OPTIMIZING ARTIFICIAL LIFT OPERATIONS THROUGH THE USE OF WIRELESS CONVEYED REAL TIME BOTTOM HOLE DATA

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INTRODUCTION

A field demonstration of the application of the bottom hole pressure data, as received from Real Time Diagnostics' wireless pressure transmission system, improved the efficiency of PanCanadian Petroleum Limited's 8A-19-38-01-W4m well in the North Bodo field of northeast Alberta, Canada. An illustration of servicing a typical North Bodo slant well on a pad of wells is shown in **Figure 1**. The Telemetry Acquisition Tool (TAS®) device, developed by Real Time Diagnostics (RTD), was installed in the production tubing below the producing zone perforations, where it was able to measure and accurately transmit bottom hole production pressures and temperatures of the well's producing horizon to the surface. The real time pressure data was relayed into a voltage loop and a surface computer which contained software designed to output an analog process signal. This signal was then sent to the Wermac Electric Limited's Variable Frequency Drive (VFD), which controls the speed and torque of the electric motor powering the bottom hole progressive cavity pump (PCP) system. PanCanadian was able to both increase the oil production and decrease the lifting costs per barrel by utilizing the actual bottom hole pressure response of the reservoir fluids flowing into the wellbore to optimize the daily rate of production.

DISCUSSION

Basic theory of signal transmission through electromagnetic wave propagation is not unique or novel; in fact, it has been around for many years. A typical oil field telemetry system includes a downhole frequency transmitter, which contains measurement sensors and a receiver located at the surface. A specially modulated electromagnetic frequency signal, representative of the measurements performed by the sensors located in the downhole transmitter, is injected into the formation where it propagates upward to the surface along the outside of the casing string, essentially creating a two wire path for the current flow to follow. By example, the casing represents one wire and the earth represents the return path or second wire. The electric signal is collected at the surface receiver system by measuring a voltage potential between the surface wellhead and a remote ground reference. The voltage potential is then amplified significantly and filtered to eliminate or reduce other electrical noises, which can be man-made or naturally occurring. These electrical "noises" can potentially interfere with the specially modulated signal containing the downhole data. The amplified and filtered signal is then relayed into a surface computer where the data measured from the bottom of the producing well is processed and regenerated from the transmitted signal through the use of proprietary signal processing software.

In general, RTD's TAS® system consists of three sections: (1) an electronics section containing a microprocessor as well as an abundance of downhole memory; (2) the data measurement section housing conventional pressure and temperature sensors; and (3) a battery section. **Figure 2** describes the design specifications of the TAS® system. The current process variables from the TAS® unit, which are downhole pressure and temperature measurements, include part of an array of data set variables that the VFD will monitor and react to accordingly. The main signal process link will be a customized proportional integral derivative (PID) control loop that is based on the measured bottom hole pressure (BHP) in the wellbore. This BHP signal will input a speed directive to the VFD for the electrically driven wellhead drive, based on PanCanadian's preset desired bottom hole pumping pressure. *This concept of the well being automatically on pump and maintaining daily oil production is analogous to the "cruise control" concept that optimally runs an automobile.* It should be noted that at the same time that the VFD is maintaining this optimum production rate, it is simultaneously sensitive to the other array inputs of "maximum and/or minimum flow line pressure", "maximum sucker rod torque and current", and "maximum and/or minimum drive speeds". Although the full explanation of the control logic is not included in the scope of this paper, a schematic representation of the subsurface signals and their corresponding surface monitoring, manipulation, and use is illustrated in **Figure 3**.

In June of 1995, the prototype TAS® tool was installed in the PanCanadian 8A-19 well where it was landed inside the production tubing below a perforated tubing pup joint, which is the downhole production pump intake. **Figure 4** is an illustration of the service rig during making up and running the bottom hole assembly (BHA) that housed the TAS® wireless pressure transmitting tool. The specific configuration of the TAS® installation within the BHA allows for an unrestricted flow path for the reservoir fluids to enter the production pump above the TAS® system, as is illustrated in **Figure 5**. The TAS® system was pre-programmed to transmit pressure and temperature measurement updates every eight hours. Each time the tool transmits, it sends 5-10 pressure and temperature measurements over a ten minute time span. These pressure and temperature readings are then relayed to the surface via the specially modulated electromagnetic signal where they are electronically verified for accuracy and authenticity just prior to the data being recreated at the surface by proprietary signal processing software. Each update consists of a multiple bit data package containing the pressure and temperature values of the producing horizon. Additionally, the wellhead vitals of speed, torque, surface pressure, and BHP are relayed by surface telemetry through a direct sequencing radio system to a host computer at the North Bodo field office. Presently all vital artificial lift equipment (ALE) operating characteristics are monitored. The speed of the rotary top drive is currently controlled by the Wermac VFD through a speed signal that the operator inputs into the computer at the North Bodo field office. Any monitored values that are out of tolerance are instantaneously alarmed and result in immediate electronic notification to the field operator on duty, through an alpha numeric pocket pager. *This has economically facilitated PanCanadian's vision to have well operators go to the wells only when necessary as opposed to the tradition of having an operator visit each well at least once each day.* With the planned implementation of the PID loop in February, 1996, the VFD drive will be able to automatically increase or decrease the speed of the bottom hole production pump based on the BHP measurements and other dynamic variables that are specific to the personnel, environmental, and mechanical safety criteria.

FIELD RESULTS

The bottom hole wireless pressure monitoring system is being successfully run in PanCanadian's oil well at North Bodo 8A-19-38-01 W4m. On September 5, 1995, the 8A-19 well was serviced to install a new prototype TAS® gauge and the PCP speed was maintained at 300 rpm with 395 psi (2,723 kPa) bottom hole pressure until October 10, while producing 345 BPD (55 CuM/d). At that point, the PCP speed was then increased to 370 rpm until November 10, resulting in an increased producing rate of 616 BPD (98 CuM/d) with 388 psi (2,675 kPa) bottom hole pressure. From November 10 to 21, the well had to be slowed down to 150 rpm due to a turndown in the main pipeline transmission system. After repairs to the pipeline were completed, the well was sped up to 400 rpm, resulting in a producing rate of 535 BPD (85 CuM/d) with 397 psi (2,736 kPa) bottom hole pressure. Since the PCP was now obviously operating at its maximum allowable pump discharge pressure without the expected increase in fluid production, the well was serviced on December 19 to install a bottom hole production pump that was capable of producing 1,400 BPD (225 CuM/d) at 1800 psi (12,410 kPa) pump discharge pressure. However, due to plant capacity problems, the well was operated at only 200 rpm until January 6, 1996. **Figure 6** illustrates the well's critical operating parameters on January 1, 1996. The bottom hole production pump speed and torque are 200 rpm and 34.3 amps respectively, while the bottom hole producing pressure was 378 psi (2,606 kPa) with the well producing 547 BPD (87 CuM/d). As of January 6, 1996, the pump speed has been steadily increased. **Figure 7** illustrates the well's critical operating parameters on January 19, 1996. The bottom hole production pump speed and torque are 325 rpm and 37.5 amps, respectively. The bottom hole producing pressure has been reduced to 361 psi (2,482 kPa) and the well is presently producing 692 BPD (110 CuM/d). By example, **Figure 8** outlines the increase in daily oil production from 12 to 17 m^3/day from September 5 to November 10, 1995. The chart, as outlined in **Figure 9**, shows the BHP decreasing as the speed of the PCP was increasing. The objective of this field demonstration was to monitor the bottom hole pressure and then utilize it as a signal for the VFD to automatically control and maintain optimum production with the existing ALE of the well. The application of this technology has enabled PanCanadian to achieve production rates that begin to approach the reservoir's capacity in a more progressively productive manner. With the application of this wireless bottom hole pressure gauge, PanCanadian's field operators were able to remotely monitor, automatically control and incrementally optimize the daily production of the well, on a real time basis. The operators can react to any anomaly at the well, on a real time basis, since the field office computer instantaneously notifies them through an electronic pager system whenever the well is not running optimally. While the operating cost per barrel was lowered, the capital exposure of the well, due to the acquisition of this telemetry technology, will also be mitigated in future production runs. The rationale for this is facilitated by the TAS® tool being positioned inside the production tubing, where it can therefore be deployed or retrieved by wireline, slickline or sucker rods, without removing the well tubing. The tool can then be used in other wells that are candidates for optimization.

Figure 10 illustrates the positive financial impact through the proper integration of the TAS® wireless telemetry technology with surface electronics and intelligence to control a well's operations based on the reservoir feeding that particular well. If PanCanadian were to apply this technology on 15 percent of its oil wells, it is estimated that a one year pay out of the capital investment is achievable if approximately two and one quarter of a percent increase in PanCanadian's overall daily oil production is realized.

CONCLUSIONS

Recent improvements in wireless electromagnetic telemetry systems have created business opportunities for which routine oil field operations can become more profitable and production can be automatically maintained or increased by measuring bottom hole producing values and transmitting that data to the surface for use on a real time basis. This publication describes the unique application in which PanCanadian Petroleum Limited has been able to increase its oil production and decrease the lifting costs at the 8A-19 well in the North Bodo field through the application of real time bottom hole pressure information that is transmitted through wireless electromagnetic telemetry. Beginning in February, 1996, this technology will be used to put the well on "cruise control", or in other words, automatically optimize the daily oil production of the well based on the bottom hole pressure response from the actual inflow capacity of the reservoir. In addition, it is also planned to observe the well's inflow performance rate (IPR) in real time by displaying a "live" IPR curve on the computer monitor at the North Bodo field office.

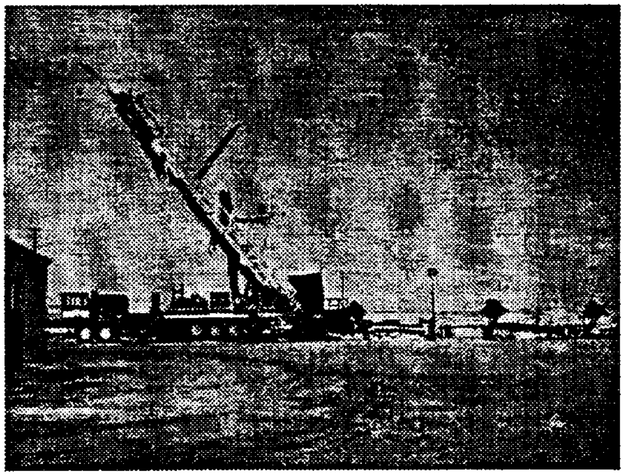

Figure 1 - Typical PanCanadian Pad Wells in North Bodo field with Rotary Sucker Rod Wellhead Drives and Surface PCP Motor Units - BC

TAS Mechanical Specifications

• Length	
– standard	10.8 feet
– extended	15.3 feet
• OD	1½"
• Max pressure	17000 psi
• Max temp	300°F
• Service environment	Acid, CO_2, H_2S
• Battery Type	"C" Cell, Alkaline or Lithium

Figure 2 - Rtd's TAS® Tool - TRB

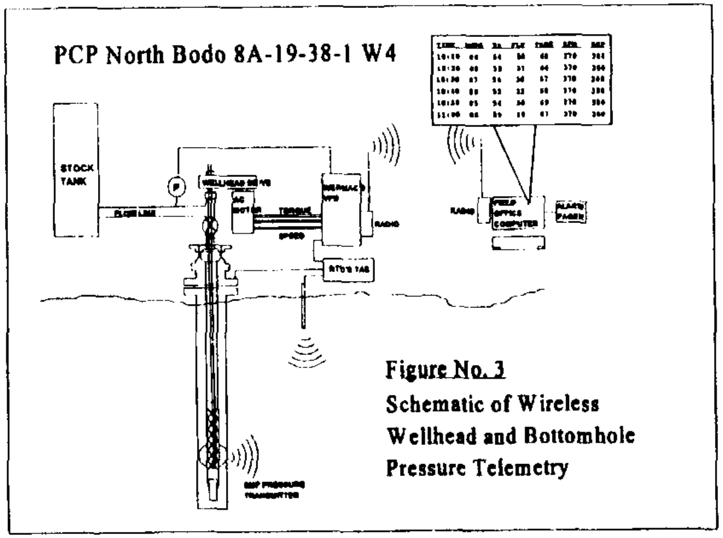

Figure 3 - Wellbore Schematic and Surface Equipment Installation

Figure 4 - Service Rig for Installing a TAS® tool - BC

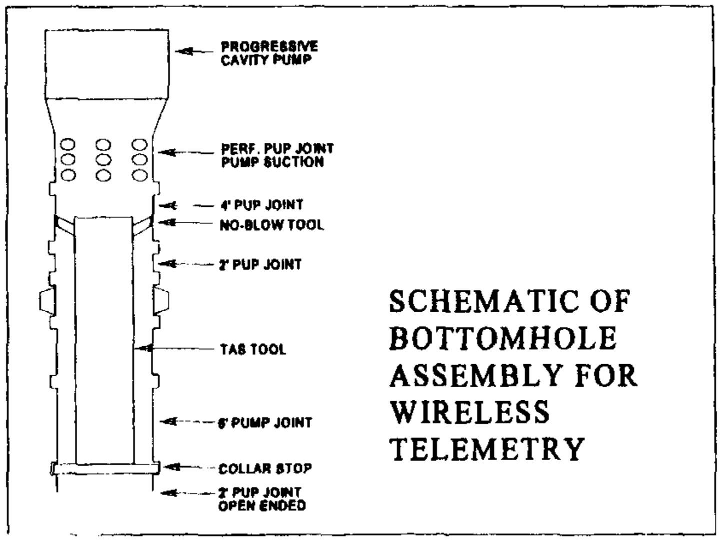

Figure 5 - Bottom Hole Assembly c/w RTD's Pressure Recorder - BC

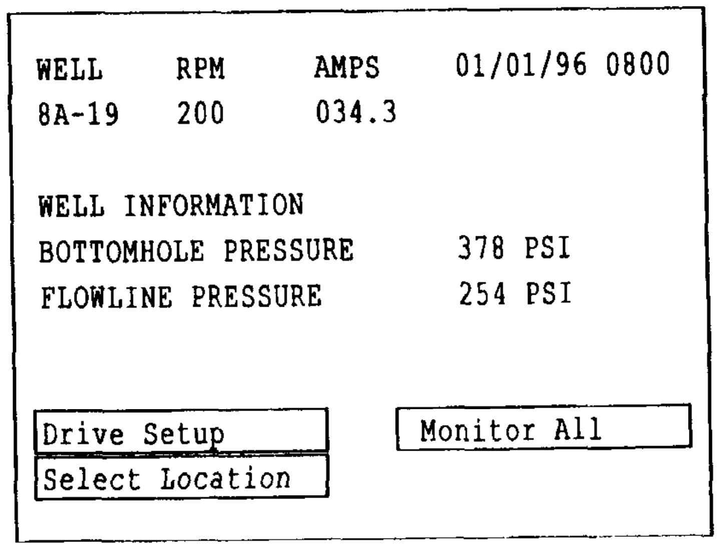

Figure 6 - Operating Parameters of 8A-19-38-01 W4m for January 1, 1995 - BC

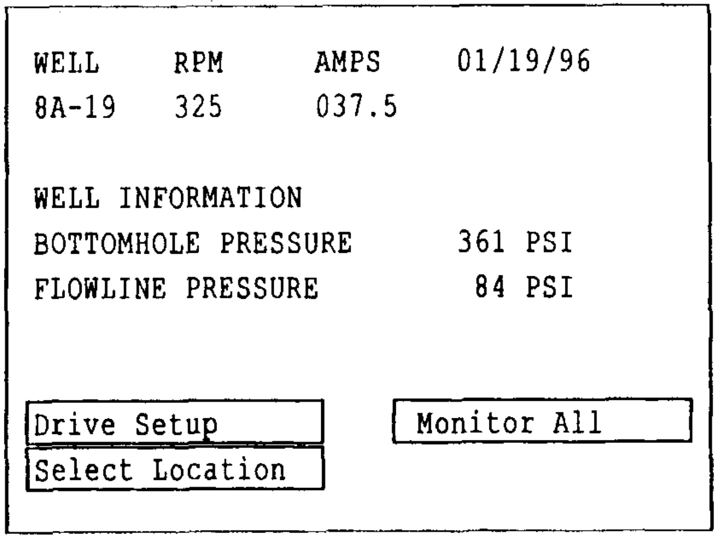

Figure 7 - Operating Parameters of 8A-19-38-01 W4m for January 19, 1995 - BC

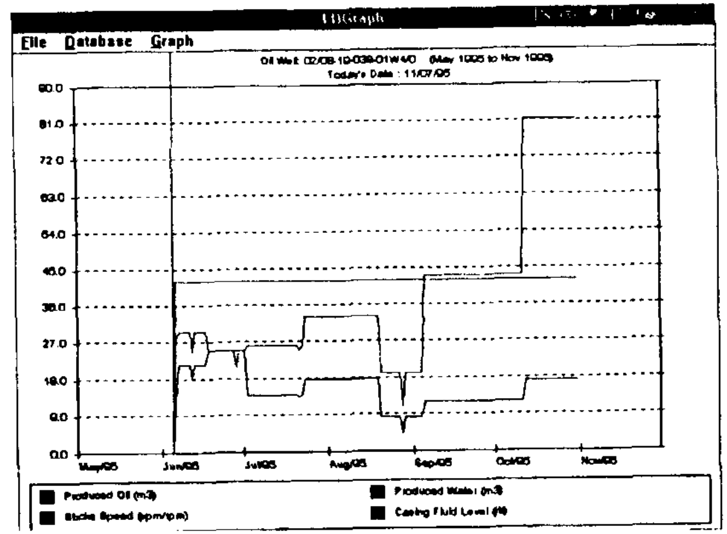

Figure 8 - Historical Production Data for 8A-19-38-01 W4m - BC

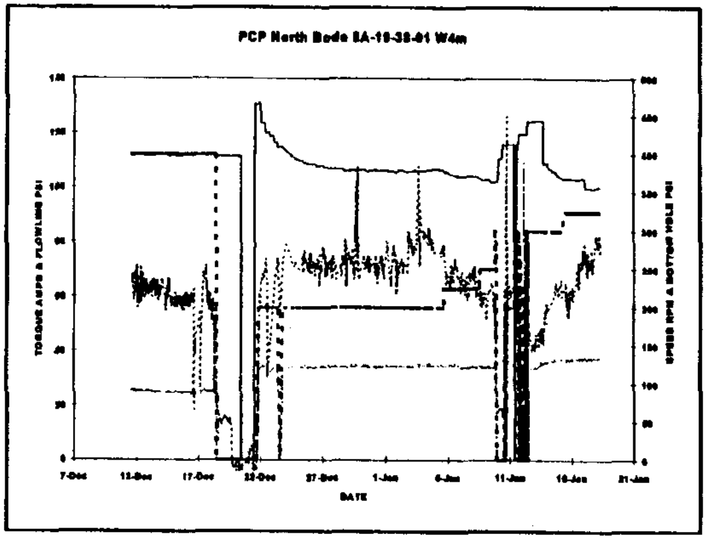

Figure 9 - Historical BHP Data for 8A-19-38-01 W4m - BC

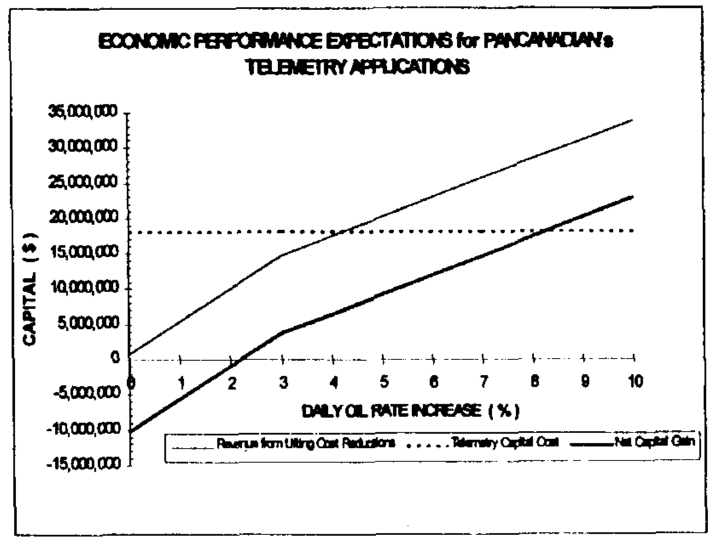

Figure 10 - Significant Financial Difference with the Application of this Technology - BC