



Control Capabilities of the SAM Well Manager

Introduction

Lufkin Automation was formed by the forging together of two companies that pioneered the field of rod pump control, Delta-X and Nabla corporations. Delta-X was an established leader in the arena of control from surface dynamograph analysis. The patented single setpoint control method was very effective and the large LCD graphics interface was very user friendly. Nabla had established a reputation in the design and analysis field with DIAG and SROD software, and introduced the first rod pump control that calculated the downhole pump card at the well site and made control decisions from analysis of that downhole card. Nabla had also developed a control algorithm for using digital signals from the motor shaft and the crank arm that did not require a polished rod load input signal. Knowing instantaneous motor speed, and using a speed/torque curve for the motor, the work being done by the motor is calculated and used as a control decision input. This motor power control concept offers low cost control since a load cell is not required.

The SAM Well Manager, utilizing a powerful new hardware platform, combines the strengths of Delta-X and Nabla by implementing the control algorithms developed by both companies. The SAM Well Manager combines the proven single setpoint surface control technology of Delta-X, the downhole pump card control expertise of Nabla and the low cost motor power technology of Nabla. New features made possible by the additional computing power and memory size have been added to the SAM Well Manager. An overview of the controller's capabilities is presented in this section.

Operating Modes

The SAM Well Manager has three operating modes:

- **Host:** The SAM Well Manager starts and stops the pumping unit based on user command. A minimum control capability for Peak and Minimum load and for end device checking is available when in Host mode. Primary function is for use in a SCADA system. By issuing a global command to program controls to Host Mode-Off, a number of wells may be shut down and left down until the operator decides to re-start them.

- **Timed:** The SAM Well Manager will cycle the pumping unit off and on for user programmed On Time and Off Time. Provided as a mode for temporarily continuing to cycle a well at an historical on/off pattern until repairs can be made to a load or position input device. A minimum control capability for Peak and Minimum load and for end device checking is available.
- **Normal:** The SAM Well Manager offers all of the features discussed below. This would “normally” be the operating mode of choice.

Normal Mode Features of the SAM Well Manager

Primary Control

The basic purpose of the SAM Well Manager is to determine when the fluid level in the well bore has been pumped down to the point that there is no longer sufficient pump intake pressure to completely fill the pump barrel with fluid in the upstroke time. This incomplete filling of the pump barrel reduces the efficiency of the pumping operation and the resulting “fluid pound” introduces extra wear and tear on pumps, tubing and surface equipment. The normal desire of an operator to pump all of the fluid available typically results in the pumping unit system being designed with more lift capacity than required. This over capacity will in time draw the fluid level down to the point that the pump is no longer completely filled and “fluid pound” occurs, i.e. the well is pumped off.

The SAM Well Manager user may select from three available methods to detect this pumped off condition:

- Single setpoint control based on surface dynagraph using polished rod load and position inputs
- Percent pump fillage based on downhole pump card using polished rod load and position inputs
- Motor power using Hall Effect inputs from motor shaft and crank arm

Load and Position Input Options

The SAM Well Manager is designed to accept load and position inputs from a number of devices as further discussed on page 2-4 of the SAM manual. Briefly, load input may be from a beam mounted strain gauge device or from a polished rod load cell. Position input may be analog from an inclinometer or digital from two Hall Effect transducers, one sensing motor RPM and the other sensing the crank arm. Any combination of load and position may be used, but there are preferred combinations for best results for the selected pump off control method. Some of the secondary malfunction type controls are not available with some combinations of inputs. Refer to **Other Control Functions** below.

Control Method Merits

The downhole pump card control mode is the most accurate of the three and is capable of controlling problem wells that surface control might have trouble with. The downhole method does require that accurate data for pumping unit dimensions and rod string design be programmed in the SAM Well Manager. The downhole control selection also includes fluid load information.

The surface dynagraph single setpoint control is easier to use for simple well control. Although it is easy, the control from the surface dynagraph is not as accurate nor does it provide the same quality of data as the more sophisticated analysis aids provided with the down hole control method.

Motor power control is the least sophisticated of the control methods. It is suitable only for stable well bore conditions typical of mature primary recovery wells with little or no gas. No dynagraph data is available, so analysis capabilities are minimal. This is the lowest cost approach since no load cell is required. Motor power control is a “fall back” control method that the SAM Well Manager automatically reverts to if the load signal input is lost.

Action on Pump Off

When a pumped off condition is detected, the SAM Well Manager is capable of either cycling the well off, or of adjusting a speed control output to a variable speed drive.

For off/on cycle type of control, setting the proper down, or idle, time is as important as setting the proper pumped off limit. That down time may be operator programmed based on experience or production tests. The SAM Well Manager also offers an Auto Downtime feature to assist users in determining the optimum down time for a given well. The Auto Downtime algorithm steps through a series of incrementing downtime steps and records the average pumping time for each step. The resulting “build up” curve is analyzed to find the knee indicating that fluid level in the well bore is approaching the static level and an optimum down time is selected. The Auto Downtime feature is discussed at length in Appendix A.

For variable speed control, optional analog output hardware must be added to the SAM Well Manager. The SAM Well Manager control algorithm adjusts an analog output to maintain a desired pump fill level. The variable speed function is compatible with both the downhole pump card control method and the surface card control method. Variable speed control is discussed in Appendix F.

Other Control Functions

Malfunction Controls

The SAM Well Manager performs many secondary control functions to detect pumping equipment malfunction, and to help protect equipment against further damage in the event of an equipment failure. The SAM Well Manager also checks for malfunction of signal input devices. The SAM Well Manager allows for a programmable number of re-tries when one of these malfunction events occurs. On the first occurrence the SAM Well Manager shuts the pumping unit off for the programmed Downtime then re-tries. If the condition has cleared the SAM Well Manager will clear the consecutive count and continue with usual operation. If the condition persists for the programmed number of re-tries, then The SAM Well Manager shuts the pumping unit down in a Malfunction

state that requires operator intervention to clear and return to a pumping state. These malfunction control features may be individually Enabled or Disabled. Malfunction controls include:

- Peak Load: Shuts the well down if polished rod load exceeds a Peak Allowed. Requires load input.
- Minimum Load: Shuts the well down if polished rod load falls below a Minimum Allowed. Requires load input.
- Malfunction Setpoint: Shuts the well down if surface load on the upstroke falls below the setpoint for the programmed number of consecutive strokes. Detects pumping equipment failures such as rod parts, or traveling valve not closing. Requires load and position input.
- Low Fluid Load: Shuts the well down if the fluid load calculated from the downhole pump card falls below a minimum allowed level. An alternative method to detect pumping equipment failures such as rod parts, or the traveling valve not closing. Also affords high fluid level detection capability. Requires load and position input. Available only when Downhole control method is selected.
- Peak Torque: Shuts the well down if the calculated maximum torque for a stroke exceeds the allowed limit. The SAM Well Manager calculates torque from a speed/torque curve for the pumping unit prime mover and digital inputs for motor shaft RPM and crank arm cycles. Requires Hall Effect position input. Available with either surface or downhole control method.
- Loss of RPM Transducer: Detects the loss of the motor RPM Hall Effect switch input. With out this input the SAM Well Manager has very limited capabilities so this is treated as a Malfunction condition to call operator attention to the need for repairs. Available only with Hall Effect position input.
- Loss of Crank Arm Transducer: Detects the loss of the crank arm Hall Effect switch input. With out this input the SAM Well Manager has very limited capabilities so this is treated as a Malfunction condition to call operator attention to the need for repairs. Available only with Hall Effect position input.
- Low Motor RPM: The SAM Well Manager will shut the pumping unit down if the measured motor RPM drops below an allowed low limit. Provides protection against stuck pump conditions with quicker response than peak load detection. Requires Hall Effect position input.
- Belt Slippage Detection: The SAM Well Manager counts the number of motor revolutions each pump stroke. If that number falls below a set reference by more than an allowed percentage and alarm flag is set to alert the operator to possible belt slippage. No control action is taken. Requires Hall Effect position input.
- Logic Expression: The SAM Well Manager has the ability to monitor wellhead conditions other than load and position. Analog or digital signals from a variety of sensors or transmitters may be used to monitor flow line pressure or temperature, casing pressure, a stuffing box leak detector, or level transmitters on a local tank battery, to name a few. A Logic Expression may be programmed in the SAM Well Manager using these inputs to make decisions to start or stop the pumping unit, or to turn on one of the extra digital outputs to start a chemical pump, sound an alarm, etc. The Logic Expression capabilities are detailed in Appendix C.

Peak Energy Management

Oil producers may have contracts with their electric power provider to minimize power consumption during peak demand times of the day in return for a more attractive rate. The SAM Well Manager has a feature that allows the user to program for shut down during those peak periods. The Peak Energy Management feature allows the use to program the desired period of the day and on which days to enable the function. All normal operation is suspended when the SAM Well Manager is in a Downtime Peak Energy Management state. Normal operation resumes at the end of the programmed period.

The SAM Well Manager also has the ability to respond to a global shut down command issued by SCADA software for emergency situations requiring wells to be shut down.

Additional Well Performance Measurements and Records

Inferred Production

The SAM Well Manager includes an Inferred Production algorithm (IPA) to calculate the total fluid production of the pumping unit. The SAM Well Manager uses measured Strokes per Minute, programmed Surface Stroke length and Pump Plunger Diameter, and a pump plunger stroke length inferred from the dynagraph card. The method of inferring plunger stroke is determined by the control method selected. Downhole control uses the pump card and surface control infers plunger stroke from the surface dynagraph. The IPA has a K factor to adjust for slippage around the pump plunger and/or shrinkage of fluid volume as gas breaks out of solution in the production tank. The IPA feature is discussed in Appendix G.

AGA Gas Flow Rate and Volume

Embedded in the SAM Well Manager firmware are the equations to perform American Gas Association rate and volume calculations. An orifice plate meter run with a Delta-P transmitter measuring pressure drop across the orifice plate is required. For more accurate results, a line pressure transmitter and a line temperature transmitter may be added. Optional analog input expansion board hardware must be added to the SAM Well Manager control. The present flow rate in MCF per day is updated once a second. Volume in MCF is accumulated. The AGA feature is discussed in detail in Appendix E.

Polished Rod and Pump Horsepower Calculation

The SAM Well Manager calculates the PRHP from the surface card and the Pump HP from the downhole card each stroke.

Rodometer and Pumpometer

The SAM Well Manager has separately re-settable accumulators to keep count of the number of pump cycles for a rod string and a pump. Another tool for a user to monitor operation of pumping equipment.

Daily History Buffers

The SAM Well Manager maintains an historical record for the previous 24 hours of the following:

- A record of the previous 1440 minutes indicating if the pump was on or off
- A record of the previous 1440 speed control outputs from the SAM Well Manager to the variable speed drive

- A record of the previous 180 eight minute averages of the calculated gas flow rate

60 Day History Buffers

The SAM Well Manager has a realtime clock and therefore has the ability to perform functions at programmed times of the day. A user programmed Gauge Off Time tells the SAM Well Manager when to perform daily record storage functions. The SAM Well Manager maintains an historical record of the previous 60 days of the following:

- The run time for the day in percent
- The Inferred Production for the day in barrels
- The highest value for the polished rod load for the day
- The lowest value for the polished rod load for the day
- The gas production volume for the day in MCF
- The highest value for Polished Rod Horsepower for the day

Last 200 Load Values

The SAM Well Manager maintains a buffer of the last 200 load samples prior to the last shutdown decision. Dynagraph buffers are only updated at the end of each stroke. A peak or minimum load violation will cause a shutdown before the completion of the stroke. The dynagraph history might therefore not have recorded the load violation. This buffer will have captured that load limit violation.

Auto Downtime Plot

The SAM Well Manager records and displays the pumping time (on the Y axis) versus the downtime steps (on the X axis) from the last time that the Auto downtime algorithm was executed. This “build up” curve is one more valuable piece of well data provided by the SAM Well Manager.

Valve Check and CBE

The SAM Well Manager will record polished rod load versus time and save a buffer of that data for analysis. The buffer is a maximum of 1200 load points sampled every 200 milli-seconds. The operator may record up to 4 minutes of data. A Pause/Resume feature gives the operator more than 4 minutes to collect that data however. The analysis feature includes the ability to calculate traveling valve leakage in Barrels per Day. The valve check feature is discussed in detail in Appendix B.

Time Stamped Data

The SAM Well Manager uses the realtime clock to date/time stamp historical performance actions. One buffer tracks 22 predefined significant events to let the user see the last time that the event occurred. This Event log covers the full spectrum of the SAM Well Manager control features. A second Shutdown event log tracks the last 20 start/stop actions of the SAM Well Manager.

Dynagraph Card Buffers

The SAM Well Manager displays a Realtime dynagraph trace for on location analysis of present pumping conditions. If the Downhole control method is selected, the downhole pump card for the stroke just completed is displayed.

The SAM Well Manager also stores a number of dynagraph cards as an historical record as follows:

- Stored Cards The five most recent strokes
- Pump Up The single stroke at the last transition from Minimum Pump Strokes to Pumping
- Shutdown Cards A buffer of the last five strokes culminating in a shut down decision is recorded for each of the last two shut down decisions.
- Standard An operator saved reference card
- Start A single stroke card at the start of the Minimum Pump Stroke well state
- Reference Pump Cards Twelve downhole pump cards for common pumping conditions provided as a quick analysis tool

All dynagraph cards may be display as Surface card only, Downhole card only, or both cards on the same screen with the downhole card displayed below the surface card.

I/O Expansion Capability

The SAM Well Manager modular design provides the ability to expand the I/O capacity to monitor and/or control other processes at oil production facilities. The firmware design provides for the following expanded I/O:

- 32 analog inputs
- 8 analog outputs
- 64 discrete points configurable as inputs or outputs
- 8 accumulators