PRESSURE ACTUATED CHAMBER TECHNOLOGY PACT A NEW ARTIFICIAL LIFT SYSTEM FOR CBM WELLS

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INTRODUCTION

In mid 2008, a new artificial lift technology referred to as PACT, Pressure Actuated Chamber Technology was introduced in the San Juan Basin.

Almost immediately CBM producers recognized the potential of this technology as an efficient and effective deliquification method.

PACT addresses a number of operational and environmental issues related to current CBM operations.
The purpose of this paper is to evaluate the use of this technology in existing applications in the San Juan Basin.
The paper contains three major sections.

1. An overview of the current technologies in use for gas well deliquification in the San Juan Basin and discuss' the advantages and limitations of these methods.

2. The operation of the PACT system and its advantages and disadvantages compared to existing methods.

3. Case studies of three wells which have had PACT systems installed. Two of the three PACT's replaced sucker rod pumping systems and the third was installed on a flowing well. The case study compares the performance before and after the installation of the PACT system.

SAN JUAN BASIN GAS WELL DELIQUIFICATION

Artificial Lift Systems (ALS) Selection

Well parameters and operating conditions vary greatly and no two wells are exactly alike. This should dictate that artificial lift system, (ALS) requirements be evaluated on a well by well basis.
A number of critical issues must be considered and some important data quantified in order to choose the best ALS for a well.

- Geographic location of the well.
- Wellbore design, vertical or horizontal.
- Depth, MD & TVD
- Production requirements, water & gas.
- Operating pressures, downhole, surface & pipeline.
- Properties of produced fluids.
- Availability of electricity.
- The company's operating/business philosophy.

ALS for CBM Wells in San Juan Basin

CBM operators have tried just about every artificial lift system (ALS), available in an effort to find the most effective and efficient means to deliquify and produce their wells.
Over the years, trial and error, success and failure have narrowed the options.

- Sucker rod pumping systems (SRPS)
- Plunger lift systems (PLS)
- Progressive cavity pumps (PCP's)
- Electric submersible pumps (ESP's)
- Compression*

Two significant factors narrow the options even further, electricity and consistent water volumes.

PCP's and ESP's have two things in common, both require electricity for power, and both are quick to fail when starved for fluid, for even a short time. Since very few fields in the Basin are electrified, this quickly eliminates these systems from consideration.

* Compression is sometimes used as the sole source artificial lift method, but usually used in conjunction with other forms of artificial lift.

Two systems currently constitute the majority of ALS used in CBM applications, SRPS and PLS.

SRPS

Sucker rod pumping systems are the most widely used form of artificial lift in the world.
In the right application, a properly designed and operated SRPS will provide years of reliable and efficient service.
The durability and flexibility of the system has made it the first choice of most San Juan Basin operators.

Although effective at removing water from the wellbore, certain well conditions and operating practices common in CBM production, greatly reduce system efficiency, increase maintenance costs and hasten failures of downhole equipment.

- **No electricity at site** requires the use of gas engines as prime movers.
  Gas engines are high maintenance and burn the gas you would like to be selling.
- **Over displacement**, many wells produce less than 20 BPD, some much less.
  It's difficult to design a SRPS to only move 20 BPD and handle gas.
  1.25" pump, 54" stroke length, 4 SPM = 39 BPD = pounding fluid 24/7.
- **Fluid pound**, from incomplete pump fillage/over displacement damages every component in a SRPS from the pump to the prime mover.
- **Gas engines,** limit the use of Pump Off Controllers (POC) to manage displacement. POC systems are available but are expensive and complicated.
  Poor combustion properties and continuous operation = high emission source.
- **Tagging the pump**, a common practice to keep pump valves from trashing up.
  Same detrimental effects to system as pounding fluid X 2.
- **Produced water** is a very poor lubricant + coal fines + CO_2 + H_2S + chlorides + dissolved solids and downhole equipment, (most of which operates metal to metal) begins to self destruct as soon as the pumping unit is turned on.
- **Stuffing boxes** require constant attention to avoid leaks and spills. Catastrophic failures result in environmental contamination and lots of paperwork.
- **Safety,** around pumping units cannot be over emphasized. Large, heavy rotating and reciprocating parts can cause serious injury and death. Every safeguard and precaution must be taken when working around these systems.

These issues, one or all, are common to most SRPS operating on CBM wells in the San Juan Basin.

PLS

Plunger lift systems are the second most widely used artificial lift method for CBM wells in the San Juan Basin.
PLS, applied and operated properly, can be a very efficient and effective deliquification tool. These systems are relatively inexpensive to install, simple in their basic operation and system maintenance is minimal.
PLS have been successfully applied to deliquify conventional gas wells for years, and recently their application has been expanded to CBM well deliquification.

One major and several minor factors limit the effectiveness of PLS in CBM applications.

- **PBHP,** in many CBM wells is to low for efficiently/effective PLS operations.
- **Sticking plungers,** can be difficult to remove from low pressure wellbores.
- **Compressor issues,** related to long casing shut-in time can make wellhead compression difficult to manage.
- **High casing pressure,** resulting from the shut-in time mitigates the inflow of water, hampering deliquification efforts.
- **Harmful emissions,** from wells that vent the tubing to achieve adequate differential pressure to bring the plunger to the surface.
- **Reservoir problems,** associated with the repeated “pressuring up / blowing down” cycles of PLS operations must be managed.

Since PLS use reservoir pressure as the energy source to operate the system, their efficient and effective use in CBM wells is very limited. Some wells may require several hours of casing shut-in time to build adequate pressure to lift the plunger. Closing the casing to build pressure mitigates the inflow of water reducing the overall effectiveness of the deliquification process. This “pressuring up / blowing down” is not an efficient way to produce any reservoir. Once you get fluid moving toward the wellbore, keep it moving and get it to the surface.
Many operators who have installed plungers have discovered that the only way to get the plunger to return to the surface is by venting the tubing. Venting reduces tubing pressure, thus increasing the differential pressure between the tubing and casing and allowing the plunger to rise.
Depending on how many plunger trips the system makes per day and the tubing volume,
a considerable amount of methane is discharged into the atmosphere each day. This process wastes the very commodity your in business to sell and it is environmentally unsound and unacceptable.

PRESSURE ACTUATED CHAMBER TECHNOLOGY (PACT)

The Pressure Actuated Chamber Technology uses gas pressure to lift fluid through a series of fluid chambers deployed directly into the well casing. The pumping system consists of 2 main components.

1. Pressure actuated chambers
2. Surface control system

The down hole pumping system consists of a series of pressure actuated chambers connected by line assemblies. The chambers are spaced at approximately 250’ intervals in the well. The fluid chambers are connected together and supported by the poly tubing line assemblies. For additional support, a stainless steel cable is connected to each fluid chamber. The control system includes a compressor and a microprocessor controlled valve system to direct fluid flow through the chambers. Compressed gas on the surface is used to apply pressure to the chambers to lift fluid from one chamber to the next.

The bottommost chamber of the pumping system is placed below the fluid level in the well. The static fluid pressure in the well causes the fluid to fill the chamber. The fluid flows into the chamber through a filter.

The operation of the pump chamber employs check balls and a float to direct fluid flow. After the fluid chamber is filled with fluid, gas pressure is applied from the compressor on the surface. The pressure that is applied to the fluid causes a check ball at the bottom of the chamber to seat. The fluid is then directed to flow past another check ball and through a product line inside the chamber. When the fluid reaches the top of the chamber it flows through the line assembly to the next higher fluid chamber. The float is placed inside the chamber and floats up and down with the fluid level. When the fluid reaches the bottom of the chamber the float seals the flow and does not allow the gas to enter into the fluid product flow. During the fill portion of the cycle the float will contact another seal when the fluid reaches the top of the chamber. The float seal keeps the fluid from entering the gas lines.

All of the fluid chambers operate using the same principle. After each chamber is filled with fluid, the compressed gas from the surface forces the fluid to the next higher chamber. The continuous pumping system operation functions by applying gas pressure to alternate chambers. As the gas pressure is increased in the even chambers the fluid is forced to the odd chambers. Subsequently when the gas pressure is increased in the odd chambers the fluid flows to the even chambers. With each full pressure cycle a chamber volume of fluid is delivered to the surface.

The control system for the pump is on the surface. This control system includes the compressor and a microprocessor controlled valve bank. The function of the valves is to connect alternating chambers to a pressure source or an exhaust source. The microprocessor has the ability to vary the pressure cycle times and also function as an on/off timer. The system can be set to operate at long cycle times for low fluid output or run for just a couple of hours a day.

This approach has many advantages over conventional methods.

- **No rods or tubing** are part of the system. The system uses poly tubing to flow fluid between chambers.
- **Pumping dry** will not damage the pump components.
- **Improved corrosion resistance** is inherent in the material selection of stainless steel, brass and plastic components.
- **No pulling unit** is required for installation.
- **No wear out parts** or tight tolerance parts are in the down hole portion of the pump. The poor lubrication effects of pumping water will not cause increased pump wear due to the elimination of sliding friction to create fluid movement.
- **Handling fines** is improved by the redundancy of the check balls in the design and the natural cleaning of the surface by the moving fluid. In addition, the lower speed of fluid flow reduces the abrasive affect of particles carried by the production fluid.
- **No reservoir energy** is required to operate the pump. The pump is not adversely affected by either high or low reservoir pressure.
- **Environmental and safety** concerns are virtually eliminated due to the fact that the system operates at a low (150psi) operating pressure and there are no moving parts on the surface. The surface footprint also improves the aesthetic value of the operating lease.

The limitations of the pump are the pumping capacity and pump depth. The system is currently limited to a pump depth of 3000’. The chart in figure 1 shows the pumping capacity vs. pump depth for the three pump designs that are in production.

CASE HISTORIES

Currently three wells are operating with the PACT system. Two of the wells are CBM wells inside the city limits of Farmington, NM and the third is an unconventional, Ojo gas well on the Jicarilla Reservation.

Merrion Oil & Gas own and operate the 2 wells in Farmington. Both wells were on SRPS prior to PACT being installed.

Panther #1

The Panther #1 was chosen because of it’s location within the city limits, it’s proximity to a high school and to reduce operating costs.

- The Panther is the deeper of the 2 wells, pump intake @ 1750’
- Producing the most water, about 22 BPD and the least gas, about 185 MCF.
- Dynamometer and fluid level data verified the well was pumped off and pounding fluid with the SRPS.
- This location has electricity.
- SRPS had an electric prime mover being controlled by a % timer, operating 15 on / 45 off.
- Stuffing box leaks were an ongoing issue with this well.

The PACT system installed in this well is shown in figure #2. The system includes 7 chambers and line assemblies.

As indicated by the production graph (figure #3), after the PACT system was installed, water production declined and consequently so did gas.

- Water production maxed out @ about 18 BPD and gas @ 165 MCF.
- Regular fluid level shots indicated 1630 FFS was about as low as the system was able to get the fluid level. Fluid level shots are shown below the production graph.

Several factors contributed to the PACT system not being able to get the well back to a pumped off condition.

- System's capacity miscalculated
- Compressor / supply gas configuration
- Freezing
- Inexperience of operator / system programmer
- Compressor downtime
- No excess capacity

In early January 2009 the PACT system was upgraded to increase system capacity in an effort to pump the well off and provide some excess production capacity. The new pump model uses larger gas lines to increase gas flow through the pump. The water production and gas production increased with the implementation of the new pumping system.

- Water production of 27 BPD allowed the system to pump off the well.
- Gas production increased to a maximum of 198 MCF and then settled at 185 MCF

Vine Com #1

The Vine Com #1 was chosen primarily for aesthetics and to reduce operating costs. This well is located just outside downtown Farmington at the corner of a main intersection.

- The Vine Com is the shallower of the 2 wells, pump intake @ 1250'
- Water production @ about 18 BPD and gas @ about 220 MCF.
- Dynamometer and fluid level data verified the well was pumped off and pounding fluid with the SRPS.
- This location has electricity.
- SRPS had an electric prime mover being controlled by a % timer, operating 15 on / 45 off.
- Stuffing box leaks were an ongoing and very visible issue with this well.

The PACT system installed in this well is shown in figure #4. The system includes 5 chambers and line assemblies.

As indicated by the production graph, shown in figure #5, after the system was installed, water production declined and gas production increased slightly.

- Water production dropped considerably, to about 6 BPD. *
- Within a couple of weeks, gas increased to about 225 MCF.
- Regular fluid level shots indicated the well was pumped off.

The decrease in water production can not be explained, but fluid level data verified the PACT system was producing all the water there was to produce.

About the time production was stabilizing, cold weather and the holidays set in.
Some of the same issues which had plagued the Panther, showed up at the Vine Com.

- Freezing
- Inexperience of operator / system programmer (me)
- Compressor downtime
- No excess capacity

In early January 2009 the PACT system was upgraded to increase system capacity in an effort to pump the well off and provide some excess production capacity. A system with larger gas lines was also employed in this well. The resulting production provides the ability for the well to be pumped off in one day. The gas production initially increased to 240 MCF and has now settled at 220 MCF.

Jicarilla 29-03-13 #2

The Jicarilla well is owned and operated by Black Hills Gas Resources. Black Hills Gas Resources has a number of formerly free flowing wells that have significantly reduced gas production due to liquid loading. This well was chosen based on a pumping simulation study. The simulation study produced 60 BFPD with a gas flow rate of 160 MCF.

The Jicarilla 29-03-13 #2 is located on the Jicarilla Reservation in Rio Arriba County, NM.

- San Jose Formation, perforations at approximately 1300'/
- Low pressure flowing gas well
- Initial production in Oct 2001 – 176 MCF, 4 BFPD
- Early 2008 production 30 MCF, 0 BFPD
- Tried wellhead compression May 2008, no uplift
- Lowered tubing and swab tested Sept. 2008

The PACT system installed in this well consists of 6 chambers and line assemblies. The PACT system was installed in Oct. 2008.

The production history for this well is shown in figure #6. The production results after installing the PACT system are:

- Fluid level pulled below the perforations after 3 weeks run time
- Initial fluid production reduced due to freezing of gas lines
- Heated building placed over surface controls eliminated freezing problems
- Flow rate stabilized at 100 MCF, 15 BFPD
- No compressor down time has allowed system to remain pumped off with constant gas production
- Fluid level shots shown below have confirmed fluid pump off condition. Fluid level shots shown in figures #7 and #8.

This installation was the first installation of a PACT system through a blow out preventer. A number of issues were noted during the system installation.

- A-frame running guide not tall enough for wellhead with BOP installed.
- Gaps between rollers on A-frame running guide caused poly tubing chamber connections to hang up when running in hole.
- Have to un-spool poly tubing and support cable separately while running in hole.
- Small pieces used in connecting poly tubing to chamber could fall in hole.
- Had difficulty removing and installing annular blow out preventer.
- Unable to land system with annular preventer installed on wellhead
- Pinch points were a safety concern.

Some of these issues have already been addressed and others are under development.

- A-frame modified to increase height and eliminate hang up on rollers
- Well openings covered during connection of chamber to poly tubing to eliminate possibility of losing parts in the well. Future designs in development will eliminate screw attachment of chamber to line assemblies.
- Operator training eliminated difficulty in removing/installing annular preventer.
- Design change to the well head adaptor allows system to connect to either a tubing hanger. System is then landed through the annular preventer. Surface connections are made through a standard pumping tee.
- Elimination of pinch points on installation vehicle is being addressed with safety engineer.

CONCLUSION

Knowledge and experience gained through trial and error, success and failure, gives us a better understanding of how to more effectively apply and operate the artificial lift technologies currently available. It also brings the realization that in many CBM applications, there needs to be a better way.

Understanding each system's advantages and limitations, the fundamental mechanics of its operation and the principals of system design, are critical to choosing the best ALS for a specific well application. Safety and environmental concerns are becoming more important criteria in selecting an ALS, and rightly so.

This knowledge, experience and understanding empowers, even requires us to seek out, test, evaluate and apply new artificial lift technology. Technology like PACT.

PACT is showing very promising results in the wells currently operating with the system.
Much has been learned about applying this technology to gas well deliquification in the last few months. Installation procedures and safety, along with well operating parameters are constantly monitored and evaluated in an effort to improve all aspects of PACT applications and operations.

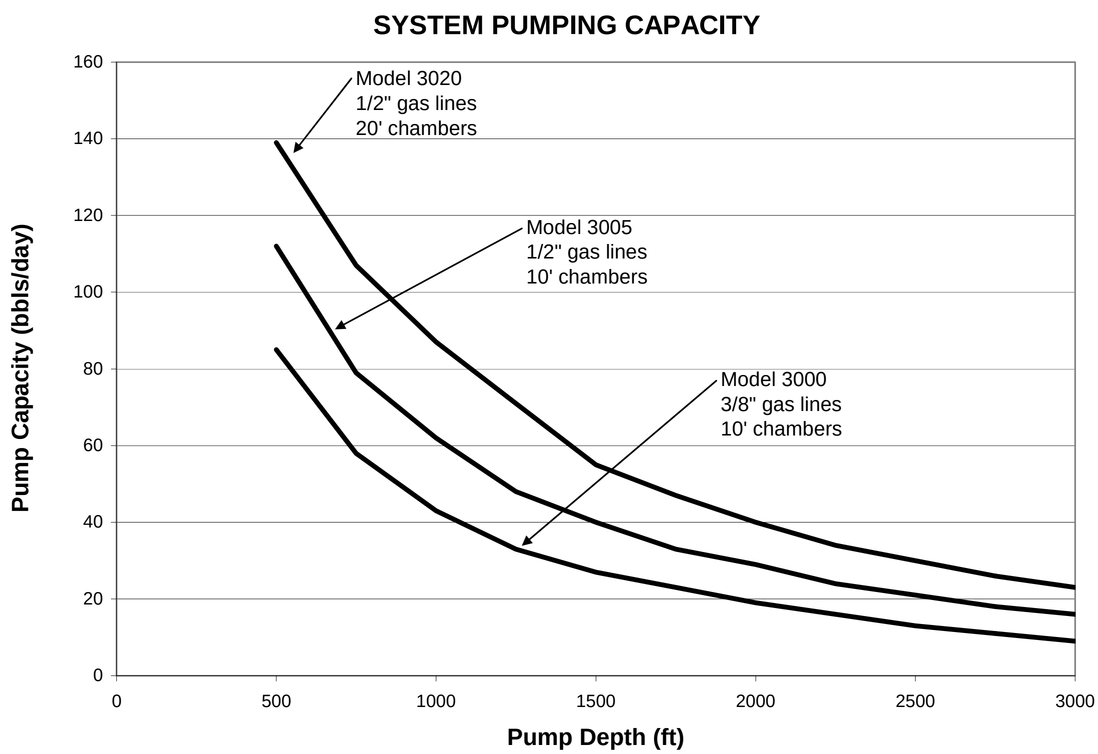

Figure 1 – System Pumping Capacity

Pumping System Configuration

Customer: Merrion Oil & Gas Corporation
Well: Panther #1
Installed: November 4, 2008
Casing: 4-1/2"   Total Depth: 1756'

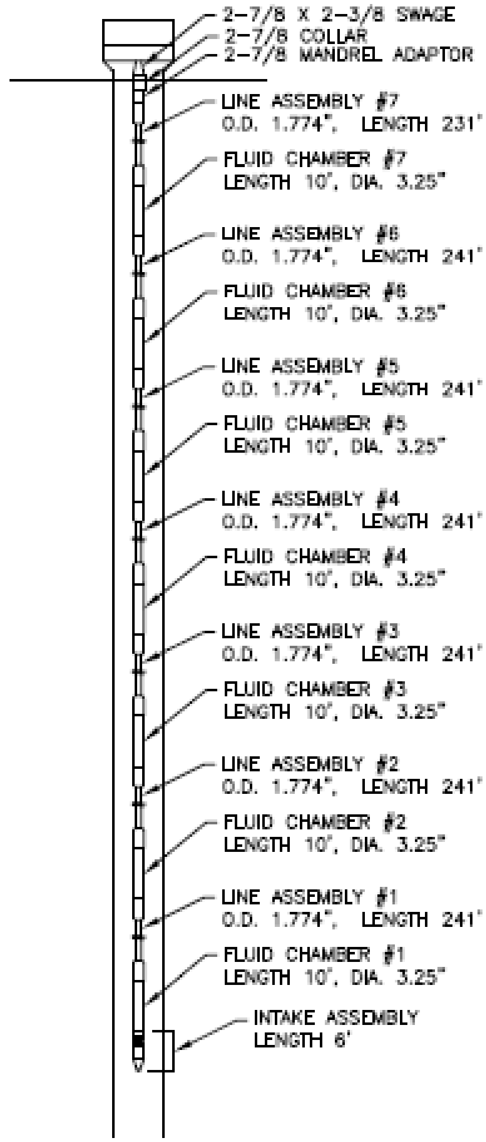

Figure 2 – Panther #1 Pumping System Configuration

MERRION

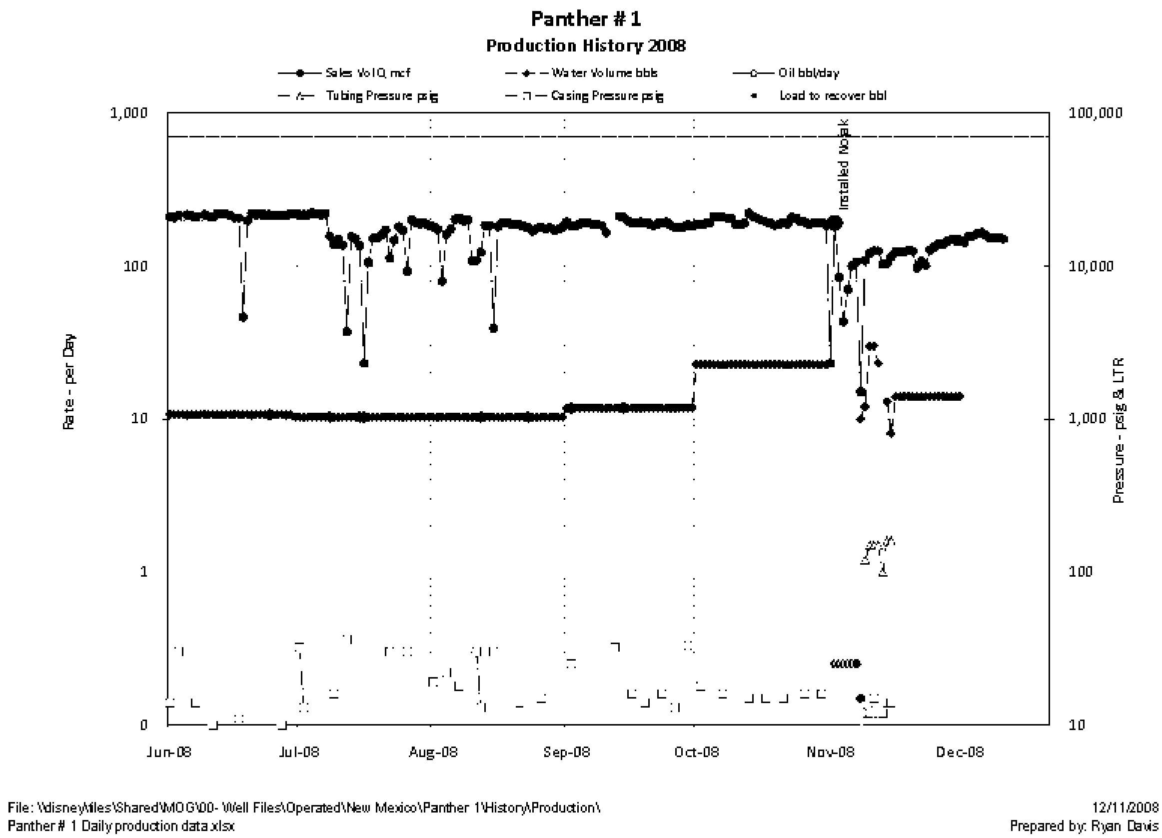

Figure 3 – Panther # 1 Production History

Pumping System Configuration

Customer: Merrion Oil & Gas Corporation
Well: Vine Com #1
Installed: November 6, 2008
Casing: 4-1/2"   Total Depth: 1248'

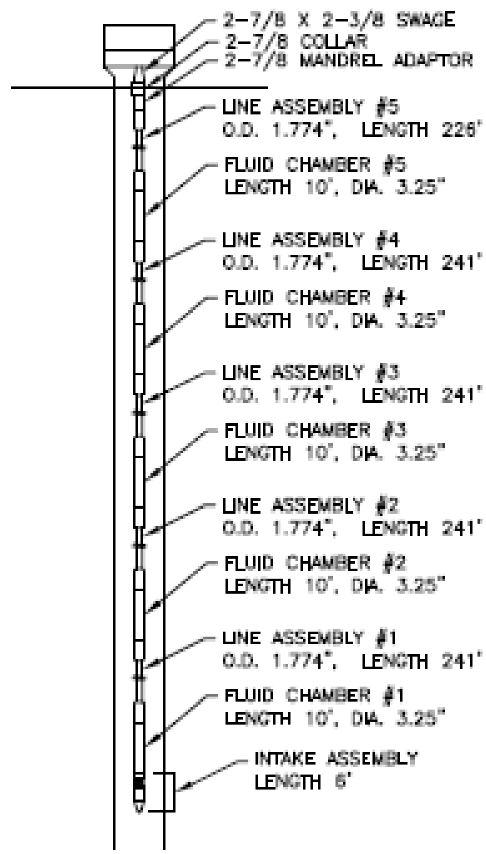

Figure 4 – Vine Com #1 Pumping System Configuration

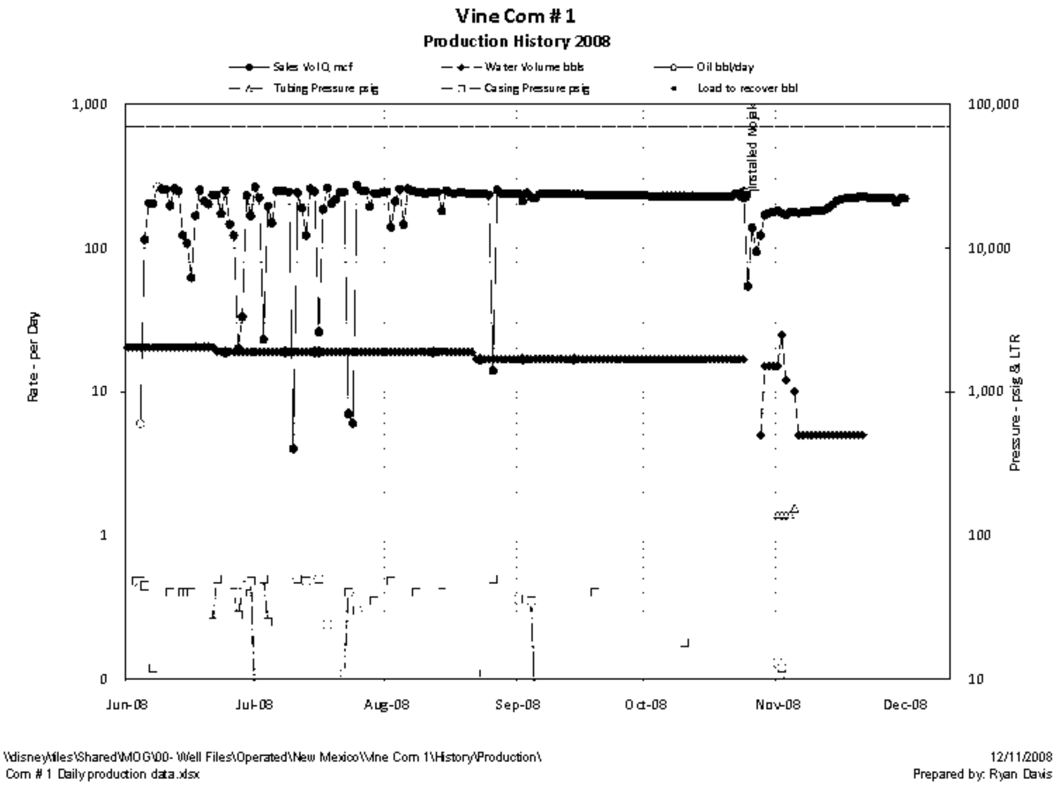

Figure 5 – Vine Com #1 Production history

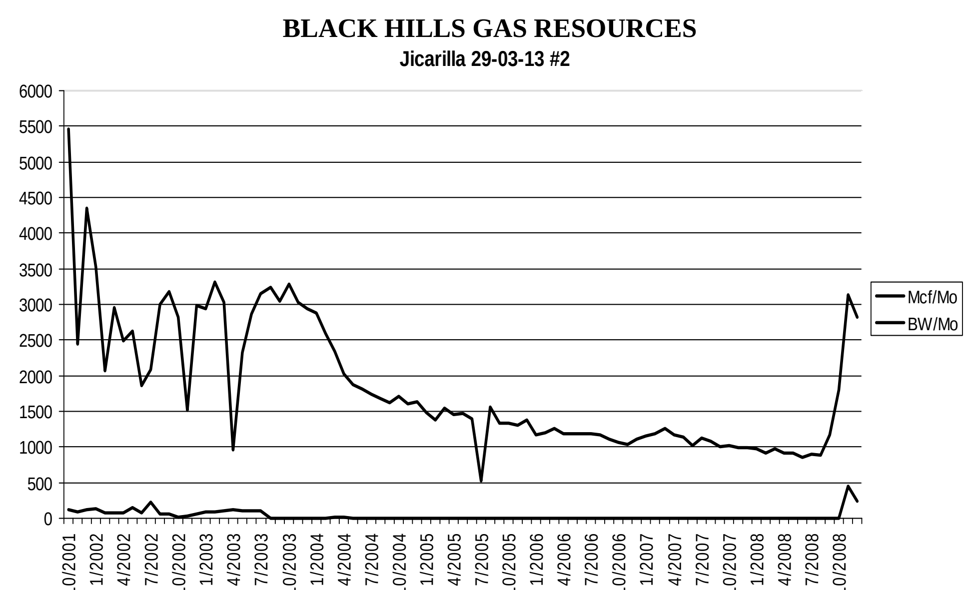

Figure 6 – Jicarilla 29-03-13 #2 Production History

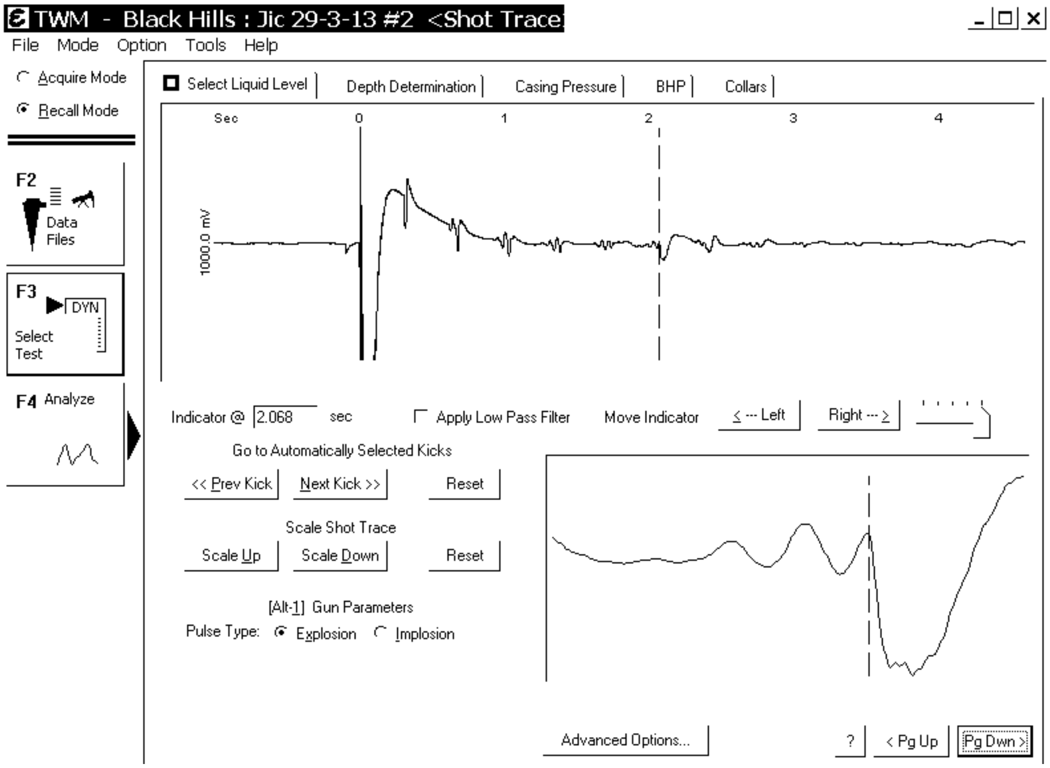

Figure 7 – Jicarilla 29-03-13 # 2 Fluid level shot

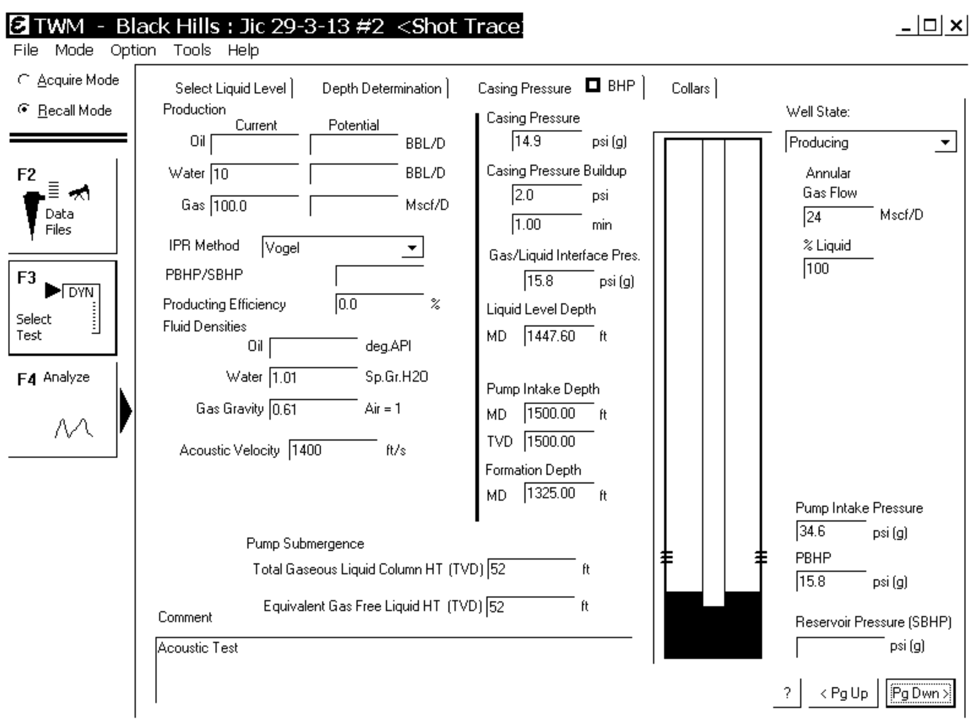

Figure 8 – Jicarilla 29-03-13 #2 Fluid level shot