Innovative Jet Pump Design Proves Beneficial in Coalbed Methane De-watering Applications

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Abstract

During the de-watering phase of typical Black Warrior Basin coalbed methane wells, an artificial lift method is needed to produce large volumes of water yet, have the ability to handle a moderate amount of produced solids such as coal fines and frac sand. In response to this scenario, the Coleman Pump Company developed a free style jet pump with a design specific to the problems encountered during coalbed dewatering operations. The unique design of flow passages in the pump allows retrieval of a very small portion of the pump while still providing a greater than normal flow capacity. In addition, the pump does not utilize any downhole moving parts which proves advantageous in a high solids environment to reduce remedial workover expense.

Meridian Oil applied the above technology to a test well in the Black Warrior Basin Coal Project. In this well, the pump was placed in the conventional threaded production tubing using a coiled tubing conveyed, concentric string, installation technique. This allowed the coiled tubing to be utilized as a power fluid path while water and gas were separated downhole and produced to surface independently through the dual annular spaces created by the concentric design. This design also provided for easy placement and retrieval of the throat and nozzle portion of the pump by using surface pump pressure. This design package provided a significant increase in water rate which resulted in an accelerated gas production rate and an overall increase in profitability for the well.

Black Warrior Coalbed Production Mechanisms

In coalbed wells, methane gas is produced from the coals by a reduction in reservoir pressure below the critical desorption pressure[1], or the point at which gas is first released from the coal. In the Black Warrior Basin, the initial reservoir pressure typically exists above this critical point therefore, large volumes of water must be produced before initiating gas production. It is economically critical to accelerate this initial water production and cut down on the time needed to reach first gas production. The reservoir pressure must continue to be lowered throughout the dewatering process so gas can desorb in a timely manner to achieve a sustained economic production rate.

Black Warrior Basin coalbed wells are completed in as many as five to six different coal groups over a large gross interval within each well. Figure (1) illustrates the perforated intervals within a typical coalbed well. Rod pumps are the popular method of artificial lift and are sized to be utilized over the life of the well. Each coal group is typically hydraulically fractured using water or gel with 20/40 mesh sand being the popular proppant. This completion technique is of importance because solids production (coal fines and frac sand) is the largest obstacle to successful production using rod pumps or any other method of artificial lift. The high solids environment causes pump inefficiencies that lead to excessive workovers to clean out or repair pumps. In addition, the wells produce 100% salt water so there is insufficient lubrication to keep a rod pump operating at a high efficiency level.

Coalbed wells have their highest water production during the early period of dewatering. After a period of time, a steady decline in water production will occur as the gas rate increases with time. This decline in water production can leave surface equipment oversized and under utilized after a short period of time. We cannot accurately predict which wells are going to be the high water producers or predict the time needed to dewater a given well prior to planning the surface design. Therefore, it is crucial to the project economics to balance initial capital investment with the long term production needs of the project.

The upper coals typically dewater first and as the fluid level in the well is lowered, the deeper coals begin to dewater. The fluid level is initially high and the wells are capable of water production rates higher than the limitations of the artificial lift system. It is possible to increase production volumes with the existing equipment by moving the pump up the hole. This allows the system the capability of achieving desired production rates while still remaining within the parameters of the system. This sacrifice of depth for rate is popular but, serves to accelerate dewatering in the upper coals while stagnating or even prolonging the process by possible dump flooding of the thicker coals below. This is because each individual coal is not capable of supporting the hydrostatic head created by high water production rates from the coals above. Although some gas can be recognized by this method, significant rates will only be achieved by timely dewatering of all coals including the thicker, higher gas content coals in the mid to lower sections of the well. To insure production from all coals, it is desirable to utilize an artificial lift system that can produce from maximum depths and be capable of a production rate acceptable to dewatering all the coals in a given well.

In summary, the capital vs reserve level in a Black Warrior coal well supports low finding cost ($/MCF) but, the long dewatering process can lower the rate of return on investment significantly. Any opportunity to decrease the dewatering time and accelerate gas production can have a large positive effect on the project economics. The artificial lift technique needed in the Black Warrior Basin should be capable of producing large volumes of water from maximum depths yet, have the ability to handle a moderate amount of produced solids. It should be versatile and require a level of investment appropriate to project economics. These needs supported the investigation of jet pumps as an alternative production mechanism for a coalbed methane environment.

Jet Pump Analysis

A jet pump is a device that utilizes the momentum of one fluid to move another[2]. A typical jet pump, as illustrated in Figure (2), consists of: (1) a nozzle that converts the pressure of the power fluid to velocity, (2) an intake that directs the suction fluid into the jet, (3) a throat where the jet fluid encounters the produced fluid and combines to reach some average velocity, and (4) a diffuser where the velocity of the mixed stream is converted back to pressure for movement out of the well.

A jet pump operates principally through a transfer of momentum between two adjacent fluid systems[2]. The pump converts potential energy to kinetic energy in the early stages of the mechanism. This kinetic energy is then transferred to pressure sufficient to lift the combination of fluids to the surface. To expand on this, the power fluid is accelerated through the nozzle to a high velocity. This increase in velocity, in response to energy conservation, results in a pressure drop creating the pump suction. The power fluid is mixed with the suction fluid in the throat section and the momentum of the power fluid is transferred to the well fluids. In turn, the velocity is reduced as the power fluid and suction fluid are combined. In the throat, the two fluids reach an average velocity proportional to the flow area and increased volume but, still retain a high level of kinetic energy. In the diffuser, the fluid passage is expanded gradually to allow the mixture of fluids to decelerate. As the fluid is decelerated, the kinetic energy is converted back to pressure necessary for lifting the fluid out of the well.

There are two basic types of jet pump installations, a fixed pump and a free pump design[3]. In a fixed design, the downhole pump is attached to the end of the tubing string and run into the well. Typically, the tubing must be pulled to retrieve or service the pump. The free pump installation is designed to allow downhole pump circulation into and out of the well inside a power fluid string. This allows the pump to be retrieved or serviced by circulation using pump pressure. There are several variances and designs that can be evolved from each installation type. The design is a function of the specific production application for a given well and the associated wellbore parameters.

Black Warrior Basin Application

The Coleman Pump Company initiated a jet pump design specific to the production needs of a Black Warrior Basin coalbed methane well. This design utilizes a free pump type installation which is the most significant feature in the coalbed application. The design permits circulation of the pump to bottom through the power fluid string and allows the pump to be reversed back to the surface for repair or sizing. The downhole pump is run in three separate components: (1) the bottom hole assembly, (2) the pump housing, and (3) the pump (or throat and nozzle portion).

The free pump design requires a pump seating assembly to be run on the bottom of the tubing string. The outside diameter of the bottom hole assembly is constructed to the dimensions of the tubing couplings. The inside diameter is constructed to the dimensions of the pump housing. This portion of the pump assembly is run on the end of the tubing string and serves as a receptacle for the pump housing and power fluid string. The bottom hole assembly is of heavy construction and designed for a long life downhole environment in excess of the tubing life.

The second component, the pump housing, consists of three main elements (1) the throat and nozzle seat, (2) the diffuser portion of the pump, and (3) a standing valve. The pump housing is fastened to the bottom of the power fluid string and run inside the production tubing. This housing stings into the pump seat at the bottom of the production tubing and seals the annular area between the production tubing and the power fluid string. The top of the housing (See Figure 2) contains the throat and nozzle seat. This seat serves as a downhole receiver and sealing assembly for the throat and nozzle portion of the pump. Downstream of this, the diffuser portion of the pump is machined into the pump housing and discharges to the side of the housing into the power string and tubing annulus. At the bottom of the housing, a standing valve is added at the pump suction opening. This allows for testing of seals above the opening during installation and for flow reversal to retrieve the throat and nozzle portion of the pump. During pumping operations, the standing valve remains open to allow well fluids to enter the pump.

Once the pump seat and pump housing are in place, the pump (throat and nozzle) is run in the hole by placing it in the power fluid string and circulating power fluid in the normal direction. When the pump enters bottom, it seats in the seal bores and begins pumping immediately. During pump out, the normal flow of fluids is reversed at the surface and pressure is applied to the discharge flow path. This reversal allows the pump to be circulated off seat and pushed back to the surface for repair or resizing.

Field Test

Meridian Oil applied the above technology to a test well in the Black Warrior Basin Coal Project. The objectives of this test were: (1) test the parameters of the jet pump in a coalbed methane environment, (2) prove the design as a viable means of artificial lift, and (3) obtain a continuous run with the pump to monitor water production and any increase in gas. If successful, this data would be used to recommend and design a permanent installation for use in further coalbed applications.

A well was selected which: (1) had been producing for a lengthy time period sufficient to generating a usable production history, (2) demonstrated a high fluid level over time, and (3) illustrated a flat or decreasing gas rate over time indicative of inefficient dewatering. Using these criteria, the test well selected was the GSP # 6-15, a well centrally located in the pilot area with sufficient interference from offset wells as to see the benefits of increased water displacement. A production log was run to observe the behavior of each coal group prior to the test and distinguish which coals were producing the majority of the gas and water.

Several variations of the Coleman design were examined and a computer program was used to calculate the optimum parameters. The pump was placed in the conventional threaded production tubing using a coiled tubing conveyed, concentric string, installation technique. This allowed the coiled tubing to be utilized as a power fluid path while water and gas were separated downhole and produced to surface independently through the dual annular spaces created by the concentric design. This use of coiled tubing as a power string was a unique feature of the design. This provided a smooth flow path for the return fluids and significantly reduced the chances for tubing leaks or washouts in the power fluid string. Figure (3) illustrates the design, tubing sizes, and overall well set up.

The surface facilities for this test needed to be portable and adaptable to the existing facilities for cost optimization. A skid mounted separator and diesel power triplex pump were utilized to tie in directly upstream of the existing facility. The separator was two phase, equipped with an upstream surge pot, and an inline desilter for handling solids. The separator was large enough to act as both a separator and feed water tank for the triplex pump. Figure (4) illustrates the flow path of the system.

Test Results

The GSP # 6-15 well had a 3 month averaged production rate of 710 BWPD and 103 MCFD prior to the jet pump test period. Production logs indicated the well had a producing fluid level from surface of 900 ft. In the month prior to the test, a tubing pump was installed at a shallow depth in an attempt to increase water production. The daily rate did increase to an average of 900 BWPD; however, only a slight change was seen in the average gas rate. The tubing pump was pulled to initiate the jet pump test.

Once the jet pump was installed, several different throat and nozzle combinations were utilized to find an optimum operating condition that would effectively balance production rate, surface pressure, and horsepower. During this time, a 2,220 BWPD instantaneous rate and 1,410 BWPD maximum daily rate were achieved. A significant amount of gas was produced up the tubing and the well flowed gas and water sporadically up the casing during the test.

After an optimum throat and nozzle combination was selected, a 15 day continuous run was initiated to test the system for run time efficiency and well production variance. During the 15 day test, the well averaged 1,224 BWPD and 177 MCFD. This equates to a 72 % increase in both average gas and water production for the test period. The maximum 24 hour water and gas rates observed during this test were 1,440 BWPD and 230 MCFD. The gas continued to incline over the 15 day period and the water rate declined slightly as the fluid level and corresponding bottom hole pressure decreased. The final rate at the end of the test period was 1,145 BWPD and 217 MCFD. This represents a 110 % increase in daily gas production over the 30 day period with a continuing decline in water rate.

During the 15 day test, the only downtime experienced was to quickly retrieve the pump for resizing or inspection and make adjustments to the surface facilities. The pump ran continuously throughout the 15 day test period with only 8 hours of downtime, equating to a 97.7 % run efficiency. The pump and equipment were removed after the test and the well was placed back on rod pump awaiting further analysis for a permanent installation.

After removal of the jet pump, the production rate reverted back to a level seen prior to the pump installation. Over the past several months, this rate has further declined which could be contributed to wear and inefficiencies typically seen with conventional pump installations as mentioned previously. Figure (5) is the production curve showing the gas and water production history for the test well over the referenced time period.

In summary, the system utilized in the test well was capable of creating a significant increase in water production with no downtime due to solids production. The system was able to achieve a significant increase in water production and the gas rate responded as expected to this increase. On the basis of this test, a cost effective permanent installation has been designed and will be installed to test the long term benefits of a coalbed methane jet pump system in the Black Warrior Basin.

Coleman Pump Design

The Coleman pump design offers several advantages over many of the systems currently in use. The Coleman Pump has been developed in response to problems associated with other jet pumps and the demand for pumps to meet requirements that cannot be met by existing designs. The unique design of flow passages in the pump allow retrieval of a very small portion of the pump while still providing a greater than normal flow capacity. This transmits to greater efficiency and more versatile applications.

The free pump portion of the Coleman pump is among the smallest in the industry. It can be manufactured in O.D. sizes of less than 0.75 inches and lengths of less than 12 inches. This allows the pump to be run in highly deviated or horizontal wells. This small sizing makes it possible to apply the jet pump technology to wells with a slim hole design and the pump can also be utilized with most sizes of coiled tubing.

The housing design for the Coleman pump incorporates large flow passages to allow well fluids to enter and produced fluids to exit the pump more freely and efficiently. This patented feature allows for larger production rates with less horsepower expended. The suction ports allow the pump greater tolerance in handling solids without plugging. This can eliminate downtime or needless remedial work.

The permanent installation will utilize essentially the same design as was used in the above test well. All surface equipment will be skid mounted for easy installation and movement. The flowlines will be segmented for easy installation. The permanent design should prove equally as successful as the test well over the long term. The jet pump system is versatile and should have numerous applications field wide over the life of the project.

Summary

The advantages jet pumps have over other forms of artificial lift are numerous. The most obvious advantage is there are no moving parts downhole and the parts that do wear have an above average life span. They are compact and adaptable to many different environments and are capable of a wide range of production volumes. The system is flexible because the rate can be regulated by controlling surface pressure. Chemicals, such as corrosion or scale inhibitors, can be easily injected downhole with the power fluid. The jet pump has no moving parts therefore, it is tolerant of abrasive well fluids and is capable of handling a moderate amount of produced solids. The pumps can be easily circulated in and out of the wellbore for maintenance or sizing. This creates the ability to operate inexpensively without the use of a pulling unit or wireline.

Each well should evaluated individually to select the optimum artificial lift system. The jet pump system utilized in this application was designed to meet the requirements of specific Black Warrior Basin coal wells. The results of this test illustrated the effectiveness of this design in coalbed dewatering applications. The pump provided a significant increase in water rate which resulted in an accelerated gas production rate and an overall increase in profitability for the well.

References

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2. Petrie, H.L., Wilson, P.M., Smart, E.E., "Jet Pumping Oil Wells" World Oil. November 1983.

3. Petrie, H.L., "Hydraulic Pumping" Society of Petroleum Engineers, Handbook of Petroleum Engineering. Chapter 6.

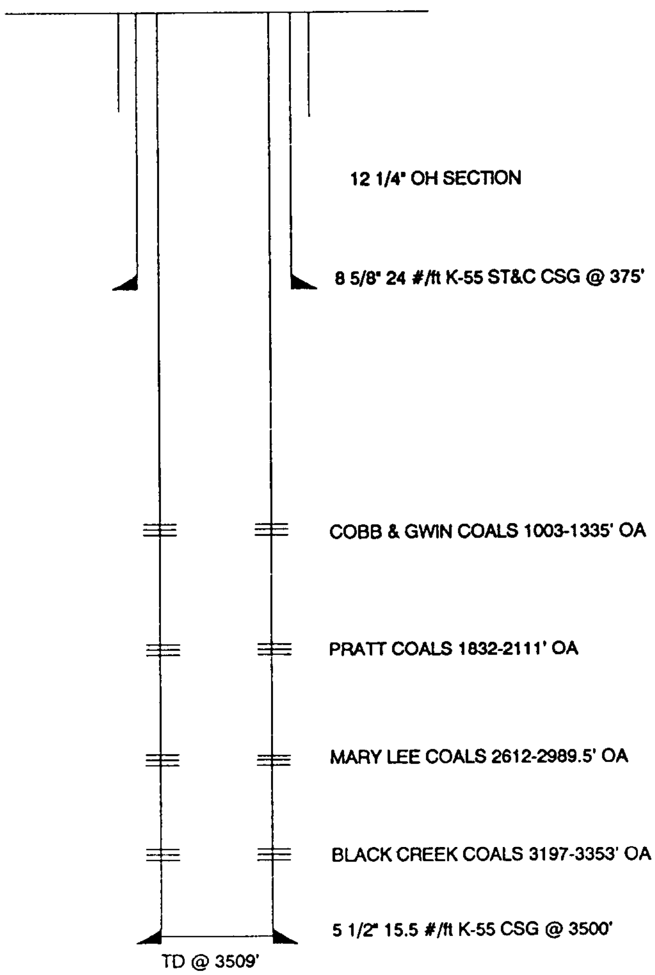

Figure 1 - GSP # 6-15
Alabama coal project well sketch

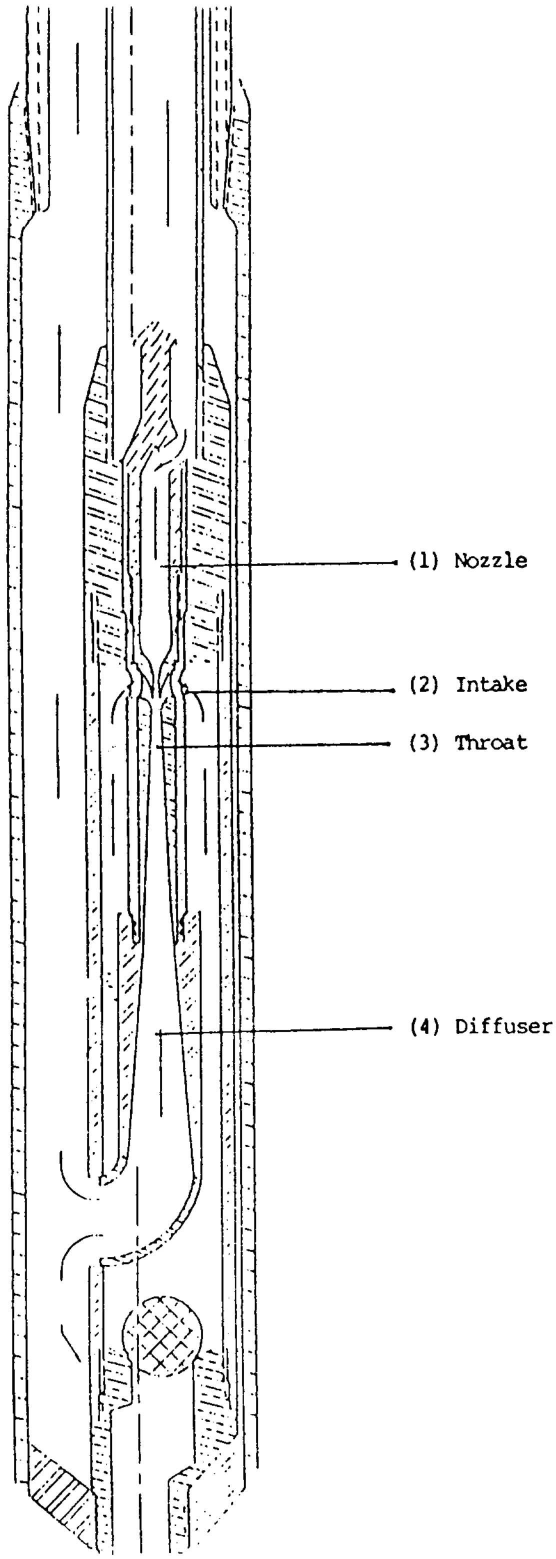

Figure 2 - Jet pump schematic

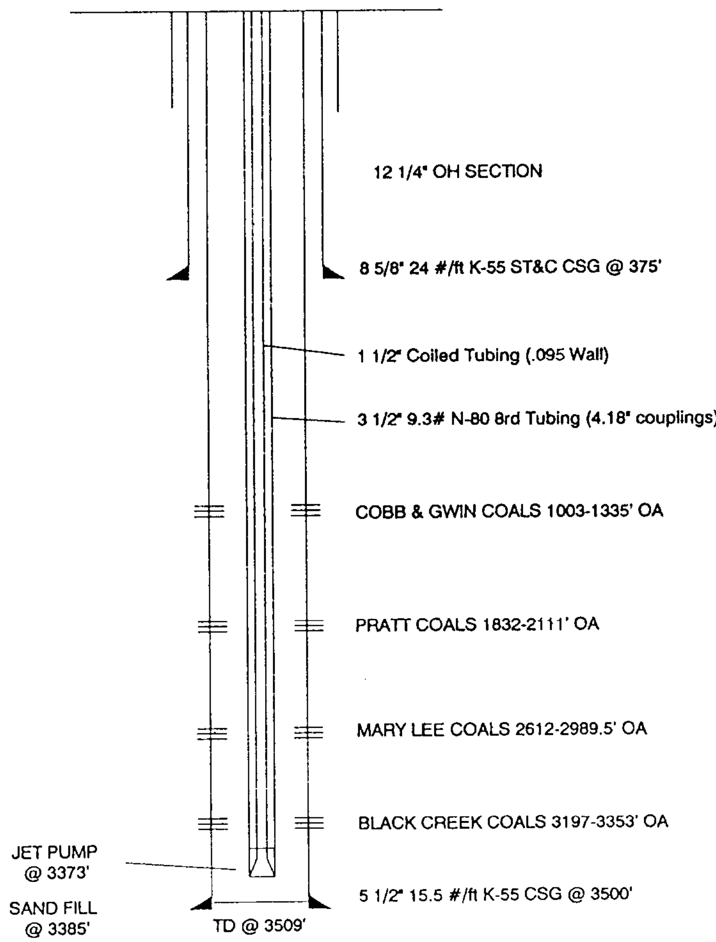

Figure 3 - GSP # 6-15
Alabama coal project well sketch

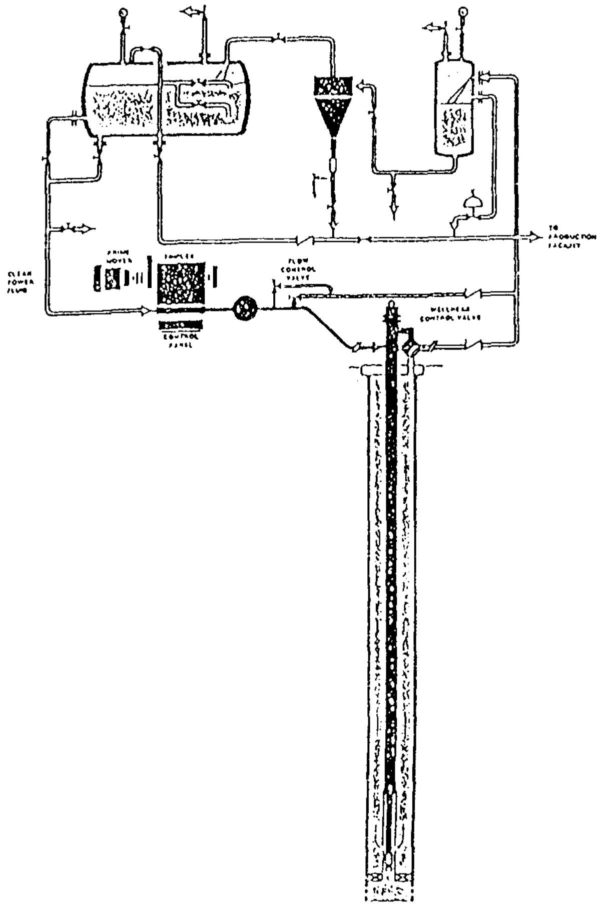

Figure 4 - System flow diagram

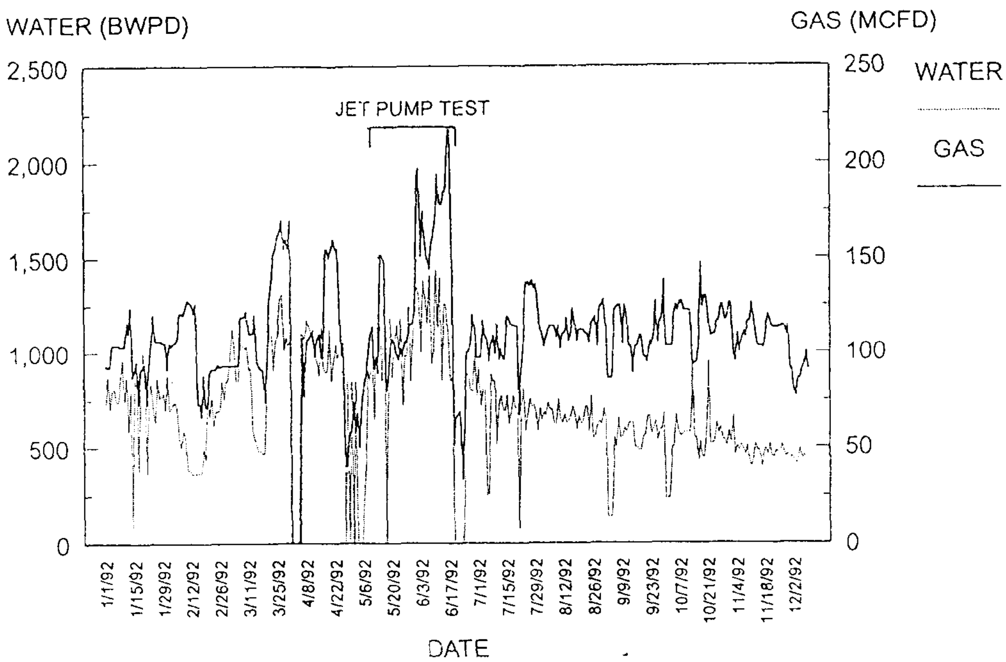

Figure 5 - GSP # 6-15
Alabama coal project