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TECHNOLOGY DEVELOPMENTS IN NATURAL GAS EXPLORATION, PRODUCTION AND PROCESSING

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The DOE Turns Up the Heat on Electronics for Deep Drilling

Efforts to find more domestic energy and the desire to more efficiently use the energy already found are driving a growing need for electronics that can withstand high temperatures during long periods of time. Energy-efficient vehicles and aircrafts require lightweight sensors that can accurately monitor internal engine performance. Drilling diagnostic tools require electronic components that can reliably measure and transmit critical downhole data at great depths. There are some differences between these applications, however. The operating life requirements for drilling electronics are less than for the automotive or aerospace industries (on the order of 1,000 hours vs. 8,000 hours or 80,000 hours, respectively), while the variety and type of the components required are greater. Also, the deep drilling market is much smaller. The number of deep wells (>15,000ft, 4,575m) being drilled, while growing, is still small compared with the overall number of wells drilled. However, the potential long-term reward in terms of domestic oil and gas supplied from economical, lower-risk deep drilling is enormous.

When exposed to the higher temperatures and pressures found within the 15,000+-ft environment, traditional electronic technology often fails. The drilling and formation diagnostics industry during the past few years has begun developing high-temperature (HT) technologies. The combination of high technical risk, limited near-term markets and potentially large longer-term public benefits provides an ideal situation for U.S. Department of Energy (DOE)/industry cooperation in HT tolerant electronics research and development (R&D).

Several years ago, the DOE's National Energy Technology Laboratory funded two projects to improve the HT capabilities of logging-while-drilling (LWD) and measurement-while-drilling (MWD) tools (*GasTIPS*, Spring 2005). The direct results of these projects led to a more robust MWD tool with a longer service life. Even more importantly, however, they highlighted the fact that a well-coordinated development program for HT electronics was critical if deep natural gas potential is to be realized.

Initial efforts toward this goal started with the DOE DeepTrek Program. Honeywell International Inc. formed a joint industry partnership (JIP) to direct and provide the necessary cost-share for an HT electronics DOE project. The JIP selected four electronic components considered essential to the development of HT downhole electronics, and within the capability and budget of the project. Since then, eight new electronics projects awarded under the DeepTrek Program have begun developing HT sensors, microcomputers, capacitors, switched-mode power supply and packaging. The efforts with Honeywell are described in an article in this issue of *GasTIPS*.

A key component Honeywell brought to the table was its silica-on-insulator (SOI) technology. Conventional semiconductor transistors exhibit current leakage problems at high temperatures. Essentially, when the transistor is supposed to be "off," the current leakage keeps it in the "on" position. SOI structures prevent this leakage over a higher temperature range; one component developed by the JIP project has performed within specifications for more than 1,000 hours at 300°C (571°F).

In another DOE-supported R&D project, Oklahoma State University is using similar technology (called silica-on-sapphire) for its Downhole Microcomputer System and Switch-Mode Power Supply projects, both of which are more fully described in an article in this issue.

The DOE's support for development of HT electronics also includes projects with General Electric to develop a solid-state gamma detector that can perform at temperatures above 200°C (391°F) and to develop HT electronics packaging technology two projects for the development of HT capacitors, and an HT rechargeable, sodium-sulfur battery capable of operating at temperatures as high as 250°C (481°F). Early research for this battery was conducted with Sandia National Laboratory.

The portfolio of projects supported by the DOE is providing a critical mass of electronic components for companies interested in developing new product designs for the growing HT drilling market. It is hoped that these new designs will enable lower-risk, lower-cost drilling for the deep resources needed to supply our growing demand for energy.

Other articles in this issue of *GasTIPS* provide some insights into projects funded through the Stripper Well Consortium and the launching of a new public/private R&D partnership under the Energy Policy Act of 2005. We hope you find this issue of *GasTIPS* informative and useful. ✧

The Editors

Uncovering Bypassed Pay in Central Oklahoma Using Statistical Analysis

By Kathryn Stilwell March, Larry Moore, Olufela Olukoga and John Robinson, *Schlumberger Consulting Services*

The intent of this study is to develop a methodology to identify behind-pipe payzones existing in various brownfields along the Nemaha Ridge trend in central Oklahoma.

Oil and gas is produced in marginal volumes from stripper wells. The Interstate Oil and Gas Compact Commission defines marginal or stripper oil wells as those producing a volume of 10 b/d of oil or less. Similarly, stripper gas wells are defined as those producing 60 Mscf/d of gas or less. There are about 397,000 stripper oil wells in the United States with average daily production of 2.14 b/d of oil. With total production of about 310 million bbl of oil in 2004, marginal oil wells account for about 29% of the domestic oil production in the United States. Marginal gas wells represent about 8% of the total natural gas produced in the United States with production of about 1 Tcf of gas in 2004, according to the Interstate Oil and Gas Compact Commission.

The Marginal Well Commission researched 48,250 marginal oil wells and 23,845 marginal gas wells in the state of Oklahoma in 2005. Marginal oil wells accounted for 67% of oil production in Oklahoma, while marginal gas wells accounted for 10% of the total gas production in the state. These statistics emphasize the importance of the stripper wells to oil and gas production in Oklahoma. New technology or methodologies of prospecting for new reserves that increases oil production and ultimate reserves benefits Oklahoma's oil industry. Oil prices are at record highs and operators of marginal wells are seeking ways to improve the productive life of their wells. Tools that will assist in identifying bypassed zones are required and methods are needed to quantify the additional pay.

This research focuses on developing a methodology for identifying bypassed pay zones in marginal wells. It entails analyzing and evaluating the dataset of large numbers of wells, identifying drilling and producing trends existing within the study area and informing the operators of wells that may contain additional pay zones. Many of the historical wells were drilled based on reports of success from adjacent operators in the area. While the original target zones proved to be successful and oil recovery was achieved from the wells, other pay zones in these fields may have been bypassed. This study aims to uncover these bypassed pay zones thereby reducing risk to local operators that are usually smaller independent companies.

The methodology was tested by evaluating the Northwest Noble field in Cleveland County, Oklahoma. The field served as an ideal model because it is a typical brownfield in Oklahoma. It consists of 16 stripper oil wells run by a small operator with limited resources. The field is also in an area that has a number of

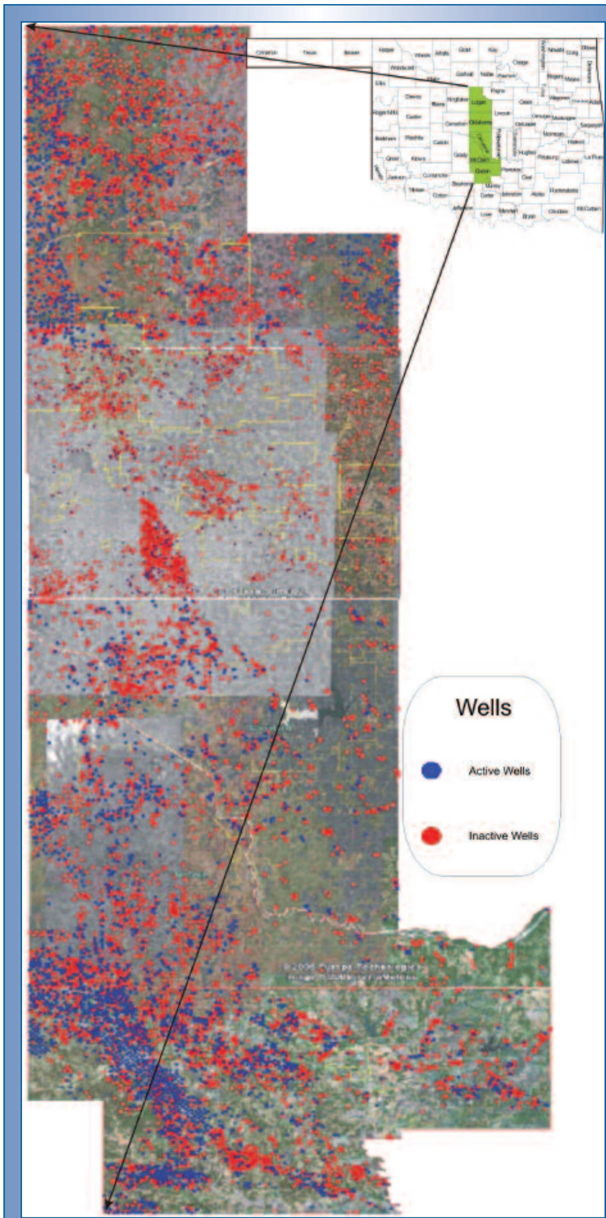


Figure 1. Wells in the study area grouped by status. (County map of Oklahoma showing the area of the study is shaded green)

productive horizons, many of which have never been completed or produced. The results obtained from the evaluation of this field are being implemented and will serve as a model for other brownfields within the study area.

Geology and background

The area of study is comprised of the five counties in central Oklahoma that include Logan, Oklahoma, Cleveland, McClain and Garvin (Figure 1). This large area contains about 14,000 wells, most of which are strippers with production rates of less than 10 b/d of oil. This area was a prolific oil producing region with total cumulative production of about 2.3 billion bbl of oil during the past 40 years. The geology within this area is well documented as many extensive studies have been performed on the formations and structures within these counties.

The study area is within a zone of transition involving five major tectonic elements: the Central Oklahoma (Cherokee) Platform; the McClain County Fault Zone; the Oklahoma City Uplift (Nemaha Ridge); the Arkoma (McAlester) Basin; and the Anadarko Basin.

The Nemaha Ridge or anticline is a major structural element extending southward from Nebraska across Kansas into central Oklahoma. This ridge is characterized by shallow Precambrian crystalline rocks along its axis and faulting along its eastern side. Its southern end appears to terminate in the Oklahoma City uplift. These structures were primarily the result of extensive folding and faulting that deformed much of southern Oklahoma (Wichita Orogeny) in Late Morrowan time. Uplift of the ridge resulted in the erosion of the crest of the Oklahoma City dome down to beds as old as the Arbuckle Group (Cambro-Ordovician). The Nemaha Ridge forms the axis of a broader feature – the Central Oklahoma Segment, which extends southward into the Lawrence uplift.

It has been observed from the recorded production history that a bulk of the oil production has occurred from the "deep" formations consisting of the Viola, Simpson-Bromide sands, Tulip Creek, McLish, Oil Creek, Joins and Arbuckle. However, a number of new completions were successful when perforated in the shallow formations of the Pennsylvanian consisting of the Cherokee formations: Prue, Skinner, Red Fork, Bartlesville sands; Deese, Hoxbar and Cisco.

Geologists have noted these shallow formations to be channel sands that consist of thin bedded sandstones laminated with shale and conductive minerals such as pyrite. The presence of pyrite usually causes low resistivity log readings; hence false interpretations of high water saturation values in these formations. This may explain why the shallow formations have been not been opened and produced in many of the wells in the study area.

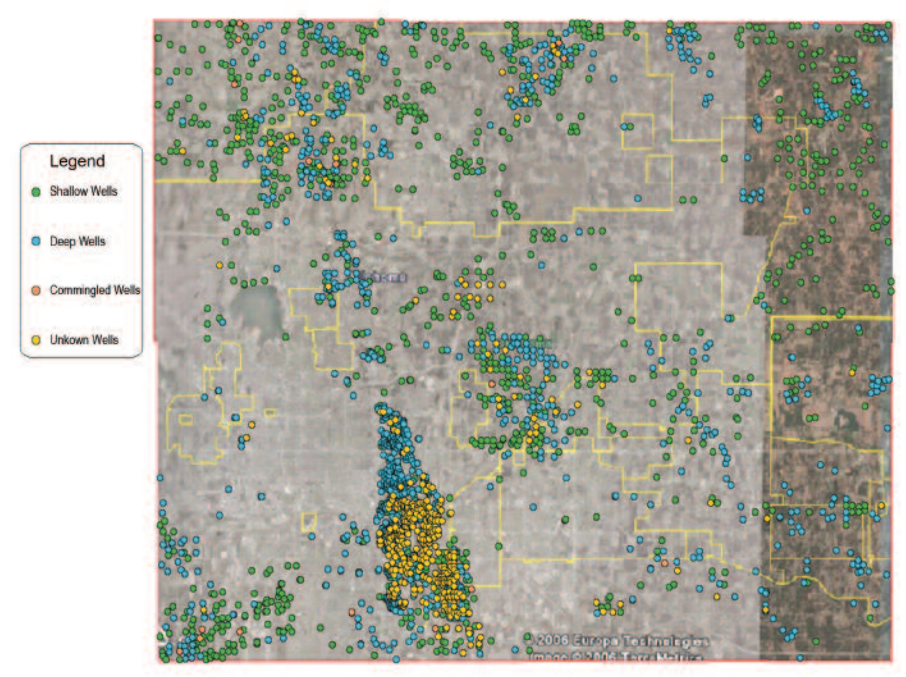


Figure 2. Oklahoma County wells grouped by producing formations

Methodology

Wells drilled and completed in brownfields have extensive production data, which serves as an important source of information for reevaluating the productive potential of the marginal wells. These huge datasets can be analyzed using computer software to make comparisons between wells and identify possible intervals of bypassed pay.

Analysis of the datasets was carried out using Moving Domain software, which enabled the investigation of historical drilling and producing trends of large areas with large numbers of wells. The Moving Domain Analysis technique used in this study entails understanding the geology of the study area, which has been previously discussed. We compared groups of wells based on their production performance, then high-graded the performance of the wells and screened them to determine any bypassed pay zones. This methodology has been successfully applied and utilized in determining possible infill drilling potential, completion optimization, stimulation evaluation and predictions of future production. Employing Moving Domain Analysis as a tool for prospecting bypassed reserves in marginal wells is a new

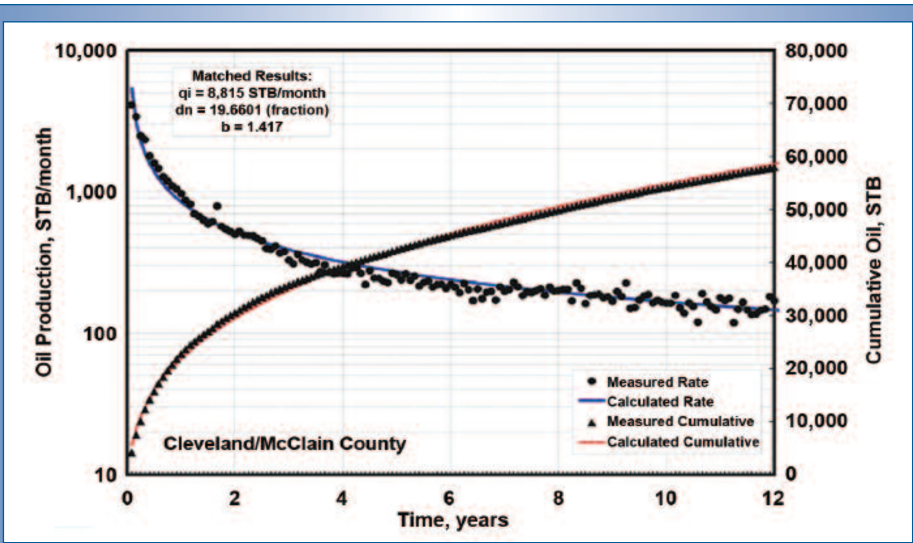


Figure 3. Production profile from the Cherokee formations in Cleveland and McClain counties

application. The workflow employed in this methodology is listed in order as follows:

- research the geology and production history of a given area;
- obtain production data for the given area from a public source;
- group the wells based on location then categorize the groups based on producing formation;
- map the producing formations of the active wells;
- high grade the producing wells based on the estimated ultimate recovery;

observe producing trends and sweet spots;

- locate active wellbores in good producing areas not open to the producing pay interval; and
- these wellbores are now candidates for further investigations and possible analysis behind casing (ABC) jobs.

The database for the study area was sorted by various criteria. The older inactive wells were noted along with the current active wells, which were defined to be wells that have recorded production in 2005. Maps of the wells were created based on the defined workflow. Figure 1 shows all wells included in the study.

The database for the five-county area was sorted by the producing formation. This process proved challenging because of the inconsistency of naming formations. Classifying these formations into three major groups based on the ages of the formations helped simplify the process. The formations in each well identified as having bypassed potential will have to be investigated in greater detail to determine the precise formation containing the possible bypassed reserves.

The formations were classified in the following major groups:

- upper formation (Permian age);
- shallow formation (Pennsylvanian and Mississippian age); and
- deep formation (Siluro-Devonian, Ordovician and Cambrian age).

These groupings ensured rocks with similar characteristics were classified together irrespective of the names they were given in their different locations.

Drilling and production trends were distinct after mapping in the currently active wells in each formation. Any formation showing a strong trend of good production was then investigated in greater detail. The wells in each county were color-coded based on the grouped producing formations. There are 3,145 wells drilled and completed in Oklahoma County. Of these wells, only 356 wells are active with 87% of the wells once completed currently inactive. The inactive wells are plugged and abandoned or shut-in and uneconomic.

Based on the classification of the formations, 1,404 completions were placed in the shallow category. As in the previous case, the shallow category contains the most productive intervals in Oklahoma County. A total of 1,104 completions were placed in the deep category. Drilling and production trends in Oklahoma County are shown in Figure 2. Similar maps were made for the other four counties.

After considering the producing trends within each county, statistical analyses of the formations of interest were performed using Moving Domain software. A composite production (Time Zero) profile of the formation was constructed from the measured production data based on single completions. The historical production data was taken from the past 20 years to obtain a good representation of the current production trends.

Decline curve parameters were calculated from the generated production profiles (Figure 3) that allowed estimates of estimated ultimate recoveries (EURs) for individual wells. We could then identify areas of good production (sweet spots) based on mapping the EURs for the wells given a particular group or category. Offset wells in close proximity to the better performing wells along the producing trend were then noted and cataloged. The completion intervals of the offset wells were also investigated to determine whether they were completed in the formation of interest. Once it was established they had not been opened in the formation of interest, these wells were noted as having behind-pipe potential. They were then listed as candidates for re-completion.

Wells producing from the deep formations are represented by the small blue circles in Figure 4. The different sizes of the green circles (Cherokee completions) correspond to the values of the EURs for these wells. This type of bubble map aids in high-grading the expected performance of the wells and visually identifying the areas with good Cherokee production (sweet spots). Wells completed in the deep formations in proximity to the Cherokee wells with the highest EUR are then noted and cataloged. These wells lie along the productive trend of the Cherokee formation. The completion intervals of these deep wells were investigated, and if the well was not completed in the Cherokee formation, there is a high probability there may be behind-pipe pay at this location. They are then noted and cataloged for possible recompletion. The identified deep wells, which are recommended for re-completion in the Cherokee formation in Cleveland and McClain counties, are shown by the pink circles in Figure 4.

ABC—Analysis Behind Casing

The premise of this study was to determine the untapped behind-pipe potential of existing wellbores in a five-county area. It would seem logical we should discuss modern techniques and logging tools that could aid operators in analyzing untapped reserves prior to re-completions, which can become costly depending on the remedial work that may be required. While perforating new zones is generally a low cost item, additional remedial work to isolate intervals using squeeze cementing techniques can become prohibitively expensive depending on the results of the work.

Today, the same high-quality formation evaluation measurements can be made in cased holes. ABC* Analysis Behind Casing services satisfy two primary requirements for operators:

- obtaining essential well log data under any conditions. Operators may prefer to case the well as soon as it is drilled if the well is having hole-stability problems. Formation evaluation can now be performed in cased hole with recent innovations; and
- finding and evaluating bypassed pay. Large amounts of bypassed hydrocarbons exist in old wells. It is considerably more cost effective to explore for those hidden hydrocarbons in old wells rather than to drill new wells.

ABC evaluation of formation petrophysical properties such as formation density, porosity and acoustic properties in cased wells is even more significant in wells for which primary evaluation data were lost, of poor quality, or never acquired. In old wells, an operator may want to re-evaluate the formation with measurements unavailable at the time the well was drilled.

Conclusions

A total of 1,470 wells were identified as possible recompletions with untapped behind-pipe pay zones in the shallow formations. The Cherokee group comprising the Bartlesville, Hart, Osborne, Prue, Red Fork and Skinner sandstone formations are especially promising.

In Logan County, 258 wells are identified for recompletion with 68 of these wells being currently active. The mean EUR for the wells producing from the Cherokee group in Logan County is 18,657 STB.

In Oklahoma County, 139 wells are identified for recompletion with 51 of these wells currently active. The mean EUR for the wells producing from the Cherokee group in Oklahoma County is 53,333 STB.

For Cleveland County, 171 wells are identified for recompletion. Of this number, 66 wells are currently active; while for McClain County, of the 465 wells identified for recompletion, 202 are presently active. The mean estimated ultimate recovery for the Cherokee formation in Cleveland and McClain counties is 46,564 STB.

In Garvin County, 438 wells have been identified for recompletion with 290 wells currently active. The mean EUR for the Cherokee formation in Garvin County is 55,175 STB.

It must be noted that this study is statistical in nature. It has screened a large number of wells for behind-pipe pay in the shallow zones. It is recommended that additional reservoir and petrophysical analysis should be performed on each well to further evaluate the feasibility of re-completing the wells. ABC tools are available to carry out this evaluation in some cases. The integrity of each wellbore also needs to be evaluated, particularly for the wells not currently active. ✧

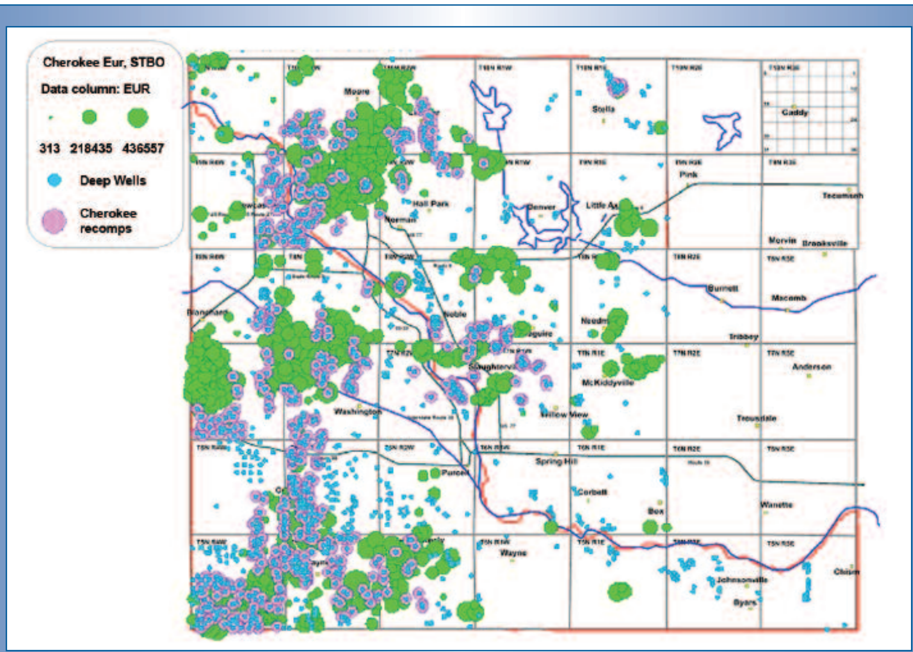


Figure 4. Recommended Cherokee recompletions – Cleveland and McClain counties

High-temperature Downhole Microcomputer System, Switched-Mode Power Supply Component Development

By Chris Hutchens, Chia-Ming Liu and Hooi Miin Soo, *Oklahoma State University*; and Timothy C. Grant, *U.S. Department of Energy/National Energy Technology Laboratory*

This article describes two projects conducted by Oklahoma State University's Advanced Technology Research Center and supported by a U.S. Department of Energy cooperative agreement as part of the DeepTrek program to develop key high-temperature electronic components.

The downhole microcomputer system (DMS) (DE-FC26-05NT42656) and the switched-mode power supply (SMPS) (DE-FC26-06NT42948) will utilize Peregrine Semiconductor's UTSi 0.5 micron silicon-on-sapphire (SOS) process for 275°C (526°F) operations. SOS and silicon-on-insulator (SOI) represent nearly identical technologies. Expanding demands for energy, driven by growing economies such as China, India and the United States, continue to economically pressure oil and gas exploration to greater depths as shallow reservoirs are depleted. This results in an increasing demand for electronics capable of operating at temperatures in excess of 180°C to 240°C (355°F to 463°F) for extended periods of time to support drilling and producing from deep reservoirs, both onshore and offshore. In oil, gas and geothermal exploration and production, electronics are used to control and steer the bit during drilling, for logging-while-drilling and measurement-while-drilling (LWD/MWD) logging, wireline logging and in situ production management.

Among the many high-temperature electronic components needed, micro-controller circuits and switch mode controllers are some of the most critical. Microcontrollers and/or microcomputers are important to accurately and efficiently control downhole equipment, communications, data acquisition and digital signal processing. A switched-mode power supply is equally critical in providing clean power to the microcontrollers' chip sets and other high-temperature integrated circuits (IC).

The downhole microcomputer is a self-contained single-chip microcontroller with the necessary processing and I/O functions located on-chip. Microcontroller functions include read-only memory (ROM) containing application software, random access memory (RAM) for data and variables, counter/timer functions, analog to digital converter (ADC), digital to analog converter (DAC) and one or more of a parallel I/O, asynchronous serial I/O, synchronous or serial I/O. A typical microcontroller with the features summarized is shown in Figure 1. Microcontrollers are generally divided into low, mid-range and high-end processing. The 68HC11 is considered a mid-range microcontroller with its 8/16-bit architecture and arithmetic function capabilities. High-end controllers based on 32-bit architectures like the Leon3 and ARM processor are more complex

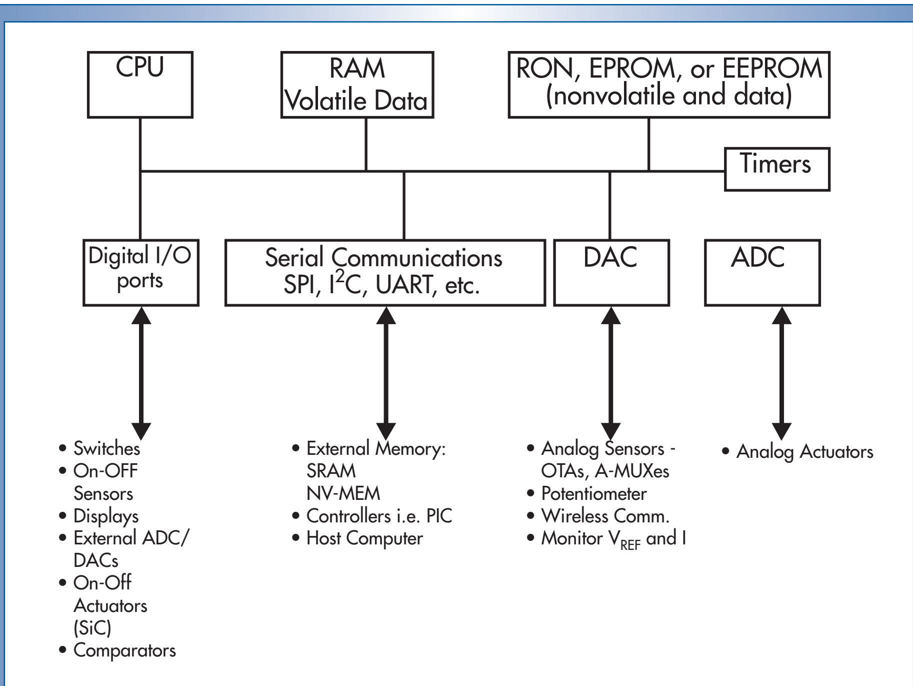


Figure 1. Diagram of a typical microcontroller circuit.

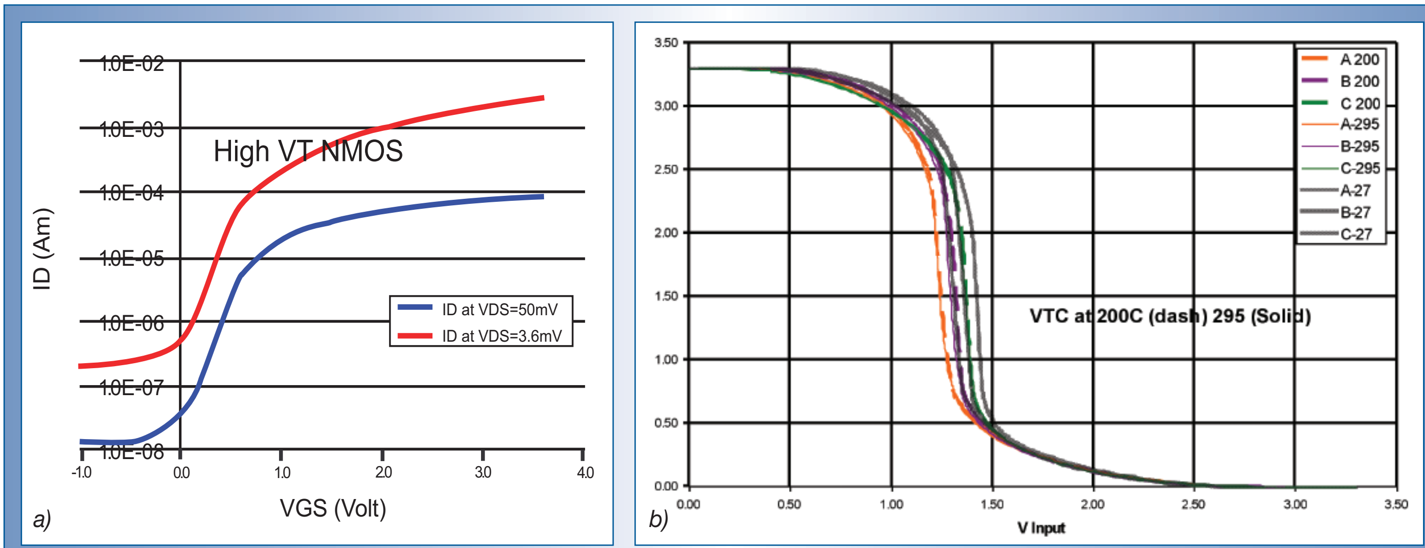


Figure 2. Diagram of (a) an off-state leakage current of Peregrine SOS NMOS process and (b) transfer characteristic of a 3-input CMOS NAND gate at 275°C.

devices, typically with high pin counts of 100 or more. High-end microcontrollers are used for complex functions such as advanced *in situ* signal processing, automatic transmission control and jet engine monitoring. They are typically high-performance pipelined devices frequently possessing math coprocessors and are well suitable for high-end digital signal processing (DSP) applications. It is feasible to implement high-end processors like the Leon3 and the ARM in the Peregrine Semiconductor's 0.5-micron SOS complementary metal oxide semiconductor (CMOS) process. For MWD and well logging applications, the 68HC11 represents an excellent general-purpose microcontroller suitable for a range of applications. Furthermore, the 68HC11 has been in existence since the mid-1980s used by the oil and gas industry. A number of existing MWD and well logging tools use the 68HC11, which provides continuity in adopting the DMS. The Motorola/Freescale 68HC11 is used in a number of existing standard LWD/MWD and logging tools. The 275°C 68HC11 offers a convenient migration path to 180°C and 240°C temperature versions of existing LWD/MWD tools.

The original 68HC11 was implemented in a bulk CMOS material. Bulk CMOS is not as well suited for extreme temperature applications as SOI because of the leakage currents associated with well isolation junctions, transistor drain-to-body diodes and a lower subthreshold slope. Leakage currents typically increase dramatically above 125°C to 150°C (256°F to 301°F). The Peregrine SOS process is designed to isolate, dielectrically, the 100-nm thick transistor bodies by an insulating substrate of aluminum oxide. The resulting leakage currents in SOS processes are low enough to allow SOS digital circuits to function in excess of 300°C (571°F). This leakage current is illustrated in Figure 2a. Here, the low drain current (ID/Amp) values show the worst case of state leakage currents for a Peregrine SOS NMOS transistor at less than 0.8uA/um for 275°C (in red) and on currents greater than 100uA/um (in blue). The magnitude of this on-to-off shift observed at 275°C would not be possible without SOS/SOI technology. In a similar manner, Figure 2b shows the transfer characteristic of a 3-input CMOS NAND gate over 27 to 295°C (562°F), illustrating its stability even at extreme temperatures.

The 68HC11 will be implemented using Peregrine Semiconductor's 0.5-micron SOS process, a commercially available SOI process that features fully depleted dielectrically isolated devices. Transistors in this process are implemented with intrinsic, low and high threshold voltages. For extreme temperature digital circuits, high-level threshold devices are used to minimize off state leakage.

Figure 3 shows the block diagram for a downhole microcomputer system based on the proposed 275°C DMS microcomputer chip set. The core of this system consists of the 68HC11 IC microprocessor as well as local, peripheral and remote devices. Remote devices include the associated boot ROM and RAM for program and memory storage, internal peripherals including a timer system, parallel I/O and a synchronous serial peripheral interface (SPI) circuit. The SPI is a low-resource, high-performance, industry standard short-range synchronous serial bus designed for communications between digital devices. The 68HC11 can access several external peripheral devices through this SPI bus. A separate masked program ROM and external data RAM are part of the DMS package. Other components that can communicate with the DMS via the SPI bus are ADC, DAC, comparators, long-range communication devices,

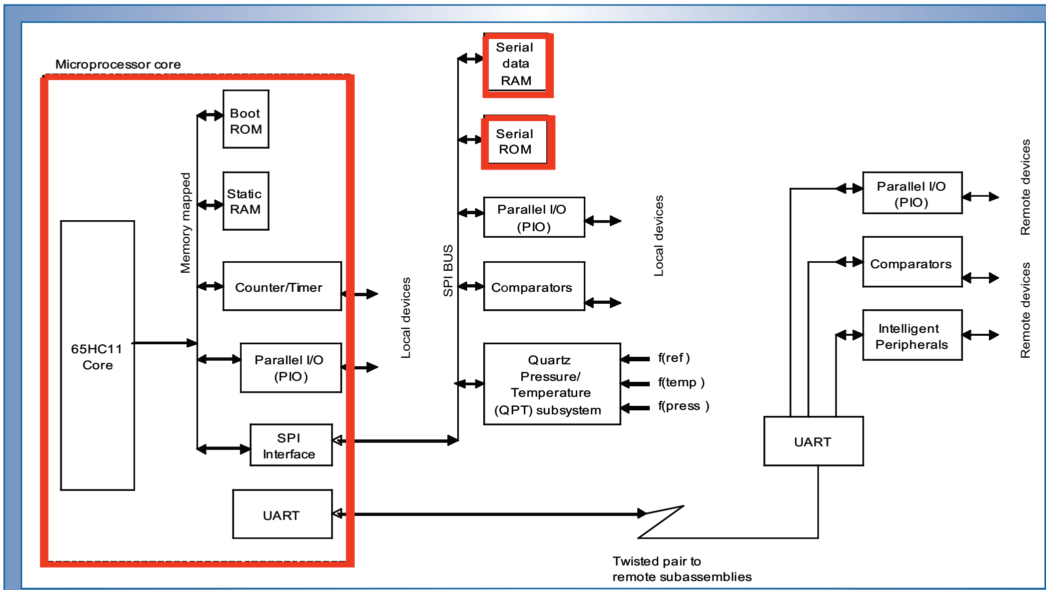


Figure 3. System block diagram for the proposed 68HC11-based 275°C downhole microcomputer system. Forth coming parts are indicted in orange.

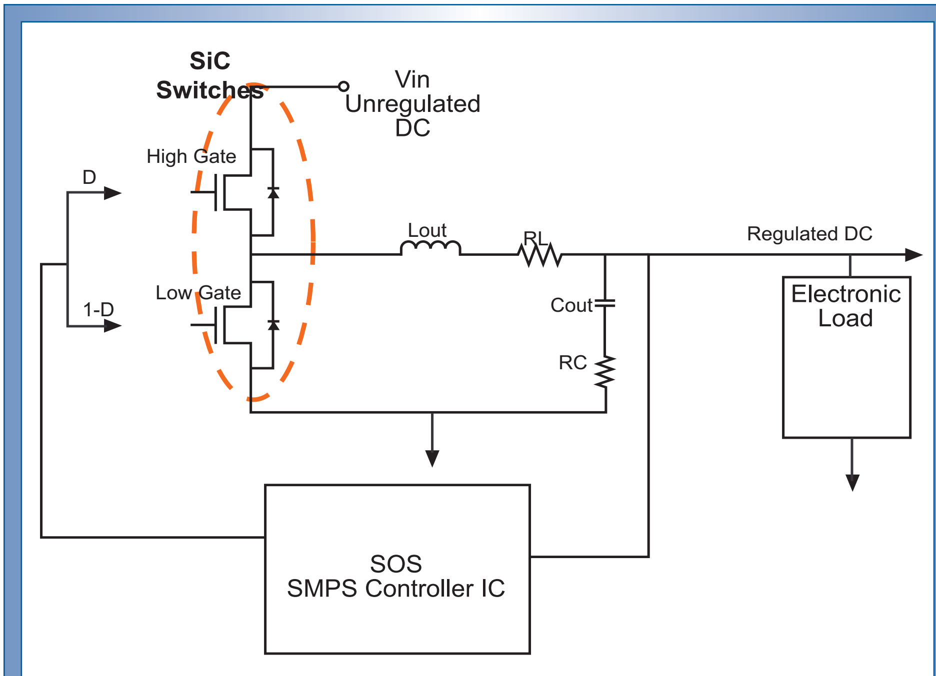


Figure 4. Simplified block diagram of the 275°C switched-mode power supply integrated circuits.

such as asynchronous serial devices (UARTs), or Manchester encoder/decoders and SPI-equipped instrumentation, such as the quartz pressure transducer (QPT) device in Figure 3.

The development of four high-temperature SOI components is a Honeywell contribution to the DOE DeepTrek project. Its ADC and electrically erasable and programmable read-only memory (EEPROM) will be able to communicate with the DMS via the SPI bus. Other SPI peripherals illustrated in Figure 3 are not yet designed for operations above 150°C. One goal is to develop a full line of SPI peripherals for the support of data acquisition and control. In DMS systems, long-range communications (between electronic subassemblies in the tool) should be accomplished using the synchronous/asynchronous communication through a SPI/UART interface or a serial Manchester encoders/decoder IC. Remote devices and microcontrollers can communicate directly through the asynchronous link or through a remote SPI/UART interface. Manchester encoder/decoders are under evaluation and development at Oklahoma State University's Advanced Technology Research Center.

The 275°C 68HC11 requires a 3.3-volt supply and uses an 8-MHz maximum oscillator frequency, resulting in a 2-MHz instruction cycle time or E clock. The parallel outputs are designed for a maximum source current and source currents in excess of 1 mA, for CMOS output logic levels of VOH = 2.5 V and VOL = 0.4 V. The total power consumption of the 68HC11 at room temperature is projected to be less than 15 MW. At 275°C, power dissipation may exceed 100 MW as a result of leakage currents.

The HC11 circuit blocks are implemented using the hardware description language Verilog HDL and Cadence encounter. The hardware synthesis of the integrated circuit layout of the 275°C 68HC11 from Verilog source files uses one of Oklahoma State University's three extreme temperature standard cell libraries. The separate functions of the DMS are assembled into mega cells prior to fabrication. Each mega cell was tested to verify function at temperatures up to 295°C before submission of the DMS for fabrication.

A second project under way at Oklahoma State University's Advanced Technology Research Center is the design of a high-temperature switched-mode power supply (SMPS). A source of steady and efficient DC power is critical for reliable high-temperature subsurface operations. The key requirements of high efficiency and small size necessitate it be a switching power regulator as opposed to a linear regulator. Figure 4 shows a simplified block diagram of the 275°C SMPS IC. Such power supplies typically use high frequency (50 kHz to 1 MHz) switching to periodically sample and store energy in an inductor and then convert stored inductor energy to charge on a filter capacitor to the desired voltage. Regulation of an SMPS is performed using a feedback control loop to vary the duty cycle of the switch, which regulates the supply output voltage. Selecting a higher switching frequency reduces the size of inductors and filter capacitors in the circuit and allows attainment of higher power conversion efficiencies of up to 95% for high performance multiple output voltage designs. Typical power efficiencies for most SMPS applications are 75% to 90%.

The goal of this project is to produce a downhole SMPS capable of operating at 275°C for 1,000 hours, tailored to well logging and MWD applications. The resulting solution can be easily modified to satisfy the needs of emerging extreme electronic systems for other industries, such as aerospace. The base components of SMPS are a V2 controller, Buck Converter and silicon carbide (SiC) power switches. The SMPS IC will utilize SOS technology. In addition to the SMPS IC, the comparators, voltage reference and the operational transconductor amplifier (OTA, an unbuffered amplifier) developed as a part of the V2 controller effort will also be modified and packaged for high-temperature use.

The power transistor switch used for SMPS converters is normally a power metal-oxide-semiconductor field-effect transistor (MOSFET). Such MOSFETs can be used up to about 200°C with careful derating. However, it is anticipated that SiC junction gate field-effect transistors (JFETs) will become the switching element of choice above 200°C. Such JFETs can operate at junction temperatures of 600°C (1,111°F). We are evaluating using SiC JFET as the switch of choice for performance at these extreme temperatures, which is assumed will require the development of new circuit topologies for power JFETs.

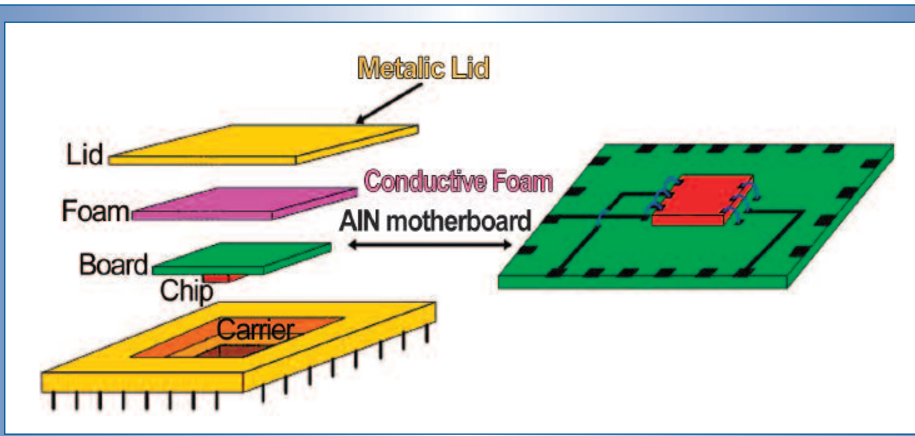


Figure 5. Illustration of flip-board packaging and the AIN motherboard (gold metalized aluminum nitride substrate) using gold ribbon wires from the die to the motherboard and gold wire bonds as crossovers for the gold traces.

There are several additional challenges to designing the feedback circuitry for voltage control in high-temperature SMPS converters, including the voltage reference and low-volume, high-valued capacitors. Packaging of the inductors and large valued capacitors with the JFETs and SOS controller IC will also be one of the greater challenges. The SMPS IC to be developed under this project will have the following features:

- an internal soft-start function;
- a sleep/enable function;
- an under-voltage shutdown function;
- an over-current protection function;
- over temperature soft shutdown; and
- an adjustable output range.

High-temperature packaging will also be developed for the SMPS. This is necessary to ensure the packaging and connections for the power supply can reliably function for extended periods over the temperature range of 25°C to 275°C.

An aluminum nitride (AIN)-based flip-board technology will be developed for an SOS V2 controller and the spinoff ICs, comparators, OTAs and voltage reference. Based on previous research, AlN is considered the most explored and best certifiable material for extreme temperature IC packages. The proposed assembly will be in the form of substrates of AIN with gold metallization one level sub-mount packaging on a motherboard with flip-board packaging. The flip-chip, wire bonding, and our proposed flip-board version of packaging will be used to accommodate the integration of b die and discrete devices, such as SiC vertical field-effect transistor into a packaged SMPS (Figure 5) and heat removal.

We have presented a 275°C 68HC11 equivalent DMS chip set and SMS IC that will be useful for LWD/MWD, well logging and other extreme temperature environments. The HC11 is used by the oil and gas industry in a number of existing tools. The 275°C 68HC11 provides a straightforward low-cost, fast to market migration path to 240°C for existing versions of LWD/MWD and logging systems, electronics to control and steer-the-bit during drilling and chronic in situ reservoir production management. These devices will help answer a need for extreme temperature electronics controllers required for drilling and producing deep energy reserves. ✧

Consortium Adds New Dimension to Research Efforts

By Brad Tomer, *National Energy Technology Laboratory*

Legislation launches expanded public/private partnership for oil and gas research.

The nation's oil and natural gas supply problem is the target of new federal legislation that will enhance historically successful government research programs with a new structure for increasing industry's involvement in developing technology-based solutions. The Energy Policy Act of 2005 (EPAct) has led to a new, three-part approach that includes:

- a core portfolio of federally-funded research and development (R&D) projects focused on technology gaps for tapping future oil and gas resources as well as helping the independent producer today;
- an industry consortium that focuses public/private R&D on in ultra-deep water, unconventional gas and technologies for small producers; and
- a complementary R&D program with fundamental research leading to breakthroughs in oil and gas exploration and production (E&P) technologies.

This article outlines each of these elements and explains how the Department of Energy/National Energy Technology Laboratory's Strategic Center for Natural Gas and Oil (DOE/NETL SCNGO) is integrating them to maximize the benefits to the American energy consumer.

EPAct, challenge of increasing domestic oil and gas supply

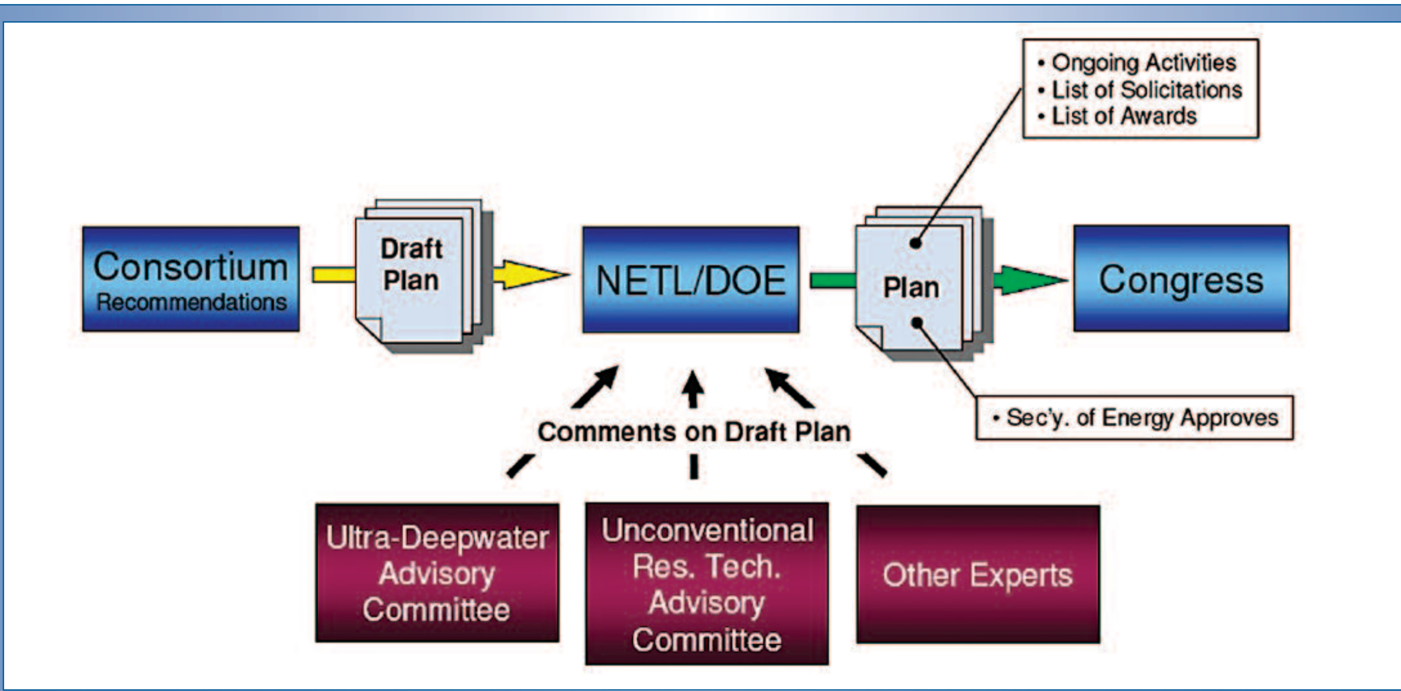
Natural gas and crude oil provide two-thirds of the United States' primary energy supply and will continue to do so for at least the next several decades, even as there is a transition to a more sustainable energy future. The natural gas resource estimated to exist within the United States is large, but because it is increasingly harder to locate and produce, new technologies are required to extract it in a timely manner that will support a growing economy. This is also true for the domestic oil resource, much of which will need to be produced from deep water, forced from residual pockets left in older reservoirs or extracted from unconventional deposits, all of which are difficult to develop with existing technology, even at current prices. Recognizing these challenges, The SCNGO has historically implemented a portfolio of R&D programs aimed at enhancing domestic oil and gas supply at reasonable prices while protecting the environment.

In August 2005, President George W. Bush signed EPAct into law making it the first national energy plan in more than a decade. EPAct Sections 965, 968 and 999 support oil and gas R&D by targeting technology challenges. The first two of these sections relate to programs the NETL is already implementing. Section 965 directs the DOE to continue to carry out an oil and gas research program similar to the existing core program, such as E&P, reservoir life extension, distribution infrastructure, gas hydrates and related environmental issues. Section 968 relates specifically to the DOE-led interagency program of gas hydrates research. Section 999, however, adds a new dimension to the overall SCNGO oil and gas R&D effort, enhancing opportunities to demonstrate technologies in the field and accelerate their implementation in the marketplace. The Ultra-deepwater and Unconventional Natural Gas and Other Petroleum Resources Program launched by Section 999 is a 10-year, $50 million-per-year, public/private partnership designed to benefit consumers by developing technology to increase America's domestic oil and gas supply and reduce the nation's dependency on imports. A portion of the funding will be directed toward cost-shared research partnerships while the NETL will use another portion to carry out complementary R&D.

Historical success

About 40% of the natural gas produced from gas wells in the United States comes from unconventional natural gas reservoirs, such as tight sands, fractured shales and coal seams, that the oil and gas industry considered uneconomic to produce 30 years ago. R&D through public and private partnerships the DOE sponsored from the late 1970s through the 1990s as well as by the Gas Research Institute during the 1980s and 1990s provided important data, tools and scientific insights that helped pave the way for new natural gas E&P technologies commercialized by industry. These technologies have helped mitigate a natural gas supply and demand gap that would have been worse in their absence.

As an example of the successful partner-



Section 999 research and development plan approval process

ships, the NETL is working with Honeywell International to develop several downhole electronic components – identified by industry as those most needed and least likely to be developed independently by industry – that will operate at 400°F (204°C) to 450°F (232°C). Three other projects are developing key elements of an advanced suite of drilling and diagnostic tools for deep wells. These include tools for evaluating formations in real time, a microprocessor to provide real-time processing of downhole measurements and control downhole equipment, and a downhole power source. (Two articles in this issue of *GasTIPS* relate to DOE-funded high-temperature electronics). These and other technologies developed under the NETL's ongoing core program will advance more efficient and safer recovery of an additional 100 Tcf of deep-formation gas through 2020.

Another successful example is the Stripper Well Consortium (SWC), a group supported with the DOE funds, that has provided more than 100 small oil and gas producers with the opportunity to participate in technology development. The 6-year-old program has already yielded commercial technologies improving performance in the nearly 700,000 marginal oil and gas wells that provide 9% of domestic gas and 17% of domestic oil production. Examples include two new pump designs, an improved chemical injector and a flow device that helps in the removal of water from low-pressure gas wells (two articles in this issue of *GasTIPS* relate to SWC projects). The SWC's research is an example of a successful collaborative effort among government, academia and industry.

Implementing Section 999 of EPAct

EPAct Section 999 states, "The Secretary shall carry out a program of research, development, demonstration and commercial application of technologies for ultra-deepwater and unconventional natural gas and other petroleum resource exploration and production to maximize the value of U.S. resources by increasing supply from these resources." The legislation identifies the NETL as the DOE entity responsible for management and oversight of the resulting Ultra-deepwater and Unconventional Natural Gas and Other Petroleum Resources Program. The legislation further states "The Secretary shall contract with a corporation that is structured as a consortium to administer the programmatic activities …"

Section 999 sets the funding for this program at a level of $50-million-per-year during 10 years, provided from federal lease royalties, rents and bonuses paid by oil and gas companies. The funds are to be directed toward research specifically targeting: ultra-deepwater resources; unconventional natural gas and other petroleum resources; technology challenges of small producers; and fundamental research complementary to these areas. The NETL is to perform the complementary research while the SCNGO is to oversee all other research the consortium administers.

RPSEA receives contract

The Research Partnership to Secure Energy for America (RPSEA), a 501(c)(3) not-forprofit corporation consisting of nearly 100-member organizations, submitted a proposal to administer part of the program in response to a competitive solicitation the NETL issued. In May 2006, RPSEA was selected by the NETL to administer the distribution of about $36 million per year in R&D contracts. The federal government will maintain management oversight of the program, and RPSEA's administration costs are limited to no more than 10% of the funds.

RPSEA has a broad membership base that includes representatives from all levels and sectors of the oil and gas E&P and R&D communities. There are 96 organizations on the RPSEA membership list, including five pending members. Of these, 16% are smaller oil and gas producers, 5% are large producing companies, 23% are universities, 26% are technology development companies of all sizes and 9% are national labs or research institutes. This breadth of membership will help ensure consortium R&D funds are directed toward key problems in ways that leverage existing industry efforts. For example, DeepStar, a common forum the offshore industry uses to address the technical issues confronting deepwater production, includes RPSEA members. DeepStar members collectively fund activities to advance needed technology and avoid duplicating work that has already been done. It will also help RPSEA do the same. More details on the progress of the program and RPSEA in general can be found on the consortium's Web site (*www.rpsea.org*).

The industry consortium approach will enhance the overall program in other ways as well. The companies, universities and organizations that receive funds through this program will provide cost-share contributions between 20% and 50% of total project costs, magnifying the impact of the public investment. The involvement of industry partners in all phases of the oil and gas R&D process will increase the likelihood of near-term demonstrations of technologies the program developed, a key step in accelerating the movement of these technologies into the marketplace.

Maximizing input from advisory groups

One of the important features of the Section 999 legislation is the incorporation of high-level advisory groups helping direct the R&D program's focus. Late last year, the NETL awarded the contract to RPSEA to begin its work Jan. 4. RPSEA is preparing its recommendations for the first Draft Annual Plan, which must be further developed and approved by the DOE before a solicitation for R&D contracts can be released. The process of approval, spelled out in the legislation, calls for input on the Draft Annual Plan from two federal advisory committees formed by the DOE as well as other industry experts (see graphic).

This approach will bring together a range of intellect to ensure the research program undertaken returns the maximum benefit to the nation in terms of domestic oil and gas supply increase.

Subsequent years' Draft Annual Plans must include details of ongoing activities; a list of solicitations, including topics of R&D, selection criteria, duration of awards and anticipated funds; a list of awards made; and an estimate of the cumulative increase in federal royalties that can be expected from the ultimate application of the results. The Secretary of Energy must approve the plan before it is sent to Congress.

Complementary research

Section 999 of EPAct also assigns the NETL the task of carrying out a complementary in-house R&D program. The organization's Office of Research and Development (ORD) will implement this portion of the overall oil and gas R&D program. Research the ORD conducts will be guided by the results of road mapping exercises and ongoing discussions with industry and university research partners.

One area of complementary research will involve the Extreme Drilling Lab, a new facility at the NETL for observing and modeling the performance of drilling equipment and fluids under high-pressure and high-temperature (HP/HT) conditions. Using physical simulation facilities unique to the industry, NETL scientists will study phenomena related to ultra-deep drilling, building unique data sets and expertise in the areas of rock mechanics, and novel drilling fluids. The lab will also enable the study of novel electronics, sensors and completion equipment in HP/HT environments. Beyond the physical simulation capabilities, the lab will also incorporate ultra-deep drilling simulation models and a rock mechanics laboratory.

Other complementary research may include fundamental studies related to domestic enhanced oil recovery (EOR), carbon dioxide sequestration, novel seismic sensors, treatment and beneficial use of produced water, and basic research into the environmental impacts of oil and gas development. The NETL is developing this plan in consultation with stakeholders.

Core oil and gas R&D

The SCNGO will continue to implement its ongoing program as appropriated by Congress.

This core program includes more than 200 research projects. Focus areas include EOR (36 projects), environmental issues related to oil and gas production (46 projects), deep drilling technologies, microhole drilling, improved seismic technologies for characterizing unconventional reservoirs and resource assessments. There is also a major interagency program, led by the SCNGO, to understand and characterize the nature, distribution and production potential of methane hydrates in deepwater and arctic regions.

The SCNGO's approach to managing this program has been to: identify areas where technology gaps exist, where there is also a significant public benefit associated with filling them in; collect a range of industry and scientific perspectives on the structure of a roadmap to developing these technologies; and manage a collection of projects that leverage the available funding through industry cost share. This approach will continue as funds are appropriated by Congress, and will be integrated with the efforts of RPSEA and the in-house research that complements the rest of the program.

The SCNGO's oil and gas R&D program has achieved a number of recent successes. Along with the HT electronics and SWC partnerships, research products include: Intellipipe, a type of drillpipe with embedded high-capacity electronic communications cable that Grant Prideco is commercializing; a specially designed hybrid microhole coiled tubing rig that recently drilled 25 test wells at a cost savings of between 25% and 35% compared with conventional equipment; Explorer, an award-winning, self-powered robotic system for live, visual pipeline inspection; and a membrane separation process for purifying low-quality natural gas that has already accounted for nearly $2.6 million in sales through a commercial joint venture. Despite these successes, the task of moving new technologies from laboratory to marketplace remains daunting.

One of the important aspects of the EPAct Section 999 legislation as well as the RPSEA-administered research it has launched is that the consortium R&D will be able to focus somewhat on near- to mid-term research. Opportunities to carry out industry-supported demonstrations of R&D products will be greater. This is an element of the commercialization process the DOE's program has sometimes lacked the funds to support.

Balanced approach

The integration of a core R&D program focused on an array of technology gaps; a public-private R&D partnership demonstrating near-to-mid-term technologies related to specific resources, such as ultra-deep water and unconventional gas; and a laboratory R&D program focused on breakthrough technologies will lead to synergies that can significantly enhance the program's overall results. The SCNGO will integrate these areas in a manner that maximizes the program's impact on domestic oil and gas production.

This integration will require close collaboration among the managements of the SCNGO, RPSEA and ORD to take advantage of individual strengths. The outcome will do much to lower domestic oil and gas production costs, broaden the resource base, reduce the gap between domestic energy supply and overall energy demand, and maintain excellence in U.S. academic research programs. ✧

High-temperature Electronic Component and Packaging Development

By Bruce Ohme,
Honeywell

DeepTrek high-temperature electronics come on-line this year.

Because drilling rigs are expensive to operate, the ability to monitor drilling progress and/or downhole conditions has become indispensable. As a result, electronics are widely used in modern oil and gas exploration to collect, log and/or process data such as heading and inclination, weight on the bit, vibration, seismic/acoustic response, temperature, pressure, radiation and resistivity of the strata. Drilling time and costs escalate when the target reservoir is very deep. This makes it even more important to be able to monitor downhole conditions in deep wells (>15,000ft, 4,575m). This creates a catch-22 situation because electronics that can reliably operate in deep-well conditions have not been available. The biggest obstacle for electronic data acquisition systems in deep wells is the high temperature (>170°C, 337°F) encountered at great depth. Commercial electronics are not designed for these temperatures, and conventional integrated circuit (IC) technology is not capable of operating at these temperatures. To overcome this limitation, the U.S. Department of Energy DeepTrek program has funded two projects led by Honeywell to develop electronic components that can handle the heat and deliver the data operators need to undertake deep-reservoir development. The first project, launched in 2003 and slated for completion this year, established a production-level IC manufacturing process along with IC design tools (software-and-simulation-elements) specifically targeting high-temperature environments (up to 250°C, 481°F). These IC technology and design tools were then employed to develop high-temperature IC components. The second project, launched in 2006 and scheduled for completion next year, will develop rugged packaging suitable for downhole shock and vibration environments, which will be used to house and demonstrate components developed in the earlier project.

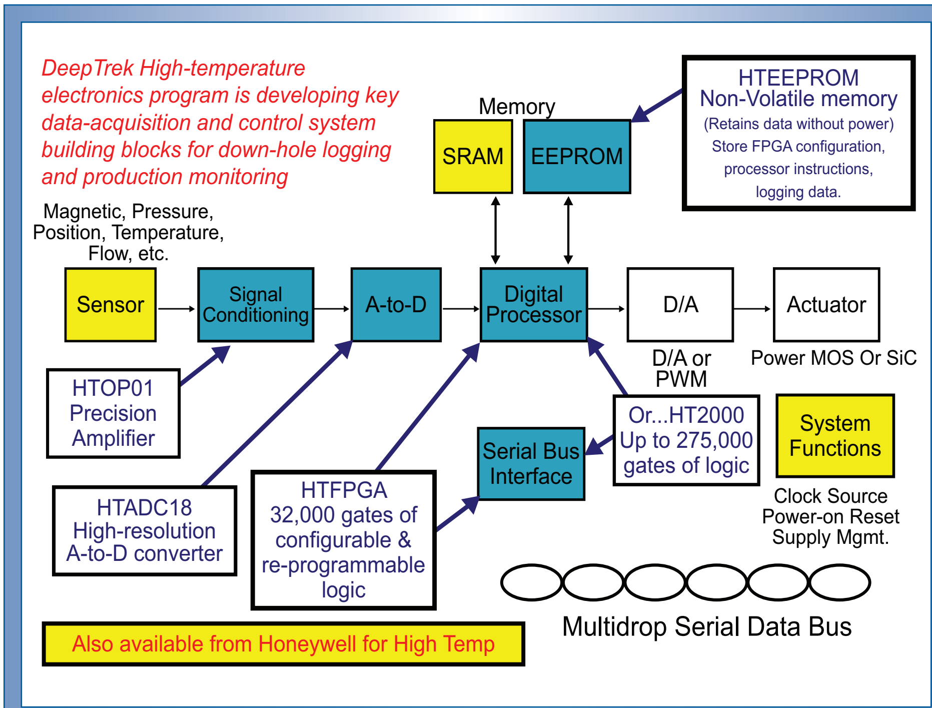


Figure 1. A generic data acquisition and control system.

Electronics for high-temperature well instrumentation

Modern electronics are predominately silicon ICs supported by small numbers of discrete passive devices such as capacitors, inductors and resistors. Commercially available consumer electronics ICs and packaging approaches are limited to a maximum operating temperature of about 75°C (166°F). Above this temperature, plastic packaging is not reliable and the design functionality is not guaranteed. For military, industrial and some automotive applications, ICs are commercially available for operation at 125°C (256°F) and in some cases 150°C (301°F). These typically use ceramic packages, which are more costly but able to withstand high temperatures. Above 150°C, the number of commercially available electronics components is limited. Downhole operators and producers are demanding electronics that operate in wells that see temperatures ranging from 170°C (337°F) up to 250°C. Approaches involving special screening and frequent component replacement (common practices in the downhole tool industry at 170°C and below) are not practical at these temperatures.

Overall, Silicon-on-Insulator (or SOI) IC processes, combined with high-temperature packaging and assembly, are the most viable and mature near-term approaches for high-temperature electronics. SOI electronics employ a manufacturing process that surrounds each transistor on the chip in silicon dioxide, a form of glass, which has excellent electrical isolation properties that do not degrade at high temperatures. As a result of the DeepTrek program, Honeywell has tailored such a process (and associated design tools) to develop components capable of 5 years of continuous operation at 250°C. Figure 1 illustrates what this means for the downhole data-acquisition and control system. The graphic shows the various functions embedded in a data-acquisition/control node, which includes a sensing function; signal-conditioning to amplify and buffer sensor inputs; analog-to-digital conversion (A-to-D) to transform analog signals to digital format; digital processing and associated memory functions; serial communications protocol formatting and transceiver functions; and digital-to-analog conversion and actuator drive and/or control function. Support functions, such as clock source and power management (voltage regulation) are also needed. The shaded blue functions are addressed by electronic components available from Honeywell as a result of the DeepTrek program. Other high-temperature SOI components are available as a result of parallel and/or previous development.

Development status of DeepTrek electronics for high temperature

An SOI manufacturing process and associated IC development design tools have been developed and commercialized by Honeywell under the DeepTrek High-Temperature Electronics project under which Honeywell has demonstrated the high-temperature capability of SOI, including operation of some components as high as 375°C (706°F). Honeywell's efforts take advantage of the SOI technology and include design, assembly, and testing infrastructure and techniques that specifically address high-temperature applications. Honeywell was the first company to use SOI technology to make IC products commercially available for specified operation above 150°C. Honeywell's first 225°C (436°F) SOI components were marketed in 1995. ICs developed under the DeepTrek program were developed specifically for long-term (5 years) product life at a continuous use temperature of 225°C. Specific component developed are shown in Figure 2.

DeepTrek high temperature IC components

HT2000 Family of Gate Arrays—A family of digital gate-array platforms is available for quick-turn development of digital processing functions. This approach uses pre-designed and fabricated arrays of transistors arranged

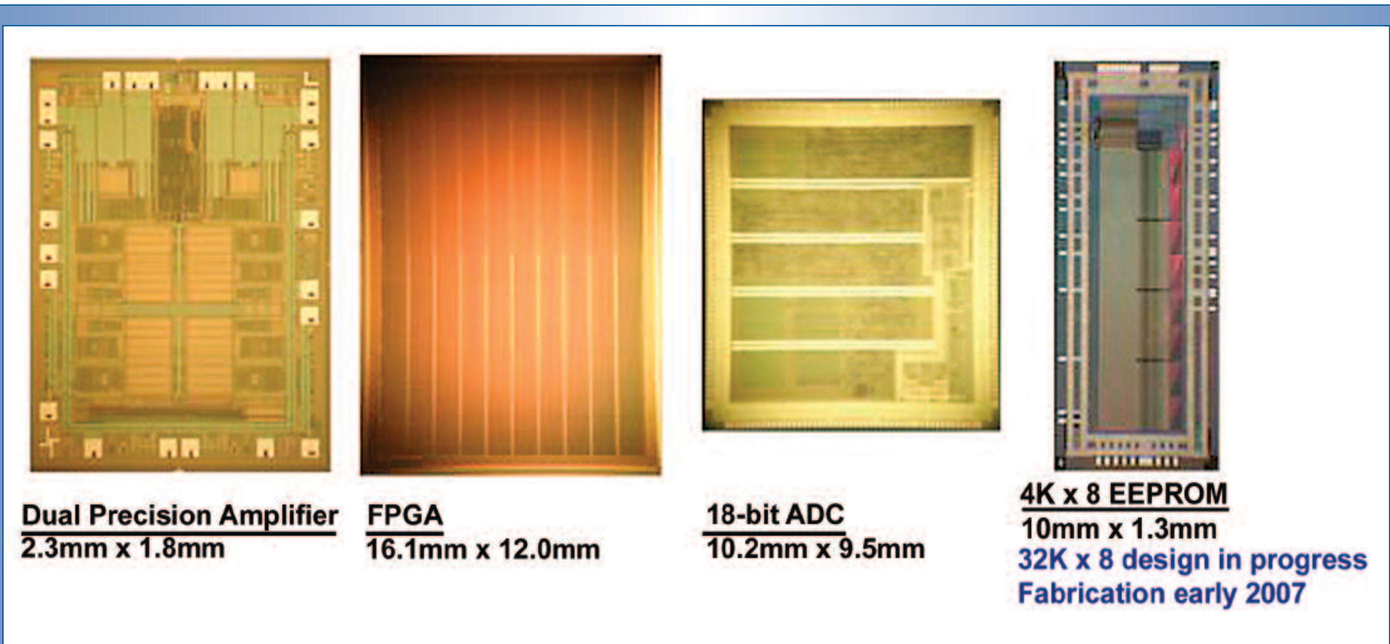


Figure 2. DeepTrek High-Temperature Electronics program standard product components (not to scale).

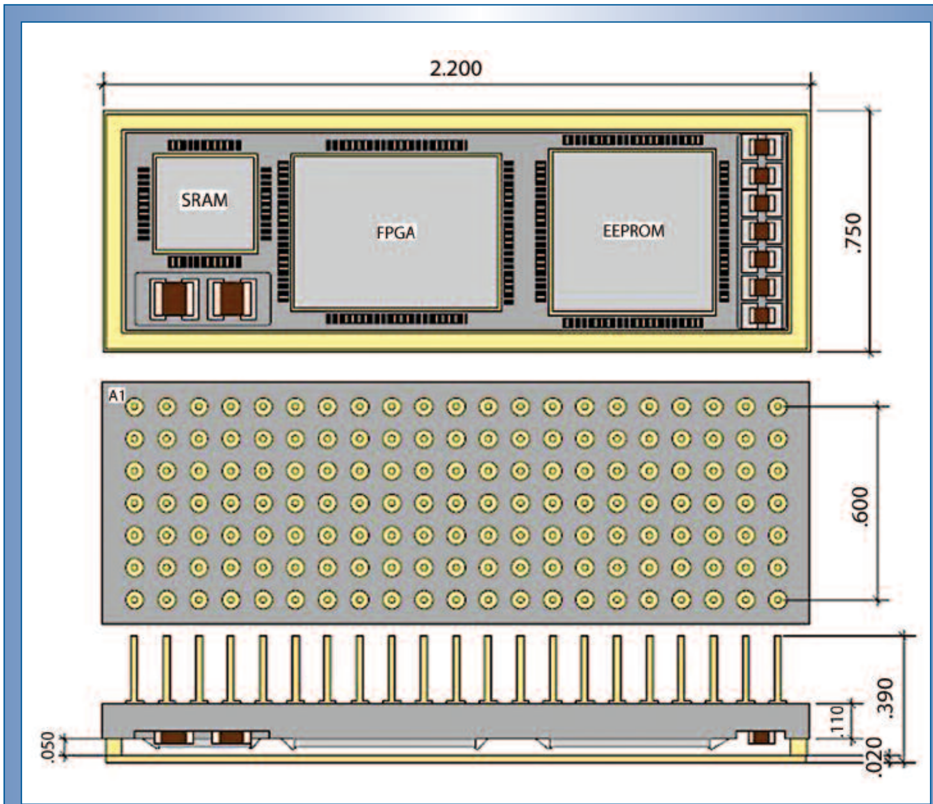


Figure 3. Re-configurable processor for data acquisition module

in a "sea-of-gates" format. These can be configured as various logic functions (logic "gates") by customizing the top-level metal layers of the design. The gate array family supports a range of functions (from a few thousand to 275,000 gates). Potential customized product examples include data processors, communications functions and control processors. Note that this approach requires some up-front design. IC tooling is completed by the end-user for each new function developed. This enables more functions to be packed into a given amount of silicon relative to the field-programmable-gate-array (FPGA) approach.

High-Temperature FPGA—Low-volume digital applications at conventional temperature ranges often are addressed by the use of programmable logic devices. These go by a variety of names, including FPGAs. The low-cost and increasing levels of functionality for which the IC industry has become famous are the result of economy-of-scale achieved by batch processing and high-volume manufacturing. FPGAs apply these economic advantages to low-volume or application-specific digital components by enabling the user to customize (on a unit-by-unit basis) components manufactured in high volumes. An FPGA, for example, can contain hundreds of thousands of logic gates where the connectivity (and thereby the functionality) of the unit is programmed for each individual component. The DeepTrek FPGA was developed as a licensed functional equivalent to a commercial FPGA, the Atmel AT6010. It is a re-programmable, SRAM-based FPGA that provides up to 32,000 logic gates and 204 programmable inputs/outputs. It has been fully verified by wafer-probe testing at 200°C (391°F). The design includes more than 3 million transistors, yet standby leakage current at 200°C is still under 0.5mA. This design will be offered in die-form, as well as in a multi-chip module described later in this article.

High Temperature EEPROM—Re-programmable FPGAs rely for configuration on some type of non-volatile memory – one that, once programmed, retains its data if power is interrupted. The data in the non-volatile memory programs the connectivity, and therefore the functionality, of the FPGA. Prior to the DeepTrek program, high-temperature non-volatile memory has not been available. The non-volatile memory gap is being filled through the development of an electrically erasable and programmable read-only memory (EEPROM).

EEPROM uses a memory cell programmed (store a logic "1") or erased (store a logic "0") by injecting or removing charge onto the floating "gate" terminal of a transistor. This process, referred to as Fowler-Nordheim tunneling, involves passing current through a thin-oxide. The oxide is normally non-conductive. Current is passed through the oxide by the application of voltages higher than those used in normal operation, including memory read-out. All the high-voltage waveforms generation required to program or erase the EEPROM are generated on the chip.

Even though the acronym implies this is a read-only memory, it can actually be addressed and rewritten many times. However, the writing process is slow relative to the read-out process. This approach required no additional process steps. A 4-K by 8-bit demonstration memory has been fabricated and verified for operation up to 250°C. A 32-K by 8-bit design that can be operated in parallel and serial mode has been completed and will be fabricated soon. This design will feature an automatic FPGA loader that can program the high-temperature field programmable gate array (HTFPGA) when power is applied. The high-temperature electrically erasable programmable read-only memory (HTEEPROM) can also be used as an independent non-volatile data storage element.

HTOP01, High-temperature Dual-precision Amplifier—This component provides high precision signal conditioning (high-gain, low offset and low noise) for DC-coupled sensor signal conditioning. Two complete operational amplifiers are contained on each chip. The design includes a shutdown mode to conserve power and is packaged in a ceramic 14-pin package. The high-temperature, dual-precision amplifier has been fully verified at 225°C with additional testing up to 375°C.

HTADC18, High-temperature A-to-D Converter—The DeepTrek high-temperature ADC targets 18-bit resolution at 100 samples/sec. It uses a second-order sigma-delta modulator with 204.8 KHz sampling clock. Digital filtering and control logic was synthesized from Verilog code and implemented using a high-temperature gate array design process. Analog circuits were designed and laid out as a full-custom block dropped into the HT2000 digital gate-array I/O frame. Test results include 17.4 bits of resolution at 225°C. The ADC incorporates an on-chip voltage reference tested up to 275°C. A 28-pin ceramic package has been developed for this device.

High-temperature Multi-chip Packaging—High-reliability, high-temperature packaging is an essential element of the downhole electronics system. Co-fired ceramic multi-chip modules (MCM) meet this need with stable performance at temperatures greater than 225°C. In downhole systems, reliability is improved by reducing the number of device inter-connections that need to be made at the circuit board level. An MCM can be likened to an electronics board implemented in a single solid piece of ceramic material. In this process, layers of ceramic materials, such as aluminum oxide, are alternated with patterned layers of interconnect metallization (such as tungsten) built into a multi-layered structure and then fired to result in a single, hermetic ceramic package. Multiple die can be attached in such a package using gold-eutectic die bonds or high-temperature adhesives and wire-bonded to internal package interconnect traces. External pins can be brazed onto the ceramic body where external metallization is plated with gold for long-term high-temperature applications. Lids made of Kovar (nickel-iron-cobalt) that are well matched to the thermal expansion properties of the ceramic can be soldered using high-temperature gold-tin solder or else welded to Kovar seal rings built into the ceramic. This technology results in high density, hermetically sealed packaging with short internal wire lengths extremely tolerant of shock and vibration and capable of withstanding extreme temperature cycles.

High-temperature IC processes and components combined with rugged packaging are being developed by government/industry collaboration.

New DeepTrek project

Re-configurable Processor for Data Acquisition (RPDA)—A new Honeywell DeepTrek project will develop a ceramic multi-chip package to house several high-temperature ICs and support components in a single module (Figure 3). The technology and approach chosen address the simultaneous need for high-temperature operation, low component development cost and small, rugged packages. Under the current DeepTrek High-Temperature Electronics project, Honeywell has developed a 30,000-gate FPGA and is developing a 32-K x 8-bit EEPROM, both developed for operation at 250°C. The RPDA will combine the HTFPGA, HTEEPROM and a 32-K x 8-bit SOI static random-access memory, in a single package tailored to the physical constraints of downhole applications. This package will also house capacitors for power-supply de-coupling.

The overall result is akin to having a flexible micro-controller with built-in non-volatile instruction memory and data memory in a single package. The package would be developed to have rugged through-hole pins in a dense pin-grid array pattern with an overall width profile of 0.7 in. or less, allowing ease of use in downhole tools and instruments. The RPDA should become available next year.

Conclusion

High-temperature IC processes and components combined with rugged packaging are being developed by government/industry collaboration. These components and technology may be used for high-temperature/high-pressure well logging, measurement-while-drilling and diagonostics-while-drilling applications. Because the electronics are capable for long-term reliable operation at elevated temperatures, this technology supports downhole permanent installation for production management as well. Other markets with needs for high-temperature electronics, such as distributed controls for turbine engines and avionics, are also expected to benefit from this product offering.

Acknowledgement

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Oklahoma Commission on Marginally Producing Oil and Gas Wells

By Regina Finney, *Oklahoma Marginal Well Commission*

In the late 1980s, a group of producers met to establish an association called Save Our Strippers. Using the foresight of experience and raw data demonstrating the dramatic declines in crude oil production, the group expanded the idea of an association into the creation of a state agency dedicated to the advocacy of preserving Oklahoma's No. 1 natural resource – one that had reached an age of maturity that would require attention for years.

In 1992, the Oklahoma Legislature responded with the passing of Senate Bill 684, now Title 52 O.S. Sec. 700. The bill allowed a small voluntary fee to be collected by the Oklahoma Tax Commission from the revenue stream of oil and gas production with the proceeds underwriting the efforts of a new state agency – the Oklahoma Commission on Marginally Producing Oil and Gas Wells. Save our Strippers remains the logo of the Marginal Well Commission (MWC) as a reminder of the dedicated producers that advocated the creation of the agency.

The Pumper/Well Tender PDA (personal digital assistant) Program for Small Producing Companies began when the MWC was contacted by a group of producers that utilized contract pumpers and well tenders to collect data in the field. There was a need for a better data collection system. Weekly gauge sheets were submitted in carbon copy form when the original was damaged because of coffee stains, erasure damage or otherwise unavailable. Pumpers and well tenders have also had to go back and estimate readings and volumes because gauge reports were lost or not collected. Producers often were unaware of problems with their well's production for days because the pumper or well tender only submitted the gauge reports once a week. The lack of proper and timely data collection and reporting was costing the producers time and money.

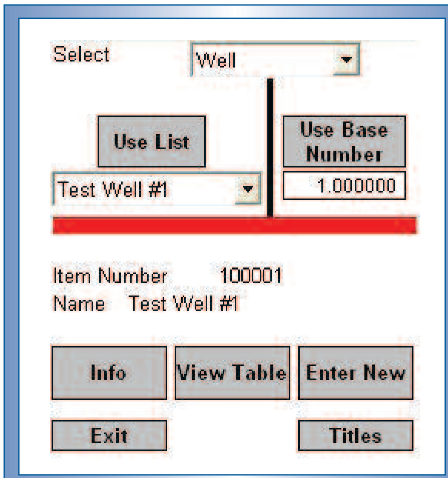

Figure 1. PDA start screen

Through research and many long hours, the MWC discovered a company capable of writing a simple software program that could collect the basic data included on a gauge report. The program is written in a Visual CE format to be transferred and viewed on a Windows mobile PDA operating system. The user interface will require a basic knowledge of database entry and in particular the Microsoft Access database. The users will also need to have knowledge of how computers function, such as software installation and equipment/peripheral installation, and the way to transmit e-mails with a database attached. The producer/home office and the pumper/well tender will need to have access to a computer. One PDA will need to be purchased to utilize all the program's features.

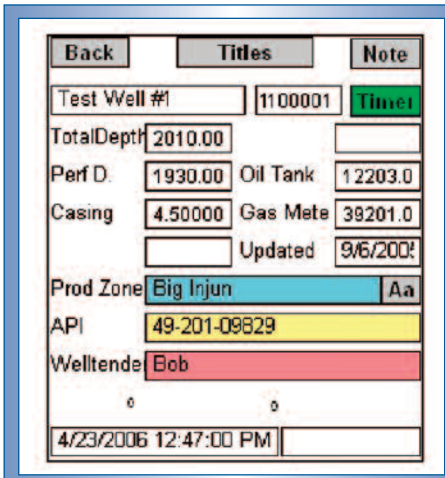

Figure 2. PDA background information screen

The final version of the program and the final draft of the manual will be mass-produced and distributed free of charge.

The MWC presented the Pumper/Well Tender PDA Program to the Stripper Well Consortium in hopes of securing a grant to fund the project. The consortium agreed to co-fund the project and MWC set out to secure the necessary contracts to move forward and start the project. The Pumper/Well Tender Program for Small Producing Companies was designed by Josh Cook of Cook Contracting LLC with the intention of giving small producers the opportunity to have their pumper/well tender gather basic information from the field and enter it into a small hand-held device in the field. The device can then be

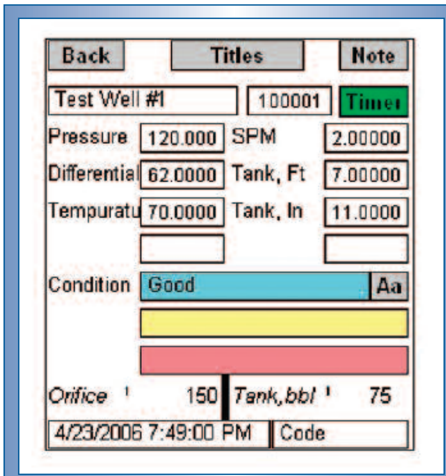

Figure 3. PDA new data screen

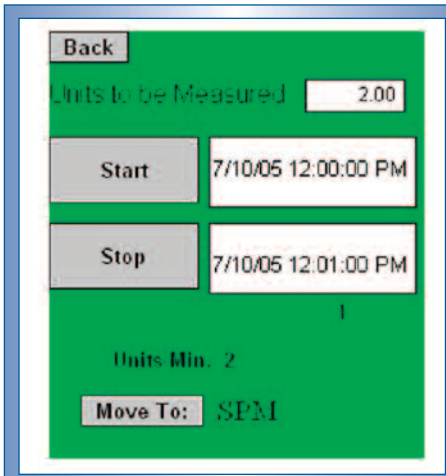

Figure 4. PDA timer screen

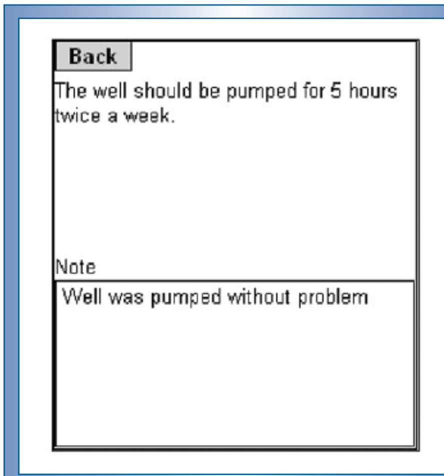

Figure 5. PDA notes screen

taken back to a home office computer and synced into a main database that will allow the pumper/well tender to track the information electronically and manipulate it into reports that can ultimately show a history of the well's production in different forms. The information the program is capable of storing was kept to a basic format that includes:

- volume of production in feet and inches;
- equipment on site;
- chemicals;
- meter readings;
- pressure readings;
- gauge measurements; and
- several notes fields.

The program is also capable of performing simple calculations, such as barrels per inch tank volume conversion and strokes per minute. The other frequently used feature standard on all PDAs is the calculator. It can be accessed and used even as the pumper has the program open entering data. The project is in the beta testing phase, where some individuals have chosen to take handheld devices into the field and provide feedback on the program's advantages or disadvantages, ease or difficulty of use and the functionality utilizing the reports. The program will be assessed throughout the beta testing period to ensure the ease of operation is optimal and any unforeseen malfunctions can be corrected.

The instruction manual will also be continually assessed throughout the beta testing period to provide the operators and pumpers/well tenders with detailed information regarding the installation, operation and function of the program. The goal is to provide a final version of the program and instruction manual that will be of the most value to small producing companies.

The program has been designed to be the most basic, yet useful tool for pumpers/well tenders to collect data and distribute it to operators. According to the Interstate Oil & Gas Compact Commission's 2006 report on marginal wells, there were a total of 401,072 marginally producing oil wells in the United States and 288,898 marginally producing gas wells. The oil produced from these marginal

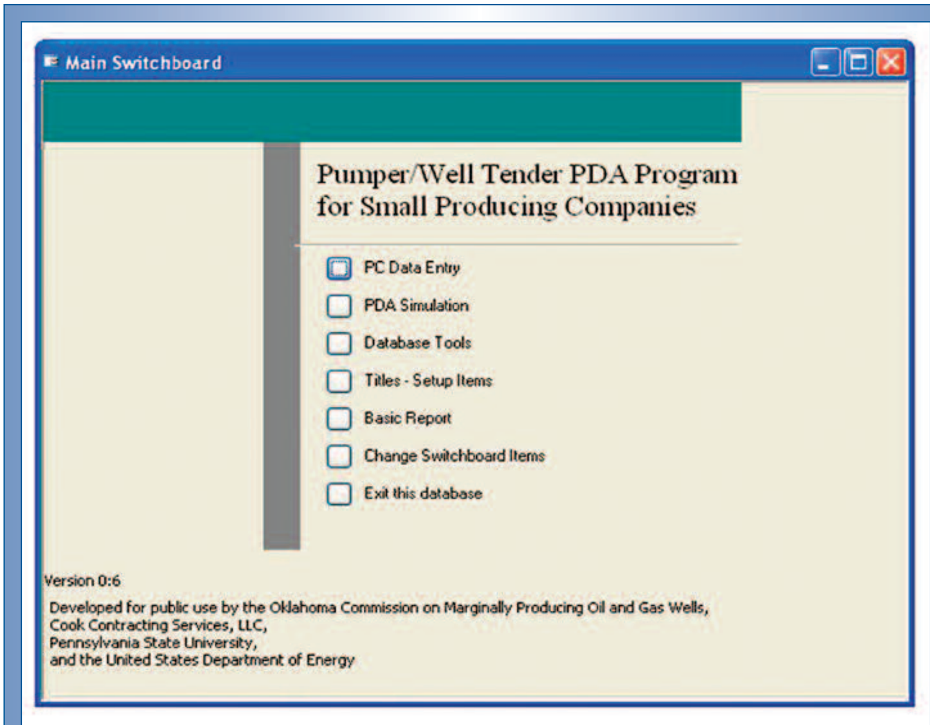

Figure 6. Main switchboard

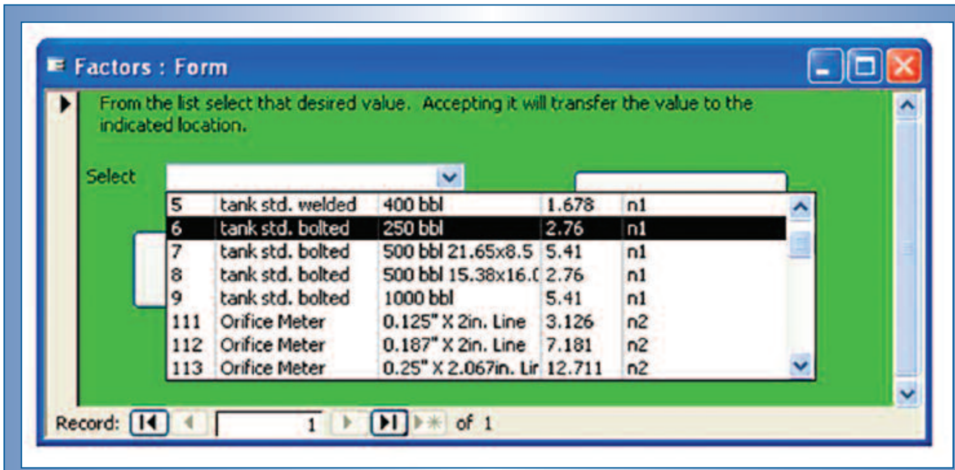

Figure 7. Factor selecting form

wells totaled 321.8 million bbl and the gas wells produced 1,760,063,552 Mcf. Together, these wells provide 17% of oil and 9% of natural gas produced onshore in the United States. Without these wells, the United States would have to increase imports by nearly 7%. By providing this program to small producing companies, it is our goal to decrease their time and effort in collecting and storing data and provide them with a means of viewing that data and arranging it so they might be able to make their production less costly and more efficient. This program is designed to eliminate the collection of data on paper, thus reducing such storage cost. It is not always economically viable for a small producer to consider purchasing such a program or contacting a company that maintains that data for them. Once it is felt that the program is at a point where it will provide the benefit, the MWC will host workshops to train individuals in the field on how to use the product. The program and manual will also be produced and distributed free of charge, which should be under way by the end of April 2007.

The commision is a non-profit state agency with the purpose to:

- define and identify appropriate categories that may be used to characterize marginally producing oil and gas wells;
- research and collect information on the number, location and operational conditions of marginally producing oil and gas wells in Oklahoma;
- identify and evaluate the economic and operational factors that may extend the life of marginally producing oil and gas wells;
- propose legislative, regulatory and operational remedies that will extend the life of marginally producing oil and gas wells;
- collect data and make available to the public any information on the contributions of marginally producing oil and gas wells to the local economies of Oklahoma;
- interact with national and regional organizations to ensure recognition of the importance of marginally producing oil and gas wells to the domestic production of oil and gas;
- make an annual report to the governor, the president pro tempore of the Senate, and the speaker of the House of Representatives on those methodologies and procedures that may aid in preserving the life of marginally producing oil and gas wells; and
- investigate any additional issues that may have any effect on the preservation of marginally producing oil and gas wells.

For more information about this program, lease contact the Oklahoma Marginal Well Commission for further information or look for the workshop notices at www.marginalwells.com. ✧

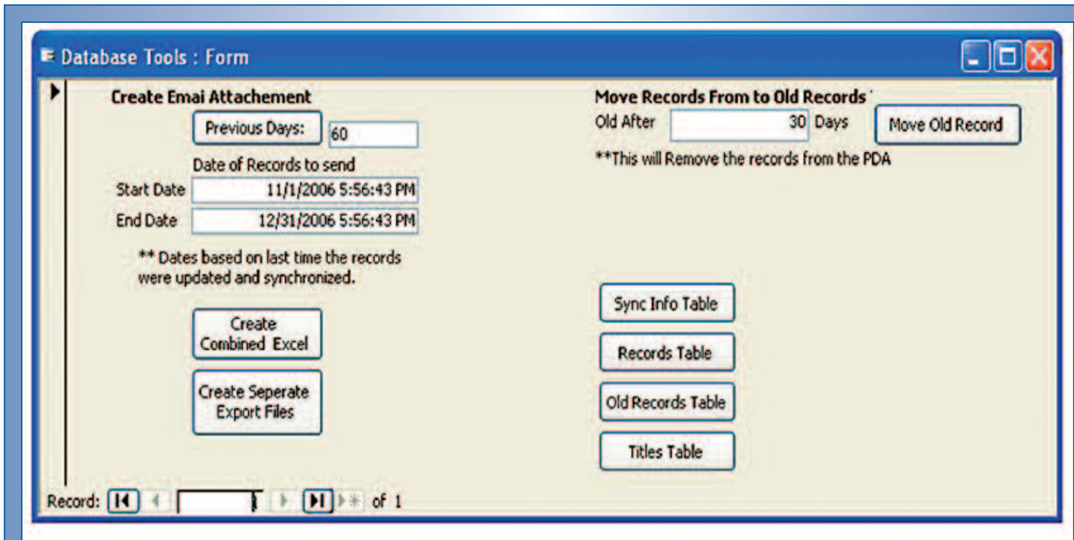

Figure 8. Database tools form

Events

▶ SPE Rocky Mountain Oil & Gas Technology Symposium

April 16–18, Denver. Making Unconventional Conventional is the theme of the 2007 Rocky Mountain Oil & Gas Symposium. Aside from coalbed methane operations and various stimulation techniques, the symposium will focus on formation evaluation, horizontal drilling, production operations and reservoir engineering (*www.spe.org*).

▶ 2007 OGIS New York

April 23-25, New York, NY. The IPAA's Oil & Gas Investment Symposium New York (OGIS New York) is the premier outlet for publicly traded independent exploration and production, and service and supply companies to present their company profiles to the investment community. Last year's symposium attracted more than 1,600 attendees, including more than 700 buy/sell-side analysts and portfolio managers as well as 100 presenting companies. Held at the Sheraton NY Hotel & Towers (*www.ipaa.org/meetings*).

▶ SPE Research & Development Conference

April 26–27, San Antonio, Texas. The Third Trillion and Beyond: The R&D Challenges to Meeting Expanding Energy Needs—The world has consumed about a trillion bbl of oil and has another trillion bbl in known reserves. We are expected to consume the second trillion in 35 years, and forecasters say meeting world demand during the next 35 to 70 years will require a third trillion. What research is needed to expand the ability to find and produce oil and gas to meet this future energy demand? Attend the first SPE Research & Development (R&D) Conference to explore these questions and others as industry leaders, scientists and conference participants discuss the big challenges facing the energy industry and R&D requirements to meet them (*www.spe.org*).

▶ Williston Basin Petroleum Conference and Prospect Expo

April 29-May 1, Regina, Saskatchewan. The 15th Williston Basin Petroleum Conference and Prospect Expo features oral presentations, poster displays and workshops focusing on practical applications of geological and engineering technology that help identify what works – and what doesn't work – in the search for new hydrocarbon accumulations and the development of known pools. Held at the Delta Regina Hotel (*www.wbpc.ca/conference2007*).

▶ Offshore Technology Conference

April 30–May 3, Houston. Founded in 1969, the Offshore Technology Conference (OTC) is the world's foremost event for the development of offshore resources in the fields of drilling, exploration, production and environmental protection. Held at the Reliant Center, last year's attendance reached a 24-year high, as 59,236 exploration and production professionals met to learn about the latest technology to find the oil and gas the world needs. OTC 2007 is expected to be even bigger and better (*www.otcnet.org/2007/index.html*).

▶ 2007 Joint Assembly (American Geophysical Union)

May 22-25, Acapulco, Mexico. Held at the Acapulco Convention Center, the Program Committee is developing a union-wide science program that will cover topics in all areas of geophysical sciences (*www.agu.org/meetings/ja07*).

▶ SPE Unconventional Gas Resources - Forum

June 3-8, Colorado Springs, Colo. This forum will focus on the uses of advanced technology to recover unconventional resources in an economically attractive manner. For each of four categories (tight gas, coalbed methane, low BTU gas and shale gas) the focus will be on the following: reservoir characterization and engineering; completion practices; efficient drilling techniques; well performance predictions; and reserves estimations. The forum will consist of formal presentations, informal talks, break-out sessions and a poster session. Apply at *www.spe.org/spe/jsp/meeting* for invitation to attend.

▶ Drilling Association Workshop

June 19-20, Galveston, Texas, Moody Gardens Hotel. For more information, contact *www.dea-global.org*

▶ Society of Exploration Geophysicists International Exposition and 77th Annual Meeting

Sept. 23-28, San Antonio, Texas, Henry B. Gonzalez Convention Center. For more information, contact *www.seg.org*

▶ Society of Petroleum Engineers Annual Technical Conference and Exhibition

Nov. 11-14, Anaheim, Calif., Anaheim Convention Center. *www.spe.org*

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