ALWORKS - AN ARTIFICIAL LIFT SURVEILLANCE TOOL

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ABSTRACT

More effective use of computing tools for production surveillance by operations and engineering personnel is critical to increases in profitability. Exxon's ALWORKS (Artificial Lift Workstation) is a software package that provides easy access to electronically stored data and provides that data to various surveillance, analysis and design applications with minimal user effort. The software has been field tested and significant increases in productivity by operations personnel have been observed, which will lead to increases in profitability.

INTRODUCTION

One of the major challenges of oilfield operations today is performing adequate surveillance of producing operations to support efforts to maximize production and minimize operating expense. Although many fields have automated data gathering facilities, the data are not always used effectively. A common reason is that the data are frequently stored in mainframe computer databases and are not easily available to operations personnel who have direct responsibility for insuring that production is maintained and expenses are kept low. Even engineering support personnel are limited in their ability to perform analysis and design of producing equipment in today's environment of decreasing staff and increasing responsibilities. Although new computing tools are useful in helping increase productivity, to be most effective, they have to be part of a larger effort that involves training personnel to use the tools and reorganizing (if necessary) to ensure that all critical tasks can be handled by the available staff.

Exxon Production Research and its operating affiliates have cooperated since 1989 in developing ALWORKS, an improved system of performing artificial lift surveillance, and have successfully tested the system in a large, mature waterflood operation in an Exxon Co., USA operated field in the Permian Basin. The success of ALWORKS in Exxon operations has come in part from having field operations personnel involved from the start. The pilot was implemented at the field level and was successful because the field had ownership in the applications and the process from the start.

SYSTEM DESCRIPTION

ALWORKS is an acronym for Artificial Lift Workstation. It is a PC-based production surveillance computing system that provides the following key elements:

- Graphical interface to software for ease of use
- Data management system that facilitates transfer of data to and from applications and that can access electronically stored data (mainframe, LAN, or PC-based) using Windows® software
- Data graphing software for trending and visualization
- Artificial lift analysis and design applications that function in the Windows® environment

The purpose of ALWORKS is to provide a package of diagnostic and design tools with easy access to data to be used to perform artificial lift surveillance by both engineering and field operations personnel.

Graphical Interface. A graphical interface was key to the concept to insure ease of use by both operations and engineering personnel. Early in the project, Microsoft introduced Windows® and this environment was adopted as the preferred means for data entry and results review. The choice has proven to be of value even greater than just ease of use. Consistency between applications is also improved, reducing the training time required to learn new applications.

Other office productivity applications such as spreadsheets and word processing for report preparation have become staples in engineering and operations environment. ALWORKS software is compatible with many of these programs through standard Windows® Dynamic Data Exchange (DDE) function as well as Object Linking and Embedding (OLE).

Data Management. A key component of the computing system is the central Data Manager. This commercially available software allows data to be retrieved from electronic data stores, placed temporarily in a separate database, and then made accessible to all applications that could use that data through the Windows DDE function. The role of the Data Manager as it relates to the other computing applications and to the data stores is represented in Figure 1.

Another feature of the Data Manager is its geographical data selection capability. Data are retrieved for a well merely by selecting a well icon on a map (or a well name from a list) and clicking on it. No complex computing commands are required. Figure 2 shows a typical field map used for the well selection process.

Data Graphing. Graphing of historical well performance data is a key element in most field surveillance programs. Obtaining the data through the graphical (map-based) interface with the Data Manager and selecting either a standardized plot or customizing one for specific needs is an easy task. Graphing of a single well or multiple wells can be done with a few clicks of the mouse. Productivity can be improved over most usual forms of data collection and analysis, even using spreadsheets and PC software. The application is fully customizable to meet the users needs and requires only basic computing skills and a little training to use it effectively. Figure 3 is an example of one of the many graphs that can be generated for trend analysis.

Analysis and Design Applications: As shown in Figure 1, in its broadest view, ALWORKS includes gas lift, rod pumping, and electric submersible pumping software applications. Not all will necessarily be used in each field. Only those that are relevant would be installed and used to minimize training and conserve computing resources (primarily hard disk space). For example, gas lift applications may not be installed in a field where only rod pumped wells existed. Table 1 provides a brief description of the various applications.

Earlier pilot projects in Canada demonstrated the utility of the gas lift applications. This paper focuses on the pilot test of the rod pump analysis, design, and data trending software.

ALWORKS DEVELOPMENT HISTORY

ALWORKS began in 1989 as a concept by engineers in Exxon's Canadian affiliate, Imperial Oil Resources, Ltd. Their concept was presented to Exxon Production Research (EPR) and the idea was supported by EPR management. A team was formed with members from other operating affiliates, including Exxon Co., USA. After pilot testing a gas lift version of the concept in Canada in 1991, the concept was expanded to include rod pumping applications. From 1992 - 1995 EPR worked with Exxon Co., USA's Midland Production Organization to develop rod pump system design and dynamometer analysis applications and to make the necessary production and well data available for improved surveillance. The effort culminated in a field pilot test of the rod pumping software.

ALWORKS ROD PUMPING PILOT

A field pilot test of ALWORKS was performed so that actual results of its use could be observed and measured. The objective was to determine if the use of ALWORKS could be justified in other field locations.

The pilot was implemented in a mature waterflood in the Permian Basin. The field has over 1100 wellbores, with approximately 600 active producers. The majority of the wells are rod pumped with a few wells produced by electrical submersible pumps. In the past, most wells were not evaluated until they failed. Proactive surveillance to catch problems before wells failed was difficult because of the number of wells involved and because of the several hours required to evaluate each well.

Pump off controllers (POCs) aided in maximizing production and providing a tool to screen well problems quickly. ALWORKS enhances the benefits from the POCs by using the POC data in conjunction with other well data. Through use of the Data Manager, data are directly input to the various analysis and design applications and within minutes the user can recommend action on a well.

Prior to beginning the pilot, field personnel were involved in the development of ALWORKS through such activities as data transfer, beta testing of rod pumping software, and beta testing of the wellbore sketch utility and data trend analysis tools.

In order to implement a proactive artificial lift surveillance plan, the duties of some field operations personnel were changed by focusing their responsibilities on production analysis and surveillance as it relates to artificial lift systems and waterflood balancing. The ALWORKS pilot involved at least six users in the field and an engineer and engineering technician from the production office. The main purposes of the pilot were to:

- fully test all applications using the database manager,
- to test the technical ability and verify the correctness and accuracy of the rod pumping software applications, and
- to determine the benefit in implementing ALWORKS in other fields.

VERIFICATION OF CALCULATION ACCURACY

One of the main benefits that was hoped to be achieved through the use of more sophisticated rod pump analysis techniques was the ability to calculate pumping fluid levels based on production data and POC dynamometer data. The objective was to use a measured surface dynamometer card to calculate a downhole dynamometer card. From a downhole card, one can determine the fluid load on the pump, and therefore calculate the pump intake pressure. With pump intake pressure, fluid level can be determined.

Although wave equation programs for modeling rodstrings and pumping units have been demonstrated to perform with acceptable accuracy, it was necessary to confirm that the calculated values provided reasonable matches to measured data. To achieve this, a total of 48 wells were tested. Measured fluid level data was obtained by use of the acoustic fluid level sounder and dynamometer cards from the POC were interpreted using the rod pumping analysis application to calculate a fluid level. The calculated and measured fluid levels were compared and are shown in Figures 4 and 5. The results of the comparison indicated that for API Grade D rods (Figure 4), the calculations were consistent and accurate to use for fluid level determination for production optimization and waterflood balancing requirements. Figure 4 shows that for shallow fluid levels (e.g. 3,000 feet above pump) the calculated fluid level can be up to 20% off the measured fluid level. However, for fluid levels closer to pump depths (approximately 6,500 feet for this field) calculated fluid levels are much closer to the measured fluid levels. The benefit is to be able to historically trend fluid levels and be able to determine when fluid levels are rising or falling. The software is consistent and provides the ability to perform this trend analysis on fluid level determination. Greater uncertainty was observed in wells having high strength rods or wells with sections of fiberglass rods. Both of these rodstring types are more sensitive to data errors than is API Grade D steel rods, and it is not clear whether the inaccuracies observed were due to data errors or calculation problems. Other commercially available software was also used to check the calculated values, and similar results were obtained in most cases.

Further verification of the calculation accuracy was done with the use of a downhole dynamometer. The preliminary conclusions from this work showed that the rod pumping software used in ALWORKS is within 5% in predicting rod loadings. The measured downhole dynamometer card matches very closely with the predicted downhole dynamometer card from the software.

MEASURES

The pilot team developed measures for determining the actual benefit of ALWORKS over the previous process described above. Users tracked the number of evaluations performed per work week along with the time savings associated with using ALWORKS as compared to the old process of data gathering off the mainframe databases. The results of this tracking are shown in Figures 6 and 7. Note that there was a fairly quick learning period (see Figure 6). Productivity increased rapidly to around 135 full evaluations per work week and 185 data trend analyses per work week. Figure 6 shows

the number of evaluations performed per user normalized to a 40 hour work week. The operations personnel doing these evaluations have other duties, therefore they were not spending full time on well evaluations. However, with the new tools, they were able to greatly increase the number of well evaluations that were performed.

A full "artificial lift evaluation" consists of:

1. performing a trend analysis of production data and failure history
2. diagnosing dynamometer cards to determine subsurface and surface equipment performance, and
3. redesigning the surface and downhole equipment to maximize production

A full evaluation may also involve trend analysis of offset wells that may affect the performance of the studied well.

A "data trend analysis only" is step one above.

In order to perform an evaluation without ALWORKS, the user was required to use the following procedure:

1. Retrieve data from four or more mainframe databases
2. Retrieve dynamometer card data from separate POC computer system
3. Retrieve data from paper well files
4. Input data to spreadsheet
5. Create graphs and charts to allow trend analysis to be performed

This process could take about 225 minutes (see Figure 7), depending upon the level of graphing performed.

Users also ran numerous comparisons of fluid level calculations using the software versus the actual measured fluid levels measured with an acoustic measurement devices. See Figures 4 and 5.

BENEFITS

One of the main benefits of ALWORKS is the easy access it provides to the data. The time spent in data gathering and manipulation is significantly reduced. The user points to a single well (or group of wells) on a map on the screen and within seconds, several applications are accessed to use in the evaluation of the desired well(s). (See Figure 2 for an example of the graphical representation of the wells.) Historical performance data is graphed to enable the user to determine past successful and unsuccessful work. (See Figure 3.) Current performance data is used in the rod pumping software to diagnose problems with the well and is also used to decide what to change or fix that will increase production or reduce probability of failure or reduce operating expenses. Several cases can be run simultaneously to determine which pumping unit system design is optimal. The goal is to maximize oil production without sacrificing long run times (no equipment overloaded) at the lowest investment and operating cost possible.

A cost benefit of ALWORKS lies in the rod pumping analysis software which calculates accurate producing fluid levels for wells with API Grade D steel rods and reduces the need to obtain acoustic fluid level measurements to determine if more fluid could be produced. Because of limited company personnel and cost of purchasing the acoustic fluid level measurement equipment and maintaining it, this service is usually contracted to a third party. This contract service can be greatly reduced and possibly eliminated with the calculated fluid levels from the rod pumping software. In addition, where fluid level measurements were obtained maybe once or twice per year per well, now a fluid level can be calculated as often as new data are available. Theoretically, this could be as often as daily if such a frequency were desired. With more data available, problems could be detected sooner, especially in a waterflood where injection is changing constantly, and thus, producing fluid levels do not stay constant.

Another cost savings is decreased downtime of the failed well. An evaluation can be performed as soon as notification is given on a failed well and a recommendation can be made within the same day. Realistically, a well can be rigged up on the same day or the next day following diagnosis of a problem, be repaired and back on production very quickly.

Through proactive surveillance of rod pumped wells many optimization opportunities can be found. Simple procedures, such as speeding up units or increasing stroke lengths on existing systems, or swapping for a bigger, surplus pumping unit can lead to significant increases in oil production at very low cost. Other opportunities, such as evaluating for high strength rods or fiberglass rods or larger bore pumps (tubing pumps) can be more costly but they can also reap benefits of more oil production. With the use of ALWORKS, these opportunities are much easier and quicker to identify on a regular basis rather than waiting for a well to fail before evaluating possible improvements. Also, with the use of ALWORKS and the rod pumping software, better rod pumping systems are designed before installation, thus wells run longer between failures. Therefore, regular optimization checks are that much more important than allowing a well to fail, which may take years, before optimizing its design.

An intangible benefit that is difficult to quantify but is easy to recognize and appreciate is the increased ownership in the data by the field personnel. Before, with mainframe computer response slow in the field locations and with most of the responsibility of the wells placed on technical staff in the office, field personnel collected and input the data, but never used the data to make recommendations on wells and their production performance. Now, field personnel are seeing the data very simply, then using the data to make recommendations that affect producing wells and their performance. This gets the data back into the hands of those who know the data best and have direct responsibility for maintaining production.

CONCLUSIONS

The work presented in this paper demonstrates that by having a vision and incorporating the key people to make the vision happen, the benefits can be rewarding. Increased oil production and lower operating costs are the drivers in petroleum production in the United States today. The conclusions of the development and pilot of ALWORKS are as follows:

1. ALWORKS provides easy access to data and to artificial lift tools that use the data to aid in maximizing oil production and reducing operating costs.

2. ALWORKS has successfully been implemented in a pilot test in a large, mature waterflood in the Permian Basin. From implementation of the pilot, key benefits were realized:
   a. Savings in contracted acoustic fluid level measurements used to determine producing fluid levels. With the calculated producing fluid level from dynamometer data off the POC, measured fluid levels are no longer needed on a regular basis for all wells.
   b. There is significant time savings associated with an evaluation of a rod pumped well leading to a recommendation of optimizing or designing a new system for the desired well. With the time savings, many more wells can be reviewed and more opportunities can be identified to increase production and/or decrease operating expenses.
   c. With creative organization of field personnel, artificial lift surveillance and responsibilities and the day-to-day response to failures and optimization efforts can be handled without the need for a full time engineer or engineering technician looking after the field. This vision aligns with current industry trends of reorganizing to reduce technical staff and to keep the artificial lift surveillance in the field where staff continuity is greater.

ALWORKS is a computer application that, with only minimal training and dedicated support, can be a powerful tool to affect a company's bottom line profit. ALWORKS provides easy access to data quickly and links it to all kinds of artificial lift applications from rod pumping to electrical submersible pump to gas lift to enable quick, thorough and efficient designs for optimizing artificial lift.

Table 1
ALWORKS Analysis, Design, and Reporting Computer Applications

APPLICATION	FUNCTION
Gas Lift Design	Gas lift valve spacing and pressure setting design
Gas Lift Allocation	Gas lift gas allocation optimization
Rod Pumping Diagnostic Analysis	Rod pump dynamometer card analysis using wave equation
Rod Pumping Design	Rod pump design using wave equation technology
Nodal Analysis	Wellbore inflow-outflow nodal analysis
Wellbore Sketch Utility	Wellbore diagram sketching
Data Trending	Data graphing, plotting, charting, trending
ESP Design	Electric submersible pump sizing design

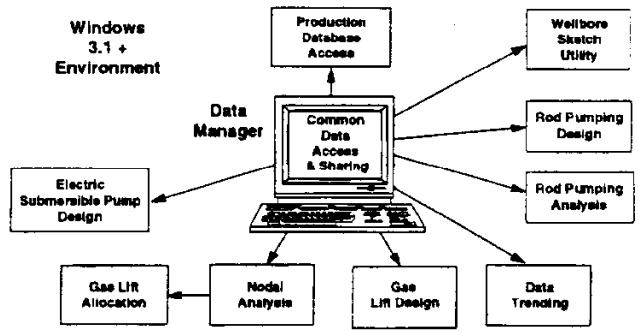

Figure 1-ALWORKS Architecture

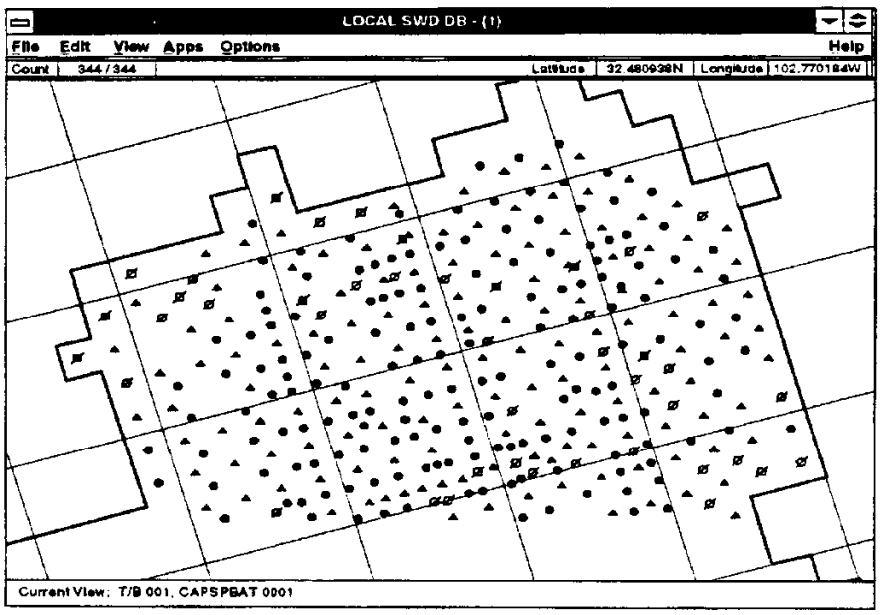

Figure 2 -ALWORKS graphical well selection scheme.

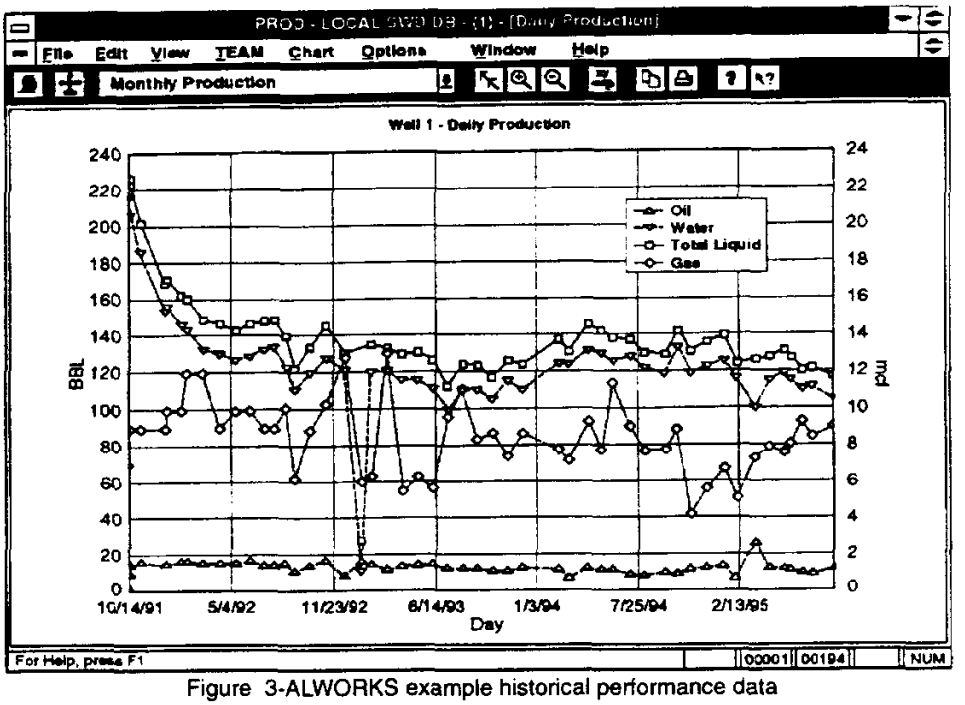

Figure 3-ALWORKS example historical performance data

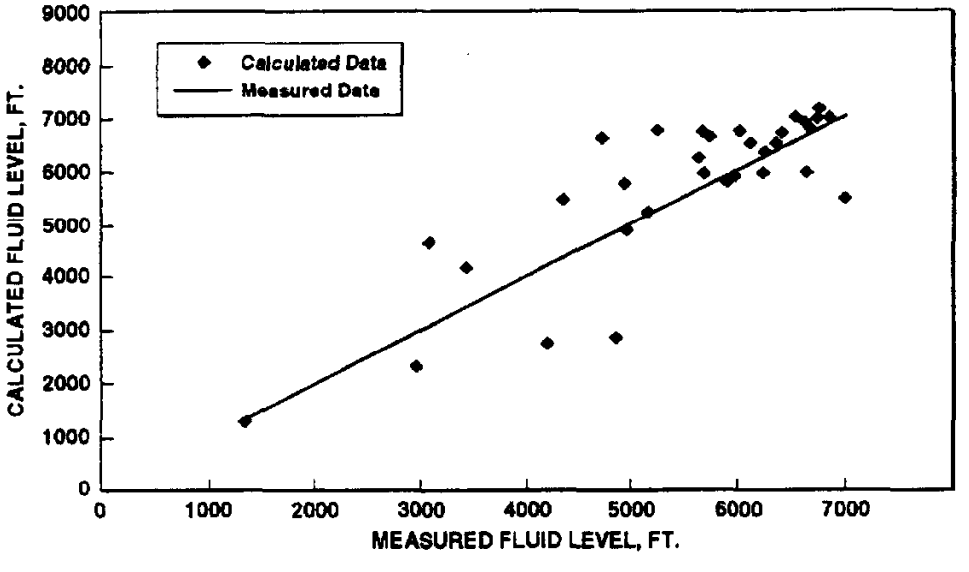

Figure 4-Measured vs. calculated fluid levels for API grade D steel rods.

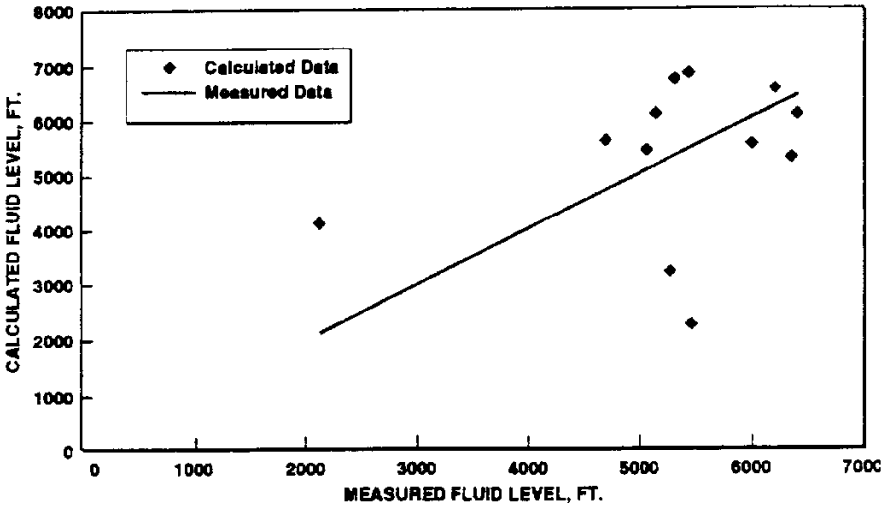

Figure 5 - Measured vs. calculated fluid levels for fiberglass rods.

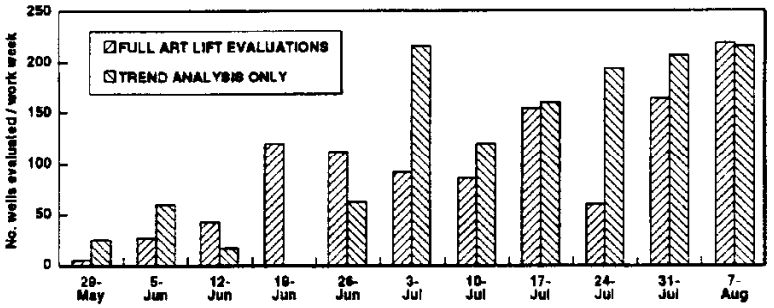

Figure 6 - ALWORKS evaluations per work week.

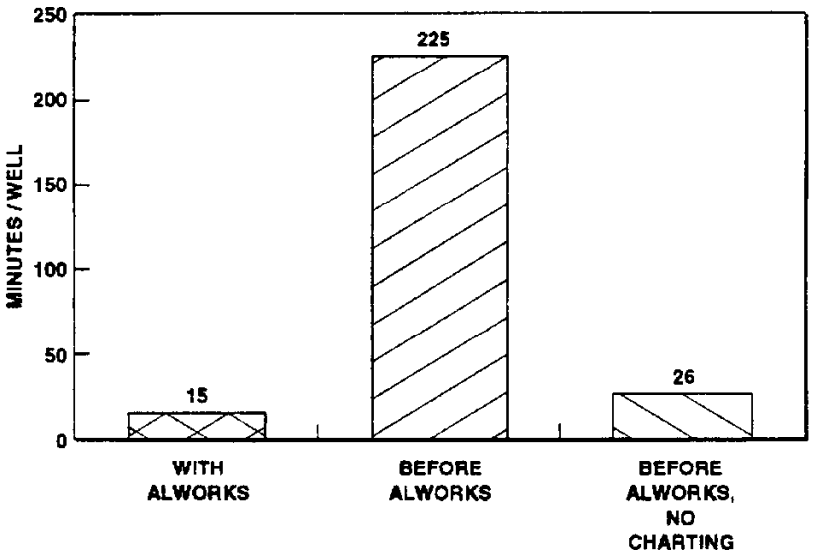

Figure 7 - Benchmark time for artificial lift evaluations