WIRELESS COMMUNICATIONS BASED GAUGE SYSTEM FOR ARTIFICIAL LIFT SYSTEM OPTIMAZATION

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INTRODUCTION

The complexity and cost of exploring for oil and gas has increased significantly in the past few years due to Intelligent Wells, Multilaterals and Heavy Oil field developments. New challenges for drilling, completing, producing, intervening in a well, environmental regulations, and wide swings in the price of oil have changed the role of technology in the oil fields. The industry is relying on technology to affect the costs of exploring for hydrocarbons in the following ways:

- *Reduce operating expenses* (OPEX) by automating the processes used to explore and produce hydro carbons, reducing the frequency of unplanned intervention, and improving information and knowl edge management to decrease operating inefficiencies.
- *Increase net present value* (NPV) by providing systems that enhance the recovery of hydrocarbons f rom reservoirs. The new technologies improve production techniques to delay and/or reduce the production of water from downhole.
- *Reduce capital expenditures* (CAPEX) by creating processes that will decrease the number of wells drilled and that will reduce the number of surface facilities required. The surface equipment require ments to handle increasingly larger quantities of hydrocarbons at these facilities should also decrease with the implementation of new technologies.

New processes for drilling, completion, production, artificial lift, and reservoir management have been created by advancements in technology in fields such as high temperature sensory, downhole navigation systems, composite materials, computer processing speed and power, software management, knowledge gathering and processing, communications and power management. Horizontal drilling and new fracture techniques have allowed operators to produce hydrocarbons profitably from areas that were uneconomical just a few years ago.

Sensor technology in conjunction with data communications techniques provide on-demand access to the information necessary to optimize hydrocarbon production levels and achieve costs goals. Surface and downhole sensors are changing the way hydrocarbons are produced by optimizing production from downhole, supporting extend the life of artificial lift systems and providing information used to update reservoir and production models.

A new technology that combines sensors with wireless telemetry provide the operators with new versatility and capability to place sensors in areas of the wellbore that were prohibitive due to technical difficulties and/or economic justification. The ability to communicate in and out of the wellbore using wireless systems can increase the reliability of the production system and decrease the amount of time required for the installation of the completion hardware in the wellbore. The elimination of cables, clamps, external pressure and temperature sensors, as well as splices on the cable that can fail inside the wellbore provides a significant advantage when attempting to place sensors in wellbores to monitor production or to optimize the pumps used in Artificial Lift applications.

WIRELESS WELLBORE DIGITAL DATA COMMUNICATIONS AND SENSING SYSTEM

The wireless wellbore digital data communications and sensing system provides the capability to communicate through the production tubing using stress waves to transmit and receive digital data and commands inside the wellbore. The system provides information from inside the wellbore that is transmitted at intervals determined by the customer and programmed before the tool is inserted in the well. The system is composed of the wireless transmission hardware, microprocessor system for data acquisition and power management, pressure and temperature gauges, a power generation unit and a surface SCADA box for data acquisition and processing.

The wireless transmission hardware creates the acoustic signals from electrical pulses generated by the electronics system. The acoustic waves are coupled to the production pipe minimizing the amount of energy losses having a very tight fit between the acoustic generator and the production pipe. The waves travel up the pipe to the surface in a

compression mode minimizing losses related to fluid coupling and tubing threads.

The electronics system provides the process control, data acquisition, data processing data encoding and operator interface. The system provides a power saver mode while in the wellbore to maximize the downhole power efficiency. The electronics samples and digitizes the information from the gauges at specific time intervals programmed before the tool is deployed inside the wellbore. The data is processed and encoded for transmission to the surface to minimize the number of bits of data required to be sent to the surface. The microprocessor then generates the electrical pulses used to drive the acoustic generator to produce the information related to the pressure and temperature data obtained inside the wellbore. Upon completion of the transmission of the information to the surface the processor places the tool in a power saver mode until it is waken to perform the data acquisition tasks again.

The sensors are composed of silicon on sapphire pressure gauges and thermocouples for sensing temperature. The sapphire gauges provide a high resolution pressure measurements on the annulus and tubing while the thermocouples located inside the pressure assembly measure temperature for pressure compensation and for well monitoring. This new sapphire technology eliminates the well fluid coupling requirements to maintain the sensor assembly free of well contamination. The sapphire is in constant contact with the wellbore fluids to provide a more accurate measurement of the pressure. Higher stability is also a major advantage of the sapphire gauges over strain gauges. The gauges are also built into the tool eliminating any outside connections.

The power for the operation of the tool comes from batteries located inside the tool. The battery cells can provide power for the tools to operate continuously inside the wellbore for 3 years. The life expectancy of the tool will vary with the data rate, well temperature, and number of build up tests performed.

The surface system provides that data acquisition, processing, storage and display capabilities for the data received from inside the wellbore. The surface system is composed of 3 modules. They are described below:

1. Surface Data Detection on Tubing – **A** surface module attached to the wellhead is used to detect the transmitted downhole signal. It converts the signal from an acoustic wave into digital electrical pulses that are transferred via surface cable to the data processing module.

2. Surface Processing Module – It provides the data acquisition, processing, display and interfaces to a pump controller or a computer. The data received from the acquisition module is conditioned and pre-processed to eliminate noise. The data is next processed in the time domain to obtain the actual parameter values obtained by the sensors inside the wellbore. The information is converted into 4-20 milliamps analog signals to be transmitted to a pump controller or recorder, and it is also converted into Mod bus protocol digital signal to be transferred to other computer systems. The surface system can interface to 6 wells and the six 4-20 milliamps allows the system to interface to 6 pump controllers.

3. **A** Personal Computer interfaces with the surface processing module to obtain the downhole information. **A** software package for the PC processes the data for viewing the information in a graphical mode or in a tabulated format.

The wireless communications tool does not disrupt the flow of production fluids because the tool provides full tubing inside diameter and since the signals are carried by stress waves in the production tubing, the data is virtually unaffected by the fluid in the well. There are 4 issues that affect the system performance. They are:

- The strength of the data signal that can be produced – The higher the energy generated inside the tool due to voltage levels and transmitter/tubing coupling, the longer the distance between the transmitter and receiver modules.
- The attenuation of the transmission path – The wellbore signal path is affected by the pipe being in contact with casing over extended lengths. The tubing has to be continuous from the tool to the surface for the signal to reach the surface detector.
- The allowable signal to noise level for data acquisition – The signal levels have to be in the micro g's for the surface system to detect the acoustic data on the tubing. The acoustic strength will decrease by an order of magnitude for every 1000 ft. The downhole tool power level has to be designed to assure that the acoustic signal will have a level that is high enough to be detected by the surface hardware.

The transmission length inside the wellbore is directly related to the data transmission rate and battery power. If the data transmission rate is slow the signal strength can be increased and the wireless system can be designed to transmit data over greater distances. The surface system is fully ruggedized for oil field applications. The system can monitor 6 wells simultaneously reducing the overall system cost.

APPLICATIONS

The wireless system will open new ways to collect data and transmit the information to the surface. The ability to eliminate cables, clamps and connectors inside the wellbore will allow for the deployment of sensors in areas that previously were not accessible due to the inability to provide a continuous cable in the wellbore. The system will also help improve the performance of the artificial lift systems by monitoring the integrity of the downhole pumps to provide the operator with early warnings of problems inside the wellbore. The system should also improve the production process by providing the information necessary to optimize the lifting process.

The system should also help decrease operating costs by providing the data required to extend the life of the artificial lift system. The wireless tool can be re-deployed in the well after the well has been worked over eliminating the cost related to replacing the electrical cable and clamps that were originally deployed in the well.

The wireless communications gauge system can open new opportunities for the optimization of the production process. Some of the applications the wireless gauge system include the following:

1. Deployment of multiple wireless tool in a single production tubing. The ability to place multiple tools in the tubing string in the lower and upper completions will allow for monitoring of formation and production parameters at different depths throughout the wellbore. The system can provide data independently or wait for a command from the surface to start sending data to the surface.
2. The tool can be deployed anywhere in the well and monitor pressure and temperature from the tubing and annulus. The tool can also monitor the performance of the artificial lift system deployed in the wellbore. The annulus and tubing pressure measurements can determine pump sand accumulation that decreases the flow of hydrocarbons through the pump and can also damage the pump. The ability to monitor tubing and annulus pressure allows the wireless system to provide information to the surface that will indicate if the pump speed should be increased, decreased or maintained at the same level.
3. Monitor short term processes such as gravel pack and fracturing and External Casing Packer setting. The system can be deployed in the work string and monitor multiple parameters inside the wellbore in real time. The information obtained at the surface can help evaluate the work being performed downhole and correct any potential problems prior to retrieving the work string to the surface.
4. The system can be placed in laterals above the sand screens for monitoring the pressure drops through the screens. The system can be permanently deployed in the lower completion and does not require any additional hardware such as wet connectors or alignment subs to interface the upper and lower completions.

SYSTEM LAYOUT FOR A SAMPLE WELL

Drawing number 1 below outlines an example of an installation using the wireless tool. The well is composed of 7 inch casing and has a depth of 4000 ft. The tubing size is 4 ½ inch. The wireless tool can be deployed at the end of the tubing and provide pressure and temperature measurements. The tool will be active and transmit data to the surface from the moment it goes into the wellbore. The signal will be monitored during the deployment of the tool in the well.

A Progressive Cavity Pump is used in this example as the means to pump the hydrocarbons to the surface. The wireless tool can monitor the fluid level to assure that the pump will operate at its optimum level. **A** slotted liner or sand screen is used in the producing lateral in conjunction with a packer or liner hanger.

The wireless tool could be deployed above the packer permanently if there was a continuous tubing string from the bottom of the PC Pump to the wireless tool.

CONCLUSION

A new and innovative system for downhole real time wireless communications to the surface has been developed. The system was created for long term downhole performance to monitor formation and production parameters. The wireless tool can also be deployed for short term monitoring of processes such as fracturing and gravel packing.

The system eliminates the need for Tubing Encapsulated Electrical Cables as well as clamps inside the wellbore. The

system also provides a higher level of reliability by eliminating cable splices that cause system failures related to electrical hot spots and weak solder joints. Another source of savings is the ability to deploy the same tool in the wellbore after a well workover. In some cases the cables and clamps have to be replaced increasing the cost of the workover significantly.

The wireless communications gauge tool can also optimize the artificial lift process significantly by providing pressure and temperature information from downhole to provide early warning of pump problems as well as clogging of the pump due to sand accumulation. This problems can cause the pump to fail and decrease the amount of hydrocarbon produced. The system can decrease CAPEX and OPEX as well as to help increase production and extend the life of the well.

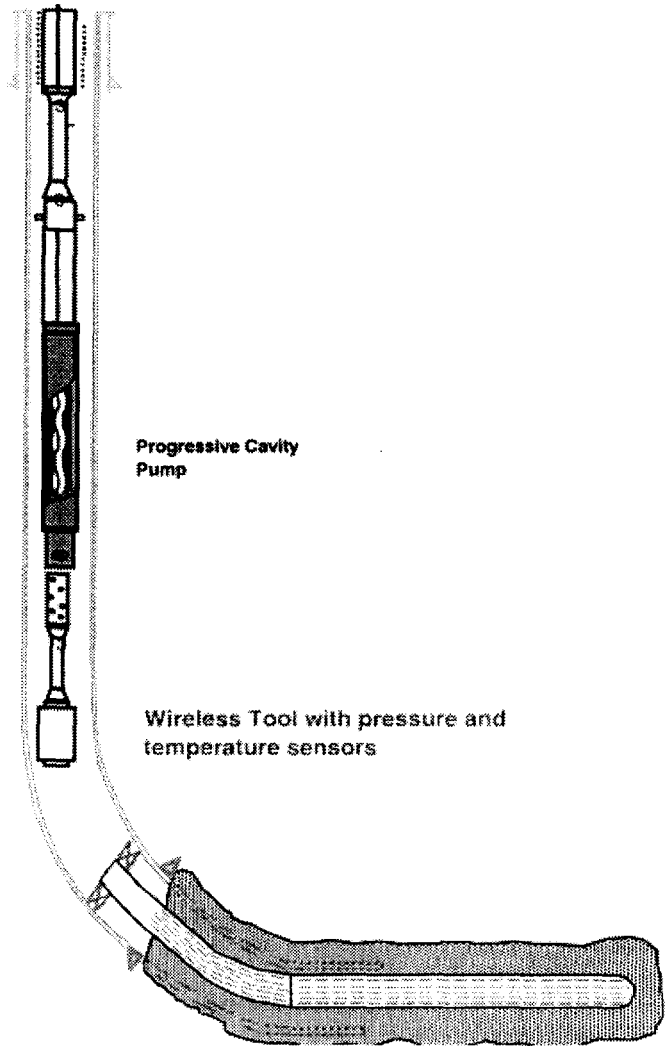

Figure 1 – Sample Well with Wireless Communications System for Progressive Cavity Pump Monitoring