RI 9282

REPORT OF INVESTIGATIONS/1989

Pressure Monitoring and Observed Effects of Mining at the Oak Grove, AL, Coalbed Degasification Pattern

By David C. Oyler

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR

Mission: As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally-owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

Report of Investigations 9282

Pressure Monitoring and Observed Effects of Mining at the Oak Grove, AL, Coalbed Degasification Pattern

By David C. Oyler

UNITED STATES DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary

BUREAU OF MINES
T S Ary, Director

Library of Congress Cataloging in Publication Data:

Oyler, David C.
Pressure monitoring and observed effects of mining at the Oak Grove, AL, coalbed degasification pattern / by David C. Oyler.

(Report of investigations; 9282)

Includes bibliographical references.

Supt. of Docs. no.: I 28.23:9282.

1. Coalbed methane drainage-Alabama-Oak Grove Region-Evaluation. 2. Coalbed methane-Alabama-Oak Grove Region-Measurement. I. Title. II. Series: Report of investigations (United States. Bureau of Mines); 9282.

TN23.U43 [TN844.6] 622 s-dc20 [622'.82] 89-600248

CONTENTS

ILLUSTRATIONS

TABLES

UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

Btu/lb	British thermal unit per pound (mass)
cm^3	cubic centimeter
cm^3/g	cubic centimeter per gram
ft	foot
ft/d	foot per day
ft^2	square foot
ft^3	cubic foot
ft^3/st	cubic foot per short ton
g	gram
gal/d	gallon per day
in	inch
lb/ft^3	pound per cubic foot
lbf/in^2	pound (force) per square inch
$lbf/in^2(ga)$	pound (force) per square inch, gauge
lbf/in^2d	pound (force) per square inch per day
$Mstdft^3/d$	thousand standard cubic feet per day
$MMstdft^3$	million standard cubic feet
pct	percent
st	short ton
wt pct	weight percent

PRESSURE MONITORING AND OBSERVED EFFECTS OF MINING AT THE OAK GROVE, AL, COALBED DEGASIFICATION PATTERN

By David C. Oyler[1]

ABSTRACT

The U.S. Bureau of Mines and the United States Steel Corporation evaluated the progress of methane drainage at the Oak Grove, AL, degasification pattern. Coalbed pressures were monitored between December 1981 and November 1985. Formation pressures, in the lower bench of the Mary Lee Coalbed, were reduced from 400 lbf/in^2(ga) in 1977 to 50 lbf/in^2(ga) in November 1985. Gas contents of coal cores obtained from monitor wells were compared with coalbed gas contents measured in 1976. Data indicated a 48- to 56-pct reduction within the pattern and a 29-pct reduction at a point 500 ft outside the pattern.

The effect of the advance of a section of the Oak Grove Mine on changes in gas and water production rates in the pattern was evaluated. Gas production increases were noted in 12 wells; water production decreases were noted in 6. The times of initial influence indicate the presence of a zone of high permeability within the pattern. This zone correlates well in orientation and location with a fracture zone mined through at the mine. The existence of such fracture zones could have a significant effect on productivity of individual coalbed methane wells.

[1]Mechanical engineer, Pittsburgh Research Center, U.S. Bureau of Mines, Pittsburgh, PA.

INTRODUCTION

In late 1981, the Bureau and the U.S. Steel Corp. began a cost-sharing project to determine the effects of gas production on the lower bench of the Mary Lee Coalbed (commonly called the Blue Creek Coalbed within the mining district) from the 23-well Oak Grove Coalbed gas production pattern (*1-2*)[2] in Jefferson County, AL (fig. 1), and also to monitor coalbed pressure changes on a long-term basis. Three monitor wells were drilled in the fall of 1981 and pressure monitoring began in December 1981. Coal cores obtained for desorption testing when the monitor wells were drilled indicated that the coalbed gas content within the pattern had been reduced. The reductions were based on comparisons made with gas content data obtained in 1976 when the original production wells were drilled and cored.

Pressure monitoring continued until the scheduled termination of the project in late 1985. A previous Bureau report (*3*) detailed the drilling and completion of the monitor wells, presented data on the effects of gas production on coalbed gas content, developed a gas content versus formation pressure relationship for the pattern area and presented, in graphical form, the pressure data through June 30, 1984. The purpose of this report is to update the project through its completion at the end of 1985, tabulate all the pressure data obtained during the project, present previously unpublished coal analysis data from monitor well M2, and to describe some observations made on the effect of nearby mining on gas and water production from the pattern wells.

[2]Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

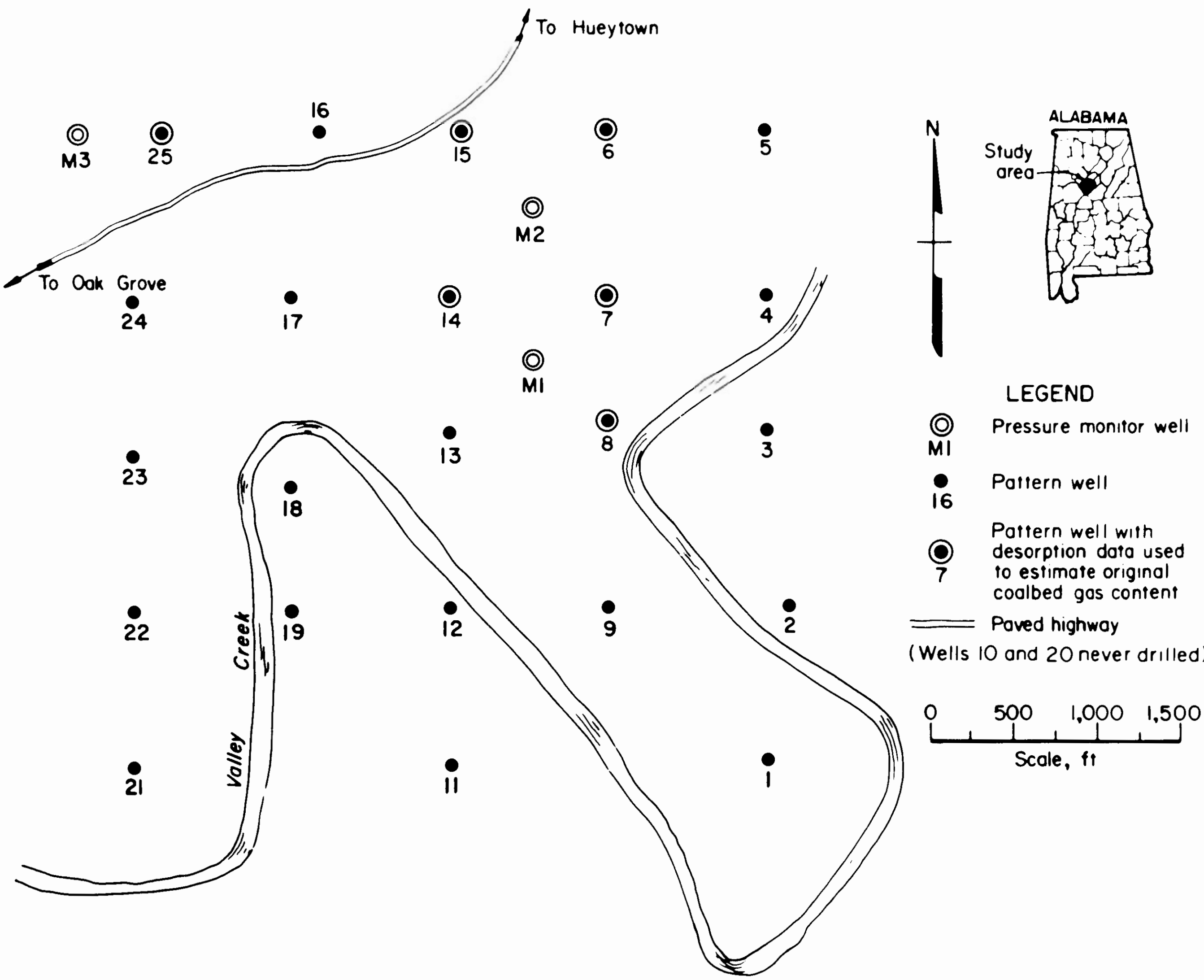

Figure 1.–Map of monitor and pattern well locations.

MEASUREMENT OF GAS CONTENT AND GAS CONTENT REDUCTION

Gas content data for the pattern area were obtained from coal cores from the original pattern wells in 1976 and from the monitor wells drilled in 1981. Both sets of gas content data were obtained using the Bureau direct method (*4*). No pressure or temperature corrections were made to the gas volumes measured from either set of samples, or to any of the values computed in this report using direct method data. A recent study (*4*) based upon direct method samples from the Oak Grove Mine area (*5*) suggests that uncorrected direct method values average about 5 pct higher than measurements corrected to standard temperature and pressure. Table B-1 details the computation of gas content for the cores obtained from the monitor wells. Four coal samples, together representing the entire lower bench of the Mary Lee Coalbed, were obtained from each monitor well. A separate gas content determination was made for each sample, and then the total gas volumes and coal weights for the four samples from each well were summed to obtain an average gas content for the coalbed at each monitor well location. Because only part of the coal from each sample was available for residual gas determination, it was not possible to directly add the residual gas volume to the lost and desorbed volumes, but instead the total gas content was determined by adding the residual gas on a per unit weight of coal basis.

The 1976 (original) and the 1981 gas content values (table 1) were compared to obtain an estimate of the reduction in gas content caused by gas production from November 1977 through October 1981. An estimate of the original gas content at a particular monitor well location was made by averaging the gas content values for those of the six production wells closest to that monitor well. Comparison of the 1976 and 1981 gas content values indicated that the gas content within the pattern had been reduced between 48 and 56 pct, while at M3, 500 ft outside the pattern, the gas content had been reduced by 29 pct (*3*).

Table 1.-Measured gas contents and formation pressures at Oak Grove degasification pattern

Sample location	Gas content,[1] ft^3/st	Formation pressure,[2] lbf/in^2(ga)
Monitor wells:[3]		
M1	244	122
M2	211	112
M3	350	247
Pattern wells:[4]		
Well 6	490	417
Well 7	439	423
Well 8	490	429
Well 14	465	422
Well 15	509	414
Well 25	490	410

[1]Not corrected to standard temperature and pressure.
[2]At time of coring.
[3]Cored in October or November 1981.
[4]Cored in 1976 before gas production initiated.

ESTIMATED PATTERN DRAINAGE AREA

The gas content reductions were used to obtain some idea of the area affected by the pattern. This was actually done by assuming a drainage area, computing the gas volume removed from that area, and comparing the computed volume to the known gas volume produced from the pattern through October 1981. A simple model was chosen assuming two areas of drainage, a central area outlined by the pattern perimeter wells, and an area outside the pattern perimeter (shaded in figure 2) to 500 ft outside of the central area.

In the central area the gas content of the lower bench of the Mary Lee in October 1981 was assumed to be 227 ft^3/st, based upon an average of the gas content values from M1 and M2. The gas content of the outer area was assumed to be 352 ft^3/st, based upon the gas content at M3.

Table 2 shows the computations made of the estimated volumes and weights of coal within these areas and the estimated original in-place gas volume. The original gas content of the lower bench of the Mary Lee Coalbed was assumed to be 480 ft^3/st for both areas. The coal thicknesses are based upon data from production wells in the pattern. The coal density is based upon data from density logs run in the monitor wells. The reduction of in-place gas volume is computed in table 3. In both tables two estimates are given, the first assuming gas production from only the lower bench of the Mary Lee Coalbed and the second assuming a contribution from the upper bench in addition to that from the lower bench.

The original estimate given by Oyler (*3*) assumed that the gas produced came only from the lower bench of the Mary Lee Coalbed. However, separation of the two benches averages about 6 ft and it is likely that the many naturally occurring vertical fractures that have been found in the rock between the two benches allow gas production from the upper bench by way of well completions in the lower bench. Where production from the upper bench has been assumed, the assumption has also been made that the upper bench had the same original gas content as the lower bench and that degasification proceeded at the same rate in both benches. The original four measurements made in 1976 for the upper bench gave an average gas content of 449 ft^3/st with a standard deviation of 93 ft^3/st.

Table 2.-Original Oak Grove pattern in-place gas volume

	Lower bench only	Upper and lower bench[1]
Area,[2] ft^2:		
Central	[3]15,016,000	15,016,000
Shaded	8,750,000	8,750,000
Total	23,766,000	23,766,000
Coal thickness .... in ..	66	86
Gas content[4] ...... ft^3/st ..	480	480
Coal density .... lb/ft^3 ..	82.4	82.4
Coal volume, ft^3:		
Central	82,588,000	107,615,000
Shaded	48,125,000	62,708,000
Total	130,713,000	170,323,000
Coal weight, st:		
Central	3,403,000	4,434,000
Shaded	1,983,000	2,584,000
Total	5,386,000	7,018,000
In-place gas volume, MMstdft^3:		
Central	1,633	2,128
Shaded	952	1,240
Total	2,585	3,368

[1]Includes estimated 60-in lower bench, 26-in upper bench. Lower bench thickness averaged from 22 production wells. Upper bench thickness averaged from 15 production wells, with an average of 6 in of rock and bone subtracted.
[2]See figure 2.
[3]Rounded.
[4]Not corrected to standard temperature and pressure.

Table 3.-Estimated reduction in in-place gas volume caused by production through October 1981

	Lower bench only	Upper and lower bench[1]
Original gas content[2] ....ft^3/st ..	480	480
1981 gas content, ft^3/st:		
Central area	227	227
Shaded area	352	352
Reduction per short ton, ft^3:		
Central area	253	253
Shaded area	128	128
Coal weight, st:		
Central area	3,403,000	4,434,000
Shaded area	1,983,000	2,584,000
Total area	5,386,000	7,018,000
Reduction in in-place gas volume, MMstdft^3:		
Central area	861	1,122
Shaded area	254	331
Total area	1,115	1,453

[1]Includes estimated 60-in lower bench, 26-in upper bench. Lower bench thickness averaged from 22 production wells. Upper bench thickness averaged from 15 production wells, with an average of 6 in of rock and bone subtracted.
[2]Not corrected to standard temperature and pressure.

NOTE.-The actual gas volume produced through October 1981 was 1,110 MMstdft^3.

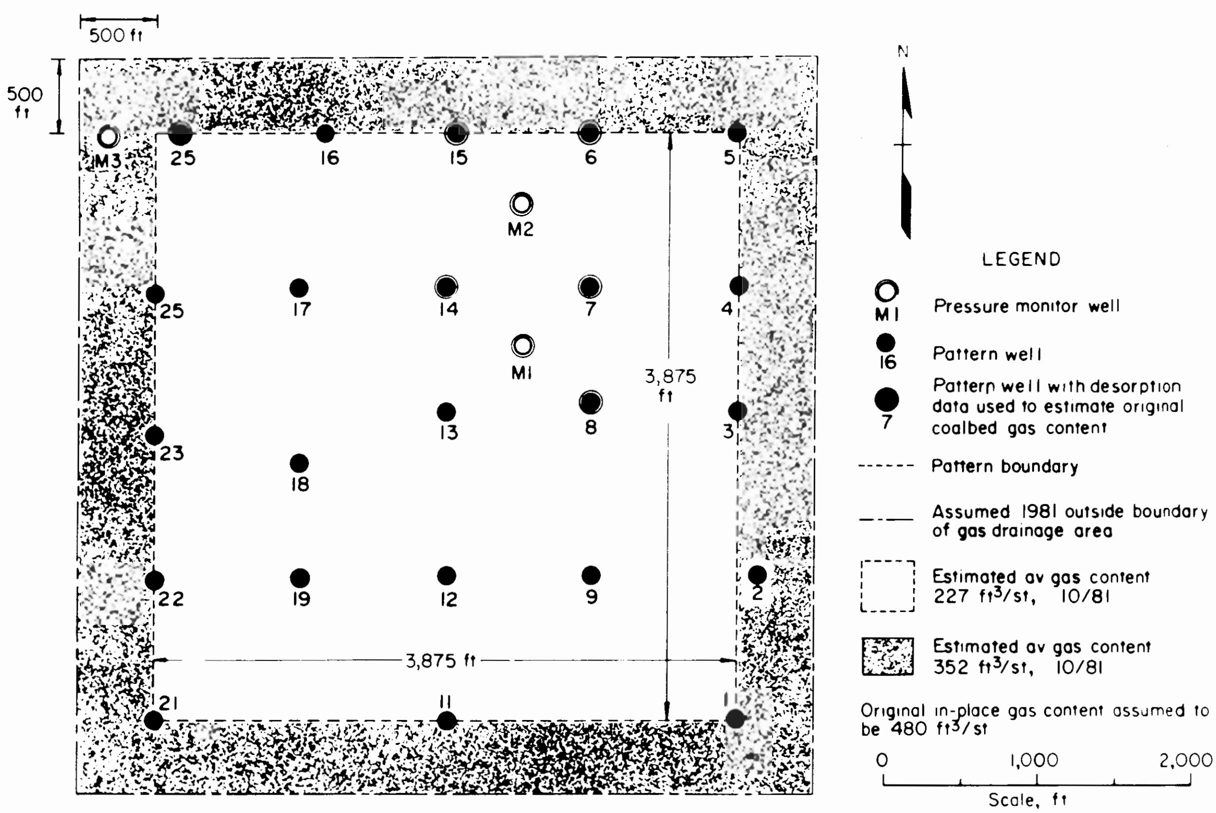

Figure 2.-Pattern area and estimated area of gas drainage.

The two estimates of the reduction in in-place gas volume are 1,115 MMstdft^3, from the lower bench only, and 1,453 MMstdft^3, from both benches. These compare favorably with the actual gas production of 1,110 MMstdft^3. Because of the uncertainty in the assumptions made in deriving these values it has not been felt worthwhile to further refine the estimates. The computations suggest that through 1981 the drainage was primarily from the lower bench. However, one factor not considered in the estimates is that the gas content from M3 may not be representative of the coalbed outside of the pattern area. Data from a recent publication by Briscoe (*6*), and production data to be discussed later in this report, suggest that M3 lies within the area of influence of a high-permeability joint or fracture zone.

If high-pressure gradients are assumed for the immediate vicinity of this zone, then it is possible that it could have caused an anomalously low pressure at M3 and therefore a low gas content. A lower than average gas content at M3 would incorrectly suggest a greater degree of drainage from the coalbed, and that the area required to account for the pattern gas production was smaller than the actual drainage area. It also suggests that a contribution from the upper bench was unnecessary to account for the produced gas. However, the information available from the three monitor wells cannot be used to determine if drainage took place from the upper bench, although it appears likely.

ISOTHERM CURVE

The available gas content data were used to develop an isotherm curve (fig. 3) for the entire pattern based upon field data. Pressure data were available from the monitor wells beginning in December 1981 and water levels had been measured in a number of production wells in 1977, prior to their stimulation and initial gas production. The curve developed from the pressure and gas content data allows pressure data from the monitor wells to be used to obtain estimates of current gas content and in-place gas volumes, and to estimate the current rates of desorption.

In October 1985 the average formation pressure at the Oak Grove pattern had been reduced to about 55 lbf/in^2(ga), from an original high value of about 420 lbf/in^2(ga). Based upon the isotherm curve, this suggests that the gas content within the pattern area was about 140 ft^3/st by the end of 1985. This is about 30 pct of the gas content (480 ft^3/st) measured in 1976 when the pattern wells were being drilled.

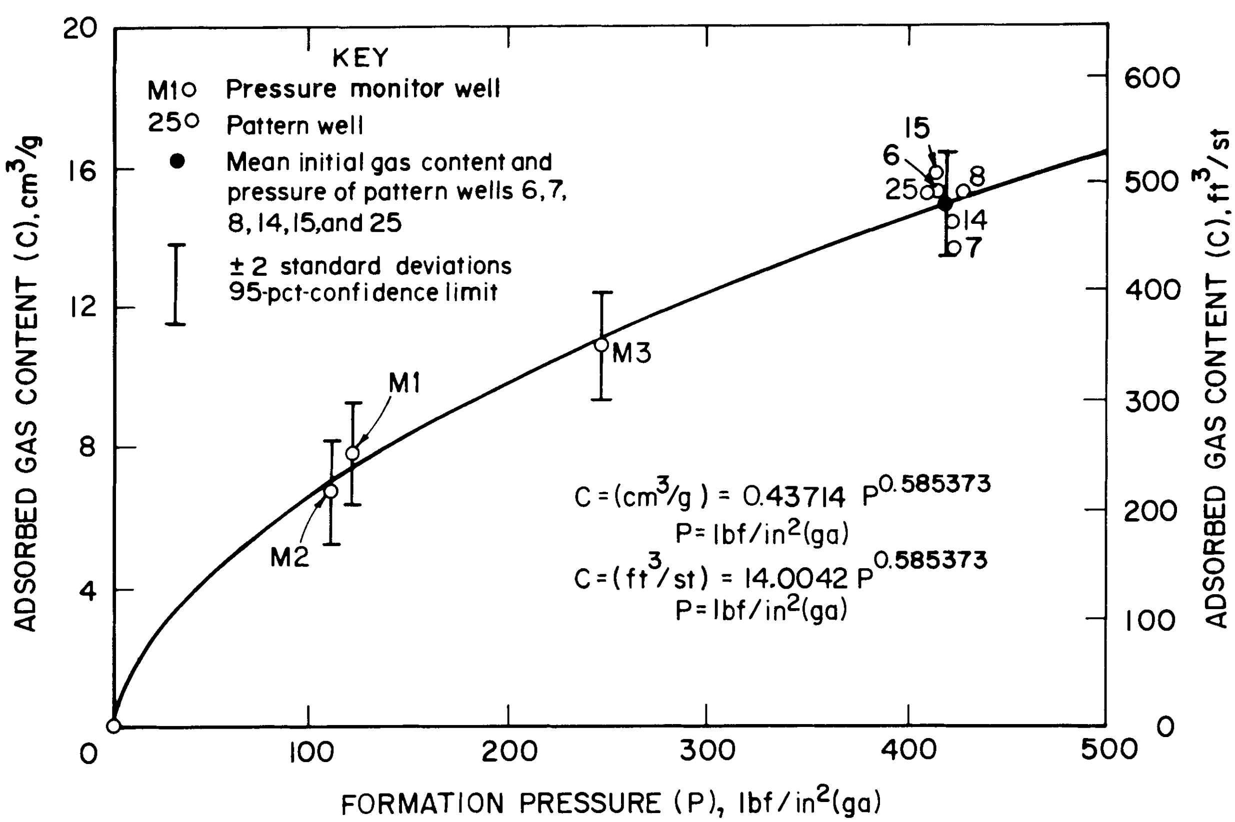

Figure 3.–Isotherm curve derived from Oak Grove gas content and pressure data.

PRESSURE DATA

Figure 4 shows in graphical form the pressure data from the monitor wells. The data are also tabulated in appendix A. Dates not shown are days upon which no measurements were obtained. Pressure monitoring began in December 1981 and continued, with some loss of data caused by surface cable breaks and instrument failures, until October 31, 1985, the end of the contract period. Surface electrical problems prevented obtaining data from M2 beginning at the end of June 1985 and from M1 at the beginning of October 1985. A final pressure reading was obtained manually from M3 on August 14, 1986, long after regular pressure monitoring had been discontinued.

The sensor used to measure pressure was the Lynes Sentry[3] tool, a device designed to measure pressure and temperature. The tool used a bourdon tube pressure sensor, connected to a digitizer, which gave the device a resolution of 1 part in 500. Because a 500-lbf/in^2 bourdon tube was used in all three instruments, each instrument could only resolve pressure changes of ± 1 lbf/in^2. During the early data reporting period, the three readings taken each day were averaged, and the pressure reported to the nearest 0.5 lbf/in^2. After April 1982 this practice was discontinued and the pressures were reported to the nearest 1.0 lbf/in^2.

Before the advance of the Oak Grove Mine began to affect them, the rates of pressure decline in all three monitor wells followed stable, linear decline curves. Table 4 shows the least squares linear equation fit to the pressure decline rates at each well. The period used in computing the equations is from November 1982 (just after adjustments made to the sensor elevations in the wellbores had caused perturbations to the pressure decline curves) until June 1984, just before the first mining effects were observed in M3. The equations all have high correlation coefficients (the R^2 value shown in the table is the square of the correlation coefficient), indicating a good fit to the data. The standard deviations of all three equations are close to 1 lbf/in^2, which is close to the instrument resolution.

[3]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

Table 4.–Pressure decline equations

(November 21, 1982, to June 30, 1984)

Well	Pressure decline equation,[1] lbf/in^2(ga)	R^2	S
M1	-0.0389T + 126.7601	0.9800	0.9470
M2	-0.0287T + 89.8334	.9816	.6551
M3	-0.0567T + 240.5442	.9825	1.3137

[1]Least squares fit to pressure data, from day 350 to 937.
R^2 Correlation coefficient, squared.
S Standard deviation.
T Time, in days from December 7, 1981.

Using the equations in table 4, the formation pressure decline at the Oak Grove pattern, due to normal gas and water production, may be estimated at between 0.03 and 0.06 lbf/in^{2}d.

The pressure decline rates may be used, along with the isotherm curve, to estimate the desorption rates at the locations of the monitor wells. When this is done the maximum desorption rates for wells M1, M2, and M3, between 1982 and 1984, are found to be 1.5, 1.3, and 1.7 ft^3/st per month, respectively.[4] If the entire pattern area shown in figure 2 is assumed to have desorbed gas at the highest rate, then the maximum rate of desorption would be about 9 MMstdft^3 per month for the lower bench only and about 12 MMstdft^3 for both benches. This is far short of the 30.3 MMstdft^3 actually produced in June 1984. These calculations suggest that from 1982 on, most of the gas produced, at least 60 to 70 pct, came from outside the immediate pattern area.

[4]Even at a constant rate of change in pressure, the desorption rate changes with the absolute pressure; increasing as the pressure decreases. The values given here are for June 1984, the lowest pressure for the period.

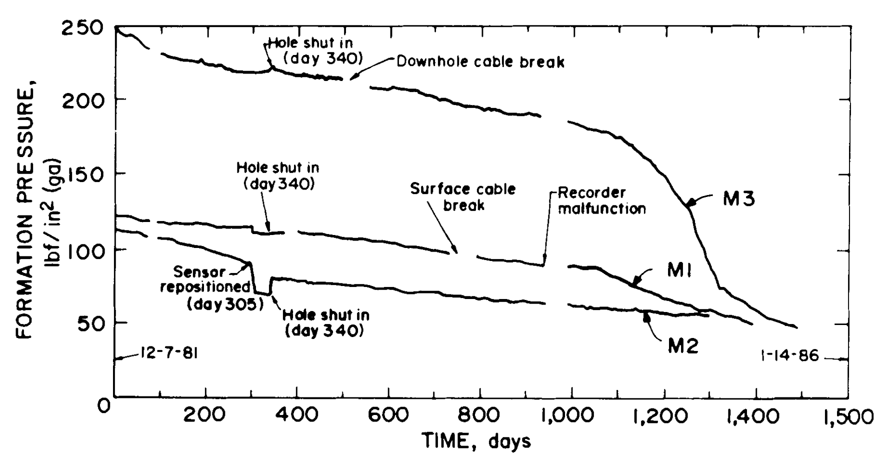

Figure 4.–Graph of pressure data for monitor wells M1, M2, and M3.

PRODUCTION DATA

Figures 5 through 12 show the daily gas and water production rates for the pattern wells. The curves actually show the production rates for every third day and have been smoothed by taking a 10-point moving average of the data (this gives a rough equivalent of a 30-day moving average on daily production data). Only every third day was plotted because the gas flow rates reported by U.S. Steel were obtained by reading totalizing meters every 2 to 4 days, with the assumption of a constant flow rate during the period. The smoothing was done in order to remove the effects of minor production changes, especially those caused by pump failures, and to allow the major trends to become more obvious. The period plotted in the figures is from November 6, 1983, to January 14, 1986. This period was chosen in order to look at the effects of mining upon gas and water production. The period before June of 1984 (day 930) was included to give a base period, free of mining influence, for comparison.

About half of the pattern wells show a roughly linear decline in gas production, while a linear decline in water production was observed in only a few wells. Most of the wells exhibiting signs of such trends in water production were at the outer edge of the pattern. Wells in the center of the pattern generally showed little overall change in water production rate during the period. The linear decline trends were interrupted when mining approached the pattern.

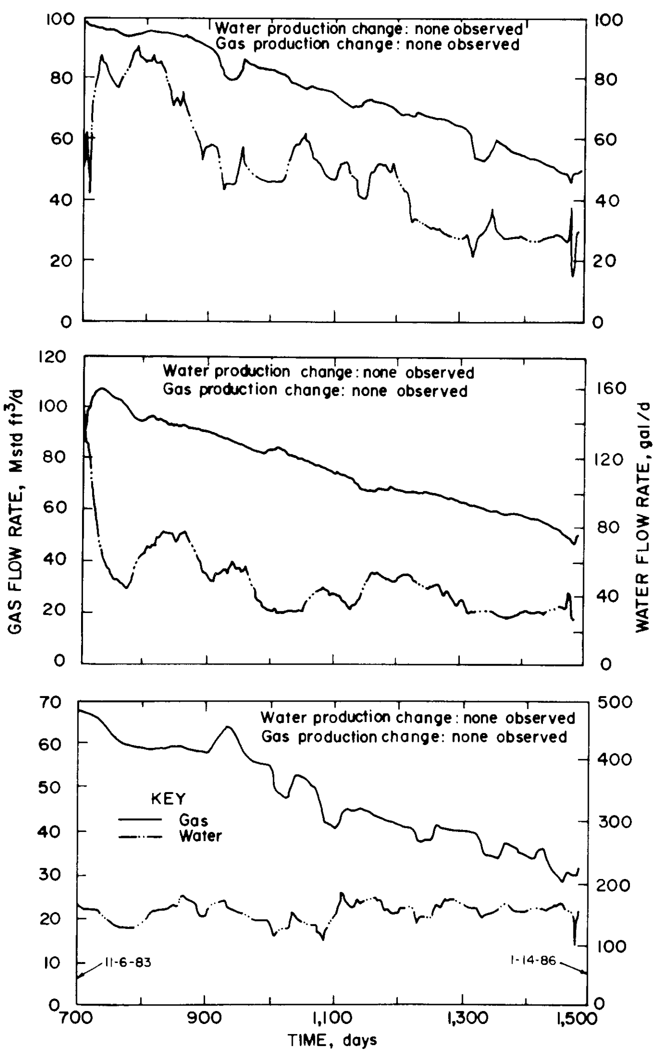

Figure 5.–Daily gas and water production rates for pattern wells 1 (top), 2 (middle), and 3 (bottom).

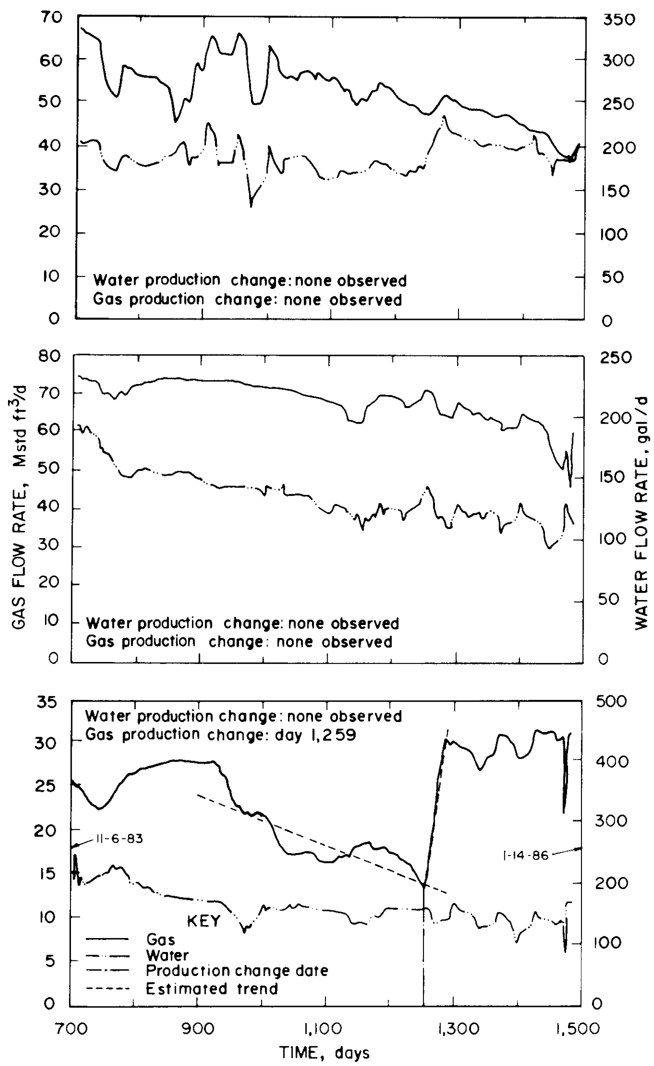

Figure 6.–Daily gas and water production rates for pattern wells 4 (top), 5 (middle), and 6 (bottom).

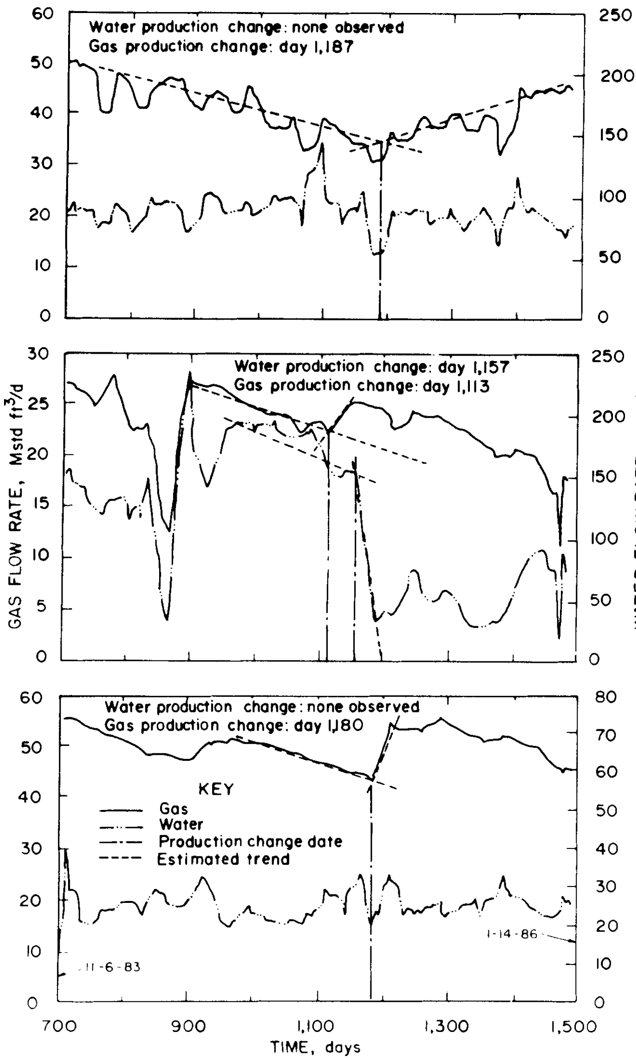

Figure 7.-Daily gas and water production rates for pattern wells 7 (top), 8 (middle), and 9 (bottom).

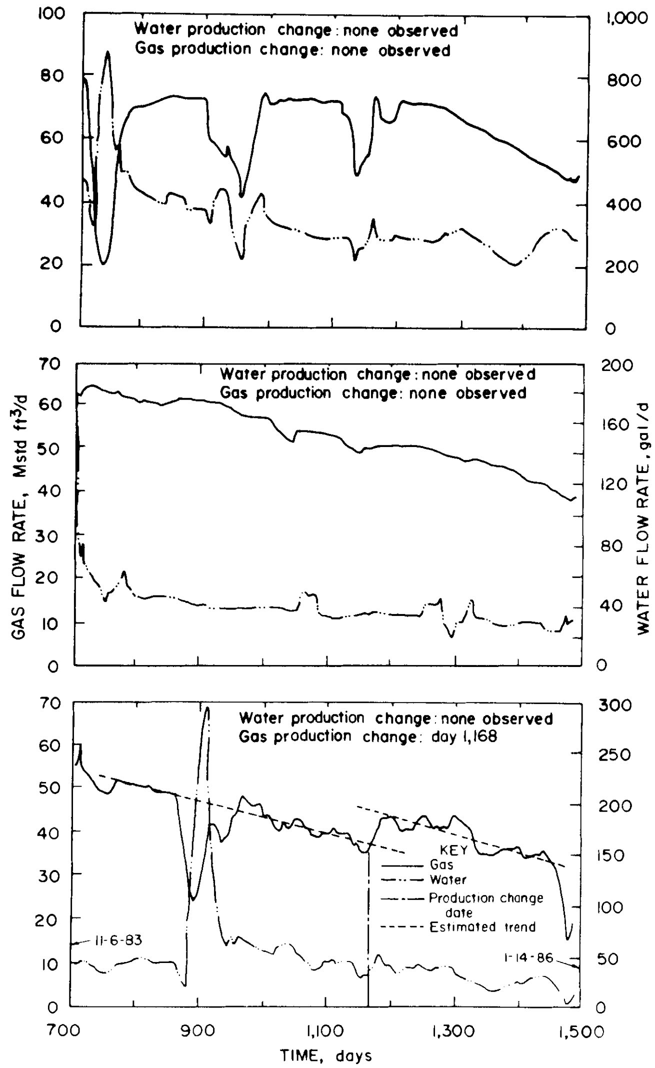

Figure 8.-Daily gas and water production rates for pattern wells 11 (top), 12 (middle), and 13 (bottom).

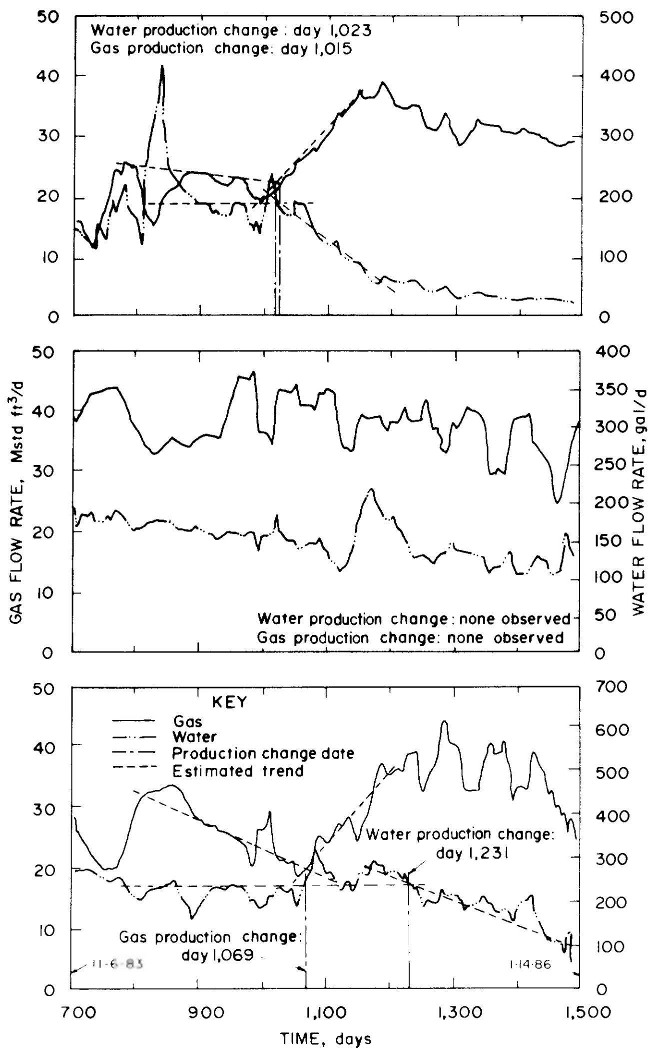

Figure 9.–Daily gas and water production rates for pattern wells 14 (top), 15 (middle), and 16 (bottom).

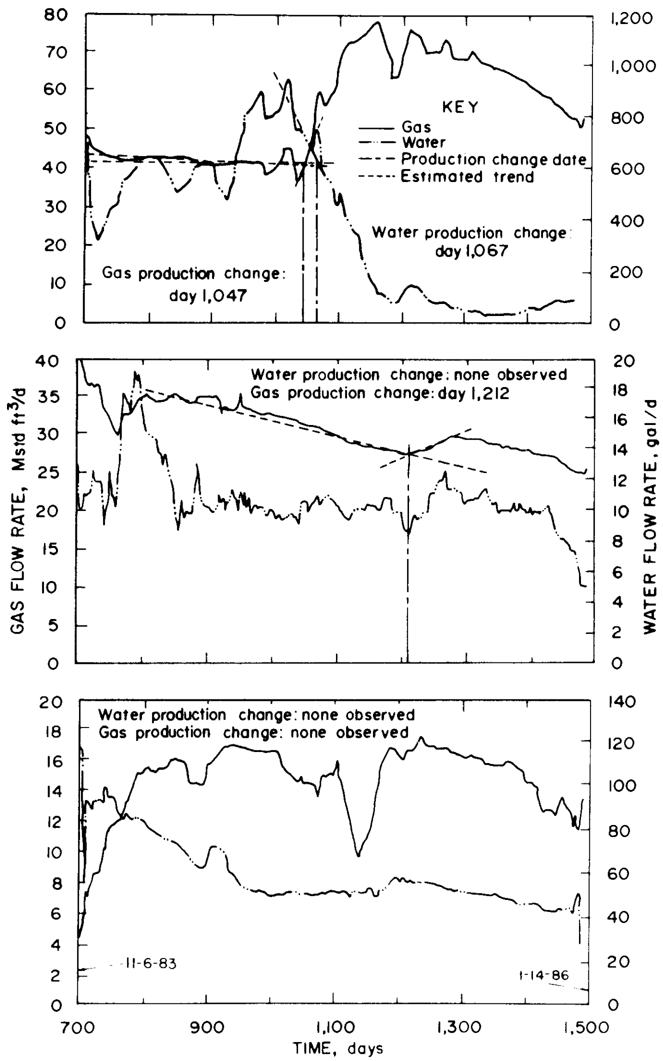

Figure 10.–Daily gas and water production rates for pattern wells 17 (top), 18 (middle), and 19 (bottom).

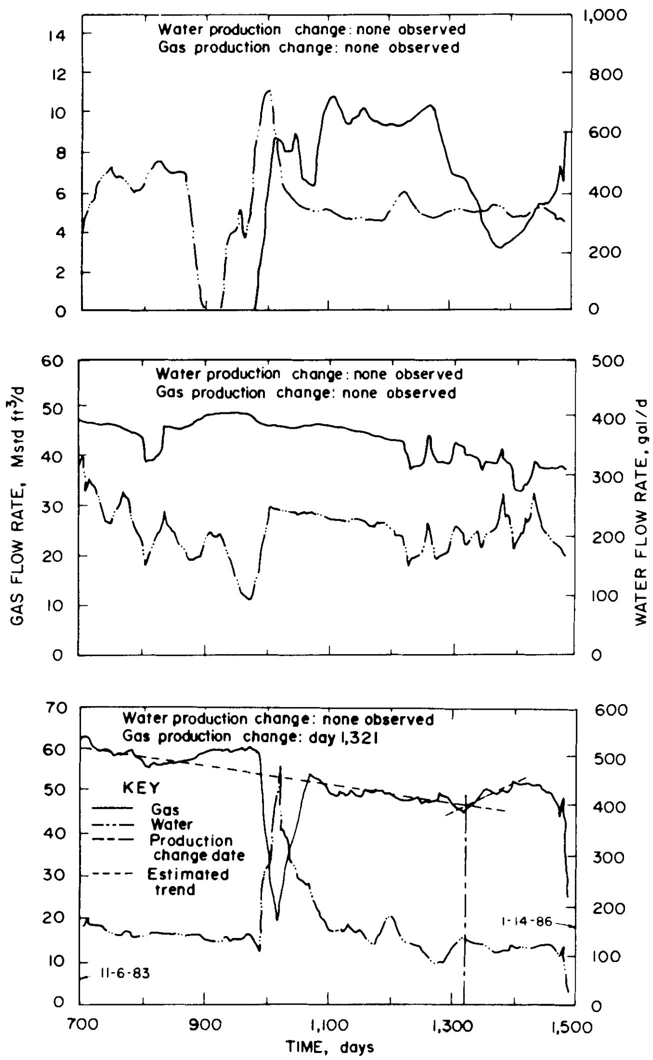

Figure 11.–Daily gas and water production rates for pattern wells 21 (top), 22 (middle), and 23 (bottom).

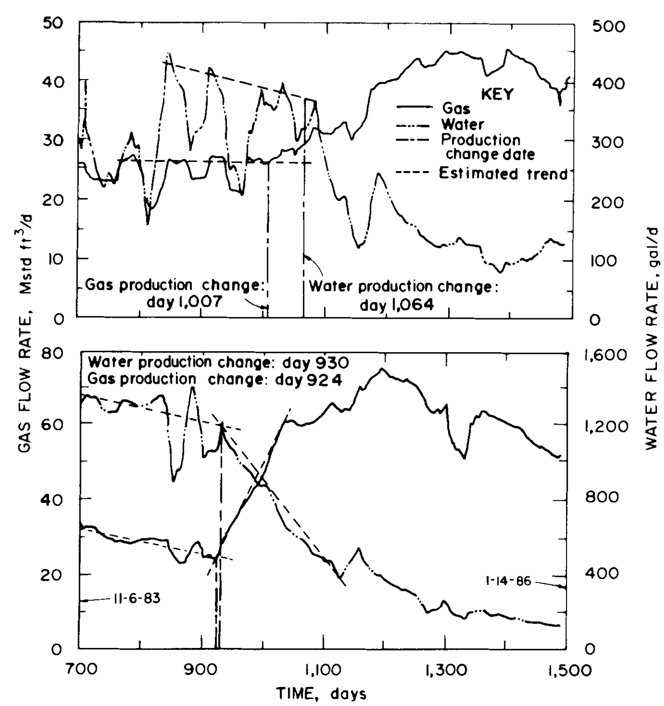

Figure 12.–Daily gas and water production rates for pattern wells 24 (top) and 25 (bottom).

EFFECTS OF MINING

In late 1983 a section of the nearby Oak Grove Mine began to approach the northwestern corner of the Oak Grove pattern (figs. 13-14) from the west. The seven-entry, 550-ft-wide section advanced due east beginning in December 1983 at 3,180 ft from monitor well M3 and 3,680 ft from production well 25. Mining continued to approach the pattern until May 1985 when the closest mine entries were 400 ft from M3. In May 1985 the mine began to drive a set of entries south, parallel to the pattern, and at a distance of approximately 1,075 ft from the western edge of the pattern. Because the contract reporting period ended in June 1985 the advance rate of this southern set of entries is not known in detail, but they eventually extended along most of the western side of the pattern.

Generally, gas production increased as mining approached the pattern and water production declined. Increases in gas production, which appeared to be attributable to the effect of mining, were observed in 12 of the 23 wells. The area of observable reduction in water production rate was generally smaller than that observed for gas production rate increases, so reductions in water production rates were observed in only six wells. The time required for a reduction in water production rate to take place was also generally longer, for any given well, than that required for a gas production change.

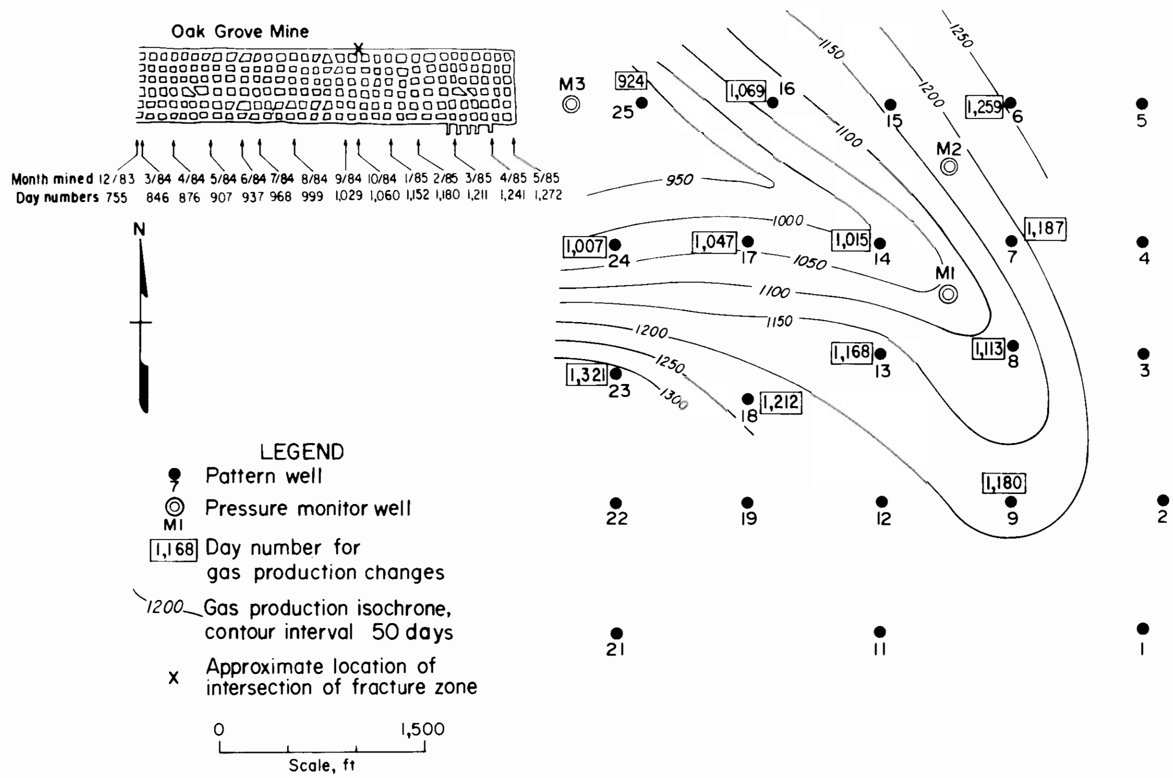

Figure 13.-Isochrone map for mining-induced gas production changes.

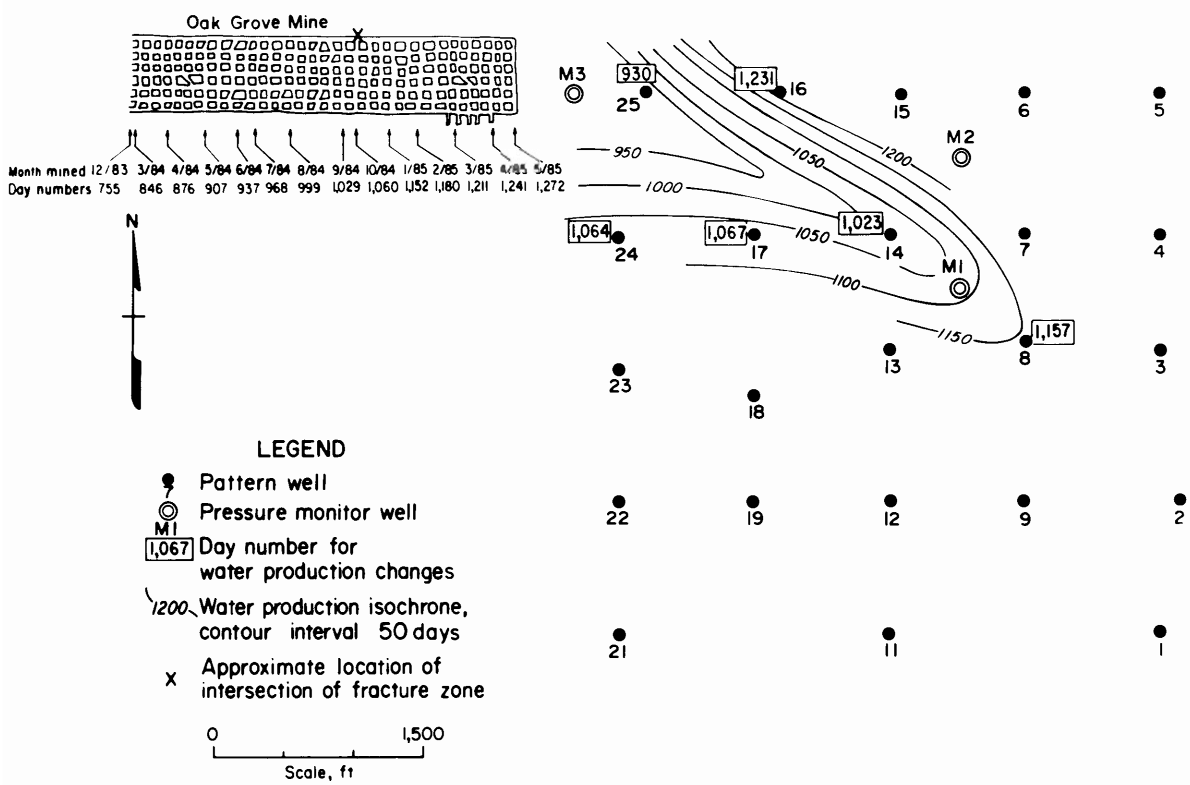

Figure 14.-Isochrone map for mining-induced water production changes.

GAS AND WATER PRODUCTION

The initial effects of mining were observed in well 25 in June 1984, when the mine entries were 2,900 ft due west (day 924).[5] In all wells where changes in both water and gas production were observed, the initial observed effect was an increase in gas production. Decreases in water production typically followed from a few days to a few months later. However, there was only a slight correlation between distance from mining and time of production response.

The day numbers of the apparent first mining effects on gas and water production are shown in figures 13 and 14, respectively, for each well. Where no number appears for a well, no obvious response was observed at that well through January 1986 (day 1,517). The face locations, at various times, are also shown on figures 13 and 14. In each figure, contour lines have been drawn of the assumed progress of the reservoir changes that caused the production changes.

It may be seen that these isochrones (equal time contour lines) are not strictly a function of face distance, although face distance is undoubtedly a factor influencing the time of the production changes. The isochrones in figures 13 and 14 suggest that there is either a directional increase in the coalbed permeability along a line roughly defined by wells 25, 14, 8, and 9, and/or the coalbed permeability within the pattern is highly directional. The direction of increased permeability, determined from the production changes, appears to be about N 60°-65° W. Prior to publication of a report by Briscoe (*6*) there was no physical evidence available for the existence of this increased permeability zone. Briscoe described the mine interception of a fracture zone at the location shown by the X's in figures 13 and 14. A more detailed discussion of this zone is given in "Possible Causes of Observed Fluid Migration Patterns" section.

COALBED PRESSURE

No mining-induced changes in formation pressure were observed until mining was about 1,500 ft from M3 (day 1,050), long after gas and water production had been affected at wells 14, 17, 24, and 25. Before day 1,050, the pressure curve for M3 (fig. 4) showed only the effects of pattern gas and water production and the pressure at M3 declined at an average 0.06 lbf/in^{2}d. Figure 4 shows a change in the pressure curve of M3 at about day 1,050. The pressure rate curve on figure 15 shows a more rapid decrease in coalbed pressure (than that caused by gas and water production), beginning between days 1,050 and 1,090. This decline rate dropped nearly to zero for a short time around day 1,100; after day 1,110 the pressure decline rate increased significantly. The pressure measured at M3 continued an accelerated decline from day 1,120 until shortly after mining to the east was stopped on day 1,272. By the time mining had come within 400 ft of M3 (fig. 16), the rate of pressure decline was more than 0.75 lbf/in^{2}d, and the rate continued to increase until about a month after mining stopped, reaching a maximum of more than 1.0 lbf/in^{2}d. After day 1,320 the rate decreased, with the last available data showing a rate of 0.3 lbf/in^{2}d.

Although there were not enough monitor wells to contour the formation pressures, it was possible to compare the times at which the effects of mining first reached the monitor wells and the rates of pressure change. The first monitor well to indicate the effects of mining was M3. Pressure changes were first observed in M3 around day 1,050, at a face distance of 1,500 ft. This is almost exactly the time when the mine intercepted the fracture zone, shown in figures 13 and 14. The time required for the pressure wave to travel through the fracture zone appears to have been very short. The fracture zone could have been intercepted by mining at any time from day 1,029 to 1,060, but was most likely intercepted around day 1,040, and the initial pressure changes at M3 were observed by about day 1,050.

The initial pressure changes in M1 were observed at about day 1,060 (fig. 4). Figures 13 and 14 indicate that M1 is located close to the fracture system, and although M1 is about 3,000 ft east of M3, only about 10 additional days were required for the pressure wave to travel the distance to M1. This gives a rough estimate for the speed of the pressure wave of about 300 ft/d.

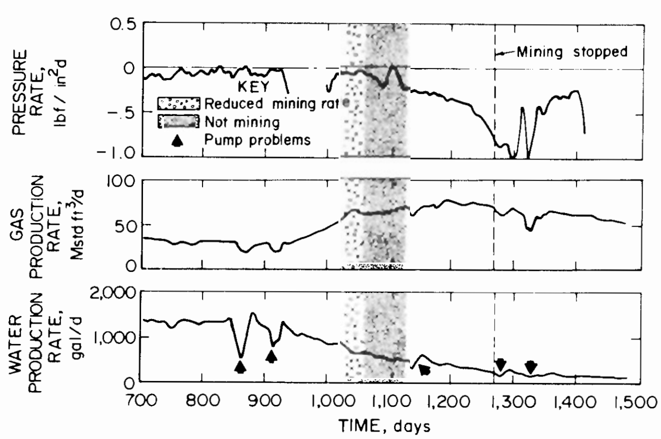

Figure 15.–Graph of water and gas production rates, and pressure rates versus time for monitor well M3 and pattern well 25.

[5]Day numbers used in this report are referenced to the first day of pressure monitoring, December 7, 1981.

No pressure changes due to mining were ever observed in M2. The pressure decline for M2 maintained the same slope from day 340 through day 1,300, when the last pressure reading was obtained from the well. The pressure decline curve observed in M2 is assumed to have resulted solely from the production of water and gas from the pattern. Had a surface equipment failure not prevented the acquisition of additional data, it is likely that a pressure decline due to mining might have become apparent at M2 before the end of the study period. However, it appears that M2 was far from both the mine and the fracture zone, and the pressure changes caused by mining probably would have been small.

When the time of initial mining effect on M3 is compared to that of the first production changes in well 25 and similar comparisons are made between wells M1 and M2 and the production wells closest to them, the times suggest that water and gas production changes take place long before any measurable (greater than 1 lbf/in^2) change in formation pressure occurs. Although M1 might appear to be an exception, in this case the pressure wave traveled quickly through the fracture zone and actually caught up with the changes in the formation associated with the changes in gas and water production, which had already been observed at well 14 by day 1,015, well before the mine intercepted the fracture zone. Prior to the time the mine cut into the fracture zone (days 1,030 to 1,060), it is assumed that the mine opening had influenced production in the pattern by intercepting water that had previously flowed from areas northwest of the pattern through coal cleat to the fracture zone and then through the fracture zone into the center of the pattern.

POSSIBLE CAUSES OF OBSERVED FLUID MIGRATION PATTERNS

Joint and cleat measurements made by U.S. Steel for the Gas Research Institute (*5*) and by the Bureau (*7*), were studied to determine possible sources of the directional permeability observed. Table 5 summarizes the work done by the Bureau prior to 1976, and by U.S. Steel more recently. The cleat studies showed that the face cleat direction was at approximately N 62° E ± 7°, and the butt cleat, while much less well defined, was approximately N 30° W ± 12°. The surface joint studies indicated that the most prominent joint set in the area was oriented at between N 62° W and N 65° W. The U.S. Steel and Bureau data showed less agreement on other joint sets, probably because the Bureau study looked at fewer joints over the entire Yolande Northeast, 7-1/2 quadrangle, while the U.S. Steel study concentrated upon the area of the Oak Grove production pattern and made many more measurements in that small area.

The joint and cleat studies strongly suggest that the source of the directional permeability increase was not the face cleat, as is often the case, but was generally related to the regional joint orientation. The direction of most rapid change in production rates was not to be northeast, as would be expected if face cleats were the most permeable paths for fluid migration, but to the southeast, which suggests that naturally occurring joints trending in that direction, and presumably in the roof, were of higher permeability than the face cleat. In both studies, a prominent set of joints was observed in the same direction (N 62° W) as indicated by the production changes. Because no cleat trending in this direction was observed in either study, this means that the actual path of fluid movement would have to be along a more localized joint system, in the strata adjacent to the coalbed. However, it should be kept in mind that because of the direction from which mining was approaching the pattern, high-permeability paths to the southeast would be expected to be much more easily observed than those to the northeast where there were no wells to allow observation of the changes in formation conditions.

Table 5.-Joint and cleat orientations

Source and type of data	Coalbed	Measurements	Direction: Primary (face cleat)	Direction: Secondary (butt cleat)
U.S. Steel (*5*):				
Surface joints	NAp	804	N 65° W N 45° E	N 20° E N 15° W
Mine cleat	Mary Lee, Blue Creek	NR	N 55° E	N 39° W
Oriented core	Pratt	34	N 69° E	N 35° W
Do	Mary Lee, Blue Creek	15	N 56° E	N 39° W
Do	Black Creek	27	N 57° E	N 35° W
BuMines (*7*):				
Surface joints	NAp	134	N 62° W N 83° E N 2° E	N 13° W N 30° E
Mine cleat	Mary Lee, Blue Creek	250	N 64° E	N 18° W N 41° W

NAp Not applicable.
NR Not recorded.

The conclusion that the face cleat was a much less permeable path is more strongly supported by the fact that the earlier times of first increase in gas production continued to occur in wells to the southeast (such as 8, 9, and 13) even after there were wells to the northeast that could have been affected. This observation of probable fluid flow through rock fractures lends support to the hypothesis that gas from the upper bench of the Mary Lee was produced from the well completions in lower bench of the Mary Lee.

As previously discussed, a section of the Oak Grove Mine advancing toward the pattern intercepted a set of fractures in the roof rock and in the lower bench of the Mary Lee Coalbed (*6*), in October 1984. The data from figures 13 and 14 clearly suggested that such a fracture system might be present, even before the physical evidence proved its existence. This set of fractures apparently produced sufficient quantities of gas and water to prevent mining for several months, although coal stockpiling and market conditions may have contributed to the length of the suspension period (the 1981-84 United Mine Workers of America contract expired during this period).

If the line of the permeability increase observed in figures 13 and 14 is extended to the mine location where the fractures were intercepted, they line up exactly. This suggests that the increased permeability zone indicated in the figures was caused by an isolated zone of fractures in the coalbed or adjacent strata, which have a higher permeability than the coalbed face cleat.

Briscoe (*6*) reported that interception of the fractures cut off the up-dip source of water to the northwestern portion of the pattern. This in turn would lead to decreased water production, decreased pressures, and to increased gas desorption rates and gas production in that portion of the pattern. Production data from well 25 do not support the theory that water production would be reduced immediately upon the interception of the fracture zone. Reductions in the rate of water production began in June 1984, well before the fracture zone was mined into. However, if it is assumed that a gradual reduction in water production would take place as the mine advanced into portions of the coalbed supplying water to the fracture zone, then this reduction could be expected to begin before the mine

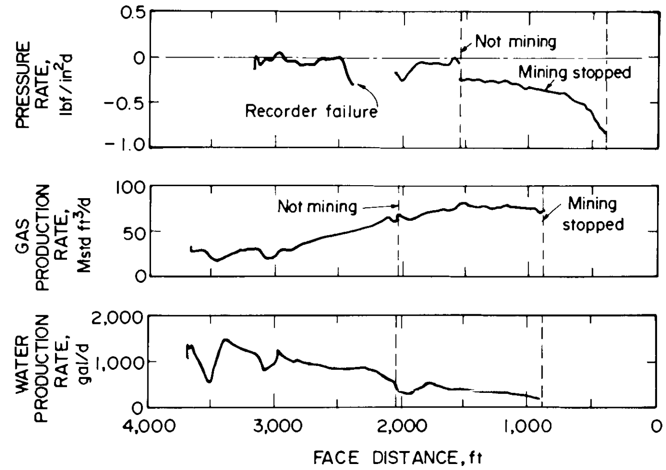

Figure 16.–Graph of water and gas production rates, and pressure rates versus face position for monitor well M3 and pattern well 25.

intercepted the fractures. This hypothesis matches the observed water production history of well 25.

The changes in production rates seemed to travel much more slowly along the face cleat direction than along the fracture zone direction. The face cleat was estimated to be between N 55° E and N 64° E at the Oak Grove site. Neither of the isochrones (for water or gas) showed any rapid change of production rates to the northeast or southwest along the face cleat direction. Through days 1,100 to 1,150 the direction of most rapid change was to the southeast. After that period the direction of most rapid change rotated to the south (between wells 8 and 9) and southwest (in the vicinity of well 13). This could indicate the termination of the fracture zone allowing the effects from the presence of cleat to dominate in that area or could indicate an actual rotation of a fracture zone. No wells northeast of wells 6, 7, 8, and 9 were observed to be affected by mining, but this is likely because the production rate changes being observed had been reduced below the limits of detection at that distance (wells 3, 4, and 5 were about 4,000 ft from the furthest eastern advance of the mine) and time.

SUMMARY

The U.S. Bureau of Mines and U.S. Steel Corporation conducted a 4-year cooperative project to monitor pressures at the Oak Grove, AL, degasification pattern. Three monitor wells were drilled to obtain cores to determine the change in coalbed gas content from the start of degasification in late 1977 through 1981. The wells were equipped with instruments to measure formation pressure. For the period of November 1982 to June 1984 the pressure decline curves for the monitor wells followed a nearly straight-line decline. The pressure decline rates were between 0.03 and 0.06 lbf/in^2d. The gas desorption rates obtained from these pressure decline rates are insufficient to account for the actual gas production volumes, unless production from outside of the pattern area is assumed.

Estimates were made of the original in-place gas volume and the reduction in in-place gas volume through 1981. The estimates of original in-place gas were made assuming gas production for the lower bench only (2,600 MMstdft^3) and for combined production from the upper and lower benches (3,400 MMstdft^3), with estimated reductions of in-place gas volume of 1,115 and 1,453 MMstdft^3, respectively. The actual gas volume produced through 1981 was 1,110 MMstdft^3.

In late 1983 the Oak Grove Mine began to advance toward the northwestern corner of the pattern. By June 1984 the wells closest to mining had begun to respond to the effects of mining. By the time mining toward the pattern had been terminated, in May 1985, 12 wells had shown increases in gas production and 6 wells had shown reductions in water production due to the effects of mining.

The initial indications of the effects of mining were plotted on a map of the pattern and the times were contoured. The contours suggested the presence of a local area of increased permeability within the pattern.

CONCLUSIONS

Data from monitor wells drilled at the Oak Grove degasification pattern show that 8 years of gas and water production (1978 through 1985) caused a reduction in the formation pressure from an original 420 lbf/in^2(ga) to about 55 lbf/in^2(ga). During that time, based on an isotherm constructed from gas content and pressure data, the coalbed gas content is estimated to have dropped an average 70 pct from 480 ft^3/st to 150 ft^3/st, in mid-1985.

Based upon pressure decline curves and the isotherm curve, it appears that since 1982 at least 60 to 70 pct of the gas being produced at the Oak Grove pattern has come from outside of the immediate pattern area. This appears to be the case despite the fact that large quantities of gas still remain within the pattern area. If the 1981 samples are representative of the coal in place, then up to 90 pct of the gas remaining in 1985 was desorbable.

The advance of mining toward the pattern in 1984 caused a very consistent set of responses. In the wells affected, gas production first began to increase for a period of time ranging from 30 to 130 days, followed shortly after by decreases in water production over a period of from 30 to 150 days. The increases in gas production ranged from 10 to 200 pct, while the decrease in water production ranged from 50 to 80 pct. Eventually as the gas desorbed by the presence of the mine opening was produced, either into the mine workings or to production wells, gas production leveled off and began to decline again. Water production remained at the lower levels, reflecting the loss of reservoir area to mining.

It would be difficult to use this type of information to predict the timing or magnitude of the production rate changes in other wells in the same coalbed, because the ranges of these rate changes were strongly controlled by the distances of the wells from the mine opening and the fracture zone. However the data do show that the advance of the mine opening toward a coalbed methane drainage well can cause large, temporary increases in gas production and permanent decreases in water production. They also suggest that the timing of these changes will vary significantly with local geological conditions.

The time of the initial indications of mining effects on the production wells suggested the presence of a localized area of high permeability in the northwestern portion of the Oak Grove pattern. Study of joint and cleat data collected by the Bureau and U.S. Steel suggested that this higher permeability was associated with either high-permeability joints or a fault. Physical evidence for a high-permeability fracture zone was finally obtained from reports of a zone in the coalbed and roof rock, mined through by the Oak Grove Mine. The quantities of gas and water reported to be flowing from the fractures shortly after mine-through indicate that the zone is of higher permeability than joints or cleat typically existing within the Mary Lee Coalbed. Fracture zones of this type could have a major effect on the productivity of methane drainage wells and upon mining activity. Knowledge of the locations of such features would be of great value, both to allow optimization of production well sites, and to minimize the detrimental effects of mining through such zones.

REFERENCES

1. Lambert, S. W., and M. A. Trevits. Methane Drainage Ahead of Mining Using Foam Stimulation–Mary Lee Coalbed AL. U.S. Dep. Energy RI PMTC-3, Jan. 1979, 22 pp.

2. Stubbs, P. B., F. X. Dobscha, and J. V. Mahoney. Degasification of the Blue Creek Coal Seam at Oak Grove Mine. Paper in Proceedings, Second Annual Methane Recovery for Coalbeds Symposium. Morgantown (WV) Energy Technol. Center, METC/SP-79/9, 1979, pp. 96-113.

3. Oyler, D. C., and P. B. Stubbs. Measuring Formation Pressures and the Degree of Gas Drainage in a Large Coalbed Gas Drainage Field. BuMines RI 8986, 1985, 15 pp.

4. Diamond, W. P., J. C. LaScola, and D. M. Hyman. Results of Direct-Method Determination of the Gas Content of U.S. Coalbeds. BuMines IC 9067, 1986, 95 pp.

5. Camp, B. S., F. H. Briscoe, P. G. Malone, and C. M. Boyer II (U.S. Steel Corp.). Rock Creek Methane From Multiple Coal Seams Completion Project, Special Data Package Preliminary Geologic Report. Gas Res. Inst., Chicago, IL, contract 5083-214-0847, May 1985, 133 pp.

6. Briscoe, F. H., B. S. Camp, L. K. Lottman, and P. G. Malone. A Study of Coal-Bed Methane Production Trends as Related to Geologic Features, Warrior Basin, Alabama. Ch. in Geology and Coal-Bed Methane Resources of the Northern San Juan Basin, Colorado and New Mexico, ed. by J. E. Fassett. Rocky Mountain Assoc. Geol., Denver, CO, 1988, pp. 237-246.

7. 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.

APPENDIX 1.–MONITOR WELL PRESSURE DATA

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge

Date	Day number	Pressure, lbf/in^2(ga)		
		M1	M2	M3
1981:				
Dec. 7	1	122	115	250
Dec. 8	2	121	114	250
Dec. 9	3	122	113	248
Dec. 10	4	121	114	248
Dec. 11	5	122	113	247
Dec. 14	8	122	112	248
Dec. 15	9	122	112	246
Dec. 28	22	123	112	245
Dec. 29	23	123	112.5	244.5
Dec. 30	24	122.5	112.5	244
Dec. 31	25	122.3	112.5	244.5
1982:				
Jan. 1	26	121.5	112.5	244
Jan. 2	27	121.5	113	243
Jan. 3	28	122	111.5	243.5
Jan. 4	29	121.5	113	244
Jan. 5	30	121	113	243
Jan. 6	31	122	112	243.5
Jan. 7	32	122	112	244
Jan. 8	33	121.5	112	NR
Jan. 9	34	121	111.5	NR
Jan. 10	35	121.5	111	NR
Jan. 11	36	120	111.5	NR
Jan. 12	37	121	111.5	NR
Jan. 13	38	120.5	110.5	NR
Jan. 14	39	120	110.5	NR
Jan. 15	40	120	111	NR
Jan. 16	41	120.5	111	NR
Jan. 17	42	120.5	110.5	NR
Jan. 18	43	120.5	110	243
Jan. 19	44	120.5	110.5	242.5
Jan. 20	45	120.5	110	243
Jan. 21	46	121	110	241
Jan. 22	47	120.5	110.5	241.5
Jan. 23	48	121	110.5	242
Jan. 24	49	120	110.5	241
Jan. 25	50	119.5	110.5	240
Jan. 26	51	119.5	110	241
Jan. 27	52	119.5	111	240
Jan. 28	53	120	110.5	240
Jan. 29	54	119	110.5	239.5
Jan. 30	55	119.5	110.5	239
Jan. 31	56	119.5	110.5	239
Feb. 1	57	119	110	239.5
Feb. 2	58	119.5	110.5	239
Feb. 3	59	119.5	109.5	238.5
Feb. 4	60	119	110.5	238.5
Feb. 5	61	119.5	110.5	238.5
Feb. 6	62	120	110	238.5
Feb. 7	63	119	110	238
Feb. 8	64	118.5	109.5	237.5
Feb. 9	65	118.5	109.5	237.5
Feb. 10	66	118.5	109	237
Feb. 11	67	119	109.5	236.5
Feb. 12	68	118	109	236
Feb. 13	69	118	109.5	236.5
Feb. 14	70	118.5	109.5	236.5
Feb. 15	71	118	109.5	236.5
Feb. 16	72	118.5	109	236
Feb. 17	73	118.5	109.5	235.5
Feb. 18	74	118	109	235.5
Mar. 11	95	118	107.5	232.5
Mar. 12	96	117.5	107.5	232.5
1982–Con.				
Mar. 13	97	118	107.5	233
Mar. 14	98	117.5	107.5	232.5
Mar. 15	99	117.5	107.5	232.5
Mar. 16	100	117.5	107	231.5
Mar. 17	101	117.5	107	231
Mar. 18	102	118	107	231.5
Mar. 19	103	117.5	107	231.5
Mar. 20	104	117.5	106.5	231.5
Mar. 21	105	117.5	106.5	231.5
Mar. 22	106	117.5	106.5	232
Mar. 23	107	117.5	106.5	231
Mar. 26	110	117.5	106.5	230.5
Mar. 27	111	117	106.5	230.5
Mar. 28	112	117.5	107	230
Mar. 29	113	117	107	230
Mar. 30	114	116.5	105.5	230
Mar. 31	115	116.5	106	230.5
Apr. 1	116	116	105.5	230
Apr. 2	117	116	105.5	230
Apr. 3	118	116.5	105.5	229
Apr. 4	119	NR	105.5	229
Apr. 5	120	NR	105	228.5
Apr. 13	128	NR	104	228.5
Apr. 14	129	NR	104.5	228.5
Apr. 15	130	116.5	104.5	228.5
Apr. 16	131	116.5	104.5	229
Apr. 17	132	116.5	104.5	228
Apr. 18	133	117	104	228.5
Apr. 19	134	116.5	104.5	228.5
Apr. 20	135	116.5	104.5	228.5
Apr. 21	136	116	104	228
Apr. 22	137	116.5	105	228
Apr. 23	138	116.5	105	228
Apr. 24	139	116.5	104	229
Apr. 25	140	116.5	103.5	229.5
Apr. 26	141	116.5	104	228.5
Apr. 27	142	116.5	103.5	228.5
Apr. 28	143	116.5	NR	228
Apr. 29	144	116	NR	228
Apr. 30	145	116	NR	227.5
May 1	146	117	104	228.5
May 2	147	117	102	227.5
May 3	148	117	102	228.5
May 4	149	116	102	227.5
May 5	150	117	102	227
May 6	151	117	102	227
May 7	152	116	102	227
May 8	153	117	102	227
May 9	154	117	102	227
May 10	155	116	102	227
May 11	156	116	102	227
May 12	157	117	102	227
May 13	158	117	102	227
May 14	159	117	102	227
May 15	160	117	102	227
May 16	161	117	102	227
May 17	162	117	102	227
May 18	163	117	102	227
May 19	164	117	102	227
May 20	165	117	102	227
May 21	166	116	102	227
May 22	167	116	102	227
May 23	168	116	102	227

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in²(ga)		
		M1	M2	M3
1982–Con.				
May 24	169	116	102	227
May 25	170	117	102	227
May 26	171	117	102	226
May 27	172	117	102	226
May 28	173	117	101	226
May 29	174	117	101	227
May 30	175	116	102	227
May 31	176	116	102	227
June 1	177	117	101	227
June 2	178	117	101	226
June 3	179	117	102	226
June 4	180	117	102	226
June 5	181	117	102	NR
June 6	182	117	102	225
June 7	183	117	102	226
June 8	184	117	101	226
June 9	185	117	101	226
June 10	186	117	101	226
June 11	187	117	101	226
June 12	188	117	101	227
June 13	189	116	101	227
June 14	190	117	100	227
June 15	191	116	100	226
June 16	192	117	100	227
June 17	193	117	100	226
June 18	194	117	100	226
June 19	195	117	100	223
June 20	196	116	100	223
June 21	197	117	100	223
June 22	198	117	100	223
June 23	199	117	99	224
June 24	200	117	99	224
June 25	201	117	99	223
June 26	202	116	98	223
June 27	203	117	98	223
June 29	205	115	99	223
June 30	206	116	98	224
July 1	207	116	99	224
July 2	208	116	98	224
July 3	209	116	99	224
July 4	210	115	98	224
July 5	211	116	98	224
July 6	212	115	98	224
July 7	213	115	97	224
July 8	214	116	97	224
July 9	215	116	97	223
July 10	216	116	97	223
July 11	217	116	97	223
July 12	218	116	97	223
July 13	219	116	97	222
July 14	220	116	97	222
July 15	221	116	97	223
July 16	222	116	97	222
July 17	223	116	97	222
July 18	224	115	97	223
July 19	225	116	96	223
July 20	226	115	97	223
July 21	227	116	96	223
July 22	228	116	96	222
July 23	229	116	96	223
July 24	230	116	96	223
July 25	231	115	96	223
July 26	232	116	95	223
July 27	233	116	95	223
July 28	234	116	95	223
July 29	235	116	94	222
July 30	236	116	94	223
1982–Con.				
July 31	237	116	95	222
Aug. 1	238	115	95	222
Aug. 2	239	116	95	222
Aug. 3	240	116	95	221
Aug. 4	241	116	95	220
Aug. 5	242	116	95	221
Aug. 6	243	116	95	221
Aug. 7	244	116	95	221
Aug. 8	245	116	95	221
Aug. 9	246	116	94	221
Aug. 10	247	116	94	221
Aug. 11	248	116	94	221
Aug. 12	249	116	94	220
Aug. 16	253	115	93	221
Aug. 17	254	116	93	221
Aug. 18	255	115	93	221
Aug. 19	256	116	92	221
Aug. 20	257	116	93	221
Aug. 21	258	116	93	220
Aug. 22	259	116	93	219
Aug. 23	260	116	93	219
Aug. 24	261	116	93	219
Aug. 25	262	116	93	220
Aug. 26	263	115	93	220
Aug. 27	264	115	93	220
Aug. 28	265	115	93	220
Aug. 29	266	115	93	219
Aug. 30	267	115	93	220
Aug. 31	268	115	93	220
Sept. 1	269	115	92	219
Sept. 2	270	115	92	219
Sept. 3	271	115	93	219
Sept. 4	272	115	92	220
Sept. 5	273	115	92	219
Sept. 6	274	115	91	220
Sept. 7	275	115	92	218
Sept. 8	276	115	92	219
Sept. 9	277	115	92	219
Sept. 10	278	115	92	220
Sept. 11	279	NR	92	NR
Sept. 12	280	115	NR	219
Sept. 16	284	114	90	NR
Sept. 17	285	114	91	219
Sept. 18	286	115	91	219
Sept. 19	287	115	91	219
Sept. 20	288	115	91	218
Sept. 21	289	115	90	219
Sept. 22	290	114	90	218
Sept. 23	291	115	91	219
Sept. 24	292	115	91	219
Sept. 25	293	115	91	219
Sept. 26	294	115	90	219
Sept. 27	295	115	90	219
Sept. 28	296	114	90	219
Sept. 29	297	115	91	218
Sept. 30	298	115	91	218
Oct. 1	299	115	87	219
Oct. 2	300	115	87	218
Oct. 3	301	115	87	219
Oct. 4	302	115	86	219
Oct. 5	303	115	86	219
Oct. 6	304	114	86	219
Oct. 7	305	NR	NR	219
Oct. 8	306	110	70	219
Oct. 9	307	110	70	219
Oct. 10	308	110	70	219
Oct. 11	309	109	70	219

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in^2(ga) M1	M2	M3
1982–Con.				
Oct. 12	310	109	70	219
Oct. 13	311	109	70	219
Oct. 15	313	110	69	219
Oct. 16	314	110	70	219
Oct. 17	315	109	70	219
Oct. 18	316	110	70	219
Oct. 19	317	110	70	219
Oct. 20	318	110	70	219
Oct. 21	319	109	69	219
Oct. 22	320	110	69	218
Oct. 23	321	110	70	219
Oct. 24	322	110	69	219
Oct. 25	323	110	69	219
Oct. 26	324	110	69	219
Oct. 27	325	110	69	219
Oct. 28	326	110	69	218
Oct. 29	327	110	69	218
Oct. 30	328	109	70	219
Oct. 31	329	110	69	218
Nov. 1	330	110	69	219
Nov. 3	332	110	69	218
Nov. 4	333	110	69	219
Nov. 5	334	110	69	219
Nov. 6	335	109	69	219
Nov. 7	336	110	69	219
Nov. 8	337	110	70	218
Nov. 9	338	110	70	218
Nov. 10	339	109	70	218
Nov. 11	340	110	68	218
Nov. 12	341	110	82	220
Nov. 13	342	110	82	222
Nov. 14	343	110	81	221
Nov. 15	344	110	81	223
Nov. 16	345	110	81	221
Nov. 17	346	110	81	223
Nov. 18	347	109	80	223
Nov. 19	348	109	81	223
Nov. 20	349	110	81	223
Nov. 21	350	111	81	222
Nov. 22	351	110	80	221
Nov. 23	352	111	80	220
Nov. 24	353	110	80	220
Nov. 25	354	110	80	221
Nov. 26	355	110	80	221
Nov. 27	356	111	79	221
Nov. 28	357	111	79	221
Nov. 29	358	109	79	221
Nov. 30	359	109	79	221
Dec. 1	360	110	78	220
Dec. 2	361	110	80	221
Dec. 3	362	111	80	220
Dec. 4	363	111	80	220
Dec. 5	364	110	80	220
Dec. 6	365	109	80	219
Dec. 7	366	110	80	219
Dec. 8	367	111	80	219
Dec. 9	368	111	80	219
Dec. 10	369	109	80	218
Dec. 11	370	109	80	219
Dec. 12	371	110	80	217
Dec. 13	372	111	79	217
Dec. 14	373	110	80	218
Dec. 15	374	111	80	219
Dec. 16	375	110	79	219
Dec. 17	376	111	79	217
Dec. 18	377	109	79	217
Dec. 19	378	110	79	219
1982–Con.				
Dec. 20	379	NR	79	219
Dec. 21	380	NR	80	218
Dec. 22	381	NR	79	220
Dec. 23	382	NR	80	220
Dec. 24	383	NR	80	219
Dec. 25	384	NR	80	219
Dec. 26	385	NR	80	219
Dec. 27	386	NR	80	218
Dec. 28	387	NR	79	218
Dec. 29	388	NR	79	217
Dec. 30	389	NR	79	216
Dec. 31	390	NR	79	216
1983:				
Jan. 1	391	NR	79	217
Jan. 2	392	NR	79	217
Jan. 3	393	NR	79	216
Jan. 4	394	NR	79	216
Jan. 5	395	NR	79	216
Jan. 6	396	NR	79	216
Jan. 7	397	NR	78	216
Jan. 8	398	NR	79	216
Jan. 9	399	NR	79	217
Jan. 10	400	NR	79	216
Jan. 11	401	NR	79	216
Jan. 12	402	NR	79	216
Jan. 13	403	110	78	216
Jan. 14	404	111	78	216
Jan. 15	405	111	79	217
Jan. 16	406	111	78	215
Jan. 17	407	111	79	216
Jan. 18	408	110	77	216
Jan. 19	409	110	78	215
Jan. 20	410	110	78	216
Jan. 21	411	110	78	216
Jan. 22	412	110	78	216
Jan. 23	413	111	78	216
Jan. 24	414	110	78	216
Jan. 25	415	110	78	215
Jan. 26	416	110	78	215
Jan. 27	417	111	79	215
Jan. 28	418	111	78	215
Jan. 29	419	110	78	216
Jan. 30	420	110	78	217
Jan. 31	421	111	78	216
Feb. 1	422	111	78	216
Feb. 2	423	110	78	216
Feb. 3	424	111	76	215
Feb. 4	425	111	77	216
Feb. 5	426	109	77	215
Feb. 6	427	110	77	216
Feb. 7	428	110	77	215
Feb. 8	429	110	77	215
Feb. 9	430	110	77	216
Feb. 10	431	110	77	216
Feb. 11	432	109	77	216
Feb. 12	433	110	77	216
Feb. 13	434	109	77	215
Feb. 14	435	110	77	215
Feb. 15	436	110	76	215
Feb. 16	437	110	77	214
Feb. 17	438	110	77	214
Feb. 18	439	110	77	215
Feb. 19	440	109	77	215
Feb. 20	441	110	77	216
Feb. 21	442	110	77	216
Feb. 22	443	110	76	217
Feb. 23	444	110	77	217

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in²(ga)		
		M1	M2	M3
1983–Con.				
Feb. 24	445	109	77	215
Feb. 25	446	110	76	214
Feb. 26	447	110	76	214
Feb. 27	448	110	77	215
Feb. 28	449	110	77	215
Mar. 1	450	109	77	216
Mar. 2	451	109	76	215
Mar. 3	452	109	77	215
Mar. 4	453	110	77	215
Mar. 5	454	110	76	216
Mar. 6	455	109	76	215
Mar. 7	456	110	76	215
Mar. 8	457	110	76	215
Mar. 9	458	109	76	213
Mar. 10	459	109	75	213
Mar. 11	460	109	75	213
Mar. 12	461	109	76	215
Mar. 13	462	110	76	214
Mar. 14	463	109	77	215
Mar. 15	464	109	77	214
Mar. 16	465	110	77	215
Mar. 17	466	109	76	214
Mar. 18	467	110	76	214
Mar. 19	468	109	77	215
Mar. 20	469	109	76	214
Mar. 21	470	109	76	NR
Mar. 22	471	109	76	NR
Mar. 23	472	110	76	NR
Mar. 24	473	109	76	NR
Mar. 25	474	109	77	NR
Mar. 26	475	108	77	NR
Mar. 27	476	108	77	NR
Mar. 28	477	108	77	NR
Mar. 29	478	109	77	NR
Mar. 30	479	109	77	NR
Mar. 31	480	108	77	215
Apr. 1	481	109	77	215
Apr. 2	482	109	77	215
Apr. 3	483	109	77	215
Apr. 4	484	109	77	215
Apr. 5	485	109	77	215
Apr. 6	486	109	77	215
Apr. 7	487	108	77	215
Apr. 8	488	108	77	214
Apr. 9	489	108	76	213
Apr. 10	490	107	76	214
Apr. 11	491	107	76	213
Apr. 12	492	108	76	213
Apr. 13	493	108	75	214
Apr. 14	494	108	75	214
Apr. 15	495	108	76	NR
Apr. 16	496	107	75	NR
Apr. 17	497	107	75	NR
Apr. 18	498	108	76	NR
Apr. 19	499	107	75	NR
Apr. 20	500	107	75	NR
Apr. 21	501	108	75	NR
Apr. 22	502	108	75	NR
Apr. 23	503	107	75	NR
Apr. 24	504	107	75	NR
Apr. 25	505	107	75	NR
Apr. 26	506	107	74	NR
Apr. 27	507	108	75	NR
Apr. 28	508	107	75	NR
Apr. 29	509	107	75	NR
Apr. 30	510	107	74	NR
May 1	511	107	75	NR
May 2	512	107	74	NR
May 3	513	107	75	NR
May 4	514	107	74	NR
May 5	515	106	74	NR
May 6	516	107	74	NR
May 7	517	107	75	NR
May 8	518	107	74	NR
May 9	519	107	75	NR
May 10	520	107	74	NR
May 11	521	106	74	NR
May 12	522	'107	75	NR
May 13	523	107	74	NR
May 14	524	106	74	NR
May 15	525	107	75	NR
May 16	526	106	74	NR
May 17	527	107	75	NR
May 18	528	106	75	NR
May 19	529	107	74	NR
May 20	530	107	75	NR
May 21	531	106	75	NR
May 22	532	106	75	NR
May 23	533	106	74	NR
May 24	534	107	74	NR
May 25	535	106	75	NR
May 26	536	106	74	NR
May 27	537	106	74	NR
May 28	538	106	74	NR
May 29	539	107	74	NR
May 30	540	106	73	NR
May 31	541	106	74	NR
June 1	542	107	74	NR
June 2	543	107	73	NR
June 3	544	107	74	NR
June 4	545	107	74	NR
June 5	546	107	74	NR
June 6	547	107	73	NR
June 7	548	107	74	NR
June 8	549	107	74	NR
June 9	550	106	74	NR
June 10	551	106	74	NR
June 11	552	107	74	NR
June 12	553	106	74	NR
June 13	554	106	74	NR
June 14	555	106	74	NR
June 15	556	105	73	NR
June 16	557	106	73	NR
June 17	558	106	74	NR
June 18	559	106	74	NR
June 19	560	105	74	NR
June 20	561	106	74	NR
June 21	562	106	73	208
June 22	563	106	74	208
June 23	564	106	74	208
June 24	565	106	74	208
June 25	566	106	74	208
June 26	567	106	74	209
June 27	568	106	74	208
June 28	569	106	74	208
June 29	570	106	74	208
June 30	571	106	74	208
July 1	572	106	73	208
July 2	573	106	73	208
July 3	574	106	73	209
July 4	575	106	73	208
July 5	576	106	72	208
July 6	577	105	73	208
July 7	578	105	73	208

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in^2(ga) M1	M2	M3
1983–Con.				
July 8	579	104	73	208
July 9	580	105	72	207
July 10	581	105	73	208
July 11	582	105	73	208
July 12	583	105	73	207
July 13	584	105	72	208
July 14	585	105	73	208
July 15	586	104	73	208
July 16	587	105	72	208
July 17	588	104	73	208
July 18	589	105	72	208
July 19	590	105	73	207
July 20	591	105	73	208
July 21	592	105	73	207
July 22	593	105	73	207
July 23	594	105	73	207
July 24	595	104	73	208
July 25	596	104	73	207
July 26	597	104	73	208
July 27	598	104	73	208
July 28	599	104	73	208
July 29	600	104	73	208
July 30	601	104	73	208
July 31	602	104	72	207
Aug. 1	603	103	73	208
Aug. 2	604	104	73	208
Aug. 3	605	104	73	208
Aug. 4	606	104	73	208
Aug. 5	607	104	73	208
Aug. 6	608	104	73	208
Aug. 7	609	104	73	208
Aug. 8	610	104	72	208
Aug. 9	611	104	72	208
Aug. 10	612	103	73	208
Aug. 11	613	104	73	208
Aug. 12	614	103	72	208
Aug. 13	615	104	73	208
Aug. 14	616	104	72	208
Aug. 15	617	104	73	208
Aug. 16	618	104	73	208
Aug. 17	619	103	73	208
Aug. 18	620	103	73	208
Aug. 19	621	103	73	207
Aug. 20	622	103	73	206
Aug. 21	623	103	73	207
Aug. 22	624	102	72	207
Aug. 23	625	102	73	207
Aug. 24	626	102	72	207
Aug. 25	627	103	73	207
Aug. 26	628	103	72	207
Aug. 27	629	103	73	207
Aug. 28	630	103	72	207
Aug. 29	631	103	72	206
Aug. 30	632	102	72	207
Aug. 31	633	102	72	207
Sept. 1	634	103	73	207
Sept. 2	635	103	73	207
Sept. 3	636	103	73	207
Sept. 4	637	102	72	207
Sept. 5	638	103	73	206
Sept. 6	639	102	72	206
Sept. 7	640	102	71	206
Sept. 8	641	103	72	205
Sept. 9	642	102	71	205
Sept. 10	643	102	71	205
Sept. 11	644	101	71	206
Sept. 12	645	102	72	206
1983–Con.				
Sept. 13	646	101	71	205
Sept. 14	647	101	71	205
Sept. 15	648	101	72	205
Sept. 16	649	101	71	205
Sept. 17	650	102	70	206
Sept. 18	651	102	70	205
Sept. 19	652	102	71	205
Sept. 20	653	102	71	205
Sept. 21	654	101	71	205
Sept. 22	655	102	70	205
Sept. 23	656	101	71	206
Sept. 24	657	102	70	205
Sept. 25	658	102	71	206
Sept. 26	659	101	71	205
Sept. 27	660	101	70	205
Sept. 28	661	102	71	206
Sept. 29	662	102	71	205
Sept. 30	663	102	71	206
Oct. 1	664	101	70	205
Oct. 2	665	101	71	204
Oct. 3	666	101	71	205
Oct. 4	667	102	70	204
Oct. 5	668	102	71	204
Oct. 6	669	101	71	205
Oct. 7	670	102	70	205
Oct. 8	671	100	71	205
Oct. 9	672	101	71	205
Oct. 10	673	100	71	204
Oct. 11	674	100	71	204
Oct. 12	675	100	70	204
Oct. 13	676	101	70	204
Oct. 14	677	100	70	203
Oct. 15	678	101	71	203
Oct. 16	679	100	70	204
Oct. 17	680	101	70	203
Oct. 18	681	100	71	203
Oct. 19	682	99	71	203
Oct. 20	683	100	71	203
Oct. 21	684	99	71	203
Oct. 22	685	100	70	202
Oct. 23	686	101	69	202
Oct. 24	687	99	70	202
Oct. 25	688	99	69	202
Oct. 26	689	99	70	202
Oct. 27	690	99	69	202
Oct. 28	691	99	70	202
Oct. 29	692	99	70	202
Oct. 30	693	100	69	202
Oct. 31	694	100	70	202
Nov. 1	695	100	69	202
Nov. 2	696	99	69	202
Nov. 3	697	100	70	203
Nov. 4	698	100	70	202
Nov. 5	699	99	69	201
Nov. 6	700	99	69	202
Nov. 7	701	99	70	201
Nov. 8	702	NR	70	201
Nov. 9	703	NR	70	201
Nov. 10	704	NR	70	200
Nov. 11	705	NR	69	201
Nov. 12	706	NR	69	201
Nov. 13	707	NR	70	200
Nov. 14	708	NR	70	201
Nov. 15	709	NR	69	201
Nov. 17	711	NR	69	200
Nov. 18	712	NR	69	201
Nov. 19	713	NR	68	199

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in²(ga) M1	M2	M3
1983–Con.				
Nov. 20	714	99	68	199
Nov. 21	715	99	69	200
Nov. 22	716	98	68	200
Nov. 23	717	99	68	199
Nov. 24	718	NR	68	199
Nov. 25	719	NR	68	200
Nov. 26	720	NR	68	199
Nov. 27	721	NR	68	200
Nov. 28	722	NR	68	200
Nov. 29	723	NR	68	200
Nov. 30	724	NR	68	199
Dec. 1	725	NR	68	199
Dec. 2	726	NR	68	199
Dec. 3	727	98	69	200
Dec. 4	728	99	68	199
Dec. 5	729	98	68	198
Dec. 6	730	98	68	199
Dec. 7	731	97	68	199
Dec. 8	732	NR	68	199
Dec. 9	733	NR	68	199
Dec. 10	734	98	69	199
Dec. 11	735	98	69	198
Dec. 12	736	98	68	198
Dec. 13	737	NR	69	198
Dec. 14	738	97	69	199
Dec. 15	739	NR	68	197
Dec. 16	740	NR	69	197
Dec. 17	741	NR	68	197
Dec. 18	742	NR	69	197
Dec. 19	743	NR	68	197
Dec. 20	744	NR	68	196
Dec. 21	745	NR	68	197
Dec. 22	746	NR	68	196
Dec. 23	747	NR	68	197
Dec. 24	748	NR	68	196
Dec. 25	749	NR	68	196
Dec. 26	750	NR	68	197
Dec. 27	751	NR	69	196
Dec. 28	752	NR	69	196
Dec. 29	753	NR	68	196
Dec. 30	754	NR	68	195
Dec. 31	755	NR	68	195
1984:				
Jan. 1	756	NR	69	196
Jan. 2	757	NR	69	197
Jan. 3	758	NR	68	196
Jan. 4	759	NR	68	195
Jan. 5	760	NR	69	195
Jan. 6	761	NR	69	196
Jan. 7	762	NR	68	195
Jan. 8	763	NR	69	196
Jan. 9	764	NR	69	195
Jan. 10	765	NR	69	196
Jan. 11	766	NR	69	195
Jan. 12	767	NR	68	196
Jan. 13	768	NR	68	196
Jan. 14	769	NR	68	196
Jan. 15	770	NR	69	196
Jan. 16	771	NR	69	196
Jan. 17	772	NR	68	196
Jan. 18	773	NR	68	196
Jan. 19	774	NR	68	196
Jan. 20	775	NR	68	195
Jan. 21	776	NR	68	196
Jan. 22	777	NR	68	196
Jan. 23	778	NR	67	194
Jan. 24	779	NR	67	194
1984–Con.				
Jan. 25	780	NR	68	194
Jan. 26	781	NR	68	194
Jan. 27	782	NR	67	196
Jan. 28	783	NR	68	195
Jan. 29	784	NR	68	195
Jan. 30	785	NR	67	194
Jan 31.	786	NR	67	194
Feb. 1	787	NR	68	194
Feb. 2	788	NR	68	194
Feb. 3	789	NR	67	194
Feb. 4	790	NR	67	195
Feb. 5	791	NR	68	195
Feb. 6	792	NR	68	194
Feb. 7	793	95	68	195
Feb. 8	794	96	68	194
Feb. 9	795	95	67	194
Feb. 10	796	96	67	194
Feb. 11	797	95	68	194
Feb. 12	798	95	68	194
Feb. 13	799	96	67	194
Feb. 14	800	95	66	194
Feb. 15	801	96	67	194
Feb. 16	802	95	67	194
Feb. 17	803	95	66	194
Feb. 18	804	95	67	194
Feb. 19	805	96	66	193
Feb. 20	806	95	67	193
Feb. 21	807	96	66	194
Feb. 22	808	95	67	193
Feb. 23	809	95	66	194
Feb. 24	810	96	67	194
Feb. 25	811	96	66	193
Feb. 26	812	95	67	192
Feb. 27	813	95	66	193
Feb. 28	814	94	67	193
Feb. 29	815	95	66	192
Mar. 1	816	95	67	193
Mar. 2	817	94	66	193
Mar. 3	818	95	67	193
Mar. 4	819	94	66	194
Mar. 5	820	95	67	194
Mar. 6	821	95	66	194
Mar. 7	822	95	66	193
Mar. 8	823	95	66	192
Mar. 9	824	94	66	192
Mar. 10	825	95	65	193
Mar. 11	826	94	66	192
Mar. 12	827	94	65	192
Mar. 13	828	94	65	193
Mar. 14	829	95	NR	193
Mar. 15	830	94	NR	194
Mar. 16	831	95	NR	193
Mar. 17	832	94	NR	194
Mar. 18	833	95	NR	194
Mar. 19	834	94	NR	193
Mar. 20	835	95	NR	194
Mar. 21	836	94	NR	192
Mar. 22	837	95	NR	193
Mar. 23	838	94	NR	192
Mar. 24	839	94	NR	193
Mar. 25	840	93	NR	192
Mar. 26	841	94	NR	193
Mar. 27	842	94	NR	192
Mar. 28	843	94	NR	192
Mar. 29	844	94	NR	192
Mar. 30	845	94	NR	192
Mar. 31	846	93	NR	192
Apr. 1	847	93	NR	192

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in²(ga) M1	M2	M3	Date	Day number	Pressure, lbf/in²(ga) M1	M2	M3
1984–Con.					1984–Con.				
Apr. 1	847	93	NR	192	June 15	922	90	63	190
Apr. 2	848	94	NR	191	June 16	923	91	63	191
Apr. 3	849	94	66	193	June 17	924	91	64	190
Apr. 4	850	93	66	192	June 18	925	90	63	189
Apr. 5	851	94	65	191	June 19	926	91	64	190
Apr. 6	852	93	65	191	June 20	927	90	63	190
Apr. 7	853	94	66	191	June 21	928	91	63	189
Apr. 8	854	93	65	192	June 22	929	90	64	188
Apr. 9	855	93	66	191	June 23	930	90	63	189
Apr. 10	856	92	65	190	June 24	931	90	64	189
Apr. 11	857	93	65	190	June 25	932	90	63	189
Apr. 12	858	93	65	191	June 26	933	90	63	189
Apr. 13	859	93	64	192	June 27	934	90	64	188
Apr. 14	860	92	65	191	June 28	935	91	63	188
Apr. 15	861	93	64	192	June 29	936	90	64	188
Apr. 16	862	93	64	191	June 30	937	89	63	188
Apr. 17	863	93	64	192	Aug. 27	995	87	62	184
Apr. 18	864	93	65	192	Aug. 28	996	87	61	185
Apr. 19	865	92	64	191	Aug. 29	997	87	61	186
Apr. 20	866	93	65	192	Aug. 30	998	87	61	185
Apr. 21	867	92	64	191	Aug. 31	999	87	61	184
Apr. 22	868	93	65	192	Sept. 1	1,000	87	62	184
Apr. 23	869	92	64	191	Sept. 2	1,001	87	61	184
Apr. 24	870	93	64	191	Sept. 3	1,002	87	62	183
Apr. 25	871	93	64	192	Sept. 4	1,003	87	61	183
Apr. 26	872	92	65	191	Sept. 5	1,004	87	61	184
Apr. 27	873	93	64	191	Sept. 6	1,005	88	61	184
Apr. 28	874	92	65	192	Sept. 7	1,006	87	62	184
Apr. 29	875	92	64	192	Sept. 8	1,007	88	62	183
Apr. 30	876	93	65	192	Sept. 9	1,008	87	62	184
May 1	877	93	64	192	Sept. 10	1,009	87	61	183
May 2	878	92	65	191	Sept. 11	1,010	87	62	183
May 3	879	93	65	191	Sept. 12	1,011	87	61	183
May 4	880	92	64	190	Sept. 13	1,012	87	62	183
May 5	881	92	65	191	Sept. 14	1,013	87	61	183
May 6	882	93	65	190	Sept. 15	1,014	87	61	183
May 7	883	93	64	190	Sept. 16	1,015	87	62	182
May 8	884	92	65	191	Sept. 17	1,016	87	61	183
May 9	885	93	64	190	Sept. 18	1,017	88	62	182
May 10	886	92	65	191	Sept. 19	1,018	87	61	183
May 11	887	91	64	190	Sept. 20	1,019	86	61	182
May 12	888	92	65	191	Sept. 21	1,020	87	61	183
May 13	889	91	65	190	Sept. 22	1,021	87	62	182
May 14	890	92	65	190	Sept. 23	1,022	87	61	183
May 15	891	91	64	191	Sept. 24	1,023	86	62	182
May 16	892	91	64	190	Sept. 25	1,024	86	61	183
May 17	893	92	64	190	Sept. 26	1,025	87	61	183
May 18	894	91	65	189	Sept. 27	1,026	86	61	182
May 19	895	92	64	190	Sept. 28	1,027	87	62	182
May 20	896	91	65	189	Sept. 29	1,028	86	61	182
May 21	897	92	64	190	Sept. 30	1,029	86	61	182
May 22	898	91	65	190	Oct. 1	1,030	86	62	182
May 23	899	92	64	190	Oct. 2	1,031	87	61	182
May 24	900	91	65	189	Oct. 3	1,032	87	60	182
May 25	901	90	65	189	Oct. 4	1,033	86	60	181
May 26	902	90	64	190	Oct. 5	1,034	87	60	182
May 27	903	91	65	189	Oct. 6	1,035	86	61	182
May 28	904	91	64	189	Oct. 7	1,036	86	60	181
May 29	905	90	64	188	Oct. 8	1,037	86	60	180
May 30	906	91	64	189	Oct. 9	1,038	86	60	181
May 31	907	91	65	188	Oct. 10	1,039	86	61	180
June 1	908	90	64	189	Oct. 11	1,040	86	61	181
June 2	909	90	65	188	Oct. 12	1,041	86	61	180
June 3	910	91	64	188	Oct. 13	1,042	87	60	181
June 4	911	90	64	189	Oct. 14	1,043	86	60	181
June 5	912	91	65	189	Oct. 15	1,044	87	61	180
June 6	913	91	64	189	Oct. 16	1,045	86	60	181

Table A-1.-Bottom hole pressure data, pounds (force) per square inch, gauge-Continued

Date	Day number	Pressure, lbf/in²(ga) M1	M2	M3	Date	Day number	Pressure, lbf/in²(ga) M1	M2	M3
1984-Con.					1984-Con.				
Oct. 17	1,046	87	61	180	Dec. 23	1,113	77	58	173
Oct. 18	1,047	86	60	181	Dec. 24	1,114	78	58	173
Oct. 19	1,048	87	61	180	Dec. 25	1,115	78	58	173
Oct. 20	1,049	86	61	180	Dec. 26	1,116	77	58	173
Oct. 21	1,050	86	61	181	Dec. 27	1,117	77	58	173
Oct. 22	1,051	87	60	180	Dec. 28	1,118	78	58	172
Oct. 23	1,052	86	61	181	Dec. 29	1,119	77	58	172
Oct. 24	1,053	86	61	181	Dec. 30	1,120	76	58	172
Oct. 25	1,054	87	60	181	Dec. 31	1,121	77	58	170
Oct. 26	1,055	87	60	181	1985:				
Oct. 27	1,056	87	60	180	Jan. 1	1,122	75	58	171
Oct. 28	1,057	86	60	181	Jan. 2	1,123	76	58	171
Oct. 29	1,058	86	61	180	Jan. 3	1,124	76	58	171
Oct. 30	1,059	87	60	180	Jan. 4	1,125	75	59	171
Oct. 31	1,060	86	60	180	Jan. 5	1,126	76	59	171
Nov. 1	1,061	86	60	179	Jan. 6	1,127	75	58	169
Nov. 2	1,062	85	60	179	Jan. 7	1,128	75	59	170
Nov. 3	1,063	86	61	179	Jan. 8	1,129	75	59	169
Nov. 4	1,064	85	60	180	Jan. 9	1,130	74	58	169
Nov. 5	1,065	85	61	180	Jan. 10	1,131	74	58	168
Nov. 6	1,066	84	60	178	Jan. 11	1,132	74	59	169
Nov. 7	1,067	85	60	179	Jan. 12	1,133	74	59	168
Nov. 8	1,068	83	60	178	Jan. 13	1,134	75	59	169
Nov. 9	1,069	83	61	179	Jan. 14	1,135	74	58	168
Nov. 10	1,070	84	60	179	Jan. 15	1,136	75	59	167
Nov. 11	1,071	84	61	178	Jan. 16	1,137	75	58	168
Nov. 12	1,072	84	61	179	Jan. 17	1,138	74	58	168
Nov. 13	1,073	83	60	178	Jan. 18	1,139	73	58	167
Nov. 14	1,074	83	61	179	Jan. 19	1,140	74	59	166
Nov. 15	1,075	82	61	179	Jan. 20	1,141	73	59	167
Nov. 16	1,076	83	60	178	Jan. 21	1,142	73	58	166
Nov. 17	1,077	82	59	178	Jan. 22	1,143	73	58	167
Nov. 18	1,078	82	59	179	Jan. 23	1,144	73	59	165
Nov. 19	1,079	83	60	178	Jan. 24	1,145	74	58	165
Nov. 20	1,080	82	60	177	Jan. 25	1,146	73	58	166
Nov. 21	1,081	82	59	177	Jan. 26	1,147	74	58	164
Nov. 22	1,082	81	59	177	Jan. 27	1,148	73	58	165
Nov. 23	1,083	82	59	178	Jan. 28	1,149	74	58	164
Nov. 24	1,084	81	59	177	Jan. 29	1,150	73	59	164
Nov. 25	1,085	82	60	175	Jan. 30	1,151	72	58	163
Nov. 26	1,086	82	59	174	Jan. 31	1,152	72	59	163
Nov. 27	1,087	80	60	174	Feb. 1	1,153	72	58	164
Nov. 28	1,088	81	59	174	Feb. 2	1,154	72	59	163
Nov. 29	1,089	80	60	175	Feb. 3	1,155	72	58	162
Nov. 30	1,090	81	60	174	Feb. 4	1,156	72	58	162
Dec. 1	1,091	79	59	174	Feb. 5	1,157	73	58	163
Dec. 2	1,092	79	60	173	Feb. 6	1,158	71	59	163
Dec. 3	1,093	79	59	175	Feb. 7	1,159	72	59	161
Dec. 4	1,094	79	60	174	Feb. 8	1,160	71	59	161
Dec. 5	1,095	79	59	174	Feb. 9	1,161	72	59	161
Dec. 6	1,096	80	59	174	Feb. 10	1,162	71	59	161
Dec. 7	1,097	80	59	174	Feb. 11	1,163	72	59	160
Dec. 8	1,098	80	60	174	Feb. 12	1,164	71	59	161
Dec. 9	1,099	79	59	174	Feb. 13	1,165	72	58	160
Dec. 10	1,100	79	60	175	Feb. 14	1,166	71	59	160
Dec. 11	1,101	79	59	176	Feb. 15	1,167	70	59	160
Dec. 12	1,102	80	59	175	Feb. 16	1,168	70	59	159
Dec. 13	1,103	78	59	176	Feb. 17	1,169	70	59	158
Dec. 14	1,104	79	58	175	Feb. 18	1,170	71	59	159
Dec. 15	1,105	79	58	174	Feb. 19	1,171	70	58	158
Dec. 16	1,106	78	59	175	Feb. 20	1,172	70	59	158
Dec. 17	1,107	78	59	175	Feb. 21	1,173	70	58	157
Dec. 18	1,108	77	58	175	Feb. 22	1,174	70	58	157
Dec. 19	1,109	78	58	174	Feb. 23	1,175	70	59	156
Dec. 20	1,110	77	59	174	Feb. 24	1,176	69	58	157
Dec. 21	1,111	78	59	175	Feb. 25	1,177	70	58	156
Dec. 22	1,112	77	58	173	Feb. 26	1,178	70	58	157

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, $lbf/in^2(ga)$		
		M1	M2	M3
1985–Con.				
Feb. 27	1,179	70	58	157
Feb. 28	1,180	70	59	156
Mar. 1	1,181	70	59	156
Mar. 2	1,182	69	59	155
Mar. 3	1,183	70	58	155
Mar. 4	1,184	69	59	155
Mar. 5	1,185	70	58	154
Mar. 6	1,186	69	58	154
Mar. 7	1,187	69	58	153
Mar. 8	1,188	68	57	153
Mar. 9	1,189	68	58	152
Mar. 10	1,190	69	57	153
Mar. 11	1,191	68	58	152
Mar. 12	1,192	68	57	151
Mar. 13	1,193	68	57	152
Mar. 14	1,194	67	58	151
Mar. 15	1,195	67	57	150
Mar. 16	1,196	67	58	151
Mar. 17	1,197	68	57	150
Mar. 18	1,198	67	57	150
Mar. 19	1,199	68	56	149
Mar. 20	1,200	68	56	149
Mar. 21	1,201	67	56	149
Mar. 22	1,202	67	57	149
Mar. 23	1,203	67	56	147
Mar. 24	1,204	67	56	147
Mar. 25	1,205	67	57	148
Mar. 26	1,206	66	56	147
Mar. 27	1,207	67	56	146
Mar. 28	1,208	67	57	146
Mar. 29	1,209	67	57	146
Mar. 30	1,210	66	56	146
Mar. 31	1,211	66	57	144
Apr. 1	1,212	66	57	145
Apr. 2	1,213	67	56	144
Apr. 3	1,214	66	57	144
Apr. 4	1,215	66	56	144
Apr. 5	1,216	65	57	143
Apr. 6	1,217	65	57	142
Apr. 7	1,218	66	57	143
Apr. 8	1,219	66	56	142
Apr. 9	1,220	65	57	142
Apr. 10	1,221	64	56	141
Apr. 11	1,222	64	57	140
Apr. 12	1,223	64	56	141
Apr. 13	1,224	65	57	140
Apr. 14	1,225	65	56	139
Apr. 15	1,226	65	57	139
Apr. 16	1,227	64	56	139
Apr. 17	1,228	64	57	139
Apr. 18	1,229	65	56	138
Apr. 19	1,230	64	57	137
Apr. 20	1,231	63	56	137
Apr. 21	1,232	63	57	136
Apr. 22	1,233	63	56	137
Apr. 23	1,234	64	57	135
Apr. 24	1,235	63	56	136
Apr. 25	1,236	64	57	135
Apr. 26	1,237	63	56	135
Apr. 27	1,238	63	57	135
Apr. 28	1,239	63	56	134
Apr. 29	1,240	64	57	132
Apr. 30	1,241	63	56	133
May 1	1,242	63	56	131
May 2	1,243	63	57	131
May 3	1,244	62	56	130
May 4	1,245	62	57	131

Date	Day number	Pressure, $lbf/in^2(ga)$		
		M1	M2	M3
1985–Con.				
May 5	1,246	63	56	130
May 6	1,247	62	57	129
May 7	1,248	63	57	128
May 8	1,249	62	56	127
May 9	1,250	62	57	127
May 10	1,251	63	56	126
May 11	1,252	62	56	127
May 12	1,253	63	56	126
May 13	1,254	62	55	125
May 14	1,255	61	56	125
May 15	1,256	62	56	124
May 16	1,257	61	55	123
May 17	1,258	61	56	123
May 18	1,259	62	56	123
May 19	1,260	61	55	122
May 20	1,261	61	56	120
May 21	1,262	61	56	120
May 22	1,263	61	55	119
May 23	1,264	61	55	119
May 24	1,265	60	55	117
May 25	1,266	61	56	117
May 26	1,267	61	55	115
May 27	1,268	61	56	114
May 28	1,269	60	56	114
May 29	1,270	61	56	114
May 30	1,271	60	55	113
May 31	1,272	61	55	112
June 1	1,273	61	56	111
June 2	1,274	60	55	110
June 3	1,275	61	56	109
June 4	1,276	60	56	108
June 5	1,277	60	55	108
June 6	1,278	60	55	107
June 7	1,279	60	56	106
June 8	1,280	60	55	104
June 9	1,281	59	56	104
June 10	1,282	60	56	103
June 11	1,283	59	56	102
June 12	1,284	58	56	100
June 13	1,285	58	55	99
June 14	1,286	58	56	99
June 15	1,287	58	55	98
June 16	1,288	58	56	98
June 17	1,289	59	56	98
June 18	1,290	58	55	98
June 19	1,291	59	55	96
June 20	1,292	58	55	94
June 21	1,293	59	55	94
June 22	1,294	59	55	93
June 23	1,295	59	55	93
June 24	1,296	58	55	92
June 26	1,298	58	55	91
June 27	1,299	59	54	90
June 28	1,300	59	55	89
July 7	1,309	NR	NR	85
July 11	1,313	NR	NR	83
July 13	1,315	NR	NR	81
July 14	1,316	NR	NR	82
July 16	1,318	NR	NR	79
July 17	1,319	NR	NR	79
July 18	1,320	57	NR	80
July 19	1,321	NR	NR	78
July 20	1,322	57	NR	78
July 30	1,332	56	NR	74
Aug. 2	1,335	55	NR	NR
Aug. 5	1,338	56	NR	73
Aug. 6	1,339	56	NR	73

Table A-1.–Bottom hole pressure data, pounds (force) per square inch, gauge–Continued

Date	Day number	Pressure, lbf/in^2(ga)		
		M1	M2	M3
1985–Con.				
Aug. 7	1,340	54	NR	72
Aug. 8	1,341	54	NR	72
Aug. 12	1,345	55	NR	70
Aug. 13	1,346	54	NR	71
Aug. 14	1,347	55	NR	70
Aug. 15	1,348	54	NR	69
Aug. 16	1,349	55	NR	70
Aug. 19	1,352	55	NR	69
Aug. 20	1,353	54	NR	68
Aug. 21	1,354	53	NR	68
Aug. 22	1,355	54	NR	68
Aug. 23	1,356	53	NR	68
Aug. 28	1,361	53	NR	67
Aug. 29	1,362	53	NR	67
Aug. 30	1,363	54	NR	67
Sept. 1	1,365	52	NR	66
Sept. 2	1,366	52	NR	66
Sept. 3	1,367	52	NR	66
Sept. 4	1,368	53	NR	65
Sept. 5	1,369	53	NR	65
Sept. 6	1,370	53	NR	64
Sept. 7	1,371	53	NR	64
Sept. 8	1,372	53	NR	64
Sept. 9	1,373	53	NR	64
Sept. 10	1,374	53	NR	63
Sept. 11	1,375	52	NR	63
Sept. 12	1,376	52	NR	63
Sept. 13	1,377	52	NR	63
Sept. 14	1,378	52	NR	62
Sept. 15	1,379	52	NR	62
Sept. 16	1,380	52	NR	62
Sept. 17	1,381	52	NR	62
Sept. 18	1,382	52	NR	61
Sept. 19	1,383	52	NR	61
Sept. 20	1,384	52	NR	61
Sept. 25	1,389	51	NR	61
Sept. 27	1,391	51	NR	60
Sept. 28	1,392	51	NR	60
Sept. 29	1,393	51	NR	60
Oct. 2	1,396	51	NR	58
Oct. 3	1,397	50	NR	58
Oct. 9	1,403	NR	NR	58
Oct. 11	1,405	NR	NR	58
Oct. 14	1,408	NR	NR	57
Oct. 15	1,409	NR	NR	56
Oct. 16	1,410	NR	NR	56
Oct. 17	1,411	NR	NR	56
Oct. 18	1,412	NR	NR	56
Oct. 22	1,416	NR	NR	56
Oct. 23	1,417	NR	NR	55
Oct. 24	1,418	NR	NR	54
Oct. 28	1,422	NR	NR	54
Oct. 29	1,423	NR	NR	54
Oct. 30	1,424	NR	NR	54
Oct. 31	1,425	NR	NR	54
1986:				
Aug. 14	1,712	NR	NR	28

NR Not recorded.

APPENDIX B.–MONITOR WELL CORE ANALYSIS DATA

Table B-1.–Gas content determination for monitor wells

Monitor well and sample	Sample interval, ft	Laboratory gas content determination: Coal sample dry weight, g: Entire sample	Coal sample dry weight, g: Residual gas portion[1]	Gas volume, cm^3: Lost and desorbed	Gas volume, cm^3: Residual[2]	Gas content, cm^3/g: Lost and desorbed	Gas content, cm^3/g: Residual	Gas content, cm^3/g: Total[3]	Estimated in situ gas content, ft^3/st
M1:									
D	1,077.00-1,078.47	1,204	382	9,237	185	7.7	0.5	8.2	263
C	1,078.47-1,079.94	1,197	462	9,137	190	7.6	.4	8.0	256
A	1,079.94-1,081.67	1,309	446	8,790	360	6.7	.8	7.5	240
B	1,081.67-1,082.60	839	378	4,934	280	5.9	.7	6.6	211
Total or average		4,549	1,668	32,098	1,015	[4]7.0	[4].6	[4]7.6	[4]244
M2:									
B	1,086.20-1,087.86	1,564	561	10,167	200	6.5	.4	6.9	221
C	1,087.86-1,089.74	1,753	857	10,736	350	6.1	.4	6.5	208
A	1,089.74-1,091.50	1,575	395	9,530	340	6.0	.9	6.9	221
D	1,091.50-1,093.20	1,493	564	8,618	350	5.8	.6	6.4	205
Total or average		6,385	2,377	39,051	1,240	[4]6.1	[4].5	[4]6.6	[4]211
M3:									
A	1,066.60-1,069.20	1,312	449	13,136	105	10.0	.2	10.2	327
B	1,069.20-1,070.11	696	312	7,215	230	10.4	.7	11.1	356
C	1,070.11-1,071.61	1,038	321	10,796	220	10.4	.7	11.1	356
D	1,071.61-1,072.50	674	292	7,473	200	11.1	.7	11.8	378
Total or average		3,720	1,374	38,620	755	[4]10.4	[4].5	[4]10.9	[4]350

[1]Residual gas was measured for only this portion of the entire sample.
[2]This gas came from crushing the part of the entire sample indicated in the column labeled "Residual gas portion."
[3]The sum of the lost and desorbed gas content and the residual gas content.
[4]Computed from totals.

Table B-2.–Proximate analysis and total sulfur, dry weight percent

Well and sample	Volatile matter	Fixed carbon	Ash	Ash-free volatile matter	Total sulfur
M1:					
D	19.2	73.7	7.1	20.7	0.52
C	19.4	71.1	9.5	21.4	.47
A	18.5	71.6	9.9	20.5	.49
B	17.9	70.5	11.6	20.2	.48
Composite[1]	18.7	71.1	10.2	20.8	.44
M2:					
B	18.9	71.9	9.2	20.8	.47
C	19.1	71.4	9.5	21.1	.47
A	19.2	73.2	7.6	20.8	.45
D	20.1	71.2	8.7	22.0	.46
Composite[1]	19.4	72.0	8.6	21.2	.44
M3:					
A	19.2	72.0	8.8	21.1	.53
B	19.8	70.0	10.2	22.0	.45
C	18.5	70.9	10.6	20.7	.48
D	20.9	73.3	5.8	22.2	.53
Composite[1]	19.3	70.3	10.4	21.5	.44

[1]Sample made of coal from samples A through D; not an average of data.

Table B-3.–Ultimate analysis and calorific value

Well	Ultimate analysis, dry wt pct						Calorific value, Btu/lb dry wt
	Carbon	Hydrogen	Nitrogen	Oxygen	Sulfur	Ash	
M1	81.72	4.38	1.66	2.37	0.44	9.43	14,133
M2	80.39	4.30	1.71	2.88	.44	10.28	13,984
M3	81.46	4.40	1.53	2.41	.44	9.76	14,010

Table B-4.–Ash composition, percent

Well	SiO_2	Al_2O_3	MgO	P_2O_5	TiO_2	MnO	CaO	K_2O_5	Fe_2O_3	Na_2O	SO_3
M1	46.35	32.84	1.02	0.54	1.62	0.02	5.65	1.51	5.63	0.44	4.19
M2	47.97	34.40	1.04	.50	1.71	.02	3.36	1.63	6.11	.39	2.79
M3	45.54	32.50	1.48	.48	1.68	<.02	5.30	1.62	6.12	.44	4.17

Table B-5.–Petrographic entity composition of samples from monitor well M2, percent

Technique and sample	Vitrinite	Exinite	Inertinite	Mineral matter	Mean maximum reflectance, in oil
Regular:[1]					
A	67.5	1.2	27.0	4.3	1.62
B	67.1	.9	26.8	5.2	1.65
C	76.0	.1	18.6	5.3	1.64
D	83.5	.1	11.5	4.9	1.59
Composite[2]	71.0	.8	23.4	4.8	1.63
Methylene:[3]					
A	64.1	6.3	25.5	4.1	NAp
B	65.1	3.8	26.0	5.1	NAp
C	73.5	3.4	18.0	5.1	NAp
D	82.2	1.6	11.4	4.8	NAp
Composite[2]	69.0	3.6	22.7	4.7	NAp

NAp Not applicable.
[1]Regular immersion lens and oil.
[2]Composite sample made up of coal from samples A, B, C, and D (not an average of data from those samples).
[3]Methylene iodide lens and oil.