PUMP-OFF CONTROL, STATE OF THE ART

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ABSTRACT

Pump-off control (POC) has been employed in significant commercial quantities for over a decade and a half. However, POC has not yet gained general acceptance.

This paper considers: (1) the development of POC equipment and philosophies, (2) the current state of the art, and (3) the possible future course of POC.

INTRODUCTION

Pump-off control (POC) is one of the relatively new applications of electronic technology to be applied in oil production operations. The feasibility of pump-off control has been greatly enhanced by the advent of low-cost linear and digital integrated circuits.

The objective of pump-off control is to increase operating efficiency of a rod pumping system through minimizing cavitation of the pump. Reduced cavitation results in longer pump runs, fewer rod parts, reduced power cost, and reduced wear on surface equipment.

Approximately 25,000 of the 600,000 rod-pumped wells in the United States are equipped with pump-off control equipment of some type.

WHERE WE HAVE BEEN

A rod pump is a positive displacement device and it is extremely difficult to exactly match the displacement of the pump to the productivity of the well. One of the first jobs that pumpers had was to regulate the pumping time or pumping speed to try to match displacement to well production.

With the arrival of field electrification, time clocks were used to regulate pumping time. Later, the percentage timer, a special type of time clock, was used. Untold man-hours have been spent in arriving at the "proper" setting for time clocks. Even with all the effort put forth, the effectiveness of time clocks leaves much to be desired.

Beginning in the mid-1960s, a number of attempts were made to develop a reliable automatic pump-off controller. Some of the earliest attempts used flow/no-flow devices in an effort to detect a fluid reduction in the pumping system. Some of these efforts had conditional success but the applications were limited, and the system required assiduous maintenance.

A number of endeavors to use motor current met with moderate success.

None of the vibration detection schemes attempted were commercially successful.

An electromechanical load/position system was used with some success in the late 1960s and early 1970s. While the concept was sound, the system hardware was prone to high failure rates.

In the spring of 1970 the first commercially successful fieldwide pump-off control installation was made in Mobil's East Mallet Unit in West Texas. The system was based on the analysis of rod loading by a minicomputer. Each well was equipped with a beam-mounted load transmitter. (Polished rod mounted load transmitters were tried but were found to lack the reliability of the beam-mounted units.) The end device transmitted load information via wireline to the central computer. All control logic was located in the central computer. This system remained in operation until late in 1986, when it was upgraded to a microprocessor-based field system.

As a result of the success of the central control system using rod loading, an analog stand-alone controller was developed. From 1972 to the present, over 10,000 of these controllers have been installed on beam-pumped wells.

In the early 1970s a motor-current-averaging POC was introduced. It, too, met with moderate commercial success.

In the mid-1970s, fieldwide installation of POC was made in a major field in West Texas. The system uses load and position measurement at the well connected to a central logic computer via wireline. The system has been in continuous use for the past 15 years.

In the early 1980s a number of microprocessor-based POC systems appeared on the market. Most of these systems use a version of the load at a point in the stroke logic. (See Reference 4.) Exceptions are a system that monitors changes in primemover shaft speed and a system which integrates the area between a reference point and the downstroke load.

WHERE WE ARE

Several thousand pump-off controllers have been installed in just about every conceivable operating condition. Numerous examples of entire fields using stand-alone and supervisory control can be cited. Over two decades of experience have shown the equipment to be accurate and reliable.

A considerable body of incontrovertible evidence attesting to the economic viability of pump-off control currently exists. In the majority of cases, return on investment has been shown to be greater than 100 percent per year.

For the convenience of those not familiar with the statistical economics of pump-off control, the average ranges are:

Reduction in run time - 30-40 percent
Reduction in power consumption - 18-33 percent

Reduction in pulling cost - 25-35 percent
Production acceleration - 1-7 percent
Payout - three months - one year

The following is a conservative estimate of the economic impact that POC has had on the oil industry:

Assumptions: 25,000 controllers installed
Average time in service - five years
Average cost (1988) funds - $1000
Payout - 0.25 year to one year

Return at one-year payout:

$1000 investment per controller x (5 years service / 1 year payout) = $5000 return per controller.

$5000 return per controller x 25,000 controllers = $125,000,000.

Return at three-month payout:

$1000 investment per controller x (5 years service / 0.25 year payout) = $20,000 return per controller.

$20,000 return per controller x 25,000 controllers = $500,000,000.

In the face of such experience and evident economic benefit, one would assume that all producers operating beam-pumped wells would be well under way toward total exploitation of the capabilities of POC. Such is not the case.

It is estimated that no more than 25,000 POCs have been installed in the past 20 years, for a twenty-year average of 1250 units per year. That amounts to less than five percent of rod-pumped wells. The current market is certainly not over 3000 units per year.

Inasmuch as a substantial amount of money and operating efficiency is at stake, at least a cursory analysis of the situation would seem to be in order.

The Vendors

Between 1968 and 1988, no less than twelve (12) POC vendors entered and departed the arena.

There are currently three to five viable POC vendors (depending upon how "viable" is defined) vying for a portion of this relatively small market. Of these vendors, only two have as much as six years of experience in the field. (Both of these companies are over 15 years old.)

The vendors fall into three broad categories:

1. Divisions of large companies
2. Companies with other product or service lines with POC as an adjunct
3. Companies with POC as a primary product line.

Companies in each of these categories are included in the group which have failed and those with current offerings. It is worth noting that the two oldest POC vendors have POC as a primary business objective.

The Users

Users fall into four categories:

1. Companies dedicated to implementation of POC in all reasonable applications -- typically with large-scale, widespread utilization of POC.

   One common characteristic of these companies is a department which is charged with the exploitation of automation in the producing operation. The existence of a group dedicated to the design, installation and enhancement of automation systems provides a level of continuity for automation projects not otherwise possible.

2. Companies with some applications but little inclination toward widespread implementation, characterized by a few installations but with no clear plan for future projects.

   Typically, the existing projects were inspired by one or more individuals with an interest in POC. When these individuals were transferred to other areas of responsibility, the POC project was left with no particular "champion."

   With little continuity in the implementation of POC, growth is slow and painful.

3. Companies with apparent interest in the subject of POC but few applications, distinguished by a past of current "evaluation" projects.

The single item that all these user companies share is that they are faithfully following the policies of their managements. The salient question would seem to be, "Why such a wide divergence in operating philosophy?"

It would appear evident that the decision to use or not to use POC is not based entirely on economics. Companies which make extensive use of POC tend to require justification for NOT installing controllers on a property. On the other hand, companies not committed to POC require extensive economic justification.

Different operating companies have varying concepts as to the best way to acquire and to exploit a producing property. It should not be surprising that they have diverse opinions on the proper role of automation in general and POC in particular.

Some of the aspects which MAY enter into the establishment of attitudes toward POC could be: previous results from automation, perceptions of return on invested money and manpower, depth of experience with POC, philosophy of manpower utilization, and staffing level.

The Equipment

Pump-off control equipment has undergone a significant change during the past several years. Early POCs were rather simple and were designed for the single task of detecting and controlling fluid pound. Considering this restraint, they did a credible job of fulfilling their required task.

In the early 1980s, the microprocessor was introduced to the POC. The advent of use of microprocessor technology in the detection and control of pump-off introduced the possibility for the collection of large amounts of data. While neither the vendor nor the user had a clear understanding of just how to use the acquired data, provisions were made for its collection and storage.

While there is little inherent wrong in doing something just because it is possible, there is a great danger in losing sight of just what is set out to accomplish. The current objectives of installing a pump-off controller are today less clear than before the advent of microprocessor-based units.

The ambiguity in application of POC arises from the fact that POCs are no longer just "pump-off controllers." While they continue to perform the pump-off detection and control functions, their role as data collection devices has been greatly expanded.

It probably is not totally accurate to assert that there is any mystery associated with the type and amount of data to be saved. There seems to be unanimity on the philosophy of "save everything forever." It is difficult to fault this approach, in that the possibility for serendipity does exist.

Load Measurement

An example of the lack of agreement on the basic nature of POC can be seen in the divergence of opinion on the nature and types of transducers most suitable for the task.

Two techniques exist for measurement of rod loading. Each technique has its advantages and disadvantages.

The most obvious and oldest method for measuring rod loading is to directly weigh the rod string by installing a load transducer between the carrier bar and the polished rod clamp.

Advantages: This measurement system has the advantage of an initial high degree of accuracy, in the order of one percent of full scale. Minimum to no calibration is required when initially installed. The device and its operation are easily understood.

Disadvantages: The location of the transducer subjects it to tremendous abuse from shock loading associated with sticking pumps and occasional rod breaks. When the transducer is oversized to protect it from overloading, measurement resolution suffers. The long-term accuracy of the measurement is questionable because of cumulative damage during operation. The transducer and its associated signal cable are subject to damage from mishandling during servicing operations. Great care must be taken in the installation of the signal cable to prevent damage during operation.

The alternate method of load measurement is the attachment of a load transducer to the pumping unit structure. The preferred location is on the walking beam, forward of the saddle bearing.

Advantages: The transducer becomes a part of the structure and is therefore subjected to no more mechanical overloading than the pumping unit itself. Few cases of damage occur during servicing operations. Maintenance cost for this type of transducer system is an order of magnitude less than the rod-mounted system.

Disadvantages: The accuracy of this system is in the range of three to five percent of full scale. Calibration is required at installation. Signal compensation is required to correct for changes in pumping unit structure as a result of differential heating.

Position Measurement

Two techniques exist for determining the position of the polished rod during the pumping cycle.

The most obvious method of position measurement is the use of a variable resistor connected to the walking beam. The potential across the leads of the device is proportional to the position of the walking beam and, therefore, the polished rod.

Advantages: The technique provides a direct measurement of the parameter of interest. Little or no calibration is required at installation.

Disadvantages: The life of the transducer is limited by mechanical wear. Installation is somewhat more difficult. Dynagraph data is doubled, increasing required data transmission time.

The second method for polished rod position detection uses a measurement of position at one point in the stroke. The remainder of the stroke position information is then derived mathematically from the period of the stroke, the geometry of the pumping unit, and the slip characteristics of the primemover.

Advantages: There are no moving parts. There is long life and low maintenance and a reduced requirement for dynagraph data transfer.

It should be noted that the disagreement over the form of load and position transducers is not related to the POC function but rather to the diagnostic requirements of the controller.

WHERE ARE WE GOING?

Given the current state of affairs, it seems likely that POC will continue to evolve as a pumping well manager. Continued investigation of the available data will establish additional worthwhile functions for the controllers to perform. In view of the considerable computing capability available with today's technology, it is reasonable to expect that more and more of the traditional MTU functions will be moved to the POC.

The current trend of "Wellhead Manager" hardware, in which only firmware is changed to fit different functional applications, will continue.

Acceleration in the rate of acceptance of POC by users would be very surprising.

SUMMARY

1. POC is not a generally accepted tool in oil production operations.
2. Current vendors are adequate in quantity and quality to fill industry demands for now and the foreseeable future.
3. Economic return on investment is not a major consideration in establishing criteria for implementing pump-off control.
4. POC is in the adolescence of its second generation.
5. A general direction for maturity is emerging but is not yet totally defined.
6. Presently available hardware is currently fully capable of filling present requirements.
7. Present firmware is very capable but is still evolving.

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