse, gate **478** will pass a signal through gate **480** to a second input terminal **482** of the oil flip flop **476**. In order for the oil flip flop **476** to produce a low on the output line **484** there must be a simultaneous application of signal on the inputs **482** and **475** thereof.

It may be pointed out that an air bank flip flop **486** and a first stage discharge pressure flip flop **488** (both of which will be further described) operate in a similar manner and require the simultaneous application of signals to the input terminals **490, 492**; and **494, 496** respectively in order to produce alarm output signals on their lines **498, 500**; and **502** respectively. What is important to note at this point, is that although the oil pressure voltage signal may be simultaneously applied to all three pressure comparators **460, 462** and **464**; the only alarm signal produced will be an oil pressure alarm signal on the output line **484** of the oil pressure flip flop **476** (by virtue of the high signal 148_{42H} being applied to the gate **478** to generate a signal on the input terminal **482** of gate **476**). While other comparisons may be taking place in the comparators **462** and **464**, their result will have no influence since their respective flip flops **486** and **488** will not be switched, (since no input signal has been applied to their input terminals **492** and **496** respectively).

Returning to the oil pressure comparison, assuming that the pressure has, in fact, fallen below the minimum safe value as established by the potentiometer **486**; a low will appear on the output line **484** of the flip flop **476**. The low on line **484** is a second input to "and" gate **424** and will drive the output **426** thereof high and apply a low (by way of theiinverting gate **434**) to the flip flop **440** which in turn produces a high on line **442** and a low on the line **444**. The high on line **442** turns on transistor **446** to light the alarm push button **90**.

AIR BANK COMPARISON

The next pressure function to be monitored by the instant invention is the air banks pressure (the air banks of a compressor are also commonly known as the receiver). As suggested previously, this pressure is monitored by a transducer 100_{38} when the indicator (such as **156** in the output channel 148_{38} of scan system **98** of FIG. 13D) is lit beneath push button **38** on the panel **10** of FIG. **1**.

With respect to air banks pressure, in a compressor it is desirable to know whether the air banks or receiver pressure exceeds or falls below pre-established maximum and minimum values respectively. So long as the air banks pressure remains within the preselected pressure range, the compressor is functioning normally. Should the air banks exceed the maximum pressure permitted, then the air banks must be operated in an unloaded state allowing the pressure thereof to reduce as by the usage of the air pressure by whatever outside device it is supplying. Conversely, should the air banks pressure fall below the minimum value, the compressor should be operated in its loaded state to build up air banks pressure. In the event of high pressure, it is desirable to have an alarm signal indicate when the air banks pressure has exceeded the predetermined range. If desired, an alarm signal will be additionally provided to indicate that the air brakes pressure has fallen below its preselected minimum value.

Assuming that the air banks pressure transducer 100_{38} of sensing system **98** of FIGS. 4A and 4B is passing a voltage signal through common line **138, 140**; through the pressure amplifier **160**; through line **174** to A-D converter **102**; and also through the branch line **448** to common line **452**; that signal will be applied simultaneously to the input terminals **454, 456** and **458** of the comparators **460, 462**, and **464** of FIG. **11**.

However, as noted previously, the comparison produced by comparator **460** will have no affect since by assumption the air banks pressure channel 148_{38} of FIG. 3D (and not the oil pressure output channel 148_{42}) is energized, such that the high signal 148_{42H} cannot be applied to the gate **478** to switch oil flip flop **476**. In like manner, since the first stage discharge pressure channel 148_{28} is not energized, the high signal 148_{28H} cannot be applied to a gate **504** in the compare system of FIG. **11** such that the first stage discharge flip flop **488** cannot be switched regardless of the output of comparator **464**. Since by assumption the air banks pressure is in fact being monitored and the output channel 148_{38} of FIG. 13D is energized, then its high signal 148_{38H} can be applied to a gate **506** in the compare system and through a gate **508** to the enabling input terminal **492** of the air banks pressure flip flop **486**. Therefore, if an high pressure alarm signal is generated on the input **490** of the flip flop **486**, it will be switched and low and high alarm signals will appear on lines **498** and **500** respectively.

The maximum air banks pressure reference voltage signal is established by a variable potentiometer **510** which, when the compressor is first started, is applied alone to the second input terminal **512** of the air banks pressure comparator **462**. The voltage on pot **510** is applied alone by virtue of normally open contact pair **514** which maintains the second adjustable potentiometer **516** electrically isolated from the first pot **510**.

Assuming that the air banks pressure builds up and finally exceeds the maximum pre-established limit, such that the signal on input **456** of comparator **462** exceeds the signal on input **512** established by the pot **510**; a low signal will appear on the output line **518** which will be applied to the input terminal **490** of the air bank flip flop **486**. The second enabling signal applied to the terminal **492** of the flip flop **86** is derived from the gates **506** and **508** upon the simultaneous application of the aforementioned "E" pulse from common line **432** and the high signal 148_{38H} signifying that the air bank's pressure channel of FIG. 13D is indeed being monitored at this time.

Thus, the flip flop changes conditions and a low appears on line **498** indicating that the air banks has exceeded its predetermined maximum pressure. As will be further described, this low on line **498** is utilized to unload the air bank and maintain it in the pre-established pressure, the lower end of which is established in the manner to be described. Simultaneously, the low signal is applied by a feedback line **520** through an inverting gate **522** to turn on a transistor **524**

which energizes a coil **526** which thereby closes the previously mentioned, normally open contact pair **514** which then throws the second potentiometer **516** into parallel with the first potentiometer **510** to establish the "minimum" air banks pressure reference voltage which is then applied to the input terminal **512** of the comparator **462**. Additionally, when the transistor **524** is turned on to energize coil **526**, the indicator light **94** is energized to display the high pressure condition on the display panel board **10** of FIG. **1**.

It may also be pointed out that the high signal appearing on line **500** of the flip flop **486** is applied by the lines **528** to a ten minute timer **530** (FIG. **12**) which, as will be further described, causes the compressor to shut down completely in the event that the high air bank pressure has not subsided within a 10 minute period.

Potentiometers **516** and **510**, now in electrical parallel, establish the low value for the air banks pressure voltage signal. Thus, comparator **462** will compare the air bank pressure signal at input **456** to the low signal at input pin **512**. The low signal on line **518** will remain so long as the air bank pressure is above the low end of the permissible range. However, once the air bank's pressure falls below the low end of the range (and assuming that this occurs within 10 minutes); the low on line **518** will disappear; and flip flop **486** will switch, driving output line **498** high and **500** low; resetting the 10 minute timer **530** of FIG. **12**. In addition to performing the function of causing the compressor to be switched back to operation in the "loaded" mode (as is to be further described), the new high on line **498** will be sent back and inverted through line **520** of FIG. **11** to turn off the transistor **524**, de-energize the coil **526**, de-energize the alarm light **94**, and open the contacts **514** thereby removing the potentiometer **516** from the parallel circuit.

The net effect of this system is that there is an alarm situation whenever the air banks is above its pre-established maximum limit and furthermore, the air banks pressure will oscillate between the maximum and minimum voltage levels established by potentiometers **510**; and **510** and **514** in parallel. Thus, and as will be described with respect to the control system **116**, whenever the air bank's pressure exceeds the upper limit of the acceptable range, the compressor will be operated in an "unloaded" state, and whenever the air bank's pressure falls below the minimum level of the acceptable range, the compressor will be operated "loaded" in order to build up air banks pressure.

FIRST STAGE DISCHARGE PRESSURE

The final parameter of the instant system which is to be compared to a pre-established level is the first stage discharge pressure which, by previous numbering, corresponds to channel **28** as identified on the panel **10** of FIG. **1**. As noted previously, if the first stage discharge pressure is to high at start-up, it is desirable to prevent the motor from being started, and to also make sure that the unloader control valve (which determines whether the compressor operates in the loaded or unloaded state) cannot be be closed (which would normally load the compressor). Therefore, assuming that the output channel 148_{28} of the scanning system **98** of FIG. **13D** is energized; transistor **152** thereof will be turned on to energize its coil **154** which in turn will close the contacts 158_{28} in the sensing sub system **96** of FIGS. **4A** and **4B** to pass the signal representative of the first stage discharge pressure to the common lines **138**, **140** and on to the pressure amplifier **160** whereby it may be passed through the now closed contact **172** and on to the analog-to-digital converter **102** for display.

Simultaneously, the voltage signal appearing at the output of the pressure amplifier **160** of FIG. **4A** will be passed by way of line **448** to the common line **452** of FIG. **11** and be applied to the input terminals **454**, **456** and **458** of the comparators **460**, **462** and **464**. However, by assumption, with only the output channel 148_{28} of the scanning system energized, only the high signal 148_{28H} will be applied to the gate **504** of the compare system **112** whose other input will be an "E" pulse generated in the pulse generator **186** and applied to the gate **504** by the common line **432** at the rate of 30 times per second. Thus, and as was the case for the comparators previously discussed, the application of the respective high signal such as 148_{28H} guarantees that only the flip flop **488** will respond to a comparison, while the flip flops **476** and **487** will not.

Thus, dealing with comparator **464**, one input **458** thereof will be the voltage signal representing the first stage discharge pressure. The second input **532** is derived from an adjustable potentiometer **534** the voltage level of which is set to correspond to the maximum pressure which is allowed for the first stage discharge port upon start up. If the first stage discharge discharge pressure should exceed the present reference voltage established by pot **534** at start up, a low will appear on the output line **536** of the comparator **464** and be applied to the input terminal **494** of the flip flop **488**. As noted previously, the second input for pin **496** of the flip flop **488** is established when there is a simultaneous application of the high signal 148_{28H} (signifying that the first stage discharge pressure is being monitored) and an "E" pulse on a line **432**. Flip flop **488** will then produce an abnormality signal on the output line **502** thereof which signal is applied (FIG. **12**) through a gate **536**, line **538**, and **540**. The output of gate **540** is utilized to turn on transistor **452** thereby energizing the "-first discharge" alarm light push button **92** previously identified on panel **10** of FIG. **1**. As will be further described in the control sub system below, the signal from the output of gate **536** is also utilized to perform a number of functions including preventing the operation of the motor and the unloader control valve at start up. Also, it should be pointed out, and will be further described that once there has been a successful start-up, the disabling function of the first stage discharge pressure alarm is removed from the system.

Summarizing the comparator system **12**, the instant invention makes possible **112**, comparison of a number of preselected parameters with pre-established reference levels and will generate appropriate alarm and control signals should these levels be exceeded. Of course, more or less parameters may be monitored if desired.

CONTROL SYSTEM

As noted previously, the instant invention includes a control system **116** which automatically takes certain steps should the comparator system **112** generate the various signals discussed above. For example, should the temperature at the first stage discharge port; the second stage discharge port; third stage discharge port; fourth stage discharge port; fifth stage discharge port; or final discharge port of the multi-stage compressor exceed their respective pre-determined safe reference levels, it is imperative that motor of the compressor be shut down. This is accomplished in the following manner.

It will be recalled from the previous description of the temperature comparator **410** of the comparator system **112** of FIG. **11**; when an alarm signal was generated, indicating that one of the particular temperature stations had exceeded its predetermined level, a low signal developed on the output line **422** of the flip flop **420** was applied to the input terminal **428** of the "and" **424** to drive its output **426** high.

Insofar as the functional control is concerned and with reference to FIG. **12**, the low signal appearing on the line **444** is applied to line **431** and is applied to an input **548** of a flip flop **546** and through an inverter **549** a high is applied to a second input **544** thereof. Flip flop **546** will switch and drive its output **550** low, upon the simultaneous application of signals to the inputs **548**, **544** as described, plus a third signal applied to its third input terminal **552** which third signal is an "F" pulse derived from the "F" pulse terminal **192** of the pulse generator **186**.

When the output line **550** of flip flop **546** goes low, a transistor **556** is turned off thereby de-energizing a coil **558**,

returning its respective contact pairs **560** and **562** to their normally open condition. When contacts **560** and **562** open, driving signals are no longer applied to the gates **564** and **566** of semi-conductor controlled rectifiers **568** and **570** respectively, whereby these SCR's are switched from their conducting to a non-conducting condition. The SCR's **568** and **570** are normally the paths for an AC current carried from the line **572**, through line **574**, through the SCR's **568** and **570** on alternate half cycles; and then through line **576** to maintain a CR coil **578** energized. AC current on line **572** is connected to a normal 110 volt 60 cycle outlet through "power" on switch **88** also shown in FIG. **1**.

When the above described circuit path is interrupted because of the switching of the SCR's **568** and **570**) the normally energized CR coil **578** is de-energized, and its normally open contact pair **584** reverts to its normally open condition thereby interrupting the motor **586** of the compressor which was the desired result. Additionally, a second CR contact pair **585** reverts to its open condition to interrupt a PSR coil **638** to be described below.

It should be pointed out that the purpose of conditioning the operation of the flip flop **546** on the presence of an "F" pulse on its input **552**, is to make sure that the changing of the conduction state of the SCR's **568** and **570** will coincide with a zero voltage appearing on such SCR's. This will eliminate transient voltages being applied to these devices. If desired, the low on line **431** could be applied through appropriate gating to flip flops **610** and **648** to initiate the functions associated with these devices (to be described). It has been found that this procedure additionally helps to alleviate problems due to transients.

LOW OIL PRESSURE CONTROL

The next function to be performed by the control system **116** is to automatically and quickly shut down the motor in the event the oil pressure falls below its pre-established limit. This is accomplished in the following manner. If the oil pressure falls below the safe value established by the potentiometer **468** of the comparator system **112** of FIG. **11**, the comparator **460** will provide a signal on the line **470** which is then passed through gate **472** and applied to the flip flop **476** to apply a low signal on the line **484** which is a second input to the aforementioned "and" gate **424**. As noted, a low applied to either input **428** or **430** of gate **424** drives its output **426** high and through gate **434** and flip flop **440** drive line **431** low, which in turn is applied to the flip flop **546** in the control system **116** of FIG. **12** to shut down the motor in the manner described immediately above. Therefore, it becomes apparent that if either of the six temperatures exceed their predetermined limits or if the pressure falls below its predetermined limit, the compressor motor **586** will be shut down, and simultaneously by virtue of the flip flop **440** of the compare system **112** of FIG. **11**, the alarm light **90** on the panel **10** of FIG. **1** will be lit.

As suggested previously, whenever the motor **586** is shut down, the oil pressure in the system drops down to a very low level. Therefore, whenever the motor is restarted, there must be some inhibiting means to initially prevent the oil pressure comparator system from generating an alarm signal which in turn will shut down the motor. This is accomplished as follows. When the CR coil **578** of FIG. **12** is energized during start up operation, a normally open contact pair **588** of the control system of FIG. **12** closes to energize a coil **590** whose normally open contact pair **592** will then close to apply a signal through gates **594, 596, 598** and **599** to a line **600** to the input terminal **602** of a 12 second timer **604**. For 12 seconds, a signal applied along the output line **606** (FIGS. **12** and **11**) of the 12 second timer **604** will inhibit the previously mentioned gate **472** of FIG. **11** and thereby prevent a low oil pressure alarm. Therefore, each time the motor is restarted, an inhibiting signal will be applied from the **12** second timer **606** to the gate **472** to prevent an oil pressure alarm signal being passed from the oil pressure alarm comparator **460** on the flip flop **476** which would normally cause the system to shut down again. Although timers per se do not form part of the instant invention, it may be noted that such timers may conventionally include unijunction oscillator circuits, the outputs of which are fed into flip flops for holding and time extension purposes. Additionally, and as will be further described the signal applied through gates **594, 596, 598, 599** is applied to flip flop **648** of FIG. **12** to start up the system, except when inhibited in the manner to be discussed under the heading "First Stage Discharge Pressure Control".

AIR BANKS PRESSURE CONTROL

The next function to be performed by the control system **116** of FIG. **12** is related to the air banks pressure. Thus, and as will be immediately described, should the air banks pressure exceed its pre-established maximum limit, the control system **116** will take steps to unload the compressor such that the air banks pressure may revert (i.e., by normal leakage or by usage) to a point where the pressure therein falls below the maximum level. Should the air banks pressure remain in its established range for a predetermined length of time, namely ten minutes, the control system **116** will take appropriate steps to shut down the motor such that the air banks do not accumulate any more pressure. Finally, when the air banks pressure falls below the minimum desired level, the control system **116** will take appropriate steps to re-energize the motor and have the compressor operate in the loaded mode by which the pressure in the air banks will increase.

Turning to the specific circuitry, and with reference to the comparator system **112** of FIG. **11**, as previously noted, when the air banks pressure voltage signal applied to the input **456** of comparator **462** exceeds the pre-established maximum value established by the single potentiometer **510**; a signal appears on the output line **518** and is applied to the flip flop **486**. Upon the simultaneous application of a signal on input terminal **492** of flip flop **486** (which, as noted previously, is dependent upon simultaneous application of an "E" pulse on line **432** and signal 148_{38H} on the gate **506**), flip flop **486** switches to produce a low signal on the output line **498** and a high signal on the output line **500**.

With reference to FIG. **12**, the low signal on line **498** is applied to one input **608** of a flip **610** through an inverting gate **611**, a high signal is also applied to input **612** of flip flop **610**. The high signal on line **500** is, as noted previously, applied to input terminals **528** of a ten minute timer. Thus, upon the simultaneous application of an "E" pulse from common line **554** applied to a third input terminal **614** of flip flop **610**; its output line **616** will go low to turn off transistor **618** which de-energizes coil **620** to open contacts **622** and **624**. As with contacts **560** and **562** in the CR coil circuitry previously described, the opening of contacts **622** and **624** removes biasing current from the gates **626** and **628** of semi-conductor controlled rectifiers **630** and **632** respectively. These SCR's will therefore switch to the non-conducting state whereby the normal current path from line **572** through line **634**; through SCR's **630** and **632** on alternate half cycles of the AC cycle; through line **636**; and through PSR coil **638** will be interrupted, such that the PSR coil **638** will be de-energized. When this coil is de-energized, its normally open contact pair **640** reverts to its normally open condition to interrupt the current flow through an unloader control valve coil **642**. Although not shown, once the unloader control valve coil **642** is de-energized, the compressor ceases to feed the air bank, which was the desired result.

It might be pointed out that the purpose of the "F" pulse being applied to the terminal **614** of flip flop **610** is to guarantee that the SCR's will be switched between conducting and non-conducting conditions at the time when there is zero voltage across these devices such that transients will be avoided.

Should the air banks pressure return to an acceptable value (and actually fall below the minimum level established by the parallel bits **510** and **514** of FIG. **11**) within the 10 minutes

established by the timer **530** of FIG. **12**, the signal appearing on line **518** of the comparator **464** of FIG. **11** will disappear; the flip flop **486** will switch to reverse the signals on the lines **498** and **500**; the timer **530** of FIG. **12** will reset; and the flip flop **610** of FIG. **12** will change its output **616** to turn on the transistor **618** to re-energize the coil **620**, which in turn will close the contacts **622** and **624** to apply signals to the gates of the SCR's **630** and **632** which will re-establish the circuit through the PSR coil **638**, close the PSR contact **640**, and thereby re-energize the unloader control valve coil **642** to cause the compressor to be operated in a loaded condition in which the air banks will again accumulate pressure.

FIRST STAGE DISCHARGE PRESSURE CONTROL

The third function performed by the control system **116** of FIG. **12** is to prevent the motor and unloader control valve from being operated at start-up in the event the first stage discharge pressure exceeds its predetermined safe value. As pointed out previously, the comparison of the first stage discharge pressure takes place in FIG. **11** at comparator **464** of compare system **112**. Should this parameter exceed the safe limit established by the potentiometer **534**, an abnormality signal will be developed on line **536** which will be applied to the flip flop **488**. Upon the simultaneous application of this signal on input **494** and the appearance of an input signal on terminal **496** (as determined by the simultaneous application of an "E" pulse and a signal 148_{28H} on the gate **504**,) output line **502** of flip flop **488** is driven high and applied to previously mentioned gate **536** of FIG. **12**. The low output **644** of gate **536** is, as previously noted, applied on the one hand to inverter gate **540** which in turn brings about the energization of the first stage discharge alarm light **92**; and on the other hand is applied to inverting gate **599** to inhibit same.

As suggested previously, during normal start-up operation (with the first stage discharge pressure blow the pre-established level therefor), the energization of the CR coil **578** closes the normally open contact pair **588** to energize a coil **590** whose normally open contact pair **592** will then close, to apply a signal through gates **594**, **596**, **598** and **599** to a line **600**. In addition to other functions already mentioned, the signal at the output of gate **599** is applied to one input **646** of flip flop **648** and simultaneously, through an inverter **649**, a second input signal is applied to the input **651** of the flip flop **648**. With the appearance of the next "F" pulse on input terminal **650** of flip flop **648**, its output line **652** is driven high to turn on transistor **654** whereby coil **656** is energized. When coil **656** is energized, its contacts **658**, **660** close to permit current to be applied to the gates **662** and **664** of SCR's **666** and **668** respectively. With the application of these gating signals, SCR's **666** and **668** switch to their conducting condition to establish a current path which includes line **572**, line **670**, the SCR's **666** and **668**, the line **672**; and the parallel system including the motor **586** and the unloader control valve coil **642**. With this circuit made, the system can be started.

However, should the first stage discharge pressure be to high at start-up, then in the manner previously described above, a signal appearing on the output line **644** of gate **536** is applied to one input of the gate **599** to inhibit gate **599** and thereby prevent the passage of the previously described start-up signal through this gate and onto the flip flop **648**. Thus, it is clear that when the first stage discharge pressure is too high, start-up cannot take place.

It should be pointed out that the first stage discharge pressure inhibiting function is only operative during a start-up operation and has to applicability once the system is started. This is accomplished as follows. Once there is a successful start-up, then the output of gate **599** (FIG. **12**) is fed back through the lines **600** to an input **537** of the previously mentioned gate **536**. This fedback signal has the effect of inhibiting gate **536** and thereby preventing any signal on the line **502**, which is indicative of high first stage discharge pressure, from being passed on through gate **536** and having any effect.

Finally, it was noted previously that in the air banks pressure comparison, should the air banks pressure fail to return to below the minimum value within 10 minutes, it would be desirable to shut down the compressor motor, such that the air banks pressure will not be further accumulated. This is accomplished in the instant invention by the 10 minute timer **530** of FIG. **12** as follows:

Upon an alarm situation in the air banks pressure comparison, a signal is applied on a line **500** to the inputs **528** of the 10 minute timer **530**. In **10** minutes, and assuming that the air banks pressure has not returned to its low value (to switch the flip flop **486** of FIG. **11** and reset the timer **530**); an output will appear on terminal **674** of **10** minute timer **530** which will be applied by gate **596** through subsequent gates **598** and **599**. It is the high output of gate **599**, as described previously, which will be applied to the flip flo0 **648** to initiate the interruption of the current to the parth including the motor **586**.

SEQUENCESYSTEM

As has been emphasized throughout the specification, the primary function of the sequencing system **98** of FIGS. **13A–13D** is to sequentially energize the output channels 148_{28} through 148_{78} corresponding to the various sensing channels at which the transducers 100_{28} through 100_{78} are located. With reference to FIG. **13B**, the immediate means for sequentially energizing these output channels is a **32** step scan counter **676** on the five output lines **678** of which are sequentially presented in binary form, signals representative of the numbers 1 through 32 at the rate of a new number being presented every one thirtieth of a second. The five lines **678** are presented to a binary-to-32 line output converter **680** which will thereby sequentially energize the channels 148_{28} through 148_{78} of FIG. **13D** as the signals representative of the numbers 1 through 32 sequentially appear in binary form on the lines **678**. It may be noted that in the instant invention, only 26 output channels are actually utilized such that six output lines of the converter **680** are not used. The counter **676** is controlled by a second 32 step position counter **684** in the manner to be immediately described.

Every 4 seconds, a 4 second oscillator **686** (FIG. **13C**) produces a pulse **688** which is applied on the one hand to a line **690** and on the other hand to a gate **692**. The pulse on line **690** is applied to a flip flop **694** whose output on line **696** then enables a gate **698** (FIG. **12A**) to pass "D" pulses (which were generated on terminal **190** of the pulse generator **186** of FIG. **12**) through gate **716** to an "advance pulse" line **718** to an "advance" input pin **720** (FIG. **13B**) of counter **676** to start the counter **676** advancing its output on line **678**.

At the same time, and assuming that the operator has selected 4 second fast scan by depressing the fast scan push button **82** on the panel **10** of FIG. **1**; the pulse **688** of FIG. **13C** is applied through the gate **692**, and to a gate **700** whose output on the line **702** is applied to set a flip flop **704**. With flip flop **704** set, one "D" pulse applied at **706** passes by way of line **708**, through gates **710** and **712** to an advance pulse line **714** which is applied to the position counter **684** of FIG. **13B** to advance its count by one increment. (The first "D" pulse resets the flip flop **704** of FIG. **13C** and prevents further "D" pulses from passing until the next four second pulse **688** is generated). For example, assuming that the position counter **684** was currently at a count "1" which corresponds to output channel 148_{28}; when a pulse is applied on the advance pulse line **714**, the position counter **784** advances one count to a number "2" corresponding to the second output channel 148_{30}. It should be pointed out, that by virtue of the coincidence circuitry about to be described, immediately prior to the time that the first counter **676** started advancing (and position counter **684** was advanced), the count on the first 32 step counter **676** was exactly the same as the count on the position counter **684**.

Returning in detail to the application of the four second pulse **688** to the flip flop **694** of FIG. **13C** and its enabling of

the gate 698 of FIG. 13A; "D" pulses generated at the terminal 190 of the pulse generator 186 are applied through gate 698, gate 716 to advance pulse line 718 which is applied at the input terminal 720 of the first 32 step counter 676. It will be appreciated that since these "D" type advance pulses are being applied to counter 676 at the rate of 30 per second; then within the span of approximately 1 second the numbers 1 through 32 will appear on the binary output lines 678 of the 32 step counter 676. As a result, within a span of approximately 1 second, all 26 output channels namely, 148_{28} through 148_{78} of FIG. 13D, will be rapidly energized and scanned to look for an alarm condition which may be occurring at the preselected parameters which are being compared in the comparator system 112 of FIG. 11. However, assuming that no alarm situation was detected in this rapid 1 second scan, the scanning will continue until the count on the 32 step counter 676 comes around the equals the new count on the position counter 684. In the assumed example, coincidence will occur and further sensing is halted when the output on the five group line 678 of the counter 676 is a binary "2". With a binary two presented on the lines 678, it is apparent that the output channel 148_{30} will now be energized to enable the appropriate transducer 100_{30} in the sensing sub system 96 of FIGS. 4A and 4B. The manner in which the 32 step counter 676 stops when its count coincides with the new count on the position counter 684 is presented immediately below.

Scanning system 98 of FIGS. 13A–13D includes a coincidence comparator 722 (FIG. 13B), one set of inputs 724, 726, 728, 730 and 732 of which are taken from the output lines of the position counter 684. The second group of inputs to the coincidence comparator 722 are the output lines 736, 738, 740 and 742 of the 32 step counter 676. Thus, when the count on the position counter 676 is the same as the count on the 32 step counter 684, coincidence logic gate 722 will produce signals on its output lines 744 and 746 which will enable a pulse generator 748 (FIG. 13A) to produce a previously mentioned pulse 218 on its output line 752. This pulse 218 performs a plurality of functions.

The first function performed by pulse 218 on line 752 is to reset the aforementioned flip flop 694 (FIG. 13C) which in turn disables gate 698 and prevents further "D" pulses from being applied from the terminal 190 to the counter 676. The coincidence pulse 218 is applied by line 752, through the gate 754 (FIG. 13A) to a line 756 to reset pin 758 (FIG. 13C) of the flip flop 694. Thus it will be appreciated that in approximately 1 second, during which all 26 channels have been scanned for an alarm situation; the 32 step counter 676 will stop at a new count which corresponds to the new count on position counter 684, with the binary output lines 678 now energizing (in the example) the second output channel 148_{30} which in turn enables the transducer 100_{30} in the sensing system 96 of FIGS. 4A and 4B such that an electrical signal representative of the second stage discharge pressure will now be passing to the analog-to-digital converter 102, sampled and converted to digital representation.

Simultaneously, the coincidence pulse 218 is applied by way of line 752, gate 760, and line (FIG. 13C) to the flip flop 206 of the transfer system 104 of FIG. 6. As explained previously, the flip flop 206, together with end of conversion pulses 202, controls the transfer of information from the converter 102 (FIG. 5) 230, 230', 230'' (and also to the auxiliary buffer storage devices in the event that a channel such as 148_{70}, 148_{72} or 148_{74} were being monitored in which case it is desirable to retain the latest magnitude for future display). From the storage system 106, the signals are passed on to the bulbs (FIG. 10) in the display section 14 (through the gating and shifting logic 108 FIG. 8 and 110, FIG. 9, respectively) such that the display bulbs will present the magnitude of the second stage discharge pressure, and, the channel indicator light 156 beneath button 30 on the display panel 10 of FIG. 1 will be energized to inform the observer which channel is being displayed.

Since the above described rapid alarm scan took approximately 1 second, it will be appreciated that approximately 3 seconds later another pulse 688 will appear at the output of the 4 second oscillator 686 of FIG. 13C. In the manner previously described, this pulse will cause the 32 step counter 676 of FIG. 13B to begin scanning all channels once again and also advance the position counter 584 one count. When the count on counter 676 comes around to equal the new count on position counter 684, further scanning stops, in which case the next channel 148_{32} will remain energized; the coincidence pulse 218 is generated; and the entire process is repeated.

It should be appreciated that since the coincidence pulse 218 is not generated until at 1 second into the next 4 second interval, then the magnitude of a parameter sensed will be displayed on the bulbs 16, 18, 20 and 22 for 3 seconds of one 4 second interval and 1 second into the next 4 second interval.

It should also be appreciated, that each time a channel is changed by the above described process, such that all 26 stations are rapidly (alarm) scanned, the latest magnitude of the three channels which are being retained for subsequent display, will be updated in the auxiliary buffer storage devices of the storage system 106 of FIG. 7.

FAST-SLOW SCAN

In the above discussion, it was assumed that the operator had depressed the fast scan button 82 to monitor the compressor at the rate of one station every 4 seconds. The actual manner of accomplishing a fast (4 second) scan is described immediately below.

When an operator depresses the "fast" push button 82, flip flop 762 of FIG. 13C switches to produce a high signal on line 764 and a low signal on the line 766. The high signal on line 764 turns on transistor 768 to energize the "fast" push button light 770 which is positioned immediately below the fast bush button 82 on the panel 10 of FIG. 1.

The low signal on line 766 is applied to a gate 772 to produce a high on its output 774 such that the gate 700, when presented with the 4 second pulse 688, can pass the same on to line 702 and to the flip flop 704 which passes the one "D" pulse which advances the position counter 684 in the manner previously described.

To convert to the "slow" scan mode (i.e., a channel displayed every 8 seconds), the slow scan push button 80 is depressed to switch the flip flop 762 (FIG. 13C) so as to produce a high signal on the output line 766 and a low signal on line 764. The low signal on line 764 extinguishes the "fast" indicator light 770 while the high signal on the line 766 turns on the transistor 776 to energize the slow indicator bulb 778 which is positioned beneath the slow push button 80 on the display panel 10 of FIG. 1.

At the same time, the high signal now appearing on the line 766 is applied to the gate 772. Gate 772, in order to produce an output on the line 774 thereof, requires the simultaneous application of the high on line 766 and the high portion 780 of a pulse 782 produced by a flip flop 784 which is energized every 4 seconds by pulse 688 through the gate 692. Even though flip flop 784 is pulsed every 4 seconds, the square wave 782 produced thereby has a high portion 780 at every other 4 second interval thereof. In effect, it is only once every 8 seconds that there will be the simultaneous application of a pair of high signals to the gate 772 to produce a signal of the output line 774 which in turn will permit every other 4 second pulse 688 to be passed by gate 70 on to the flip flop 704.

Thus, when the slow push button 80 is depressed, it is every other 4 second pulse 688 which is passed through the gate 700. Thus it is once every 8 seconds that a "D" pulse is produced at the output of flip flop 704 to advance the position counter 684 to its next count such that the value of the particular parameter will be displayed on the bulbs 16, 18, 20 and 22 for 8 seconds.

However, every 4 second pulse 688 sets flip flop 694 and enables "D" pulses from the terminal 190 (FIG. 13A) to be

applied to the advance pin **720** of the 32 step counter **676**. Thus, even though the system is in the 8 second scan mode, every 4 seconds the counter **676** will alarm scan all 26 stations (in approximately 1 second). Of course, the alarm scan will stop when the count on counter **676** comes around and back to the same count as the position counter **684** when the coincidence pulse **218** will reset the flip flop **694** of FIG. 13C.

During the scan mode (either at 4 second or 8 second intervals) there are two situations in which an alarm situation might occur. In the first situation, the system might be monitoring a particular channel which has been preselected for alarm comparisons when an alarm situation does in fact occur. For example, if the system were monitoring the temperature at the first stage discharge port (corresponding to station **66** on the panel **10** of FIG. 1), and the temperature at this station exceeded the safe value established by the first stage discharge potentiometer 406_{66} of the compare system **112** of FIG. **11**; not only is it necessary to energize the alarm light **90** of FIG. 1 and **11** and shut down the system (as previously described) but it is also necessary to stop sequencing system **98** such that the display system **14** will continuously display the value of the new temperature which caused the alarm situation.

The second possibility for an alarm situation might happen as follows. Suppose the position counter **684** of FIG. **13B** has just advanced one count from output channel 148_{28} to output channel 148_{30}. As noted, within approximately 1 seocnd, all 26 stations are quickly "alarm scanned" for the occurrence of an alarm situation. Thus, it is possible that during this 1 second alarm scan, it will be found that a parameter such as the first stage discharge temperature (station **66**) may have exceeded its safe limit. In such a situation, it is necessary not only to energize the alarm light **90** of FIG. 1, and shut down the motor system of FIG. **12**; but also, it is required that the display system **14** visibly display the magnitude of the parameter which caused the alarm situation.

Returning to the first possible situation, and using as an example the output channel 148_{66} (corresponding to the first stage discharge temperature), the following events will occur. With channel 148_{66} of FIG. 13D energized (for example during the last 3 seconds of a 4 second interval) the appropriate transducer 100_{66} of the sensing system of FIGS. 4A and 4B will be passing the voltage representative of first stage discharge temperature to the A-D converter **102** of FIG. **5** and at the same time to compare system **112** of FIG. **11**. As previously described, should the first stage discharge temperature exceed its preset value as established by the potentiometer 406_{66}; a flip flop **440** will switch to produce a high on the output line **442** and a low on the output line **444**. The high on the line **442** will turn on the transistor **446** to energize the alarm light **90** on the panel **10** of FIG. 1. Simultaneously the low signals on lines **431** of FIG. **12** will be applied to the flip flop **546** of the control system **116** of FIG. **12** to shut down the motor **586** in the manner previously described.

To prevent further scanning at the end of the three second interval, and thereby permit the display sub system **14** to continue displaying the magnitude of the first stage discharge temperature; the high signal on line **442** of the flip flop **440** of the compare system **112** of FIG. **11**, is applied to a gate **786** of FIG. 13A which has the effect of grounding the advance pulse line **718** to prevent further "D" type advance pulses from being applied to the 32 step counter **676**. Thus, the binary output lines **678** of the 32 step counter **676** of FIG. **13B** will continue to present a signal corresponding to the 14th channel, namely output channel 148_{66} and the value of the first stage discharge temperature will be continuously displayed.

Since the value of the first stage discharge temperature which ultimately caused the alarm situation is higher than the value which was earlier transferred into storage buffer **230**, **230'** and **230''** of FIG. **7**; some means must be provided to transfer the alarm value from the A-D converter **102** of FIG. **5** to these storage devices such that the display **14** will present the new alarm value.

This is accomplished by the low signal on the output line **444** of the flip flop **440** of the compare system **112** of FIG. **11** being applied to an input of an auxiliary pulse generator **788** of FIG. **13C** which in turn applies a read pulse **218'** through gates **790** and **792** to the line **220** which in turn passes the auxiliary pulse **218'** to the transfer logic **104** of FIG. **6** such that the alarm value of the parameter being sensed at the first stage discharge channel can be passed on to the display system **14**. It will be appreciated, of course, that because output channel 148_{66} of FIG. 13D remains energized, its respective indicator **156** will remain lit under the first stage discharge push button **66** on the panel **10** of FIG. **1** to indicate to the observer that the alarm condition being displayed is the first stage discharge temperature. Furthermore, he will know that it is an alarm situation by virtue of the fact that the alarm light **90** is energized.

Returning now to the second possibility, an alarm may occur during the 1 second alarm scan which accompanies each change of channel. For example, let it be assumed that the position counter **684** has just been switched from a count of 1 to a count of 2, indicating that output channel 148_{30} of FIG. 13D is to be energized and output channel 148_{28} de-energized. As indicated previously, the 32 step counter **676** of FIG. **13B** will be rapidly scanning at the rate of a channel each 30th of a second until, if no alarm occurs, the 32 step counter **676** would come around and its count on lines **678** would be equal to the new count now appearing at the output of position counter **684**. It is this coincidence which enables the pulse generator **748** of FIG. 13A to produce the read pulse **218**. However, if during this one second rapid alarm scan, an alarm occurs in one of the channels such as 148_{66}; the high and low signals **442** and **444** respectively in the compare system **112** of FIG. **11** will be applied to the grounding gate **786** of FIG. 13A and the auxiliary pulse generator **788** of FIG. 13 C to (1) prevent further scanning and (2) to produce an auxiliary read pulse **218** which will transfer the alarm value of the first stage discharge temperature to the display **14**. Similarly, channel 148_{66} will remain energized such that its indicator light **156** will remain lit beneath the first stage discharge push button **66** of FIG. **1** to indicate which parameter caused the alarm, while the alarm light **90** will indicate that in fact an alarm situation is occurring.

RESET

Turning now to the reset operation, there are two possible situations when the operator depresses the reset button **90'** on the panel **10** of FIG. **1** (see also FIG. **11**). First, there is the possibility that the alarm situation which caused the shut down has subsided. Secondly, there is the possibility that the alarm situation still prevails. Let it first be assumed that the operator has depressed the reset button **90'** after the dangerous condition has subsided.

Depression of the reset button **90'** of FIG. **11** will apply a reset pulse by way of line **794** to the reset pin **796** of the flip flop **418** of the compare system of FIG. **11**. Thus, the flip flop **418** will reset to remove the abnormality signal on the line **422** and the previously described "and" gate **424**. Lines **431** will revert; flip flop **546** in the control system of FIG. **12** will revert, and the system may be restarted by the close of a suitable switch to energize the CR coil **578** of FIG. **12** which as noted previously closes contacts **588** to initiate the start-up signal at the input of gate **594**. Simultaneously, the flip flop **440** will reset to remove the high signal from the line **442** and the low signal from the line **444**. Consequently, the alarm light **90** will be extinguished and no longer will the alarm signals be applied to the grounding gate **786** of FIG. 13A and the auxiliary pulse generator **788** of FIG. **13C** of the sequencing system **98**. When these signals disappear from these respective components, normal operation is restored by virtue of the fact that the advance "D" type pulses may continue along the line **718** to advance the 32 step counter **676** of FIG. **13B**.

It may be pointed out that in the system presently being constructed, even during an alarm situation, the position counter **684** is stepped at the rate of every 4 (or 8) seconds. Therefore, once the alarm is cleared, the count on the position counter **684** will really be a function of how long the system has been standing in the alarm situation. For example, if 24 seconds have elapsed since the alarm condition, and the system were operating in the 4 second scan mode; the position counter will have advanced 6 counts when the alarm is removed, and the 32 step counter **676** begins scanning again. It will be appreciated that in this situation, the rapid scanning by the 32 step counter **676** will pick up and continue until such time as its count reaches the new count on the position counter **684** after which the coincidence which occurs will produce a read pulse **218** (FIG. 13A) which not only activates the transfer logic **104** of FIG. **6** in the manner previously described, but also stops further advancement of the 32 step counter **676** by resetting the flip flop **694** of FIG. 13C which controls the "D" pulses passing through gate **698** and on to the advance pin **720** of the 32 step counter **676**. In other words, after an alarm situation, the channel which will be next displayed on the display system **114** will not necessarily be that channel which immediately follows the channel which generated an alarm, but in reality may very well be some other channel dependent upon the length of time that the system was standing in the alarm condition. Of course, if desired, some appropriate inhibiting means might provided to restrain the position counter **684** in the event of an alarm.

Turning now to the second situation, where the alarm condition still prevails when the operator pushes the reset button **90'**, a signal will be applied to reset the flip flop **418** of FIG. **11** and remove the alarm signals from the lines **442** and **444** respectively regardless of the fact that an abnormality signal may still be in existence on the line **416** (the output of the comparator **410**). With the signals removed from the lines **442** and **444**, and the grounding gate **786** of FIG. 13A disabled as previously described, the sequencing system **98** will begin to function again.

Since the assumption is that the alarm condition still exists, then during the first second, when all **26** channels will be quickly scanned, the alarm situation will reoccur in the comparator system **112** of FIG. **11** which will develop a low signal on the line **416** which will switch the flip flop **418** to re-ignite the alarm light **90**; shut down the system and produce the high and low signals on the lines **442** and **444** respectively of the flip flop **440** which in turn will de-activate the sequencing system as previously described. The net affect of this entire operation, is to update the information in the main buffers **230**, **230'** and **230''** and to also update the auxiliary storage buffer devices in the storage system **106** of FIG. **7**.

THE HOLD MODE OF OPERATION

Thus far, the operation of the instant invention has been described in terms of the sequencing system **98** operating in a scan mode, i.e., sequencial energizing of the output channels every 4 to 8 seconds with rapid alarm scanning at every 4 second interval. As noted previously, however, the instant invention may be operated in a "hold" mode by which a desired channel may be continuously monitored and displayed. The manner of switching between the scan mode and the hold mode will be presented immediately below.

When the power push button **88** on the display panel **10** of FIG. **1** is depressed to turn on the power, a flip flop **798** (FIG. 13A) in the sequencing system **98** is biased to produce a high signal on the output line **800** thereof which is applied to the previously mentioned gate **710** to enable it to pass the advance "D" pulse to the gate **712** and on to advance the position counter **684** at every 4 second interval. Similarly, when the power comes on, a flip flop **802** is so biased as to produce a low signal on the output line **804** thereof which is applied to a gate **806** to produce a high signal on the line **808** thereof which in turn is the enabling signal for the gates **716** and **712**. As previously noted, gate **716** is one of the gates which permits the continuously generated "D" pulses at **190** to pass through the line **718** to advance the **32** step counter **676**, while gate **712** is one of the gates which permits the single "D" pulse to be applied to the position counter **684** at each 4 (or 8) second interval. Thus, when the power comes on the system will normally be operating in the scan mode.

Assume now, that the operator wishes to switch from the scan mode to the hold mode in the sense that he wishes to continuously display channel **78** which from FIG. **1** is the temperature of the water being used in the compressor (for example for cooling purposes) as it leaves the compressor. He does so by depressing the "water out" push button **78** on the display panel **10** of FIG. **1** which as seen in FIG. 13C will open the normally closed contact pair **810** and close normally open contact pair **812**. When contact pair **812**. When contact pair **810** opens, the normally grounded path running through these normally closed contacts of the push buttons is interrupted to establish a high signal (relative to ground) on the line **816** (FIG. 13A) which in turn is passed through an inverting gate **818**; applied to an anti-bounce prevention flip flop **820**; and finally to a pulso generator **822** which in turn produces a pulse **824** at the output thereof. The pulse **824** performs a multitude of functions as follows:

The first function performed by the pulse **824** is to reset to the count "1", both counters **684** and **676** of FIG. 13B. As will be further explained, the purpose of resetting both of these counters to count "1" is to get them at the same place such that they will end up at the appropriate selected position at the same time. The counters are reset to one by virtue of the pulse **824** passing through line **826**, gate **828** and line **830** to the rest pins **832** and **834** (FIG. 13B) of the counters **684** and **676** respectively.

The next function of the pulse **824** is to switch the condition of the flip flops **798** and **802** from their scan condition to a hold condition which as will be immediately apparent permits the now reset counters **684** and **676** to be advanced simultaneously from the count "1".

The switching of the flip flop **798** and **802** occurs by virtue of the pulse **824** being passed through the line **826**, gate **828**, line **836**, and to the two input pins **838** and **840** respectively of the flip flops **802** and **798**. When this signal is applied to the pins **838** and **840**, and the flip flops switch; the following events take place. First, the previous high appearing on the line **800** of flip flop **798** changes to a low, while the previous low appearing on the output **804** of flip flop **802** switches to a high. The low signal now appearing on line **800** prevents any "D" pulses on line **708** from being passed to the position counter **684**. The high now appearing on the output line **804** of flip flop **802** enables gate **806** to pass "D" pulses **190** from a line **810** directly through gate **806**, to be applied on the one hand to the gate **716** (to the line **718** to advance the 32 step counter **678**); and on the other hand by way of the line **842** and the gate **172** to the advance pulse line **714** to advance the position counter **684**. In this manner, the position counter **684** and the 32 step counter **676** will advance simultaneously under the influence of "D" pulses from terminal **190**.

The next function performed by the pulse **824** is to reset flip flop **694** (FIG. 13C) such that the gate **698** is in fact disabled and the "D" pulses generated at **190** will in fact pass only through the alternate by-pass line **810**. This is accomplished (FIG. 13A) by the pulse **824** being applied through the line **826** through the line **844**; through gate **846**, through line **756**, and to reset pin **758** of the flip flop **694**.

Finally, when the flip flop **798** of FIG. 13A is switched by the application of the pulse **824** to its pin **840** thereof, a high signal appears on the output line **848** thereof. This high signal appearing on line **848** passes through an inverting gate **850** in the slow-fast circuitry of FIG. 13C to apply a low signal on the line **764** to turn off the transistor **768** and de-energize the fast light **770** (if in fact it were energized). Simultaneously, the high signal appearing on line **848** is applied to an inverter **852** (FIG. 13C) and the low signal appearing as an output thereof

is applied to the output line **766** of the slow-fast flip flop **762** to cut off the transistor **766** and de-energize the indicating bulb **778** in the event the system had been operated in the 8 second scan mode.

Returning now to the counters **684** and **676**, it was previously described that by virtue of the pulse **824**, "D" pulses from the terminal **190** are applied to these counters to advance them simultaneously from a count "1" (recall they were reset to one by virtue of the same pulse **824**). After 26 advances, and within approximately 1 second, the binary output on the lines **678** of the 32 step counter **676** of FIG. **13B** will finally reach the selected station **26**, such that the output channel 148_{78} of FIG. **13D** (corresponding to the channel for which the push button **78** of FIG. **13C** was depressed) will become energized. Thus, it's indicator light **156** will be lit beneath the push button **78** on the panel **10** of FIG. **1**, and simultaneously its coil **154** will become energized to close the appropriate contacts and enable the appropriate transducer 100_{78} in the sensing system **96** as has been previously described.

Simultaneously, the low signal 148_{78L} produced at channel 148_{78} of FIG. **13D** will be applied to the now closed contact pair **812** of FIG. **13C** (closed by virtue of the depression of the push button **78**) to provide a low signal on the line **852** FIGS. **13C** and **13A** which is passed through gates **854** and **856** to line **858** which in turn resets the previously mentioned flip flop **802**. Thus, the output line **804** of the flip flop **802** switches to low to disable gate **806** and prevent any further "D" pulses from terminal **190** from being passed therethrough.

With no further "D" pulses being applied to either of the counters **684** or **676**, further scanning is prevented and the output of **32** step counter **676** remains at **26**, continuously energizing the output channel 148_{78}. Finally, when the flip flop **802** resets as just described, a signal is applied by way of the line **860** to another auxiliary pulse generator **862** (FIG. **13C**) which produces an auxiliary read pulse **218''** which is passed by the gate **790** and **792** and the line **220** to the transfer logic system **104** of FIG. **6** to permit the information from the A-D converter (representative of the parameter at station **78**) to be passed on to the display system.

In the event that an alarm situation occurred in any of the earlier channels scanned while the system was racing toward the selection station, then as previously described, an alarm low signal would appear on the output line **444** of the flip flop of the compare system **112** (FIG. **11**). This low signal on the line **444** is applied at an input terminal **864** of the previously mentioned gate **856** (FIG. **13A**) and the line **858** to reset the flip flop **802** as previously described. This would have the affect of stopping further "D" pulses from being passed to counters just at the time that the counter **676** was presenting a signal on the binary output lines **678** representative of the particular channel which just generated the alarm situation. Thus, the particular channel of FIG. **13D** which caused the alarm will remain energized; its respective indicator **156** would light on the panel board beneath the appropriate push button, to indicate that there was an alarm; and by virtue of the auxiliary read pulse **218''** applied to the transfer logic **104** of FIG. **6** the value of the particular parameter which caused the alarm situation will be passed from the analog-to-digital converter **102** of FIG. **5** to the display system **14**.

Assuming, it is now desirable to switch from the hold mode of operation back to a scan mode of operation, the operator would depress either the slow push button **80** or the fast push button **82** on the panel **10** of FIG. **1** (and FIG. **13C**) with either event interrupting a high signal which normally appears on the line **866** of the slow-fast circuitry when the buttons are not depressed. When the high signal is removed from the line **866**, the flip flop **798** (FIG. **13A**) will switch, such that the low signal to enable the gate **710**. With gate **710** enabled, the "D" pulse from line **708** (which occurs every **4** or **8** seconds) will now be passed on through the gate **712** to advance the position counter **684** independently of the 32 step counter **676** in the manner which was previously described for the scan mode of operation.

In the description presented thus far, the assumption was that when the power came on, the flip flops **798** and **802** would be so biased as to cause the system to operate in the scan mode. However, it will be appreciated that if desired, these flip flops **798** and **802** could be so biased to throw the system into the hold mode of operation when the power came on.

MEMORY FUNCTION

It is another function of the instant invention that after an alarm situation, it may be desirable to monitor stations to find out what their values were immediately prior to the alarm.

As described previously, this is accomplished by continuing updating the auxiliary storage devices **240**, **242** and **244** of FIG. **7** (and their respective prime auxiliary storage devices), each time there is a rapid alarm scan of the 26 output channels. As an example, it was pointed out that three channels were to be retained for subsequent display; namely the third stage discharge temperature, the fourth stage discharge temperature, and the fifth stage discharge temperature. Thus, each time the output channels 148_{70}, 148_{72} and 148_{74} of FIG. **13D** were energized during a rapid scan, transfer logic **104** of FIG. **6** transferred the latest value of the particular station into the auxiliary storage device such as **240**, **242** or **244**.

Now, assuming there has been an alarm situation and further assuming that the viewer wishes to have the system display the value of one of these three stations as it existed immediately prior to the alarm situation; he would merely depress the push button corresponding to the stored channel he wished to view. For example, assuming the viewer wishes to display the value of the third stage discharge temperature immediately prior to alarm, he would depress the push button **70**, of FIG. **13C** and the lines **868** would apply the appropriate signals to gates **870** (FIG. **13A**) such that the lines **872** would apply the proper signals to the memory logic system **118** of FIG. **14** which in turn would provide the proper output signals to the transfer gating **108** of FIG. **8** so that the value of the parameter in the respective auxiliary buffer devices would pass on to the display system **14** rather than the value in the main buffer (which happens to be the magnitude of the paratmeter which caused the alarm).

Without repeating the entire operation of the transfer gating **108**, it may be noted that the operation is the same as previously described except that the memory logic **118** will enable a gate such as **272** such that information would be transferred from the auxiliary buffer devices **244**, **244'** and **244''**, rather than a gate such as **270** which corresponds to the main buffer storage device **230**, **230'** and **230''**. Of course, if desired, more than three channels may be retained for subsequent display by by simply adding more auxiliary buffer storage devices and appropriate logic circuitry for passing the information from these devices when the appropriate push buttons were depressed.

HARDWARE

Although it is apparent that the instant invention is related to system operation rather than to hardware per se, a few additional comments should be made with respect to the hardware utilized to implement the invention. For example, the 10 minute timer **530** and the **12** second timer **604** are conventionally implemented by the use of unijunction oscillators which feed into flip flops for holding and time extension purposes. The 10 minute timer **530** would preferably include an additional flip flop and a field effect transistor to increase the basic RC time constant.

The pulse generator **186** is basically a synchronization system and provides the three basic synchronizing signals to the various sections of the invention. The synchronization signals are derived from a 60 cycle line frequency and include: a 30 cycle "d" signal which is off for 1/120th of a second and on for 1/40th of a second; the "E" signal which is a 0.4ms pulse occurring every 1/30th of a second, 1/120th of a second after the rise of the "D" signal; and an "F" signal which is a 0.4ms pulse occurring at each 60 cycle zero crossing.

The readout display section 14 includes as noted, four seven bar alpha numeric incandescent display bulb. They are preferably driven from a 6 volt DC supply by way of transistors illustrated at 876 in FIG. 10 which are base driven by the binary-to-seven bit convertors such as 340.

The various DC voltage levels indicated throughout the Figures of the drawings are derived from a power supply 878 (FIG. 12). The power supply includes appropriate rectifying and regulating circuitry to produce the desired DC levels along the output side designated 880.

The various gates used throughout the system are conventional, off-the-shelf logic devices, the functions of which (such as "and, "or" inverter etc.) have been described as the description of the invention unfolded.

Finally, it will be appreciated that although various specific components including gates, oscillators, flip flops, etc., have been described as cooperating to perform specific functions various other arrangements of available hardware could be appropriately designed by those having ordinary skill in the art to perform the same function. Thus, the invention is not to be thought of as residing in the specific hardware which has been chosen to illustrate the invention, but rather in the overall interrelation and cooperation of various functional systems and sub systems therein which cooperate in a novel and unobvious manner.

Although this invention has been described with respect to its preferred embodiments, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of the invention be limited, not by the specific disclosure herein, only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

each of said signals produced by said plurality of transducers is an analog voltage signal the magnitude of which represents the instantaneous value of the respective parameter which said transducer is monitoring;

wherein said display means includes analog to digital conversion means for converting said analog voltage signal to a corresponding digital signal as said analog signals are sequentially presented to said display means;

wherein said display means first includes display bulb means responsive to said digital signal for visibly displaying the decimal value of said digital signal; and further including:

pulse generator means for producing a repetitive initiation pulse which is applied to said analog-to-digital conversion means to initiate the conversion process;

said A-D conversion means producing an end of conversion pulse each time said conversion process is complete;

main buffer storage means intermediate said A-D conversion means and said display bulb means for temporarily storing said digital signal and impressing same on said display bulb means;

read pulse generating means for generating a repetitive read pulse at a predetermined interval of time; and

enabling logic circuit means responsive to the simultaneous occurrence of one of said read pulses and one of said end of conversion pulses for enabling said main buffer storage means to receive and store said digital signal from said A-D conversion means.

2. The apparatus of claim 1 and further including auxiliary buffer storage means intermediate said A-D conversion means and said display bulb means for storing predetermined ones of said digital signals until some predetermined subsequent time when it may be desirable to display the value stored in said auxiliary buffer storage means;

said enabling logic means being further responsive to said sequencing means and the occurrance of one of said end of conversion pulses for enabling said auxiliary buffer storage means to receive said predetermined ones of said digital signals corresponding to particular parameters the latest magnitudes of which it is desired to retain for subsequent display.

3. The apparatus of claim 1 wherein during each conversion process said A-D conversion means produces a predetermined number of groups of digital signals representative of a decimal number have said predetermined number of mathematical places; and

wherein said main buffer storage means includes a plurality of main storage devices equal in number to said predetermined number of groups and wherein said display bulb means includes a plurality of display bulbs equal in number to at least one more than said predetermined number of groups; and

wherein said enabling logic circuit means enables each of said plurality of main storage devices to receive one of said plurality of groups.

4. The apparatus of claim 3 and further including auxiliary buffer storage means intermediate said A-D conversion means and said display bulb means, said auxiliary buffer storage means comprising a first plurality of auxiliary storage devices equal in number to said predetermined number of groups;

said enabling logic means further responsive to said sequencing means and the occurrance of one of said end of conversion pulses for additionally enabling said first plurality of auxiliary storage devices to respectively receive and store said predetermined number of groups of digital signals when it is desired to retain and store the latest magnitude of a preselected parameter for subsequent display.

5. The apparatus of claim 4 wherein said auxiliary buffer storage means includes a second plurality of auxiliary storage devices equal in number to said predetermined number of groups;

said enabling logic means being further responsive to said sequencing means and the occurrance of one of said end of conversion pulses for additionally enabling said second plurality of auxiliary storage devices to respectively receive and store said predetermined number of groups of digital signals when it is desired to retain and store the latest magnitude of a different preselected parameter for subsequent display.

6. The apparatus of claim 4 wherein at least one of said parameters customarily requires at least one more than said predetermined number of mathematic places to represent its magnitude, and further including display logic circuit means responsive to the monitoring of said one of said parameters for transferring said groups of digital signals representative of said one of said parameters from said plurality of main storage devices to respective ones of a first group of said display bulbs equal in number to said predetermined number of mathematical places and for causing an additional display bulb, less significant in terms of its mathematical place with respect to said first group of said display bulbs, to display a "0".

7. The apparatus of claim 6 wherein said display logic circuit means will transfer groups of said digital signals from said plurality of auxiliary storage devices to respective ones of said first group of said display bulbs and will cause said additional bulb to display a "0" when it is desired to display one of said preselected parameters which have been stored in said auxiliary storage devices and said preselected parameter requires at least one more than said predetermined number of mathematic places to represent its magnitude.

8. The apparatus of claim 6 wherein the group of digital signals stored in the mathematically "least significant" main storage device will be transferred to the two mathematically least significant display bulbs; and

wherein said display logic circuit means provides an overpowering "0" signal to the least significant of said two display bulbs when one of said parameters which requires one more than said predetermined number of places is being monitored.

9. The apparatus of claim 6 wherein others of said parameters require only said predetermined number of mathematic places to represent their magnitude; and

wherein said display logic circuit means transfer said groups of digital signals from said main storage devices to respective ones of a second group of said display bulbs equal in number to said predetermined number of places and causes a mathematically more significant one of said display tubes to display a blank.

10. The apparatus of claim 9 wherein said group of digital signals stored in the mathematically "most significant" main storage device will be transferred to the two mathematically most significant display bulbs and wherein said display logic circuit means will produce a overpowering "blanking" signal which will cause the most significant of said two bulbs to display a "blank".

11. The apparatus of claim 9 wherein said display logic circuit means will transfer groups of said digital signals from said plurality of auxiliary storage devices to respective ones of said second group of said display bulbs and will cause said mathematically more significant one of said display tubes to display a blank.

12. The apparatus of claim 3 wherein at least one of said parameters customarily requires at least one more than said predetermined number of mathematic places to represent its magnitude, and further including display logic circuit means responsive to the monitoring of said one of said parameters for transferring said groups of digital signals representative of said one of said parameters from said plurality of main storage devices to respective ones of a first group of said display bulbs equal in number to said predetermined number of mathematical places and for causing an additional display bulb, less significant in terms of its mathematical place with respect to said first group of said display bulbs, to display a "0".

13. The apparatus of claim 12 wherein others of said parameters require only said predetermined number of mathematic places to represent their magnitude; and

wherein said display logic circuit means transfers said groups of digital signals from said main storage devices to respective ones of a second group of said display tubes equal in number to said predetermined number of places and causes a mathematically more significant one of said display tubes to display a blank.

14. The apparatus of claim 2 wherein said sequencing means includes:

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers; and

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels; and

wherein said enabling logic means for enabling said auxiliary buffer storage means is responsive to the occurrance of one of said end of conversion pulses and to the energization of the output channel of said sequencing means which corresponds to the transducer which is monitoring the particular parameter the latest magnitude of which it is desired to retain for subsequent display.

15. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

said output channels including primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

a first plurality of said transducers are monitoring a first parameter and a second plurality of said transducers are nomitoring a second parameter;

and further including additional enabling logic circuit means responsive to the energization of any one of said output channels which corresponds to a transducer in said first plurality of transducers for permitting signals generated by any one of said first plurality of transducer to pass to said display means; and

said additional enabling logic circuit means being further responsive to the energization of any one of said output channels which corresponds to a transducer in said second plurality of transducers for permitting signals generated by any one of said second plurality of transducers to pass to said display means.

16. The apparatus of claim 15 wherein said additional enabling logic circuit means includes:

a first normally de-energized coil having a normally open contact pair interposed between said first plurality of transducers and said display means;

a second normally de-energized coil having a normally open contact pair interposed between said second plurality of transducers and said display means; and

inverter means disposed before said second coil;

energization of any one of said output channels which corresponds to a transducer in said first plurality of transducers causing the energization of said first coil which closes its respective contact pair to complete a circuit from said first plurality of transducers to said display means;

non-energization of any one of said output channels which corresponds to a transducer in said first plurality of transducers causing said inverter means to energize said second coil which thereby closes its respective contact pair to complete a circuit from said second plurality of transducers to said display means.

17. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

said plurality of transducers are monitoring various variable parameters associated with the operation of a motor driven device;

further including motor disabling circuit means responsive to the occurrence of said first alarm signal for shutting down said motor;

further including second comparator means responsive to the signals produced by preselected ones of a second group of said transducers and other preselected reference signals for providing additional alarm signals when any one of said signals produced by said preselected ones of said second groups of transducers exceeds its corresponding other reference signals;

wherein said second group of transducers monitor various pressure locations of a motor driven multi-stage compressor; and

wherein said second comparator means includes an air bank comparator responsive to the signal produced by one of said second group of transducers which monitors air banks pressure and to adjustable minimum and maximum air banks pressure reference voltage signals for producing an air banks control signal when the signal produced by said air banks monitoring transducer falls below or exceeds said minimum and maximum air banks pressure voltage signals.

18. The apparatus of claim **17** wherein said motor driven device is a multi-stage compressor.

19. The apparatus of claim **17** wherein said motor is in electrical series with a pair of motor control contacts which are normally maintained closed by the energization of a motor control coil;

said disabling circuit means causing the de-energization of said motor control coil upon the reception of said first signal.

20. The apparatus of claim **19** wherein said motor control coil is in electrical series with at least one semi-conductor controlled rectifier, the control gate of which normally maintains said SCR conducting, said control gate being in electrical series with a pair of control gate contacts normally maintained closed by the energization of a control gate contact coil;

said disabling circuit means causing the de-energization of said control gate contact coil upon the reception of said first alarm signal.

21. The apparatus of claim **20** and further including a source of AC power for said apparatus, and wherein said motor control coil is in electrical series with a second SCR which conducts current to said motor control coil during the second half of an AC cycle;

the control gate of said second SCR normally maintaining said second SCR conducting by being in electrical series with a second pair of control gate contacts normally maintained closed by the energization of said control gate contact coil.

22. The apparatus of claim **21** and further including rectifying means responsive to said AC power source for producing a plurality of preselected DC voltage levels utilized in said apparatus.

23. The apparatus of claim **21** and further including pulse generator means for producing a repetitive "zero voltage" pulse at each instant in time that said SCR's experience zero voltage thereacross; and

said disabling circuit means includes gate means responsive to the simultaneous application of said first alarm signal and one of said "zero voltage" pulse for de-energizing said control gate contact coil;

whereby the conduction state of said SCR's will be changed only when they are experiencing zero voltage thereacross to thereby reduce transients.

24. The apparatus of claim **18** wherein said first group of transducers monitor a preselected group of temperatures associated with preselected locations of said multi-stage compressor.

25. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels; and wherein each of said output channels includes primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

wherein sais preselected reference voltages are established by a plurality of adjustable potential sources;

further including circuit means for conveying the signals produced by said preselected ones of said first group of transducers to said first comparator means; and further including reference voltage enabling means responsive to the energization of the output channels corresponding to said preselected ones of said first group of transducers for applying the corresponding reference voltage to said first comparator means;

wherein each of said enabling means comprise a normally de-energized primary coil having a normally open primary contact pair in the circuit of its corresponding transducers;

energization of said coil, in response to energization of its respective output channel by said sequential energizing means, closing said normally open contact pair to allow said signal to pass from said transducer, and wherein said reference voltage enabling means comprises a plurality of auxiliary coils each being in electrical parallel with the normally de-energized primary coil of the primary enabling means of the output channels which correspond to said preselected ones of said first group of transducers, and each of said auxiliary coils having an associated normally open auxiliary contact pair interposed between a respective one of said adjustable potential sources and said first comparator means;

energization of one of said output channels which corresponds to one of said first group of preselected transducers energizing said channel's primary coil and its aumiliary coil to

1. close the primary contact pair thereof to pass the signal produced by the respective transducer to said display means and to said first comparator means; and
2. to close the aumiliary contact pair thereof to pass the corresponding preselected reference voltage to said first comparator means.

26. The apparatus of claim **25** wherein each of said auxiliary coils includes a second associated normally open contact pair which normally prevents a gating pulse from being applied to a normally inhibiting device which also receives said first alarm signal as an input thereto;

energization of one of said auxiliary coils additionally causing the closing of its respective second contact pair to permit a gating pulse to be applied to said inhibiting device such that if a first alarm signal is produced by said first comparator means, said first alarm signal will be passed through said inhibiting device.

27. The apparatus of claim 26 and further including reset means for returning said normally inhibiting device to its blocking condition.

28. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

second comparator means responsive to the signals produced by preselected ones of a second group of said transducers and other preselected reference signals for providing additional alarm signals when any one of said signals produced by said preselected ones of said second groups of transducers exceeds its corresponding other reference signals;

wherein said second group of transducers monitor various pressure locations of a motor driven multi-stage compressor;

wherein said second comparator means includes an oil pressure comparator responsive to the signal produced by one of said second group of transducers which monitors oil pressure and to an adjustable oil pressure reference voltage signal for producing a low oil pressure alarm signal when the signal produced by said oil pressure monitoring transducer falls below said oil pressure reference voltage signal;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

wherein each of said output channels includes primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

further including circuit means for conveying the oil pressure signal produced by said oil pressure monitoring transducer to said oil pressure comparator; and

further including a normally inhibiting device which prevents said low oil pressure alarm signal from passing further into said apparatus unless the output channel corresponding to said oil pressure monitoring transducer has been energized.

29. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

second comparator means responsive to the signals produced by preselected ones of a second group of said transducers and other preselected reference signals for providing additional alarm signals when any one of said signals produced by said preselected ones of said second groups of transducers exceeds its corresponding other reference signals;

said second group of transducers monitor various pressure locations of a motor driven multi-stage compressor;

said second comparator means includes an oil pressure comparator responsive to the signal produced by one of said second group of transducers which monitors oil pressure and to an adjustable oil pressure reference voltage signal for producing a low oil pressure alarm signal when the signal produced by said oil pressure monitoring transducer falls below said oil pressure reference voltage signal;

motor disabling circuit means responsive to the occurrence of said low oil pressure alarm signal for shutting down said motor; and

first adjustable delay means for preventing said low oil pressure alarm signal from being passed to said motor disabling circuit means until some predetermined time has elapsed after said motor is restarted.

30. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

second comparator means responsive to the signals produced by preselected ones of a second group of said transducers and other preselected reference signals for providing additional alarm signals when any one of said signals produced by said preselected ones of said second groups of transducers exceeds its corresponding other reference signals;

said second group of transducers monitor various pressure locations of a motor driven multi-stage compressor; and

comparator means includes an air banks comparator responsive to the signal produced by one of said second groups of transducers which monitors air banks pressure and to adjustable minimum and maximum air banks pressure reference voltage signals for producing an air banks control signal when the signal produced by said air banks monitoring transducer falls below or exceeds said minimum and maximum air banks pressure voltage signals.

31. The apparatus of claim 30 wherein said adjustable minimum and maximum air banks pressure reference voltage signals are established by:

a first potentiometer which establishes the maximum voltage signal;

a second potentiometer which, together with said first potentiometer, establishes said minimum air banks pressure voltage signal; and

circuit means for connecting said first and second potentiometers in electrical parallel whenever the signal produced by said air banks pressure monitoring transducer exceeds said maximum voltage signal, and for disconnecting said second potentiometer from said first potentiometer when the signal produced by said air banks pressure monitoring transducer falls below said minimum voltage signal.

32. The apparatus of claim 30 and further including compressor disabling means responsive to said air banks alarm signal for unloading said compressor.

33. The apparatus of claim 32 and further including motor and compressor disabling means responsive to the existance of said air banks alarm signal for a predetermined interval of time for shutting down said motor and unloading said compressor.

34. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

second comparator means responsive to the signals produced by preselected ones of a second group of said transducers and other preselected reference signals for providing additional alarm signals when any one of said signals produced by said preselected ones of said second groups of transducers exceeds its corresponding other reference signals;

said second group of transducers monitor various pressure locations of a motor driven multi-stage compressor;

said second comparator means includes an oil pressure comparator responsive to the signal produced by one of said second group of transducers which monitors oil pressure and to an adjustable oil pressure reference voltage signal for producing a low oil pressure alarm signal when the signal produced by said oil pressure monitoring transducer falls below said oil pressure reference voltage signal; and

said second comparator means includes an air bank comparator responsive to the signal produced by one of said second groups of transducers which monitors air banks pressure and to adjustable minimum and maximum air banks pressure reference voltage signals for producing an air banks control signal when the signal produced by said air banks monitoring transducer falls below or exceeds said minimum and maximum air banks pressure voltage signals.

35. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

second comparator means responsive to the signals produced by preselected ones of a second group of said transducers and other preselected reference signals for providing additional alarm signals when any one of said signals produced by said preselected ones of said second groups of transducers exceeds its corresponding other reference signals;

said second group of transducers monitor various pressure locations of a motor driven multi-stage compressor; and

said second comparator means includes a first stage discharge comparator responsive to the signal produced by one of said second groups of transducers which monitors first stage discharge pressure and to an adjustable first stage pressure reference voltage for producing a first stage alarm signal when the signal produced by said first stage discharge pressure monitoring transducer exceeds said adjustable first stage pressure reference voltage.

36. The apparatus of claim 34 wherein said second comparator means includes a first stage discharge comparator responsive to the signal produced by one of said second group of transducers which monitors first stage discharge pressure and to an adjustable first stage pressure reference voltage for producing a first stage alarm signal when the signal produced by said first stage discharge pressure monitoring transducer exceeds said adjustable first stage pressure reference voltage.

37. The apparatus of claim 35 and further including motor and compressor disabling means responsive to the existance of said first stage discharge alarm signal for preventing operation of said motor during a start up operation.

38. The apparatus of claim 37 wherein said second comparator means includes an oil pressure comparator responsive to the signal produced by one of said second group of transducers which monitors oil pressure and to an adjustable oil pressure reference voltage signal for producing a low oil pressure alarm signal when the signal produced by said oil pressure monitoring transducer falls below said oil pressure reference voltage signal;

and further including motor disabling circuit means responsive to the occurrence of said low oil pressure alarm signal for shutting down said motor;

and further including first adjustable delay means for preventing said low oil pressure alarm signal from being passed to said motor disabling circuit means until some predetermined time has elasped after said motor is restarted; and

further including circuitry for activating said first adjustable delay means once said motor is restarted after having been shut down by said motor and compressor disabling means.

39. The apparatus of claim 35 and further including energizable indicating means responsive to said first stage alarm signal for providing a visable indication thereof.

40. The apparatus of claim 38 and further including circuit means for activating said first adjustable delay means in the event said motor is shut down by some means other than the activation of said motor disabling means or said motor and compressor disabling means and then restarted.

41. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

wherein each of said output channels including primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal; and

further including circuit means responsive to the occurrence of said first alarm signal for stopping said sequential energizing means at the output channel which corresponds to the transducer whose output signal caused said first alarm signal.

42. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

each of said output channels including primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

first means for sequentially maintaining each of said output channels energized for a preselected length of time;

second means for sequentially energizing each of said output channels within a period of time less than said preselected length of time each time said first means maintains one of said channels; and

selectable scan control timer means for varying the magnitude of said preselected length of time.

43. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signals of the magnitude of one of said variable parameters;

display means responsive to any one of said signal s for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

said output channels including primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

first means for sequentially maintaining each of said output channels energized for a preselected length of time;

second means for sequentially energizing each of said output channels within a period of time less than said preselected length of time each time said first means maintains one of said channels;

each of said output channels includes an energizable indicator associated therewith;

said indicator being energized when its respective output channel is maintained energized by said first means; and

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and corresponding reselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal whereby said preselected ones of said first group of transducers will be compared to their respective reference signals each time said second means sequentially energized each of said output channels within said period of time.

44. The apparatus of claim **43** and further including "discontinuous scan" circuitry responsive to the occurrence of said first alarm signal for preventing said second means from energizing any further output channel than the one output channel which corresponds to the transducer the magnitude of whose output signal caused said first alarm signal.

45. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

each of said output channels including primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

first means for sequentially maintaining each of said output channels energized for a preselected length of time;

second means for sequentially energizing each of said output channels within a period of time less than said preselected length of time each time said first means maintains one of said channels;

a channel position counter which sequentially produces a higher numbered channel signal each time said channel position counter is pulsed by a channel position advance pulse which occurs once every preselected length of time;

said second means includes a second counter for sequentially producing a higher numbered channel selection signal at a rate greater than the production of said channel clock position pulses; and

further including coincidence comparator means for stopping said second counter whenever the numbered channel selection signal produced by said second counter equals the channel signal produced by said position counter.

46. The apparatus of claim 45 wherein each of said signals produced by said plurality of transducers is an analog voltage signal the magnitude of which represents the instantaneous value of the respective parameter which said transducer is monitoring;

wherein said display means includes analog to digital conversion means for converting said analog voltage signal to a corresponding digital signal as said analog signals are sequentially presented to said display means;

wherein said display means first includes display bulb means responsive to said digital signal for visably displaying the decimal value of said digital signal;

and further including pulse generator means for producing a repetitive initiation pulse which is applied to said analog-to-digital conversion means to initiate the conversion process;

said A-D conversion means producing an end of conversion pulse each time said conversion process is complete;

and further including main buffer storage means intermediate said A-D conversion means and said display bulb means for temporarily storing said digital signal and impressing same on said display bulb means;

read pulse generating means for generating a repetitive read pulse at a predetermined interval of time; and

enabling logic circuit means responsive to the simultaneous occurrance of one of said read pulses and one of said end of conversion pulses for enabling said main buffer storage means to receive and store said digital signal from said A-D conversion means;

said read pulse generator means comprising said coincidence comparator means and said read pulse comprising a coincidence signal produced by said coincidence comparator means when said numbered channel selection signal equals the channel signal produced by said position counter.

47. The apparatus of claim 46 and further including first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

and further including "discontinuous scan" circuitry responsive to the occurrence of said first alarm signal for preventing said second means from energizing any further output channel than the one output channel which corresponds to the transducer the magnitude of whose output signal caused said first alarm signal;

and further including auxiliary read pulse generating means responsive to the occurrence of said first alarm signal for producing an auxiliary read pulse which, together with one of said end of conversion pulses, enables said enabling logic circuit means such that said main buffer storage means will receive and store the digital signal from said A-D conversion means which corresponds to the signal with which brought about said first alarm signal.

48. The apparatus of claim 47 and further including alarm indicating means responsive to the occurrence of first alarm signal for providing an observable indication of the occurrence of said first alarm signal.

49. The apparatus of claim 47 wherein said plurality of transducers are monitoring various variable parameters associated with the operation of a motor driven device; and

further including motor disabling circuit means responsive to the occurrance of said first alarm signal for shutting down said motor.

50. The apparatus of claim 49 and further including means to prevent the operation of said motor disabling circuit means should an operator desire to operate said motor even upon the occurrence of said first alarm signal.

51. The apparatus of claim 74 wherein each of said signals produced by said plurality of transducers is an analog voltage signal the magnitude of which represents the instantaneous value of the respective parameter which said transducer is monitoring;

wherein said display means includes analog to digital conversion means for converting said analog voltage signal to a corresponding digital signal as said analog signals are sequentially presented to said display means;

wherein said display means first includes display bulb means responsive to said digital signal for visibly displaying the decimal value of said digital signal;

and further including pulse generator means for producing a repetitive initiation pulse which is applied to said analog-to-digital conversion means to initiate the conversion process;

said A-D conversion means producing an end of conversion pulse each time said conversion process is complete;

and further including main buffer storage means intermediate said A-D conversion means and said display bulb means for temporarily storing said digital signal and impressing same on said display bulb means;

read pulse generating means for generating a repetitive read pulse at a predetermined interval of time; and

enabling logic circuit means responsive to the simultaneous occurrence of one of said read pulses and one of said end of conversion pulses for enabling said main buffer storage means to receive and store said digital signal from said A-D conversion means;

said read pulse generator means comprising said coincidence comparator means and said read pulse comprising a coincidence signal produced by said coincidence comparator means when said numbered channel selection signal equals the channel signal produced by said position counter;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal;

and further including "discontinuous scan" circuitry responsive to the occurrence of said first alarm signal for preventing said second means from energizing any further output channel than the one output channel which corresponds to the transducer the magnitude of whose output signal caused said first alarm signal;

and further including auxiliary read pulse generating means responsive to the occurrence of said first alarm signal for producing an auxiliary read pulse which together with one of said end of conversion pulses enables said enabling logic circuit means such that said main buffer storage means will receive and store the digital signal from said A-D conversion means which corresponds to the signal with which brought about said first alarm signal;

reset means for removing said first alarm signal and for disabling said "discontinue scan" circuitry whereby said second means can continue to energize said output channels, said reset means removing said first alarm signal and disabling said "discontinue scan" circuitry regardless of whether the condition which causes said alarm has subsided or not;

whereby all of said output channels will be scanned once again before the occurrence of a subsequent first alarm signal will activate said "discontinue scan" circuitry.

52. Apparatus for monitoring and displaying the magnitude of a plurality of variable parameters, said apparatus comprising:

a plurality of transducers each producing a signal representative of the magnitude of one of said variable parameters;

display means responsive to any one of said signals for displaying the magnitude of the respective parameter which said signal represents;

sequencing means for sequentially presenting each of said signals to said display means;

a plurality of output channels at least equal in number to said plurality of transducers, each of said output channels corresponding to one of said transducers;

wherein said sequencing means further includes sequential energizing means for sequentially energizing each of said output channels;

each of said output channels including primary enabling means for enabling its corresponding transducer to pass its respective signal to said display means;

said enabling means of each of said channels being normally de-energized and being energized only when its respective output channel is energized by said sequential energizing means;

holding circuitry means for energizing any selected one of said output channels;

said hold circuitry means includes a selector switch for each of said output channels, activation of a specified selector switch initiating the energization of the corresponding output channel;

a pulse generator responsive to the activation of said specified selector switch for producing a scan-to-hold pulse;

wherein said sequential energizing means includes:

first means for sequentially maintaining one of said output channels energized for a preselected length of time;

second means for sequentially energizing each of said output channels within a period of time less than said preselected length of time each time said first means energizes one of said channels;

wherein each of said signals produced by said plurality of transducers is an analog voltage signal the magnitude of which represents the instantaneous value of the respective parameter which transducer is monitoring;

wherein said display means includes analog to digital conversion means for converting said analog voltage signal to a corresponding digital signal as said analog signals are sequentially presented to said display means;

wherein said display means first includes display bulb means responsive to said digital signal for visibly displaying the decimal value of said digital signal;

and further including pulse generator means for producing a repetitive initiation pulse which is applied to said analog-to-digital conversion means to initiate the conversion process;

said A-D conversion means producing an end of conversion pulse each time said conversion process is complete;

and further including main buffer storage means intermediate said A-D conversion means and said display bulb means for temporarily storing said digital signal and impressing same on said display bulb means;

read pulse generating means for generating a repetitive read pulse at a predetermined interval of time;

enabling logic circuit means responsive to the simultaneous occurrence of one of said read pulses and one of said end of conversion pulses for enabling said main buffer storage means to receive and store said digital signal from said A-D conversion means;

said read pulse generator means comprising said coincidence comparator means and said read pulse comprising coincidence signal produced by said coincidence comparator means when said numbered channel selection signal equals the channel signal produced by said first counter;

said scan-to-hold pulse being applied to said first and second counters to reset them to one;

said scan-to-hold pulse being further applied to scan-to-hold flip flop circuitry to apply advance pulses to said first and second counters simultaneously until said specified output channel is energized;

first comparator means responsive to the signals produced by preselected ones of a first group of said transducers and to corresponding preselected reference signals for providing a first alarm signal when any one of said signals produced by said preselected ones of said first group of transducers exceeds its corresponding preselected reference signal; and

further including disabling means responsive to the occurrence of said first alarm signal for preventing said advance pulses from being applied to said first and second counters once a channel which corresponds to a transducer the output of which caused said first alarm signal, has been energized.

53. The apparatus of claim **52** wherein each of said signals produced by said plurality of transducers is an analog voltage signal the magnitude of which represents the instantaneous value of the respective parameter which said transducer is monitoring;

wherein said display means includes analog to digital conversion means for converting said analog voltage signal to a corresponding digital signal as said analog signals are sequentially presented to said display means; and

wherein said display means includes display bulb means responsive to said digital signal for visably displaying the decimal value of said digital signal;

and further including pulse generator means for producing a repetitive initiation pulse which is applied to said analog-to-digital conversion means to initiate the conversion process;

said A-D conversion means producing an end of conversion pulse each time said conversion process is complete; and further including:

main buffer storage means intermediate said A-D conversion means and said display bulb means for temporarily storing said digital signal and impressing same on said display bulb means;

read pulse generating means for generating a repetitive read pulse at a predetermined interval of time;

enabling logic circuit means responsive to the simultaneous occurrance of one of said read pulses and one of said end of conversion pulses for enabling said main buffer storage means to receive and store said digital signal from said A-D conversion means;

and further including additional read pulse generating means for producing a read pulse in the event said disabling means is energized.

* * * * *