# FROM LIABILITY TO COST EFFECTIVE DATA GATHERING OPPORTUNITY

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## ABSTRACT

Many tight gas accumulations have been known to exist in North America for decades. However, it has only recently become possible to get economic production from 5 μ–Darcy rocks using massive hydraulic fracture completions. Even today getting simple pressure measurements in this setting remains a challenge.

However, observing pressure depletion would be the most straightforward method to establish drainage areas, which is key to optimize economic development of these fields. Initially we considered drilling a pilot well to observe the pressure changes in individual sand packages in one well as a result of production of the other. Since it was unclear whether we would be able to obtain accurate pressure measurements, it was difficult to justify the expenditure. Using a to-be-abandoned well avoided those issues.

Instead of a conventional abandonment with a few plugs isolating the existing perforations, a large number of permanent plugs can be installed with pressure gauges below them measuring pressure responses of old and new perforations. By using a cable-less communication system, pressure data can be transmitted to the surface for a number of years after abandonment. The system existed for a single station, but was extended to accommodate a great number (>10) of stations for our project, doubling the number of worldwide installations in a single well. Apart from giving indications of depletion, it also provided us with the first reliable virgin formation pressure data in the field.

## INTRODUCTION

Vast amounts of gas bearing rocks with permeabilities of only a few μ–Darcy were known to exist in North America for decades. Nevertheless it has only recently become possible to get economic production from them using massive hydraulic fracture completions. However, even today getting simple pressure measurements in this setting remains a challenge. With conventional wireline formation testers one tends to end up with a measurement of the mud pressure, with supercharged pressures, or with no stable build up at all, because the matrix is simply too tight. We had some success with cased-hole formation pressure testers, but not enough to establish a pressure profile. Moreover these require a larger casing size than the 4 ½” we tend to use for our completions. Furthermore one loses casing integrity in the process, which is essential for effective control of hydraulic fracture stimulations we use for our well completion.

Our field has only been on production for a few years and it is still unclear what the drainage area and therefore the appropriate well spacing should be. Most tight gas fields in the area start off with a 40-acre (about 500 meters) well spacing and subsequently down-space to twenty acres or even ten acres. Getting the spacing right early in the development is an essential ingredient for cost effective exploitation of an asset. Some operators use 20 acres production pilots, drilling 20 acres offset wells and looking for production interference, to justify down-spacing. However, it may be difficult to detect the interference between wells that contain over 50 fluvial reservoir sandstones spread over a 6000 ft gross section and are completed with dozens of frac stages. Modeling shows that production interference will only occur after a few years. It may be difficult to interpret this production interference, since the lateral continuity of these fluvial sandstones is unknown. Therefore the better test would be to drill a pilot hole and observe the pressure rather than production changes in individual sand packages in one well while producing the other. Unfortunately this delays and possibly compromises production of the observation well. Using a to-be-abandoned well avoids those issues.

## HOW WOULD THIS WORK?

There was a well earmarked for abandonment 450 ft away from a new well. Various options were considered to use this as a pressure monitoring well.

One could do time lapse cased hole formation pressure testing, but the virgin reservoir pressure was not known, the time it would take for the depletion to be measurable in the observation well was uncertain and it was considered unlikely that it would occur in all sands at the same time. This led us to longer term and more extensive pressure monitoring options. The simplest option we considered was running a great number of memory pressure gauges between retrievable plugs. Unfortunately one would be unable to monitor progress and would not know anything until the gauges were retrieved. Retrieval chances are good especially if you are willing to use the expensive option of a rig, but are not certain. Looking for alternative, more permanent options we selected the Cableless Telemetry System (CaTS) marketed by The Expro Group. The signal is modulated on a current loop through the tool and the casing. A minute fraction of this current travels up the casing to the surface and can be detected and decoded. The system had originally been designed for one or two measurement stations, but was extended to allow for multiple (>10) systems in a single well. Without any cables there was no need to retrieve the tools, because normal abandonment plugs could be employed and cement plugs could be set where required. Therefore one could simply leave the systems down hole as part of the permanent abandonment. In a standard setup the deepest station can only be at 95% of TD or for a 10,000 ft well 500 ft off bottom. However, by using a downhole pick up just above the top of the reservoir around 7500 ft this could be reduced to 125 ft off bottom. It has the added benefit of reduced power requirements for the shallower stations leading to longer operational life for this battery-powered system. The technology is relatively new and the installation in this well doubled the number of CaTS deployments worldwide. This was also the first application of multiple CaTS sensors in a single wellbore. The completion diagram for our well is shown in Fig. 1. In total we monitor 9 intervals, which are separated by permanent bridge plugs and a few cement plugs to comply with government regulations for permanent abandonment.

Three intervals contain old completions in this well. They all have a very distinct pressure profile like the one shown in Fig. 2. Initially they display a very steep decline of hundreds of psi/month. In general this decline is very smooth, but occasionally a little hump appears, which is probably related to some minor x-flow between layers. The most significant event occurs after about 4 months, when the pressure hits a minimum value and starts climbing again. This behavior can be explained in the following way. The wellbore during production was a major pressure sink with a very steep pressure gradient around the well, when the well was killed with a heavy mud to carry out the abandonment the near wellbore area was pressured up to the mud pressure, but as soon as the plugs were set this pressure started leaking off. After 4 months we reach a point where we started seeing the effect of the production draw down again and we now observe the equilibration of the pressure, because the production has stopped. In the future we should see another drop in pressure, when we start seeing the influence of the production of the new well if the sand body is connected between the two wells.

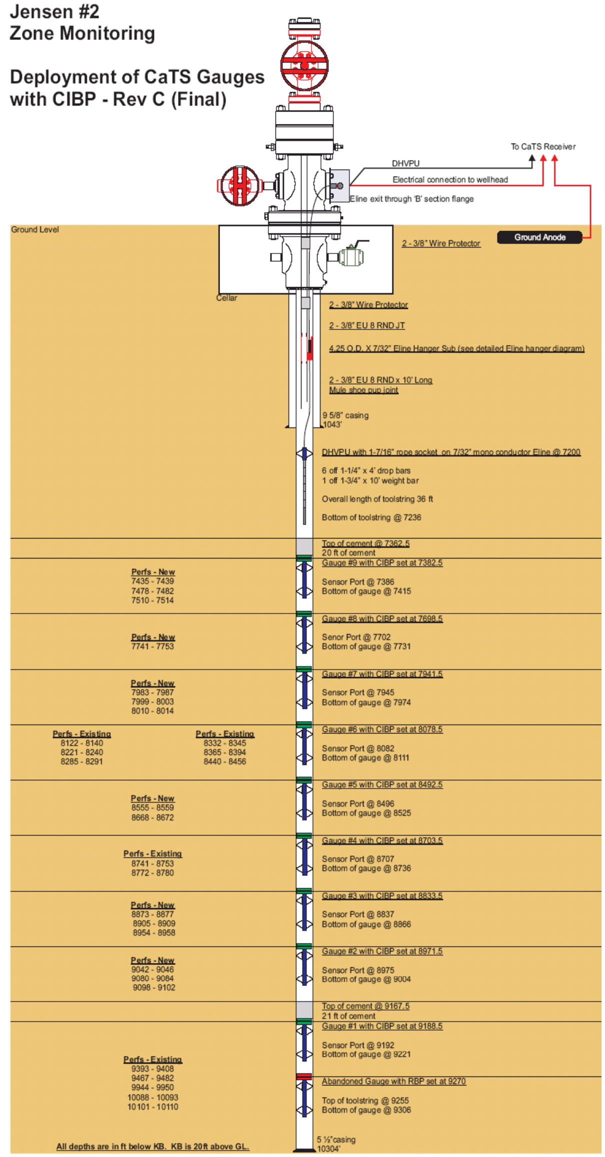


Fig. 1 Completion diagram abandoned monitor well

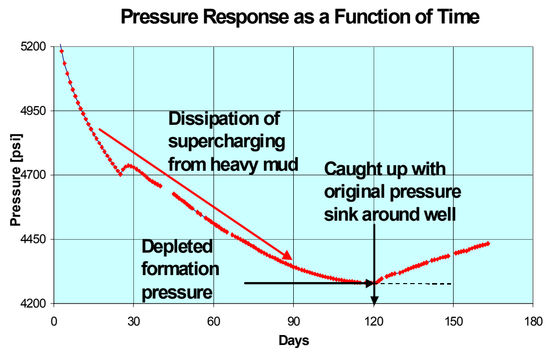


Fig. 2 Pressure response for an old frac stage.

In Fig. 3 we show an example of a correlatable 5 μD sand that starts experiencing depletion from the production of the new well after some 40 days of production. Here we see an initial rise in pressure, which is simply mud between the gauge and the perforation being displaced by gas, i.e. removal of the hydrostatic head. The well stabilizes at the virgin formation pressure for a few weeks before the production decline kicks in. These stable pressures spread over 2000 ft in the well provided us are our first accurate pressure profile in the field. Previously the formation pressure profile had to be inferred from mud weights used to drill the wells and DFITs (formation integrity tests), which are inherently less accurate.

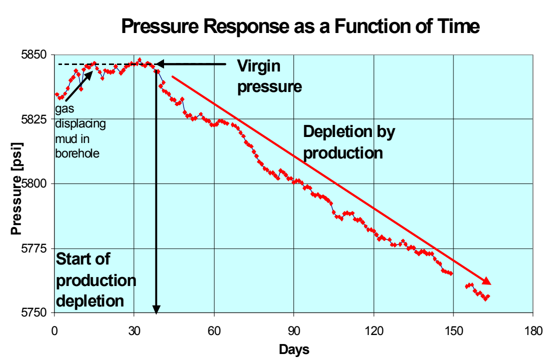


Fig. 3 Pressure response for a correlatable 5 μD sand.

In Fig. 4 the pressure response of a fairly tight poorly connected sand is shown. It takes much longer for the gas to displace the mud between perforations and the gauge. Depletion as a result of production in the new well also occurs significantly later. Moreover the depletion appears to be less severe.

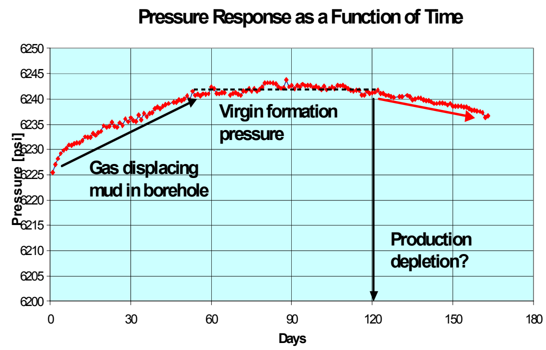


Fig. 4 Pressure response for a tight, poorly connected sand.

The new detailed pressure information, which is still being recorded, is being used to construct a detailed static and dynamic model. This will help to determine drainage areas, which will facilitate optimum field development.

We have also successfully used old wells prior to abandonment to acquire micro-seismic data and fluid samples. This way the liability of to be abandoned old wells can be turned into data acquisition assets.

## FUTURE

Unfortunately the old wells in the field are generally relatively shallow and allow only for pressure data acquisition above 10,000 ft whereas the producing reservoir extends below 13,500 ft. Based on the successful deployment in the abandoned well we are currently exploring the possibility of mounting such telemetry systems with gauges on the outside of the casing. With this method the casing integrity is not compromised and the well can be completed normally once the monitoring is finished.

## REFERENCES SECTION

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**Paul Huckabee** has a BS and MS degree in Electrical Engineering from Louisiana State University. Paul has been with Shell for over 25 years and specializes in well completions and stimulation. His experience includes low permeability reservoirs in South Texas, California, West Texas, Alaska, China, and Wyoming and high permeability reservoirs in the Gulf of Mexico. Paul has spent 12 years in Shell's technology organizations and is currently a member of the Tight Gas Task Force.