SUCKER ROD PUMPING SYSTEM ANALYSIS UTILIZING PORTABLE DATA UNITS AND REMOTE ANALYSIS USING MICROPROCESSOR CONTROLLER UNITS

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ABSTRACT

Reduction of preventable problems inherent in beam pumping systems can be achieved by continuous monitoring of system loads with electronic equipment and software systems developed by Delta-X Corporation. Electronic monitoring equipment was developed for permanent installation on electric prime mover driven beam pumping units. This equipment provides instantaneous polish rod load versus stroke position data. The equipment's self-monitoring mode allows the pump-off controller (DXI-30) to interpret polish rod load versus displacement and make a logic decision to shut the well down for a predetermined time when a pumped-off condition is detected. Rod parts and other major downhole problems are also detected and result in setting of an alarm and shutting down the unit until visually inspected and manually restarted.

Interfacing capacity is designed into the system to allow plotting load versus position data with a dynamometer or the storing of such data, for later retrieval, in an electronic memory card. These data may be later recalled, using a computer program, to recreate a dynamometer card shape, calculate gearbox torque, and/or a downhole pump card. Introduction of the new DXI-40 microprocessor controller with a communication system allows remote access to all load data. System control can also be effected from a remote location.

INTRODUCTION

Good production practice widely accepted by the industry to artificially lift fluid requires the use of beam pumping systems with lift capacitites greater than reservoir yield capacity. The net result pounding fluid, was thought to be "getting all there was to get". Pumping unit, gearbox, pump and rod string failures were accepted as a price that had to be paid to produce all the fluid. Times have changed.

Ever increasing lifting costs spurred by higher electric, rods, pumps and labor costs necessitate optimization of rod pumped systems to eliminate fluid pound without sacrificing production. Recent innovations in electronic hardware and technology have permitted the design and manufacture of monitoring/controlling equipment that may be permanently mounted on electric motor driven beam pumping units. The scope and flexibility of these units is such that, now, wells may be continuously analyzed and controlled. The resulting lifting cost savings have been substantial.

While the DXI-30 system achieves the objective of precise pump off control and acquisition of quantifiable loads and displacement, all data must be acquired and controlled at the wellsite. The recent introduction by Delta-X of the DXI-40 microprocessor controller contains all the features of the DXI-30 plus the ability to store data, communicate status, control all functions, perform calculations, etc.

OPERATING PRINCIPLES

Dynamometer cards are utilized to determine many operating characteristics such as pump filling, load, proper operation of traveling and standing valves. Interpretation of other conditions is as much an art as it is a science and many hours of deliberation are sometimes necessary to fully analyze a given pumping situation.

While each set of operating conditions generates a different dynamometer card, Figure 2 represents a pump that is filling properly and is operating correctly. Figure 3 is another card on the same well with the pump partially filling. Note that in Figure 3, the downstroke load remains high, as compared to Figure 2, until the pump plunger impacts the fluid within the pump barrel. When this occurs, the traveling valve opens and the load transfers to the tubing resulting in the loss of load on the polish rod.

Various conditions exist which create a partial pump filling. For example, a restriction at the pump intake, malfunctioning standing valve, or insufficient flow from the formation into the well bore, thereby causing improper pump filling. Partial pump filling due to a restriction or malfunctioning standing valve are considered mechanical problems that may be remedied. Insufficient flow of fluid resulting in a "pumped-off" condition will be addressed from this point found in this paper.

SYSTEM COMPONENTS

The load cell is cylindrical (doughnut) shaped and has three strain gauges located 120 degrees apart. It mounts permanently over the polished rod between the carrier bar and polished rod clamp. A wire strap holds it stationary. Should a rod rotater, shock absorber, or etc., be used, the load cell will not interfere or be affected.

The position transducer mounts on the sampson post and is mechanically linked, via position arm and cable, to the walking beam. Installation requirements ensure free movement of the position arm such that regulation of voltage signal through a potentiometer is proportional to the angle swept through by the walking beam. The DXI-30 design avoids normal sideloading problems, and usage of durable potentiometers extend the working life of the position transducer (which is normally 3 to 5 years).

Both load and position data are transmitted to the control box, usually located near the power box, through a cable. The control box contains the electronics necessary to monitor the load versus position of the polish rod continuously (i.e. internally, via circuitry, draw a dynagraph each pumping stroke cycle), determine rod part, and output a calibrated dynamometer card to an external plotter.

The internal circuitry of such system is designed to interface with existing and/or optional accessory data acquisition equipment so that the user may (1) obtain a fully calibrated dynamometer card; (2) utilize the dynamometer card for instantaneous analysis and control of pumping-off conditions; and (3) record the data in a memory card for future use via computer interface.

Components of the system, manufactured under the name DXI-30, are shown in Figure 1. These consist of a load cell, position transducer, and a control box. The control box accepts information from the load cell and position transducer. An access portal built into the control box allows interfacing with a standard X-Y plotter or calibrated electronic dynamometer to obtain fully calibrated dynagraphs useful in analysis or adjusting the point at which the DXI-30 will shut down the pumping unit during pumping-off conditions.

Additional interfacing equipment includes: (1) pump-off control set point and polish rod load zero switch box (DXI-30 converter) which allows setting of desired shutdown point during pumping-off cycle and instantaneous determination of zero load on the polish rod; and (2) a Surface Data Recorder (SDR-01) which records the load and position data onto a solid-state memory card. The memory card, through a Data Input Unit (DIU-01), may be used to input data into a computer program designed to calculate gearbox torque and downhole pump card analysis.

PUMP-OFF CONTROLLER (DXI-30

The DXI-30 control box utilizes load versus position data to compare downstroke load with a predetermined load level. Figure 4 (dynagraph) represents a well that is pumping off from a full pump condition. A dot (.) is shown to represent a preselected pump off control set point. When the logic center of the control box detects the load on the downstroke to be greater than the reference point, a memory latch is set. If this condition is repeated, that is, exists two successive strokes, the pumping unit is shut down for a predetermined time. The well then restarts after downtime has elapsed and monitoring begins again. The pump off control set point may be moved to any position in the stroke to allow user to select percent pump barrel filling desired before shut down. While some fluid pound is unavoidable, sustained or excessive pounding is not recommended and should be avoided. Consideration of resultant fluid pound loads within the system should be exercised prior to selection of a set point.

Flexibility in the control circuitry allows the DXI-30 to monitor for rod parts by examining the loads on the upstroke. Should the load on the upstroke be less than the reference point (pump off control set point - Y axis) the control circuitry shuts off the pumping unit and sets an alarm to indicate a rod part has occurred.

In addition, the control circuitry may be utilized to output data necessary to plot a fully calibrated dynamometer card, using a standard X-Y plotter or Delta-X dynamometer directly, through an interface box, to the DXI-30. Traveling and standing valve measurements as well as counterbalance effect may then be taken conventionally using the DXI-30 load cell and position transducer. Polish rod load zero may be achieved by pressing an appropriate button on the DXI-30 interface box. These data then allows the user to perform a total analysis of the pumping system.

By interfacing with the DXI-30 load and position transducers via the control circuitry, the operator is allowed to determine quickly and accurately fundamental pump operations such as valve leaks and pump fill. Detailed analysis, which may include gearbox torque, downhole pump card or rod stress, requires the use of a computer to perform required calculations in an expedient manner. The data may be stored for computer entry in a magnetic memory card.

NOTE: CONTROL feature is patented. See U.S. Patent No. 4,286,925

MEMORY CARD AND SURFACE DATA RECORDER

The solid state memory card uses digital memory and accepts one full pumping stroke (cycle) of the pumping unit. The memory card is self-contained, has its own battery pack and retains the recorded card shape for up to three years depending on use. The memory card plugs into a Surface Data Recorder (SDR) which interfaces with the X-Y plotter or a Delta-X dynamometer (Dynalog: DXD-02). A new memory card may be inserted for a subsequent well pumping stroke, or to record the card shape from other wells being tested. This allows the operator to record data from several wells during any one field trip. After each well is analyzed, the memory card can be erased or recorded over.

To obtain maximal useable life from an information storage/retrieval system, several design parameters must be considered. The means of storing data are solid state so that there are no moving parts exposed to the dirt and oil present at well sites.

NOTE 2: Digitizing technique is patented. See U.S. Patent No. 4,307,395

The data recording unit features a playback mode to allow the operator to immediately play back onto the plotter the recorded data for verification. The data recording system is all digital to insure compatibility between all system components and avoid slewing of data which frequently occurs when analog and magnetic equipment are interfaced.

The data recorder divides each pumping stroke into up to 256 discreet intervals and records them versus equal time increments in the memory card. The number of data points stored depends on the strokes per minute (SPM) of the pumping unit. The Surface Data Recorder (SDR) may also be interfaced directly to a dynamometer so that well data can be recorded from wells lacking the pump-off controller.

COMPUTERS, WELL ANALYSIS AND REMOTE CONTROL

Several major automation projects centered around quantitive load and position data gathered at the polish rod and incorporated with pump off control features have proven the economic viability of such projects. Data gathered at the wellsite is transmitted via wire or radio to host computers for status and control. In most cases the host computer will be in a field office location with a telephone link to any region or home office location.

Delta-X System 40 is a complete package intended for the field automation of beam pumping systems. The focal point of the system is a standard load cell, position transducer, pump off control system utilizing a DXI-40 microprocessor at the pumping unit. This computer/controller utilizing our software and a communication link with the host computer permits remote access to any data, status or control function requested or required by the operator. In addition to pumping unit data, the DXI-40 can control on/off status of multiple pieces of equipment in the same location based on internal calculations or as directed at the host computer.

Some typical data, status and control features available in the Delta-X System 40 are:

All control and status functions are transmitted to the host computer and can be governed at that point.

Continuous sequential polling of all wells on systems and reports problems.

Interrogation of problem well retrieves and displays last five cards stored prior to malfunction.

All control points, such as, maximum and minimum allowable loads, pump-off control point, etc. can be set at host computer.

Current status of any well can be requested.

Quantative dynamometer cards can be displayed and retrieved or submitted to computer programs for analysis.

Shut down and start up can be controlled at host computer to override microprocessor if desired.

Percent run time last 24 hours is continuously computed.

24 hour cumulative run time computer.

Time elapsed in its current status.

A "standard card" can be stored for comparison to recent cards.

Exception reports can be generated and displayed for all wells on malfunctions or indicating an abnormal run time.

SUMMARY

The system is available today, "off the shelf" either as stand alone pump-off controllers or incorporated in a total automation system. This system offers the operator great flexibility to control and monitor his oil fields, small or large. Cost reductions in power, equipment and planned maintenance of downhole pumps prior to total failure are available today. Increased production via accurate control and quick response to problems are resulting in higher producing profits to the operator.

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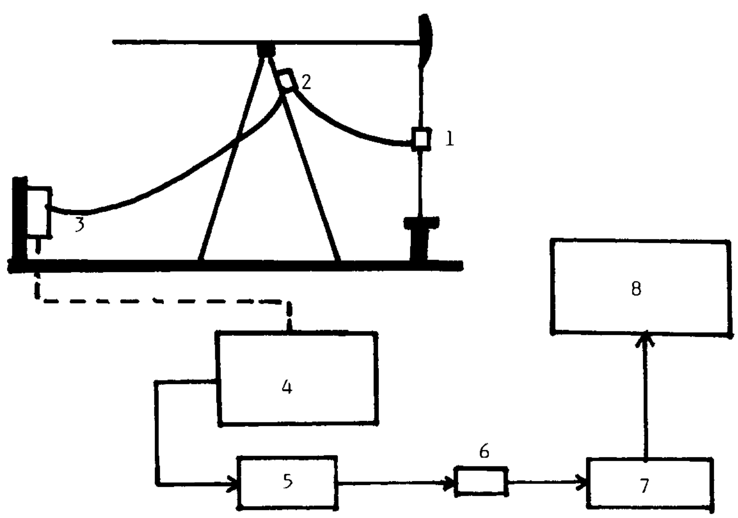

Figure 1 - Components of the DXI-30 Pump-off Controller System. 1: Load Cell; 2: Position Transducer; 3: Control Box; 4: Electronic Dynamometer; 5: Surface Data Recorder; 6: Memory Card; 7: Data Input Unit; 8: Computer

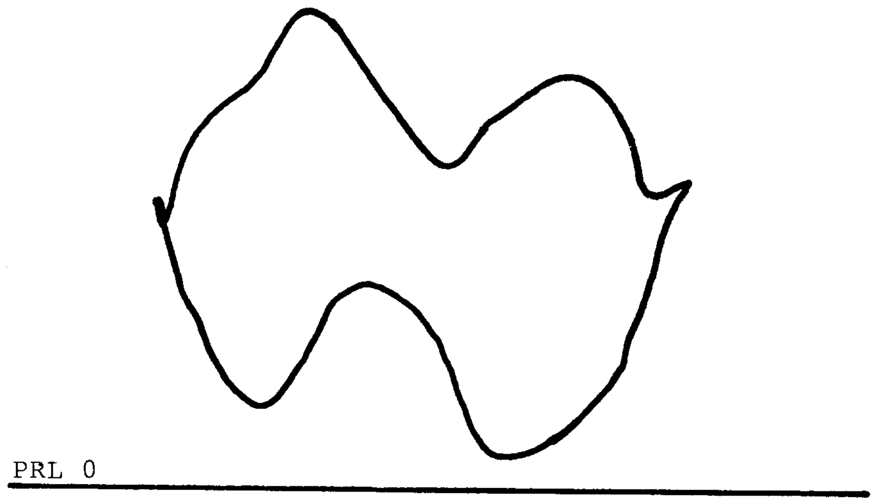

Figure 2

Figure 3

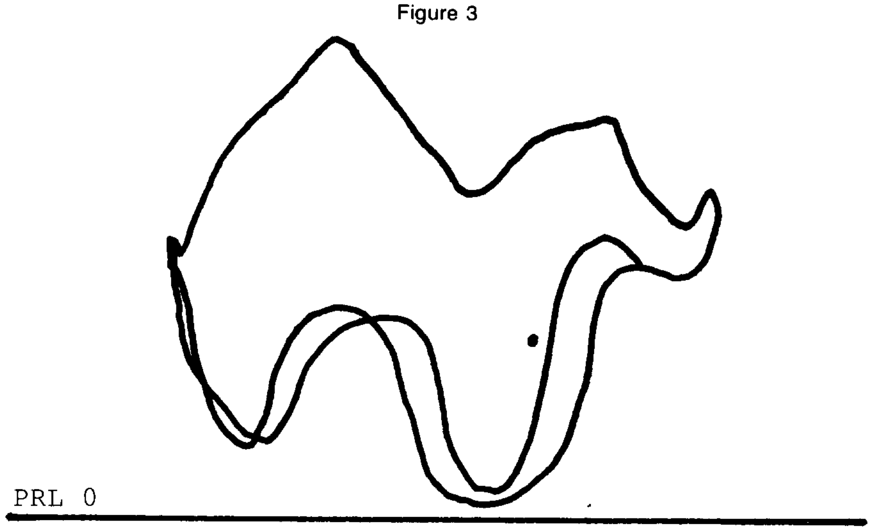

Figure 4