TECHNICAL PUBLICATION

Title:	**Permanent Downhole Monitoring in Gas Well Applications**	*Page 1/7*
Author:	**Tim Conn, PROMORE – A Core Laboratories Company**	
Publication Number:	**PROMORE 005**	

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ABSTRACT

The utilization of permanent downhole monitoring (PDM) systems in gas applications is increasing on a global basis. Although the applications of PDM are far more prevalent in oil wells, there are a number of emerging uses of the technology in gas wells. This technical overview will profile gas well PDM applications such as well stimulation (fracturing), reservoir surveillance, rate-transient analysis, sour and remote wells and *gas deliquification schemes*.

TECHNOLOGY OVERVIEW

Permanent Downhole Monitoring Systems (PDM) continues to provide benefits to operators in various applications on a global basis. The number one driver for utilization of these systems has been to reduce well intervention costs associated with acquiring bottomhole pressure and temperature data, typically in offshore areas. The benefits and knowledge acquired in these areas is supporting more and more migration of PDM towards land-based regions. To date, the predominant use of PDM has been in oil reservoirs for applications related to enhanced oil recovery schemes, artificial lift systems (optimization and control) and reservoir surveillance.

The technology has been well suited in:

- Lower cost producing environments where operators need the benefits of high quality data, to proactively assess reservoir performance and improve well/field production on a continuous basis.
- Higher cost producing environments where operators need the benefits of quality reservoir data where the primary driver is to reduce well intervention costs through continuous monitoring, concurrently with improving well/field production on a continuous basis.

The primary value to operators has been in the areas of reducing operating costs and increasing well and field productivity. PDM allows for more proactive interpretation of pressure and temperature data in real-time, providing more accurate information about reservoir permeability, size, boundaries, drive mechanism, interwell communication, etc. Prediction of reservoir performance allows operators to interpret production problems early and take effective action to reduce a detrimental impact. These are the lessons that can be learned from users of the technology in oil reservoirs and applied to the benefit of gas reservoirs in the future.

GAS WELL APPLICATIONS

PDM systems have been applied on a more limited basis in gas reservoirs, probably due to the fact that most typically produce relatively dry-gas. It is very difficult, if not impossible to purvey a PDM system when surface gas pressure measurements provide an easily extrapolated bottomhole pressure to datum. This explains the relatively “crowded market” of vendors selling various systems to monitor gas well performance from the wellhead. The story however, changes in gas condensate environments where it is difficult if not impossible to predict BHP (bottomhole pressure).

Prediction of BHP during fracturing operations through the improvement of fracturing models continues today to be an inexact science, resulting in poor fracturing designs and increased costs to operators. Measured BHP during fracturing operations from a bottomhole perspective has proven to provide operators a very real opportunity to increase hydraulic fracturing effectiveness.

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As reservoirs age be it oil or gas, water encroachment becomes an increasingly costly problem. PDM has been used to predict water migration early and take effective action. In areas where operators are motivated to install artificial lift (AL) equipment to pump-off water to reduce formation pressure, PDM systems provide necessary shutdown capabilities to protect AL equipment. Flowing BHP can also be used to understand reservoir performance and enhance nodal analysis.

In emerging technologies related to downhole gas water separation, protection of associated downhole equipment and AL systems is facilitated through the use of PDM. This becomes even more important in areas where the operator will be pilot testing downhole water separation in conjunction with downhole disposal.

Data from laboratory, theoretical and field studies have shown that when pressure around a well drops below the dewpoint pressure, retrograde gas condensation can occur. Gas condensates reduce reservoir permeability to gas, reduce production and increase operating costs. Control of drawdown pressure using PDM provides some likely benefits.

In the last few years the use of computer software for reservoir analysis has revolutionized the ease at which complex mathematics can lend hand to the assessment of gas reserves. Until recently most well testing techniques involved the usage of software for Pressure Transient Analysis. However, the quality of software is beginning to surpass the quality of the data that companies are collecting with conventional memory recorders. The use of PDM allows for the usage of real time quality data for real time quality analysis. With the arrival of Rate Transient Analysis it is easy to determine expected ultimate recovery and Gas-in-Place accurately and efficiently, as well as, perform material balance analysis analyses, without using any shut-in data.

CASE STUDIES

Following is a number of case studies related to PDM in gas well applications:

Sour Gas Wells

Situation

- Flow and buildup tests were necessary for ongoing quantification of reserves in a critical sour gas well in a remote, environmentally sensitive area.
- In comparison to conventional memory recorders, these tests would take up to 14 days of shut-in, resulting in a 5-10 mmscf/day of lost production totaling $220,000 not including wireline service and tool rental costs.

Objective

- Reduce the costs of conventional flow and buildup tests
- Use improved reservoir analyses methods to reduce well downtime and still achieve good test results
- Reduce well intervention in sour wells to improve safety and minimize environmental impact.

Results

- Improved reservoir Engineering through access to more accurate flowing and shut-in BHP's
- Eliminate and/or reduce costs, safety issues and environmental impact in critical sour gas wells.
- Initial savings of over $160,000

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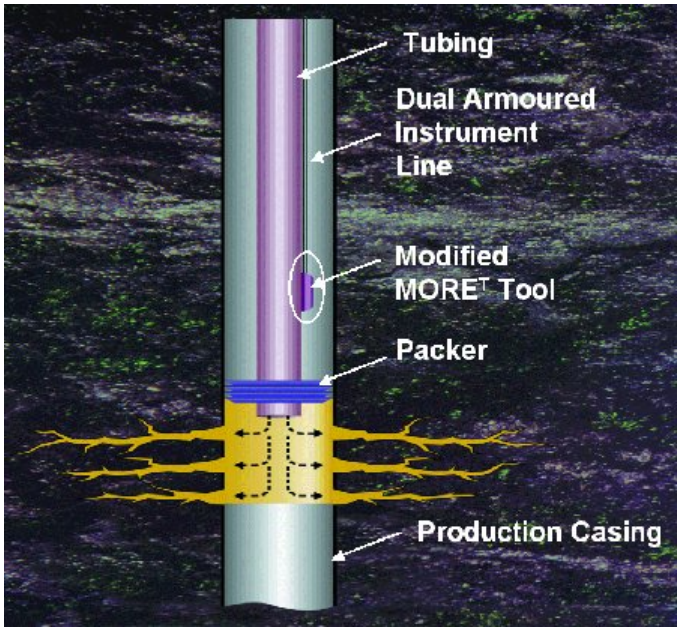
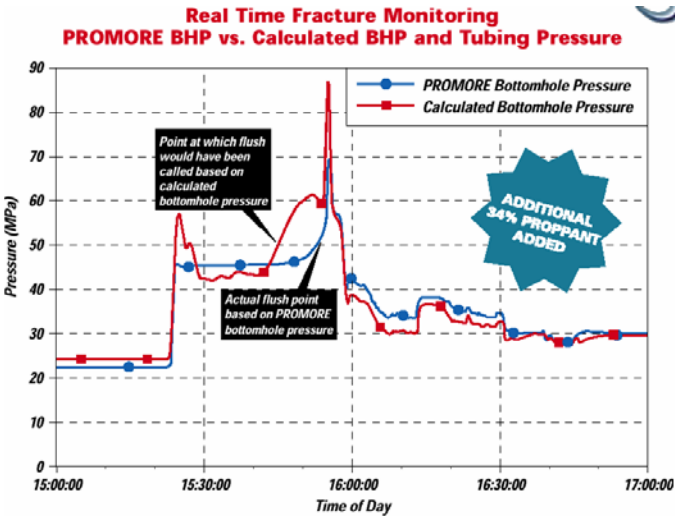
Improving Well Stimulations (Fracturing Operations)



The continued advancement of fracturing fluids technology and increasing complexity associated with the fracturing of deeper wells has predicated the need for more accurate methods of predicting BHP. There exist various models that use surface measured tubing pressure and various other parameters to predict BHP, but the industry still struggles to achieve accuracy with these methods. This leads to poor frac designs and increased costs associated with fracturing operations in the field.

In 2000, PROMORE was invited by a major operator to provide a system that would be able to accurately measure BHP during frac operations. The goal of the operator was to greatly improve data fracs and associated main frac designs along with reducing the costs associated with screen outs in the field. To date more than 50 deep well fracs have been monitored with exceptional results in both oil and gas wells.

One of the better examples of the data provided through PDM in fracturing operations is presented below. It demonstrates that the operator was able to increase proppant delivery by 34%. The overall impact of course was higher well productivity, however the actual increase was not directly quantified.



Further technical details can be found in award winning SPE Paper 71699, "Economic Real-Time Fracture Optimization Using Bottomhole Monitoring Systems"

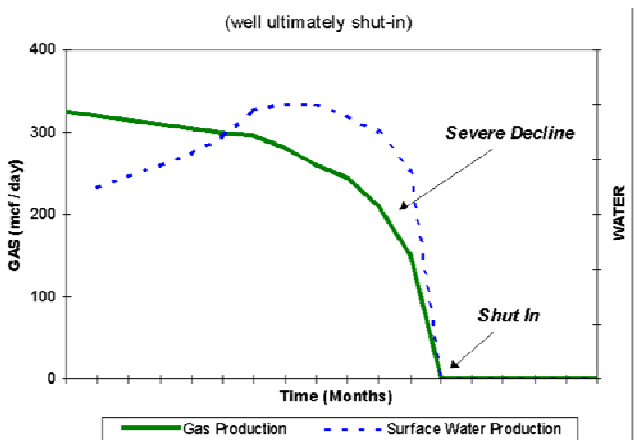
Deliquification Schemes

Deliquification as it applies to conventional low pressure, high deliverability reservoirs is an emerging science. The primary driver is to increase the economic longevity of gas wells experiencing adverse water production. Proven recoverable reserves are often left behind when water production exceeds sustainable fbhp.

Conventional approaches to dealing with adverse water production include blowing wells down from time to time to unload liquids, running soap sticks to reduce liquid column pressure, increasing well compression to reduce back pressure on the reservoir or modifying the well completion.

Producing coal bed methane requires the removal of water to reduce the bhp so the methane will release from the coalface. Water level in the annulus may also be required to remain at a specific level to maximize

production and prevent loss of the wellbore in certain types of completions. Too fast a drawdown can result in severe permanent damage to the reservoir. Solids typically are produced with the water resulting in increased torque at the pump. By knowing the fluid level in the annulus (via pdm) the operator can determine if increased power draw is a result of lack of fluid (pump running dry) or a slug of solids passing through the pump.

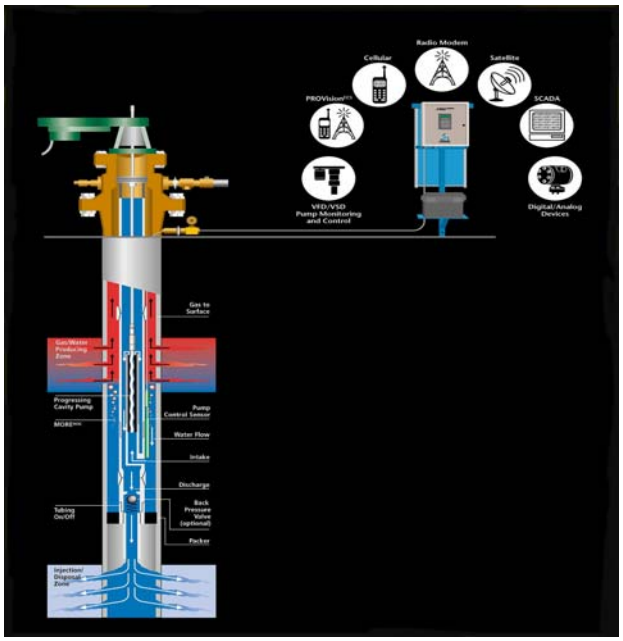


Gas Wells Watering-Out – A Common Problem

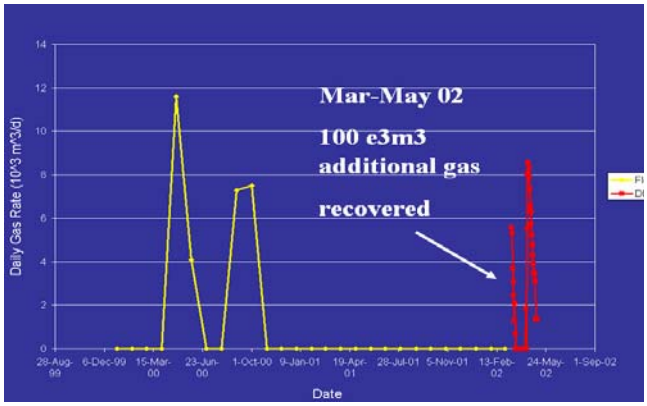
More aggressive approaches include retrofitting the well(s) with pump to surface methods, which reduce formation pressure and increasing gas production. Another emerging approach sees the utilization of DWIT technology (downhole water injection tools) to separate gas and water downhole and inject into a lower or upper disposal zone. This method has the primary advantage of recovering gas reserves that would otherwise be left behind and secondary benefits of eliminating water handling, treatment and disposal costs.

Several installations of the technology in North America have shown promising results. In a multiple well trial in Southern Alberta, a Canadian Operator was successful in proving the merit of the technology in recovering previously watered-out gas production. The diagram below shows combination of a PCP pump, DWIT tool and PDM system(s).

According to the customer, controlling pump speed based on fbhp was key to protecting artificial lift equipment and maximizing gas rates. Initial field trials indicated that PCP driven DHGWS (downhole gas water separation) was a feasible technology provided a suitable injection/disposal zone is available. Best candidate wells are those that watered-out prematurely with good gas rates, not those that watered out slowly before being suspended.



Downhole Gas Water Injection Tool System



Incremental Gas Recovery Using DHGWS Systems

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Gas Condensate Reservoirs

Gas condensate reservoirs are common in many areas of the world. Natural thermodynamic properties of these reservoir gases, cause retrograde condensate dropout when produced at an fbhp below the dewpoint. PDM provides operators the opportunity the monitor fbhp on a real-time basis to avoid producing at pressures below the bubble point. Retrograde gas condensate formation reduces reservoir gas effective permeability to dry-gas; resulting is active formation of gas condensate "rings" proximal to the wellbore.

PDM pressure maintenance combined with optimized drawdown rates, which maintain pressure above the bubble-point, can help to reduce or eliminate gas condensate development, which increases operating costs and reduces ultimate reserves recovery.

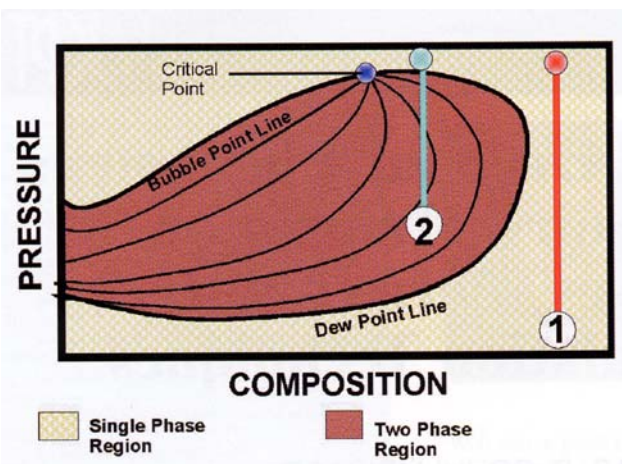


FIGURE 1: Illustration of typical pressure-composition.

The figure above provides a pressure-composition diagram for a typical hydrocarbon system at a fixed temperature level. The shaded portion of this figure represents an area of two-phase equilibrium at the specified composition and pressure condition. This is generally a region where an immiscible hydrocarbon liquid and gas phase co-exists in thermodynamic equilibrium. Outside this area, is a single-phase region, where only one continuous and homogeneous uniform phase exists. It is therefore critical, that an operator understand the relationship between pressure, temperature and composition to maintain suitable drawdown rates to avoid retrograde gas condensate formation.

Rate Transient Analysis

Traditionally, reservoir parameters such as gas-in-place, drainage area, permeability, skin and fracture half-length are determined from flow and buildup tests. New advancements in production decline analysis have now enabled reservoir characterization and the determination of hydrocarbons-in-place without loss of production by shutting the well in.

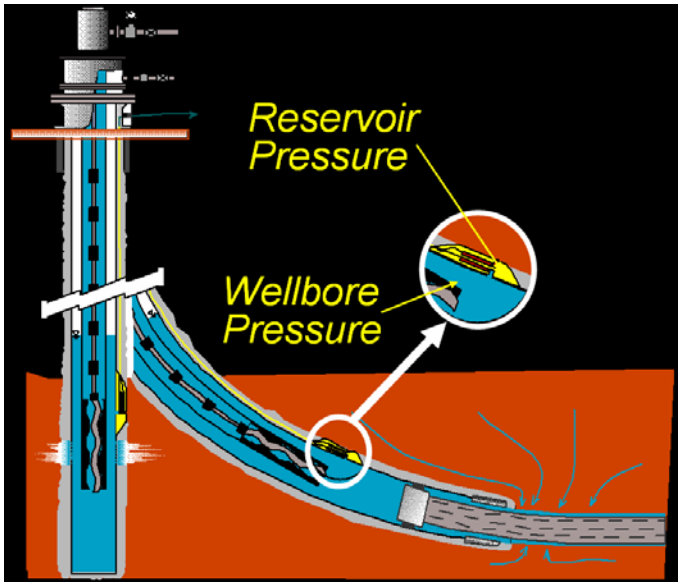
F.A.S.T. RTA™ (Rate Transient Analysis) is cutting edge decline analysis that analyzes both rates and flowing pressures. RTA incorporates eight different analysis methods including traditional decline analysis, Fetkovich, Blasingame, Agarwal-Gardner, NPI, and Transient typecurves and an analytical history match model.

Reservoir drive models include empirical (Arps), single and multiple well volumetric and water drive. With RTA you can evaluate infill potential, characterize your reservoir and estimate reserves with unprecedented ease and efficiency. RTA is also an effective diagnostic tool to identify liquid loading and interference, as well as pressure support from reservoir communication or waterdrive.

PDM provides accurate assessment of continually changing fbhp. This helps to improve the accuracy of reserves determinations and improve the understanding of critical early time data.

For more information, check out the hyperlinks below:
http://www.fekete.com
http://www.nickles.com/tech.asp

Tight-Gas Reservoir Development



PDM systems have been used to support the development of tight gas fields. As an example, an operator in the Alberta/BC Foothills was unsure of the commercial viability of a particular field. A "best practices" approach was needed to support planned stimulation activities (see the previous real-time fracturing example) and ongoing reservoir evaluation. A 5 well program would be used to assess the economics of a 100+ well ($150M) drilling program.

PDM resulted in a $40,000 saving per pilot well compared to the running and pulling of conventional (memory) tools. Information gained allowed the client to optimize the stimulation process resulting in an approximate $6,000/day production increase.

Summary and Conclusions

PDM (Permanent Downhole Monitoring) is a commonly used technology to increase the recovery of hydrocarbons. Although primarily utilized in oil reservoirs in various applications, it does not negate the fact that PDM can provide real cost benefits to operators focused on gas reservoir development. This paper has provided some real examples related to sour gas field development and improving fracturing operations. PDM has been used to support emerging technologies related to deliquefication (gas de-watering) to enhance gas recovery and protect downhole-pumping equipment. From a reservoir management and development perspective, PDM can help to mitigate retrograde gas condensate formation and support Reservoir Engineering. Newly emerging RTA (Rate Transient Analysis) techniques are greatly enhanced through the availability of PDM pressure and temperature data. The ultimate goal of PDM is to improve the recovery of hydrocarbons in both oil and gas reservoirs. It is expected that the worldwide emphasis on increasing natural gas reserves will be a catalyst towards the increased utilization of PDM in gas production environments.

Authors' Bibliography

Tim Conn is Marketing Manager for ***PROMORE, A Core Laboratories Company.*** He is currently responsible for business development activities in Europe, China and Japan. Tim has published several articles in the Journal of Canadian Petroleum Technology, American Oil and Gas Reporter and Nickles New Technology Magazine.

ACKNOWLEDGEMENTS

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Kimberly Ziobrowski, David Hill, Tim Conn

FEKETE & ASSOCIATES
Casey O'Shea et al

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