AUTOMATED WELL HEAD MANAGEMENT

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ABSTRACT

More than ten years ago oil and gas producers expressed the need for a generalized system for the automation of well head operations.

A well-head supervisory controller has been developed that provides a general, simple, small, low cost hardware platform with extensive firmware capabilities for well head automation.

The operating firmware for the system is written in a high level language, which allows flexible application development at reasonable cost in a reasonable time. Communication for the system employs a widely used, well known, standard protocol.

To date, firmware applications for the unit include: general RTU, pump off control, AGA-3/NX19 gas flow measurement, gas flow data logging, plunger lift control, intermittent gas lift control, continuous gas lift control, water injection control, CO_2 injection control, liquid flow control, gas flow control, pressure control and tank level measurement. Additional applications including compressor monitoring and control, VRU (vapor recovery unit) control, LACT unit monitoring and control, net oil computer applications, oil theft detector, hydraulic pump monitoring and control and ESP monitoring and control are in the queue for development. The scope of well head and facilities applications for the system are only limited by the types of equipment in the field and imagination of the user and the manufacturer.

BACKGROUND

To know where we are it is well to look at where we came from and how we got here. A brief review of the early history of field installed microprocessor devices is in order.

Hardware

In 1981 the first supervisory well head controller, employing a microprocessor as a digital injection controller, was introduced to the oil industry. Between 1981 and 1985 several manufacturers introduced pump off controllers, plunger lift controllers and gas lift controllers, all of which took advantage of the capabilities of the microprocessor. There were numerous methods of implementation of microprocessors. The hardware designs ranged from specifically designed circuits using specialized processors to essentially striped down personal computers. Naturally the complexity of the circuitry involved varied widely.

Firmware

In general the operating firmware used in the early microprocessor devices employed ether BASIC or assembler language. The BASIC language is not very efficient but is relatively easy to use. Assembler programming is very efficient but is much more difficult to use than high level languages.

There was also a wide divergence in programming philosophy of the early systems. In some systems all possible calculations, such as parameter scaling used only for information, are made in the field unit. In other cases the raw data along with scaling factors was transmitted to the master terminal or portable terminal unit where the scaling was done.

Communications

Most of the initial offerings of microprocessor based well head controllers were designed for stand alone applications with no direct provision for communications into a SCADA (supervisory control and data acquisition) system. It was quickly recognized by the manufacturers and users that remote communications with the microprocessor based controllers was of benefit.

In as much as there was no communications standard each vendor developed his own communications protocols and communications methods. Often the vendors were secretive about their protocol. In the mid 1980s a concerted effort was made to establish a standard communications protocol for use in oil field automation. Over one hundred people, users and vendors, were contacted and an amazing 40% responded. The vendors were universally in favor of establishing a standard communications protocol through the API or SPE. Surprisingly, the users were at best not supportive of the idea and in the case of two of the largest users they were openly antagonistic. No standard for data communications in the oil field was established at that time.

It now seems that a defacto standard for communications protocol is evolving. The protocol is based on a specification used by a major manufacturer of programmable logic controllers. Ironically one of the users who was the leader in killing a standard communications specification ten years ago is the leading advocate of the current defacto standard.

EVOLUTION

The majority of design effort for early microprocessor field controllers was directed toward pump off control and quiescent alarm systems. Shortly thereafter a number of vendors introduced microprocessor based gas flow measurement units. Other vendors produced microprocessor based plunger lift controllers, gas lift controllers, compressor alarm systems and so on. Each unit was specifically designed by vendors in a particular field to accomplish a given task. A pump off controller could not measure gas flow and a gas flow meter could not control the operation of a plunger. It was necessary for a user to purchase automation equipment from a number of vendors in order to automate the operation of a producing field.

The Need for A Well Site Manager

At the first SPE (Society of Petroleum Engineers) artificial lift forum session at Jackson Hole, Wyoming in the mid 80s the need for a universal well site manager system was expressed. At the time the requirement for an economical, generalized hardware platform for field automation was quite difficult, given the state of development of electronic hardware. The I/O (input/output) requirements for a gas flow measurement are quite different from those of a pump off controller or a plunger lift controller. Providing I/O for all possible well head and local facilities applications would have caused the cost of the hardware to be excessive.

As the state of the art of digital electronics advanced it appeared that an economical general well site manager might be possible. Many of the required functions of the system were combined into a single chip. This consolidation lead to lower parts count, lower circuit broad real estate requirements and therefore lower production cost. Additionally, developments in the electronics increased the capacity and reduced the cost of the memory required for the system.

An Early Attempt

The first attempt (in the late 80s), known to the writer, consisted of a small hardware platform with four analog inputs, four digital input, four control outputs, one high speed accumulator and one low speed accumulator. The architecture of the unit was designed to allow a number of firmware applications within the hardware platform.

While the controller was applicable to a number of applications it was soon realized that in some cases there were too few analog inputs with most of the digital inputs unused. In other cases there were too few digital inputs and some of the analog inputs were not needed. Although the unit was applicable to a number of field applications it fell short of the goal of a general solution to field automation problems.

DEVELOPMENT OF A WELL SITE MANAGER

When the decision was made to attempt to develop an economical an effective well site manager a survey of the capabilities and shortcomings of existing equipment was made. The following primary design goals were established to provide a system that would provide a flexible and reliable system at the lowest possible cost.

Hardware Requirements:
Based on past experience with field automation a set of general design goal was established for a well site manager. The design goals and solutions include;

Low parts count, to reduce production cost, repair cost and increase reliability.

> The design goals were met by selecting currently available parts that offer enhanced capabilities for their physical size.

Small physical size, to reduce packaging and installation costs.

> The minimum physical size of the unit in one dimension is established by the size of the field terminals. In order to reduce the size of the unit terminals with 0.2" spacing were selected.
>
> While surface mount technology could have reduced the physical size of the boards it was felt that the additional difficulties in acquiring and installing parts in the repair process precluded its use. The resulting unit is still rather compact at 9" wide by 6" tall by 2" deep.

Integral communications modem, to reduce application cost and complexity.

> Since one of the major requirements for equipment in an automation system is for data communications between the field unit and a central terminal unit a Bell 202 compatible modem with an open collector to ground push to talk is provided.

Local digital communications, to assist in commissioning and operating the unit.

> A RS232 communication port is provided for interfacing with a lap top computer based portable test unit.

Flexible I/O structure, to allow broadest application of the hardware.

> Eight analog inputs, one high speed accumulator and four open collector control outputs comprise the field I/O. One of the analog inputs is equipped with an optional high gain differential amplifier for use with strain gage load traducers in pump off control application. Another analog input is equipped with an optional adjustable gain amplifier for use with position transducers in pump off control applications.

Sufficient memory to provide operating program, parameter and historical data storage.

> Three forms of memory are provided; PROM (programmable read only memory) for the operating system and applications firmware, RAM (random access memory) for dynamic operations and BRAM (battery back up RAM) for parameter and data storage. Memory is now much more economical than in the past.

Operator interface (keypad/display), to assist the operator in monitoring operations.

> A sixteen key keypad and a sixteen character LCD display are provided. The decision was made not to provide a graphic display due to cost vs benefits considerations.

Flexible architecture, to allow use in a broad range of applications.

The controller is comprised of two sperate circuit cards, an engine board with the processor, memory, keypad/display and modem and an I/O board with field terminations, signal conditioning, surge protection and power supplies. The boards are connected electrically through a bus plug connector. Four 1/4 turn stand off attachment are used to physically connect the boards. The engine board has significantly more I/O capability than is exploited by the I/O board. If future requirements justify expanded I/O the existing I/O board can be replaced by one with more points.

Economical interfacing to external devices, to reduce production, installation and maintenance cost.

The RJ11 (modular telephone connector) connection system is used to interface the well site manager to the portable test unit (lap top computer) and to the data radio. Bell Labs spent considerable time, effort and expense to develop this low cost and highly reliable cable connection system, which has proven highly satisfactory for field use.

Low power requirement, to reduce production cost and to allow use in solar power applications.

While the unit is not specifically designed for extremely low power consumption the power drain is only slightly higher than a 2 watt data radio in the un-squelched receive mode.

Transient surge protection, to reduce operating cost due to surge damage.

One of the major problems in the applications of electronic and electrical equipment is the exposed to damage from transient surges (lightening). In the design of the I/O board care was taken to provide maximum economical protection from surges. Techniques including high input impedances, clamping devices, low resistance ground path and large physical conductors are used to minimize damage from surges.

Field Serviceability, including plug on terminals, quick mounting fixtures, to reduce service time and cost.

All too often the field service technician is forgotten in the design of field mounted electronics. An effort has been made to reduce the time and effort reacquired to service the well site manager through the use of plug on terminals and quick mounting stand offs. The entire electronics unit can be exchanged using only a screw driver and requires less than two minutes.

Repairbility, including parts availability and physical structure, to reduce maintenance cost.

The low level of complexity of the circuits reduces trouble shooting difficulty. The parts used are readily available form multiple sources. The processor and PROM chips are mounted in sockets, both for repariablity and for ease in modifying the firmware. Through hole construction is used for ease of physical repairs.

Firmware Requirements

The firmware requirements were established to take advantage of the current state of the art of hardware and to provide maximum flexibility in the application of the well site manager.

High level language, to allow quick development of applications firmware and to provide ease in firmware maintenance.

The "C" language was selected because of the efficiency of the language and it's broad general use. The nature of the language provides a good deal of self documentation.

The availability of relatively large amounts of memory allows the use of a high level programming language, in this case "C". The use of the high level language has a number of advantages including a certain amount of self documentation, ease of modification and modularity.

Modular applications, to allow transportability of common functions between applications to reduce development cost.

In general the firmware for this unit is written in operational modules, some of which are transportable from one application to another. This transporatibaility reduces the effort and therefore the cost of development of additional applications.

Input flexibility, to allow the use of inputs in a number of different ways.
One of the innovations in the firmware structure is the ability to treat each input as an analog, digital input or accumulator. This ability provides flexibility in applying the hardware to in various control and data collection applications.

APPLICATIONS FIRMWARE

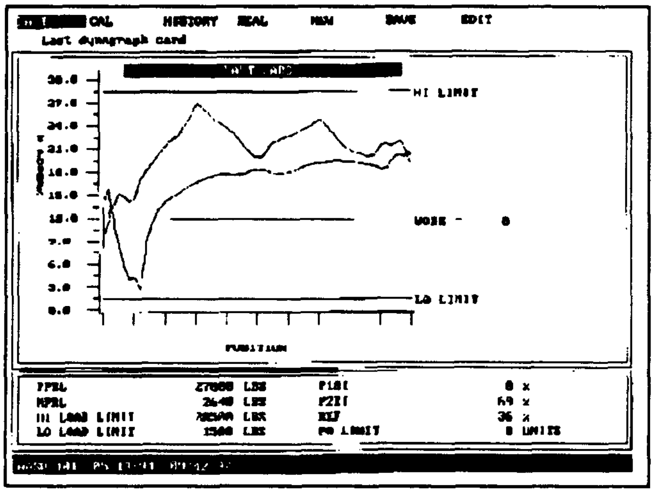
Pump Off Control (POC)

The first application for the unit was for pump off control. The requirements for the pump off control were given a great deal of consideration. There is a current trend in pump off controllers to do a lot of things just because they can be done. In developing the specifications for the pump off control firmware a through review of existing pump off control features was made. The features fall into seven (7) categories; pump off detection, transducer interface, data collection and storage, well operation anomaly detection and control, POC equipment malfunction detection and control, data communications and compatibility with existing systems.

Pump Off Detection

Given the current state of the art of pump off control and the litigious nature of some of the manufacturers, great care was given in selecting a pump off control algorithm that was effective and yet did not infringe any existing patents. Due to past experience various methods of pump off detection the decision was made to use polished rod loading as the primary input parameter.

The effect in the pumping system which indicates pump off is the traveling valve being closed during a portion of the down stroke. One of the more effective means of detecting pump off is to compare the polished rod load to a reference at a point in the down stroke. Due to patent considerations it was decided to eliminate the necessity for the use of a position measuring transducer and to rely upon comparing the rod load to a user stable reference for a user specified TIME during the down stroke. The time relationship works well in as much as the reference point is normally in the upper half of the down stroke and that the time error is small due to the relatively small amount of motor slip caused by the effects of pump off.



Transducer Interface

There are a number of load and position transducers available for use in pump off detection and data collection. One of the major design goals was to allow the employ any of the know transducers with a minimum of effort on the part of the user.

Load Transducers At least two classes of load transducers, beam mounted and polished rod mounted. There is a good deal of controversy as to the relative merits of the two classes of load transducers. The polished rod transducer offers better initial quantitative measurement while the beam mounted load transducer is generally lower in initial cost and a substantially lower maintenance cost.

The beam transducer is affected by stresses produced by differential heating of the walking beam. Some provision must be made to compensate for the zero drift caused by this effect. The method used to compensate for load zero shift consist of comparing the peak load each stroke to a user adjustable set point. If the peak polished rod load does not match the set point the transducer bridge is biased through the use of a D/A converter. Since the automatic zero control is not required for polished rod mounted load transducers a provision is made to disable the automatic zero function.

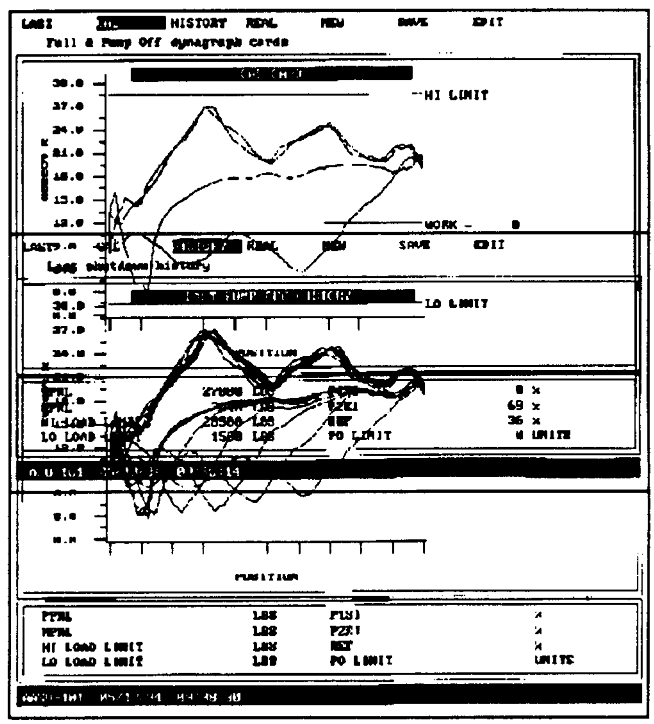
Position Measurement Since the control logic is time based all that is required for control operations as a time marker as some point in the pumping stroke. All control functions are then based on a time after the position event.

The simplest and least expensive application of a time mark is the use of peak polished rod load as the position event. This method allows the use of a load transducer only to establish both load and position for control operations.

A position switch which senses the passage of the crank arm can also be used to generate a position event from which the top of stroke and the pump off comparison period can be determined.

When peak load or a position switch is used for position detection it is necessary to use a computation to establish the relative position relationship in order to produce dynagraph plots. The determination of the position of the polished rod at a given time in the stroke is accomplished using the fact that the motion of the pumping unit is sinusoidal.

Even when an analog position transducer is used to provide measured position data for use in constructing dynagraph plots a time relationship is still used for the purposes of pump off control. That is the position event is detected as the mid point of the up stroke and the timing from that event to the top of stroke and to the end of pump off comparison is used.



Data Collection and Storage
A major part of the evolution of the pump off controller has been the in the area of data collection and storage. The advent of the microprocessor has made it possible to measure and store operational information which can be helpful in diagnosing operating problems.

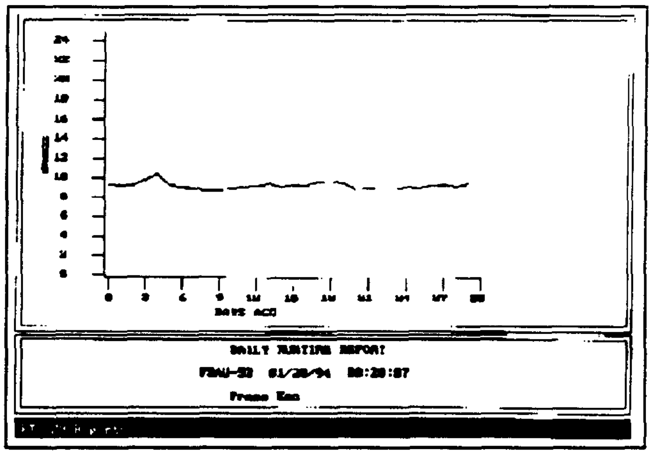
Dynagraph Data One of the most useful tools in diagnosing the operation of the downhole pumping equipment in a rod pumped well is a polished rod dynamometer. Since the controller already employs at least half of the information required to produce a dynagraph plot of load vs position and the other half is readily available it is relatively simple to collect dynagraph data.

The use of the dynagraph plot for the last pumping stroke is most useful in initially setting the control parameters, pump off reference, high load limits and low load limits.

The live dynagraph plot is useful for checking the settings of the control parameters.

A plot of the dynagraph card for the last stroke prior to shut down superimposed over a dynagraph card for the full pump condition provides both a comparison of the full pump and pumped off dynagraphs and provides a useful reference for future trouble shooting of the pumping system.

The plot of dynagraph data for the six (6) strokes preceding shut down will give an indication of how fast the well pumps off, how much gas interference is affecting the well operation or a record of a pumping system failure.



Run Time Information provides one of the most powerful tools in early detection of developing well problems. An increase in run time indicates a worn pump of response to enhanced recovery. A decrease in run time indicates such problems as restricted pump suction, formation damage and loss of effectiveness of enhanced recovery efficiency. The controller records the daily run time for the past thirty days. The portable test unit and master terminal unit software present the data in digital and graphic formats.

Cycle Time Information is most useful when the controller is first commissioned. Wide variations in the cycle operating times can indicate a pump off detection which is set incorrectly, gas interference or other operating problems. The controller records the cycle run time for the past thirty cycles. The portable test unit and master terminal unit software present the data in digital and graphic formats.

Peak Polished Rod Load Information can be used to monitor increases in polished rod load (when a polished rod load transducer is used). Some operators use such data to determine the need for hot oil treatments to remove paraffin.

Events Reports are most useful for the technician charged with maintaining the controller operations. Information on the last power on, power off, shut down, start up and the last time that new data was written to the controller from the key pad or through the communications port.

Well Operation Anomaly Detection and Control

Low Load Range can be used to detect rod parts. In general, if the difference between peak and minimum polished rod load decreases by as much a 50% it is likely that the rods have parted.

High Polished Rod Load can be used to detect problems such as a sticking pump of excessive friction due to paraffin accumulation.

Low Polished Rod Load can be used to detect problems such as sticking pumps and defective stuffing boxes.

System Self Diagnoses

A **Watch Dog Timer** is used to assure that the processor is operating properly. If a reset signal is not received form the processor every few milliseconds the watch dog circuit produces a "power on reset" to the system. The power on reset initiates the operation of the processor and the memory, placing the controller in a know state.

A **Parameter Validity Test** is accomplished by performing a CRC test on the values of all of the user adjustable parameters stored in RAM on a periodic basis. If the CRC fails the parameters are reloaded into RAM from BRAM.

Load Transducer Failures are declared when the load signal reaches either extreme of the load range, 0 or 255 A/D counts.

Position Transducer Failures are declared when the processor fails to detect a position event within a time period equal to twice the normal pumping stroke period.

Transducer Cable Failures are declared when the load signal reaches both 0 and 255 A/D counts within the same pumping stoke.

Auto Zero Failure is detected when the value of the D/A value from the processor to the auto zero circuit reaches 255 counts. This condition indicates that the auto zero is unable to maintain the peak load at the desired level and that the controller is therefore unable to reliably control the well.

If a transducer failure, auto zero failure or a transducer cable failure is detected the controller is placed in the production timer mode. In the production timer mode the controller shuts the pumping system down for the programmed down time and allows the pumping system to run to a time equal to the current average of the pumping cycle time.

Data Communications are provided through the use of a local RS232 port, a Bell 202 compatible FSK (frequency shift key) modem and local keypad/display. All user adjustable parameters may be read and written through the use the modem, serial port or the keypad/display. Stored data can also be read from the modem and the local serial port.

The modem is provided to allow easy and economical interfacing with radio telemetry systems for use in SCADA (Supervisory Control And Data Acquisition) systems. The modem is equipped with a push to talk circuit to facilitate the interfacing with radio transmitters.

The local RS232 port is provided for use in conjunction with a PTU (portable test unit) to assist the operator in commissioning the controller, gathering operating data and trouble shooting the pumping system and the control system.

Comparability with existing systems was given a good deal of consideration in the design to the controller. There are large number of POC systems installed for which there is limited support available. The ability to provide firmware which is compatible with existing systems should provide an economic as well as operating benefits to the operators using the existing equipment. It should be noted that due to legal and physical constraints it is not possible to "clone" existing systems. Rather, the approach taken is to provide compatibility in format and communications. To date firmware for the Well Site Manager has bee developed to provide compatibility with EDI 803CS, EDI 860, Highland Model 2000 and Baker CAC 8500 POC as well as Automation Associates version of POC.

REMOTE TERMINAL UNIT (RTU)

The well site manager system has the ability to act as a small RTU. In the RTU applications the firmware is basically dumb. That is, the well site manager simply reads conditions on it's inputs and when polled reports the conditions. There is no local control logic provided.

In the RTU configuration the well site manager is equipped with eight (8) general inputs, one (1) turbine meter input and four (4) control outputs. Each of the general inputs is equipped with three registers, one for analog values with the current analog value of the input, one for status values which contains the status state of the input (input voltage high or low) and one for accumulator value which is the count of the number of times that the status state has changed from less than 128 to greater than 128. The user reads the appropriate register for a particular input which contains the information of interest. There are no hardware modifications or firmware changes required.

Scaling factors are provided for each of the inputs to allow the operator to scale the analog inputs to engineering units.

The turbine meter input is provided with a scaling factor which will convert the pulse rate from a turbine meter to barrels per day.

The four (4) control outputs are open collectors suitable for driving interposing relays. Open collector outputs are provided for both economy and flexibility. The sizing of relays for control outputs is difficult when the control requirements are unknown.

While the RTU version of the well site manager is void of control logic, firmware modifications can be made for various control applications.

Tank Level Monitoring and Control

One or more of the analog registers can be used to monitor the output of a level transmitter attached to oil or water storage tanks. Virtually any level transmitter with an analog output can be used to provide level data to the well site manager. The well site manager's analog scaling factor(s) can then be used to convert the level data to engineering units, feet, inches and fraction of inches.

For volume measurements look up tables from tank strapping information can be used to allow volume calculations.

Compressor Monitoring / Control

The RTU version of the well site manager can be used to monitor various parameters in gas compression operations. Pressures and temperatures of both the compressor and engine can be input as analog or status variables. The scaled analog values, status and accumulated values can then be transmitted to central location to provide an operator information on the operation of the compressor system.

Additional logic can be installed to allow the operator to set high or low set points which will stop the operation of the compressor in the event of failures in critical functions such as oil pressure or cooling systems.

Operating data such as run time and down time can be stored for retrieval from a central point or through the key pad and display unit.

LACT Monitoring

The accumulator capabilities of the well site manager can be used to store volume data from a pulse transmitter connected to the LACT meter. The readings at gage off time, usually 7:00 AM, are stored for thirty days.

The status function can be used to monitor the position of the "bad oil" divert valve and the tank level function can be used to monitor the level in the sales and bad oil tanks.

PLUNGER LIFT CONTROL

Plunger lift is a long used, highly effective and economical method of lifting fluid in wells that are in the stage between flowing and requiring mechanical lift. Plunger lift has been practiced for many years on a limited basis. The major impediment to the wide spread application of plunger lift has been the time and effort required to determine the proper operating parameters for individual wells.

The advent of affordable microprocessors have given rise to a new breed of plunger lift controller. The optimizing controllers have the capability of monitoring the operation of the well and adjusting the off time, or after flow time to optimize the operation of the plunger lift operation. This form of automation greatly reduces the manual intervention required to establish and maintain successful plunger lift operations. The addition of the ability to monitor the operation of the well and adjust parameters remotely through a SCADA system further enhances the viability of the plunger lift method.

The energy added to the producing reservoir through CO_2 injection has greatly increased the number of wells that are candidates for plunger lift operations. In some CO_2 operations the plunger is used for paraffin control as well as lift assist.

The combination of improved control techniques and CO_2 enhanced recovery has given rise to renewed interest to an old and proven lift method that can significantly reduce lifting cost and increase operating profits.

The well site manager can be equipped with firmware to optimize the operation of plunger lift equipped wells and provide SCADA access to operating data and allow the changing of parameters from a central terminal unit. The firmware allows the operator to chose between oil and gas mode using either pressure or time operation. In all modes the well site manager employs a proportional control algorithm to make corrections to the operating parameters. The operator has complete control over the rate of adjustment through the use of a gain factor.

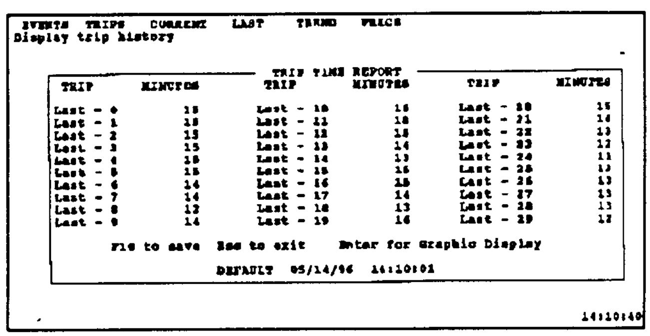
In the oil mode the initial conditions, off time or casing pressure set point, are modified to optimize the well operation. In the gas mode the afterflow time is adjusted.

Time Control

When the controller is in the time mode the operator establishes desired off time, on time and trip time. The operator also enters a gain factor to be used in making automatic corrections to the off time.

Each cycle the controller compares the actual trip time to the desired trip time. The error between the actual and desired trip time times the gain factor is uses to modify the operating parameters to achieve the optimum operating cycle times.

In the oil mode the well site manager modifies the off time in proportion to the error between the desired and actual trip time.



EVENTS TRIPS CURRENT LAST TREND PRICE
Display trip history

TRIP TIME REPORT

TRIP	MINUTES	TRIP	MINUTES	TRIP	MINUTES
Last - 0	15	Last - 10	16	Last - 20	15
Last - 1	15	Last - 11	18	Last - 21	14
Last - 2	15	Last - 12	15	Last - 22	13
Last - 3	15	Last - 13	14	Last - 23	12
Last - 4	18	Last - 14	13	Last - 24	11
Last - 5	15	Last - 15	16	Last - 25	13
Last - 6	14	Last - 16	15	Last - 26	13
Last - 7	14	Last - 17	14	Last - 27	13
Last - 8	12	Last - 18	13	Last - 28	13
Last - 9	14	Last - 19	16	Last - 29	12

F10 to save Esc to exit Enter for Graphic Display

DEFAULT 05/14/96 14:10:01

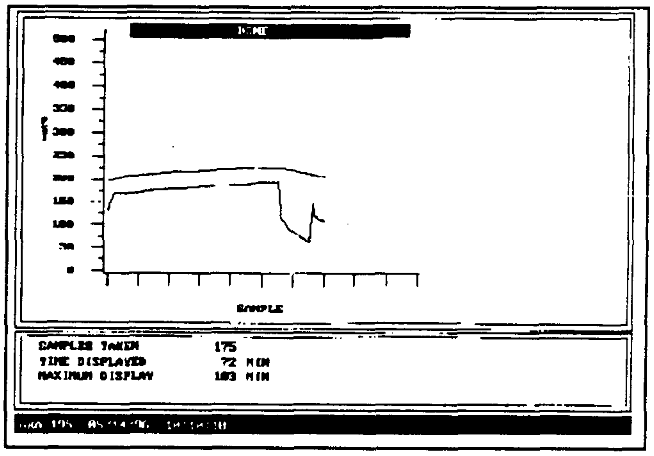
14:10:40

In the gas mode the well site manager modifies the afterflow time in proportion to the error between the desired and actual trip time.

In order to assist the operator in tracking the operation of the well the well site manager stores the trip times for the last thirty (30) trips.

Pressure Control

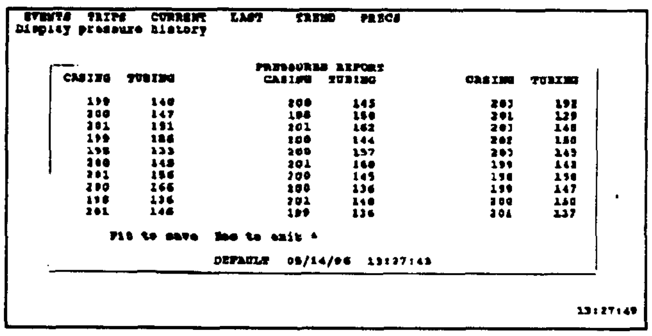
The pressure in the casing/tubing annulus is a measure of the energy available to lift the fluid from the formation to the stock tanks. The pressure in the tubing gives an indication of the amount of fluid to be lifted. When the casing pressure high enough to provide the required lift energy and tubing pressure is large enough fraction of the casing pressure a successful trip ofthe plunger and fluid slug can be made. The operator enters the minimum casing pressure at which a trip will be attempted. The operator also enters the minimum relation ship of the tubing pressure to the casing pressure, expressed as a percentage, which the casing pressure will lift. You will note that the relationship between the casing pressure and tubing pressure is not a fixed differential but rater a percentage. When both pressure conditions are met the controller opens the flow line valve and starts a plunger trip.



Each operating cycle the well site manager compares the desired trip time to the actual time required for the plunger to reach the surface after the flow line is opened. The error between the desired and actual trip times in conjunction with a user adjustable gain factor is used to adjust the pressure set point.

The well site manager stores pressure data for each operating cycle. The stored data can be useful in assisting the operator in optimizing the operation of the well.

The well site manager also stores the values of casing pressure and tubing pressure at the beginning of each trip for the last thirty cycles. The pressure information in combination with the trip time can be useful in reaching the pressure settings required to obtain the maximum number of operating cycles each day.


EVENTS TRIPS CURRENT LAST TREND PRECS
Display pressure history

PRESSURES REPORT

CASING	TUBING	CASING	TUBING	CASING	TUBING
199	140	200	145	203	192
200	147	198	150	201	129
201	151	201	162	203	148
199	126	200	144	202	150
198	133	200	137	203	143
200	143	201	160	199	142
201	156	200	145	198	158
200	166	200	136	199	147
198	136	201	140	200	150
201	146	199	136	201	137

F10 to save Esc to exit ^

DEFAULT 08/14/96 13:27:43

13:27:49

Time Control with Pressure Override

The well site manager can be set to operate in the time mode with pressure override. When the off cycle expires the controller checks the casing pressure to assure that the pressure is at or above the minimum value required to trip the plunger and the fluid slug to the surface. If the pressure is low the flow line valve will remain closed until the required pressure is reached.

If the tubing pressure is found to be too low a bypass valve between the casing and the tubing is opened and remains open until the tubing pressure reaches the required percentage of the casing pressure.

GAS FLOW MEASUREMENT (AGA-3/NX19 or AGA-8)
The most prevalent method of gas flow measurement employs an orifice plate with absolute static pressure, differential pressure and absolute temperature measurement. The well site manager can be equipped with firmware to measure the required parameters and make the necessary calculation to determine gas flow rate and volume. The well site manager uses the basic flow equation $Q = C'[(P_a dp)/T_a]^{0.5}$ or $q_m = F_b\ F_r\ Y\ F_{pb}\ F_{tb}\ F_{tf}\ F_{gr}\ F_{pv}\ [h_w p_{f1}]^{0.5}$

F_b, also known as the beta ratio, is determined in the well site manager from the tube diameter (D) and the orifice diameter (d) entered by the operator. The values of D and d can be changed by the operator when changes are made at the meter run.

The C factor is calculated in the well site manager from values of F_r, Y, F_{pb}, F_{tb}, F_{tf} and F_{gr} entered by the operator.

F_{pv} is determined in the well site manager using a four by four matrix look up table consisting of supercompressibility factors for four pressures and four temperatures. The operator enters the pressures, temperatures and supercompressibility factors from the key pad or through the use of the portable test unit.

Once each second the well site manager reads the values of the pressure, differential pressure and temperature and using the calculated value of C' makes a flow rate calculation.

Flow volume is calculated by integrating the calculated value of the flow rate. $V = \int_{t1}^{t2} Q\,dt$

The daily flow volume is stored for thirty (30) days.

The gas flow calculation can be combined with other well site manager functions such as pump off control or RTU.

The unit can be placed in the calibrate mode to allow calibration of the input transmitters. In the calibrate mode the last read values of P, dp, and T are used to calculate the flow volume during the calibration period. At the end of the calibration period the unit is returned to normal operation. The calibration mode is limited to thirty (30) minutes to prevent long term inaccuracies if flow rate and volume measurements.

GAS FLOW LOGGING
By adding BRAM the well site manager can log the hourly values of P, dp and T as well as hourly flow volummes for eight hundred forty (840) hours, or thirty five days. As might be expected a good deal of time is required to read the 3360 data points in the gas flow log.

INJECTION CONTROL - PRESSURE CONTROL WITH FLOW OVERRIDE
The goal of the injection control algorithm is to allow the injection of the maximum amount of fluid while maintaining the pressure and flow rate below user selected values.

The well site manager uses proportional jog pulse control to a reversible electric valve actuator. One control is used to open the valve and a second control is used to close the valve.

The operator inputs a pressure set point and a flow set point and a gain factor. Each second the controller reads the pressure and the flow rate and compares them to their respective set points. If either variable is above it's set point the controller calculates the error, multiplies the error by the gain factor and uses the result to calculate a time duration for the close control pulse. The timed control pulse is issued to the valve and the process begins again.

If both variables are below their set points the controller selects the higher variable for correction. The controller calculates the process - set point error, multiplies the error by the gain factor and uses the result to calculate a time duration for the open control pulse. The timed control pulse is issued to the valve and the process begins again.
The flow variable used for control can be acquired from a liquid turbine meter, a gas turbine meter or from an orifice meter. The use of the four by four matrix look up table with specific gravity entered for four values of pressure and four temperature values allows the controller to measure and control the injection rate of CO_2.

GAS FLOW CONTROL
Gas flow control can be used in gas well production, compressor control or other operations requiring gas flow control. The well site manager can be used for gas flow control by disabling the pressure control function and enabling the gas flow control function.

LIQUID FLOW CONTROL
The well site manager can be used for liquid flow control by disabling the pressure control function and enabling the gas flow control function.

PRESSURE CONTROL
Pressure control can be used in bypass operations of positive displacement pumps, gas production, separator control, water flood plant control and many other applications. The well site manager can be used for pressure control by disabling the flow control function. The operation of the control system can be reversed by reversing the connection of the control relays.

WATER FIELD CONTROL
A special case of the well site manager is used to monitor the level of a water storage tank and to start and stop supply wells and booster pumps based on levels of the water in the tank. The well site manager program also provides rotation of the operation of the supply wells and booster pumps to allow uniform wear of the pumps.

CONCLUSIONS
1. The current well site manager equipment is not the complete answer to all of the desired requirements for a universal well site manager.

2. The current state of the art of electronics allows the design and production of equipment which much more closely approaches the goal of a universal well site manager.

3. Given the rate of advancement in the capabilities and cost of electronic components it is highly likely that a more comprehensive well site manager can be produced in the future.