PROGRAMMABLE LOGIC CONTROLLERS INCREASE THE RELIABILITY OF LACT UNITS AND OTHER UNATTENDED AUTOMATIC LEASE EQUIPMENT

BILL WATKINS AND JOHN TAYLOR
C-E NATCO

ABSTRACT

For decades the oil industry has attempted automation projects with mixed success. The mechanical nature of most electrical components and the short shelf life of first generation electronic components brought many early automation attempts to partial or total frustration. And then came the integrated circuit (IC). This micromineaturization allowed us to travel to the moon and back, to replace slide rules with light powered business-card-size calculators, to enjoy coffee brewed for us in the moments just before we awake and so on. This same technology is now at work in our watches, cars, televisions, typewriters, radios, homes and offices...touching us through nearly every aspect of work and play with reliability second to nothing that precedes it.

Seeing this technology as filling a much needed gap C-E Natco has selected from the highest end of the quality spectrum a programmable logic controller (microprocessor) and coupled it with the thousands of man years of design fabrication, operation and troubleshooting experience to create hardware/software packages capable of performing the demanding tasks of a demanding industry. These systems operated LACT units, vapor recovery systems, filter plants, burner firing and shutdown systems, steam generators and a host of others...with the emphasis on reliability.

INTRODUCTION

Almost every automatic function we come in contact with as consumers is controlled by a microprocessor. Microprocessors, micro-computers and programmable controllers have become common terms to all of us. Historically the petroleum production industry has lagged behind other industries in the field of high technology. Ironically, when economic slow-downs occur, technology moves forward at a rapid pace. There are four basic reasons for this rapid technological development during the slow downs; 1) Large capital expenditures are not readily available for new equipment 2) Manpower is based on budget restraints 3) Efficiency requirements escalate for existing equipment and 4) Personnel familar and comfortable with high tech equipment are beginning to move into management positions. These developments come up during the slow down which was experienced over the last several years, has allowed Natco and others to develop and enter the microprocessor based controls arena with a strong commitment to furnish customers with the state of the art high tech process controls. The specific controls will be discussed in a moment, but first I would like to explain the philosophy behind our development of the various control systems, which will help to explain why some subtle features show up in the software programs. Our primary aim which has become commonplace throughout the entire scope of these controls is reliability and standardization.

RELIABILITY

It is reliability which will allow the process which is being monitored and/or controlled to continue to serve its user in an effective and efficient way so the down time due to control malfunctions or wear are reduced. This reduction in down time yielded increased operation and therefore increase revenue as opposed to higher maintenance costs.

STANDARDIZATION

Standardization on the other hand has allowed us, as you will see in a moment, to produce a complete family of control systems, using the stand alone or master slave configuration to perform numerous tasks in the control and monitoring of their individual assigned pieces of equipment.

Through standardization, by the selection of a totally adaptable base system, economies occur in design, manufacture and programming. Inventory has reduced the overall cost of this much more reliable control system to in many cases less than the old relay and stepping switch control groups of yesterday. The software programmable logic control is combined with full math computing power which is programmed for the various operations by our own in-house automation control system staff. By working with oil and gas equipment every day of the week, we are very familar with the operation and variables involved in production equipment. For this reason, predictably desirable responses can be loaded into the control to satisfy at least 90% of all future requirements. Rather than designing a control system which must be added to for additional inputs or outputs, many of these are already included, and have been documented as available in the instruction manuals.

The introduction of the programmable controller into the control systems which are provided on the various parts of C-E Natco equipment has yielded a very high degree of acceptance in the field. We find that many production companies have been going down the same path on their own, with some very adequate systems which have been developed out of their own necessities. We must assume that if this equipment had been available from an equipment supplier several years ago, its existence would have

precluded the necessity for in-house programming and hardware acquisition.
Probably the most simple control system to design, and understand, is the Lease Automatic Custody Transfer or LACT system which is engineered and designed for the continuous and unattended transfer of crude oil from the producer's lease to the purchasing carrier (Figure 1.)

The purpose of a LACT unit is to handle and transfer a crude product with a minimum of expense and secure the necessary quantity and quality determinations which are required for accounting and transfer of payments. A transfer system is required to be continuous and unattended, and this in turn requires the system to be automatic. Therefore, it must: 1) Sense the levels in a transfer tank and automatically transfer the crude product to the purchasing carrier or divert to the treating system in the event of excess BS&W content. It must stop the transfer at a predetermined low level. 2) It must measure with consistent accuracy the quantity of crude product transfered to the purchaser. 3) It must monitor the quality of the crude product and prevent transfer of a crude product that has become contaminated and is below quality. 4) Secure a representative sample of that product transferred and store it at conditions which will minimize the changing quality. 5) Monitor those required functions and components which might give cause to error in either the quality or quantity determinations.

The characteristics of automatic customer transfer system by virtue of its design and operating characteristics offers the following benefits: 1) Reduction of dollar investment in lease storage facilities, 2) Improved measurement accuracy, 3) Reduction of tank weathering losses, 4) Reduction in manual operation to tank switching and gauging, 5) Improved run scheduling and thereby minimizing loss of income at the end of the month, 6) Increase operating efficiency and assistance in simplification of accounting procedures.

Let's look at the model 283 LACT control panel which is designed to control a variety of C-E Natco LACT units and can be retrofit into existing panels manufactured by Natco, as well as the majority of those supplied by other manufacturers. The heart of the control system is a logic controller which has been programmed with our LACT 283 software package. This combination together with other field proven components makes LACT 283 a state of the art control panel. Significant advancement has been made with terms of reliability, simplicity, accuracy and economy.

While Natco has utilized various brands of computers and programmable controllers in our control systems, including but not limited to IBM, Westinghouse, Texas Instruments and Modacon by our own choice or through customer specifications, we have come to rely on the building block system which was introduced to the market by GTE's/Sylvania and is presently known as Challenger Electronics. The smallest stand alone in this group of controllers is the intelligent industrial relay, which we call the I^2R. This is the smallest programmable controller utilized, and will take 8 inputs and yield 4 outputs, with a 2K memory which is stored on the EMPROM chip. The various steps of the process monitoring system, and the annunciation system which is unique to the industry, is programmed in a modified basic language which is quite easy to work with, and can be readily changed based on unique requirements. The variety of 8 inputs and 4 outputs seems to cover most of the bases for systems such as LACT's, vapor recovery systems, natural draft heaters, back-washable filtration systems, and some other product transfer systems.

The stand alone can be linked to a slave unit, which doubles the inputs to a total of 16, and the outputs to a total of 8 for more sophisticated forced draft burner systems, multiple stage filtration equipment, multi-lease LACT units, small gas plants, and the smallest of the battery control systems which we are presently developing. The next step from this master-slave arrangement is the MC8, 10, and the largest MC16, which are all available with analog inputs, in a variety of additional power functions, which have been utilized in various water treating and steam generation applications.

The I^2R, or stand alone programmable controller is modified when it is received with regards to its internal programming. A heater is also added to the outside of the chassis which allows the controller to have a much more rapid start-up when the ambient temperature is below its published operational temperature of 0°. Environmental testing has proven that the unit will be operational in 8-12 minutes following a standing -40° start with this 25 watt heater. The controller mounts on standard electrical rack and is inexpensive enough to be almost a throw-away item. The various control programs are written, edited, and finally burned into the chips which are cataloged and documented for future reference.

A fourteen input list must be satisfied in the chip security system before a program can be released to be burned into a chip. This security check off list includes customer name, shop order #, fabrication program, chip designation, all reference drawing numbers, project engineer, and additional in-house variables to insure that a proper record is being maintained in our own filing system so that any chip which has ever been created can be reproduced exactly as it was originally printed. The chips are then provided with a serial number and date and released to the EMPROM-PROGRAMMER which "impregnates" the chip with the specific program which has been requested.

The chip is then placed in the controller, wired into the control panel, and checked out prior to release to our warehouse as a stock item, or sent directly to the shop floor for assembly if it is a non-stock, or specialized system.

Assuming that this controller had been programmed with the LACT 283 program. Let's proceed into the description of its operation and keep in mind that the more automated and reliable the system can be made, the more efficient and maintenance free the operation will become.

Let's review the simple operation, and variables that are available for field selection under the top cover of the PLC are located four rotary selector switches each numbered 0-9 (Figure 2). The extreme left switch is used to set the adjustable divert delay. The numbers in this switch indicate seconds times ten. If a delay of 20 seconds is desired between detection of high BS&W and the diverting of the product flow this switch should be set at 2. The maximum delay available on the standard LACT 283 is 90 seconds.

Any delayed diverting is followed by a 10 second delay for the return of the divert valve to the transfer position. If we want an instantaneous divert and return for wet oil we would set this switch at zero.

The other three switches are used to set the meter failure/low flow detection circuit in terms of gallons per minute. Since each switch has ten positions, numbered 0-9 the range is 0-999 gallons per minute. We would first determine the normal operating flow rate of the LACT unit from its design information. We would then set these three switches to read the normal flow rate in gallons per minute. For instance normal flow rate of 67 gallons per minute would require a switch setting of 067. This circuit functions by measuring the combined open and closed periods of the impulse switch which is mounted in the delivery meter register. If a flow rate would drop 20% below the normal rate, the combined periods would be excessively long and the controller would shut down and lock up a transfer pump on a low flow rate condition. If on the other hand, the flow rate would increase above 20% of the normal flow rate, these combined periods would be short, and the transfer pump would be locked out on the high flow rate condition. When one product is being diverted this circuit is disabled as nothing would be delivered through the meter. It is also shut down due to low run tank level or some other alarm condition.

The alarm and reset indicator become active during either wet oil divert or unit shutdown condition. The indicator light from the BS&W monitor will allow an operator to distinguish between a wet oil divert condition and a shutdown In addition, during any period where product flow is diverting the alarm indicator will flash continually at a rapid rate. The alarm indicator also serves as the first-out shutdown annunciator. When a shutdown condition occurs, the indicator light is turned on. The operator can acknowledge the alarm by momentarily pressing the reset switch which is this alarm indicator itself. This action does not reset the shutdown circuit however, it causes the alarm indicator to flash a number code that represents the first alarm conditions responsible for causing the shutdown (Figure 3). For example, if a shutdown occurs because of a meter failure the alarm indicator would flash on and off four times in succession wait for 5 seconds and then flash on and off four times in succession again. This flash code will repeat every 5 seconds until the problem has been corrected and the controller has accepted a reset. Thus the operator simply counts the number of flashes and identifies the cause of the shutdown. Following the correction of conditions which caused the shutdown to begin with, the unit is reset when the operator again presses the reset switch and holds it depressed for 5 seconds, until the alarm indicator has gone out. Control now goes through its normal start up routine. The controller itself is a solid state device and does not require a warm up period however the BS&W monitor is a vacuum tube device and will require a moment of warm up before it will operate properly. Therefore after a power up condition, or after a reset, the controller holds in an idle mode with all outputs off for three minutes, this allows the BS&W monitor sufficient time to operate. During the warm up period, the alarm indicator will flash continuously at a slow rate of 30 flashes per minute. At the end of the warm up period, the panel circuits assume normal operating mode.

All of the above operation, including timing circuits, monitoring functions, and first out annunciation is resident in the program which is contained in the stand alone controller. Depending on the number of critical inputs and outputs, this controller will handle most of the day-to-day requirements of individual pieces of process equipment. It is also possible that less critical inputs can be serialized, or added together in a series so that if either one of two sensors indicates an alarm condition, the combination of the two will become annunciated. As the critical functions increase, the required inputs increase and normally the outputs will increase as well. Standardization upon a single stand alone controller with varying chips as memory has provided us with the opportunity to standardize number of individual control units. The panel shown in Figure 4 is the LACT 283 panels which I already discussed. The panel shown in Figure 5 is a vapor recovery control system. The very simple change required between the two panels is the replacement of the chip and the instruction manuals including the wiring diagram. This immediately transforms the custody transfer control system into the vapor recovery unit control system. The installation of the burner control chip, and the replacement of the motor starter by a Honeywell Flame Relay detection box for UV flame detection converts this panel or a similar panel into a burner, or flame maintenance control box. Additional wiring is not necessary as the program which is inherent in the various chips redirects input and output pulses so that an electricians screwdriver is barely necessary following installation.

The question which commonly arises concerns field programmability. The TI-5 programmable controller for instance can be totally programmed in the field with a hand held input panel. It is our preference to allow certain field modifications to be made by utilizing the four 0-9 switches but to retain the ability to protect the rest of the program intergrity in the chip so that it can be further duplicated, and modified as necessary by knowledgable programmers as opposed to someone who has just received their 4th copy of the latest programming magazine.

We've mentioned vapor recovery systems. Figure 5 indicates a standard single stage vapor recovery control panel and operational diagram which is controlled by that panel. The features include compressor high discharge pressure shutdown, compressor bearing temperature shutdown, suction scrubber high level shutdown, compressor lube oil low flow shutdown, high tank pressure start, intermediate tank pressure compressor bypass, tank pressure stop, low/low tank pressure shutdown, while the fold bypass is adjustable from 0-99 minutes, the high discharge pressure restart delay is adjustable from 0-9 minutes, and 0-9 restarts are allowed. These adjustable features again are controlled by the 4 settable switches behind the cover plate of the stand alone controller. The nnunciator section function is the same as the LACT control except it has different coded shutdowns for the various numbers of flashes.

A similar control system is illustrated in Figure 6 which is the single burner natural draft controller. It also features the following controls:

- Five safety shutdown inputs
- A flame failure safety shutdown
- Early flame detection shutdown
- Adjustable prepurge time 15 to 990 sec.
- Fixed post purge
- Selectable 0 to 9 ignition trials
- Selectable safety shutdown input by-pass
- Fixed 10 sec. ignition trial time
- The annunciator function is the same as that of the LACT control, with the exception of the alarm/reset indicator. The program. software is written such that the alarm/reset indicator operates as a start, stop, alarm interrogator and reset operator.

These three basic controller systems are all available in the Nema 4, Nema 12, and Nema 7 enclosure configurations. They are also of course the most simple control systems which are available.

More sophisticated control systems which include the forced draft and other higher input/output or IO systems are available simply by adding a slave unit to these units. We've covered some very basic control systems which are available and have become standard on all of their related pieces of process equipment. A look into the future which, by the time this paper is presented, may very well become past, includes control systems which can communicate with a main-frame system, or simply report back to a centralized computer which will analyze the data, review any previous shutdown, and make modifications in the operation within the selectable parameters. It is our belief that in the next 12 months an automated system will be installed which will have ultimate control based in a simple off-the-shelf computer located at least 25 miles from the installation. It will be capable of controlling and monitoring all of the following pieces of equipment which may be installed at that particular lease site.

The Pumping Unit will have an automatic on-off control system which will detect any major catastrophic failures, deviations within minor limits based on a dynagraph curve, and will be programmable based on what the various dynagraph limits. It will determine whether the operation is actually producing within the designed efficiencies, and will prevent rod stress and monitor down hole abnormalities which will be reported back to a collector for a more technical review over a radial link.

The Treater will be monitored for fuel consumption and combustion efficiency.

The Tank Levels will be gauged via sonic impulses and this data will be compared with the controller based custody transfer system so that any thefts or abnormal tank level drops can be monitored. Should for instance, an abnormal drop be indicated, while the custody transfer system is not in operation, three phone calls may be placed to the sheriff, to the owner of the lease, and to the pumper. All of this could be automated very easily, and has been available for sometime.

The Vapor Recovery System which is also micro-processor controlled, will be increasing the value of the liquid stored, all of the same time producing the salable gas, or providing gas for the treater. It will also send the rest of the gas through the automated meter monitor and recorder for sales.

If a Gas Dehydration System is on line, it is very possible that the gas dewpoint at the discharge of the absorber will be measured and show an analog input. This will cause the glycol recirculation pump to either increase or decrease its rate of speed so that a predetermined level of water content per thousand standard cubic ft. which has been corrected mathematically by the on board math package, to guarantee that the pipe line discharge will be 7 pounds per 1,000 cubic ft. for example.

The Test Separator, if various wells were feeding into the same tank battery and all of the control valves could easily be linked, and selected from the control computer whether it was located in Denver or Dallas. All of the equipment mentioned above could be operated and polled with little if any human presence at the site. Everything which has been mentioned is presently available, but the remarkable thing is that 18 months ago this particular system was only being dreamt about by the production companies in their research departments.

CONCLUSION

To summarize, the last several years have yielded the ability, due to the technology jumps which have occurred in other industries, of the oil patch to utilize these advancements in microprocessor based control systems. The result is increased productivity and higher efficiency in manpower, process equipment, and communication control. The net result of our small steps in control technology will yield great steps into the future for those producers, suppliers, and employees of all companies that realize that the future in process controls based on computer technology is here, TODAY.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to C-E Natco for the privilege and approval to publish this paper.

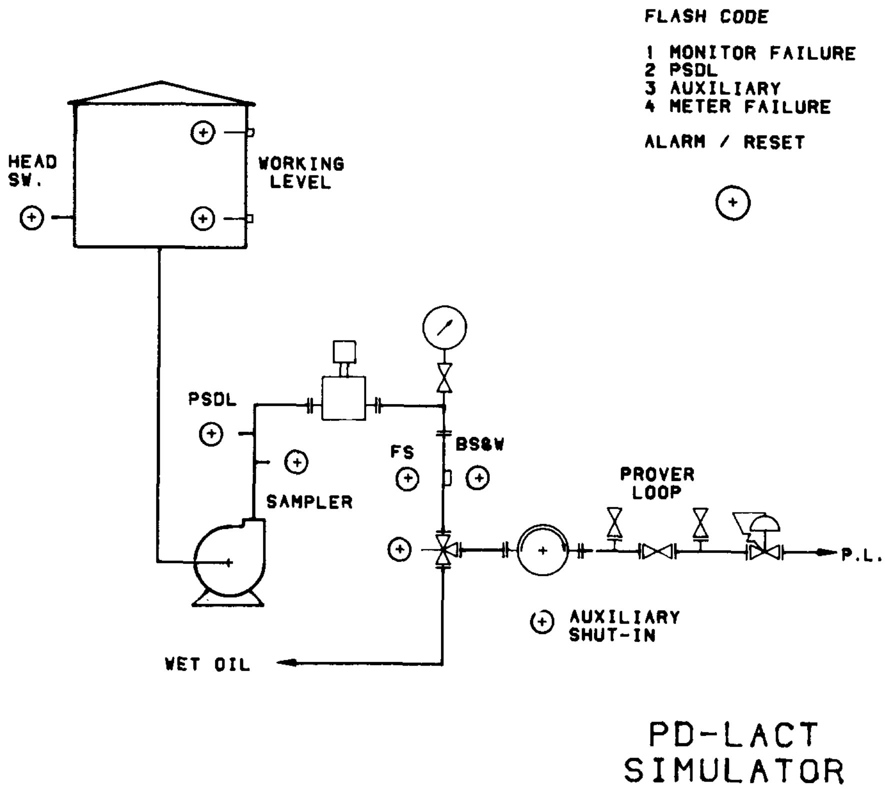
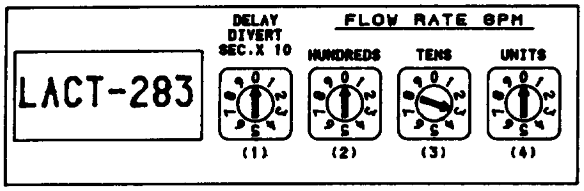


Figure 1



LACT-283 - the program chip, which is removable and reprogrammable.
(1) = BS&W (Wet Oil) Signal timer adjustment - timing range, 0 to 90 seconds.
(2), (3), (4) = Flow rate (meter monitor) - adjustable from 0 to 999 GPM.

Figure 2

FLASH CODE

1-BS&W MONITOR FAILURE
2-LOW PUMP PRESSURE
3-AUXILIARY SHUTDOWN
4-METER FAILURE / LOW FLOW
5-HIGH FLOW

Figure 3

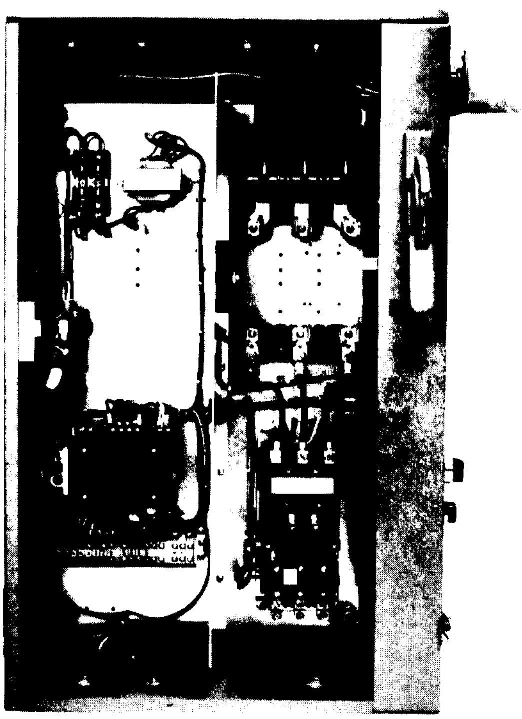
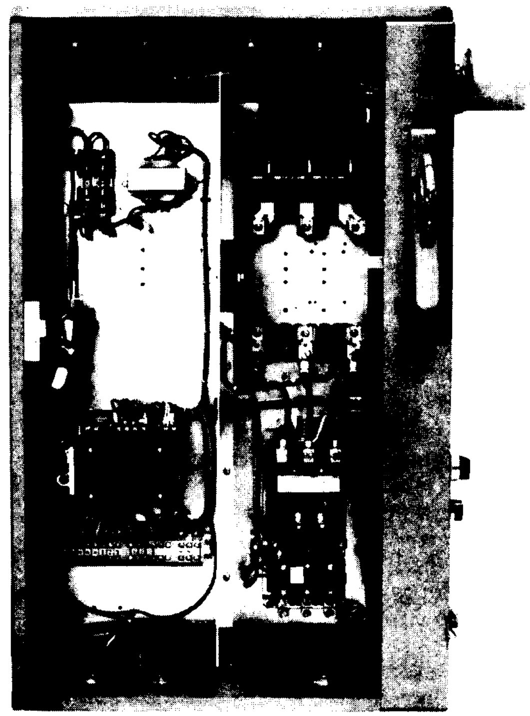


Figure 4

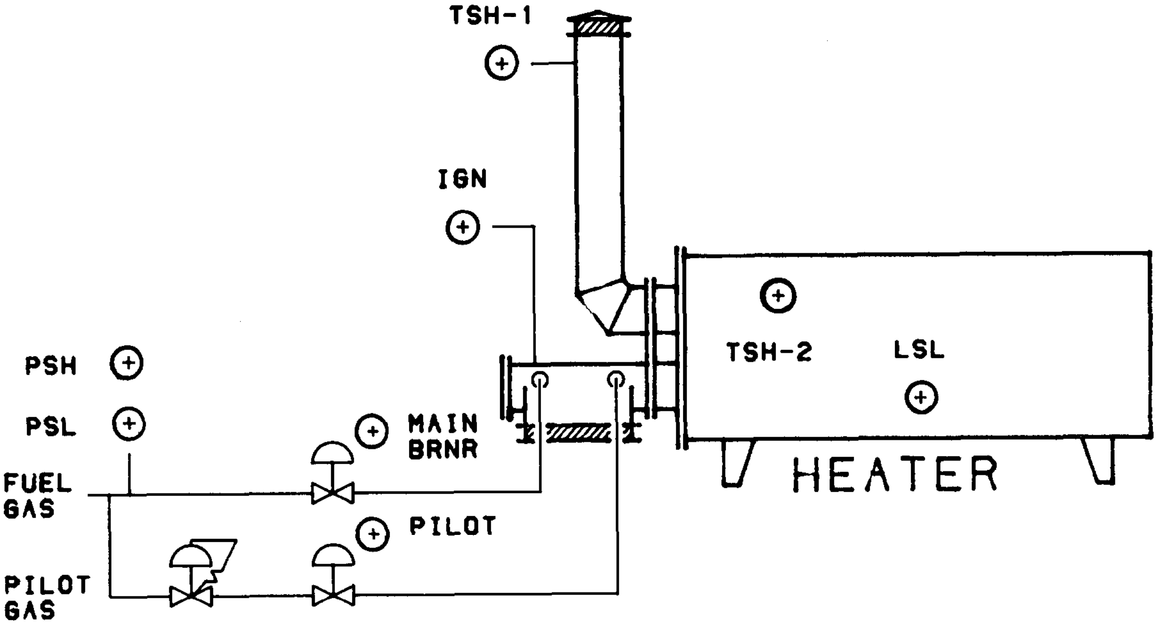


The Vapor Recovery Control panel is designed to control a variety of vapor recovery unit systems including but not restricted to C-E Natco systems.

Features:

- Compressor high discharge pressure shutdown
- Compressor bearing temperature shutdown
- Suction scrubber high level shutdown
- Compressor lube oil low flow shutdown
- High tank pressure start
- Intermediate tank pressure compressor partial bypass
- Low tank pressure compressor full bypass
- Low/low tank pressure stop
- Adjustable 0-99 minute time limit for compressor bypass
- Fixed 5-second compressor start bypass
- Fixed 10-second compressor lube oil low flow rate start bypass
- Adjustable 0-9 minute high discharge pressure restart delay
- Adjustable 0-9 restart limits
- Tank pressure switch malfunction
- Complete installation instructions

Figure 5



NATURAL DRAFT HEATER CONTROL

ANNUNCIATOR LIGHT / PUSHBUTTON LEGEND

NO. OF FLASHES	CONDITION	
FLASH CODE		
1	**LOW FUEL PRESS.**	**(PSL)**
2	**LOW LEVEL**	**(LSL)**
3	**HIGH FUEL PRESS.**	**(PSH)**
4	**HIGH STACK TEMP.**	**(TSH-1)**
5	**HIGH MEDIA TEMP.**	**(TSH-2)**
6	**EQUIPMENT FAILURE**	
7	**FLAME FAILURE**	
8	**EARLY FLAME DETECTION**	
9	**MANUAL SHUTDOWN**	

IF A SHUTDOWN OCCURS THE ALARM LIGHT WILL BE ON-STEADY. DEPRESS THE RESET BUTTON / ALARM LIGHT MOMENTARILY TO START THE ANNUNCIATOR SEQUENCE.

WHEN THE ALARM CONDITION HAS BEEN DETERMINED, DEPRESS AND HOLD THE RESET BUTTON UNTIL THE ALARM LIGHT GOES OUT. (APPROX. 5 SECONDS)

WHEN THE ALARM LIGHT IS IN A CONSTANT RAPID FLASH CONDITION, THE UNIT IS IN STANDBY AND READY FOR STARTING. PRESS AND RELEASE THE RESET BUTTON TO START.

NOTE: PRESSING THE RESET BUTTON / ALARM LIGHT WHILE THE UNIT IS RUNNING WILL CAUSE A **MANUAL SHUTDOWN**

Figure 6