# USING VERTICAL BOREHOLES TO REMOVE METHANE FROM THE MARY LEE COALBED, WARRIOR BASIN, ALABAMA - A CASE STUDY

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## INTRODUCTION

One of the primary interests of the United States Department of Energy's Mine Planning Division is to fully develop avenues of technical research which potentially offer positive effects on coal mine productivity. One such area of research involves the removal of methane gas from unmined portions of coalbeds through vertical wells drilled from surface locations. As coalbed methane content is reduced, less gas is available for flow into the mine, and consequently ventilation requirements are decreased and/or coal extraction rates increase. Another attractive aspect of the vertical borehole drainage method is that it presents an opportunity to recover and utilize significant quantities of methane gas, which would otherwise be wasted to the atmosphere.

The viability of removing gas from the Mary Lee coalbed using stimulated vertical boreholes was first suggested by Elder and Deul as a result of a United States Bureau of Mines' drilling project conducted from 1971 to 1974 (4). Other United States Bureau of Mines' studies forecasted that degasification would eventually be necessary in the Mary Lee coalbed because most new or expanding mine development would take place at depths exceeding 1 000 feet (305 meters), where the methane problem would be severe (3) (13).

In 1975 a large-scaled drilling program was designed in order to supply industry's anticipated need for a degasification technology in the Warrior coal basin, Alabama. The results of this government/industry sponsored effort were to be specifically applicable to the Mary Lee coalbed, the most extensive and economically important deep minable coal present in the area. Major technical objectives of this program are twofold: (1) to measure the effects of various well completion designs, particularly hydraulic stimulation, on mining and (2) to determine the effects of well spacing on gas drainage rates.

A cooperative agreement was established with United States Steel Corporation in late 1975 and field work began shortly thereafter in the proximity of a newly developing mine near Oak Grove, Alabama. Government responsibility for this program was transferred from the United States Bureau of Mines to the United States Department of Energy in October 1977.

To date, as a result of this program, twenty-one wells have been completed into the Mary Lee coalbed at the Oak Grove site. Seventeen of these wells were drilled on an experimental grid pattern located two miles from the active mine. These grid wells are primarily being used to generate data necessary to determine the effects of well spacing on gas drainage rates and will also provide a large amount of information regarding the long-term effects of degasification on mining. The four remaining wells (designated TW1 through TW4) were placed near the mine so that the full effects of completion could be studied within the short time required for underground interception. Results gathered from the first two test wells (TW1 and TW2) have been reported in detail (10) and indicated that several improvements were necessary to increase gas drainage rates. Hydraulic stimulation was one of the most important aspects of well design that required improvement. Nitrogen-charged foam stimulation treatment was used at TW3 and TW4 instead of the gelled-fluid type stimulation used at the first two near-mine test wells.

## TEST WELL LOCATIONS

Figure 1 shows the position of the test wells in relation to active mining at the time when borehole production began. The induced fractures propagated from TW3 were intercepted by mining on October 6, 1977. The well had been stimulated November 21, 1976, approximately 950 feet (290 meters) ahead of mining. TW4, stimulated 1 010 feet (308 meters) away from the mine on July 18, 1977, was intercepted on November 16, 1977. Both test wells are located near the town of Oak Grove, Alabama.

## DRILLING AND COMPLETION

TW3 and TW4 were rotary drilled to approximately 1 100 feet (335 meters) penetrating the 5-foot (1.5-meter) thick lower bench of the Mary Lee coalbed and logged geophysically. The holes were cased with 4.5-inch (0.1-meter) steel casing from the top of the coalbed and cemented to the surface using a cement packer shoe, casing centralizers, and cement baskets. A latex-base, low-fluid-loss cement was used to set the casing in place.

## STIMULATION

The coalbed was stimulated using foam (75 percent nitrogen, 25 percent water) to carry sand proppant. TW3 was treated using 20 600 gallons (78.0 meter$^3$) of foam, 10 000 pounds (4 536 kilograms) of 80/100-mesh sand and 15 000 pounds (6 804 kilograms) of 20/40-mesh sand proppant. The original treatment design for TW4 was identical to that used at TW3. Stimulation procedures, however, were aborted early at TW4 when foam containing sand was observed coming to the surface around the well casing. As a result, total volume of materials used at TW4 were approximately 12 000 gallons (45.4 meter$^3$) of foam, 10 000 pounds (4 536 kilograms) of 80/100-mesh sand, and 2 500 pounds (1 135 kilograms) of 20/40-mesh sand.

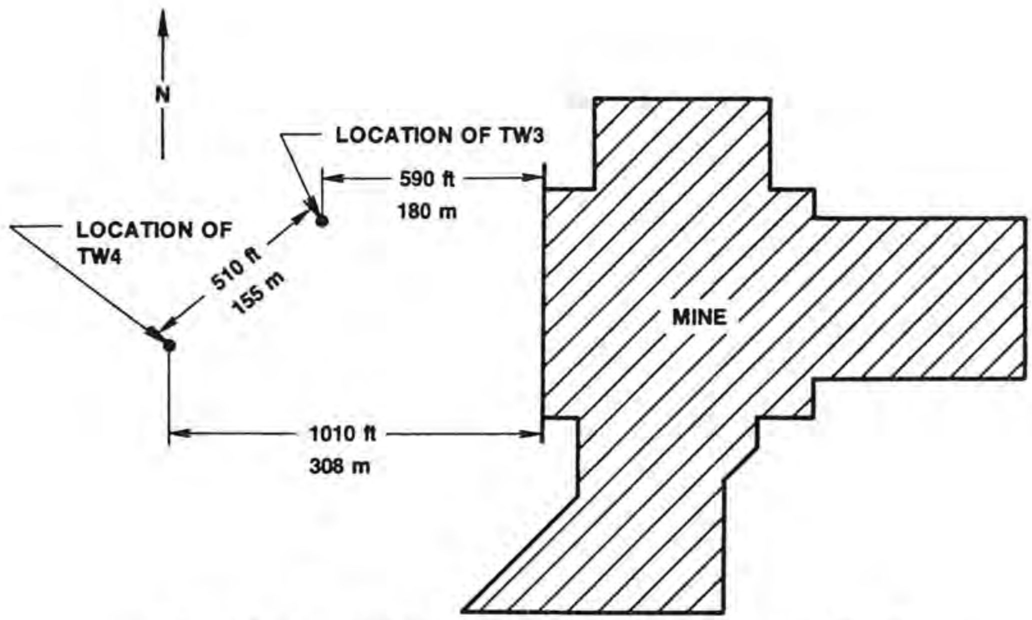


Figure 1. Position of Test Wells in Relation to Active Mining at Time of Initial Well Production

Initial formation "break" occurred at both wells at 700 psig; treating pressures were approximately 1 400 psig; injection rates averaged 10 bpm (1.6 $meter^3$/minute). Both wells were treated through 2-3/8-inch-diameter (0.1-meter) tubing and packer set in casing near the bottom of the hole.

The wells were allowed to flow back immediately following stimulation through a small diameter choke nipple. In this manner, downhole flow velocity was restricted minimizing the possibility of carrying large amounts of proppant back to the wellbore. TW3 was allowed to "blow back" for 7 days after stimulation. TW4 was allowed to "blow back" water and gas without the use of a pump throughout the life of the well. A pump was installed at TW3 and both wells were equipped with meters to monitor production.

Secondary Stimulation, TW3

The Mary Lee coalbed is comprised of two benches in the area of Oak Grove, Alabama (13). The lower bench is the thicker of the two and is currently being mined. The upper bench is thin, contains several shale partings, and occurs about 7 feet (2.1 meters) above the lower coal. A plan to stimulate the upper coal bench was implemented at TW3 approximately 7 months after stimulation of the lower coal unit.

The upper bench was relocated precisely using a neutron-Gamma ray log and perforated with shaped charges. The coal was then stimulated through tubing using 5 000 gallons (18.9 $meter^3$) of foam, 3 400 pounds (1 542 kilograms) of 80/100-mesh sand, and 3 600 pounds (1 633 kilograms) of 20/40-mesh glass beads. Formation "break" was recorded to be 600 psig. Average injection rate was 5 bpm (0.8 $meter^3$/minute).

PRODUCTION

Test well No. 3 was put on production December 20, 1976. An initial period of rather unsteady, but generally high, daily gasflows is attributed to several unloading episodes similar to those described by Lambert and Trevits (11). Gasflow from the well soon became less erratic but generally declined from over 140 000 cfd (39 700 $meter^3$/day) to 50 000 cfd (14 200 $meter^3$/day) after 55 days of monitoring. Daily water flow from TW3 also declined during this period from 75 (11.9) to 13 bpd (2.1 $meter^3$/day). During the next 161 days of production, gas rates increased gradually to 85 000 cfd (24 000 $meter^3$/day) while water flow dropped only slightly to 10 bpd (1.6 $meter^3$/day). After 216 days of production, the gasflow was stopped by flooding the well with water to permit stimulation of the upper bench of coal. Pumping operations resumed 25 days later. This time, water production was over 75 bpd (11.9 $meter^3$/day) for 7 days and then decreased to 18 bpd (2.9 $meter^3$/day) during the last 30 days of production. Gasflows from the well rose to 45 000 cfd (12 750 $meter^3$/day) as water flow decreased. The complete production history of TW3 is shown on Figure 2.

Gas production from TW4 is shown on Figure 3. Estimates of gasflow from TW4 during the initial production period indicated a rate of more than 180 000 cfd (51 000 $meter^3$/day). Twenty-three days after stimulation, measurements using an orifice and a manometer showed daily gas production to be 183 000 cfd (51 800 $meter^3$/day). A meter, installed at TW4 several days later, indicated that daily gasflows were very high, but erratic. Flows averaged about 150 000 cfd (42 500 $meter^3$/day) until a sharp drop occurred around October 1, 1977. Gas rates declined to about 40 000 cfd (11 300 $meter^3$/day) the day before the well was plugged.

It is important to remember that the TW4 was never equipped with a pump to remove water from the wellbore, which explains, in part, the erratic flows shown on Figure 3. Also, portions of TW3 gas and water production (shown on Figure 3) indicate that both test wells interfered with each other, accounting for some of the unsteady production from TW4.

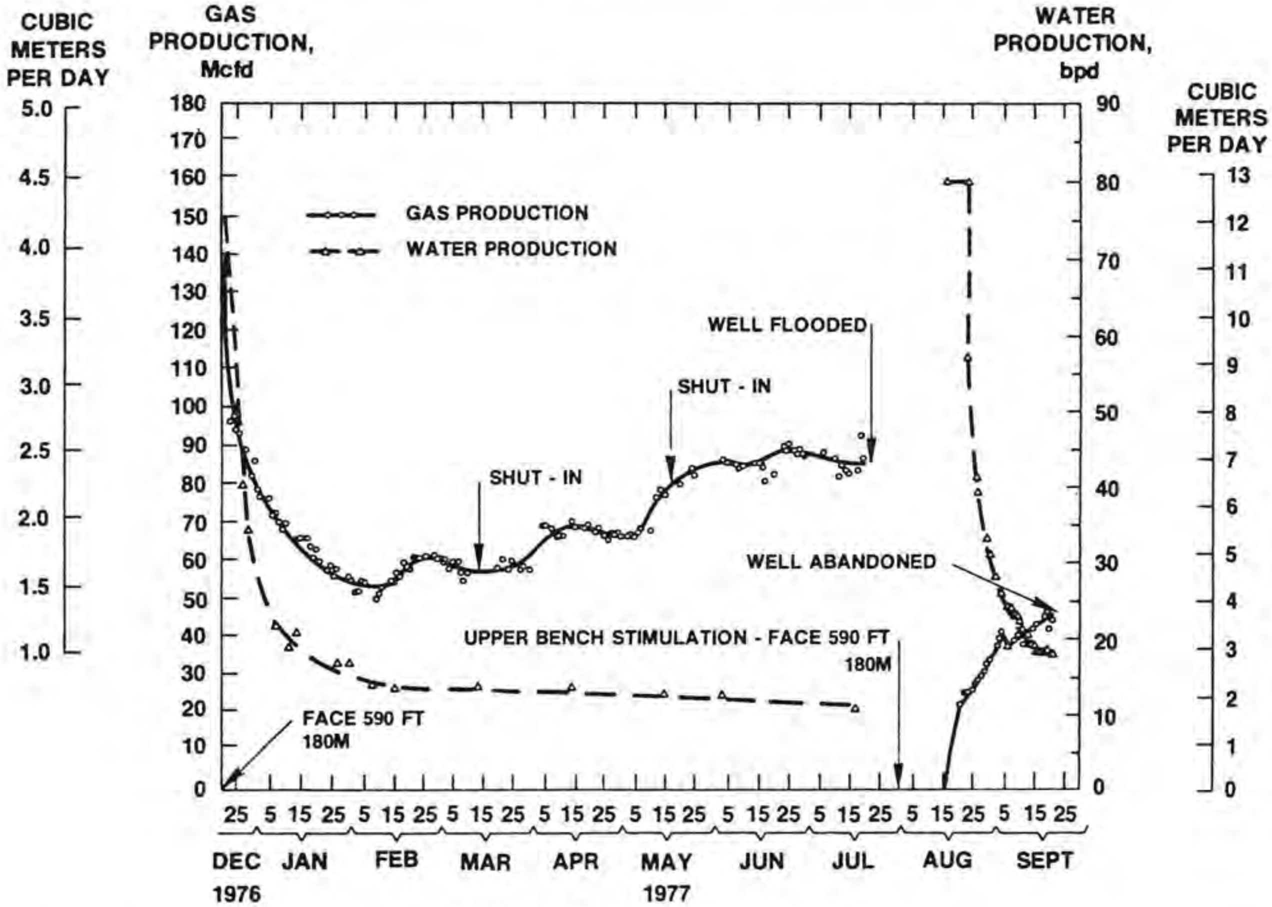


Figure 2. Production Curves for TW3

Gas and Water Analyses

The composition of gas produced from TW3 and TW4 is shown on Table 1. Analysis of gas sampled 2 days after TW3 was put on production indicates that only a small percentage of the nitrogen used to stimulate the well remained in the coal at this time. Similarly, gas produced from TW4 contained less than 7 percent nitrogen and almost 93 percent methane only 2 days after the well was stimulated.

## UNDERGROUND INVESTIGATION

Earlier underground studies of TW1 and TW2 showed that fractures induced by drilling, cementing, and stimulation were extended in directions parallel to existing natural joints or coal cleat (10). A similar study of TW3 and TW4 was conducted to determine if foam-induced fractures had also propagated in directions corresponding to coal cleat and rock joint trends.

An area of the mine near TW3 and TW4 was divided into twenty-three stations as shown on Figure 4. The direction of all visible roof joints and at least 15 coal cleats within each station were measured. Directions of all stimulated fractures containing propping agent, fluid-loss material, or cement were also measured. A composite rose diagram for the entire area is shown on Figure 5. The average direction of the stimulated fractures was N 67° E, while the average roof joint direction in the northeast quadrant was N 66° E.

Figure 6 is a plan view of the mine showing the test well locations and the traceable lengths of the fractures induced by stimulation. Features associated with the coalbed, such as highly slickenedsided "roll" areas and slight structural displacements, are also noted on Figure 6.

Propagated fractures examined were vertical. Each typically began as a hairline crack about 3 feet (0.9 meter) above the base of the coal, and gradually widened to approximately 3/16 inch ($5.0 \times 10^{-3}$ meters) at the top of the coal. The fractures continued upward for an undetermined distance into the roof.

Cement used to set casing was contained within the same vertical plane as the sand to lateral distances of up to 80 feet (24.4 meters) from the test wells. Microscopic examination of samples of this cement showed that the cement contained coal particles, but no sand. A large quantity of casing cement was found below the packer shoe at TW4.

Fractures observed within the coalbed contained mostly 80/100-mesh-size sand; the sand taken from the fractures in the roof was largely 20/40-mesh-size. The glass beads used to stimulate the upper bench at TW3 were not present in the lower bench examined underground.

## MINE GAS EMISSION STUDY

Methane gas emissions were measured and recorded by the mine operators while mining the two sets of entries

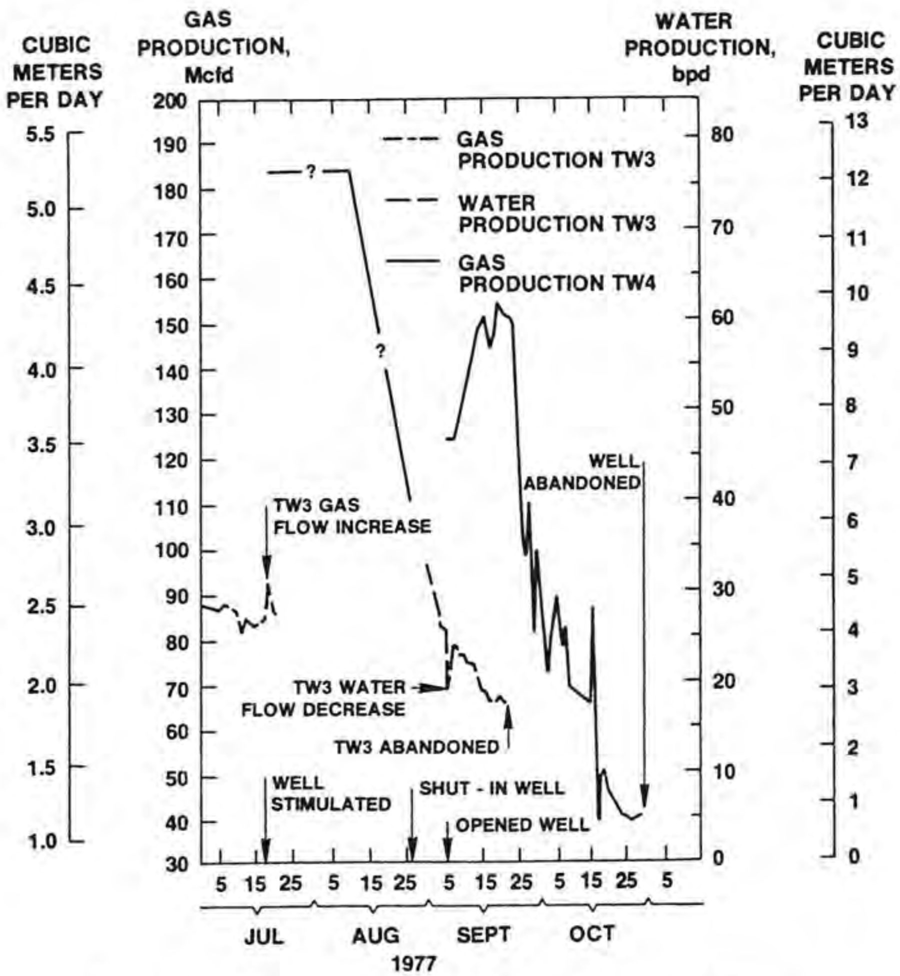


Figure 3. Production Curve for TW4 and Portions of TW3

Table 1. Gas Analyses from TW3 and TW4

| Date gas sampled | Percent gases in sample $CO_2$ | $O_2$ | $N_2$ | CO | $CH_4$ | $H_2$ | $C_2H_6$ | $C_3H_8$ | $C_4H_{10}$ | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TW3: Foam stimulated November 21, 1976; put on production December 20, 1976 | | | | | | |
| 12/22/76 | 0.03 | 0.42 | 4.5 | no | 94.6 | no | 0.0030 | <1 ppm | no | |
| 01/14/77 | 0.02 | 0.06 | 2.3 | no | 97.6 | no | 0.0083 | no | <1 ppm | |
| 02/15/77 | 0.02 | 0.08 | 2.0 | no | 97.9 | no | 0.0058 | no | no | |
| 07/18/77 | 0.03 | 0.06 | 1.6 | no | 98.3 | no | 0.0043 | no | no | 10:20 a.m. * |
| 07/18/77 | 0.03 | 0.06 | 3.2 | no | 96.7 | no | 0.0044 | no | no | 3:22 p.m. * |
| 07/18/77 | 0.03 | 0.10 | 6.5 | no | 93.4 | no | 0.0046 | no | no | 4:54 p.m. * |
| 07/19/77 | 0.03 | 0.08 | 2.5 | no | 97.4 | no | 0.0052 | no | no | |
| 09/13/77 | 0.03 | 0.03 | 1.9 | no | 98.1 | no | 0.0067 | no | no | |
| | | | | TW4: Foam stimulated July 18, 1977; put on production July 18, 1977 | | | | | | |
| 07/20/77 | 0.06 | 0.50 | 6.7 | no | 92.8 | no | 0.0049 | no | no | |
| 08/10/77 | 0.02 | 0.04 | 1.1 | no | 98.8 | no | 0.0008 | 0.0002 | no | |
| 09/13/77 | 0.05 | 0.05 | 0.9 | no | 99.0 | no | 0.0067 | no | no | |
| 10/16/77 | 0.02 | 0.06 | 1.1 | no | 98.9 | no | 0.0061 | no | no | |
| 10/17/77 | 0.02 | 0.10 | 1.2 | no | 98.7 | no | 0.0074 | no | no | |

*TW4, 510 feet (155 meters) away from TW3, was foam stimulated from 2:14 p.m. to 2:42 p.m. on July 18. Note the significant increase in $N_2$ gas produced from TW3 shortly after.

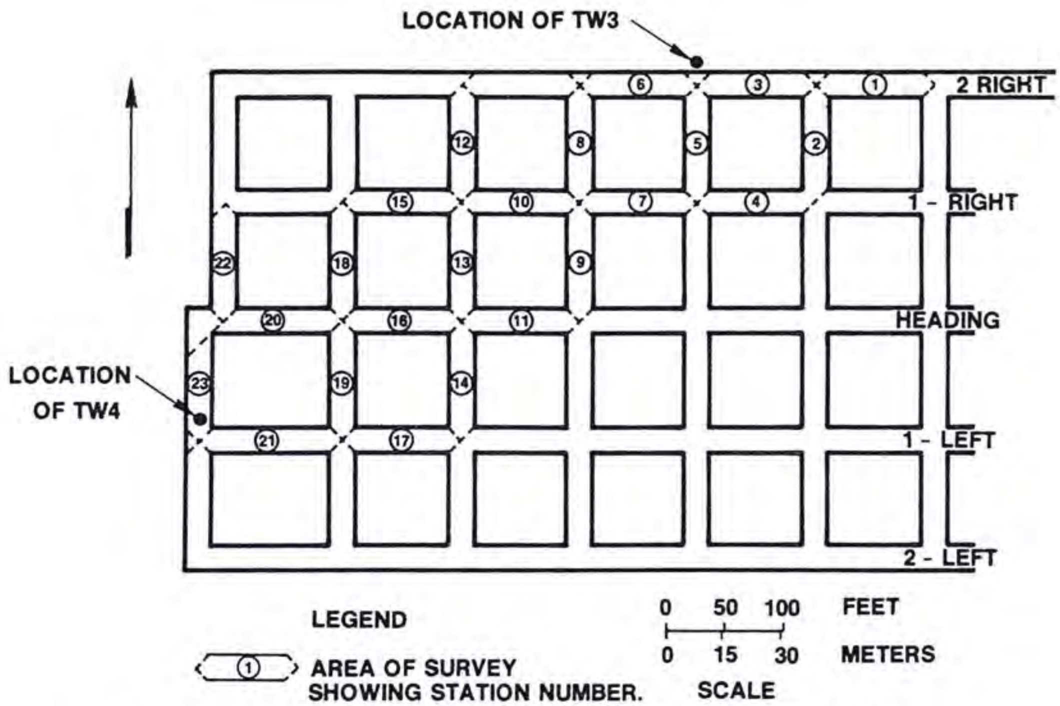


Figure 4. Survey Stations Dividing Area of Mine Near TW3 and TW4

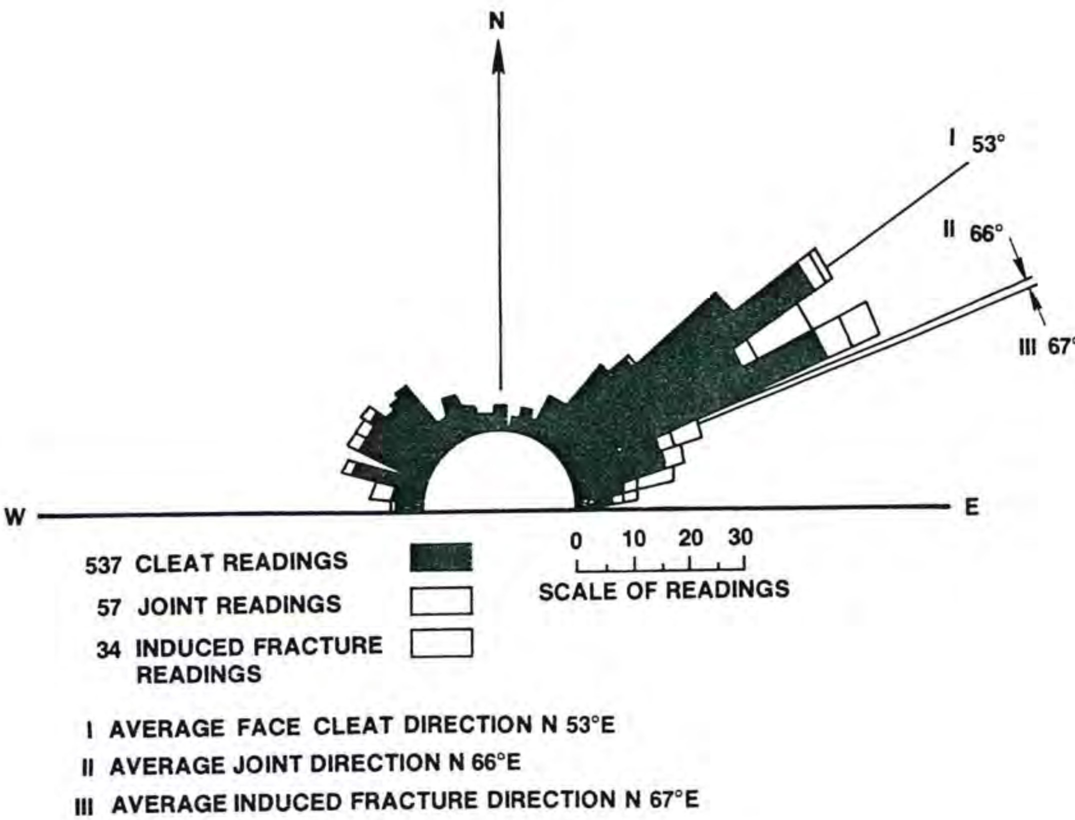


Figure 5. Composite Rose Diagram of Survey Area Showing Cleat, Roof Joints, and Induced Fractures

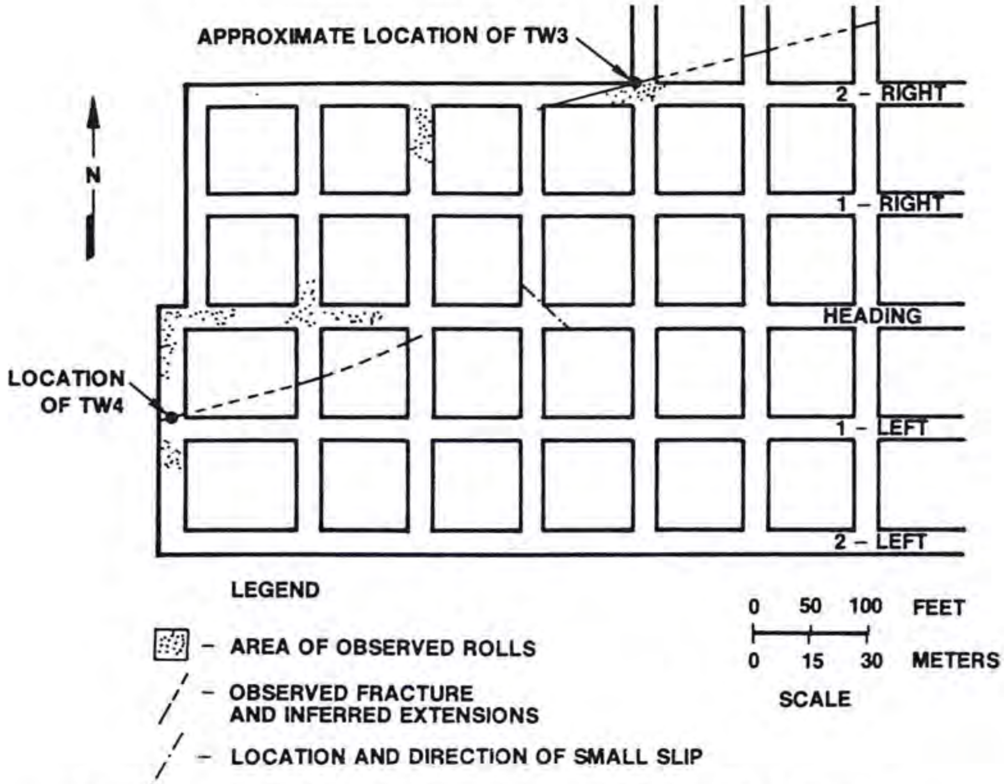


Figure 6. Plan View of Mine Showing Test Well Locations, Traceable Induced Fractures and Other Features as Observed

shown on Figure 7. The east entries were driven 590 feet (180 meters) into non-degasified virgin coal during a 70-day period and encountered a total of 61 million $ft^3$ (17.2 million cubic meters) of methane. Mining operations then turned west and, within 63 days, reached TW3, also 590 feet (180 meters) from the main north entries. The amount of gas measured while mining towards this test well was 37 million $ft^3$ (10.5 million cubic meters), 40 percent less than that encountered while mining east. The difference in methane emissions between the east and west set of entries is graphically illustrated on Figure 8.

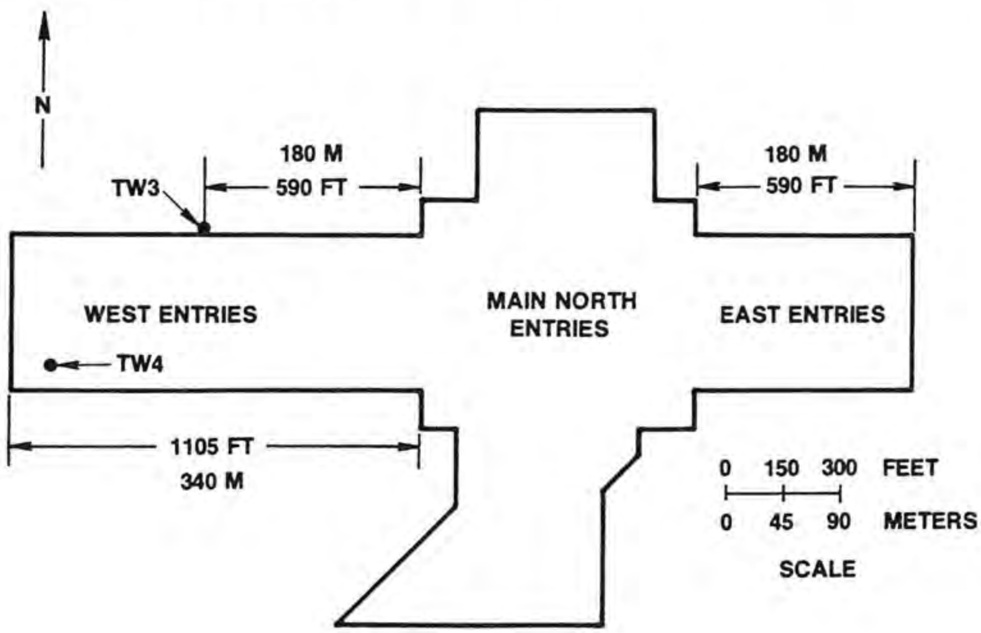


Figure 7. View of Mine Showing Test Well Locations and Entries Studied for Gas Emissions

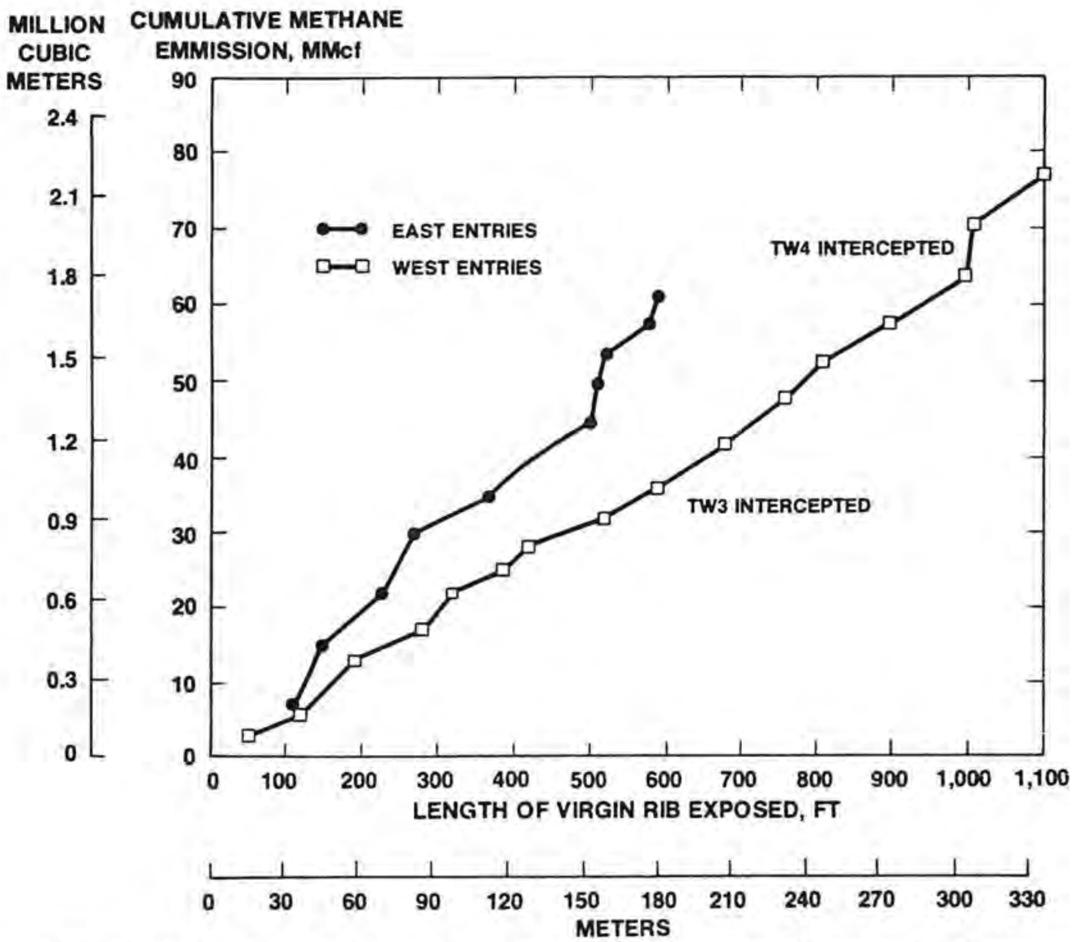


Figure 8. Graph of Cumulative Methane Emissions Versus Length of Virgin Rib Exposed

## EVALUATION OF EXPERIMENTAL WORK

This report has described several phases of TW3 and TW4 development, from well completion specifications through the underground examination of the results. In this section, a large portion of this experimental work is evaluated on the basis of original method intent or design, versus the actual results.

### Drilling and Completion

The method used to set casing in the test wells employed a cement packer shoe. Such a device allows drilling of the borehole to total depth using a minimum of rig time. This also affords the opportunity to log the entire borehole rock sequence, including the target coal zone—a slight deviation of standard methods used in the past (4). The use of a packer to seal off lower exposed zones, however, is by no means a guarantee to the operator that these zones will be protected. Packer failures (the inability to seal off the coal zones) occurred at both test wells. At TW4 this failure was observed directly at the underground test site. A similar failure is indicated to have occurred at TW3 because casing cement was found in the coal 80 feet (24.4 meters) from the borehole location.

### Stimulation

Total extension of traceable partings induced during foam stimulation were 200 feet (61 meters) to over 300 feet (91 meters) from TW4 and TW3, respectively. Actual total distances could not be determined since most of the proppant was contained in strata above the lower coal bench. Nitrogen gas communication to TW3 when TW4 was stimulated indicates that the induced fracture distances are probably much greater than those measured underground (see Table 1). Also, only a small fraction of the 175 ft$^3$ (50 meter$^3$) of prop sand could be accounted for in the traceable partings observed. The major portion of the sand-filled parting must exist in higher rock strata, and could extend several hundred feet laterally beyond the points to which the induced partings were observed directly.

As was concluded from earlier studies of TW1 and TW2 (10), a strong and direct relationship exists between the hydraulically induced parting directions and the natural fracture trends within the coalbed and overlying roof rock. Results of fracture surveys in the mine near TW3 and TW4 show that the stimulated partings were propagated within 8 degrees of the combined average cleat and roof joint directions.

Contrary to earlier studies (5, 10, 6), partings extended into coalbeds by well stimulation are not necessarily confined to the coalbed exposed in the borehole. Underground examination in the vicinity of both TW3 and TW4 shows that stimulated vertical partings extended upwards into overlying roof rock. There is evidence from the underground survey indicating why the stimulation treatment did not remain in the coalbed:

1. The fine-mesh sand used as a fluid-loss agent was the only sand found to be contained in the coal.

This sand is thought to have caused the propagating fracture to clog or "screen out" in the coal early in the treatment. With continued pumping, it is possible that the fracturing fluids diverted upward into a pre-existing plane of weakness in the shale roof rock. It is unlikely, however, this this very hard roof rock was actually "broken" by the 1 400 psig pressure used during stimulation.

2. Cement used to set casing in TW3 and TW4 was found in the roof, and up to 80 feet (24.4 meters) away from the wellbores. This indicates that the roof strata was already fractured some time before casing was cemented in the test wells, probably just after the holes were drilled.

Production

In several respects, the production histories of TW3 and TW4 are not similar to those presently being recorded at wells located far from mining. Periods of blow-back after foam stimulation (considered in this paper as being the earliest phase of well production), water production rates, and length of time required to produce gas at TW3 and TW4 contrast with measurements at the wells far from mining.

"Blow-back" from foam-treated wells at great distances from the mine last about 1 day, during which time formation water fills the borehole to a level where gasflow stops. In contrast, TW3 and TW4 each blew back gas more than 7 days after stimulation. The prolonged blowback periods recorded at TW3 and TW4 become even more significant considering foam treatment size. Treatment volumes used were less than half the volume at wells far from the mine.

Water production was comparatively low at test wells near mining. To demonstrate this, water flow rates were measured before stimulation of TW3 and several other wells completed far from active mining. Flows from TW3 were less than 1 bpd (0.2 meter$^3$/day) while flows from the other wells were more than 6 bpd (1.0 meter$^3$/day). Water flow rates were again compared over a 2-month period after stimulation at these same wells. This time, rates from TW3 averaged 15 bpd (2.4 meter$^3$/day), while rates measured from the wells far from mining averaged nearly 100 bpd (15.9 meter$^3$/day).

Wells completed near the mine (TW1 - TW4) produced gas much sooner, after water pumping began, than wells placed very far from the mine. Three of the four test wells, completed less than 1 000 feet (305 meters) from active mining, made gas within 12 hours after the water pumps were first turned on. The remaining well (TM4) produced gas with no pumping time required at all. On the other hand, several weeks and sometimes months of continuous water pumping is normally required before gas begins to flow from the wells located miles away from the mine.

Comparatively low water production, prolonged blowoff periods, and the well's ability to produce gas very soon after water pumping began, or without pumping at all, indicate that the coalbed in the vicinity of TW3 and TW4 had been partially drained of water and gas <u>before</u> the completion of each of the wells. Such drainage established comparatively low pressure and water saturation levels in the coalbed, allowing more gas to desorb while enhancing the ability for gas to flow (9, 12). These conditions are much more suitable for high initial gas production rates than are virgin coalbed reservoir conditions far from the mine.

Effects on Mining

The removal of coalbed fluids ahead of mining cause two important changes to occur in the coalbed. These are: (1) a general decrease in pressure and (2) a lowering of water saturation. Increasingly larger amounts of gas are desorbed from the coal as pressure is reduced (12). This gas then travels to the borehole via the natural and/or induced fracture systems. Because wells also remove water from these same fracture systems, the ability for gas to flow through the coalbed is enhanced (9, 7). In summary, producing wells create favorable conditions for gas release and migration within the area of the coalbed affected by drainage.

If mining intersects an area of the coalbed which is being depressurized and desaturated by a drainage well, the conditions become extraordinarily favorable for methane to flow into active mine workings. This potential problem was avoided during this test well program because the coalbed around each test well was <u>resaturated with water</u> before interception. Very large volumes of water were pumped into TW3 near the end of the productive life of the well. TW4 was not equipped to remove water from the coalbed and thus the coalbed near the well became resaturated when TW3 was taken off production. This is indicated on Figure 3 by the sharp decrease in gasflow rate which occurred after TW3 was abandoned.

Fortunately, the same coalbed conditions which enhance gas release and migration are ideal for water resaturation or infusion. In reality, a combination of techniques, <u>degasification</u> and <u>water infusion</u> (1) were employed to achieve the comparatively low mine gas emission rates indicated earlier in this paper.

The effects stimulated drainage boreholes have on mine roof is a primary concern to both government and industry research. To date, government and industry have cooperated in the stimulation of six vertical boreholes which have been intercepted by mining. The first two tests were in the Pittsburgh and the Illinois No. 6 coalbeds. These test results were reported by Elder in 1977 (6). Elder found "that the resulting fractures were limited to, and contained within, the coalbed" and that "there was no adverse effect on the stability of the overlying rock strata, or on mining operations". The remaining four well tests have all been conducted in the Mary Lee coalbed and have yielded somewhat different results which show that stimulated fractures are not always limited to the coalbed.

Mine management assessed the effects of TW3 and TW4 stimulation on the mine roof; their evaluation is as follows:

> "Because the roof of the mine in the general vicinity of TW4 was of a quality which required installation of more roof support than used in many other portions of the mine, it was difficult to assess the effect of the fracture on the mine roof at this location. However, no further increment of supplemental roof support was required at the base of the borehole or along the fracture wings.
>
> The roof in the general area of TW3 was of a quality typical of most of the mine developed to date however, in the immediate area of the bottom of TW3, in which both the upper and lower coal seams had been fractured, it was necessary to install supplementary roof support. This supplemental roof support was required when mine management observed roof movement along the west rib of

the entry drive due north of the bottom of the borehole, additional draw rock separation, roof becoming excessively drummy, and water seeping out of the cracks in the roof. The supplemental roof support consisted of boxing the intersection immediately to the south of the borehole with 6-inch (0.2-meter) H-beams, installing 4-inch (0.1-meter) H-beams supported by timbers for distances of 70 feet (21.3 meters) to the east and 40 feet (12.2 meters) to the north of the borehole, and installing 10-foot (3.1-meter) long expansion-shell anchored roof bolts between the standard 4-foot (1.2-meter) long resin roof bolts to ensure that the bolts anchored in the solid rock above the upper coal seam.

Installation of the supplementary supports required additional time as well as close inspection by mine management to ensure its adequacy; however, it was possible to mine through this area without experiencing any roof fall during mining operations."

Previous geologic inspection of the mine near TW4 showed the well to be nearly surrounded by minor deformation and dislocations in the coal associated with lenticular shale ridges projecting from the roof. Areas of the mine where these features, called "rolls", were observed are shown on Figure 6. Because inherent rock weaknesses develop near such features, these areas generally require some degree of additional roof support. The necessity for more roof support near TW4 than in many other portions of the mine, as reported by mine management, may be attributed to this geologic phenomenon rather than stimulation of the test well. The fact that additional roof support was not required at the base of TW4 nor was it required along the fracture wings suggests borehole stimulation was not the cause for providing additional roof support.

The entry nearest TW3 is also shown on Figure 6 to be a location of natural roof disturbances. Geologists also noted the presence of many wet roof joints in this area. Except for the single sand-filled crack leading from TW3 (Figure 6), no evidence could be found to indicate that these wet roof joints had been created by stimulation. Unusually large amounts of seepage from roof openings near TW3 could, however, be due to the borehole's presence, since it is an accumulation point for water within a coal unit only 7 feet (2.1 meters) above the open entry.

The full extent and resulting effects of roof strata deterioration attributable to TW3 and TW4 stimulation cannot be evaluated at this time. Since such deterioration could result from relatively slow chemical processes, many months or years may be required to measure stimulation's complete effects on the mine.

## CONCLUSIONS

1. Favorable results obtained from wells stimulated using nitrogen-charged foam far exceed those obtained from previous near-mine stimulation designs using gelled fluid. The most notable of these results are much higher drainage rates, reduced onsite logistical requirements, and considerably less treatment fluid clean-up time.

2. Properly completed foam stimulated wells which are allowed to remove gas, even for a relatively short period of time, can have a significant positive impact on mine ventilation requirements for mines working in the Mary Lee coalbed.

3. Near-mine well production is influenced positively by the presence of the mine in that a degree of "pre-drainage" accurs. The radius of this influence from the mine has not been defined, although it is suspected to be on the order of 1 000 feet (305 meters) or greater. Somewhere within this pre-drained coalbed area, it is even possible to produce wells without a dewatering pump.

4. Fractures induced during stimulation tend to propagate parallel to existing coal face cleat and natural rock joint directions. It is indeed possible to predict induced fracture orientation prior to stimulation in this area.

5. It is possible to extend fractures outside the coalbed using injection pressures below those necessary to "break" the surrounding rock material. The existence of incipient rock fractures is considered to be the ultimate reason why induced fractures sometimes propagate into roof rock.

6. The geologic history of the coalbed and associated rock strata does not allow meaningful prediction of the effects of stimulation on roof stability. However, since these effects appear to be minimal and the potential gas problem severe, the decision to employ stimulation is considered truly justifiable at this time.

## REFERENCES

1. Cervik, J., A. Sainato, and M. Deul, "Water Infusion of Coalbeds for Methane and Dust Control," BuMines RI 8241, 1977, 27 pp.

2. Culbertson, W. C., "Geology and Coal Resources of the Coal-Bearing Rocks of Alabama," Geol. Survey of Ala., Bull. 1182-B, 1964, 79 pp.

3. Diamond, W. P., G. W. Murrie, and C. M. McCulloch, "Methane Gas Content of the Mary Lee Group," BuMines RI 8117, 1976.

4. Elder, C. H., and M. Deul, "Degasification of the Mary Lee Coalbed Near Oak Grove, Ala., by Vertical Borehole in Advance of Mining," BuMines RI 7968, 1974, 21 pp.

5. Elder, C. H., and M. Deul, "Hydraulic Stimulation Increases Degasification Rate of Coalbeds," BuMines RI 8047, 1975, 17 pp.

6. Elder, C. H., "Effects of Hydraulic Stimulation on Coalbeds and Associated Strata," BuMines RI 8260, 1977.

7. Fulton, P. F., and A. A. Reznik, "The Measurement of the Flow Properties and Capillary Pressure Relationships of Certain Coals Pertaining to Underground Coal Gasification," Quarterly Rept. for the Period Dec. - Feb. 1976-77, Univ. of Pgh. Chem. and Petrol. Engr. Dept. under ERDA Contract No. E(11-1)-4129, March 1977.

8. Kissell, F. H. and J. C. Edwards, "Two-Phase Flow in Coalbeds," BuMines RI 8066, 1975.

9. Lambert, S. W. and M. A. Trevits, "Methane Drainage Experience with Hydraulic Stimulation Through Slotted Casing," BuMines RI 8295, 1978.

10. Lambert, S. W., and M. A. Trevits, "Improved Methods for Monitoring Production from Vertical Degasification Wells," BuMines RI 8309, 1978.

11. Lambert, S. W., and M. A. Trevits, "Effective Placement of Coalbed Gas Drainage Boreholes," Dept. of Energy RI PMOC-2(78) UC-88, 1978.

12. Murrie, G. W., W. P. Diamond, and S. W. Lambert, "Geology of the Mary Lee Group of Coalbeds, Black Warrior Coal Basin, Alabama," BuMines RI 8189, 1976, 49 pp.

13. Natural Academy of Sciences, Board of Mineral Resources, Commission on Natural Resources, Natural Gas from Unconventional Geologic Sources, 1976, 245 pp.

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