Automation in Cyclical Rate Primary Reservoir Significantly Reduces Beam Pump Failures

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Abstract

Conoco, Inc. operates the Dagger Draw field in Eddy County, New Mexico (see Figure 1). The field produces 2500 BOPD/8500 BWPD/11000 MCFPD from 35 wells on beam pump. The typical well utilizes an API 87 high strength rod design with either a 912 or 1280 conventional pumping unit running 8-9 SPM with a 168" stroke length. The 7,900-ft reservoir is under primary development.

A 20-month study is documented during which automated Pump-Off Controllers (POCs) were installed to reduce the high rod failure in the field. Data collected for six months prior to installation indicated that 35 wells averaged 9.8 rod failures per month. In the 14 months following POC installation, rod failures have been reduced 76% to an average of 2.4 per month. Automated surveillance of the POCs using a central computer has resulted in increased efficiency. Manpower requirements have been reduced by one employee in the field.

A previously unknown seven to eight day variable production cycle was observed field wide. This discovery helps to explain the failure of Conoco's previous attempts to control the fluid pound or gas pound with time clocks.

History

Beam pumps were installed at Dagger Draw in early 1993. The 35 high rate dolomite wells had produced for two - ten years on ESP (Electric Submersible Pump) and had declined to 400 - 700 BFPD/well. Conoco made the decision to change from ESP operation to beam pump operation to reduce operating cost.

A high strength 87 rod design was selected for all the wells based on API RP11L calculations. All installations were 912 or 1280 conventional pumping units. Sizes were dependent on fluid volume. Down hole pumps were an API insert design and ranged from 1-1/2" to 2" plunger diameter. Pumps were optimized for high compression ratio and installed 100' below perforations in the 7" casing to combat gas interference. The 2-7/8" production tubing was anchored with the pump intake set at 7,900'.

The pumping units were set up to pump an average of eight strokes per minute. To avoid over pumping, Conoco installed percentage cycle "time clocks" to assure that the wells would stop pumping when a pumped-off condition was reached. The time clocks were adjusted by the production specialist based on weekly fluid level readings. Fluid levels were measured with an acoustic well sounder. Additional time clock adjustments occurred when the production operators observed fluid or gas pounding conditions. The time clock program was followed as aggressively as possible to minimize fluid levels and maximize production.

The operators discovered that fluid levels significantly fluctuated from week to week despite their best efforts. Changes in time clock settings of up to 20% were not uncommon to compensate for varying fluid levels. Wells were frequently found in a gas or fluid pound condition and adjustments were made to decrease the pumping time. Often, upon the next visit, the operators would find a high fluid level resulting in oil production decreases. Frequent time clock adjustments continued, but no stabilized time clock setting was found.

High maintenance and down time occurred throughout the field. Rod failures averaged 9.8 failures/month for the 35 wells during the six months before POC installation. The high rod failure rate was causing 16.8 downtime days equal to 80 BOPD for the field (see Figures 2, 3, & 4).

A production technician was assigned full time to the field due to the high rod failure rates. A program was instituted to more aggressively measure fluid levels. The technician started obtaining fluid levels two to three times per week at each well. Fluid levels continued to fluctuate although measurement frequency and time clock adjustments increased. The high rod failure rate continued despite best efforts.

Failure Evaluation

In late 1993, a beam pump task force was formed to study the high rod failure rate and to provide recommendations to reduce failures. Team members were a cross section of industry. The team consisted of the production engineer, field foreman, production technician, sucker rod vendor, chemical vendor, pump vendor, pump shop repair foreman, and a Conoco beam pump professional. Team members were encouraged to explore all ideas to reduce failures.

Rod failure analysis confirmed that most of the rod failures were rod-body breaks due to compressional forces. The rod-body breaks exhibited a double tang stress fatigue pattern. This is representative of compressional stress. Dynagragh analysis supported the assumption that gas and fluid pounds were the source of the compressional forces.

The team reconfirmed the basic rod design with few recommended changes. A suggestion was made to look into automated pump-off controllers and the team unanimously agreed that several should be immediately implemented as a pilot project.

Pump-off Controller Selection

Conoco evaluated available Pump Off Controllers and selected a "load and position" type control system. Selection of the specific model was made because of the "user friendly" operator interface software and the graphics display with keypad, which is mounted on each of the controllers. It was felt that this system would make the controller significantly easier for the production operators to use and understand.

A pilot program was started and five wells were selected. These wells were selected because of their history of erratic fluid level fluctuation and high rod failures. POC installation began in February 1994. It was apparent within a few weeks that the POCs were successful. The fluid and gas pounds had been eliminated on the pilot wells and the frequent rod parts stopped. This provided the impetus for field wide implementation of the POCs. Installation of the controllers was completed field wide by June 1994.

The Pump Off Controller system consisted of the controller electronics housed in a Nema-4X fiberglass enclosure and included a 450MHZ data radio, a load measuring position (motion) measuring device, and a solid state relay mounted in the starter panel to turn the pumping unit on and off. A mounting stand, antenna, and antenna mast was also included in the installations. The operators were capable of changing set points, observing real-time dynagraphs, and retrieving data by using the keypad and graphics display on each controller. Laptop computers or other external devices were unnecessary for operator access.

Conoco selected a combination beam mounted strain gauge load transducer with an integrated position measuring device (inclinometer) from several load and position transducer options offered by the manufacturer. The manufacturer advertised the load accuracy within 5% of actual weight which was acceptable to Conoco. It was felt that the beam mounted design had the advantage of being more reliable compared to a polished rod load transducer, and because of its location, was out of the way of well servicing crews.

The microprocessor based controller accepted load and position signals through analog inputs provided on the controller. The controller then processes these signals to create a dynagraph. The controller was able to measure the load changes and to detect when the fluid level in the well bore dropped to a level where there was no longer sufficient hydrostatic head to fill the pump completely.

The POC used a patented "single set point method" to detect load changes in the dynagraph. The set point logic allowed the unit to run as long as the visible set point was inside the dynagraph (see Figure 5). The POC shut the well off when the shape of the dynagraph changed sufficiently to cause the set point to be outside the dynagraph, indicating a gas or fluid pound condition (see Figure 6). The unit remained shut down for a predetermined period of time to allow the well bore to refill.

Central POC Computer

A centralized computer system consisting of an Intel-80486 processor based PC (personal computer) was purchased. The POC manufacturer provided a "Microsoft Windows" based software package, which included a third party "SCADA" (Supervisory Control and Data Acquisition) package. The vendor's own communications and dynagraph packages were included to provide an integrated, "graphical" Automated Pump Off Control and "SCADA" system. The base station equipment included the computer, software, 450MHZ base station radio, omni-directional antenna and a "UPS" (uninterruptible power supply) in the field office. A telephone modem was also purchased.

Using the centralized computer, the operator arrives each morning and accesses alarm information from the POCs to pinpoint problem wells. The operator is able to request and obtain current dynagraphs from each well, access historical dynagraphs, and see graphical trends of runtime and polished rod load. They are also able to access all programming and set points and make appropriate changes to each from the central computer.

Practical information on the status of each well is obtained from the centralized computer, therefore problems are identified faster and the operator uses the information to prioritize his work. Deviations from the expected runtimes are used to alert the pumper to changing well conditions which may signal problems such as worn pumps, etc.

History Since POC Installations

The POCs quickly reduced failure rates once installation and calibration was complete. Compressional failures became a rare occurrence with remaining rod failures originating from corrosion pits. The rod failure rate for the 14 months following initial POC installation was reduced 76% to 2.4 failures per month. Downtime has been reduced to 5.4 days/month with production losses averaging 18 BOPD (see Figures 2, 3, & 4). Dynagragh analysis indicated full pump fillage with very little fluid or gas pounding.

Manpower requirements were initially reduced by 1.25 employees due to POC use. The operators were able to access real time well data each morning from the field office. Problem wells were quickly identified at the central computer workstation. The operators were able to go directly to the problem wells instead of using a process of elimination to find lost production.

Production technician duties changed from full time daily fluid level sounding to bi-monthly POC inspections. The production technician was able to focus his time on other fields.

Lessons Learned

Although the Dagger Draw POC installation resulted in markedly reduced rod failures, a recent lesson was learned regarding maintenance and calibration. Failure rates were low until January, 1995 when 8 rod failures occurred. Upon investigation, it was discovered that 5 POCs were in need of calibration or maintenance which had not been performed.

Following field wide POC installation in July 1994, almost no maintenance or adjustments had been made to the controllers. The production technician was being utilized elsewhere and was checking POCs only on a bi-monthly basis. The operators, although initially trained, had not worked enough with the controllers where they felt competent to make set point adjustments or other inspections. They did not understand all of the information being provided by the controllers and did not realize that well conditions had changed. Some computer programming errors were present. Thus the operational condition of the controllers deteriorated to a point where several were shut off or out of service due to set point mis-adjustment.

The POC manufacturer was contacted and performed the required adjustments. Since January 1995, rod failure rates have returned to the previous low levels. The manufacturer also provided several sessions of "on-site training" in basic dynagraph interpretation , POC troubleshooting and calibration. The office Central System computer program was also modified. It is now felt that the operators and technician can perform the required maintenance without requiring field service from the manufacturer. In addition, an outside telephone access system was installed to allow the manufacturer personnel and Conoco in Midland to view the data from the POCs via computer modem. Individual well data and dynagraphs can be directly obtained. They can now help the operators assess or interpret problems they may be having or answer any questions about the system.

January's high failure rate taught Conoco two lessons:

1. It verified the value of POCs. Failure rates increased to pre-POC levels when the units ceased to function normally.

2. POCs are not maintenance free. POC maintenance and inspection must be performed on a regular basis. The production operators must make the pump off controller a part of their overall maintenance responsibilities in the field. They must be sufficiently trained to assure that they receive full benefit from the information that the controller provides in foreseeing and alerting the operator to well problems or controller problems. Acceptance of this responsibility by the field personnel is important.

As a result of these experiences, the production technician now performs additional oversight and maintenance on a regular basis. Operators have an increased awareness of POC operation and alert the technician as problems arise. A recalculation of the manpower reduction through use of automated POCs since January reveals a long term manpower savings of one man.

Cyclic Production Trend

The POCs automatically controlled the runtime of each pumping unit based on dynagraph loads as described above. The runtime information is retained in the controller for 30 days. A graphical trend is available at each well site on the controller display or at the Central computer.

After several months of POC operations, the technician began to notice that the 30 day runtime trends were developing a pattern. It was noticed that the runtimes fluctuated throughout the field by as much as 20% over a 7 to 8 day period (see Figure 7). The cause of the cyclical production trend has not yet been identified but appears to be reservoir related. It is beyond the scope of this paper to explain the cyclic trend, but it is repeatable and has been verified over time.

The discovery of the cyclic trend verified the earlier observations of erratic performance. It also explained why the focused manpower effort in the six months prior to POC installation failed to reduce beam pump failures. Apparently the reservoir fluctuated sufficiently that it was impossible to maintain ideal pumping conditions using manually adjusted time clocks. Therefore rod pounding had been occurring despite the best efforts of the operators and technician, which resulted in the high rod failure rate using the manual time clock method.

Conclusions

1. Results of the 20 month study were favorable. Rod failures were reduced by 76% with the use of automated POCs in a primary recovery field.
2. A cyclic production trend was observed through the use of automated POCs. Runtimes fluctuated by as much as 20% on a 7 to 8 day cycle. The cause of the production cycle is not known.
3. Previous attempts at controlling fluid pound using time clocks were ineffective due to the cyclical nature of the reservoir.
4. Operational efficiency increased through central POC monitoring and resulted in a manpower reduction of 1 field employee.

Acknowledgments

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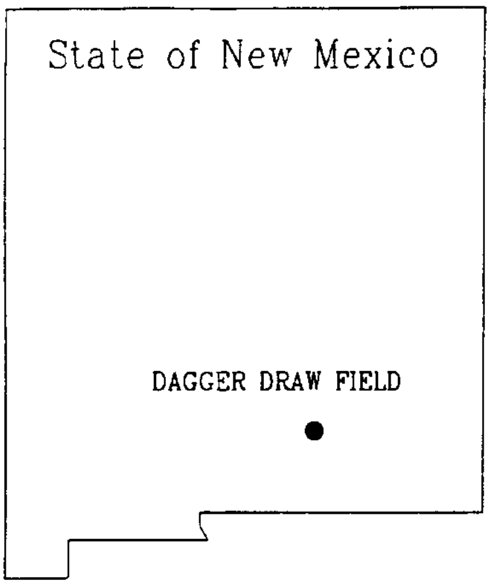

Figure 1 - Dagger Draw Field Location

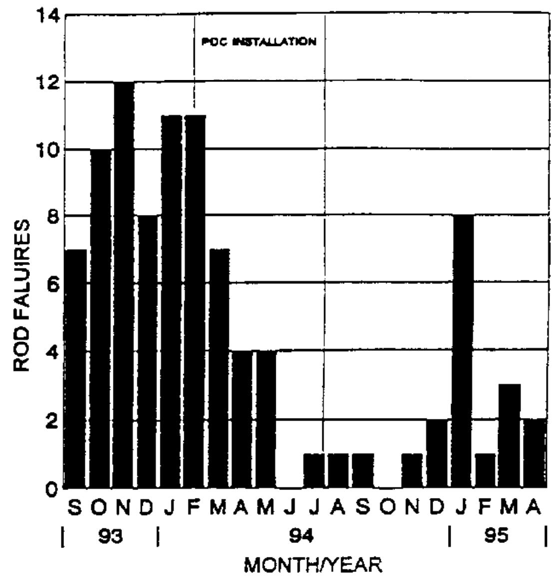

Figure 2 - Dagger Draw Rod Failures

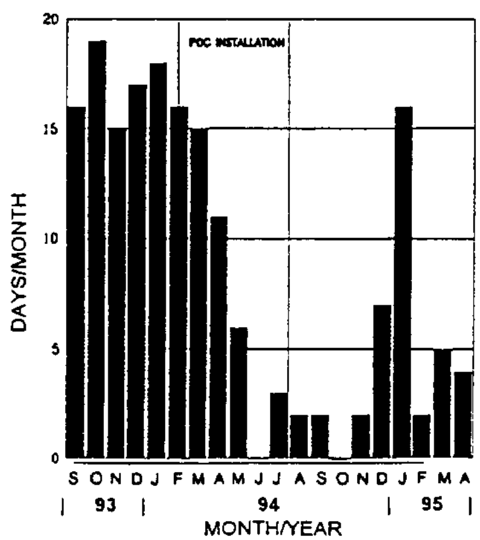

Figure 3 - Dagger Draw Downtime Due to Rod Failures

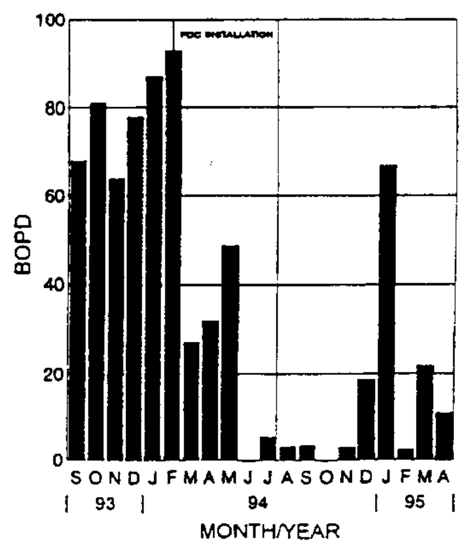

Figure 4 - Dagger Draw Lost Production Rod Failures

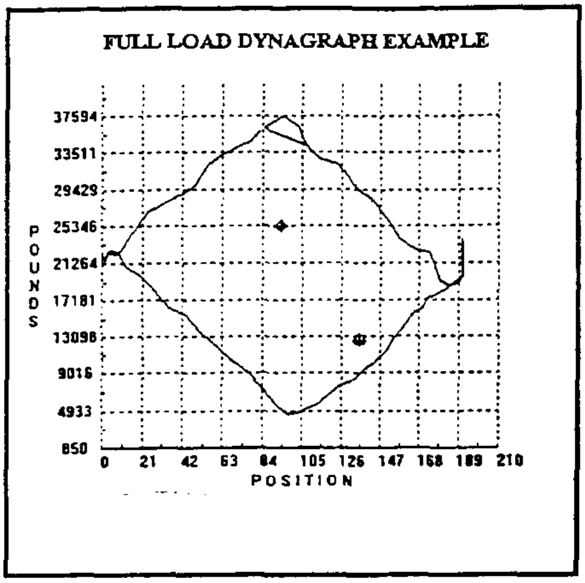

Figure 5

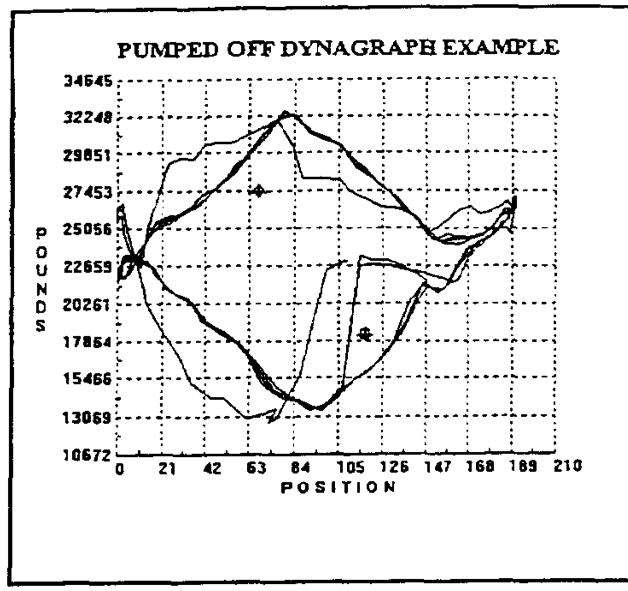

Figure 6

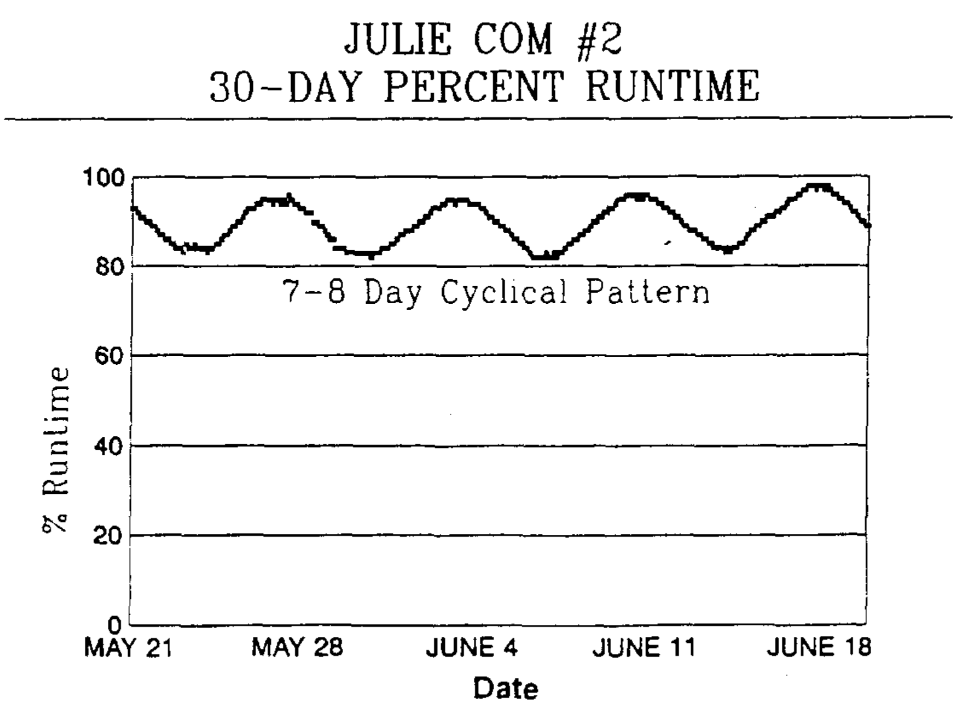

Figure 7