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Improved Methods for Monitoring Production From Vertical Degasification Wells

UNITED STATES DEPARTMENT OF THE INTERIOR

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By S. W. Lambert and M. A. Trevits

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Cecil D. Andrus, Secretary

BUREAU OF MINES

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ILLUSTRATIONS

IMPROVED METHODS FOR MONITORING PRODUCTION FROM VERTICAL DEGASIFICATION WELLS[1]

by

S. W. Lambert[2] and M. A. Trevits[2]

ABSTRACT

In this Bureau of Mines investigation, production was monitored for 1 year at over 30 coalbed gas-drainage boreholes located in Alabama, Pennsylvania, and West Virginia. Results indicate that the quality of data gathered from such wells can be improved greatly if potential problems are anticipated and prevented in the early stages of well production.

Major water-monitoring problems include solids buildup, freezing, the presence of gas in surface waterlines, and improper pumping interval settings. Such problems may be avoided by incorporating in the original well design waterline filters, sand screens, separator tanks, and systems to automatically control pumping intervals.

Problems related to measurement of coalbed gas flow include large quantities of water vapor contained in the gas, especially during winter months; freezing and subsequent obstruction of flow; sudden, uncontrolled release of gas pressure; and solids buildup in metering equipment. The installation of commercially available items, such as filters, separators, and insulation, and the thoughtful application of a basic knowledge of coalbed gas reservoir characteristics will prevent most production-monitoring problems.

INTRODUCTION

In July 1974, a project was initiated to establish optimum well density for coalbed gas-drainage boreholes. Project design called for degasification of large tracts of land with possible eventual expansion to an entire coal basin. An early phase of project development was to design and implement an accurate means of measuring production from drainage boreholes.

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[1]The work described in this report was performed by a component of the Bureau of Mines that was transferred to the Department of Energy on October 1, 1977.

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Calculations of the effectiveness of any degasification program depend upon the quality of data collected as mining approaches and intercepts a borehole. Correlation of borehole production to reductions in face emissions and the derivation of coalbed reservoir parameters can be provided if sound information is available for analysis.

ACKNOWLEDGMENTS

The authors thank Leon DeBardelaben, drilling superintendent, and L. Graves, president, both of Graves Well Drilling Co., Inc., for their technical assistance in the field and helpful comments regarding pump design.

GENERAL WELL COMPLETION

Coalbed gas wells may be drilled or cored through one or several gas-producing coalbed horizons. An additional length of borehole is drilled below the lowest coalbed to allow water to drain from producing zones and provide a collecting pool from which water is pumped to the surface.

Boreholes that produce gas from a single horizon are typically cased and cemented from immediately above the coalbed to the surface, blocking excessive drainage from upper water-bearing formations (fig. 1). Casing may also be set through several coalbeds along the full depth of the borehole. Gas is produced through openings which are either cut or pierced into the casing at each coalbed horizon. This manner of completion allows simultaneous production of gas and water from any number of selected horizons (fig. 2).

METHODS OF REMOVING AND MEASURING WATER

Water produced from exposed formations collects in the sump and is removed by means of a sucker-rod pump. Water is pumped up through 4- to 8-inch-diameter cased holes via production tubing, which is normally 1-1/2 to 2-3/8 inches in diameter. The water is then piped through a positive-displacement meter and measured. The mechanical configuration used to drain water from coal gas wells was adapted from oilfield applications and has proved to be effective when water production is less than 100 bpd.

A timing mechanism installed within the electric power circuit to the pump motor automatically controls pumping intervals. In this manner, a pump may be preset to operate only during designated intervals of each 24-hour period.

PROBLEMS OF MONITORING WATER PRODUCTION

Solids in waterlines have caused significant meter inaccuracies and pump malfunctions. Subfreezing temperatures have resulted in loss of water production data and permanent damage to wellhead equipment, pipes, and meters. Improper pumping intervals have allowed water to rise in boreholes to levels above the coalbed, thereby reducing gas production; or have allowed water to fall to the pump horizon, resulting in excessive wear of equipment. Such water-related problems can result in higher maintenance costs in terms of

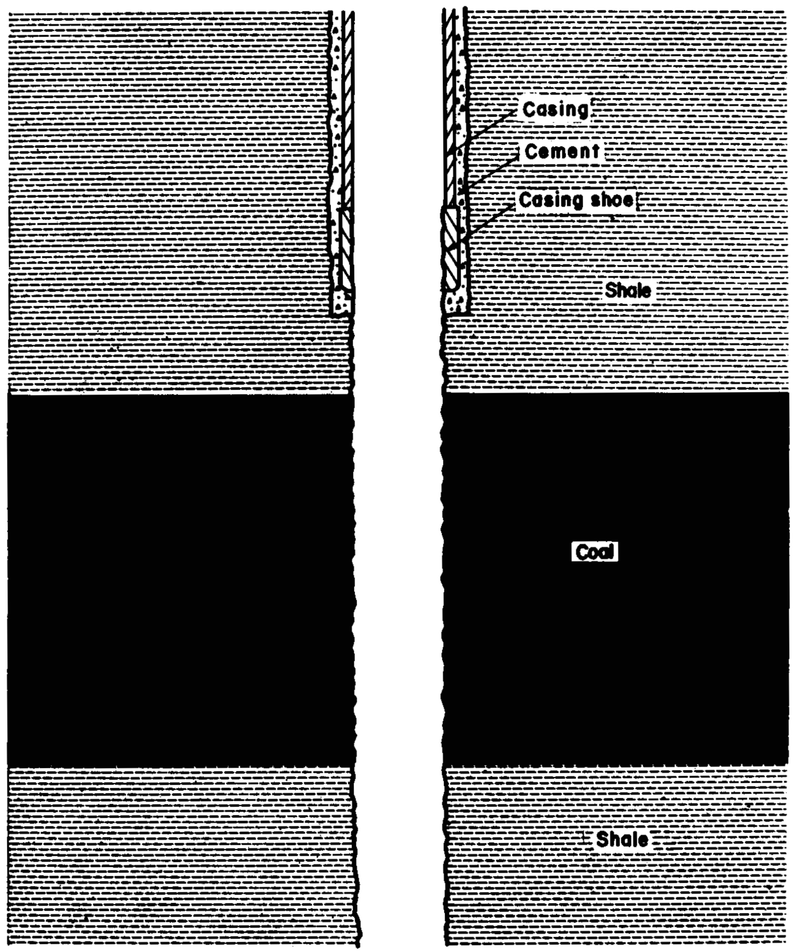

FIGURE 1. - Single-horizon (open hole) completion.

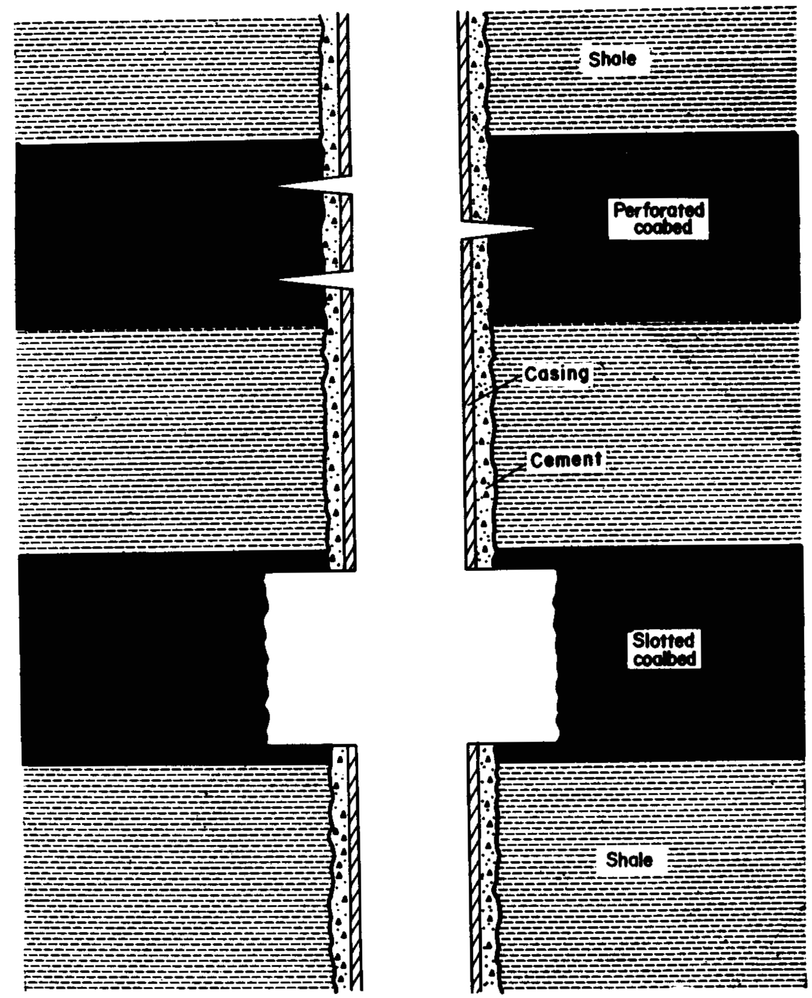

FIGURE 2. - Multiple-horizon completion.

meter repair, rig time, and number of man-hours prescribed to insure proper well operation.

Solids in Waterlines

Water produced from coal gas wells, especially during early stages of production, normally contains small amounts of coal or other rock fines. Scale resulting from oxidation of casing and tubing is another common ingredient of the water produced. If formation waters contain large percentages of salts, precipitates may enter surface flow lines, thus adding to the total solids content of the water.

Except for very large particles, most solids pass through the water-production-and-monitoring system without difficulty. The small percentage of solids remaining in the system usually accumulates in the housing chamber of the water meter, impairing and eventually stopping the measuring mechanism. At some wells, water meters have performed several months without clogging; at many wells, however, meters have repeatedly clogged within 1 week.

Rock material sometimes becomes lodged in valve openings in the downhole pump mechanism. Usually, this material is coal or shale that has sloughed off formations exposed in the wellbore. Pump stoppage due to lodging of rock material is most likely to occur during the first few days of production and especially after the well has been stimulated.

Freezing

In low temperatures, wellbore water sometimes freezes inside surface lines, restricting flow and causing leakage. Extended subfreezing conditions result in permanent damage to wellhead equipment, pipes, and meters.

Gas-producing coals are normally several hundred feet deep, and the water drained is usually quite warm compared with winter surface temperatures. If pumping is controlled by a timing mechanism, there are periods when no water moves through surface lines. Water remaining in the lines during these periods cools rapidly and may freeze.

Improper Pumping Interval

To achieve maximum gas production from coalbed gas wells, borehole water levels must be kept below the lowest producing coalbed. This is accomplished by either operating pumps continuously, or time-cycling pumps to operate for certain intervals each day.

Continuous pump operation over extended periods (months) may result in excessive wear of moving parts within the motor and the pump jack. Downhole pump components may also be worn quickly, especially when borehole water has been lowered to the pump horizon. Large volumes of gas are drawn into the pump causing dry to semidry conditions, which increase frictional wear.

Several wells were equipped with a timing mechanism to control pumping intervals. Ideally, the mechanism is set to pump continuously when flow to the wellbore is high, and then adjusted as prescribed by changes in flow. At all sites, it was found that pumping intervals were improperly set. In some cases, the interval was too long, causing excessive pump wear and significant volumes of gas in the waterlines. Where the interval was too short, the fluid level was constantly above the coalbed, thus limiting gas and water production.

Gas in Waterlines

Gas passing through positive-displacement water meters is measured as water and may account for significant errors in production records. Such errors were found to be common, occurring to varying degrees at all wells examined. In some cases, gas accounted for up to 75 percent of the metered water volume. Gas may enter waterflow lines in the dissolved state (as minute bubbles of gas coming out of solution) or as free gas drawn directly into lines by the downhole pump.

The solubility of coalbed gas increases directly as pressure increases, and diminishes as temperature increases. As much as 4 cubic feet of gas can be dissolved in 1 barrel of water at a depth of 1,000 feet, based on a hydrostatic pressure of 433 psig and a formation temperature of 100° F.[3] As pressure gradient is reduced around the wellbore, some of the dissolved gas comes out of solution and is produced through gas flow lines; however, a percentage of the dissolved gas remains in the water as it is pumped. As a result, gas comes out of solution while being brought to the surface and is measured through the water meter. Field tests to determine the degree of meter error resulting from such dissolved gases were conducted at several wells. At the start of the tests, borehole water levels were known to be at a static level well above the downhole pump horizon, which prevents large quantities of undissolved gas from entering waterlines. The meters used were checked for accuracy prior to and subsequent to the field tests. Results indicate that dissolved gases may account for 10- to 23-percent errors in measurements of water production.

Improper cycle settings or continuous pump operation may lower water level in a borehole to the downhole pump horizon. If this occurs, gas is drawn directly into waterlines and pumped to the surface, causing large errors in metered water measurements. Tests conducted at wells where fluid levels were known to be at or near the base of the downhole pump show meter readings to be from 20 to 75 percent greater than the actual volume of water removed during testing.

IMPROVED METHODS FOR MONITORING WATER PRODUCTION

The gas contained in waterlines can be removed before the water is metered by incorporating a 30- to 50-gallon-capacity, vented separation tank in the surface waterflow system. Such tanks have been field tested at four

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[3]Uren, L. C. Water in Oil and Gas Reservoirs. Petrol. Production Eng., 3d ed., 1953, pp. 30-32.

producing wells where gas in waterlines had severely decreased meter accuracy. After the tanks were installed, meter accuracies increased to over 98 percent in all cases. The suggested position and installation design suitable for use at coalbed gas wells are shown in figure 3.

Most large pieces of solid debris carried through waterlines settle in the separation tank. The remaining solids, suspended in the flow system, can be taken out of the water with a dirt-and-rust water filter installed downstream from the separation tank (fig. 3). The type of filter used at test well sites was a small plastic unit with a 3/4-inch-diameter connection and a replaceable filter cartridge.

Downhole pump stoppage owing to lodging of large pieces of coal or other rock material can be averted by installation of a screen (12 openings per inch to 4 openings per inch) at the lower end of the water-production tubing (fig. 4). Stainless steel screens identical to those used in the water-well industry have been used successfully at three of the four wells tested. The failure at the fourth test site was due to the extremely small size of openings in the screen used.

Cycled pumping, if properly controlled, is effective in controlling borehole water levels without causing unnecessary wear of equipment. Pump cycles must, therefore, be checked frequently and reset with every significant change in water production if optimum benefits are to be realized. (See appendix A.)

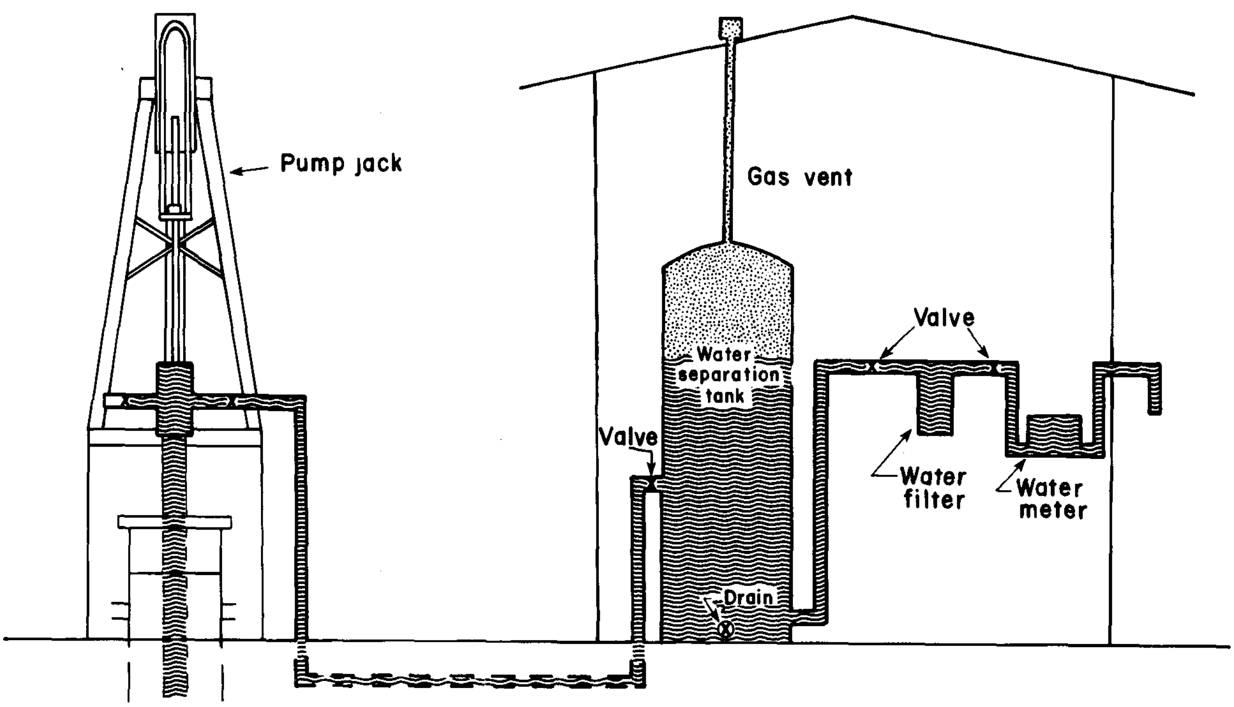

FIGURE 3. - Downhole water-production equipment.

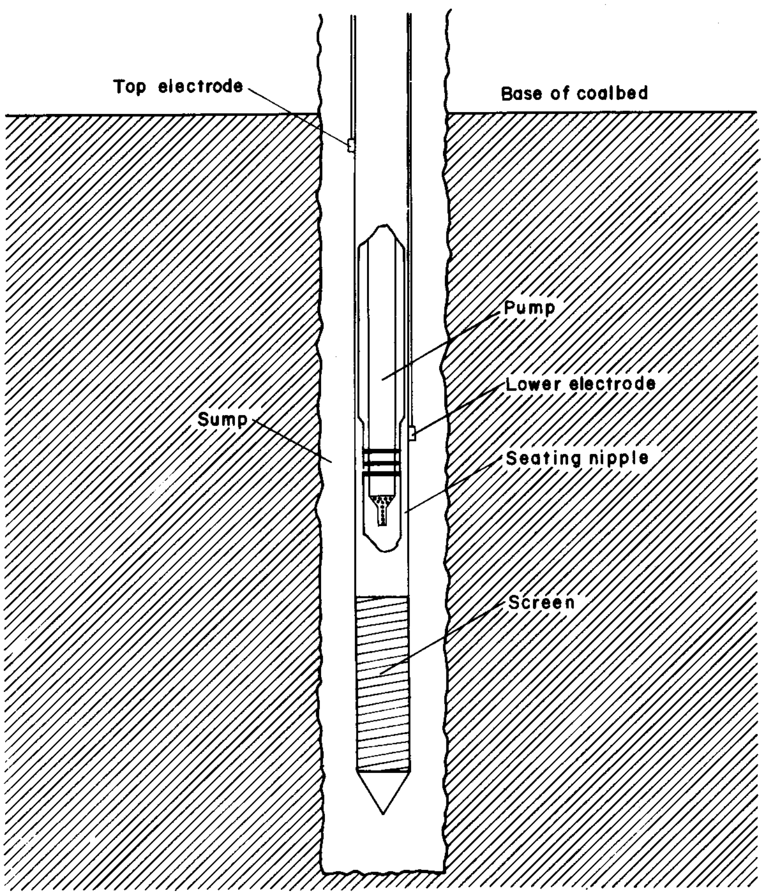

FIGURE 4. - Surface water-monitoring equipment.

A system that automatically controls pumping intervals to maintain water level below the coalbed is being tested at several well sites. Two electrode wires are fastened to water-production tubing as the tubing is lowered in the hole. One electrode is positioned near the bottom of the tubing and the other is placed just below the base of the coalbed. When the borehole water level rises to the top electrode, a circuit is completed that activates the pump jack motor (fig. 4). Water continues to be pumped from the well until the fluid level drops below the lower electrode. This system is expected to eliminate the frequent need to monitor fill-up rates (appendix A) and the possibility of drawing large volumes of gas through waterlines because the downhole pump is always submerged in fluid.

An alternative method to cycled pumping is the use of a variable-speed control on the pump. After the borehole water has been lowered to the pump horizon or near the intake, pump speed is reduced so the fluid level is held constant. Periodic checks for changes in the well's productivity might indicate a need to change the pumping interval. After shut-in periods or maintenance, the pump is adjusted to full capacity to dewater the wellbore rapidly. Conditions favorable for unloading may be created; therefore, adequate precautions should be taken (appendix B).

To prevent freezing, surface waterlines are wrapped with heat tape and then covered with fiberglass insulation. In areas where severe and prolonged low temperatures are common, waterlines are buried below the frostline. In addition, meters, water filter, and separator tank should be contained in small, insulated meter houses. Heat lamps installed in meter houses have proved to be a simple, effective, and inexpensive preventative against freezing. (All houses should be ventilated to some degree, especially those in which heat lamps are employed.)

METHODS OF REMOVING AND MEASURING GAS

Gas from coalbeds is produced through the annular space between water-production tubing and borehole casing. Wells produce under no-back-pressure conditions to optimize coalbed gas desorption and formation-water drainage. Once the gas reaches the surface, it is piped through a positive-displacement meter where it is measured (fig. 5). Three types of meters have been used to measure coalbed gas production, depending on the volumes of gas produced. Diaphragm meters are normally used on nonstimulated wells that produce less than 10,000 cfd. The most common kind of meter used to monitor gas flow from stimulated wells is the rotary meter with a measuring capacity of up to 84,000 cfd. Four-inch turbine meters have been used to monitor flows of over 84,000 cfd.

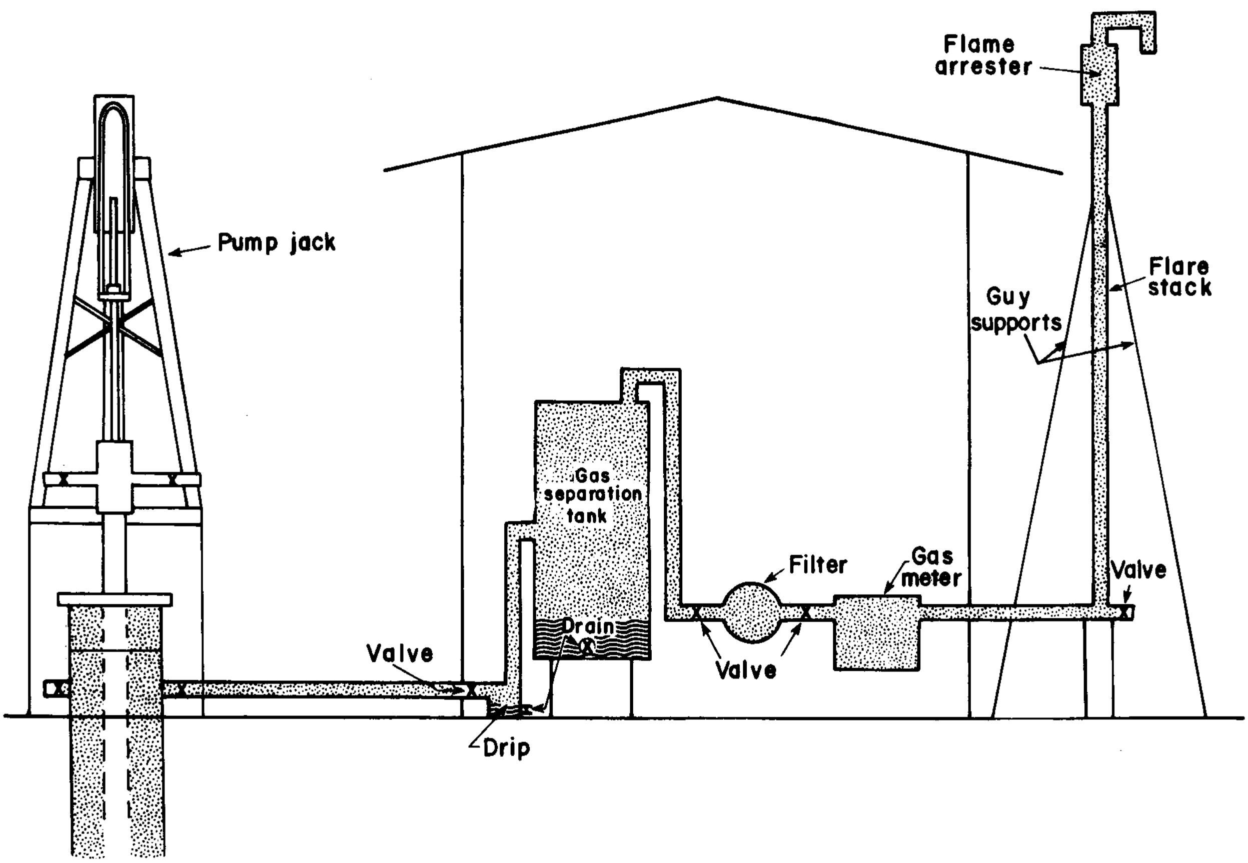

FIGURE 5. - Gas-production and monitoring equipment.

PROBLEMS OF MONITORING GAS PRODUCTION

Gas produced from coalbeds contains water vapor that condenses and collects along various points in the gasline, including the meter. Field studies indicate that water buildup decreases meter accuracy and, in many cases, permanently damages working components. The effects of even small quantities of water in gaslines are most pronounced during periods of subfreezing weather conditions. Sudden pressure release after wells have been shut in results in temporary, large-volume gas flows, which are usually greater than can be accurately measured by the gas meter. Rock fines normally accumulate within the gas meter over a period of time, but solids buildup may accelerate if excessively high gas volumes are allowed to flow through lines.

Water in Gaslines

As warm coalbed gas is subjected to cooler surface temperatures, some of its ability to carry moisture is lost; therefore, condensation occurs. The water condensate accumulates at low points along the pipeline and in metering devices. The problem occurs frequently during winter months, when differences between gas temperature and surface temperature are the greatest.

Reduction of gas flow velocity also causes water to separate from gas; this occurs in areas where pipe diameter increases, thus providing favorable sites for liquid accumulation.

Finally, water is stripped from the gas stream at angled sections along surface flow lines and meter locations where temporary turbulent flow occurs; this results from the collision or impingement of gas against pipe walls or meter chamber, causing some moisture to be extracted from the flow.

Freezing

The problem of water in gaslines is greater during periods of low temperature because conditions for condensation are intensified. The problem becomes acute when temperatures drop to below freezing. Even small amounts of ice in gas flow lines cause back pressure, resulting in apparent low coalbed gas production. Formation of ice in gas meters has damaged many of the instruments since the Bureau first began its coalbed gas-drainage program several years ago.

Sudden Pressure Release

Sudden, uncontrolled release of gas pressure has been a major cause of meter inaccuracies and has resulted in severe meter damage on many occasions.

Gas flow from the well is shut off routinely for pipe or meter maintenance, or to test for pressure buildup. During the shut-in period, gas continues to flow from the coalbed, building pressure in the wellbore. When the pressure is released quickly, a sudden surge of gas, or pressure wave, strikes the meter. Diaphragm meters are especially vulnerable to this surge and are almost always damaged. Rotary and turbine meters, although not damaged as easily, have been rendered inoperable by sudden surges of pressure.

Although damage to the meter may not occur, significant errors have resulted from recording measured gas volumes during a period of gas-pressure release. When gas is moving under pressure, more volume (at standard temperature and pressure) passes through the meter than is actually indicated on the meter index. If the necessary correction multipliers for gas flow under pressure are not applied, incorrect volume measurements may result.

Sudden pressure release has occurred at several wells because water was allowed to build up in the wellbore. Normal pumping operations may be temporarily interrupted for a number of reasons, such as electric power failure, mechanical malfunction, or general maintenance. As the fluid level rises, gas production to the surface decreases in proportion to the increasing hydraulic pressure exerted on the coalbed. Field studies indicate, however, that gas continues to accumulate around the wellbore periphery, building pressures similar to those exerted by the increasing hydraulic head. Once pumping is resumed and the borehole water level is lowered, disequilibrium is created in which gas pressure in the coalbed exceeds hydraulic head. As a result, violent eruptions occur at the surface as large volumes of expanding gas travel up the wellbore to reestablish pressure equilibrium. Sudden gas-pressure release of this nature is referred to as "unloading."

Solids in Gaslines

Particles of rock or other solid material accumulate in most gas meters over extended periods of time under normal flowing conditions. If left unchecked, solids cause malfunctions in all types of meters used. Field experience indicates that rotary meters are the most susceptible to malfunction caused by solids because of the close clearance between components of the inner rotating cartridge. Diaphragm meters usually do not stop functioning with small amounts of solids buildup, but meter accuracy diminishes as a portion of the measuring reservoir is filled with solids. Turbine meters will normally allow very small (less than 1 millimeter in diameter) material to pass through inner mechanisms.

Larger solids are normally carried through gaslines when well pressure is suddenly released, especially when unloading occurs. Such solids almost invariably clog and usually damage inner meter components.

IMPROVED METHODS FOR MONITORING GAS PRODUCTION

Commercially available filters have been designed to remove fine solid particles with very little pressure drop (0.5 psig or less), which makes them suitable for use on coalbed gas wells. Filters have been tested only on gaslines equipped with rotary meters, but they are adaptable to other meter types. Fiberglass is normally the filtering element used. At one test well equipped with such a filter, the gas meter operated for over 1 year without malfunctioning or losing accuracy. Suggested in-line placement of gas filters is indicated in figure 5.

The moisture content of coalbed gas has to be sufficiently low to assure accurate measurement of gas flow. In addition, coalbed gas sold commercially must meet requirements specifically noted in purchase agreements which normally limit the water content to approximately 7 pounds of water per million cubic feet of gas measured at standard temperature and pressure. During cold weather periods, test wells (ranging from 1,053 to 1,076 feet deep) have been found to contain from 31 to 103 pounds of water per million cubic feet of gas produced.[4] Although gasline condensate buildup has been a chronic problem at many Bureau vertical test wells, experimentation with water-gas separation devices has been limited because most of the gas produced is not sold.

The basic means used to remove moisture from coalbed gaslines are cooling, absorption, and impingement.[5] Devices used to remove liquid impurities are drips and separators.

The basic function of a drip is to remove liquid from the gas stream or liquid that has accumulated within the pipeline. A drip catches liquid in a gas stream by reducing the velocity of the gas stream, which causes the liquid to drop out. Liquid that has accumulated at low points within the pipeline is removed by use of a drip equipped with a drain which operates automatically or manually.

The primary function of a separator is to remove entrained fluids from the gas stream. Baffles, deflectors, tubes, rare elements, and gravity separation chambers are some of the mechanisms used within a separator device to remove moisture. There are several commercially designed separators that meet requirements for a single well or for several wells in the same pipeline system.

Meter inaccuracy and possible meter damage caused by sudden pressure release can be avoided by allowing gas pressure to bleed off gradually while maintaining flow pressures within the given meter range. To do this, a pressure gage is installed in the gas flow line near the meter. Flow pressures are periodically recorded and are then calculated into a standard equation solving for actual flow.

Sudden pressure release that results in unloading can be avoided if a few precautionary steps are taken, such as gasline shut-in, resumption of pumping, and subsequent slow bleedoff. Detailed description of actions to be taken if unloading is anticipated is included in appendix B. These methods have been field tested on several occasions and have proved to be very effective.

Ice formation in gaslines near the wellhead is prevented by properly insulating and heating meters and other points favorable to water accumulation (fig. 5). The number of routine field inspections of wells should be

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[4]Based on volumes of condensate accumulated in a flare stack similar to that shown in figure 5.

[5]Rumbaugh, J. R. Gas Conditioning Before Measurement. Pres. at 36th Appalachian Gas Measurement Seminar, Pittsburgh, Pa., Aug. 10-12, 1976; available for consultation at Department of Energy Mining Operations, Pittsburgh, Pa.

increased during especially cold periods to assure minimum condensate buildup. At the test wells examined, gaslines that had been wrapped with electric heat tape and covered with fiberglass insulation were rarely found to contain sufficient amounts of ice to cause significant back pressure. In addition, well sites equipped with insulated meter houses containing heat lamps yielded accurate, uninterrupted production information, even during prolonged subfreezing weather conditions.

CONCLUSION

Results of this study indicate that the quality of data gathered from degasification wells can be significantly improved if potential problems are anticipated and prevented during the early stages of well production. Problems related to the measurements of both gas and water can generally be avoided by equipping wells with commercially available items and by applying a basic knowledge of the coalbed reservoir throughout the productive life of the well.

APPENDIX A.--PROPER PUMP-CYCLING PROCEDURES

1. Pump the well continuously until a marked decrease in water production (compared with specified pump capacity) is observed. At new wells, it may take several weeks for this decrease to occur. At wells that have been pumped regularly, the decrease in water production rate may be observed in a few hours. At wells where pumping has been continuous, no decrease will be observed.

2. Measure and record the continuous, low-volume flow, using a device *other than the water meter*. A 5- or 10-gallon container and a stopwatch are sufficient to record such flow rates.

3. Turn off the pump jack and allow fluid to rise above the position of the downhole pumping mechanism. This usually takes less than a few hours. (The rate of waterflow into the well is known from item 2. The approximate volume of water and the time necessary to raise the level of water above the downhole pump is calculated from the known dimensions of the borehole and the production tubing within.) Unnecessarily long periods (days) of nonpumping should be avoided (appendix B).

4. Resume pumping and monitor flow as specified in item 2. Waterflow will increase rapidly to the current maximum pump capacity and remain at this high flow rate until the water level in the borehole is lowered to the downhole pump horizon. Once this occurs, water flow rate falls quickly (within 5 to 10 minutes) and is usually accompanied by an increase in gas flow through the waterlines.

5. Allow the pump to operate continuously until water flow rate is similar to that measured in item 2.

6. Given the rate of waterflow into the borehole (measured in items 2 and 5) and the dimensions of the wellbore and production tubing, the time (pump "off" cycle) required to fill the sump below the coalbed is calculated. Given the current real pump capacity (measured in item 4), the time (pump "on" cycle) required to remove water from the sump can also be calculated. Pump cycles are set accordingly and rechecked periodically to assure proper coalbed water drainage.

APPENDIX B.--METHODS TO PREVENT AND CONTROL WELL UNLOADING

1. In most cases, gaslines should be closed as soon as possible after pumping has been interrupted. The objective is to build gas pressure in upper portions of the borehole above the water column. However, if well maintenance requires gaslines to remain open, the borehole should be filled with water before work begins.

2. Once pumping is resumed, water production should be monitored closely at the wellhead (not through the water meter) for one of the following indications that the borehole water level has been lowered to or near the downhole pump horizon:

a. Sharp reduction of water production rate (compared with pump capacity).

b. Sharp increase in the quantity of gas coming through waterlines.[1]

3. Gaslines may be opened as soon as borehole water level is determined to be at or near downhole pump horizon. Gas valves should be opened very slowly to allow *gradual* bleedoff of gas pressure.

4. If well has shown a tendency to unload, allow pump to operate continuously until initial high formation pressures are reduced. Several months of continuous pumping may be required.

[1]Because the borehole is under pressure, large volumes of water (several times pump capacity) sometimes accompany gas through waterlines. If this should occur, pumping should be discontinued until pressure in the wellbore is reduced.

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