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Report Title: Low Cost Wireless Communications based Pressure and Temperature Gauge for Production Optimization Applications

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Abstract

The goal of the project was to develop a low cost gauge based on an existing commercial high end wireless gauge developed by Tubel Technologies to monitor pump performance; monitor fluid level to optimize lifting operation and to lower lifting costs; monitor bottom hole pressure to optimize drawdown and for build up tests. The build up tests will provide reservoir pressure information for the optimization of the hydrocarbon production. This project provided the research, develop and test a lower cost, high reliability, real time wireless gauge composed of compressional acoustic waves based wireless communications transmitting data in real time through the production tubing, strain gauge pressure sensor and a temperature sensor for measurements of downhole pressure and temperature, surface module to acquire the transmitted signal from downhole and process the data. The new wireless gauge can be deployed anywhere in a production and injection well. The gauge utilizes low power electronics and sensor technology to acquire and process in real time well data related to production and formation parameters. A battery pack provides power for operation of the system downhole.

All goals for the project were achieved and a low cost wireless real time downhole gauge system was developed and tested successfully.

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Introduction

The DoE/Penn State sponsored project provides the ability of automating and optimizing the production of hydrocarbons from Stripper Wells. The increase in hydrocarbon prices due to the higher consumption levels of petroleum and natural gas throughout the world has created the need to extract the greatest amount of hydrocarbons from existing wells at the most efficient way possible.

The new Wireless Real Time Low Cost Downhole Gauge system can be deployed in wellbores permanently or for short periods of time for service applications. The system can be used to monitor formation parameters in pressure build up tests during production and also be used to monitor the health of a pump used to lift the hydrocarbon from downhole. The early indication that the pump is not performing well will allow the operator to schedule an intervention in the well before the pump fails preventing a loss of production.

The Wireless Gauge can also be used to optimize production by monitoring fluid levels during the lifting process to assure that the pump is only in operation when the fluid accumulation is optimum for lifting. That process will decrease the fuel cost for lifting the hydrocarbon and minimizing the wear on the pump.

The system can also be used for service applications such as frac jobs, acid jobs, gravel packing and pressure build up tests. The utilization of real time wireless gauges in service applications will replace memory gauges and provide the operator with information while the task is being performed in the wellbore. The pressure and temperature information will help the optimization of the frac jobs to assure that the frac work is done properly to maximize production. The pressure build up tests performed in real time will allow the operator to assure that the data is being provided as the test is being performed and provide the option to terminate the test earlier than scheduled if the required data necessary

to perform the formation evaluation is available before the test is completed. The early termination of the test will allow the operator to re-start production sooner.

The Wireless Real Time Gauge system is a tool used inside the wellbore to provide pressure and temperature information from the annulus and tubing sections of the wellbore. The information obtained inside the well is processed by the electronics and transmitted to the surface using acoustic waves traveling through the production tubing carrying digital information related to pressure and temperature data obtained by the gauge. The system is composed of 2 pressure and temperature gauges, an electronics module provided analog to digital conversion, data processing and data frame setup, an acoustic generator driver and an acoustic generator. The mandrel is composed of 4140 steel tubing and a pressure housing to seal the system and to maintain the electronics at a atmospheric pressure level. A surface acoustic to electrical converter and a data processing surface panel complete the system.

Figure 1. Donwhole Real Time Wireless Pressure and Temperature Gauge

Executive Summary

The Low Cost Wireless Communications based Pressure and Temperature Gauge for Production Optimization Applications project was completed successfully. The project created a new wireless gauge for low end applications and for small casing sizes. The highlights of the accomplishments for this project are listed below.

1. The project achieved its goal of developing a low cost wireless gauge for downhole applications. The system transmit data from downhole using compressional acoustic waves traveling through the production tubing to the surface where it is decoded and processed in real time.
2. The project allow Tubel Tech to develop a wireless gauge that can be deployed in casing diameters as small as 4 ½ inches.
3. The system works to 125^0 Celsius and 6,000 psi.
4. The Wireless Gauge project developed a new sapphire pressure sensor that is small enough to be placed in a 3 .5 inches mandrel.
5. The new electronics is capable of power management to provide 3 years life inside the well transmitting data every 5 minutes.
6. The new Wireless Gauge was able to generate 2.5 times more energy at the production tubing than the existing commercial Tubel Technologies 2 7/8 inches tubing wireless gauge.
7. The newly developed mandrel is composed of 2 sections: One module houses the sensors and the other module houses the remainder of the wireless gauge. The 2 module tool is easily manufactured and at a low cost.

8. The acoustic data transmission distance between the transmitter and receiver from downhole to the surface can reach 10,000 ft.
9. The system has a small diameter for applications with coil tubing.

Experimental

Experimental Apparatus –

The tests performed during this project were:

1. Dead weight tester with a pressure accuracy of 0.015% of full scale for testing and calibration of the pressure gauge.
2. Pressure Chamber to test the entire tool. The chamber was capable of operating to pressures up to 15,000 psi and it used a closed loop control to assure that the pressure exerted onto the tool was correct.
3. Production tubing deployed at the surface for evaluation of the acoustic wave attenuation. The 1,000 ft of 3 ½ inch tubing was deployed in a field in the Dallas area with standard tubing threads for connection to the wireless gauge.
4. Temperature tests were performed on the electronics module for long term operation of the system.

Experimental and Operating Data –

The results of the tests were as following:

1. The deadweight test results indicated that the pressure sensors operated linearly with temperature. The results also indicated that the tool was able to maintain 0.1% accuracy with the sensors and a 1.25 psi of resolution for a 5,000 psi sensor.
2. The pressure chamber tests indicated that the tool does not collapse or is damaged in anyway when 5,000 psi pressure is exerted onto the wireless gauge.

3. The pipe tests were obtained by placing the wireless gauge at one end of the tubing and the receiver on the other end of the pipe. An accelerometer driver with an oscilloscope was used to measure the acoustic energy on the receiver end of the pipe. Multiple frequencies were used to evaluate the acoustic attenuation through the tubing. The results indicated that the attenuation was approximately 10 db/1000 ft.
4. The electronics were tested for temperature performance and reliability and the results were successful. A new flash processor was qualified for downhole applications that allow the software inside the tool to be modified without having to replace the microprocessor.

Results and Discussion

The low cost wireless gauge development has been completed and the results have surpassed all performance expectations at Tubel Tech. All modules are working properly and the entire system has shown to perform better than previous systems developed by Tubel. The first prototype should be deployed in a well in early June 2004. The test will be performed using a coil tubing for the transmission of the real time data from downhole to the surface. The application will be a frac job in a coalbed methane application.

The low cost wireless gauge system has some unique features developed for this project including the following:

1. A 2 piece tool mandrel instead of 3 modules which decrease the cost and increase the reliability by eliminating a metal to metal seal connection.

2. Small diameter pressure gauges reduces the overall diameter of the tool allowing the system to have 3.675 OD and can be used in wells with 4 ½ inches casing.

3. The system uses a flash memory based microprocessor which allows the software for the downhole tool to be upgraded without having to remove the processor from the PC Board.

4. The system uses a new technique for acoustic data transmission developed for the high pressure high temperature wireless gauge DoE project which will reduce the amount of energy required to transmit data to the surface from downhole.

5. The system is low cost and high performance.

6. The system can be used in service applications for temporary deployment in wells.

Conclusion

The conclusions and achievements for this project are as following:

- The entire tool has been developed successfully. The entire system performance has met and exceeded all specifications created for the system in the beginning of the project.
- The wireless gauge is low cost and can be used in stripper well applications for permanent and service applications.
- The system can operate in casing sizes as small as 4 ½ inches.
- The system can provide data at high speed and operate at pressures in excess of 5,000 psi.
- The system software will allow the data to be recorded in memory continuously as well as to provide real time information for service applications.
- The system has a new power reduction module to minimize battery power to extend the life of the system in the wellbore.
- The system has 2 pressure and temperature gauges that are deployed to measure tubing and annulus pressures in real time. The new pressure sensor was developed to minimize its diameter to fit in the outer diameter of the wireless gauge.

- The surface system was developed to process the data in real time and display the information as well as to store the information for later retrieval into a PC or data network.

References

There are no references related to this project and work.

Bibliography

There is no bibliography related to the work being performed.

List of Acronyms and Abbreviations

There are no acronyms or abbreviations in this report.

Appendices

System Specifications

KEY FEATURES

- **Wireless Communications**
- **High Reliability**
- **Operation up to 125^{0}C**
- **From 0 to 5,000 PSI range**
- **Data Rate 10 bits/sec**
- **Life Expectancy 3 years**
- **Built-in Pressure Gauges**
- **Battery Operated**

APPLICATIONS

- **Coal bed Methane**
- **Production Permanent Monitor**
- **Liner Pressure Drop Monitoring**
- **Production Automation**
- **Intelligent Well Applications**
- **Artificial Lift Automation**
- **Gravel Pack monitoring**
- **Frac Pressure Monitoring**

Wireless Reservoir Monitoring Tool

A new low cost technology has been developed to transmit data from inside a wellbore to the surface without cables. This new system employs stress waves in the pipe string to communicate throughout the wellbore. The system has built-in pressure and temperature gauges for tubing and annulus measurements.

The new low cost wireless system does not block fluid flow providing full bore access. The tool was developed for production automation and optimization in coal bed and stripper well applications. It can be deployed in production wells to measure and transmit production parameters to the surface without a hardwired connection. It is also used for bottom hole pressure and temperature measurements for frac jobs, drillstem testing and gravel pack.

S P E C I F I C A T I O N S

Transmission range :	6,000 ft (2,000 meters)
Rate	Up to 10 bits per second
Tubing Size	2 3/8 inches (2 7/8, 3 ½ inches available)
Operating temperature :	-20 to 125 °C
Signal type	Stress Waves
Power	Battery
Life Expectancy	Based on data rates and battery size
Pump Noise	Immune
Maximum External Pressure	6,000 psi
Pressure Gauge	0- 5,000 psi
Pressure Resolution	12 bits (24 bits available)
Pressure Accuracy	0.1% of FS
Pressure Measurements	Annulus and Tubing
Length	82 inches
Tool OD	3.675 inches
Tool ID	1.81 inches
Burst Pressure	7,000 psi
Max Tension	45,000 lbs
Max Torque	1,200 ft-lb
Std Connection	2 3/8 NU 10rd