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Drilling, Completion, Stimulation, and Testing of Hardy HW#1 Well, Putnam County, West Virginia

Final Report

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ABSTRACT

This report discusses the detailed field operations in drilling, logging, casing, completing, stimulating and testing the Hardy HW#1 well located in Union District, Putnam County, West Virginia. The project was designed and managed by BDM in cooperation with Cabot Oil and Gas Corporation. The well was spudded on November 29, 1989 and was completed at a total measured depth of 6406 feet on December 29, 1989. The well was drilled on an average azimuth of 335 degrees with a total horizontal displacement of 2618 feet. Approximately 1035 feet of the well had an inclination higher than 86 degrees, while 2212 feet of the well had an inclination greater than 62 degrees. The well was partitioned into five zones for stimulation purposes. Four zones were stimulated during three stimulation operations (Zones 3 and 4 were stimulated together). Zone 1 stimulation was a successful foam frac while the stimulations on Zones 2, 3-4 were partially successful. Initial gas production rates were 4.5 times greater than the natural production rate. After 21 months, gas produced from the BDM/Cabot well has declined at a rate about one-half that of a conventional vertical well in the area. This horizontal well is projected to produce 475 million cubic feet of gas over a 30-year period.

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1.0 EXECUTIVE SUMMARY

The Cabot Oil & Gas Hardy HW#1 well was spudded on November 29, 1989, and drilling was completed at a total measured depth of 6,399 feet on December 29, 1989. The well was drilled on an average azimuth of 335°, with a total horizontal displacement of 2618 feet. Approximately 1035 feet of the well had an inclination higher than 86° (horizontal), while 2212 feet of the well had an inclination greater than 62 degrees. The well was turned to a 90 degree inclination over a measured course length of 1346 feet which is a true vertical depth (radius) of 829 feet.

The inclined well encountered 59 shows of gas with a calculated volume of more than 2 mcfpd. Twelve gas shows had calculated volumes greater than 50 mcfpd, the largest of which was 178 mcfpd.

After reaching the kick-off point at 3253 feet, it required only 35 hours of drilling time to turn the well to a 90 degree inclination (horizontal at an average penetration rate of 41.0 feet per hour). The horizontal section was drilled with conventional rotary tools with a 7-7/8" bit and the rate of penetration was 46.5 feet per hour. During drilling of the shallow vertical section of the hole, the average rate of penetration was 26.6 feet per hour for drilling both the 17 1/2" and 12 1/4" hole down to the KOP. When a strong flow of water was encountered in the Big Injun Sand and the well was mudded up, penetration rate dropped to 12.2 feet per hour.

Steering tool operations were the most costly and time consuming during drilling. Seven steering tool failures were encountered which resulted in delays of four days in the drilling operations.

Logging operations were beset with operational problems which provided an incomplete video survey of the borehole (to a depth of only 4550 feet) and successful geophysical logs going into the hole only. The available logs along with the mud logs were used to select the locations of the five external casing packers and the four ported collars in the casing string.

The improvements in downhole motors have increased penetration rates to the point where they are nearly equal to those of vertical air-drilling rates. The Hardy HW#1 well was drilled in twenty-eight days less time than the first air-drilled horizontal well which was drilled in 1986 (RET#1).

The well was completed with five (5) casing packers and five (5) port collars included in the string of J-55, 10.5 lb/ft 4.5 inch casing. A section of the casing in the inclined portion of the wellbore was cemented with 130 sacks of class A cement between 4057' and 3500' as a permanent barrier to water. Thus the wellbore was configured into four separate zones for stimulation purposes.

During stimulation activities, the port collars did not function as advertised by the vendor, and their opening and closing tools had to be modified in the field to make them work. This made stimulation and clean-up operations much more difficult and costly than anticipated.

Zone one (1) was broken down with nitrogen and fraced with 80 Quality foam and sand. Although the actual volumes injected were somewhat less than planned, the first stimulation was accomplished without too many problems. Zone two (2) was a different story. Two attempts were made before the well was partially fraced with foam at a much lower injection rate than originally planned. Zones 3 and 4 could be pumped into with nitrogen, but they would not accept foam, even at very low injection rates and without sand. These two zones were finally stimulated by pumping straight nitrogen into the zones at the highest rate possible without exceeding the established pressure limit.

The well was cleaned-up after stimulation, and pressure build-up and drawdown tests were conducted to determine the success of stimulation operations. An improvement ratio of 4.5 times natural production rate was determined as a result of the well testing activities.

The well is expected to produce 475 million cubic feet of gas over the next 30 years. Ultimate production before abandonment could well be double that amount. Production records examined for the first 21 months

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The well is expected to produce 475 million cubic feet of gas over the next 30 years. Ultimate production before abandonment could well be double that amount. Production records examined for the first 21 months of production indicate the rate of production decline from the horizontal well is about half the rate exhibited by vertical wells in the area.

2.0 INTRODUCTION

As part of an ongoing Department of Energy Program to test emerging technology as methods of producing additional natural gas resources at economic rates, the Morgantown Energy Technology Center has for more than twenty years been exploring the concept of horizontal drilling as an advanced technology concept to improve gas and oil recovery efficiency.

The first successful air-drilled horizontal well was designed and drilled by BDM International for DOE in 1986 (Reference 1) in Wayne County, West Virginia, in conjunction with a small industry partner. BDM Engineering Services Company (BDMESC), a subsidiary of BDM International, was awarded a second competitive contract in 1989 to continue to explore the economics of drilling, completing and producing horizontal wells in tight, resource rich, Devonian shales of the Appalachian basin.

BDMESC proposed a cost sharing arrangement with Cabot Oil and Gas Corporation whereby they provide leases for drilling, share in the well costs, and serve as operator for drilling and production operations. BDMESC conducted geologic studies, selected the drill sites to be approved by Cabot and DOE , designed the well, and supervised drilling and completion operations.

3.0 LEASE ACQUISITION AND LOCATION DEVELOPMENT

The results of a detailed geologic study and reservoir analysis of three areas in Putnam County, West Virginia, where Cabot Oil and Gas had 40,000 acres under lease were reported in a topical report "Selection of Geographic Area and Specific Site for Drilling a Horizontal Well in Cooperation with Cabot Oil and Gas Company." Area 2 in Union District near the village of Extra was selected as the specific area. The specific site and orientation of the well with respect to structure on the base of the Huron Shale is shown in Figure 3.1. Location of postulated fracture zones is indicated by the dashed line on Figure 3.1.

The location was presented to Cabot Oil and Gas who then proceeded to develop a production unit outline and to clear the titles for the leases included for drilling operations. The proposed production unit is shown in Figure 3.2 along with the location of a postulated 300 million cubic feet production fairway which would be crossed by the horizontal well.

Considerable problems were encountered by Cabot in obtaining a clear title for the included leases as a result of a survey problem which occurred thirty or more years ago. The lease was finally cleared after three months of legal examination and resurveying of the involved properties. The staked location was surveyed on the ground and a drilling permit obtained from the West Virginia Oil and Gas Division of the West Virginia Department of Mines and Mineral Resources.

4.0 DRILLING PLAN SUMMARY

The Hardy HW#1 Well was to be drilled as a horizontal well in the Lower Huron Shale to improve productivity. The well was designed to be drilled vertically to a kick-off point 716' below the top of the Berea Formation (approximately 3236' below GL). A string of 13 3/8" surface casing was to be set at 655' to isolate fresh water and coal. A 9 5/8" intermediate string was to be set through the Berea Formation to isolate potential water and hydrocarbon bearing intervals.

At the kick-off point, the inclination was to be built with a downhole motor and steering tool at a rate of 8°/100' to an inclination of 87°. Then, 2000 feet of wellbore would be drilled in the target interval with a rotary assembly. The assembly would be designed to drop angle at approximately 0.25°/100' causing the wellbore to drop out of the target interval at the end of the 2000 feet.

The preferred azimuth of the wellbore was 340° which is nearly orthogonal to the natural fractures in the area. Provided the well stayed within the pooled acreage, direction would not be a problem. In relation to

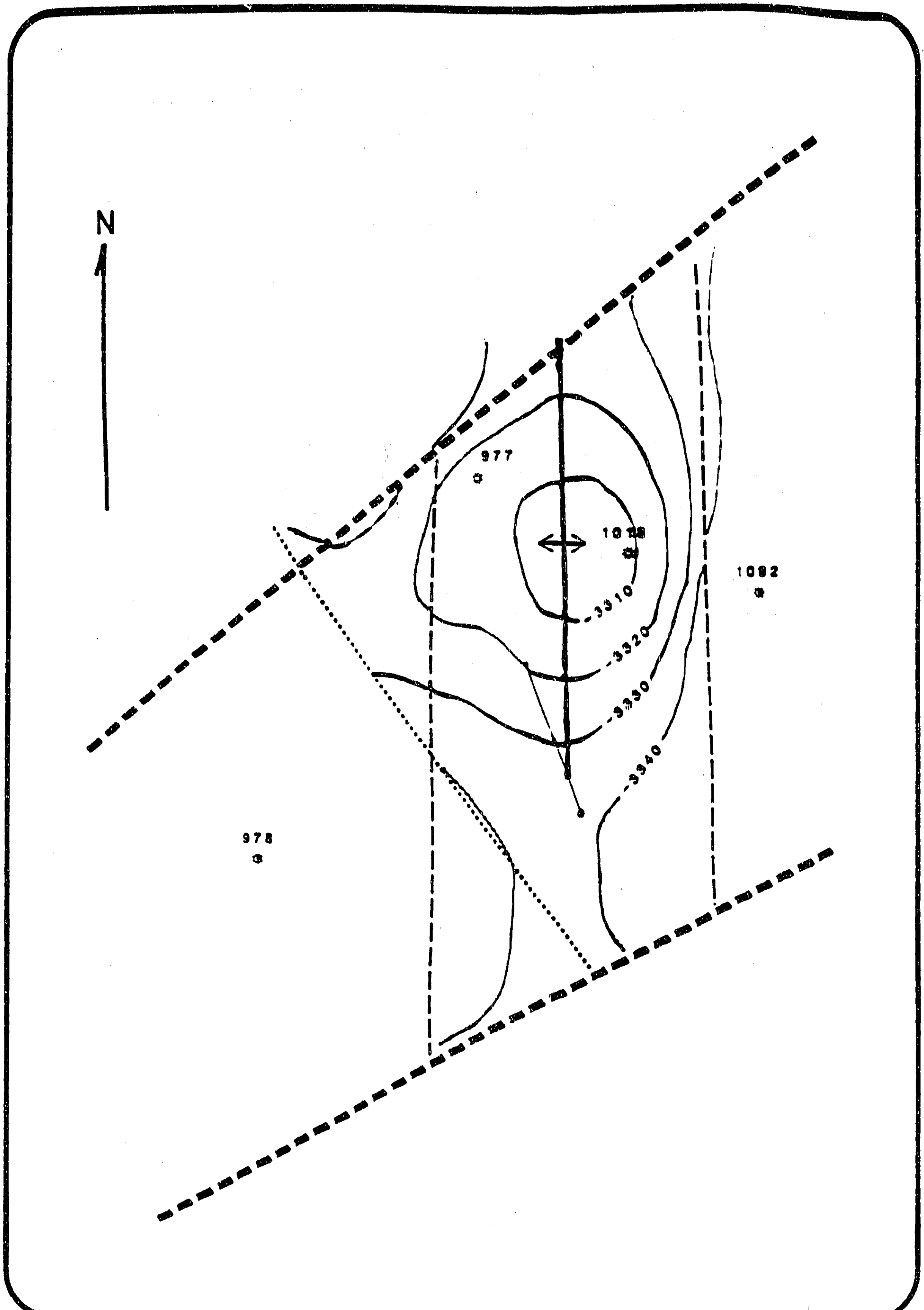

Figure 3.1 - Relationship of the Planned Wellbore Trajectory to Structure on the Base of the Huron Shale

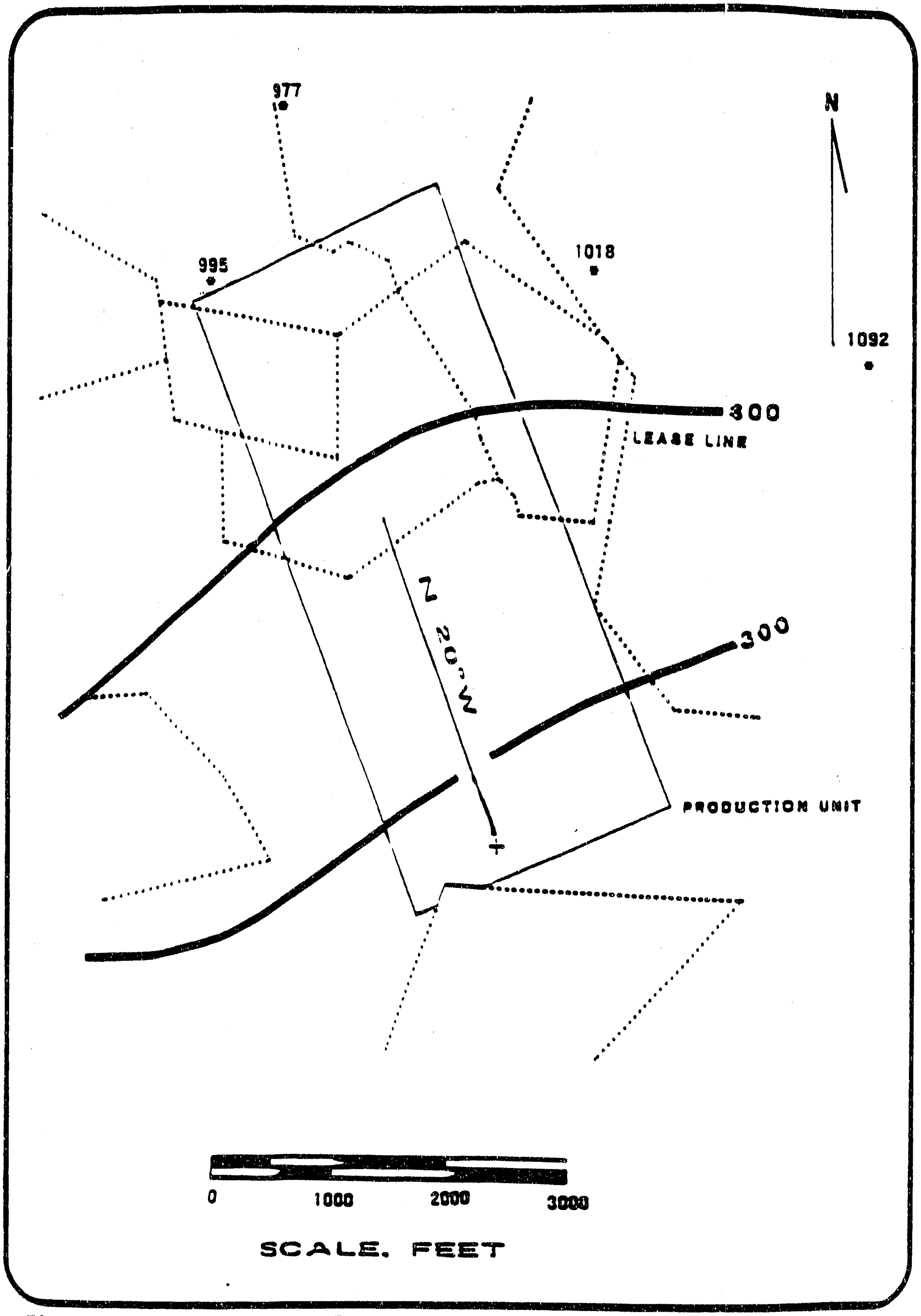

Figure 3.2- Location and Trajectory of Planned Horizontal Well Across a 3-Lease Production Unit

TVD, the top of the target interval was 1431feet below the top of the Berea and the bottom was 1610 feet below the top of the Berea. Total target thickness was 179 feet.

After reaching total depth, the well would be logged with wireline free fall and drill pipe conveyed open hole logs and a video camera. Then 4 1/2" casing would be run using external casing packers to isolate individual producing intervals. The placement of the external casing packers and port collars would be determined using mud log data, open hole geophysical well logs, and the video camera.

5.0 DRILLING OPERATIONS

5.1 Introduction

Drilling operations were conducted at the site between November 29, 1989 and January 2, 1990. Total days on location were 30 compared to the anticipated 24 days (excluding the four day shut down over Christmas). A plot of depth versus time in days can be seen in Figure 5.1 with the plot comparing actual and projected times.

Drilling the vertical portion of the well to the kick-off point took four days longer than anticipated because of an excessive water flow and stuck drill pipe. The angle build section required eight days to drill compared to a planned seven days. Steering tool problems slowed drilling this section of the hole. The horizontal section was planned to be drilled in five days which was the actual time required. Logging required four days of rig time compared to an estimated three days. Drilling from kick-off point to release of the rig took two days longer than had been anticipated.

The horizontal section of the wellbore started at a deeper TVD than had been planned because of problems associated with building inclination with the Eastman motor. The planned build rate was 8°/100' and the Eastman motor assembly averaged 6.7°/100'. The amount of wellbore within the target interval was still 2020'.

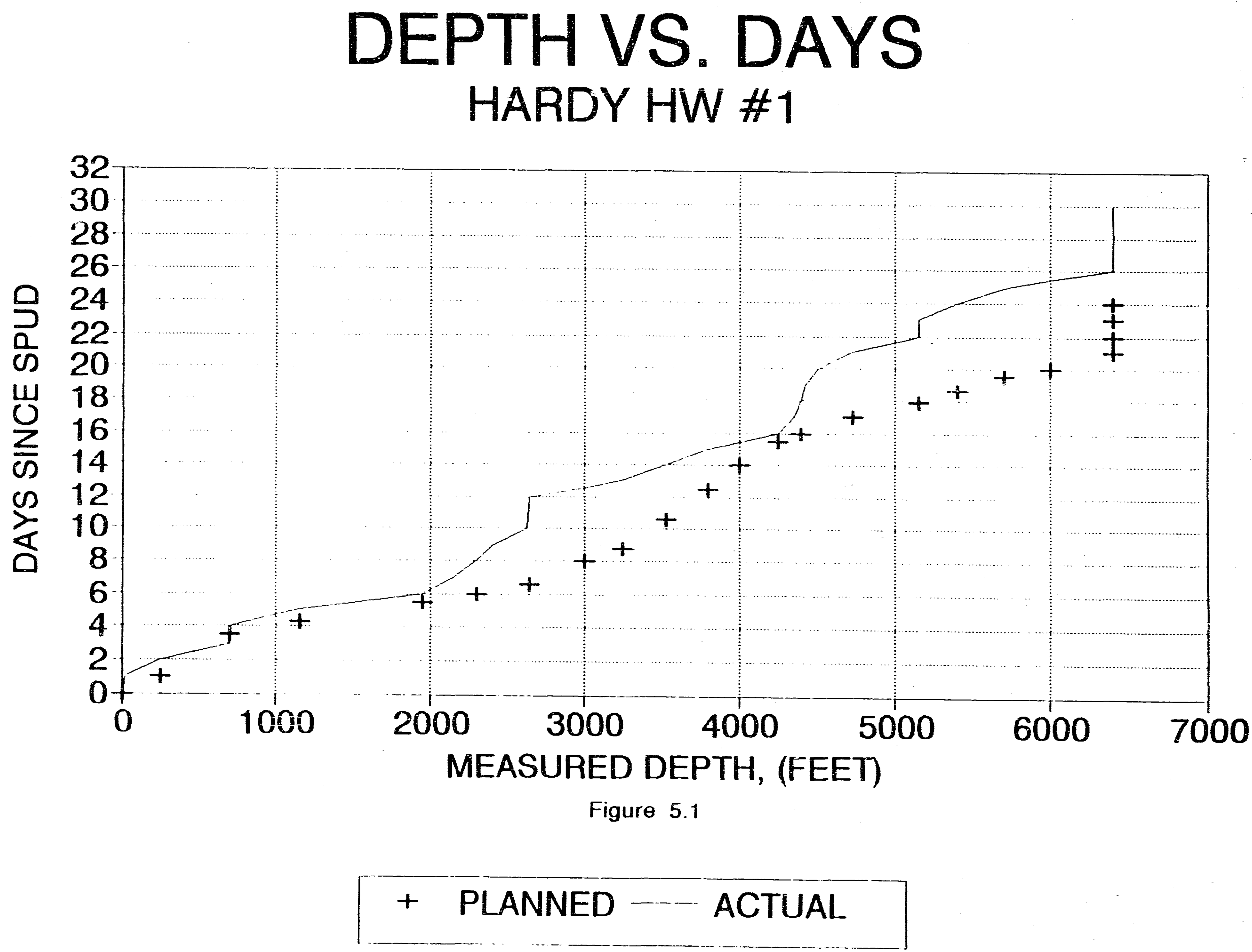
DEPTH VS. DAYS
HARDY HW #1
DAYS SINCE SPUD
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
0
1000
2000
3000
4000
5000
6000
7000
MEASURED DEPTH, (FEET)
+ PLANNED
ACTUAL

Figure 5.1

5.2 Vertical Hole To 3253'

The vertical portion of the well to the kick-off point was drilled on a footage basis by Great Western Drilling[1]. The well was spud at 11:00 pm on November 29, 1989. The conductor hole was drilled to 32 feet below ground level and a 20" conductor pipe was set. A 17 1/2" surface hole was drilled to 696' KB through fresh water zones and coal.

Sixteen joints of 13 3/8", 54.5#/ft, J-55, ST&C casing were run and set at 668' KB (654' GL) to isolate fresh water zones and coal sections as required by the state of West Virginia. The casing tally can be found in Appendix A-1. The casing was cemented to surface with 460 sacks of Class "A" cement containing 2 percent $CaCl_2$. The cement was mixed at 15.6 ppg with a yield of 1.18 ft^3/sack.

The 12 1/4" intermediate hole was drilled to a depth of 1860' when a 3" water flow was encountered in the Maxton sand section. Water from the Maxton had not been expected. The fresh water in the second reserve pit was drained to allow room for the formation water.

Drilling continued using mist until a large water flow was encountered in the Big Injun Formation (2105') where water had been anticipated. A third reserve pit had been constructed to accommodate the additional water. Air and mist drilling continued for less than one hour until the third reserve pit was full. The well was making water in excess of 300 bbls per hour. Air drilling could not continue because there was no place to put the formation water.

At this point, the well was mudded up. A day's worth of rig time was used to rig up a mud pit, mud pump and shale shaker. Once circulation was established, drilling continued with partial returns. Initially, the well was losing around 40 bbls per hour and the loss slowly tapered off.

Drilling was stopped at 2301' feet while the rig crew worked on transferring more water into the mud pit (to make up for partial lost

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[1] Use of company names and/or trademarks are for identification only and do not imply endorsement of a service or product.

circulation). When the crew came back to continue drilling, the drill pipe was differentially stuck. The drill pipe was worked for several hours but remained stuck.

To free the pipe, both aerating the mud and spotting oil were debated as possible solutions. It was assumed that aerating the mud might tear up the hole. So, 80 bbls of crude oil were spotted around the drill collars. Once the oil was spotted, the drill pipe came free in a short period of time.

Drilling then continued to 2657 feet which was the intermediate casing point. The drilling plan called for setting the 9 5/8" casing fifty feet below the base of the Berea Formation. The mud logger showed the top of the Berea to be at 2579 feet.

A string of 9 5/8", 36#/ft, J-55, ST&C casing was run and set at 2654' KB. The 9 5/8" pipe tally can be found in Appendix A-2. The casing was cemented as follows:

> Pumped 15 bbls of fresh water, 330 sacks of Halliburton light cement followed by 100 sacks of Class "A" cement containing 3 percent $CaCl_2$ and 1/8 pps flocele. The cement was displaced with 204 bbls fresh water and the plug was bumped with 1200 psi. The light cement was mixed at 13.6 ppg with a yield of 1.54 ft^3/sack. The Class "A" cement was mixed at 15.6 ppg with a yield of 1.18 ft^3/sack.

While waiting on cement, a gamma ray correlation log was run showing the top of the Berea Formation to be at 2577 feet or about the same depth as picked by the mud logger. The kick- off point would then be 3295 feet; 716 feet below the top of the Berea.

After waiting on cement for 12 hours, the 13 3/8" casing was cut off and welded to the 9 5/8" casing for support. The mud system was rigged down and the air system rigged back up. The BOP's were nippled up and the casing drilled out with an 8 3/4" bit. Drilling continued, dusting, to 3253' when a survey was taken to determine inclination and well direction. The survey showed an inclination of 1° and an azimuth of 279° at a depth of 3191 feet.

5.3 Build Section

Based upon the Berea top, the kick-off point should have been 3295'; however, the kick- off point was changed to 3253' to provide some margin for failure to build angle at the planned rate. The Eastman motor was picked up along with a new 8 3/4" bit. The bend in the motor was set at 1.1° with an 8 3/8" stabilizer below the bend. An 7 7/8" integral blade stabilizer was placed above the motor. (See BHA data in Appendix B-1.)

The motor was tested at the surface and it operated normally. Three 16/32" jets were placed in the bit to reduce air flow rates past the steering tool and increase steering tool life. The jets should have increased the pressure above the motor by 100 psi.

The motor was tripped to bottom and Smith's steering tool was run through a side entry sub to orient the motor. The first motor run drilled from 3253' to 3487' (234') at an average penetration rate of 47 feet per hour. Unfortunately, the build rate (not dogleg severity) experienced with the motor configuration was only 5.9°/100'. Build rates can be seen in the Build and Walk Rate Table in Appendix C. The motor was pulled from the hole to change the adjustable bend and lay down the top 7 7/8" integral blade stabilizer.

The bend was set at the maximum angle of 1.3° which according to Eastman's design program should yield a dogleg severity of 9.5°/100'. The motor was tripped back in the hole and drilling continued to 3603 feet. The build rate after changing the motor configuration was still 6.3°/100'. It would not have been possible to hit the target at that build rate.

The motor was again pulled from the hole. This time a 1.5° bent sub was placed on top of the motor. No experience was available to be able to project build rate for this BHA, so the anticipated build rate was unknown. The motor was tripped back to bottom and the well drilled to 3817 feet. The motor was now building inclination at an average rate of 6.6°/100' which was still not fast enough to hit the target. Formation tendencies were assumed to be contributing to the lower build rates.

Prior to plugging back and sidetracking, one more attempt was made using the Eastman motor. The motor was tripped out of the hole and checked to make sure the bent sub and bent housing were still aligned. The bit size was reduced to 8 1/2" and the jets were left out of the bit. The motor was then tripped back in the hole.

The build rate achieved in the smaller diameter hole was 8.4°/100'. At that rate, the well would be nearly horizontal at TVD of approximately 4100' which was barely acceptable. Drilling continued to 4249' MD when the motor rotated 90° to the right on a connection. The motor was worked back up to high side and the well was drilled to 4324' MD. The survey data from the steering tool indicated that the well was turning to the left and not building much inclination. The geometry of the motor assembly in the hole had changed or the steering tool was no longer oriented properly.

The steering tool was pulled to check and make sure it was working properly. The orienting stinger (mule shoe stinger) had been pulled loose from the probe section when the tool was pulled from the monels. The stinger was left in the latch in. Since the steering tool had been pulled apart (took around 500 lbs of overpull, which is the same as the latch in should take), it was not possible to determine if the tool had still been oriented. The orientation of the probe in relation to the stinger should not have changed as long as the tool was still together.

Not knowing whether the problem was caused by the steering tool or the motor assembly, it was decided to also change out the motor assembly. The Eastman air drilling motor was laid down and a Baker motor with a 2° bent housing was picked up. The Baker motor was run without any stabilizers.

The Baker motor was run in the hole with the same 8 1/2" bit, but the bit was dressed with one 11/32nd and two 14/32nd inch jets. The motor drilled 98 feet but problems with the steering tool prevented drilling any further. However, the survey data indicated that the hole had turned to the left and not built any inclination. It was then obvious that the steering tool had caused the problem with the previous motor run.

At a depth of 4422', the motor was pulled from the hole because of steering tool problems. No more steering tools were available on location so the Geoscience Electronics Electromagnetic MWD (EMWD) was picked up and run in the hole. The jets in the bit were changed to two 11/32nd and one 14/32nd inch to increase the pressure above the motor and reduce the vibration on the EMWD tool.

The motor tagged up ninety feet off bottom. The EMWD was having problems sending information to the surface and the operators felt that having the bit on bottom drilling would increase the signal strength. An effort was made to wash the bit to bottom without success. All indications were that the bit was beginning to drill a new hole. After washing (drilling with little resistance) five to ten feet, the motor was pulled from the hole. Drilling ahead without tool face data was deemed too risky and drilling operations were halted until a steering tool was obtained.

Smith's three axis steering tool arrived on location and the motor was run back in the hole. It was not possible to get the motor back in the old hole and the well ended up sidetracked above 4338'. The motor drilled to 4502' and the steering tool failed again. The tool had come apart and the motor had to be pulled to retrieve the remainder of the steering tool.

The motor was run back in the hole and drilled to 4610' at which point the inclination should have been 90° with an azimuth of 340°. The motor was pulled and laid down. The rest of the well was drilled with rotary assemblies.

A multishot survey (See Appendix D) later showed that the well reached 90° at a TVD of 4082' which was 72 feet deeper than planned.

Hole cleaning was still a minor problem in the build section while running the motors. As in the previous well, cuttings would build up at an inclination of around 60° and the hole would have to be circulated to remove the drill pipe. Although, without foam as a lubricating fluid, fewer joints had to be circulated out of the hole. When running rotary assemblies, no hole cleaning problems were experienced even at the same air flow rates.

5.4 Horizontal section

The horizontal/slant section was drilled from 4610' MD to 6399' MD using rotary assemblies. The drilling plan had called for using the same rotary assembly that had been used in the Wayne County well. That assembly had dropped approximately 0.25°/100' while drilling the horizontal section. Since the TVD was deeper than expected, the button cutters in the near bit reamer were replaced with flat cutters to reduce the amount of side cutting by the reamer while drilling. The effect should be to decrease the rate of drop or to increase inclination.

Bottom hole assembly number 6 was run in the hole at 4610'. (See Appendix B-2). The hole size was reduced to 7-7/8" so that the build section would not have to be reamed and so that the external casing packers would have a better chance of sealing in a washed out area. The 7-7/8" bit was dressed with three 16/32" jets.

The area of the hole that had been sidetracked at approximately 4338' stopped the rotary assembly; but with a little work, the assembly passed without a problem. The assembly drilled to a depth of 5126' MD.

The wellbore needed to drop back through the target interval so the building assembly was pulled and a dropping assembly run. The dropping assembly is assembly number 7 in Appendix B-2. The assembly should have dropped inclination at a rate of 1 to 1.5°/100'. Unfortunately, the assembly would not go into the right hole. At the sidetrack, the assembly kept going into the short hole. Apparently, the assembly was too stiff to make the corner. A more limber dropping assembly was run hoping it would go into the correct hole. Assembly number 8 (Appendix B-3) with a 10' pony collar in front of the lead reamer was run. Drop rates would probably be higher than that desired but other refinement could not be made in the wellbore. The 10' pendulum assembly had no problem getting into the correct hole.

Drilling operations were shut down over Christmas from 8:00 am on 12/22/89 to 8:00 am on 12/26/89.

When drilling operations continued, the 10' pendulum assembly was run to drill the remainder of the well. Only one more problem was experienced with the sidetracked hole. While trying to take a survey at 5422' MD, the assembly went into the wrong hole several times. After retrieving the survey tool, the assembly went into the correct hole. From then on, the bit was not pulled above the sidetrack point in order to survey.

After reaching a depth of 5670', the pipe would no longer fall into the hole because of excessive down drag. The air rate was increased from 2000 to 2900 scfm for two connections but the hole drag remained constant. Hole cleaning was not a problem. The drill pipe had to be rotated with the slips to get it into the hole. Drill pipe connections were taking 30 to 45 minutes each.

Hole drag also prevented taking additional surveys. Surveys were taken by pulling the bit out of the hole to a depth of 4390'. The singleshot was run into the hole on Smith's releasing overshot. The releasing overshot used a monel sensor to operate. Whenever the tool sensed it was in a nonmagnetic collar, the sensor would activate a motor that would release the survey tool. The slick line and sensor were removed from the hole and the survey tool tripped to bottom. After waiting for the time to take the survey, the bit was again tripped to 4390'. A standard overshot was run on the slick line and the survey tool retrieved. The BHA was tripped back to bottom to continue drilling.

The maximum time that could be set on the survey tool time was 99 minutes. Having to rotate the pipe to bottom, tripping consumed too much time, and the timer would activate before the survey tool ever reached bottom. Therefore, no singleshot surveys were taken below 5372'.

At this depth, it appeared the 10' pendulum was dropping at a rate of 2 to 2.5°/100'. Without good survey data and having limited options available with respect to BHA's, the well was drilled to total depth. Total depth was determined by two factors: when predominantly grey shale was being drilled and no more shows were seen by the mud logging unit. The cuttings showed mostly grey shale below 6220' and the last mud log show was seen at 6168'. Drilling was terminated at a measured depth of 6406'.

The pipe was strapped out of the hole and the measured depth was found to be 6391.47' KB. (See drill pipe tally 12/29/89 in Appendix E). To be certain of the depth, the pipe would be carefully strapped again during the multishot survey.

After reaching total depth, the well was logged. Free fall logs were run first with the video camera falling to 4100' where the inclination was (60°). The open hole logs fell to 4325' where the inclination was (74°). The drill pipe conveyed video log was run to 4550'. Logging was terminated because no signal was being received from the tool. The drill pipe conveyed, open hole logs were run to 6360' depth. For more information on the logs, see Section 6.0 Logging.

After the logging, a multishot survey was run. Surveys were taken every stand (61-62') from 3200' to total depth. Without the reamer, the pipe went in the hole easier. It did not have to be rotated in the hole but still had to be worked down.

The multishot survey showed that the wellbore entered the target interval at a measured depth of 4178' (4010' TVD) and dropped out of the target at a measured depth of 6198' (4178' TVD). These depths corresponded with mud log shows and samples. The drill pipe measurement showed a total depth of 6399.40' KB and the total depth was corrected to that depth. (See multishot pipe strap 1/1/90 in Appendix F.

The azimuth of the surveys between 5000 and 5500 feet showed magnetic interference. The azimuth was almost 180 degrees off. Therefore, the azimuth was left at 339 degrees for calculation purposes. Table 5.1 shows the multishot data. The singleshot data can be found in Appendix G.

Plots of the planned versus actual wellbore path are exhibited in Figures 5.2 and 5.3.

After laying down the drill pipe, 140 joints of 4 1/2", 10.5#/ft, K-55, ST&C casing (including four pup joints) were run in the hole. The casing contained five external casing packers and four port collars. The

Table 5.1

Hardy #1 BDM/DOE/CABOT Horizontal well Multishot Survey

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	TRUE VERTICAL DEPTH	RECTANGULAR COORDINATES NORTH	RECTANGULAR COORDINATES EAST	CLOSURE DISTANCE FEET	CLOSURE AZIMUTH DEGREES	DOGLEG SEVERITY DEG/100'
0.00	0.00	252.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3194.00	0.75	252.00	3194.00	3194.00	0.00	0.00	0.00	0.00	0.00
3256.00	1.50	288.00	62.00	3255.99	0.00	-1.20	1.20	270.00	1.61
3318.00	4.75	322.00	62.00	3317.39	1.91	-3.93	4.37	295.95	5.81
3379.00	8.75	328.00	61.00	3378.45	7.78	-8.03	11.18	314.07	6.65
3441.00	12.50	328.00	62.00	3439.38	17.47	-14.09	22.45	321.11	6.05
3503.00	16.25	326.00	62.00	3499.43	30.38	-22.47	37.79	323.51	6.10
3565.00	20.50	325.00	62.00	3558.25	46.48	-33.54	57.32	324.19	6.87
3627.00	24.25	327.00	62.00	3615.57	66.04	-46.74	80.91	324.72	6.17
3688.00	28.25	330.00	61.00	3670.27	89.04	-60.83	107.83	325.66	6.91
3750.00	32.25	330.00	62.00	3723.32	116.08	-76.44	138.99	326.64	6.45
3812.00	36.50	330.00	62.00	3774.98	146.39	-93.94	173.94	327.31	6.85
3874.00	41.75	330.00	62.00	3823.06	180.26	-113.49	213.02	327.81	8.47
3936.00	46.50	329.00	62.00	3867.55	217.45	-135.40	256.15	328.09	7.74
3997.00	51.75	328.00	61.00	3907.46	256.76	-159.49	302.26	328.15	8.70
4059.00	57.00	328.00	62.00	3943.56	299.48	-186.18	352.64	328.13	8.47
4121.00	62.00	330.00	62.00	3975.02	345.26	-213.69	406.04	328.25	8.53
4183.00	66.75	332.00	62.00	4001.82	394.13	-240.78	461.86	328.58	8.19
4244.00	70.25	330.00	61.00	4024.18	443.76	-268.29	518.56	328.84	6.50
4306.00	72.75	324.00	62.00	4043.85	493.05	-300.30	577.30	328.66	10.02
4368.00	77.50	323.00	62.00	4059.76	541.20	-335.93	636.98	328.17	7.82
4430.00	83.25	326.00	62.00	4070.12	590.94	-371.41	697.96	327.85	10.43
4491.00	84.25	333.00	61.00	4076.76	643.15	-402.16	758.54	327.98	11.52
4553.00	87.25	337.00	62.00	4081.35	699.17	-428.28	819.92	328.51	8.05
4615.00	90.50	338.00	62.00	4082.57	756.43	-452.00	881.19	329.14	5.48
4677.00	91.75	339.00	62.00	4081.35	814.11	-474.72	942.41	329.75	2.58
4739.00	92.25	338.00	62.00	4079.19	871.76	-497.43	1003.69	330.29	1.80
4800.00	93.00	338.00	61.00	4076.40	928.25	-520.26	1064.11	330.73	1.23
4862.00	93.25	339.00	62.00	4073.02	985.85	-542.95	1125.48	331.16	1.66
4924.00	93.75	338.00	62.00	4069.23	1043.43	-565.63	1186.88	331.54	1.80
4986.00	94.00	337.00	62.00	4065.04	1100.98	-588.30	1248.30	331.88	1.66
5047.00	94.25	339.00	61.00	4060.65	1157.79	-610.10	1308.70	332.21	0.41
5109.00	94.75	339.00	62.00	4055.79	1215.49	-632.25	1370.09	332.52	0.81
5171.00	94.00	339.00	62.00	4051.06	1273.20	-654.40	1431.53	332.80	1.21
5233.00	92.75	339.00	62.00	4047.41	1330.98	-676.58	1493.08	333.05	2.02
5294.00	91.75	339.00	61.00	4045.02	1387.89	-698.43	1553.71	333.29	1.64
5356.00	90.25	339.00	62.00	4043.93	1445.76	-720.64	1615.41	333.51	2.42
5418.00	89.00	339.00	62.00	4044.34	1503.64	-742.86	1677.13	333.71	2.02
5480.00	87.25	339.00	62.00	4046.37	1561.49	-765.07	1738.84	333.90	2.82
5542.00	85.50	339.00	62.00	4050.29	1619.25	-787.24	1800.48	334.07	2.82

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	TRUE VERTICAL DEPTH	R E C T A N G U L A R C O O R D I N A T E S NORTH	EAST	CLOSURE DISTANCE FEET	CLOSURE AZIMUTH DEGREES	DOGLEG SEVERITY DEG/100'
5603.00	83.75	340.00	61.00	4056.00	1676.13	-808.51	1860.94	334.25	3.30
5665.00	82.75	340.00	62.00	4063.29	1733.99	-829.56	1922.21	334.43	1.61
5727.00	81.00	339.00	62.00	4072.05	1791.48	-851.06	1983.35	334.59	3.24
5789.00	79.25	338.00	62.00	4082.68	1848.31	-873.44	2044.29	334.71	3.24
5850.00	78.75	337.00	61.00	4094.32	1903.63	-896.36	2104.10	334.79	1.81
5912.00	77.00	336.00	62.00	4107.35	1959.21	-920.53	2164.69	334.83	3.23
5974.00	75.50	335.00	62.00	4122.08	2014.01	-945.50	2224.91	334.85	2.88
6036.00	73.25	333.00	62.00	4138.78	2067.67	-971.67	2284.60	334.83	4.78
6097.00	71.25	332.00	61.00	4157.38	2119.20	-998.50	2342.65	334.77	3.63
6159.00	69.75	330.00	62.00	4178.07	2170.31	-1026.83	2400.96	334.68	3.89
6221.00	67.75	329.00	62.00	4200.54	2220.10	-1056.15	2458.52	334.56	3.56
6283.00	65.50	328.00	62.00	4225.14	2268.62	-1085.89	2515.11	334.42	3.92
6345.00	64.00	327.00	62.00	4251.58	2315.91	-1116.02	2570.79	334.27	2.83
6399.00	62.65	326.00	54.00	4275.83	2356.15	-1142.65	2618.60	334.13	3.00

VERTICAL VIEW
HARDY HW #1

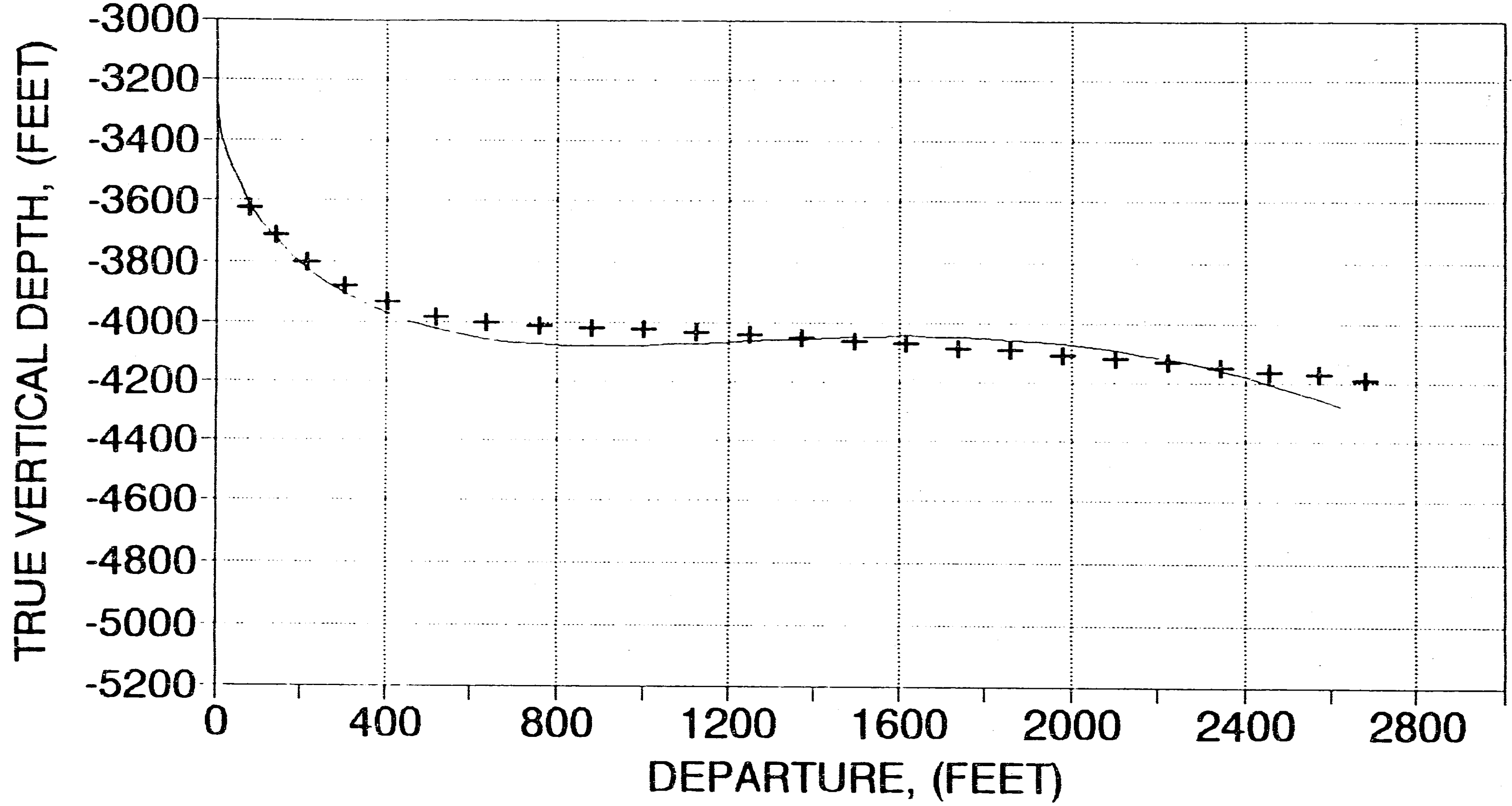


Figure 5.2

+ PLANNED —— ACTUAL

PLAN VIEW

HARDY HW #1

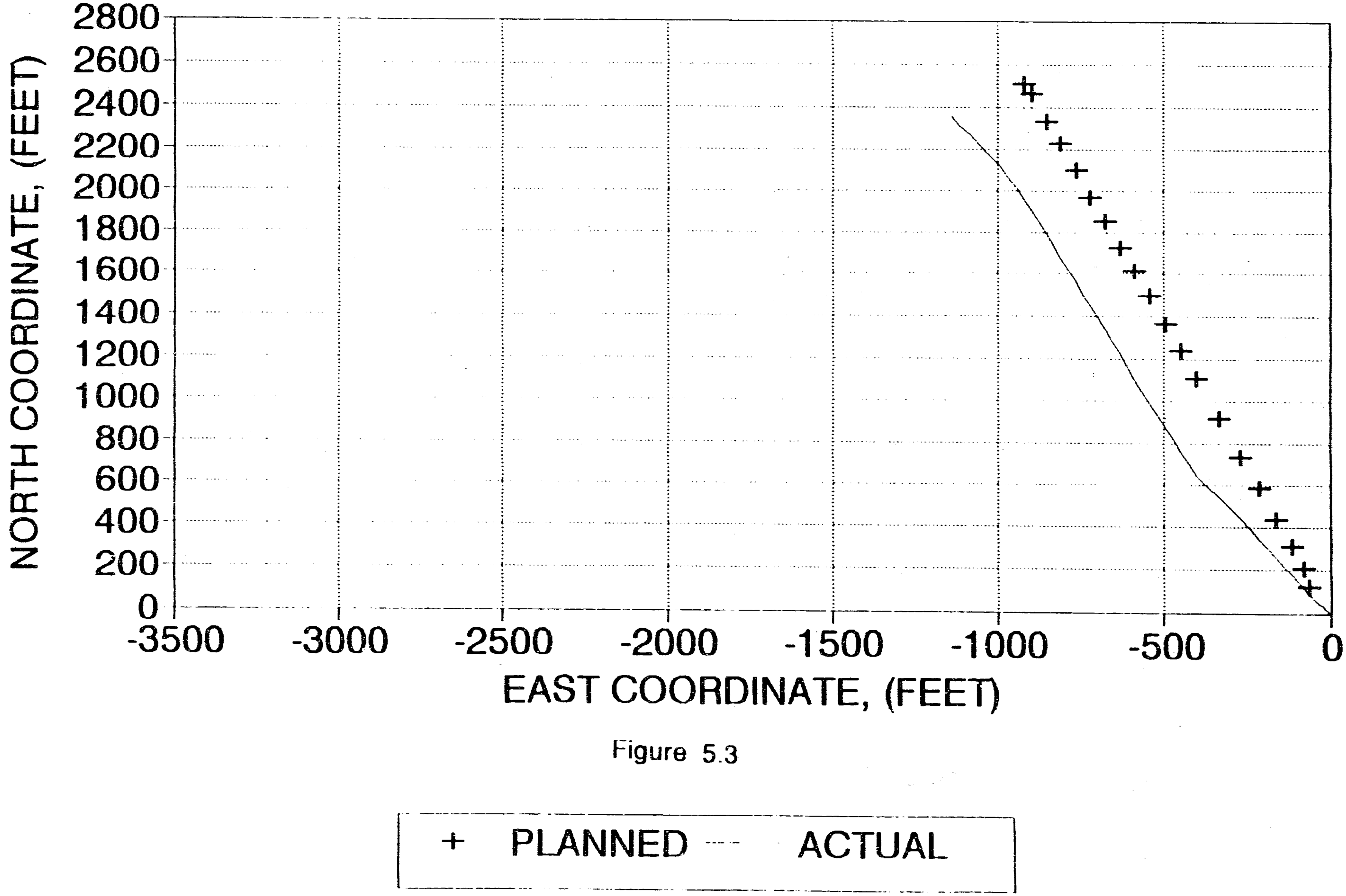


Figure 5.3

casing tally and setting depth of the packers and port collars can be found in Appendix A-3.

The casing was landed in the wellhead slips and the rig released.

6.0 LOGGING OPERATIONS

6.1 Introduction

Logging of this well was planned to identify key stratigraphic units used in the location of the kick-off point, and in the determination of hydrocarbon gasses present in the target formation. Logging was also used to determine the points where external casing packers were to be placed in the casing string. The location of points where significant gas shows were encountered was determined to aid in the selection of zones where the well is to be stimulated (if required). Conventional geophysical logs were obtained as well as hydrocarbon mud logs.

6.2 Mud Logging

Mud logging of the well was initiated at a depth of 800 feet. A fairly complete record of shallow and deep sandstones, limestones, coals and shales was obtained. A record of all hydrocarbon gasses encountered was also made. This data was plotted on the log as units of hydrocarbon gasses per foot of depth drilled. This data was used in locating the intervals where external casing packers were located in the casing string. Mud logging was accomplished by capturing a portion of the return air stream and sending it through a gas chromatograph to determine the various components. The system was calibrated at the beginning of logging operations so that calculations could be made to estimate the volume of gas encountered by the drill bit. Appendix H lists the depths and the calculated volumes of gas encountered during drilling operations.

6.3 Shallow Hole and Free Fall Logging

Original plans were to run a correlation gamma ray log from the surface to the bottom of the 12 1/4" hole, however, in an effort to reduce costs, the well was not logged until all drilling operations had been completed. The purpose in running the correlation logs was to accurately locate the Berea sandstone top for measurement to the planned kick-off point. The free fall logs were run to make sure that the entire wellbore would be logged since the side-door sub could not be moved downhole beyond the bottom of the 9 5/8" casing. This meant that only 2600 feet of inclined and horizontal hole could be logged by pushing the logging tools when attached to the drill string since the 9 5/8" casing was set at 2650 feet.

Free fall logs were obtained down to a depth of 4327 feet. The logging suite consisted of gamma ray, compensated density, temperature and differential temperature, and caliper logs. The logs revealed that the Berea sandstone was found at a depth of 2667 feet below ground level. The top of the Huron Shale was found at a measured depth of 3767 feet below ground level or 2944 feet below sea level.

6.4 Horizontal Section Logging

The inclined and horizontal sections of the well were logged by attaching the logging sonde to the front end of the drill string and pushing the tools through the open wellbore. Logging operations started at a depth of 3850 feet on the way in (labeled down log) and continued in to a total depth reach of 6360 feet. The down log was recorded in 60 foot sections which is the length of two joints of drill pipe which can be stacked on the rig floor. Depths were correlated by comparison with the strapping of each joint of drill pipe as it was run in the hole. When the up logs were run, a little slack left in the wireline cable which looped around the drill pipe and could not be pulled out. As a result the up logs were not scaled properly and were not usable. Strapping the pipe out of the hole and correlating the depth of each joint will prevent the accumulation of slack in the cable.

By using multishot survey data of the inclination of the borehole, the logging company was able to reconstruct a True Vertical Depth (TVD) presentation of the log. This TVD log is for correlation with nearby vertical wells to determine the various stratigraphic layers that were penetrated by the horizontal well. Figure 6.1 is a presentation of the TVD log of the well and the target interval of the well.

7.0 MOTOR PERFORMANCE AND BOTTOM HOLE ASSEMBLIES

7.1 Introduction

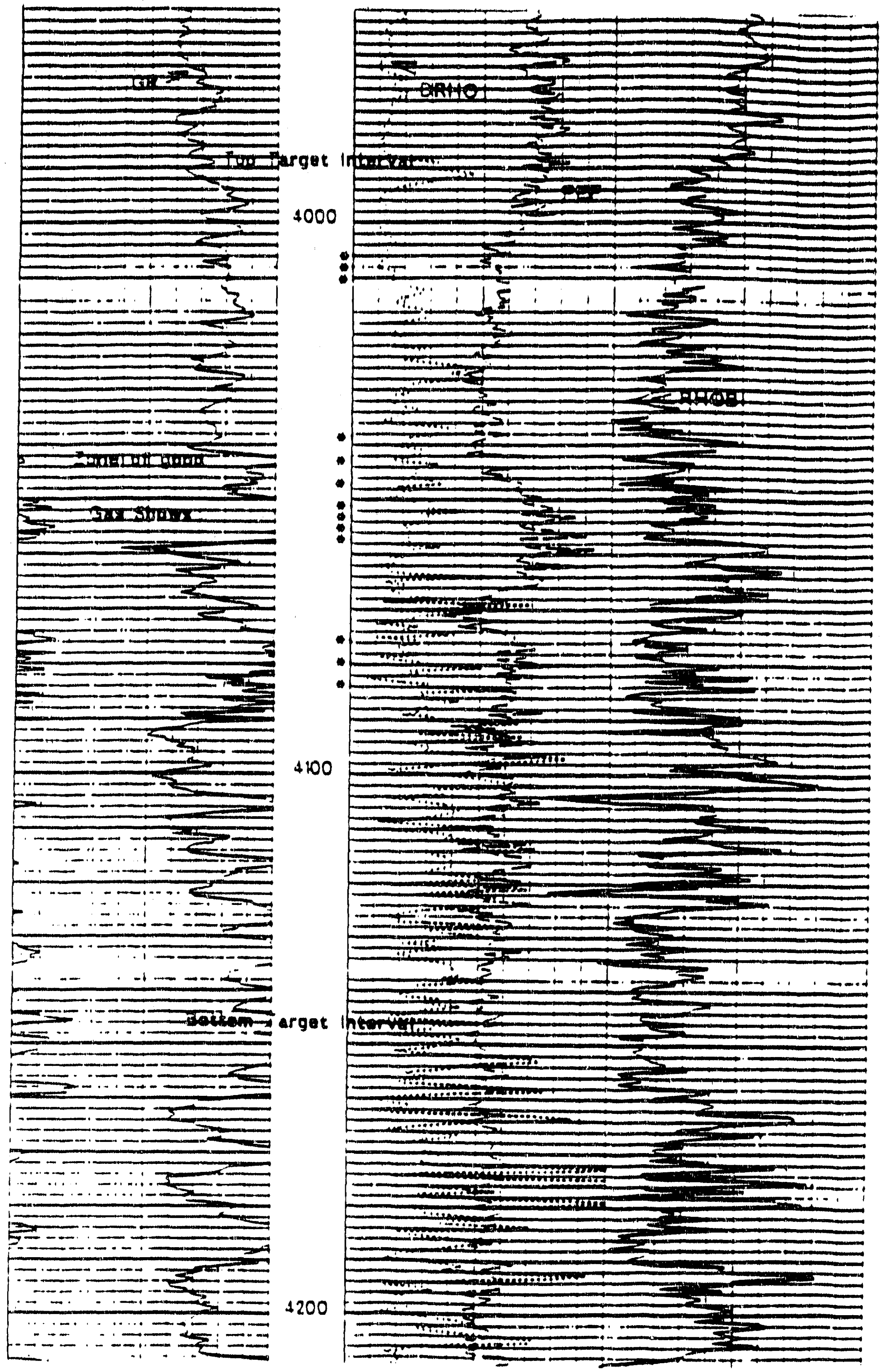
Motor performance during drilling of the inclined section of the well is extremely important and can have considerable effect on the overall economics of the drilling operation. BDMESC has attempted to determine the optimum motor to be used in the Appalachian area which is traditionally an air drilling country. Two motors were tested in this well to determine which motor would provide the best economics of operation. Eastman Christensen recently introduced a high torque air motor designed to build angle at a rate of 9.5 °/100'. A Baker Hughes Drilling Systems adjustable bent housing motor was also used during the angle building phase of drilling operations. Initial plans were to test the motors under a high pressure system (600 psi) but those were changed to test the economics of lower pressure systems (200 - 300 psi) which are less costly and more readily available in the Appalachian area.

7.2 Motor Performance and BHA's of the Angle Building Section

The first motor to be run at kickoff point was the Eastman Mach IAD which is an air drilling motor. The motor drilled from 3253' to 4324' (1071') in four separate runs. The first run was from 3253' to 3487' (234') in five hours. The motor was pulled to change the configuration because if was not building fast enough. The average rate of penetration was 46.8 ft/hr.

The motor was run with an air rate of 2000 scfm. The bit contained three 16/32nd inch jets in hopes that the lower air velocity around the steering tool would prolong the life of the steering tool. The standpipe pressure was 290 psi and the average calculated flow rate through the motor was 810 ppm. Oil was injected at an average rate of 10 gallons per hour.

True Vertical Depth Presentation of Well Logs Through the Horizontal and High-Angle Section of the Hardy HW#1 Well with Gas Shows



TVD LOG

Figure 6.1

Initially, SAE 30 motor oil was used. Eastman indicated that a much higher viscosity motor oil would probably be better. The oil was changed to hammer oil which increased the standpipe pressure and slowed the motor penetration rate slightly. Changing back to the motor oil reduced standpipe pressure and increased penetration rate.

The bend in the motor had been set at 1.1° with 8 3/8" stabilizer near the bit and a 7-7/8" integral blade stabilizer above the motor. The motor generated an average dogleg severity of 5.9°/100'. According to Eastman, the motor should have built at 8°/100'.

Run number two was from 3487' to 3603' (116') in 2.75 hours. The motor was pulled because it was not building fast enough. The average penetration rate was 42 ft/hr.

The bend in the motor had been set at 1.3° (maximum) and the top stabilizer was left off. Eastman predicted the motor would build at 9.5°/100'. The operating parameters were the same as the first run.

The motor generated an average dogleg severity of 5.6°/100' as calculated from the multishot data. The build rate still was not fast enough. The motor was pulled from the hole to make another adjustment.

On the third motor run, a 1.5° bent sub was placed on top of the motor leaving the bend in the motor set at 1.3°. Eastman could not predict the build rate with their computer program. The third motor run drilled from 3603' to 3817' (214') in 6.75 hours. The average penetration rate was 31.7 ft/hr. The average dogleg severity was 7°/100' which still was not enough.

The motor was pulled and the hole size was reduced to 8 1/2". No jets were put in the 8 1/2" bit in order to increase the penetration rate. The bent sub and housing were not changed. This fourth motor run drilled from 3817' to 4324' (507') in 10.75 hours. The average penetration rate was 47.2 ft/hr. The average dogleg severity was 8.4°/100' which was not enough to hit the target TVD of 4010' but would allow the well to be horizontal at a TVD near 4100'.

The equivalent flow rate throughout the motor was 1563 ppm with a surface pressure of 185 psi. The oil rate was gradually reduced from 5 gallons per hour to no oil injection at all. However, there was still plenty of residual oil in the drill string.

The motor was pulled because the steering tool failed. At the time, its was not known whether the steering tool or the motor configuration caused the problem, so the Eastman motor was not rerun. The average rate of penetration of the Eastman motor was 42.0 feet per hour.

The Baker Hughes Drilling Systems Adjustable Bent Housing Motor was run slick (no stabilizers) with the bend set at the maximum of 2 degrees. Four separate runs were also made with the Baker motor. The motor drilled from 4324' to 4610'; a total of 370'. The total length drilled is more than the measured depth along the wellbore because the hole was sidetracked. Approximately 103 feet of side track was drilled which could not be used.

The first run with the Baker motor (motor run #5) drilled from 4324' to 4374' (50') in 1.25 hours. The average penetration rate was 40.0 ft/hr. The motor was pulled because of a problem with the steering tool.

The second run (motor run #6) drilled from 4374' to 4422' (48') in 1 hour. The average penetration rate was 48 ft/hr and the motor was again pulled because of steering tool problems.

The third run (motor run #7) with the Baker motor sidetracked the well at 4338' and drilled to 4502' when the steering tool failed. The motor drilled 164' in 4.25 hours with an average penetration rate of 38.6 ft/hr.

The remainder of the build section was drilled with the fourth run (motor run #8). The motor drilled from 4502' to 4610' (108') in 3.25 hours. The average penetration rate was 33.2 ft/hr.

The only change made with the motor was to change the bit jets between runs number two and three. The jet nozzles were changed from one 11/32nd and two 14/32nds to two 11/32nds and one 14/32nds. For the first two motor runs, the equivalent flow rate through the motor was 622 gpm. For the last two motor runs, the equivalent flow rate through the motor was 549 gpm. Both flow rates exceed the manufacturers recommended maximum, but no problems were experienced with the motor.

The flow rate at the surface was 1600 scfm. The surface pressure for all four motor runs ranged from 280 to 320 psi with the lower pressure corresponding to the larger jet sizes. The 300 psi pressure was selected to find out if the motors could be run without a high pressure air package. The high pressure package is not readily available in the area and is expensive to rent. Being able to drill with lower pressures would reduce the overall cost of the well.

Also, it was noted that taking the jets out of the bit with the Eastman motor increased the penetration rate. Using the larger jets in the Baker motor also increased the penetration rate. Larger jets increase the equivalent flow rate through the motor and therefore, the rpm. The Baker motor averaged 38.3 ft/hr in this well compared to 20 ft/hr in the DOE-Sterling Drilling Roane County well. There was considerably more siltstone drilled in Roane County than Putnam County. No significant change in maximum bit weight was observed.

An air-mist drilling fluid system was not used with the Baker motor. For lubrication, SAE 30 motor oil was injected into the drill string at a rate of 5 to 10 gallons per hour. The motor operated the same as it had on the Roane County well which was drilled with an air-mist system under 600 psi pressure. It seems likely that the high pressure reducing flow rate through the motor produced a lower penetration rate for the same motor.

The average dogleg severity generated by the Baker motor was 9.5°/100'. The dogleg severity in the Roane County well was also 9.5°/100'.

The Eastman motor had 25.25 drilling hours and 0.75 circulating hours (total 26 hours). The Baker motor had 9.75 drilling hours and 11.25 circulating hours (total 21 hours). The Baker motor had more circulating hours, because the pipe had to be pumped part way out of the hole each time the motor was tripped out. The Eastman motor had a faster rate of penetration by 3.6 feet but could not build angle at the well design rate of 8°/100 feet of penetration. Table 7.1 compares the two motors during their eight motor runs.

7.3 Rotary Directional Drilling Assemblies for Horizontal Section

Two rotary, directional drilling assemblies were used to drill the horizontal/slant section of the well from 4610' to total depth. The first assembly consisted of a 7 7/8" bit, float sub, 3-pt reamer, x-o sub, and two monels. The assembly is the same as that used in the BDM/DOE Wayne County well except the button cutters in the 3-pt reamer had been replaced with flat cutters. Since the TVD was already deeper than desired, dropping much more inclination would not have been desirable. It was assumed that the flat cutters would reduce the dropping tendency or even cause a slight building tendency.

The building assembly is BHA #6 in Appendix B. The assembly drilled from 4610' to 5126' (516') and built inclination at a rate of 0.7°/100'. No consistent walk tendency was established. The inclination at 5126' was projected to be 95°, and the wellbore needed to drop through the rest of the target interval. Without running a dropping assembly, it would not have been possible.

Botttomhole assembly #7 (Appendix B) was run to drop inclination at about 1 to 1.5°/100'. Unfortunately, it would not go into the sidetracked hole. Each time it was tried, the assembly would go into the hole that ended at 4422'.

Bottomhole assembly #8 was run as an alternative assembly. The assembly consisted of a 7 7/8" bit, bit sub, short drill collar (10.75'), 3 - pt reamer, x-o, float sub, and two monel drill collars and is considered a short pendulum assembly. The pendulum would probably drop faster than necessary, but the options were limited by the sidetrack at 4338'.

BHA #8 drilled from 5126' to 5763'. One slight modification was made in the assembly at a depth of 5763'. To help reduce drag going into

Table 7.1 Comparison of Rates of Penetration of Motors During Angle Building Drilling

MOTOR RATE	RUN #	DRILLING TIME	FOOTAGE	RATE(FT/HR)		AVG BUILD
EASTMAN	1	5 hours	234	46.8		5.9 Deg/100'
AIR	2	2.75	116	42		5.6 Deg/100'
MOTOR	3	6.75	214	31.7		7.0 Deg/100'
	4	10.75	507	47.2		8.4 Deg/100'
SUBTOTAL		25.25	1071	41.9	AVG	6.7 Deg/100'
BAKER	5	1.25	50	40.0		7.82 Deg/100'
BENT HOUSE	6	1.0	48	48.0		10.43 Deg/100'
MOTOR	7	4.25	164	38.6		11.52 Deg/100'
	8	3.25	108	33.2		8.05 Deg/100'
SUBTOTAL		9.75	370	40.0	AVG	9.5 Deg/100'
TOTAL		35 hours	1441	41.2	AVG	8.9 Deg/100'

the hole, one of the two monels were laid down and is shown as BHA #9 in Appendix B.

The average drop rates for BHA #8 and BHA #9 were 2.34°/100' and 2.75°/100', respectively. Because of the problems with the multishot surveys, the walk tendency of BHA #8 can not be determined. BHA #9 walked 1.94°/100' to the left.

All the rotary assemblies were run with a bit weight of 20,000 to 25,000 pounds and rotary table speed of 60 rpm. The lower bit weight was to keep the drill pipe from bucking in the horizontal and build sections. Drill collars were placed at the top of the build section to provide the weight necessary to keep the drill pipe from buckling in the vertical section of the hole. The collars were also used to help push the pipe into the hole on trips and connections. The placement of the collars can be seen in Appendix B for each of the rotary assemblies when they were run in the hole. Drilling continued until the collars reached a maximum inclination of 45°. Then the pipe was tripped and the collars moved up the hole.

8.0 DIRECTIONAL CONTROL OPERATIONS

8.1 Introduction

In drilling a horizontal or slant well, one of the most important aspects of the drilling operation is obtaining data relative to the azimuth and inclination of the drill bit. In areas where mud is the preferred circulation medium, tools have been developed, which provide this data reliably and consistently, however, in the Appalachian area where air is used as the circulating medium, tools have not yet been hardened to provide reliable operations expected from mud drilling in other parts of the country.

8.2 Steering Tool Operations

Problems with the steering tool were the most costly and time consuming problems encountered during the drilling of the well. The steering tool had been pulled from the hole seven times because it was not performing properly. In addition, almost two days of rig time were spent waiting on steering tools.

Smith International had initially brought four, two axis probes to the location. The first probe operated without any problem from the kick-off point to around 3900' whe it failed. The probe apparently shorted out after the driller's panel was sprayed with water on the rig floor.

The second probe was run and drilled 1.5 hours before it was pulled (at approximately 3960'). The tool face had been bouncing around and it became difficult to tell which way the motor was pointed. Even though the tool had not failed, a third probe was run inside a fiberglass case (instead of steel). The fiberglass case was supposed to reduce the vibration on the tool.

The tool face still bounced significantly while drilling and became progressively worse as the inclination increased. The air rate was lowered to as much as 1400 scfm but it made no difference. Surveys had to be taken after connections because it took over ten minutes for the probe to settle down. As soon as the air was turned back on, the probe would again vibrate.

At a depth of 4249', the probe had turned 90° to the right with respect to the motor tool face. Initially, it was thought that the motor had actually turned 90°. Drilling continued to 4324' when the surveys indicated the well was turning left. In reality, the steering tool barrel had rotated with respect to the mule shoe stinger. A nut holding the mule shoe stinger fixed in place had vibrated loose allowing the barrel to turn while making a connection. The tool was pulled out and the motor tripped out to retrieve the stinger.

The third probe was run back in after repairing the barrel. Drilling continued for one half hour but the tool was bouncing around too much to get any good information out of it. The fourth and last probe was run and drilling continued for three quarters of an hour before it was pulled for the same reason.

The probes would not give accurate tool face information above an inclination of 70°. A three axis probe was required. Eastman's steering tool which has a three axis probe was ordered out.

The Eastman tool was run in the hole. While tripping to bottom, the generator quit and had to be restarted. When power was returned to the tool, it was no longer working. Eastman felt that a power surge probably shorted out the tool.

The first tool was pulled and a second Eastman steering tool run. As soon as the air was placed on the well, the tool began to bounce around. A total of 48 feet was drilled, but the tool face was so erratic that it was not possible to tell which way the motor was oriented. The second Eastman probe was pulled from the hole and the drill pipe tripped out.

An attempt was made to orient the motor using Geoscience's Electromagnetic Measurement While Drilling Unit (EMWD) but the tool could not get a signal to the surface. No drilling was done with the EMWD while waiting for additional steering tools to arrive on location.

Smith arrived with two, three axis probes shortly after tripping out of the hole. The three axis probe was run and performed much better than the two axis probes. The tool face still bounced around but not enough to halt drilling.

On a connection at 4502', the steering tool again failed. The tool was pulled from the hole and the barrel was found to have parted above the probe. The pipe was tripped out of the hole to recover the remainder of the steering tool. The barrel was repaired and drilling continued to 4610' when the desired inclination and direction were obtained.

Judging from the difference between the performance of the two and three axis probes, Smith's two axis probe was not capable of giving a reliable tool face above 70°. Smith had thought there would be no problem obtaining tool face; however, surveys would have had to be run to get inclination and direction.

8.3 MWD Tool Operations

Geoscience Electronics has modified MWD tools which were used successfully in fluid systems for drilling river crossings for application in the harsh air drilling environment of the Appalachian Basin. The early system failures were related to extreme buffeting by the 2,000 to 3,000 cfm air flow volumes. These problems have been reduced by continued work with DOE so that they do not loom as a major factor in the potential application.

The tool was placed in the drill string for testing and use when the wireline steering tools had failed and while waiting on replacement probes. The system was tested on the surface when going in the hole, and again every 500 feet going down 3200 feet, but when the tool was in position at the bottom of the hole at 4222' (inclination of 83°) a signal with tool face orientation data could not be received back at the surface. Apparently the problem was a mixture of lack of signal strength caused by a mismatch in formation impedance. It would seem that impedance matching at the location based on offset well resistivity log data is a flexibility that will be required to make this unit function in any future horizontal well applications. A mid-drill string signal, repeater may be required to boost signal strength while maintaining battery life of the primary unit.

9.0 ANALYSIS OF DRILLING OPERATIONS

This drilling project was planned to be drilled in the most economic manner to obtain data for analyzing the economics of slant/horizontal drilling in the Devonian Shales. This report was prepared to discuss the results of new drilling techniques that were tested and the performance of current "off the shelf" technologies utilized during the drilling operations.

The major success during this drilling operation was the increase in the rate of penetration during the angle building phase of the operation. This is due to the use of high torque, low speed downhole motors which were operated at pressures of 250 to 350 psi with air flow rates ranging from 1700 to 2000 cubic feet per minute (cfm) of air. Another innovation was the use of oil which was injected at slow rates (5 gallons per hour) to lubricate the downhole motors. This method prevented damage to the formation from water in the normal foam-air mist system used and saved several thousand dollars in chemical costs for the air-mist mixture.

The biggest problem which continued to plague the air-drilling aspect of directional drilling was the steering tools which need to be hardened for air-drilling operations. This resulted in four or five additional days of daywork repair costs. Steering tool service companies are lagging behind in this aspect of directional drilling operations.

Another test was made of the electromagnetic measurement while drilling system (EMWD) which failed because the equipment could not put enough power into the signal so that it could be detected at the surface. There seemed to be a problem of impedance matching of the transmitted signal to the formation being penetrated. This system seems to have promise when the problem can be solved and the signal can be received back at the surface.

Mud logging operations have been very successful and useful on the air-drilled directional wells. Continuous monitoring of the air stream has shown where gas was being produced from the target horizons and helped in the placement of external casing packers for completion operations. It would be difficult to know the formations penetrated without the use of a mud logging unit and sample examination.

Conventional geophysical logging operations continue to be difficult and fraught with numerous problems which can impact the quality of logs obtained. A good set of logs were obtained when the tools were being pushed into the hole on the drill string, but failure to keep proper tension of the line resulted in unusable logs on the return trip and the destruction of about 3,000 feet of logging cable.

The video log, which is considered a key log in a horizontal well because of the information that can be obtained about the spacing and of natural fracture orientation, was a failure during this operation. Video cameras require special cables and, therefore, accommodating the cable in side-door subs and power connect operations seemed to be the major source of problems which produced the failure in the Hardy HW#1 well operations. The tool worked to a point where the hole had reached ninety degree inclination when the "hot connect" which provided power for the lights and camera failed ostensibly because of the lack of slack in the line below the side-door sub.

10.0 COMPLETION OPERATIONS

10.1 Introduction

The completion design of the Hardy HW#1 well was based largely on the results of the successful completion of the previous DOE-sponsored horizontal well in Wayne County, West Virginia (BDM/RET#1). The BDM/RET#1 well had been successfully completed with a 4-1/2" casing liner with 7 different zones being isolated from each other by inflatable casing packers. Access to each zone was provided by two port collars which could be open and closed using special tools. This system allowed testing, production, and stimulation of individual zones or group of zones as necessary.

The BDM/RET#1 well was an experimental well and more zones were isolated for completion than would normally be done in a well completed for purely commercial purposes. One of the purposes for the Hardy HW#1 well was to replicate the previous BDM/RET#1 test, but to do so using drilling and completion technology more representative of that which would be more likely to be used by industry in a purely commercial well. Therefore, the completion design was limited to the identification of four zones for appropriate stimulations. Figure 10.1 shows each of the four zones on the wellbore schematic and Figure 10.2 shows where the zones occur with respect to the true-vertical-depth (TVD) log of the well.

As can be seen from Figure 10.2, the best gas "shows" were in intervals at 4004-4010 feet TVD and 4050-4058 feet TVD. Both Zone 1 and Zone 2 penetrated the lower interval of good shows. Zone 4 penetrated both intervals of good shows. Zone 3 did not penetrate either of the two

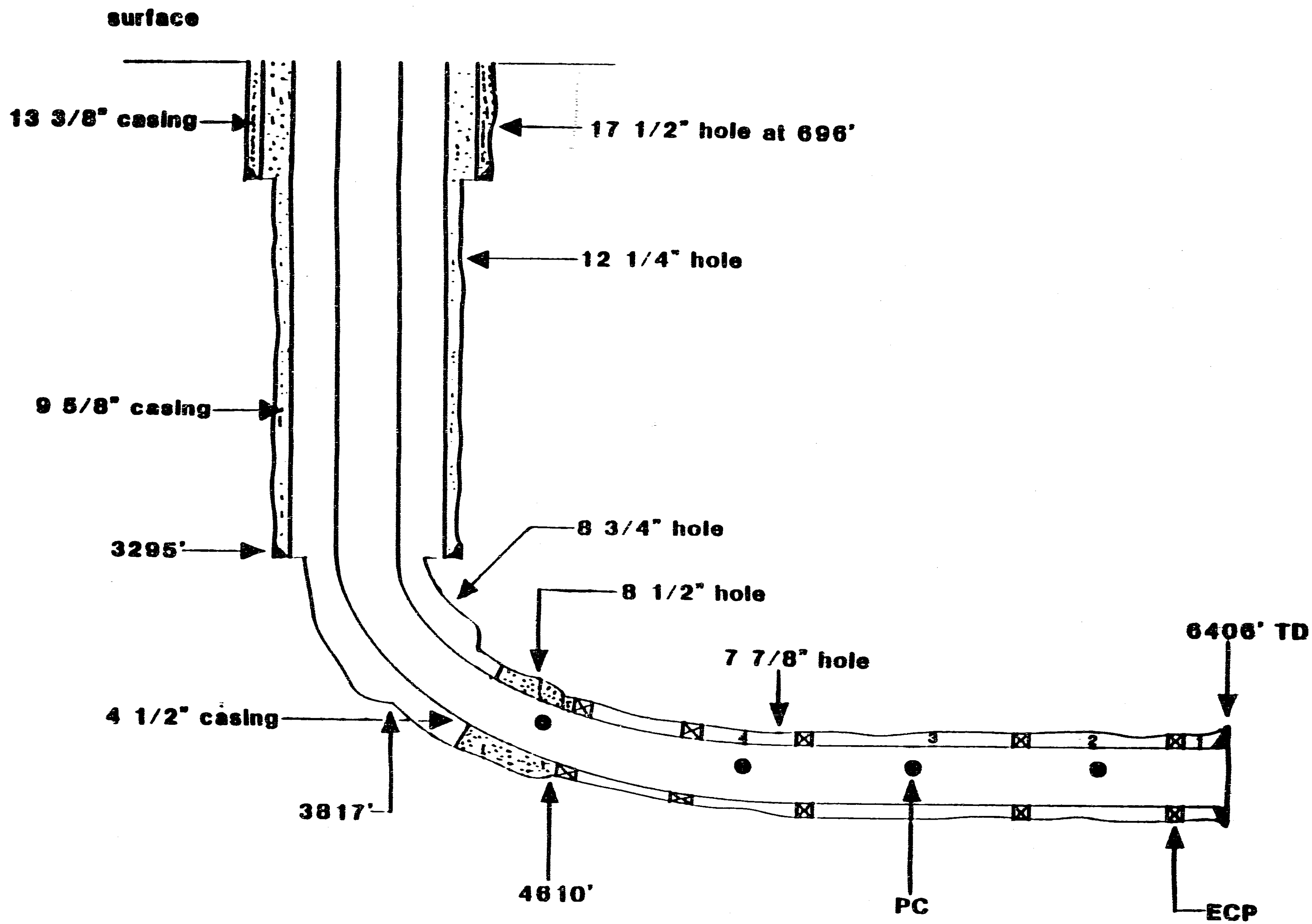


Figure 10.1 Hardy #1 Well Schematic

best intervals but did penetrate an interval which had gas shows at 4075-4081 feet TVD.

10.2 Casing design

In order to isolate the four zones for individual stimulation, the well was cased with 4-1/2 inch, 10.5#/ft, J-55, ST&C casing. Options considered for isolating the individual zones included conventional cementing of the casing with perforations to access the individual zones, use of inflatable casing packers in the casing string with port collars to access the zones as was done in the BDM/RET#1 (Reference 1) well, a combination of these two techniques.

Because of the relatively successful completion of the BDM/RET#1 well, the casing packer - port collar option was selected for completing the Hardy HW#1. Five TAM International, Inc. casing packers were placed in the casing string at measured depths of 6014, 5515, 4765, 4390, and 4106 feet. The original completion plan called for 5 TAM International, Inc. port collars to be placed in the casing string with one of the port collars fitted with a "bull plug" for opening with applied pressure and another fitted with a "baffle" for opening by dropping a ball and applying pressure. This design should have allowed the farthest two zones to be accessed and stimulated with a conventional ball-and-baffle technique and without having to use an "opening tool" to open the port collars. The final design, however, utilized only three of the five available port collars because the two specially-fitted port collars could not be run. This was because of a decision not to complete the lower-most section of the wellbore and to isolate the section with a casing packer. The casing packer would have been impossible to inflate and set with the bull-plugged port collar above it. The three remaining port collars were placed in Zones 1,2, and 3. (The lower zone numbers indicate zones farthest from the wellhead.) Zone 4 was left without a port collar because it was in a position where it could be conventionally perforated using wireline equipment. A fourth "spare" port collar was placed above the shallowest casing packer for use in cementing the casing in that part of the hole.

The size, weight, and grade of the casing, 4-1/2 inch OD, 10.5#/ft, J-55; respectively were designed to meet stimulation requirements. Based on hydraulic fracture treatments on nearby vertical wells, bottomhole treating pressures were expected to be approximately 1200 psi. Using the bottomhole treating pressure and service company friction factors for the injection of foam, tophole treating pressure for injecting 60 barrels per minute of 80-quality foam down 4-1/2 inch casing was estimated to be less than 3500 psi. After derating the pipe to account for bending stresses in the inclined hole, it was determined that 10.5#/ft, J-55 grade pipe would meet all design requirements.

10.3 Inflation of Casing Packers

The procedure selected for inflating the Tam International casing packers was to first inflate and then test the uppermost packer, (Packer #5) which would be supporting the cement to be injected above the producing zone as a permanent water barrier. Upon the successful inflation of packer #5 and cementing the casing above it, the remaining packers would be individually inflated and tested. If packer #5 could not have been successfully inflated, then packer #4, the next uppermost packer, would have been used to support the cement column. The fluid of choice for inflating the packers was nitrogen, a non-damaging fluid in the event of a packer element failure. After the inflation of a packer, the remaining nitrogen would then be used to inject into one of the zones adjacent to the packer while observing flow from the zone on the other side of the packer to verify the packer's integrity.

Packer #5 was successfully inflated after two attempts. The close spacing (approximately two feet) of the inner cups on the TAM Combo Tool required precise positioning of the tool to inflate the packers. Normally, the tool is used to inject through port collars and the tool is automatically in position upon using the tool to open the port. To position the tool for inflating the packers, it was necessary to locate the nearest port collar, and then move the tool the measured distance to the packer. On the first attempt to inflate packer #5, the tool apparently was located a few inches too low. The second attempt was successful after one of the inner cups on the Combo tool was removed to expand the working length of the tool to 2.9 feet. It was later learned that the Combo tool did not always provide positive identification of the port collars and that tubing drag could cause the port collars to be mislocated. The tool was later modified in the field to give it an even longer working length and to better centralize its opening dogs to provide positive engagement of the port collar shifting ring.

The procedure described above was used to individually inflate the remaining packers. With the modified tool, minimal problems were encountered in inflating the rest of the packers. Rig time to inflate the first packer, packer #5, was approximately sixteen hours. Rig time to inflate the next packer using the longer tool (12-foot cup separation) was about 6.5 hours.

10.4 Cementing

Although the basic completion method for this well was essentially open-hole with a liner, one section of the casing was cemented in place. The casing immediately above the uppermost casing packer was cemented from approximately 4057 feet to 3500 feet measured depth with 130 sacks of Class A cement. The purpose of this cement was to establish a permanent barrier against any water that might enter the wellbore above the productive interval.

The cementing operation was conducted by pumping the cement through a port collar immediately above the upper most casing packer using TAM International's "Combo" tool. The Combo Tool is a specially-built tool for selectively opening or closing ports while simultaneously providing the capability of injecting or producing fluids (e.g. cement slurries) via the tubing through an opened port between opposing cups on the tool. The cement was displaced from the tubing with water and a rubber plug. The cement was "overflushed" with approximately half a barrel of water, the plug was "bumped" with 800 psi, and the tubing head valve was closed. The port was left open and the combo tool left in place while the cement set overnight because differential pressure on the combo tool cups prevented movement of the tool. Even though the cement had been flushed from the tubing with a half-barrel of excess water, the combo tool was difficult to move the next day. After it was recovered from the well, the tool was found to have several pieces of cement in it.

11.0 STIMULATION

11.1 Introduction

The Hardy HW#1 was stimulated with 80-quality foam and 20-40 sand as the proppant in Zones 1 and 2. Zones 3 and 4 were stimulated as a single zone using nitrogen only as the working fluid. Only Zone 1 was stimulated as originally planned. The stimulation treatments for Zones 2,3, and 4 had to be modified in the field in order to obtain at least partial success.

The initial stimulation designs for the Hardy HW#1 well were based primarily on the favorable results of the stimulations conducted on the BDM/Eneger/DOE well in Wayne County, WV. Because of the ease with which the Wayne County stimulations were executed, the stimulations for the Hardy HW#1 were very similar except that much higher rates were planned for the Hardy well. The high rates were used to assure adequate treatment volumes and rates for treating multiple fractures with sand-laden fluid. Table 11.1 summarizes the stimulations originally planned and those which were actually performed on each zone. As is illustrated in the table, the original intent was to size the treatment volumes approximately proportionate to the length of the respective zones.

11.2 Treatment of Zone 1

As can be seen in Table 11.1, Zone 1 was expected to have the highest treating pressure of all zones. The zone was farthest from the wellhead and would be expected to have the highest frictional pressure loss. In fact, however, Zone 1 was found to have the lowest treating pressure, and was the only zone for which design rates and volumes were achieved.

The closure pressure for Zone 1 was estimated at approximately 1600 psig (bottomhole) based on stimulations of nearby vertical wells. The actual closure pressure based on the breakdown of the formation with nitrogen was about 1200 psig (see Figure 11.1). Total frictional pressure losses were estimated to be 2800 psi based on service company correlations. Adding the friction pressure to the estimated closure

Table 11.1

Summary of Frac Treatments for the Hardy HW #1

Planned	Zone 1	Zone 2	Zone 3	Zone 4
Fluid Type	Foam	Foam	Foam	Foam
Volume (bbl)	2000	2800	1500	1200
Amt Sand (lbs)	170,000	250,000	125,000	100,000
Rate (bpm)	60	60	60	60
Max. Pressure (psi surface)	3800	3550	3300	3150

Actual for each zone	1	2	3-4 (Combined)
Fluid Type	Foam	Foam	Nitrogen
Volume (bbl)	1800	450	420 (foam),1.3 mmcf N2
Amt Sand (lbs)	140,000	5000	8000
Rate (bpm)	60	20	60 bpm, 50,000 scfm
Treating Pressure	2900	3200-4000	3200-4000

Table 11.2

Flow-back Summary for Frac Job on Zone-1

Choke Water

Water Gas Flow

Date	Time	Diameter (inches)	Pressure (psig)	Recovery (bbls)	Recovery (pct)	Measurement (mscf/day)
02/14/90	1625	0.250	1200	0	0	—
02/15/90	0800	0.250	720	6	1.7	—
02/15/90	1100	0.375	—	—	—	—
02/15/90	1545	0.375	—	9	2.4	—
02/15/90	1610	0.438	95	—	—	—
02/15/90	2330	0.563	65	—	—	—
02/16/90	0200	0.563	40	45	12.5	—
02/16/90	0800	2.000	40	47	12.9	557
02/16/90	1230	2.000	—	—	—	163(mist)
02/16/90	1530	2.000	—	47	13.1	313
02/17/90	0800	0.375	472	—	—	—
02/17/90	1100	0.563	—	56	15.5	—
02/17/90	1700	0.563	—	60	16.6	267
02/18/90	0800	0.563	493	60	16.6	—
02/18/90	1600	2.000	—	64	17.7	292

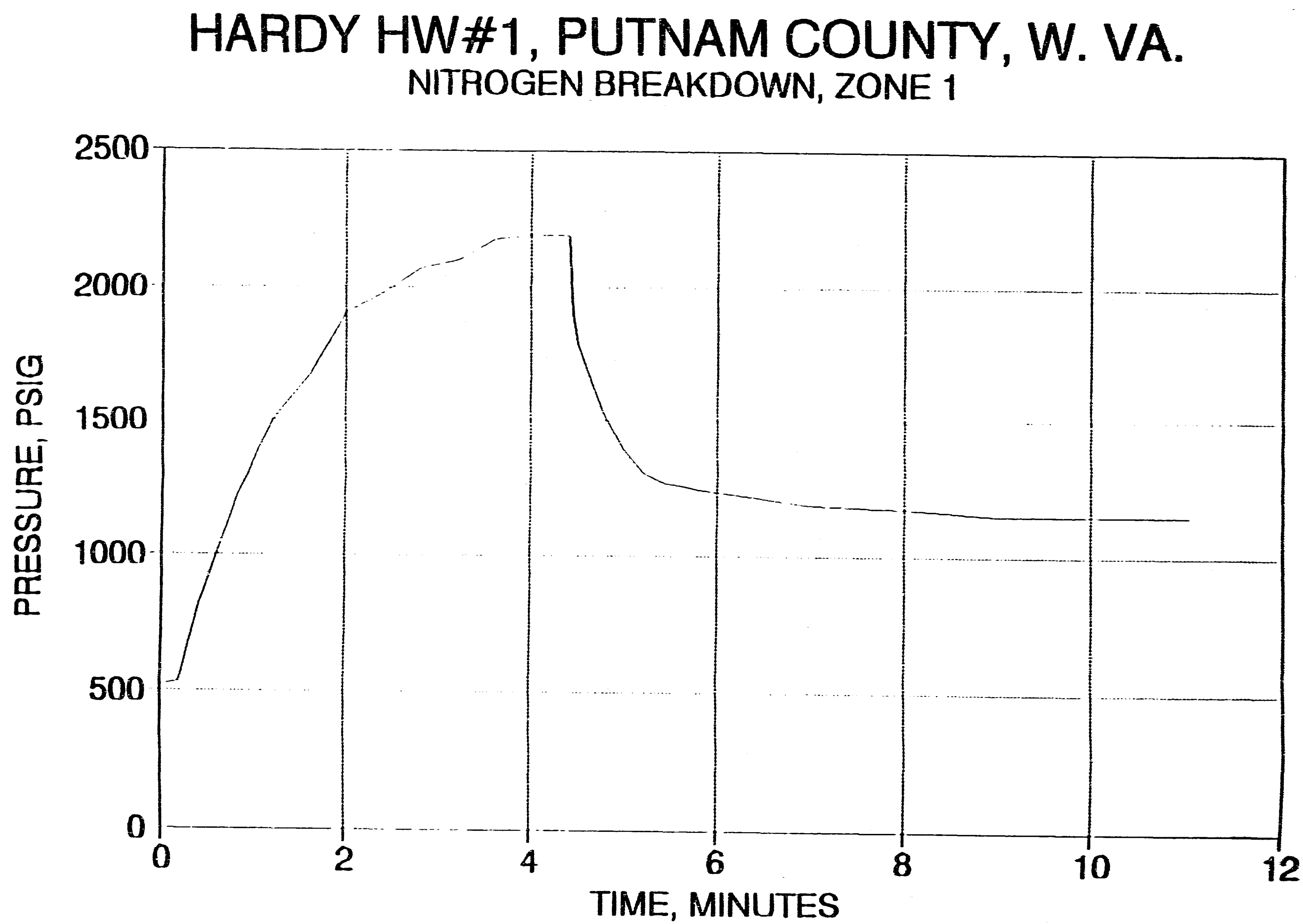


Figure 11-1, Nitrogen Breakdown (Prepad) on Zone 1 pressure of 1600 psi and then subtracting the hydrostatic pressure of the foam column (approximately 600 psi) resulted in the estimated treating pressure of 3800 psig. The actual treating pressure never exceeded 3000 psig, however, suggesting either lower frictional losses, a lower closure stress, or both.

Most, if not all, of the difference in estimated versus actual treating pressure was due to lower-than-predicted frictional losses. Although the nitrogen breakdown indicated a closure stress of 1200 psi or about 400 psi less than predicted, analysis of the shut-in period after stimulation indicated that closure stress had increased to approximately 1650 psi (see Figure 11.2). Therefore, the lower-than-expected treating pressure was due mainly to less total friction than predicted.

The stimulation of Zone 1 was executed with very few problems. The only major problem in execution resulted from malfunctioning service company monitoring equipment and a miscommunicaton of remaining sand volume. As a result, only 140,000 of the planned 170,000 pounds of sand was actually used in the job.

Following the treatment, the well was flowed back on a 0.25-inch choke overnight. Choke sizes were then increased stepwise during the next two days of flow back to a full 2-inch opening. Table 11.2 shows the flow back summary for Zone 1. Only 64 barrels or about 1/6 of the treatment water was recovered during the flow back period. The gas open flow rate after being open eight hours on the fourth day of flow back was measured at 292 mcf/day.

11.3 Treatment of Zone 2

The overall plan for Zone 2 was to close the port collar to Zone 1, open the port collar to Zone 2, and then to stimulate Zone 2 with a foam frac treatment similar to, but proportionately larger than, Zone 1. Because of difficulty in being able to positively engage, open, and close the port collars with TAM International's "Combo Tool," an excessive amount of time was spent attempting to position the port collars for the stimulation of Zone 2. Over eighty hours of service rig time was utilized in attempting to position port collars and in placing a retrievable plug

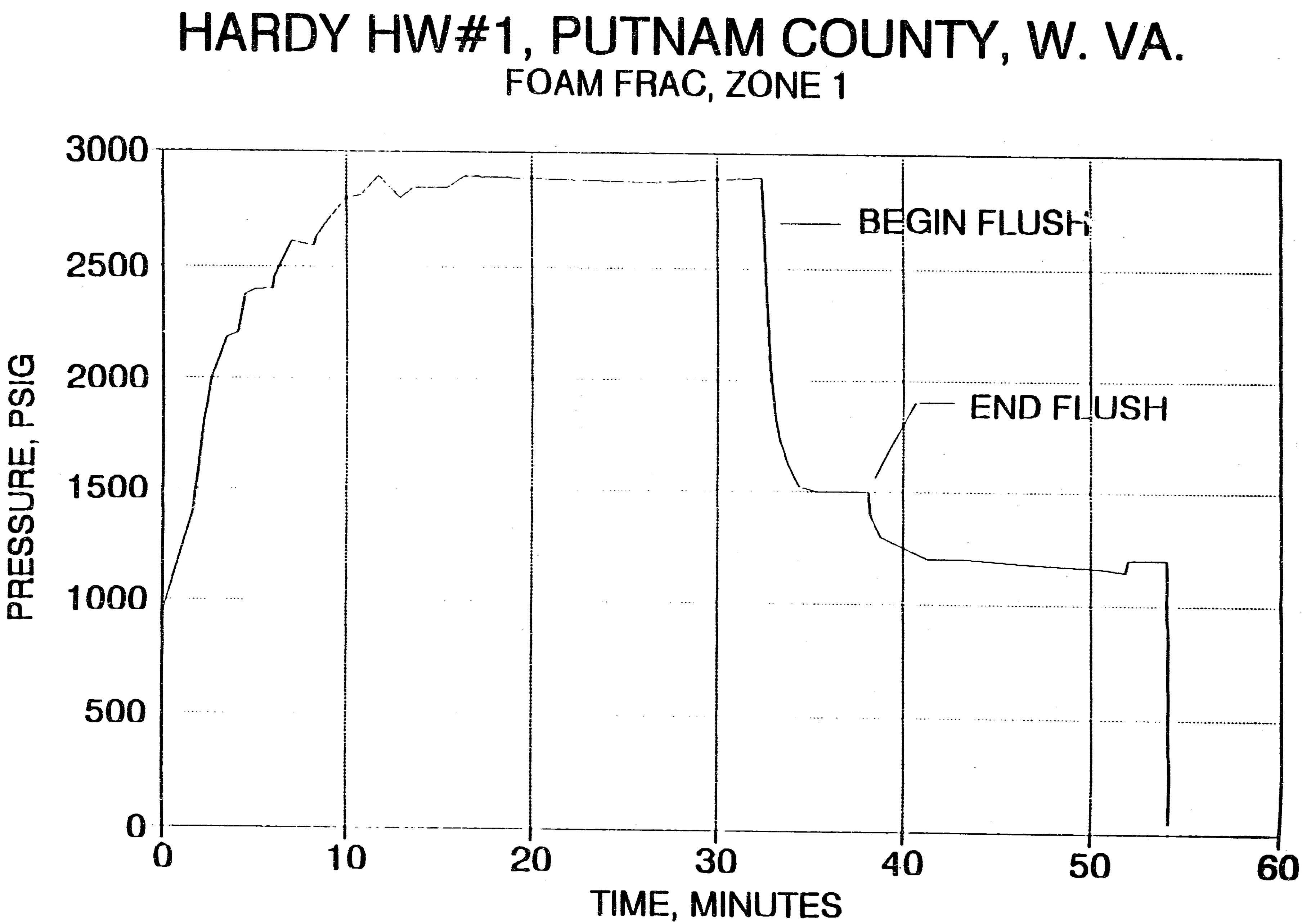


Figure 11-2, Foam fracturing treatment on Zone 1, Hardy HW#1, Putnam County, WV below the port collar serving Zone 2 prior to the first attempt to stimulate Zone 2.

After a series of unsuccessful attempts to close the port collar to Zone 1, an inflatable packer (plug) was placed in the casing between Zone 1 and 2. Initial attempts to set the packer by inflating it with nitrogen failed, and the packer was then set by inflating it with water. The port collar to Zone 2 was then opened so that the zone could be accessed for stimulation.

The first attempt to stimulate Zone 2 failed. Figure 11.3 shows the nitrogen breakdown chart for Zone 2. The similarities and differences between Figures 11.1 (Zone 1) and 11.3 (Zone 2) are worthy of note. Both curves flattened at about 1900 psig, but the pressure began to rise again on Zone 2 before flattening again at about 2300 psi. The falloff curves for the two zones are also quite different in that Zone 1 fell off rapidly dropping 800 psi within the first minute, then leveling off at about 1000 psi. Zone 2, on the other hand, took twice as long to drop 800 psi and never really leveled off at all except for a brief time at about 1300 psi. The distinct change in the rate of pressure decline at 1300 psi indicated a bottomhole closure pressure of approximately 1500 psig or about 300 psi more than was estimated from the nitrogen breakdown of Zone 1. The fact that the pressure continued to decline at a relatively rapid rate after fracture closure indicated that one or more natural fractures were continuing to accept nitrogen at a relatively high rate (2 to 3 mmscf/day) even though pumping had ceased. As shown in Figure 11.3, the pressure declined to 800 psi within 13 minutes, after which pressure was no longer monitored.

During the initial nitrogen breakdown, a nitrogen pump truck malfunctioned causing an overnight delay in executing the frac treatment. On the day following the initial breakdown, a second breakdown or nitrogen "pre-pad" was injected into the formation. Injection rates were similar to the initial breakdown, but the pressure response was somewhat different (see Figure 11.4). The pressure climbed to nearly 3100 psig before leveling off compared to 2300 psig the previous day. It should be noted, however, that the final injection rate during the initial breakdown was only 24,000 scfm compared to more than 30,000 scfm during the

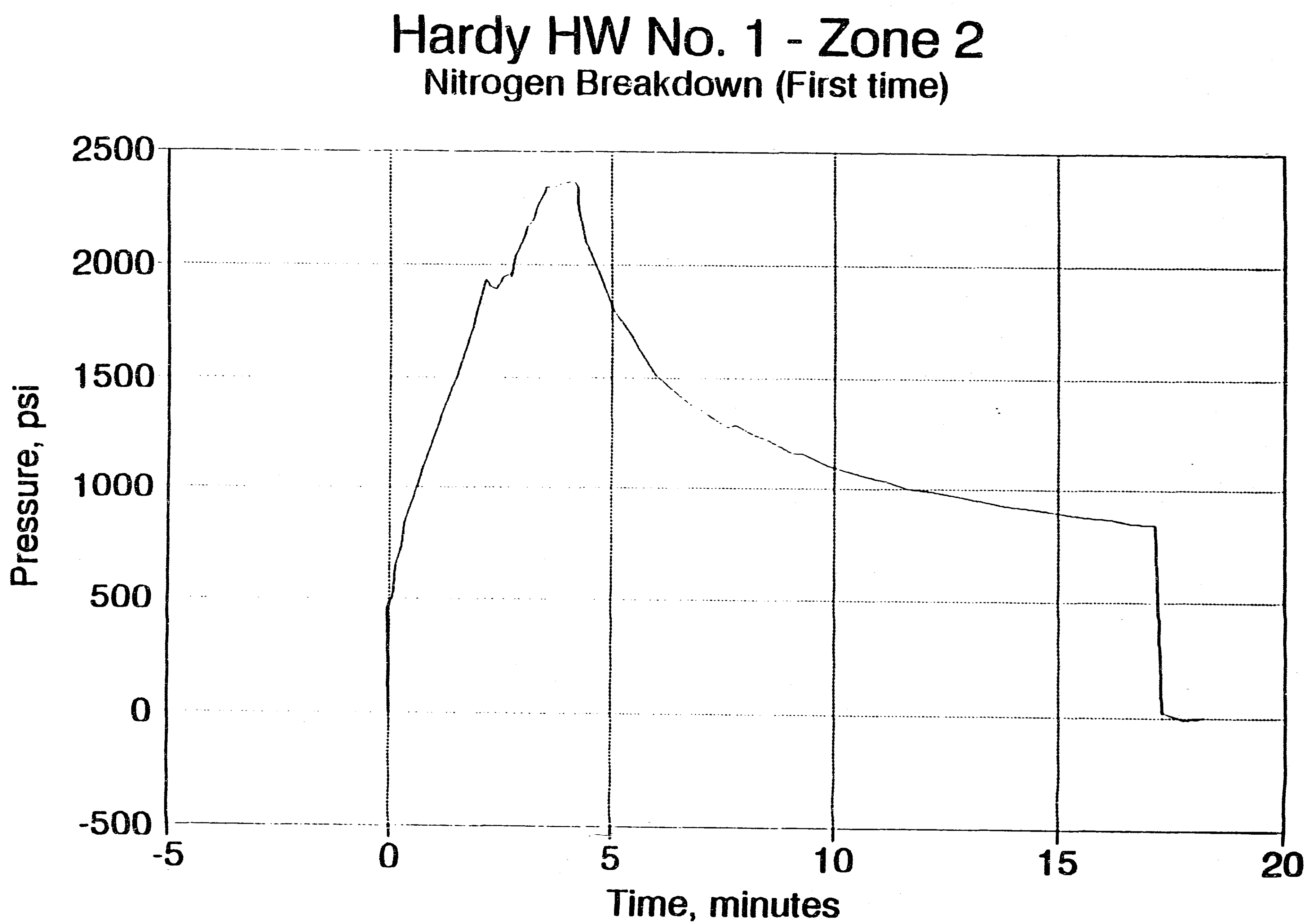


Figure 11-3, Nitrogen Breakdown (Prepad) of Zone 2 (First Time)

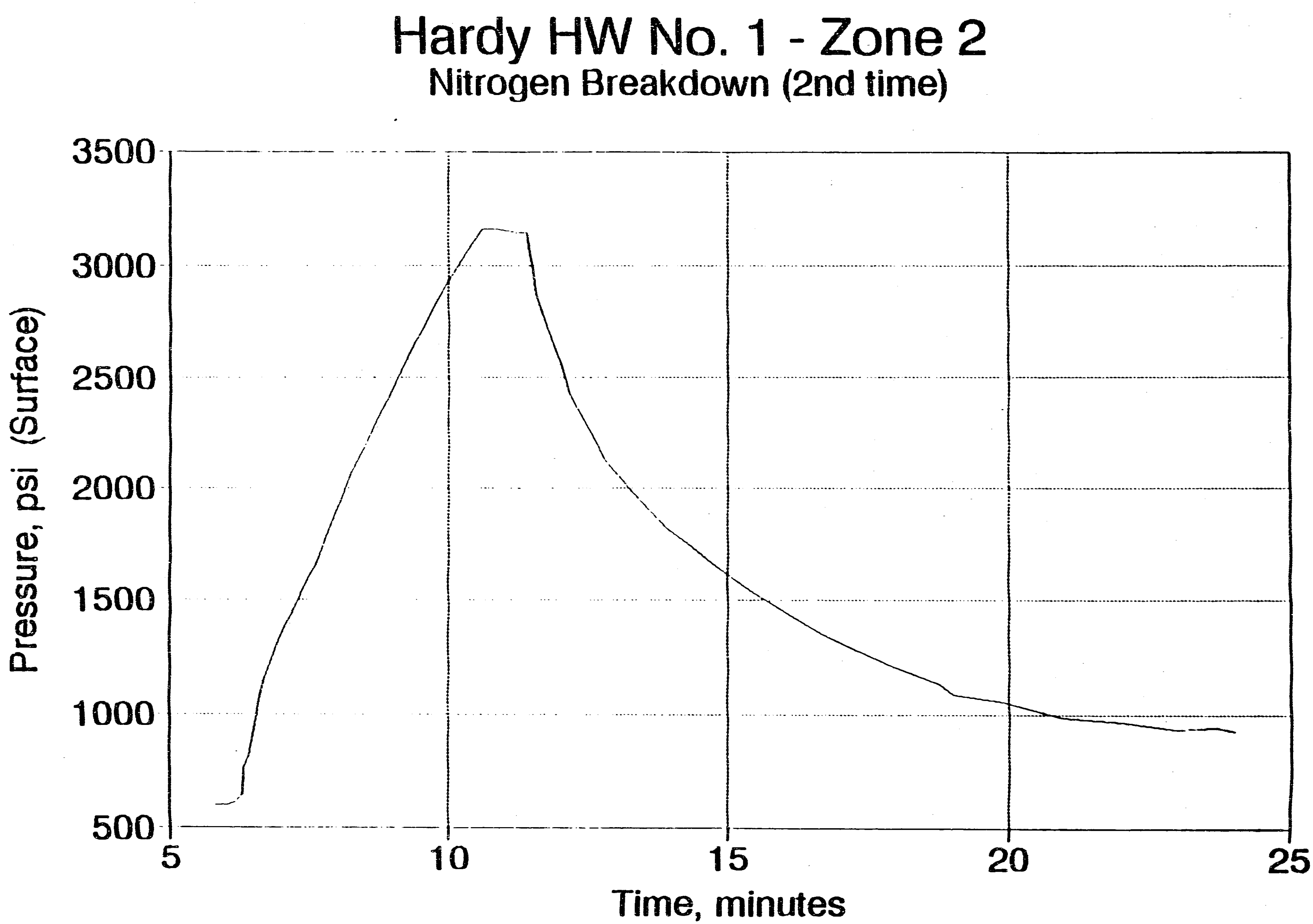


Figure 11-4, Second Nitrogen Breakdown (Prepad) for Zone 2 second injection period. Therefore, the increase in injection pressure was most likely due to the higher frictional losses associated with the higher rate.

After the nitrogen prepad was injected, a 50-barrel foam pad was injected at three rates increasing stepwise from 20 bpm to 40 bpm and 60 bpm. Figure 11.5 shows the pressure response that resulted from the foam pad injection. As shown in Figure 11.5, the injection pressure quickly grew to over 4000 psig, which was above the design safety pressure thus shutting down the frac job before any sand-laden foam could be injected.

Because of the apparent increase in frictional losses associated with this zone compared to Zone 1, it was believed possible that the retrievable packer had shifted after the initial breakdown and had partially blocked the port collar. After a series of attempts, the packer was finally retrieved and replaced by a new packer and another attempt was made to frac the well. Figure 11.6 illustrates that aborted attempt. On the possibility that the port collar accessing Zone 2 might be partially closed, the casing adjacent to Zone 2 was perforated with thirty 0.47-inch holes to assure access to the formation and to minimize friction loss within the casing system.

After the 30 perforations had been placed in the casing adjacent to the zone, a final attempt was made at fracing Zone 2. Pressures associated with the nitrogen prepad injection are shown in Figure 11.7. The pressure response was typical of previous attempts, with the maximum pressure reaching over 3250 psig at an injection rate of approximately 33,000 scfm. Figure 11.8 illustrates the predictable results at injection rates of 60 and 40 bpm of 80-quality foam. The job "sanded off" at approximately 17 minutes into the job while injecting a foam slurry with 1.5 lb/gallon of 20/40 sand. (See Figure 11.9).

11.4 Analysis of Problems in Fracing Zone 2

During the several attempts to frac Zone 2, various hypotheses were proposed to explain the peculiar behavior of the zone. These hypotheses ranged from downhole equipment problems to pre-stressing of the

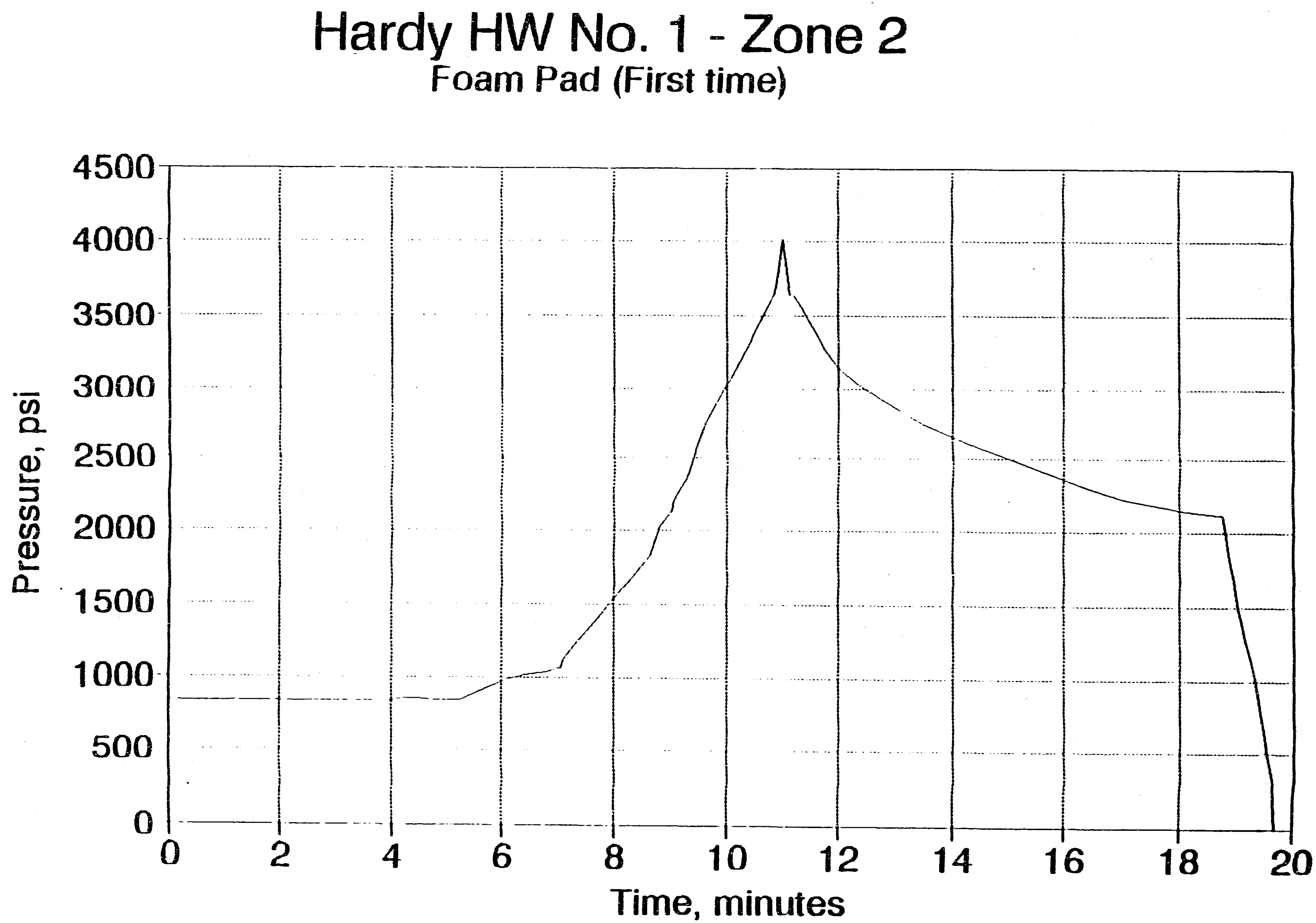


Figure 11-5, Pressure Response during Initial Foam Pad Injection

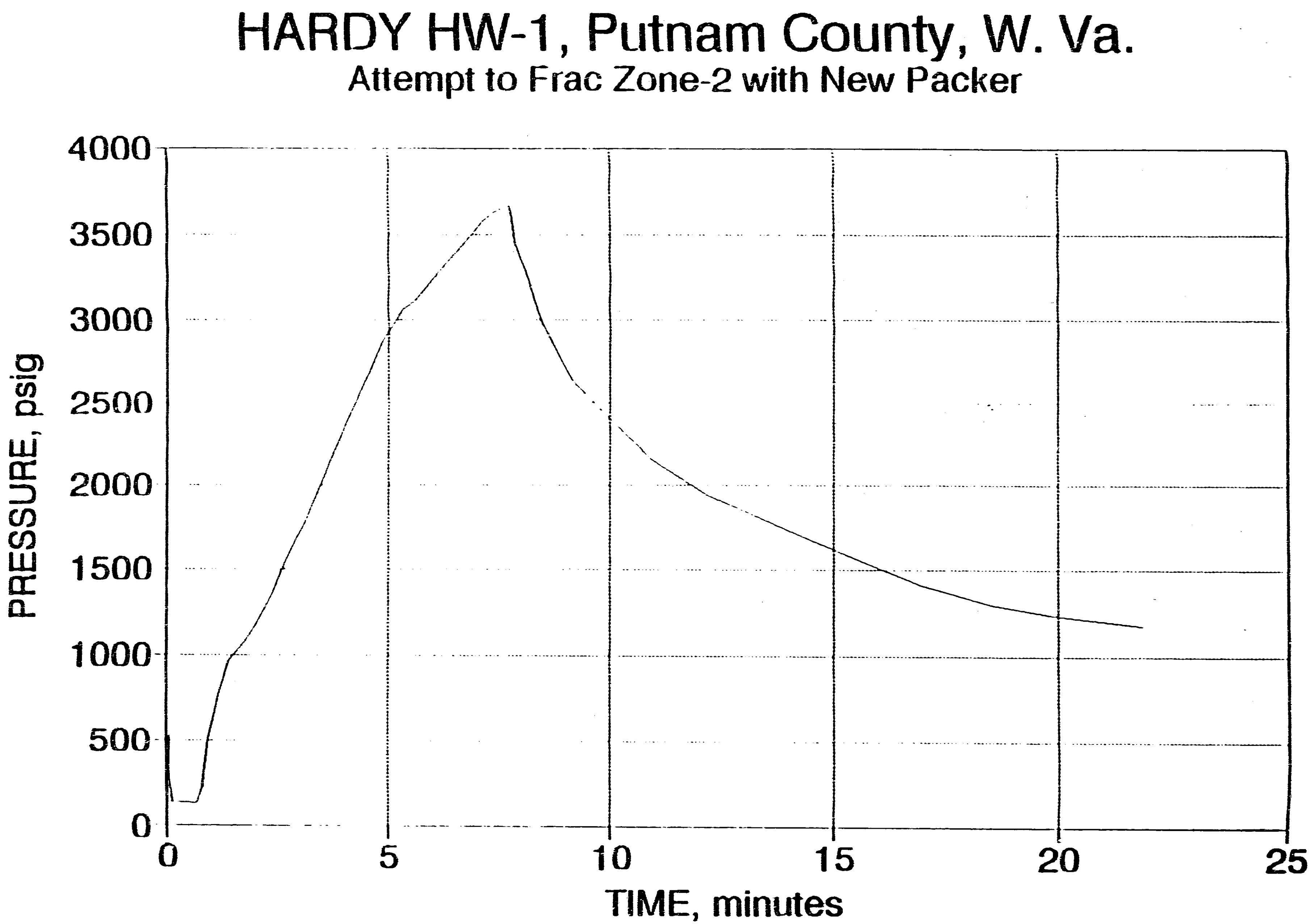


Figure 11-6, Aborted attempt to frac Zone-2 after Replacing Packer.

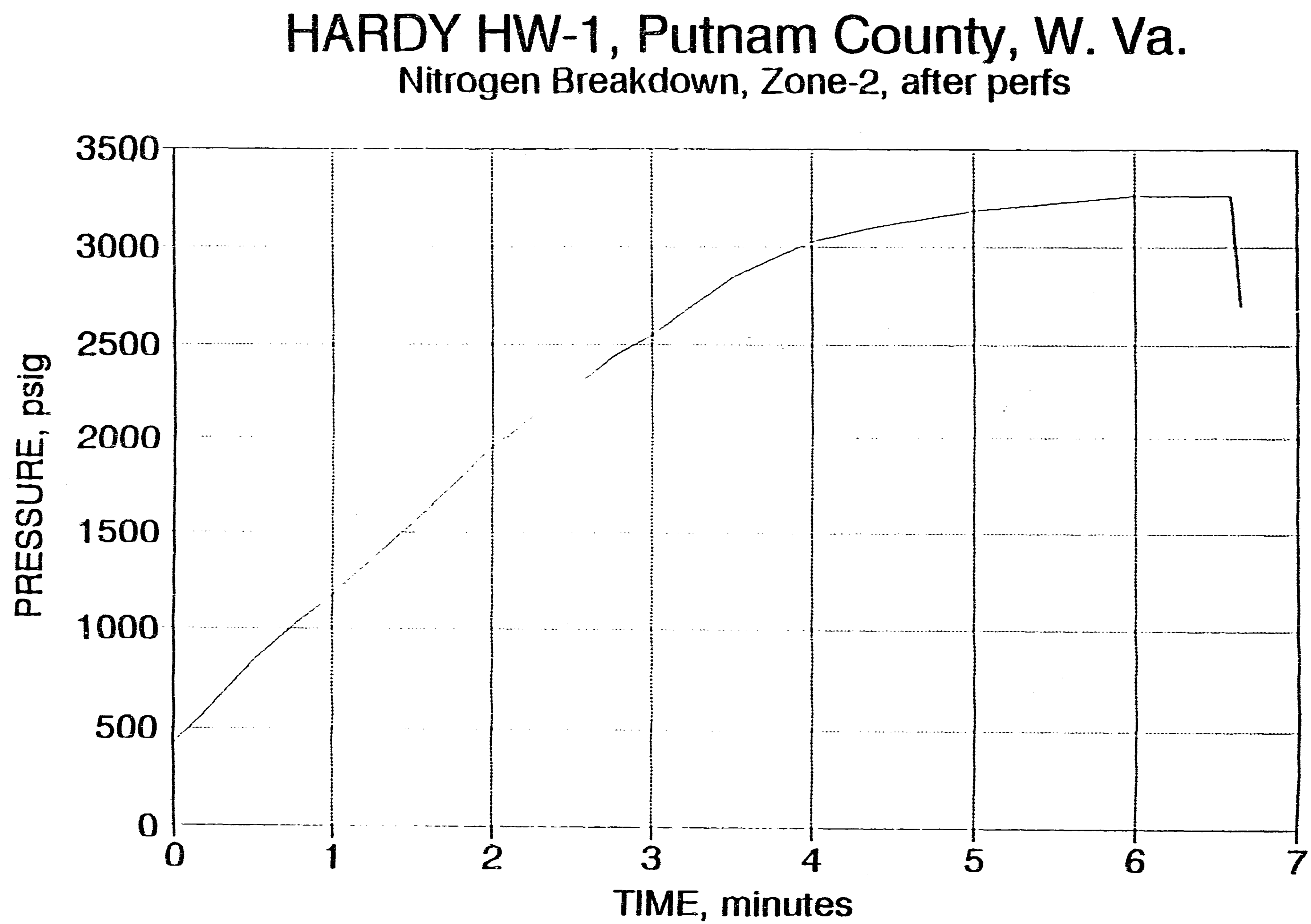


Figure 11-7, Nitrogen Pad injection into Zone-2 after perforating.

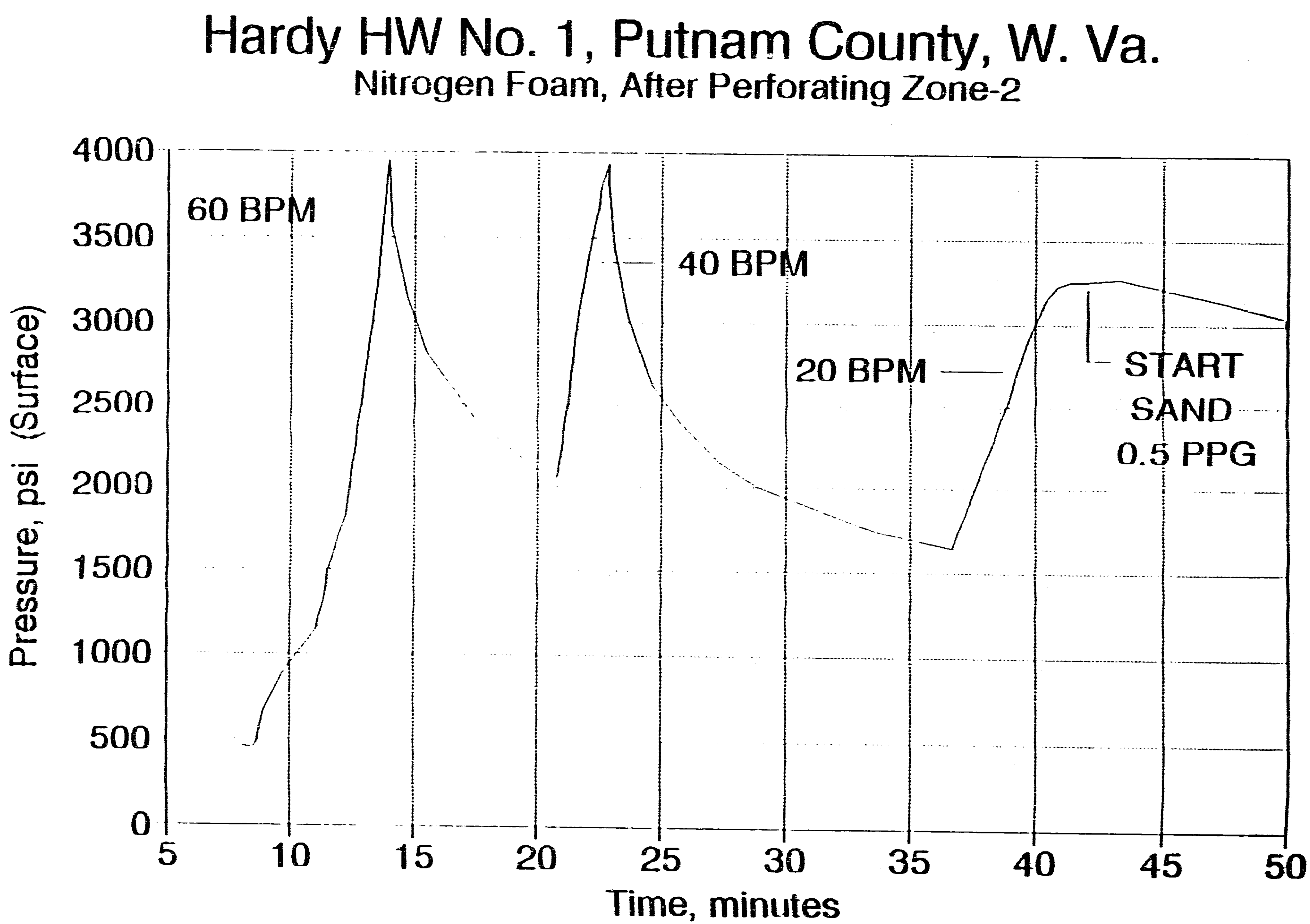


Figure 11-8, Foam frac on Zone 2

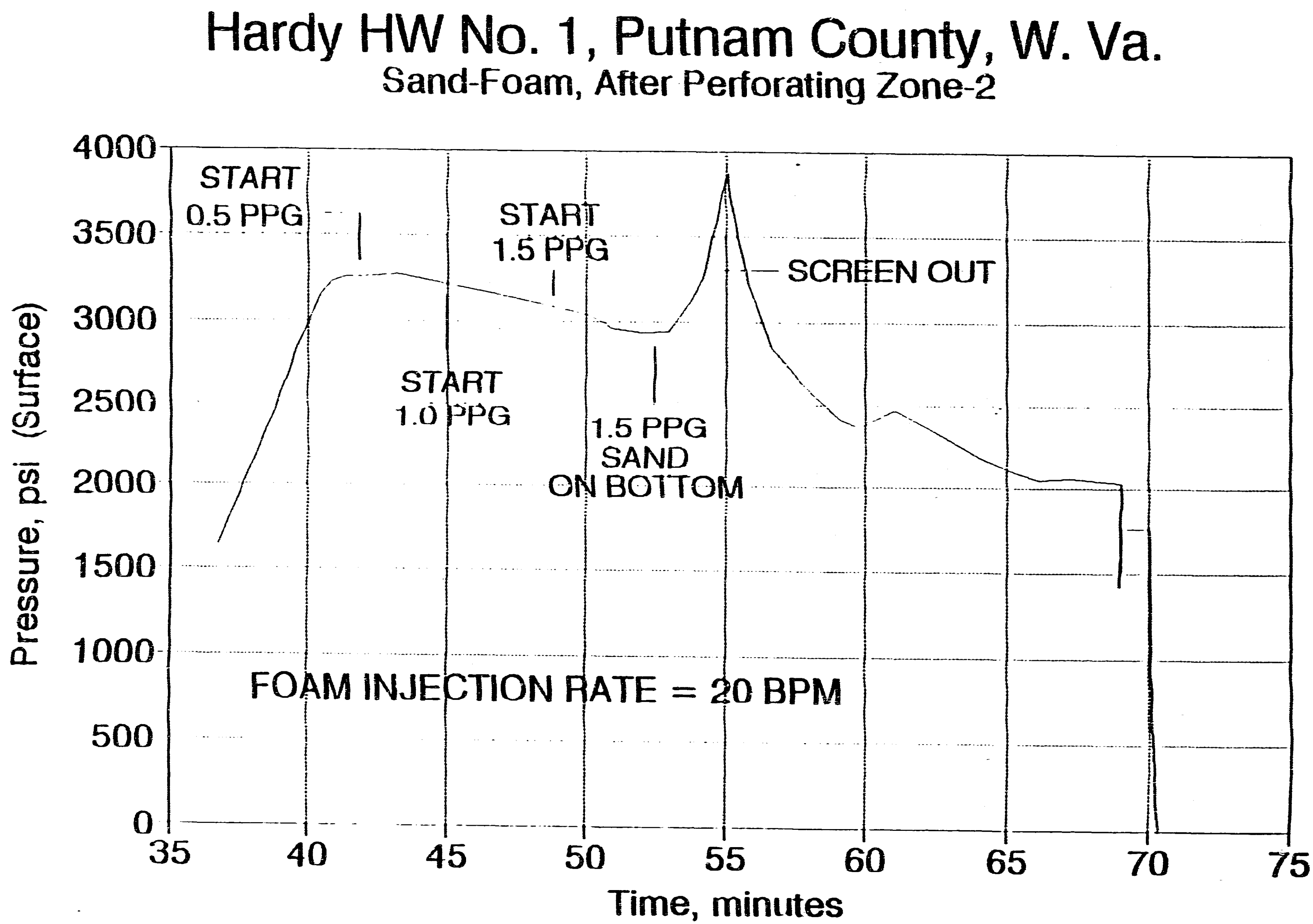


Figure 11-9, Foam frac on Zone 2 showing Screen out formation by the preceding frac treatment on Zone 1. Suggested explanations included the following:

1. Blockage of port collar by retrievable packer
2. Closed or partially closed port collar
3. Mud, sand, or rubble behind the casing
4. Zone 2 fractures filled by sand when Zone 1 was fraced.
5. Stress build-up in formation by prior frac in Zone 1.
6. Too many natural fractures to inflate for the available rate.
7. Interval too long for effective stimulation.

Initially, the first three suggested explanations appeared to have the most merit; however, after careful examination of the data, the latter two appear to be closer to the answer. The first two suggestions, both of which imply restricted exit from the casing, were essentially ruled out when additional perforations failed to correct the problem. Although explanation number three cannot be completely ruled out, it would seem likely that loose material subject to cyclic fluid movement in the annular space behind the casing would cause more erratic pressure behavior than was observed. Likewise, explanation number four cannot be completely ruled out, but it does not seem likely to have occurred, especially at the pressures observed during the Zone 1 frac treatment. While frac fluids probably "leaked off" from Zone 1 into Zone 2, the movement of sand into Zone 2 fractures would have to have involved a fracture parallel to the wellbore, not a likely occurrence at the observed frac pressures.

Explanations six and seven are essentially the same in that a longer zone implies more fractures, and this is close to the most logical explanation. To initiate a fracture in shale in a horizontal wellbore in a plane other than one containing the wellbore itself, there must be pre-existing natural fractures. Otherwise, the shale is so uniformly impermeable that it would be impossible for fluids to break out of the wellbore without first initiating a longitudinal fracture along the wellbore. The same problem exists with a uniformly permeable formation where the frac fluid enters the formation on a uniform front along the length of the horizontal wellbore. Since no differential stresses are created parallel to the wellbore except at the very ends of the injection zone, it is nearly impossible to create a fracture that is perpendicular to the wellbore, regardless of the minimum stress orientation. A situation similar to this very well may have existed in Zone 2.

Zone 2 had a number of fractures recorded on the mud log. Based on the ability to inject nitrogen into the zone at relatively high rates (2-3 mmcfd) while at relatively low pressures (less than 1100 psig), it would appear that several fractures were capable of accepting fluid. If these fractures are in clusters of relatively closely-spaced fractures, then it may have been almost impossible to drive one or more fractures perpendicular to the wellbore and of a width sufficient to accept a high-density sand-laden fluid. Figure 11.10 illustrates the difficulty of inflating closely-spaced fractures from the horizontal wellbore. At the final rate of 20 bpm with foam and 1.5 ppg sand, the estimated bottomhole treating pressure was over 4000 psig, far above the calculated minimum horizontal stress value of approximately 1500 psig.

11.5 Stimulation of Zones 3 and 4

After the extreme difficulty encountered in fracing Zone 2, plans for the stimulation of Zones 3 and 4 were modified. A shrinking budget necessitated reducing the cost of the remaining stimulation work. Therefore, Zones 3 and 4 were combined and stimulated as a single zone (Zone 3-4). Because a large amount of sand remained on location after the failure to execute the large treatment on Zone 2, another high volume, high rate foam frac was attempted on Zone 3-4.

Zone 3-4 was perforated with 42 holes between measured depths of 4207 and 4476 feet. Ten of the holes were in Zone 3 between 4430 and 4476, measured depth, and 32 holes were in Zone 4 between 4207 and 4370 feet, measured depth. The "select-fire" perforating gun on rollers fell freely to 4420 feet (81° of inclination from vertical) and was pumped to 4476 (85° using nitrogen (8000 scfm).

Zone 3-4 was then stimulated with an 80-quality sand-laden foam. Figure 11.11 shows the pressure response during the stimulation of Zone 3-4. Sand concentration reached a maximum of 1.5 lbs/gal into the fracture(s) before "screening out." This screen-out was similar to the

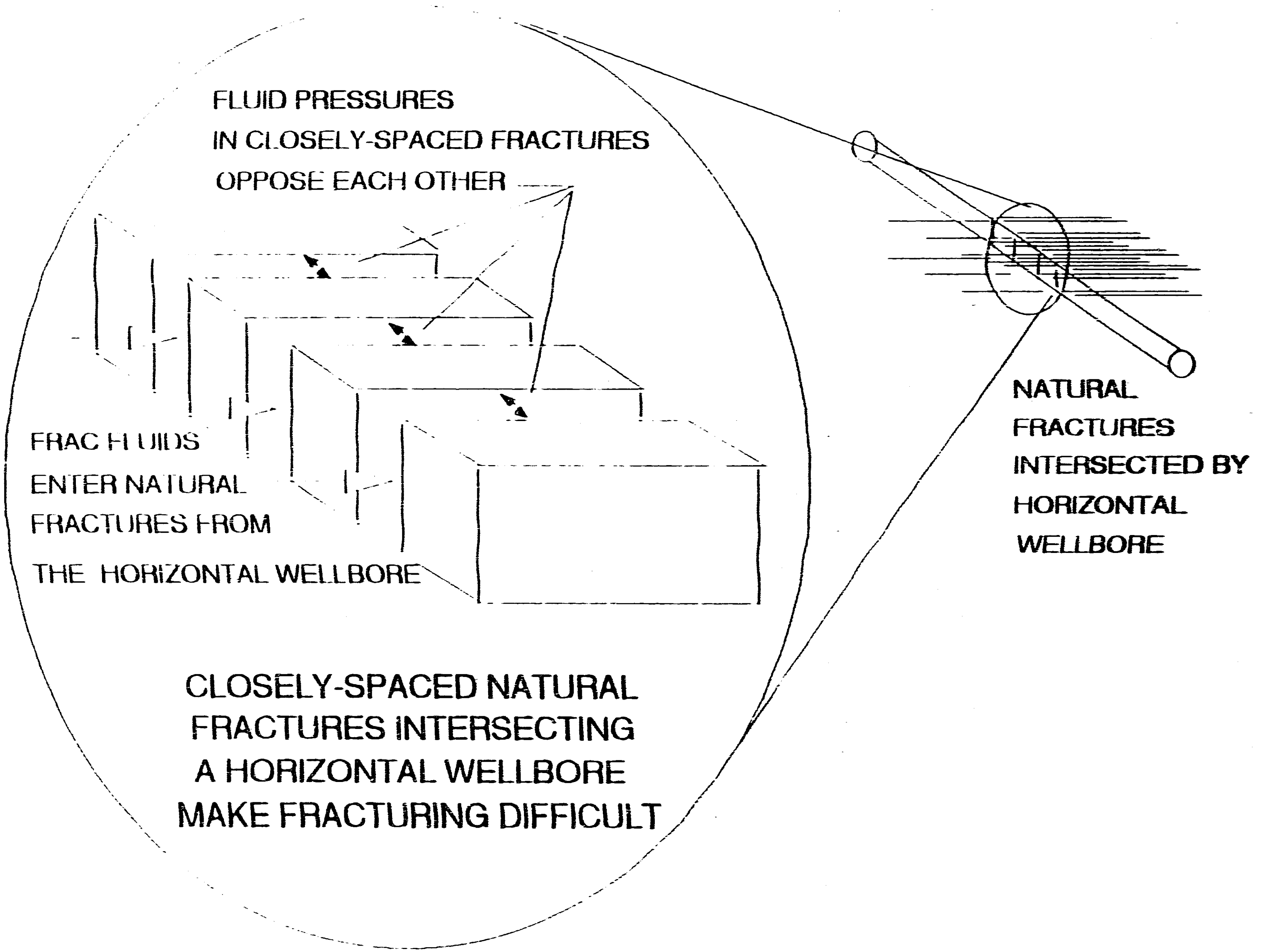


Figure 11-10, Difficulty associated with attempting to inflate **closely-spaced** natural fractures from a horizontal wellbore.

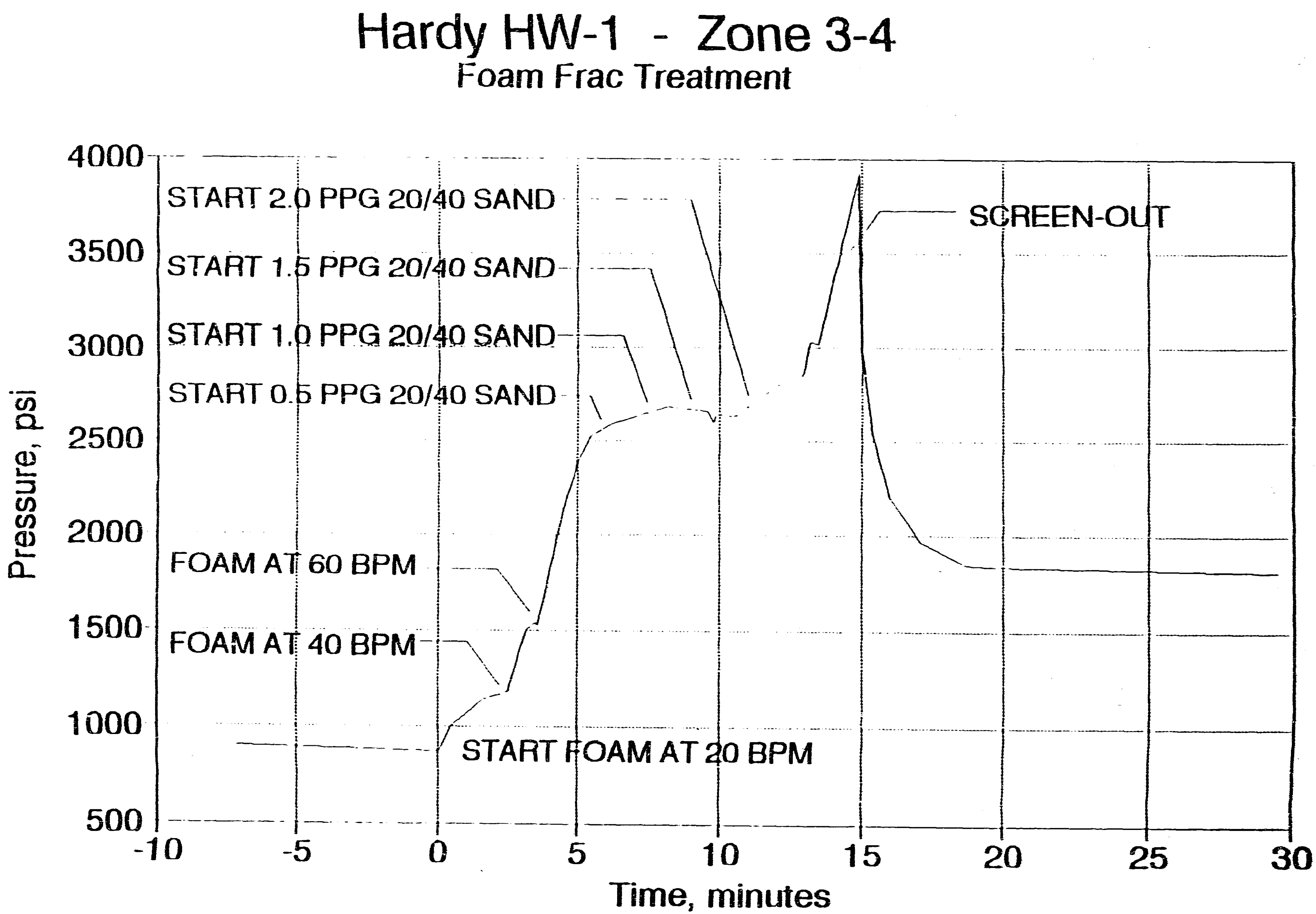


Figure 11-11, Initial attempt to frac Zone 3-4 using sand-laden foam screen-out in Zone 2 in that the maximum sand concentration reached was 1.5 lbs/gal; however, the Zone 3-4 screen-out occurred while foam was being pumped at 60 bpm compared to 20 bpm that had been pumped into Zone 2. In both cases, however, the screen-outs occurred almost simultaneously with the arrival of the 1.5 lbs/gal sand concentration at the formation face. Prior to the screen-out in Zone 3-4, nitrogen breakdown and pre-pads of 134 mcf and 135 mcf had been injected at 35,000 scfm and 1900 psi (surface). Just prior to the screen-out, the surface injection pressure was approximately 2700 psi (estimated BHP was 1600 psi. based on service company correlations). Total sand-laden fluid injected into the formation was only 1000 gallons.

After partial clean-up of fluids from the first attempt to foam frac Zone 3-4, a second attempt was made. During this attempt, no sand was injected. Very quickly, after the arrival of the 80-quality foam at the formation face, the injection pressure rose to 3700 psi (surface) and the treatment was halted (Figure 11.12). The foam was allowed to flow back from the well and the treatment was continued using only nitrogen. The final stimulation of Zone 3-4 consisted of 2,867,000 scf of nitrogen injected at an average rate of 50,000 scfm. The treating pressure ranged from 2850 to 3400 psi (surface) with the highest pressure being recorded within the first four minutes after restart of the treatment with nitrogen (Figure 11.13).

11.6 Analysis of Problems in Fracing Zone 3-4

Unlike the problems associated with fracing Zone 2, the problem of fracing Zone 3-4 appeared to be a more conventional screen-out. Zone 2 treated at 20 bpm with a bottomhole pressure of about 4000 psi, but Zone 3-4 treated at 60 bpm with a bottomhole pressure of approximately 1600 psi immediately prior to the screen-out.

Zone 3-4 was also a candidate for injection into multiple fractures simultaneously. This would also help explain the screen-out in that the multiple fractures would cause the equivalent of high fluid loss, limiting the achievable bottomhole pressure and, hence, the average fracture width. Once a number of these fractures became filled with sand near the

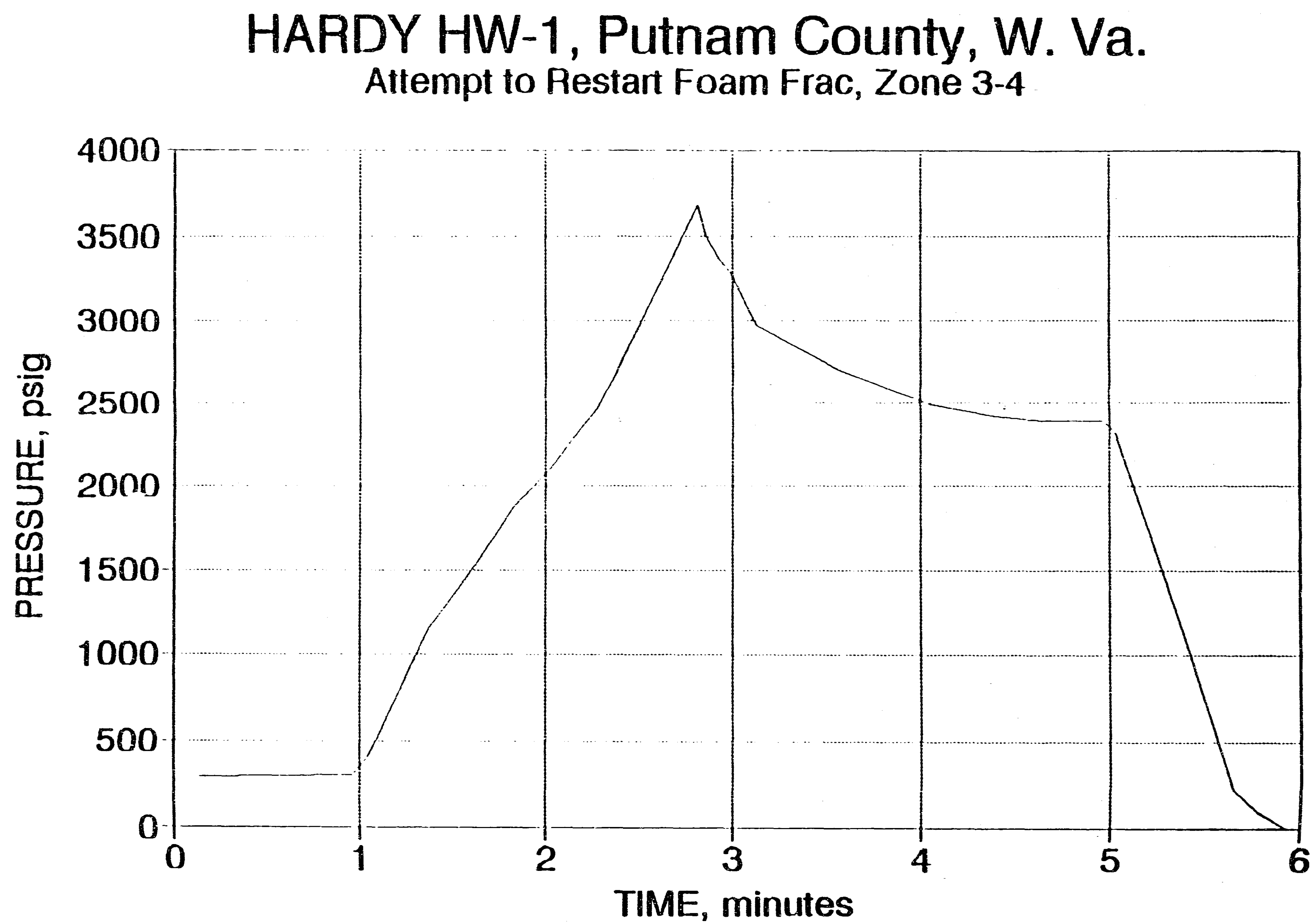


Figure 11-12, Attempt at injecting foam after screen-out in Zone 3-4

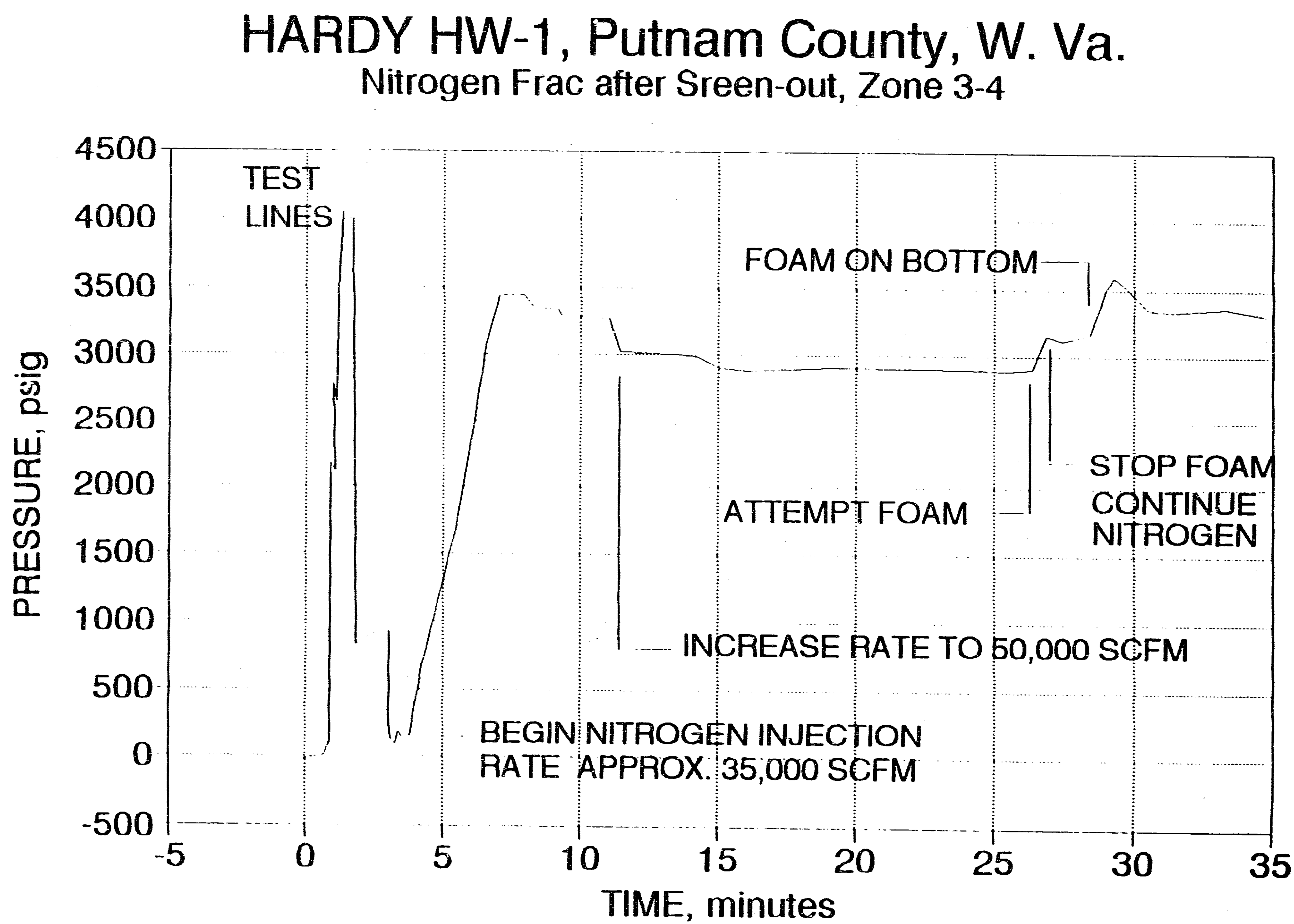


Figure 11-13, Nitrogen Frac of Zone 3-4 following sand-foam screen-out.

wellbore, it would be difficult to continue injecting at the relatively high rates being used.

12.0 WELL TESTING OPERATIONS AND ANALYSIS

Pre- and post-stimulation well testing were conducted on BDM/Hardy #1. On January 26, 1990 an 11-day pre-stimulation pressure build-up test was conducted.

Following the stimulation of the four zones, a 14-day post-stimulation pressure build-up test was conducted. Pressure measurements were recorded at the surface using pressure charts. In addition to the pressure build-up tests, the well was produced at a fixed rate which allowed BDMESC engineers to monitor the pressure decline, and therefore, analyze the drawdown data. The results of the pressure build-up and drawdown analyses contributed to the basic understanding of the various reservoir parameters which control the production of BDM/Hardy #1.

12.1 Pressure Build-up Testing

Reservoir parameters which control the productivity of horizontal wells could be estimated/calculated as a result of the analysis of pressure build-up test data. Pre- and post stimulation results when compared, reflect the effectiveness of the stimulation techniques applied on the wells. In particular, pressure build-up test results are of importance in cases where the productive horizontal section is divided into several zones where each zone could be tested and produced separately. Pre-stimulation and post-stimulation pressure build-up testing was performed on the entire horizontal section for BDM/Hardy #1. Individual zone testing (four zones) was not attempted.

Early time pressure build-up testing data can reveal important information/values of vertical permeability. Vertical permeability data when combined with estimated horizontal permeability values using late pressure-time data, will help verify permeability control along the horizontal wellbore.

12.1.1 Pre-Stimulation Testing and Analysis

An 11-day pressure build-up test was conducted on BDM/Hardy #1 using downhole electronic pressure measuring devices. In addition, surface pressures were recorded using pressure chart recorders. The pressure values were recorded every one minute for a period of eleven days. Table L-1 (Appendix L summarizes the recorded pressure values). Due to time constraints and the cost associated with testing each zone separately, BDMESC and DOE/METC elected to test BDM/Hardy #1 when all the zones were in communication in order to arrive at general reservoir parameter values for BDM/Hardy #1.

To account for gas properties such as viscosity, and compressibility, pressure and time values were converted to equivalent adjusted pressures and adjusted effective times (Table L-1). The procedure for converting actual recorded pressure and time values to equivalent adjusted values is documented in a GRI report (Reference 2).

As a first step in estimating the pre-stimulation reservoir properties such as the stabilized reservoir pressure, average formation capacity (K_eh), and formation damage, the Rectangular Hyperbolic Method, RHM (Reference 3), was implemented to determine/estimate an average initial reservoir pressure value. A plot of pressure as a function of inverse time (Figure 12.1.1) was generated and a simple linear regression model of the best fit for pressure versus inverse time was determined. Table 12.1.1 lists input values used in the pre-stimulation data analysis.

The following equations were used to determine the various reservoir properties using the RHM technique:

$$Bg,av = \text{Formation volume factor} = \frac{5.04\,(Zav)T}{(Pav)} \quad \text{(RB/MCF)} \qquad \text{.........12.1.1}$$

where Zav = average gas deviation factor, dimensionless
T = reservoir temperature, (°R)
Pav = average reservoir pressure, (psia)

Therefore,

$$Bg,av = \frac{(5.04)(0.919)(571)}{389} = 6.80 \text{ RB/MCF}$$

ANALYSIS OF PRE-STIMULATION DATA USING RHM TECHNIQUE, HARDY #1

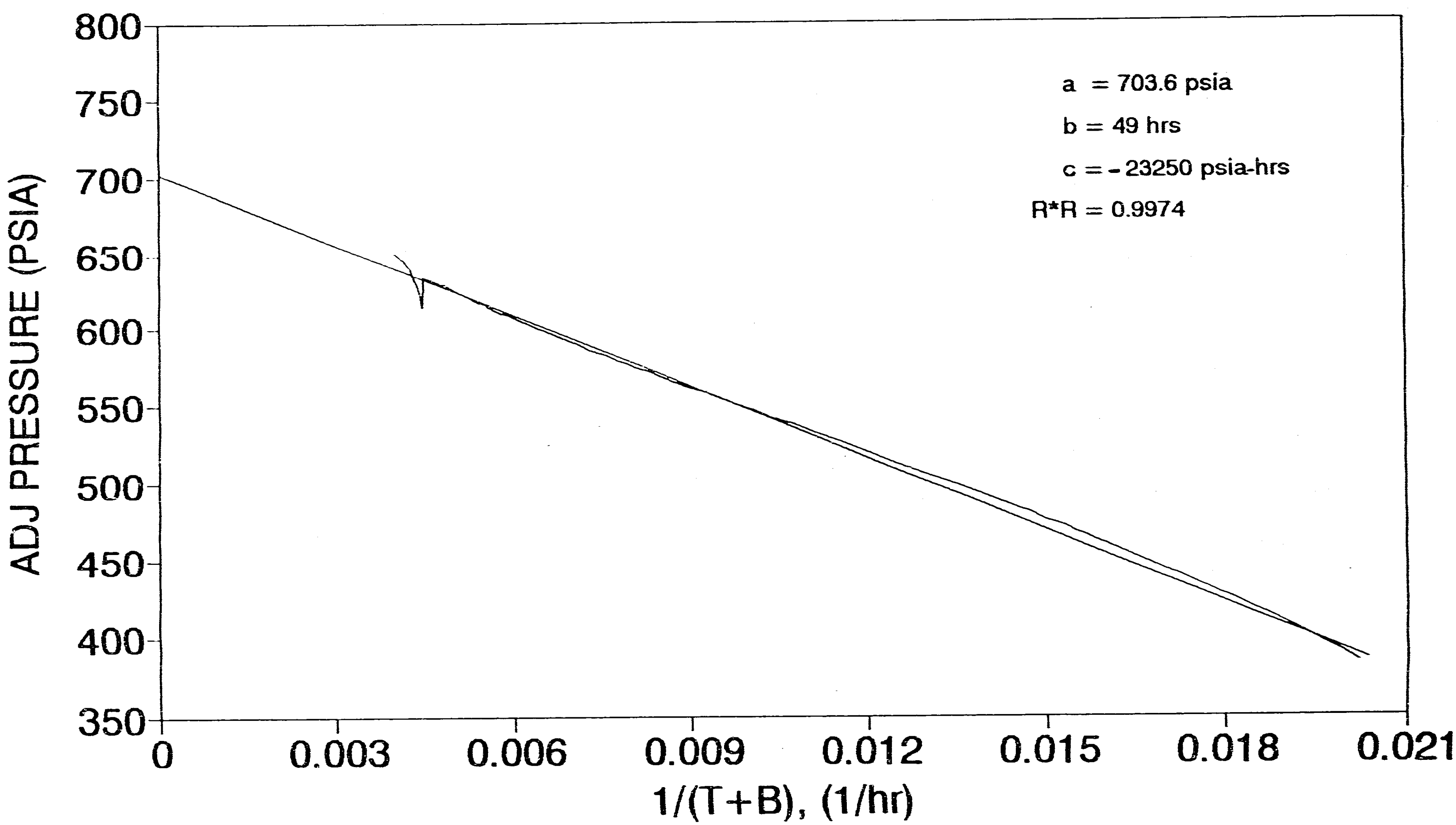


Figure 12.1.1

Table 12.1.1 BASIC RESERVOIR AND WELL DATA

HARDY #1

Input Values:

Well length (L):	2020	ft
Well radius (r_w):	0.328	ft
Reservoir gross thickness:	180	ft
Productive thickness:	50	ft
Porosity:	0.01	
r_{wD}:	0.0003	
L_D:	20	
Reservoir pressure:	700	psi
Gas viscosity:	0.010216	cp
Gas compressibility:	0.00180	$psia^{-1}$
Gas deviation factor:	0.9197	
Gas formation volume factor:	6.8	RB/mvf
Reservior temperature:	571	°R
Flow rate pre-stimulation	18	mcfpd
Flow rate after-stimulation	100	mcfpd

From Figure 12.1.1 the y intercept = a = Initial reservoir pressure (psia) = 704 psia

c = value of the slope = -23250 psia-hr

b = constant for the linear regression model at a regression coefficient, R^2, equal to unity, in this case b = 49 hours at $R^2 = 0.9974$.

Therefore,

$$m = \frac{2.303(-c)}{4\ (b)} \qquad \text{.........12.1.2}$$

m = equivalent to Horner's slope = 273.19 psia/cycle

$$K_e h = \frac{282.39(Bg\,av)(b)(\mu\,av)(q)}{-(-23250)} \qquad \text{.........12.1.3}$$

where q = gas flow rate, mcfpd.

Therefore $K_e h$ = 1 md ft

This technique is valid and accurate in estimating the initial reservoir pressure independent of other reservoir parameters.

In addition, to the RHM technique, type curves were implemented for the pre-stimulation data analysis. A Flopetrol Johnston/Schlumberger type curve for vertically fractured wells and pseudo steady state interporosity flow, Figure 12.1.2, was used.

A plot of change in adjusted pressure versus adjusted effective time, Figure 12.1.3, was best-fit in the aforementioned type curve. The match point values are used to estimate the average formation capacity, $K_e h$, and the apparent skin, S', value. Therefore:

$$K_e h = \frac{(141.2)q(Bg\,av)(\mu\,av)(P_D)}{(\Delta Pa)} \qquad \text{.........12.1.4}$$

where PD = dimensionless pressure value from type curve, (match point)

ΔPa = change in adjusted pressure value, (match point)

$$K_e h = \frac{(141.2)(18)(6.80)(0.012159812)(7.0)}{(1000)} = 1.47 \text{ md-ft}$$

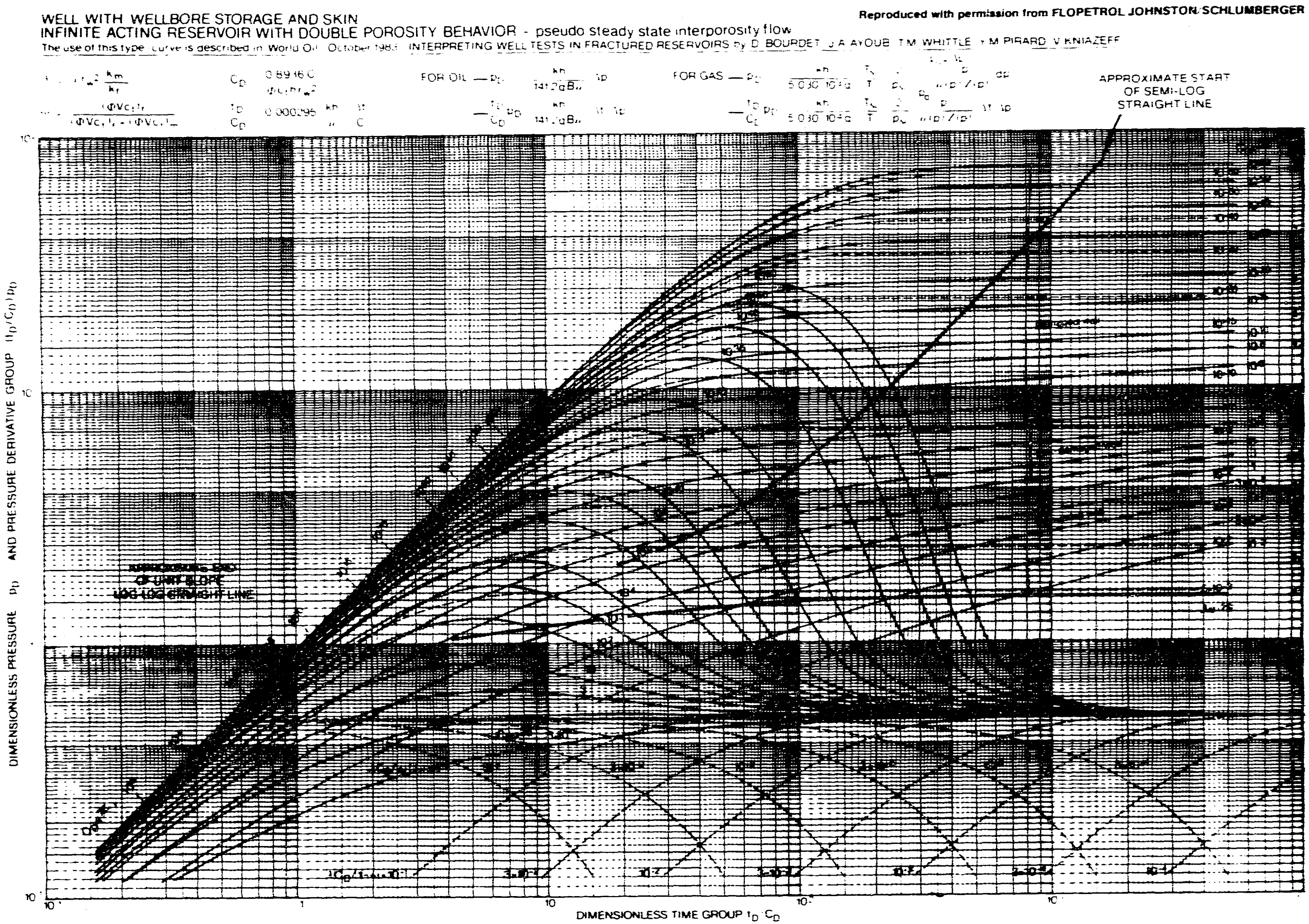

WELL WITH WELLBORE STORAGE AND SKIN
INFINITE ACTING RESERVOIR WITH DOUBLE POROSITY BEHAVIOR - pseudo steady state interporosity flow
Reproduced with permission from FLOPETROL JOHNSTON/SCHLUMBERGER
FOR OIL
FOR GAS
APPROXIMATE START OF SEMI-LOG STRAIGHT LINE
APPROXIMATE END OF UNIT SLOPE LOG-LOG STRAIGHT LINE
DIMENSIONLESS PRESSURE p_D AND PRESSURE DERIVATIVE GROUP $(t_D/C_D)p_D'$
DIMENSIONLESS TIME GROUP t_D/C_D

Figure 12.1.2

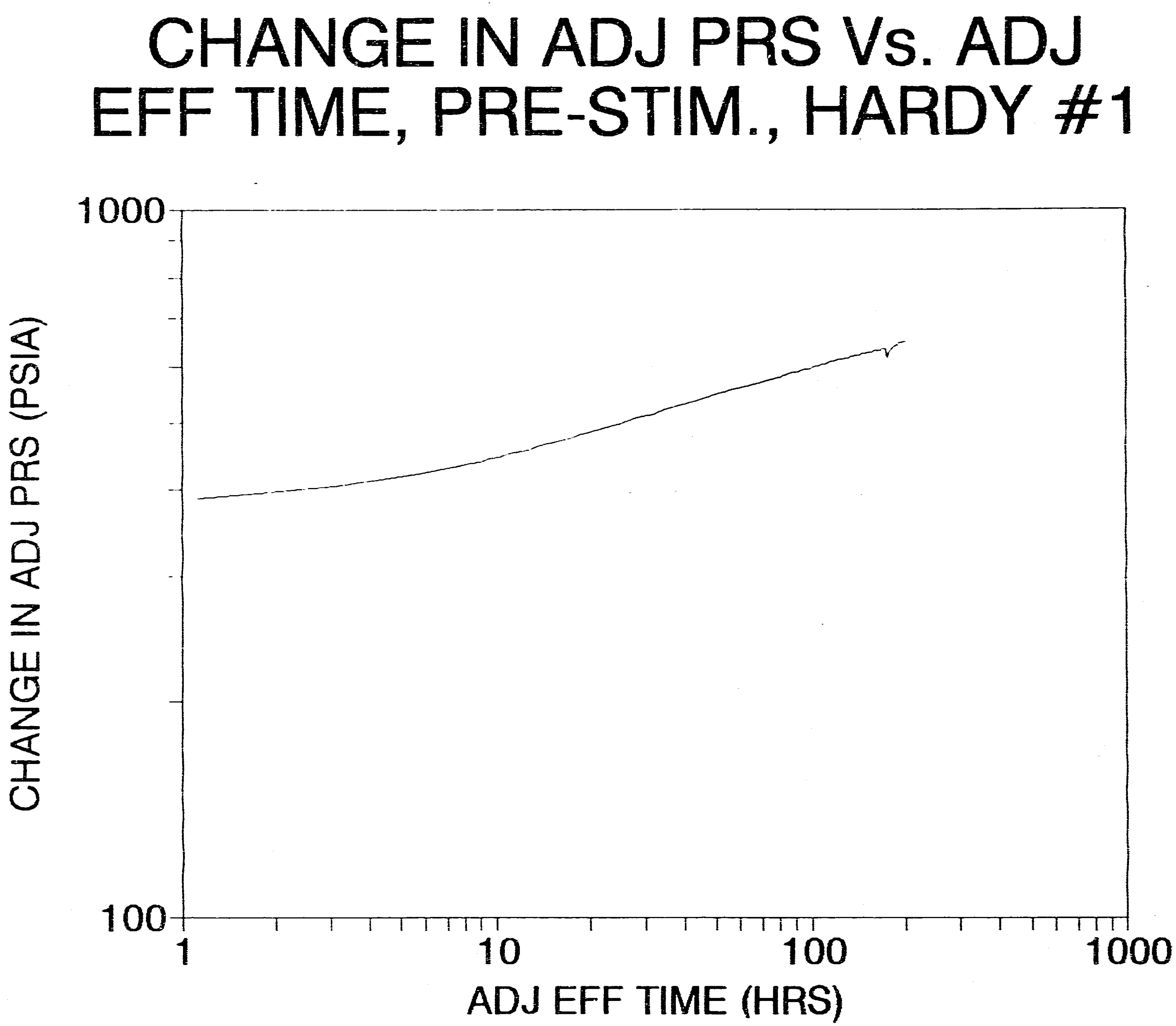

CHANGE IN ADJ PRS Vs. ADJ EFF TIME, PRE-STIM., HARDY #1
1000
100
CHANGE IN ADJ PRS (PSIA)
1
10
100
1000
ADJ EFF TIME (HRS)

Figure 12.1.3

Assuming a productive formation thickness of 50 feet, average formation permeability is estimated at 0.029 md.

In order to compute the apparent skin factor, a value of dimensionless wellbore storage constant, C_D, needs to be calculated as such:

$$C_D = \frac{(0.0002637)(k)}{(\emptyset,av)(C_t)(r_w^2)(\mu,av)} * \frac{\Delta t_{ae}}{(t_D/C_D)} \qquad \text{........12.1.5}$$

where $\emptyset$,av = average formation porosity, (fraction)
C_t = total formation compressibility, (psia^{-1})
rw = wellbore radius, (ft)
t_D/C_D = match point from type curve
Δtae = change in adjusted effective time, (match point)

$$C_D = \frac{(0.0002637)(0.029)}{(0.01)(0.0018044)(0.16625)^2(0.012159812)} * \frac{10}{(2.6x10^2)}$$

$C_D = 48.5$

Using the dimensionless wellbore storage constant, C_D, equation 12.1.6 can be used to compute the apparent skin factor, S'. Therefore:

$$S' = 0.5 \ln \frac{(C_De^{2s})}{(C_D)} \qquad \text{......12.1.6}$$

where C_De^{2s} = match point value from type curve

$$S' = 0.5 \ln \left(\frac{1}{(48.2)}\right) = -2.0$$

Horner's technique was implemented in order to validate the estimates/values of the reservoir parameters using the other techniques. A plot of adjusted pressure versus adjusted Horner time was generated (Figure 12.1.4). The y-intercept at Horner time equal zero is equivalent to the estimated reservoir pressure. Therefore:

P_i,av = 767 psia
m = slope of Horner's line = -190 psia/cycle

$$K_eh = \frac{(162.6)(q)(\mu,av)(Bg,av)}{(m)} \qquad \text{.........12.1.7}$$

PRESSURE BUILD-UP ANALYSIS FOR PRE-STIM. DATA USING HORNER'S TECHNIQUE

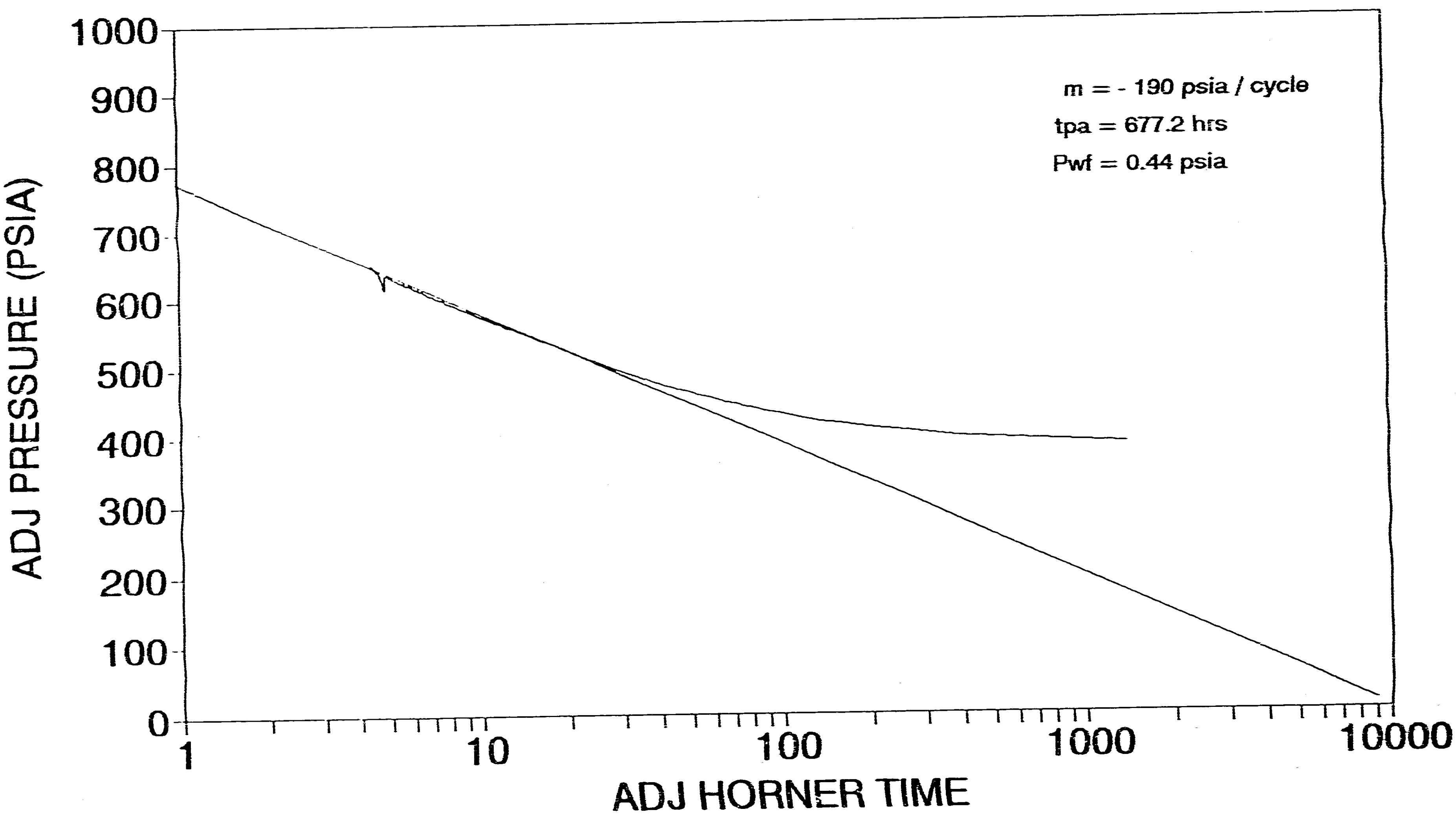


Figure 12.1.4

$$K_e h = \frac{(162.6)(18)(0.012159812)(6.80)}{(190)} = 1.25 \text{ md-ft}$$

In order to determine the skin factor/value using Horner's technique, the adjusted pressure at adjusted time equivalent to one hour needs to be determined. Using the Horner's straight line equation, Pa,1hr is determined as follows:

$$y = mx + b$$

$$y = m \log \frac{(tpa + \Delta ta)}{\Delta ta} + b \qquad \text{.........12.1.8}$$

$$y = (-190) \log \frac{(tpa + \Delta ta)}{\Delta ta} + 767$$

where tpa = adjusted production time, hrs = 677.2
Δta = adjusted shut-in time, hrs = 1 hr

Therefore

$$Pa,1hr = (-190) \log \frac{(677.2+1)}{1} + 767 = 229 \text{ psia}$$

$$S' = 1.1513\left(\frac{(Pa,1hr - Pa,wf)}{m} - \log\frac{(k)}{(\O \mu C_t r_w 2)} + 3.23 + \log\frac{(tpa+1)}{tpa}\right) \qquad \text{.........12.1.9}$$

$$S' = -5.0$$

Finally, type curves which were generated for horizontal wells (Reference 4) were used for analyzing the BDM/Hardy #1 pre-stimulation data. Earlier these type curves were used in the analysis of the BDM/RET#1 horizontal well pressure data. A dimensionless pressure versus dimensionless time type curve for horizontal wells with wellbore storage effects was used for the analysis (Figure 12.1.5).

Based on the available geologic and engineering data, several assumptions were made in order to compute the necessary variables needed for the analysis. In order to determine the dimensionless values of L_D and rw_D, where:

$$L_D = \text{Dimensionless well length} = \frac{L}{2h} \text{ SQRT} \frac{(Kv)}{(Kh)} \qquad \text{.........12.1.10}$$

and $$r_{wD} = \text{Dimensionless wellbore radius} = \frac{2rw}{L} \qquad \text{.........12.1.11}$$

TYPE CURVES FOR HORIZONTAL WELLS
LD = 20, RWD = 3E-04

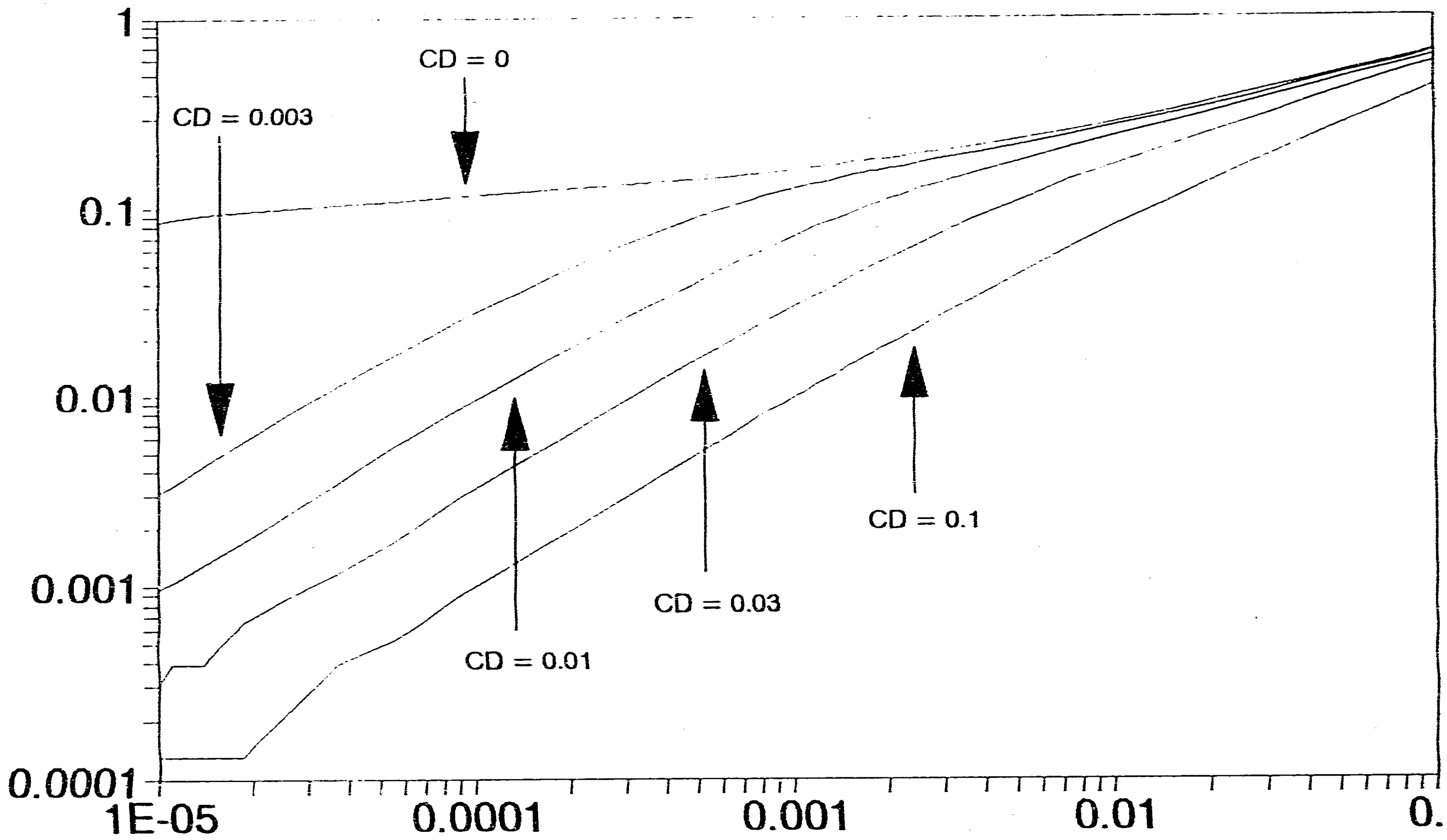


Figure 12.1.5

a value of productive formation thickness of 50 feet was assumed based on geophysical well logs.

Using the appropriate type curve and matching the pressure buildup data as exhibited in Figure 12.1.6, the following match points were obtained with L_D = 20 type curve.

$P_D = 0.215$	$\Delta Pa = 1000$	$C_D = 0.0$
$t_D = 100$	$\Delta t_{ae} = 0.0005$	

Therefore, using equation 12.1.12, an average formation capacity value was computed as follows:

$$K_e h = (141.2)(q)(Bg,av)(\mu,av)\frac{(P_D)}{(\Delta Pa)} \qquad \text{.........12.1.12}$$

$$K_e h = (141.2)(18)(6.8)(0.01215\ 9812)\frac{0.215}{1000}$$

$$K_e h = 0.045 \text{ md-ft}$$

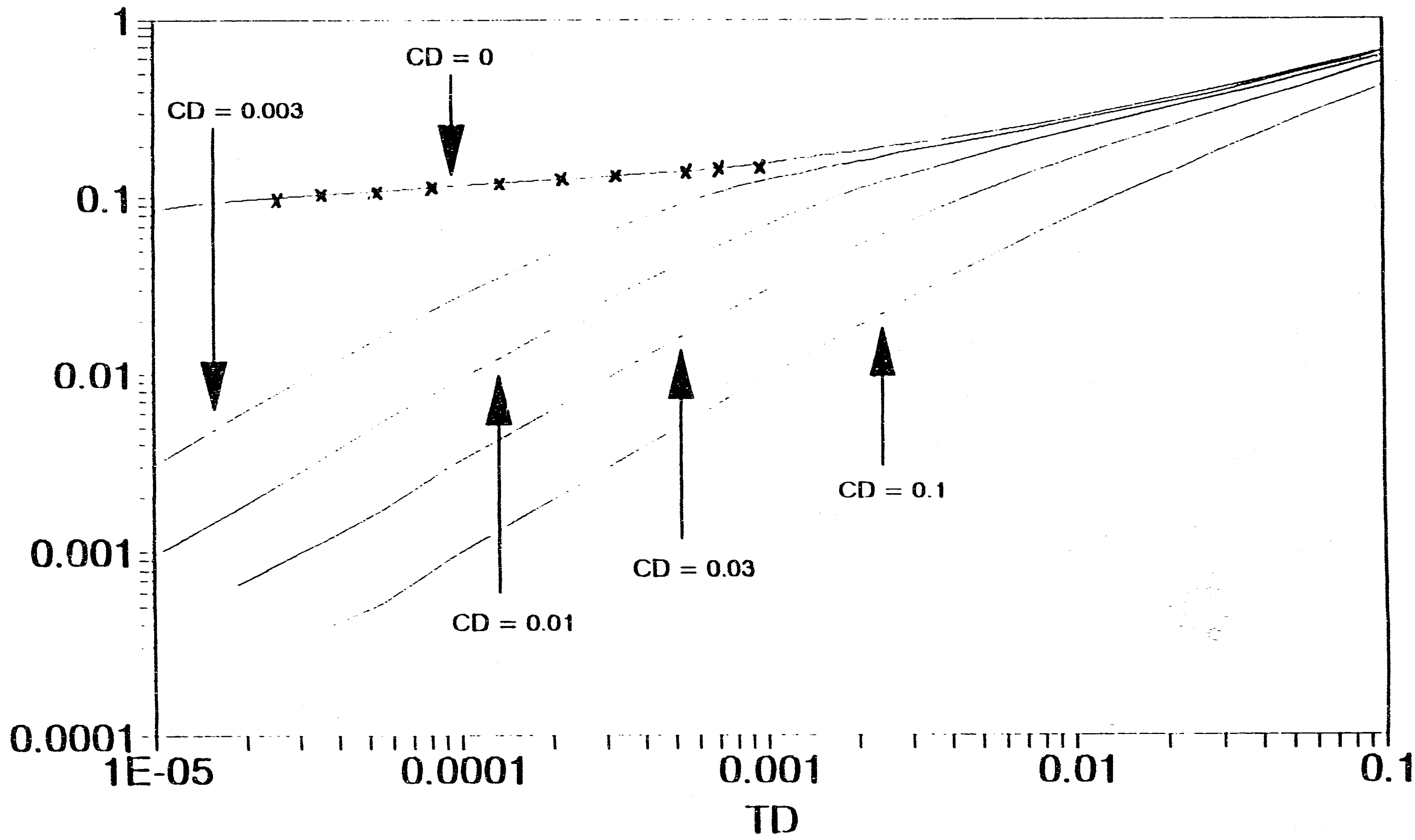
Using Equations 12.1.10 and 12.1.13, the results of the pre- stimulation analysis indicate an effective length of 900 feet and a K_v/K_h of 4 which represents an anisotropy ratio of 4:1.

$$Le = \frac{0.001055}{\O \mu C_t} \; \frac{Ke\ (\Delta t_{ae})}{(t_D)\ MP} \qquad \text{.........12.1.13}$$

12.1.2 Post Stimulation Testing and Analysis

Following the stimulation of BDM/Hardy #1, where Zones 1,2, and 4 were stimulated and attempts were made to stimulate Zone 2, a 14-day pressure build-up test was conducted where surface pressure values were measured. Surface pressure values were then converted to bottomhole conditions. The data collection and analysis is exhibited in Table L-2 (Appendix L). It is important to note that the pressure build-up test was performed when all the zones were in communication rather than on a zone-by-zone basis. A zone-by zone testing would have helped determine the effect of the stimulation techniques. An overall testing when all the zones are in communication will generate a basic understanding of the effect of the stimulation techniques on the well's productivity.

TYPE CURVES FOR HORIZONTAL WELLS LD = 20, RWD = 3E-04



HARDY #1 Pre-Stimulation Type Curve Match

Figure 12.1.6

As mentioned in Section 12.1.1, values of adjusted pressures and adjusted effective time were used for analyzing the post-stimulation pressure data (see Table I-2). Input values for post-stimulation data analysis are summarized in Table 12.1.1.

In a first attempt, type curves were used to determine the end of the wellbore storage effects. The following are the match point values obtained from the type curves for vertically fractured wells as a result of matching Figure 12.1.7.

$\Delta t_{ae} = 100$	$t_D/C_D = 370$
$\Delta Pa = 1000$	$P_D = 5.2$

$C_D e^{2s} = 0.3$

Therefore, in order to compute values of formation capacity and effective skin, equations 12.1.1, 12.1.4, 12.1.5, and 12.1.6 were used for the analysis as follows:

$$B_{g,av} = 5.04 \frac{(0.919)(571)}{418} = 6.32 \text{ RB/MCF}$$

Where P,av = average reservoir pressure = 418 psia
Z = gas deviation factor = 0.919

Using equation 12.1.4, the average reservoir formation capacity value was computed at $K_e h$ = 5.64 md-ft at an average flow rate equivalent to 100 mcfpd.

Values of C_D and S' were determined at 1326.3 and - 5.0 respectively.

From the type curve analysis, the data falling within the semi-log region were analyzed using Horner's technique. Figure 12.1.8 which exhibits a plot of adjusted pressure versus adjusted Horner's time revealed a straight line with a slope m = -230.55 psia/cycle.

Using equation 12.1.7, 12.1.8, and 12.1.9 values of formation capacity and apparent skin were estimated at 5.42 md-ft and -6.0 respectively.

CHANGE IN ADJ PRS Vs. ADJ EFF TIME, POST-STIM., HARDY #1

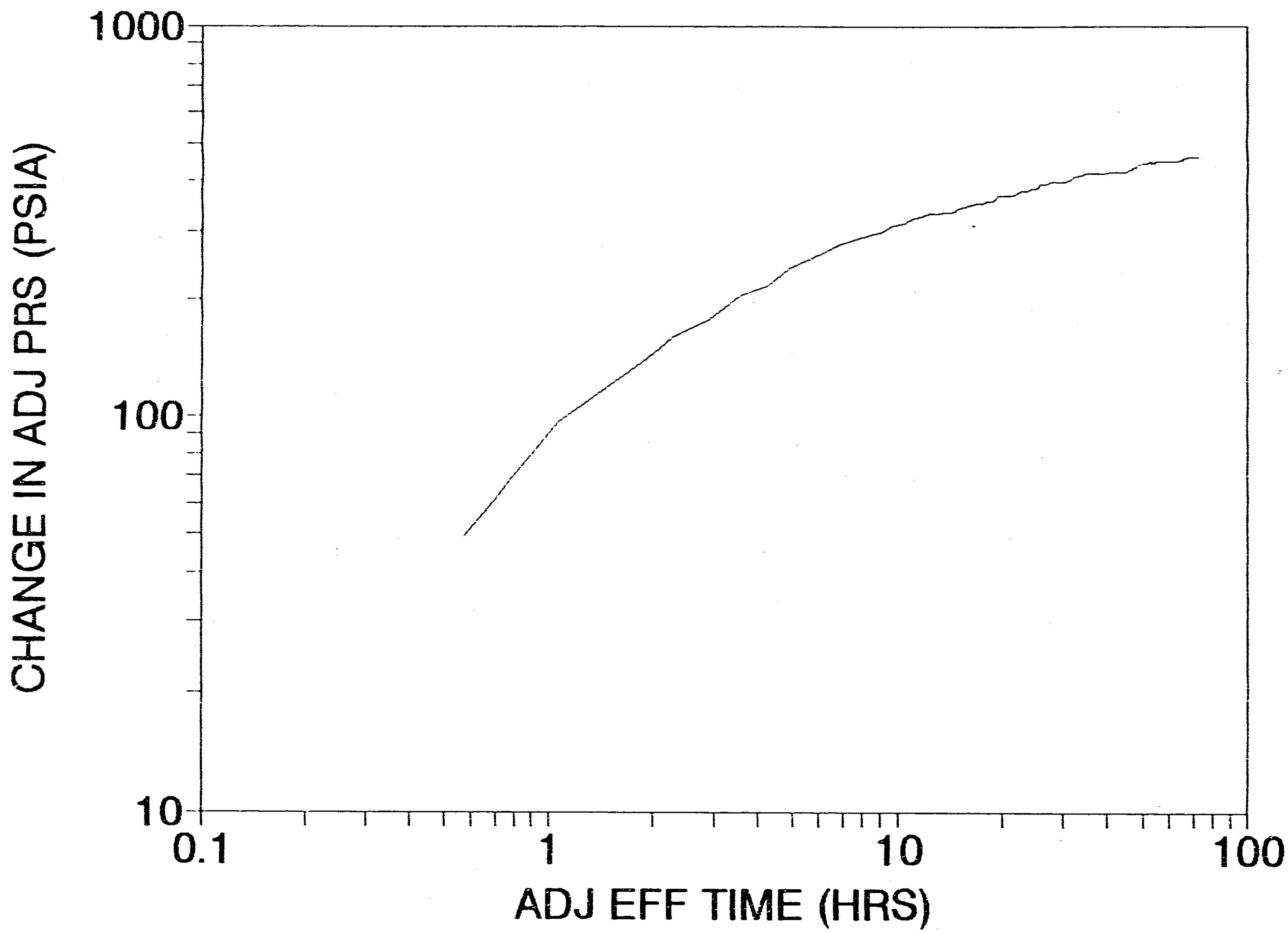
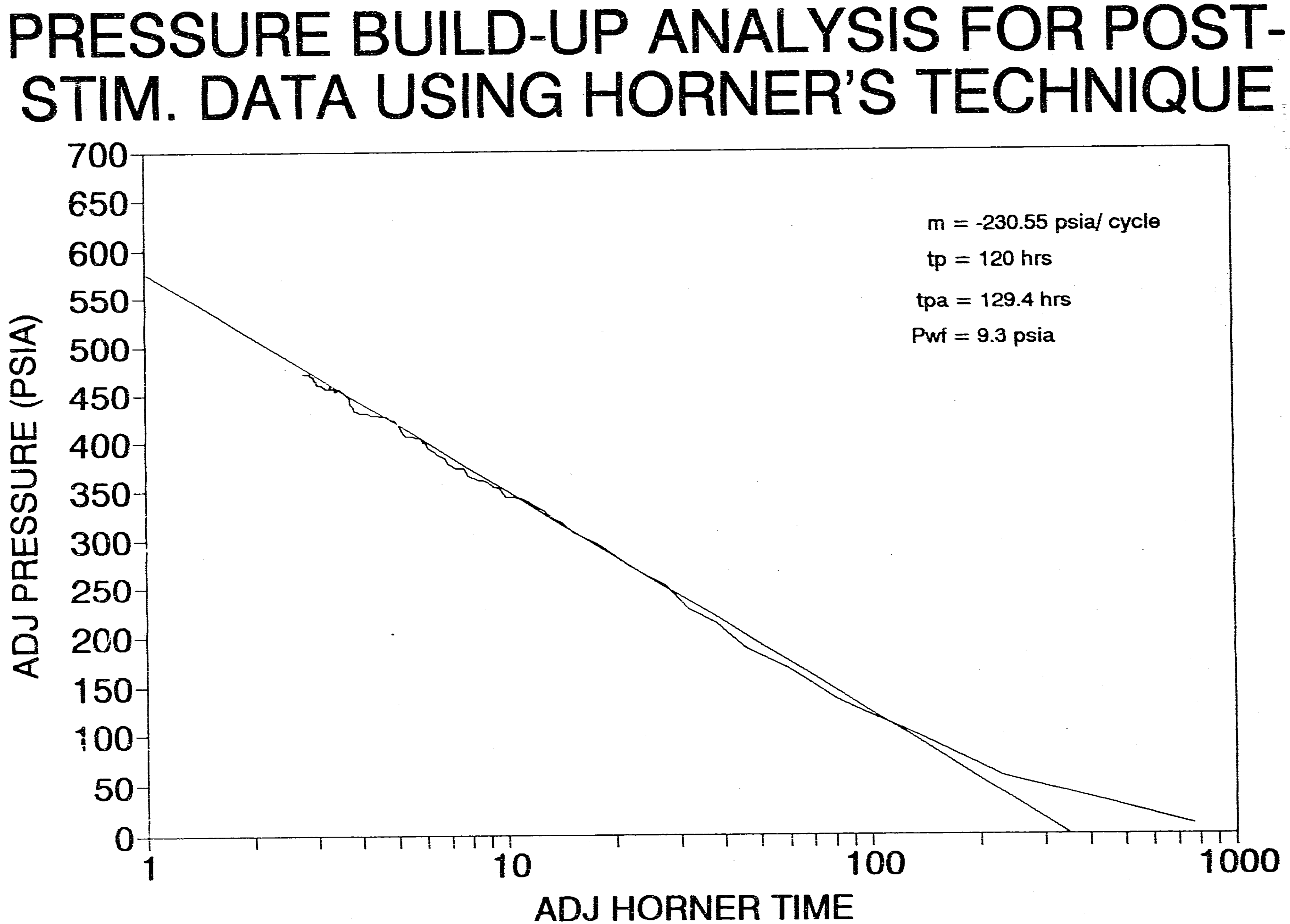


Figure 12.1.7



PRESSURE BUILD-UP ANALYSIS FOR POST-STIM. DATA USING HORNER'S TECHNIQUE
ADJ PRESSURE (PSIA)
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1
10
100
1000
ADJ HORNER TIME
m = -230.55 psia/ cycle
tp = 120 hrs
tpa = 129.4 hrs
Pwf = 9.3 psia

Figure 12.1.8

Finally type curves generated for horizontal wells were implemented for the analysis of the post-stimulation data. Figure 12.1.6 was used to determine the curve match. The following is a list of the match points as a result of the matching procedure:

$\Delta t_{a} = 0.10$ $\Delta Pa = 1000$

$t_D = 0.00032$ $P_D = 0.3$

$C_D = 0.1$

Therefore, using equation 12.1.12 an average formation capacity value was determined as follows:

$$K_e h = \frac{(141.2)(100)(6.32)(0.0121598)(0.3)}{1000}$$

$$K_e h = 0.325 \text{ md-ft}$$

12.2 Drawdown Testing -Post Stimulation

Following the post-stimulation pressure build-up test, the well was placed line against a line pressure equivalent to 70 psia. A constant well flow rate of 100 mcfpd was attempted while the well's pressure was monitored at that rate. At early times, approximately the first six days, there was a fluctuation in production rate due to freezing at the wellhead. The average production rate for the first six days was approximately 61 mcfpd. This value was determined by computing the cumulative production at 364 mcf and determining the average daily rate. Therefore:

$$q_1 = \frac{364}{6} = 61 \text{ mcfpd}$$

After the first six days the production rate was successfully maintained at 100 mcfpd. Figure 12.2.1 illustrates the relationship between the flow rates, well pressures, and cumulative production with time.

For the accuracy of this analysis a two-rate production test was implemented in order to provide information about the formation capacity and apparent skin. Wellbore storage effects are often thought to be minimized or eliminated by two-rate tests. In fact, wellbore storage effects last just about the same amount of time in a two-rate test as in a normal build-up, drawdown, or falloff test. However, a two-rate test

HARDY HW#1, PUTNAM COUNTY, WV
INITIAL PRODUCTION DATA

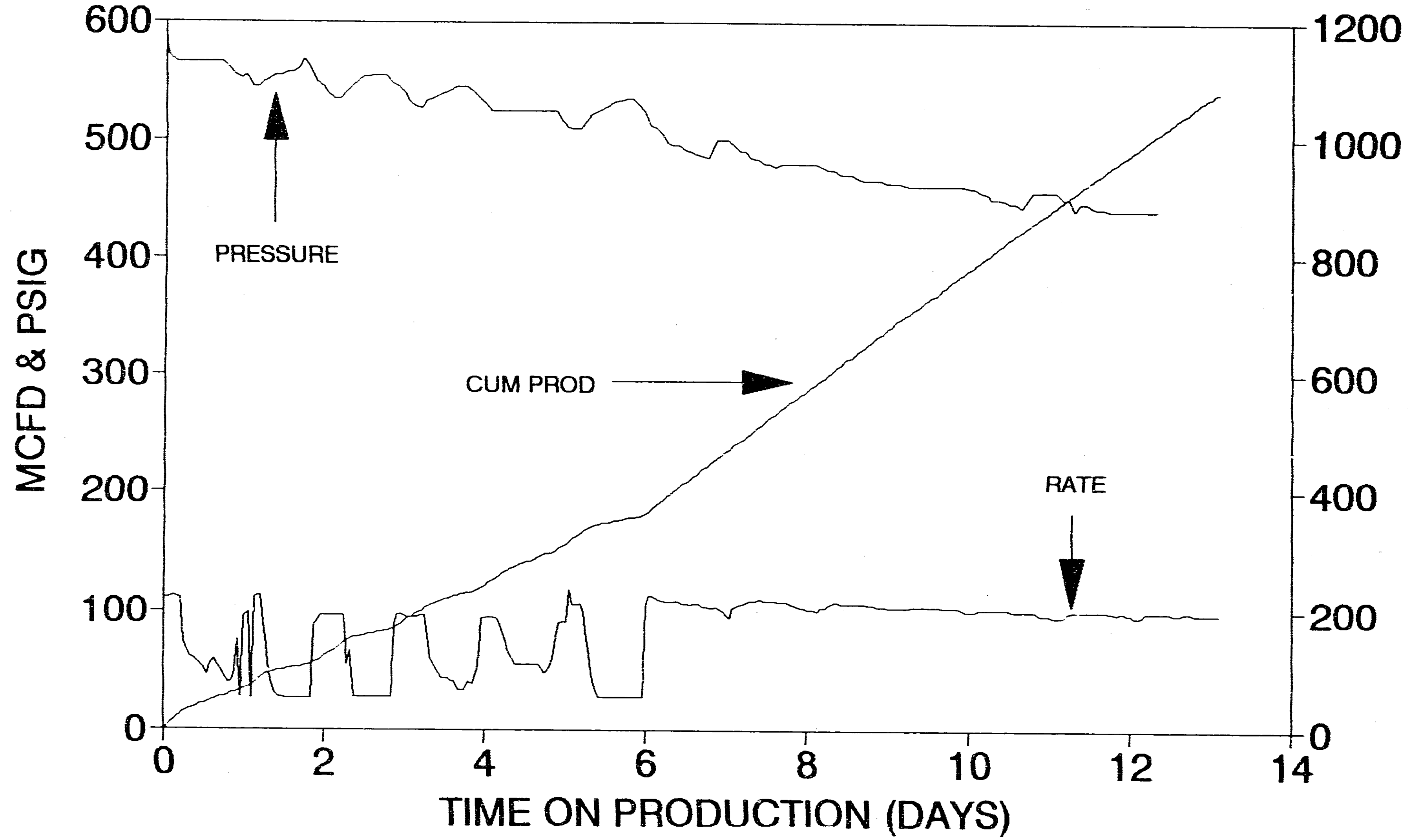


Figure 12.2.1

often can be used to prevent a wellbore storage increase, thus providing analyzable test when one otherwise might not be possible.

The collected data were analyzed as shown in Table L-3. Pressure and time data were converted to adjusted pressure and time values. In order to determine the respective values of permeability and apparent skin the analysis technique suggested in Chapter four[4] was used. The general equation for two-rate flow test analysis (equation 4.6, Reference 5) was used and a plot of adjusted pressure versus log of flow time and flow rates was generated (Figure 12.2.2). A best fit using simple linear regression was used to generate a straight line with slope m_1'.
Therefore:

$$k_e h = \frac{162.6\,(B_{g,av})(\mu_{av})(q_1)}{m_1} \qquad \text{.........12.2.1}$$

$$k_e h = \frac{(162.6)(6.3)(0.02159812)(61)}{(104)}$$

$$= 7.31 \text{ md-ft } @h = 50' \quad K = 0.1462 \text{ md}$$

The value of skin is calculated using equation 4.11 (Reference 5).

Therefore:

$$S' = 1.1513\,\frac{(q_1)}{(q_1-q_2)}\left((P_{a,wf}(\Delta t=0) - P_{a,1hr}) - \text{Log}\,\frac{(k)}{(\emptyset\mu C_t r_w^2)} + 3.2275\right) \qquad \text{.........12.2.2}$$

$$P_{a,1hr} = -104.2\left(\log\frac{(t_1+\Delta t)}{\Delta t} + \frac{q_2}{q_1}\text{Log}\,\Delta t\right) + 651$$

where $P_{a,int} = 651$ psia

$$P_{a,1hr} = -104.2\left(\log\frac{(144+1)}{1} + \frac{100}{61}\log(1)\right) + 651$$

Therefore using equation 12.2.2 S' = -4.44

To evaluate the P*, reservoir false pressure, which is used to estimate the initial average reservoir pressure the following equation was used.

$$P_a^* = P_{a,int} - \frac{q_2}{q_1-q_2}(P_{a,wf}(\Delta t=0) - P_{a,1hr}) \qquad \text{.........12.2.3}$$

TWO RATE FLOW TEST ANALYSIS
POST STIMULATION HARDY #1

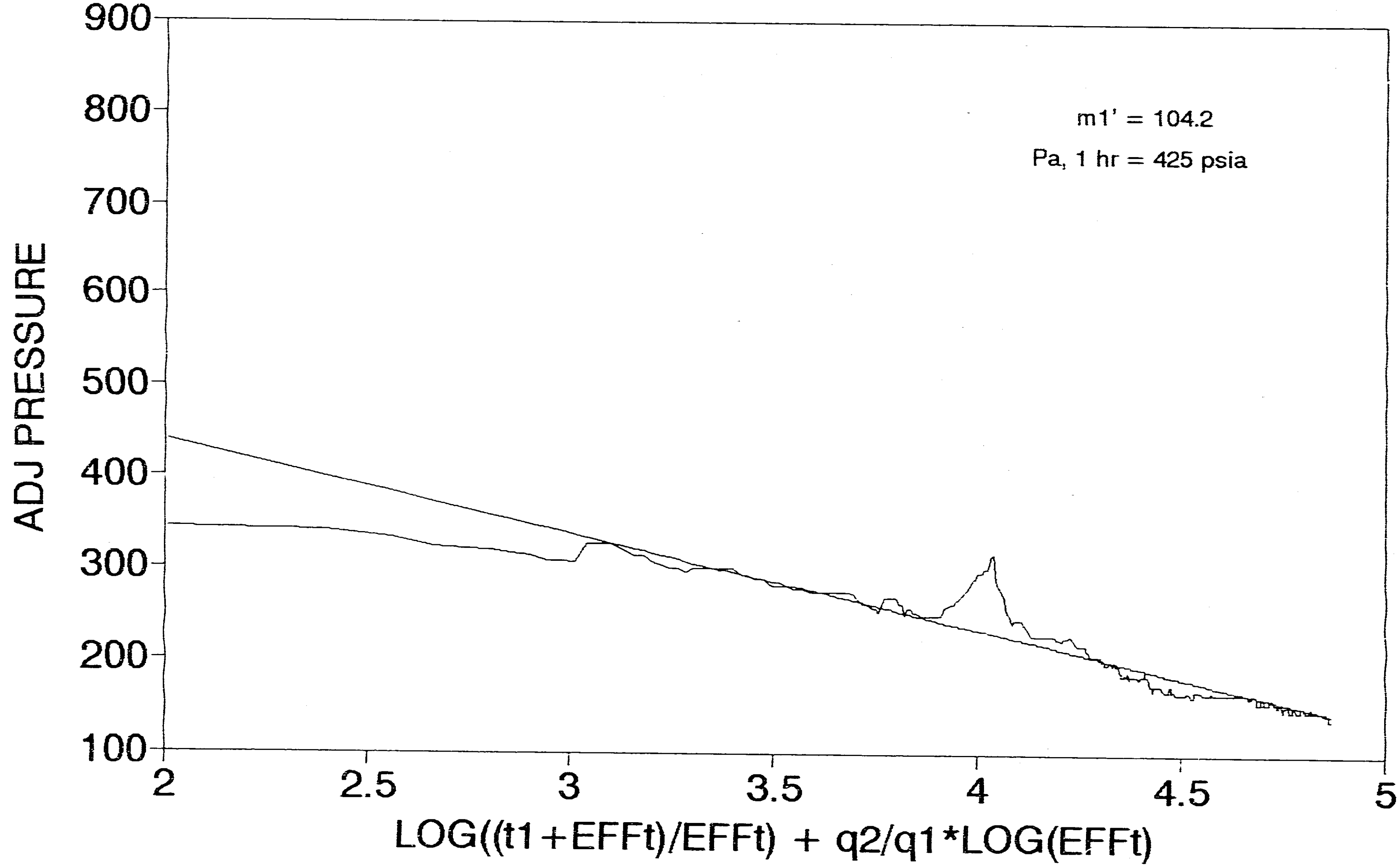


Figure 12.2.2

$$Pa^* = 651 - \frac{100}{61-100}(445-425)$$

$$= 702 \text{ psia}$$

To estimate the drainage volume average pressure by the MBH method (Chapter 6, Reference) first we obtain the false pressure value P*. Then the average pressure is estimated from

$$P = P^* - \frac{m P_{DMBH}}{2.3025}(t_{pDA}) \qquad \text{.........12.2.4}$$

$$t_{pDA} = \frac{0.0002637(k)(t_p)}{\O \mu C_t A} \qquad \text{.........12.2.5}$$

$$= \frac{(.0002637)(.146)(144)}{(.01)(.0121598)(.0018044)(\pi)(1490)^2} = 0.004$$

Using Figure 6.24 the value of PDMBH = 0

Therefore P = P* = 702 psia

Type curves for horizontal wells were used to estimate the effective formation capacity, effective horizontal wellbore length, and K_V/K_H values. Using the pressure-time matches at $C_D = 0.1$, $L_D = 20$, and $r_{wD} = 3\times10^{-4}$ (Figure 12.2.3), values of $K_e h$, L_e, and K_V/K_H were estimated using equations 12.1.10, 12.1.12, and 12.1.13.

The match points were:

$\Delta Pa = 100$ $\quad \Delta t = 100$

$P_D = 0.048$ $\quad t_D = .0053$

$$K_e h = (141.2)(q)(Bg,av)(\mu,av)\frac{(P_D)}{(\Delta Pa)\ MP}$$

$$K_e h = (141.2)(100)(6.32)(0.012159812)\frac{0.048}{100}$$

$$K_e h = 0.52 \text{ md-ft}$$

Values of L_e and K_v/K_h were computed at 1000 feet and 4 respectively.

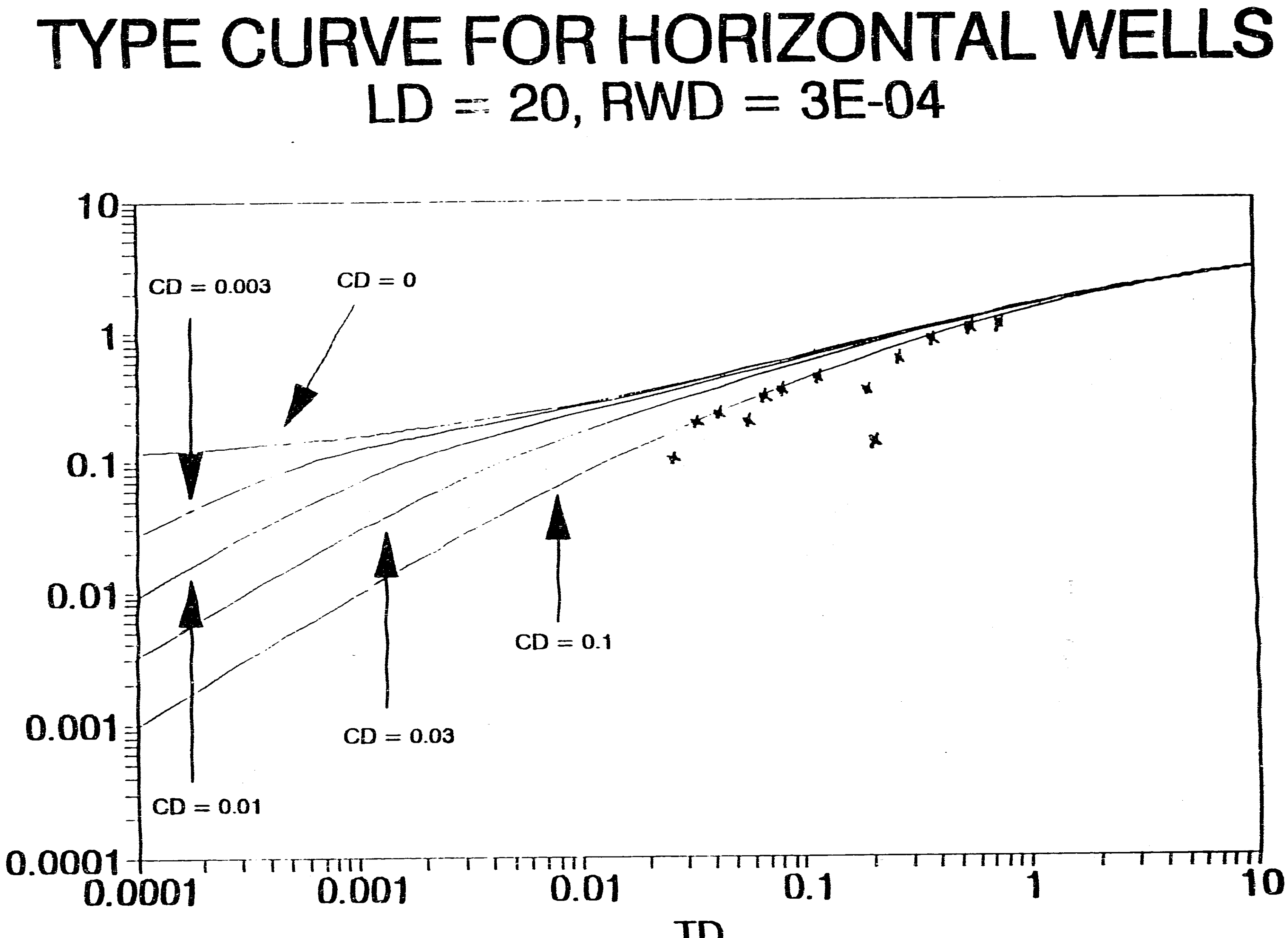


Figure 12.2.3 **Hardy #1 Drawdown Pressure Type Curve Match**

12.3 Well Test Results and Conclusions

Tables 12.3.1 and 12.3.2 summarize the results of the various pre- and post-stimulation well tests conducted on BDM/Hardy #1. The RHM technique estimated a pre-stimulation initial reservoir pressure of 704 psia. This technique is valid and accurate in estimating the initial reservoir pressure independent of other reservoir parameters since the basis for this technique is solely statistical in nature.

The computed values of K_V/K_H for both wells based on horizontal well type curve analysis indicates a 4 to 1 ratio. Assuming $K_e = (K_V/K_H)^{.5}$ and using the computed K_V/K_H ratios, values of K_V and K_H were estimated for the different tests results as exhibited in Table 12.3.3. The K_V and K_H values do not reflect the exact permeability values but rather establish the ranges of permeability based on computed L_e values and the assumption of a productive thickness based on geologic data and geophysical well logs.

The Horner technique, applied to the post-stimulation data indicated an improvement ratio in the K_eh value of 4.5 as a result of stimulation compared to an improvement ratio of 7.0 using horizontal well type curves. Post-stimulation flow rate testing has shown an increase in average production rate for BDM/Hardy #1 from 18 mcfpd (510 m^3/day) (open flow) to 100 mcfpd (2831 m^3/day) at a producing pressure of 130 psig (896×10^3 Pa) indicating an improvement ratio of at least 5.5.

The low formation capacity values computed using horizontal well type curves, compared to the higher values using conventional techniques applicable for vertical well test analysis, indicate that conventional techniques applied to horizontal wells may yield composite value of K_eh which incorporates the horizontal well length and formation capacity. When horizontal well type curves are applied to the same data, the true effective formation capacity can be derived.

From horizontal well type curves, L_e values were computed for BDM/Hardy #1 based on pre- and post-stimulation test results. L_e value of 1000 feet (305 m) was determined for BDM/Hardy #1. The actual drilled horizontal wellbore length for BDM/Hardy #1 is approximately 2000 feet (610 m). The difference between actual and effective horizontal wellbore lengths is due to the fact that horizontal well type curves assume a single-

Table 12.3.1 PRE-STIMULATION WELL TEST ANALYSIS RESULTS

HARDY #1

Buildup Well Test:	$K_e h$ (md-ft)	S'	P (Psia)	L_e (ft)	K_v/K_H
Conventional type curves ΔP_a = 1000 Δt = 10 P_D = 7.0 $t_D/C_D = 2.6 \times 10^2$	1.47	-2.0	-	N/A	N/A
Horner	1.25	-5.0	760	N/A	N/A
RHM	1.0	-	704	N/A	N/A
Horizontal well type curve ΔP_a =1000 Δt = 0.0005 P_D = 0.215 t_D = 100 CD = 0.0	0.045	-	-	900	4

Table 12.3.2 POST-STIMULATION WELL TEST ANAYSIS RESULTS

HARDY #1

Buildup Well Test:	K_eh (md-ft)	S'	P (Psia)	L_e (ft)	K_V/K_H
Conventional type curves ΔP_a = 1000 Δt = 100 P_D = 5.2 t_D/C_D = 370	5.64	-5.0	-	N/A	N/A
Horner	5.42	-6.0	575	N/A	N/A
Horizontal well type curve ΔP_a =1000 Δt = 10 P_D = 0.3 t_D = 0.00032 CD = 0.003	0.325	-	-	1000	4
Drawdown Testing:					
Two-rate test	7.31	-5.0	700*	N/A	N/A
Horizontal well type curve ΔP_a = 100 Δt =100 P_D = .048 t_D = .0053 C_D = 0.1	0.56	-	-	1000	4

* Based on the two rate test the initial average reservoir pressure was estimated

N/A: not applicable

Table 12.3.3 ESTIMATES OF K_V and K_H VALUES BASED ON HORIZONTAL WELL TYPE CURVE ANALYSIS

	K_e(md)	K_V/K_H	K_V(md)	K_H(md)
Hardy #1				
Pre-Stimulation Buildup	$9x10^{-4}$	4	$1.8x10^{-3}$	$4.5x10^{-4}$
Post-Stimulation Buildup	$6.5x10^{-3}$	4	0.013	$3.25x10^{-3}$
Post-Stimulation Drawdown	0.0112	4	0.023	$5.6x10^{-3}$
RET #1				
Pre-Stimulation Buildup	$3.3x10^{-3}$	4	$6.6x10^{-3}$	$1.65x10^{-3}$

porosity homogeneous reservoir; whereas, the actual reservoirs are very heterogenous, with considerable variation in permeability along the length of the wellbore.

The application of horizontal well type curves resulted in lower than expected formation capacity values for the Devonian Shale strata in the test wells. This may help explain the need to stimulate horizontal wells in order to achieve the desired production rates. As a result of the stimulations, certain reservoir parameters appeared to be enhanced such as the formation capacity and effective horizontal wellbore length. These improvements were also reflected in the pre- and post-stimulation production flow rate tests.

This study illustrates some of the problems that may be encountered in applying conventional techniques to horizontal wells and the value of horizontal well type curves for better estimates of reservoir parameters. Conventional techniques when applied to horizontal well tests may yield only composite or relative values. With the horizontal well type curves used in this study, estimates of vertical and horizontal permeability values are possible only if productive thickness is known.

13.0 ANALYSIS OF COMPLETION, STIMULATION, TESTING, AND PRODUCTION OPERATIONS

13.1 Completion Operations

The completion planned for this well was designed to test open hole, cased, and cemented completions in the same formation and wellbore. The purpose being to gain data and insight into the differences in stimulation efficiency between the two types of completions.

The original completion plan was to separate the horizontal interval into four (4) five hundred (500') foot long open hole sections with a liner incorporating external casing packers to insure isolation, and to cement the angle build section of the wellbore.

After the drilling operations were completed, examination of the mud log and geophysical logs provided information and data which led to a modification of the completion plan. The wellbore exited the target formation interval before the planned horizontal length had been drilled and the operator and others decided to eliminate this interval from consideration for stimulation. Approximately 116 feet of the wellbore was below the target interval, and another 278 feet which had few gas shows (see figure 13.1) was also eliminated from further consideration for stimulation.

The remaining wellbore was segregated into four zones as shown in figure 13.2. Zone one (1) was 492 feet long and contains the largest number of gas shows in the well. The second zone (2) was 750 feet long and contained six (6) gas shows along the wellbore. Zone number three (3) was 368 feet long , and zone number four (4) was 276 feet long. It is believed that modifying the completion plan in this manner was fully justified based on the data and information available at the time. Evaluation of the final openflow production rates after stimulation from three other horizontal or slant wells indicated that fracture efficiency was reduced when open hole sections longer than 350 feet were stimulated. The area of the wellbore shallower than zone four (4) was cemented. This section contained several small gas shows and minor oil shows. Consideration was originally given to conducting at least one stimulation in this section, however, problems encountered in stimulating the openhole sections resulted in excessive costs being incurred and this idea was abandoned.

In future horizontal well open hole type completions, careful consideration should be given to the length of open hole sections to be stimulated. Some combination of cased and cemented borehole and openhole completion should be considered. Depending upon the situation, perhaps no more than four zones should be stimulated, and these probably should not be longer than 350 feet.

13.2 Stimulation Operations

An attempt was made to improve the efficiency of stimulation operations by using sliding sleeve ported collars for access to the wellbore behind the casing. The units were originally designed so that the first port collar which would be placed in zone 1 would open just by pressuring up on the casing. This could be done during the frac job itself, and a second stage could be initiated by dropping a ball which would

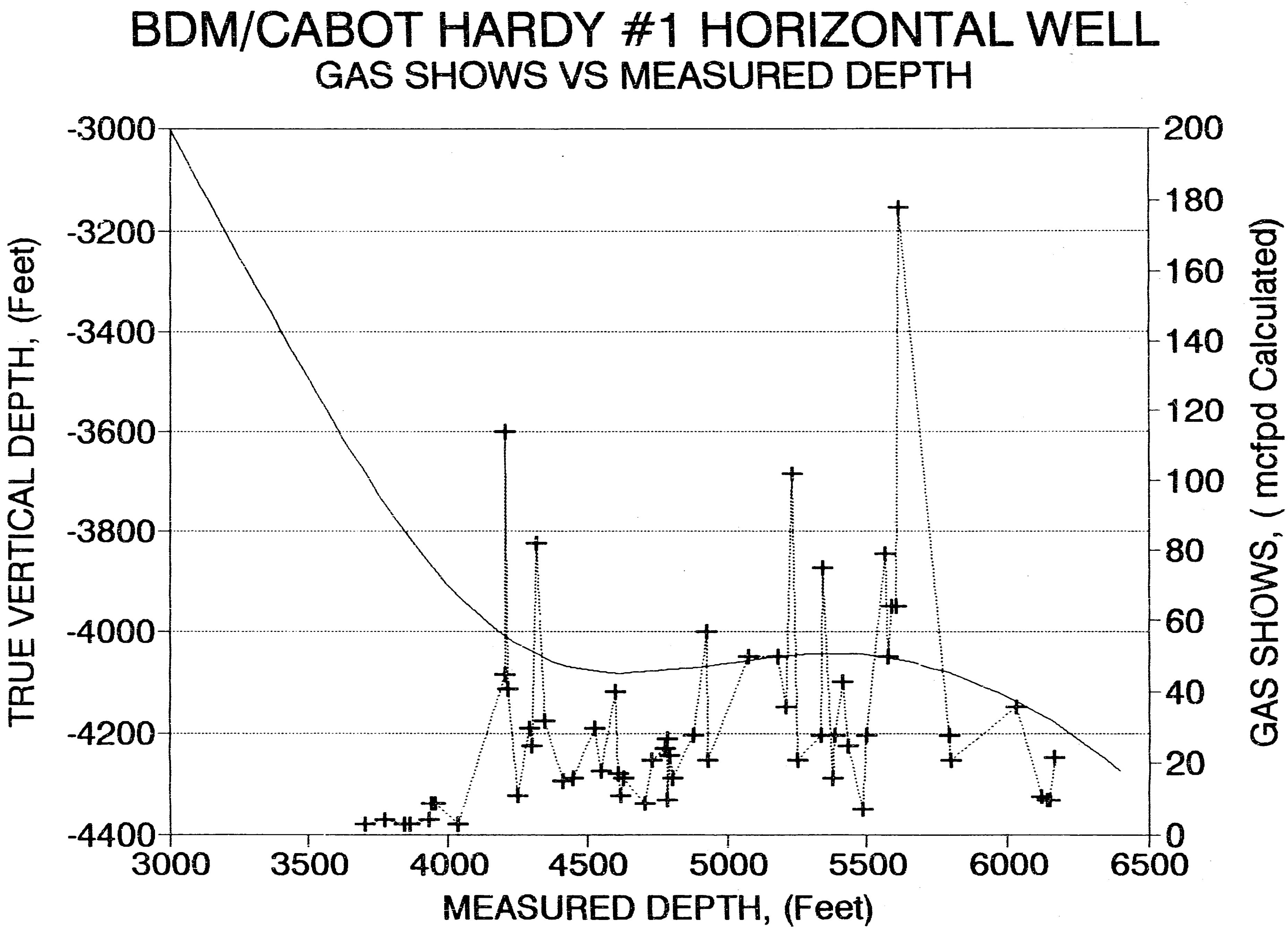

BDM/CABOT HARDY #1 HORIZONTAL WELL
GAS SHOWS VS MEASURED DEPTH
TRUE VERTICAL DEPTH, (Feet)
-3000
-3200
-3400
-3600
-3800
-4000
-4200
-4400
3000
3500
4000
4500
5000
5500
6000
6500
MEASURED DEPTH, (Feet)
GAS SHOWS, (mcfpd Calculated)
200
180
160
140
120
100
80
60
40
20
0

Figure 13.1

HARDY #1 WELLBORE CONFIGURATION

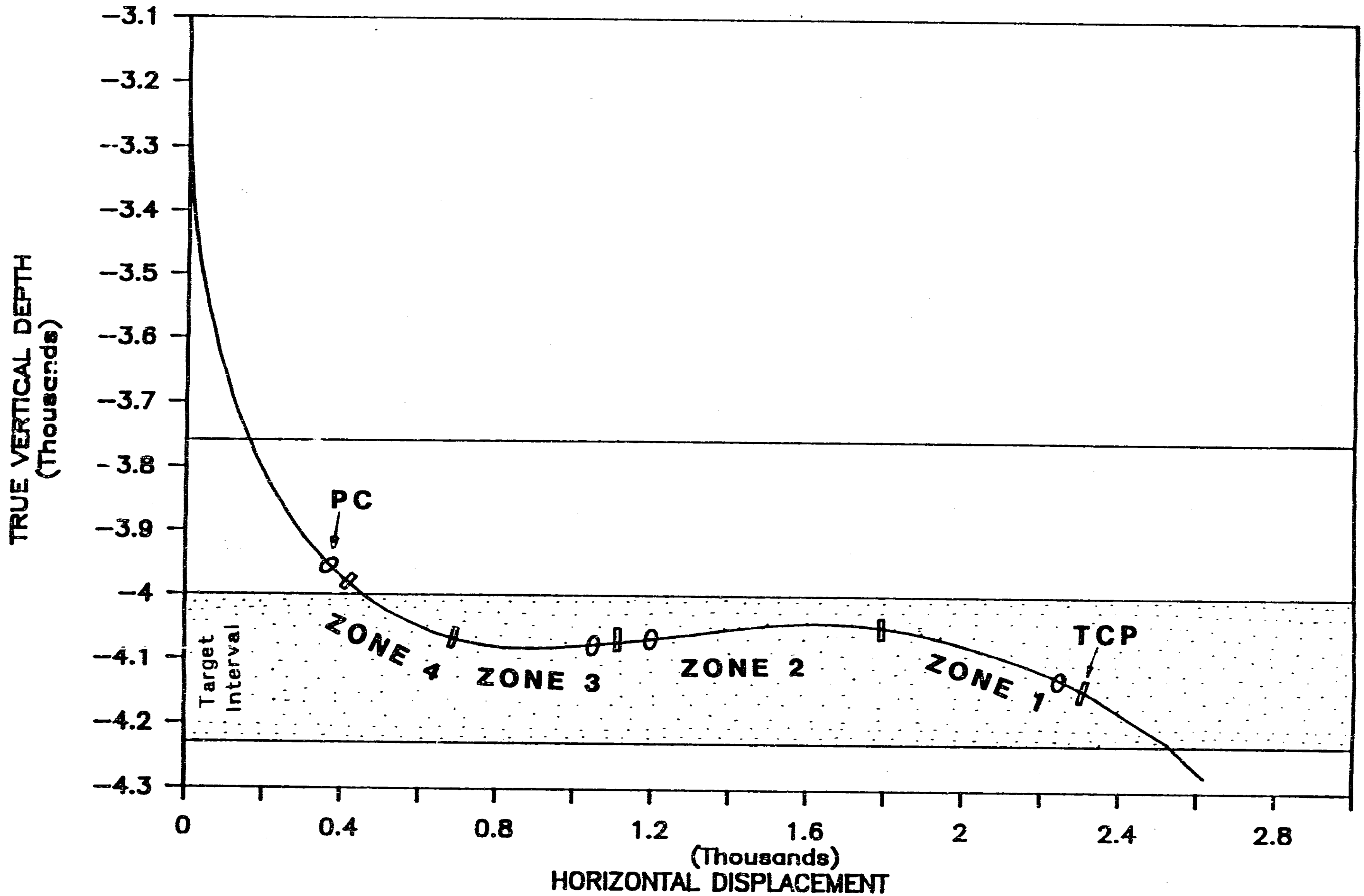


Figure 13.2

lodge in a baffle inside the second port collar, therefore opening the second port collar, and thus allowing two stages of stimulation to be conducted back to back. The pressure required to open the first port collar had to be set higher than the setting pressure of the external casing packers. However, the selection of an option to leave the first zone as a zone not to be stimulated prevented the use of the tool in the second zone and this ball and baffle technique was not tested. This would certainly be an option that should be given consideration in future horizontal holes and particularly in slant holes.

Cost effective options to consider for access to the formation for stimulation should include one or two joints of slotted casing. Isolation of one zone from other zones would be achieved with retrievable bridge plugs.

Zone one stimulation was conducted as expected except for a lower closure pressure (1200 psi) than projected. Failure to pump all of the sand available was unfortunate but not catastrophic. The zone cleaned up well and the open flow rate of 292 mcfpd after 8 hours on the fourth day after stimulation was encouraging. There was a curious phenomena which was observed but not explained. Breakdowns on both days for the stimulation was with nitrogen, with the first breakdown pressure being at 1900 psi while twenty-four hours later it was 2200 psi or 300 psi higher. Apparently during the overnight shut-in, the nitrogen gas which was injected moved through the fracture system increasing pressure and apparent stress as a result of the previous operation. The gas left in the wellbore most likely added 300 psi to the combination of horizontal earth stress and reservoir pressure that had to be overcome to open and propagate fractures.

As the stimulation process continued in Zone 2, a similar phenomena occurred with breakdown pressure increasing from 2300 psi to 3100 psi after an overnight delay. Increased friction pressure can account for part of this 800 psi increase but not all.

This phenomena suggests that further studies with stress models may be required to consider methods of optimizing stimulation procedures in horizontal wells when four stimulations are planned. Such modeling could examine the potential beneficial effects of completely modeling could examine the potential beneficial effects of completely flowing a stimulated zone back until it returns to ambient reservoir conditions prior to stimulation.

13.3 Well Testing Operations

Well testing operations on horizontal wells is a very important aspect of the total operation. Well test results could aid in projecting well production and evaluating economics of drilling, completion stimulation, and production operations. Since the technology is new and still in the development stage, this analysis was helpful in determining the economics of the well as drilled and completed.

During the site selection process, BDMESC obtained complete records on all of the Cabot wells that were drilled in the area plus records from a few other companies which had production in the area. Analysis of this data showed that the average production rate for wells in the area started at about 60 mcfpd and declined to 40 mcfpd in 50 months. Based on a projected gas value of $2.00 per mcf, a commercial horizontal well in the Devonian Shale would need to have an IOF rate close to 200 mcfpd as shown in Figure 13.3. The results of BDMESC's well testing and analysis indicated that the Hardy #1 needed reduced cost or improved production rates are to make horizontal drilling more attractive. Economic analyses of this well is contained in the final project report prepared for DOE.

The type curve analysis methodology used by BDMESC is believed to be an adequate method of projecting reserves for horizontal wells. Review and analysis of the production data from this well at 5, 10, and 15 year intervals will confirm the predictive ability of the methodologies used in the study.

13.4 Production Operations

The results of well test analyses were used to simulate the post-stimulation productivity of Hardy #1 using a three-dimensional reservoir simulator. The post-stimulation well test analysis indicated a formation capacity value of 7.31 md-ft (Kh) and an effective wellbore length of 900'. Using this data, the projected cumulative gas production after 30 years is 475 mmcf (Figure 13.4).

PROD DECLINE ANALYSIS FOR VERTICAL AND HORIZONTAL SHALE WELLS, PUTNAM CO., WV

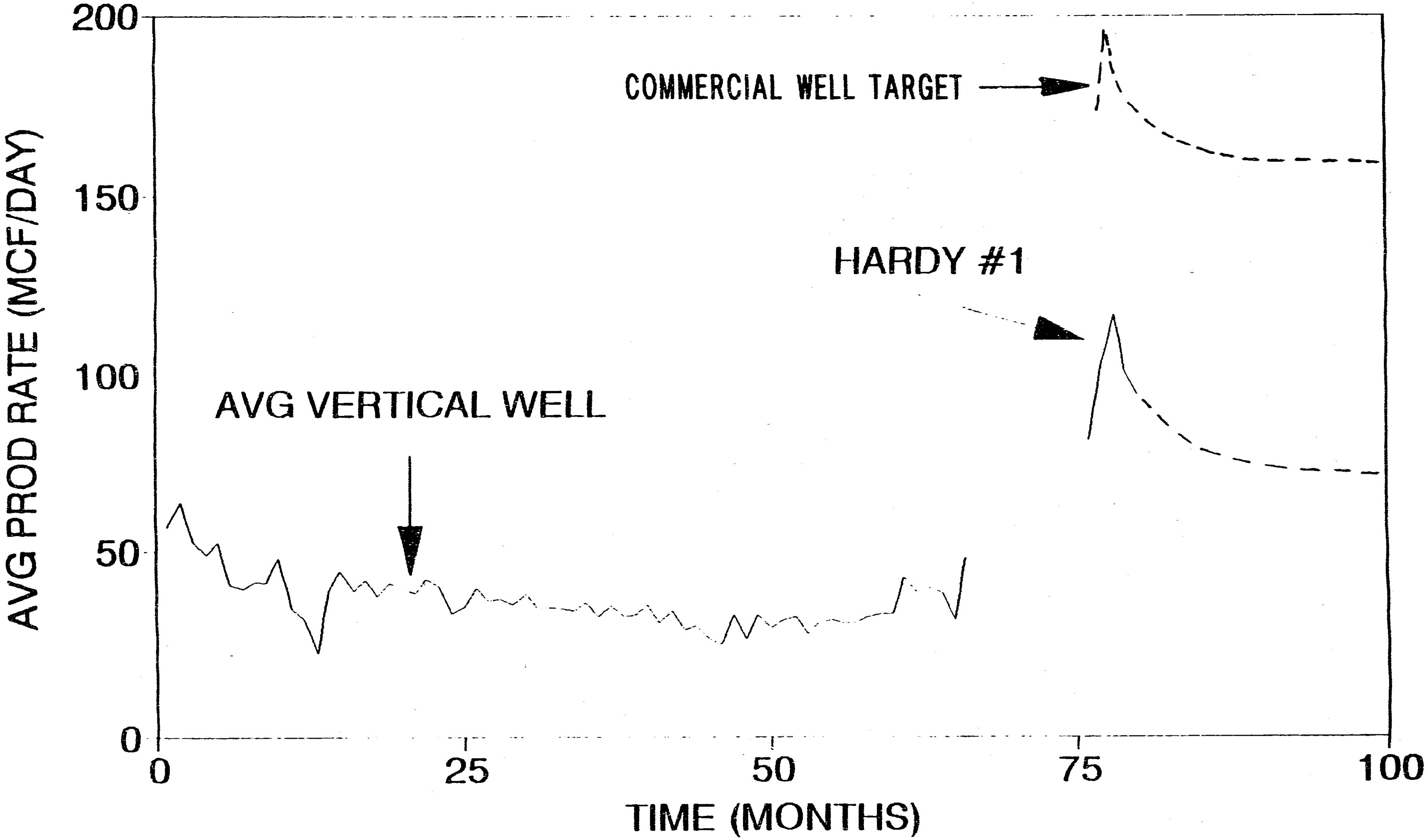


Figure 13.3

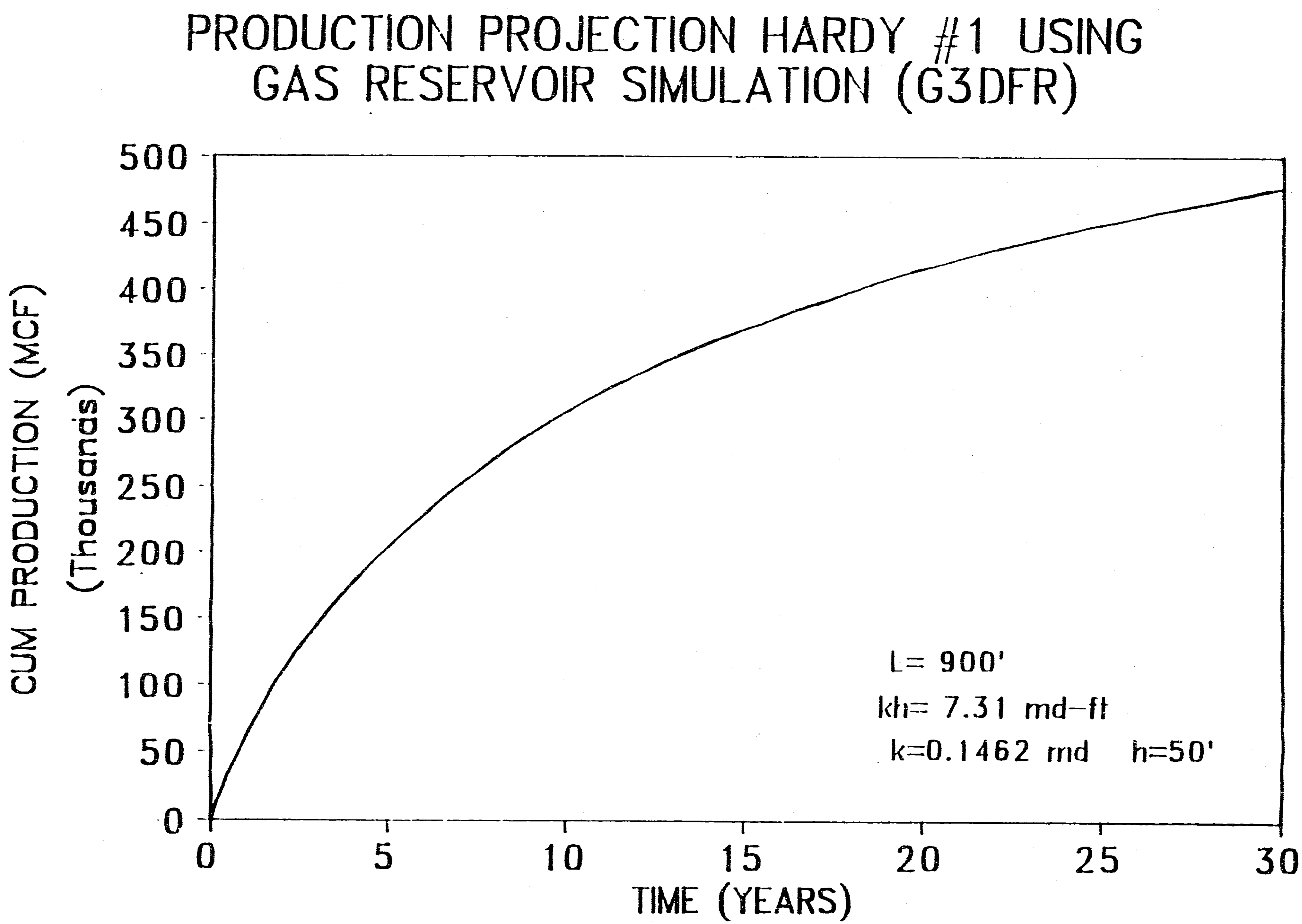

PRODUCTION PROJECTION HARDY #1 USING
GAS RESERVOIR SIMULATION (G3DFR)
CUM PRODUCTION (MCF)
(Thousands)
500
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
TIME (YEARS)
L= 900'
kh= 7.31 md-ft
k=0.1462 md h=50'

Figure 13.4

Hardy #1 was turned into the gas sales line on May 16, 1990. Figures 13.5 and 13.6 present the actual daily production rate and the cumulative production respectively for the period of May 1990 to March, 1992, a period of twenty months.

As indicated in Figure 13.5, Hardy #1 produced at an average rate of 70 mcfd for most of the first two years. It is believed that if Zones 2 and 3-4 were stimulated successfully, the production from Hardy #1 would have been double the current rate.

The production decline rate for the horizontal well is about half the decline rate of a typical vertical well in the area. This is believed to be a function of the much larger drainage area defined by the horizontal well as compared to the vertical wells.

Figure 13.7 is a match of the actual production data and the production decline type-curve based on actual well data from the area. Using the decline curve match, the projected cumulative gas production after 30 years is 415 mmcf (Figure 13.8).

14.0 WELL COST ANALYSIS

Well cost was reduced significantly for Hardy#1, when compared to the well cost of RET#1, the first air-drilled horizontal well. This cost reduction is attributed to improvements in drilling and completion technologies over a period of four years. The major reduction in cost was in the drilling phase where drilling time was reduced from 58 to 30 days.

Table 14.1 exhibits the cost involved in drilling, completing, and stimulating Hardy#1. The high stimulation cost is mainly attributed to problems and associated delays encountered when attempting to manipulate the port collars, and perforate the casing to stimulate zone 2 and combined zone 3-4., which would not accept sand-laden foam at concentrations greater than 1 lb/gal.

A single vertical well drilled and completed in the Putnam County area, costs approximately $180,000.00. The total cost for the Hardy #1 well was $921,211.00, which is 5.1 times the cost of a vertical well. The average vertical well in the area of the Hardy#1 well had projected

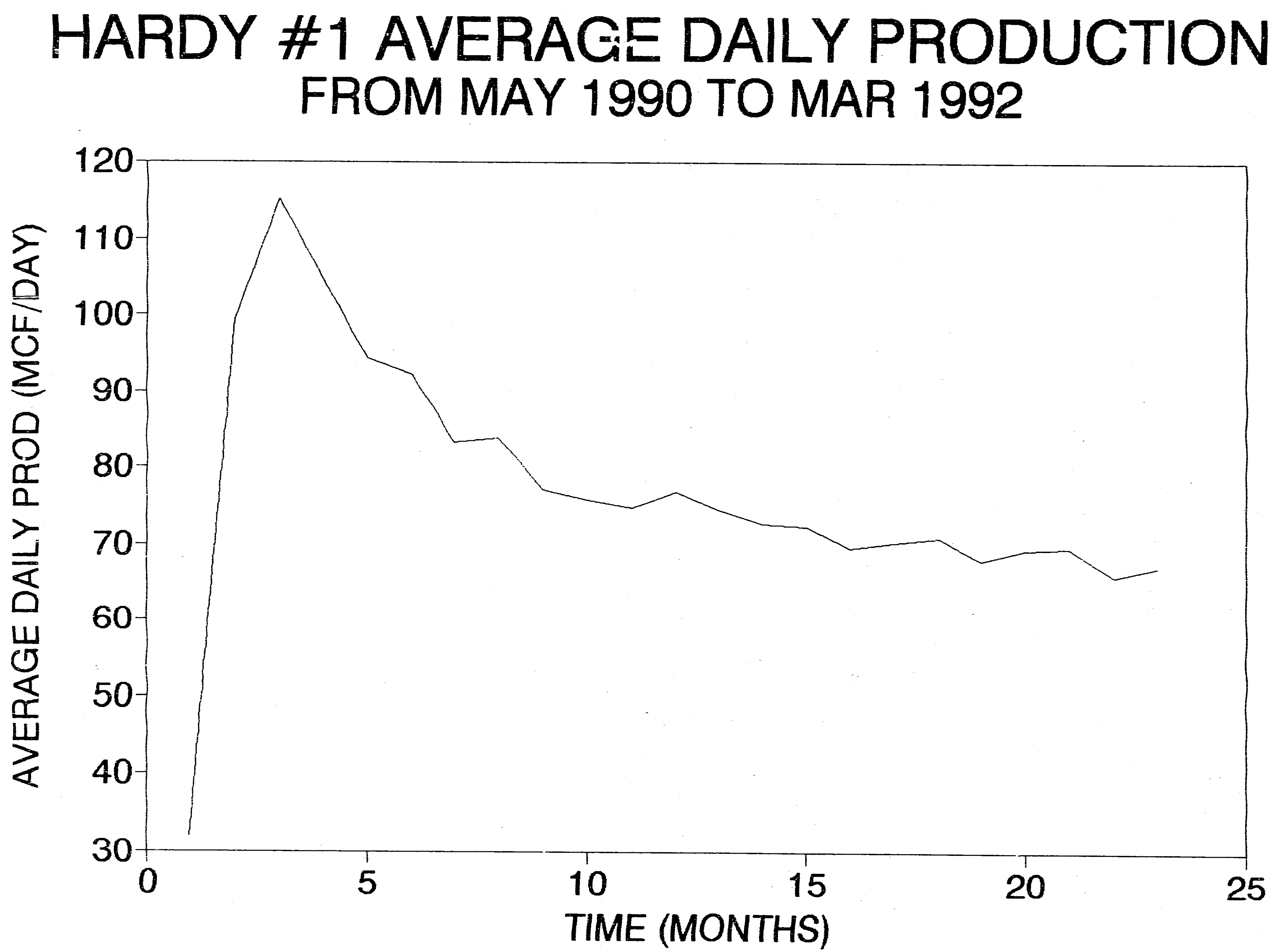

HARDY #1 AVERAGE DAILY PRODUCTION
FROM MAY 1990 TO MAR 1992
AVERAGE DAILY PROD (MCF/DAY)
120
110
100
90
80
70
60
50
40
30
0
5
10
15
20
25
TIME (MONTHS)

Figure 13.5

HARDY #1 CUM PRODUCTION DATA
FROM MAY 1990 TO MARCH 1992

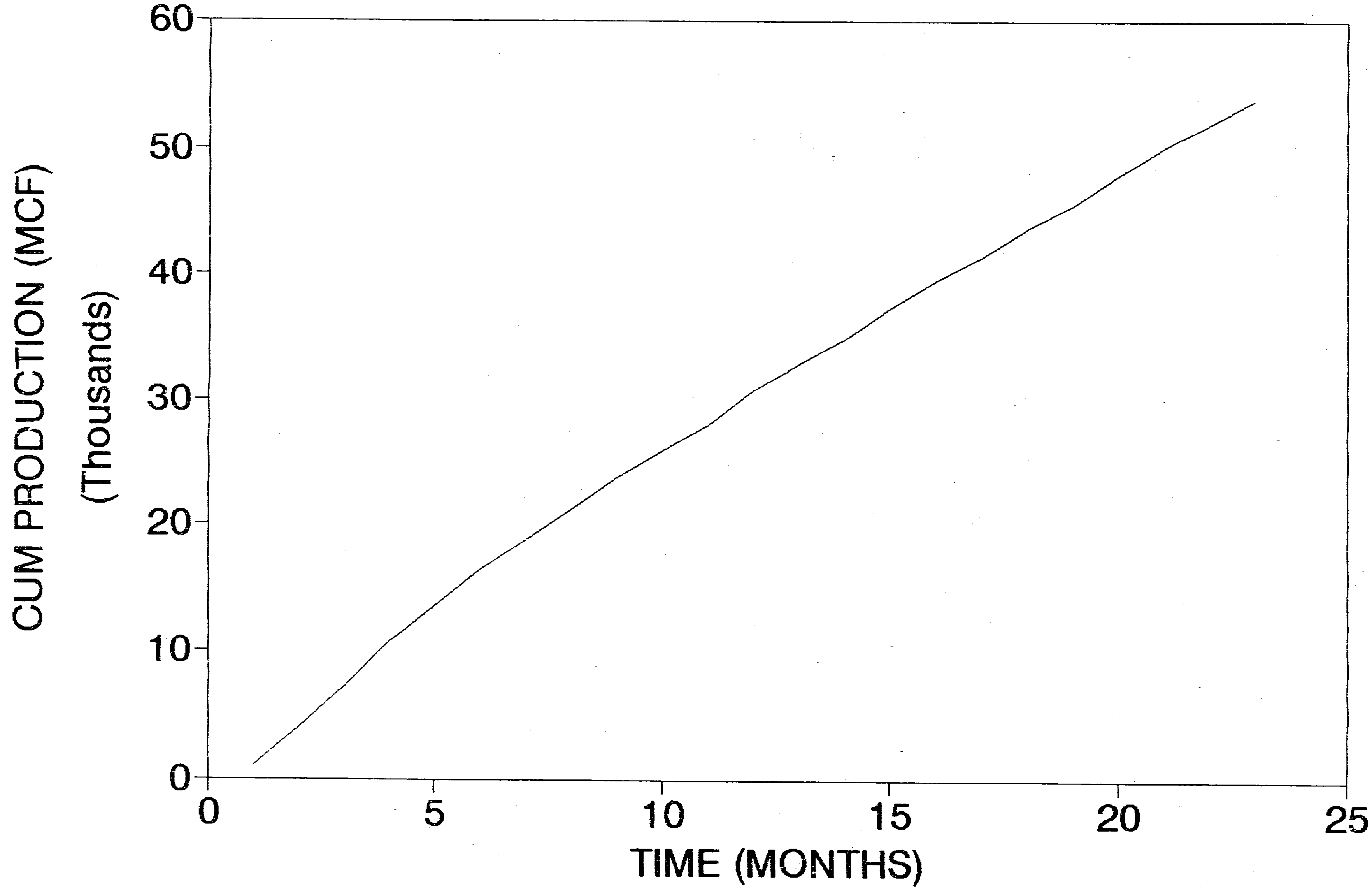


Figure 13.6

Table 14.1 - Cost Data BDM/Cabot Horizontal Well

ITEM DESCRIPTION	BDM/CABOT/DOE
DRILLING ACTIVITIES	
Drilling & Services	205,575
Directional Driller Services	33,757
Steering Tool & Directional Tool Rental	28,907
Directional Consultant Engineer - GSM	7,085
Rentals (Reamers, Stabilizers, Other)	3,558
Drilling Fluid Additives	9,300
Tubulars	89,680
Cementing	13,681
External Casing Packers & Port Collars	19,277
Build Location, Reclamation & Dozer	57,172
Mud Logging	11,133
Field Engineer (Vertical Hole)	7,448
Drill Pipe Inspection	5,303
Power Tongs	630
Permit & Survey	7,525
Neter Setup & Testing	2,438
Miscellaneous (Trucking & Field Services)	3,370
DRILLING SUBTOTAL	505,888
CORING AND LOGGING ACTIVITIES	
Coring	0
Shallow Logging	23,212
Deep Logging	40,933
CORING/LOGGING SUBTOTAL	64,145
STIMULATION ACTIVITIES	
Setup & Testing ECP's & PC's	6,074
Dozer & Road Work	4,890
Production Tubing, Tank Rental & Water Hauling	19,382
Video Camera Runs	2,810
Operate ECP's & PC's Services	27,936
Fishing Equipment	10,789
Frac Fluids & Stimulation Equipment	150,943
Perforations	13,977
Field Engineer	24,910
Tool Rental & Testing	18,464
Pip Disposal/Reclamation	4,904
Clean-Up	59,183
Trucking & Miscellaneous	6,918
STIMULATION SUBTOTAL	351,178
GRAND TOTAL HORIZONTAL WELL COST	921,211

HARDY#1 POST STIM. PRODUCTION RATE MATCH OF ACTUAL WITH AVG. DECLINE CURVE

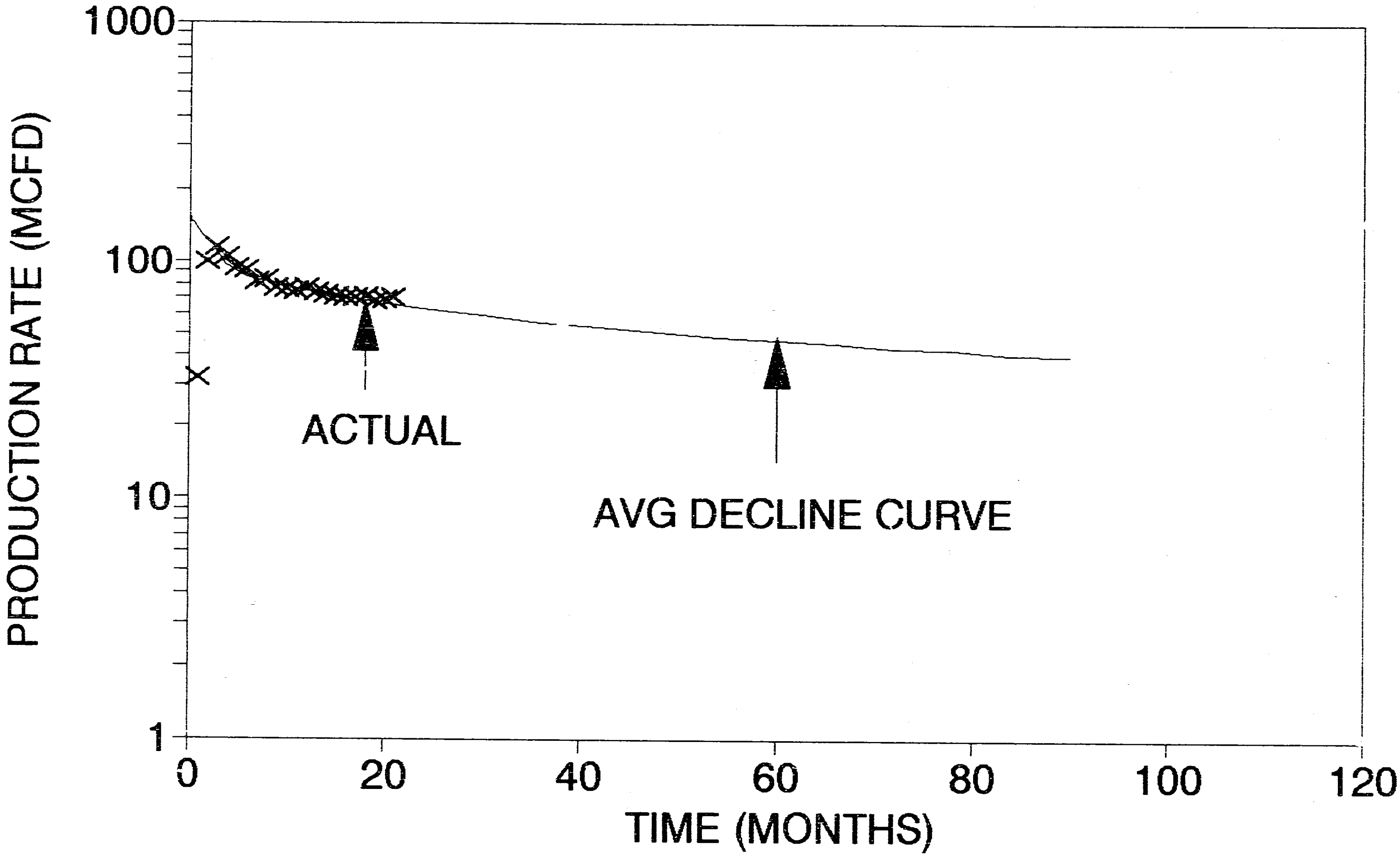


Figure 13.7

HARDY#1 PROJECTED CUM PRODUCTION BASED ON TYPE CURVE MATCH OF AVG WELL DECLINE

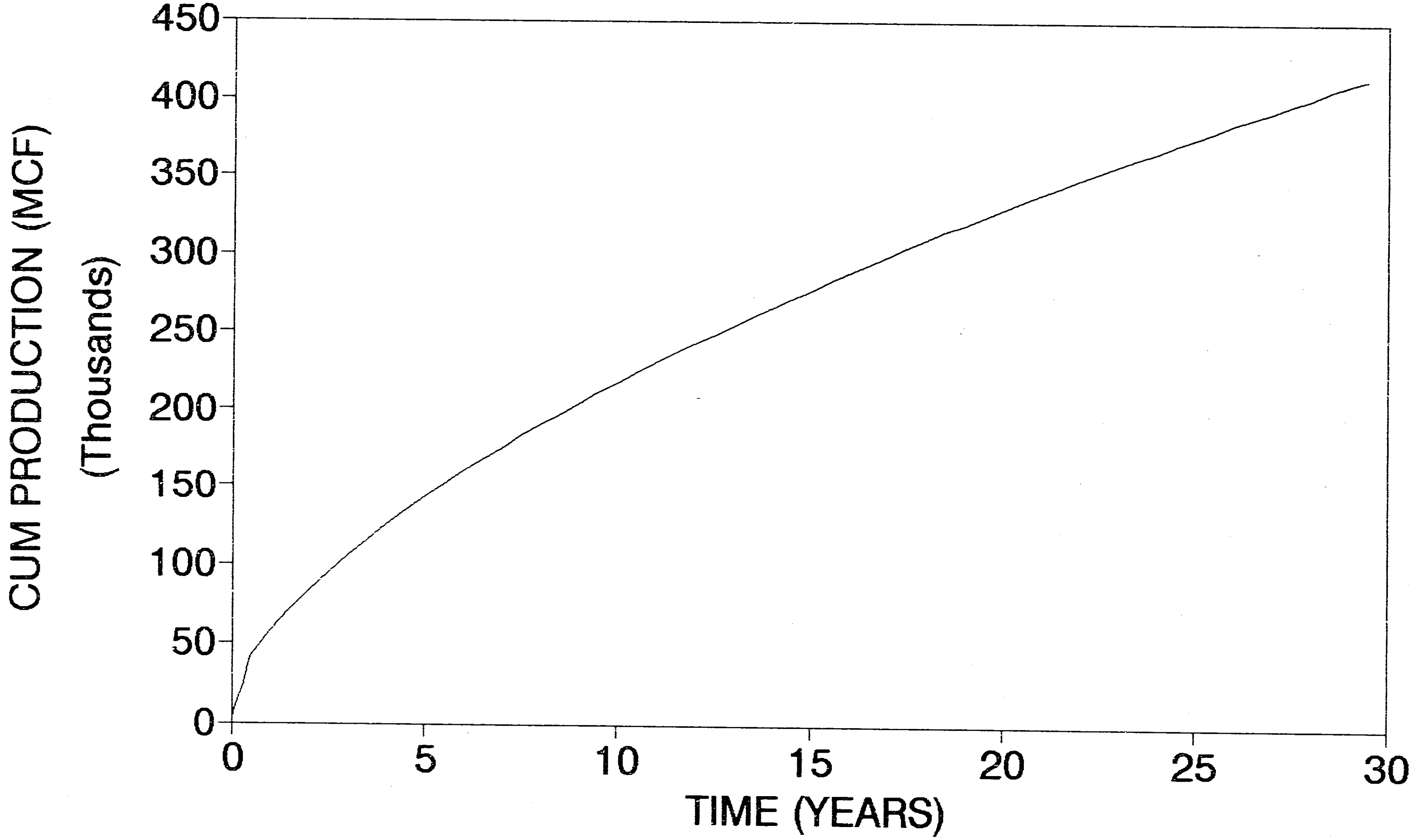


Figure 13.8

ultimate recoveries of 231 mmcf of gas compared to a projected 475 mmcf of recovery over 30 years for the Hardy #1 well.

The economics of the BDM/Cabot well are documented in the Final report to the DOE ("Site Selection, Drilling, and Completion of Two Horizontal Wells in the Devonian Shales of West Virginia"). Gas production achieved by the BDM/Cabot well as compared to the average vertical well drilled in the area is not sufficient to overcome the learning curve costs associated with this first well. The well is considered to be marginally economic based on present conditions of cost and gas sales price.

15.0 SUMMARY AND CONCLUSIONS

The Hardy HW#1 was drilled without any major problems during the inclined angle building phase except for steering tool operations. Reliable tool face data acquisition equipment needs to be developed and tested to further reduce drilling costs.

Geophysical logging operations are far too costly for the data provided. Operators may choose to rely on mud logging data as the primary source of data for completion operation decisions. Video logging can be very useful but low cost reliable high resolution systems must be developed to make them attractive to Appalachian area operators.

Actual drilling operations were reduced from fifty-eight days in 1986 (RET#1 well) to thirty days on the Hardy HW#1 well although the length of footage drilled was only twenty feet less than the RET#1 well. The increased rate of angle building saves more than twenty days in drilling time.

One of the most important aspects of drilling a successful slant/horizontal well is the site selection process. Selection of an area that has high probability of providing enough reserves for payout of the drilling operation is a key goal.

Drilling with air as the circulation medium and oil as a lubricant for downhole motors operated at 250 to 300 psi pressure is a viable alternative to drilling at higher pressures (600 psi) even if there is no improved hardening of the steering tools to reduce vibration at lower pressures and higher volume through-puts.

Port collars which operate by rotation rather than reciprocation are very difficult to operate in a horizontal hole and are not an efficient design for this type of operation.

In an open hole type of completion where access to open natural fractures are provided, the length of treatment zones should probably be limited to 350 to 400 feet. This suggest that a 1400 to 1600 foot horizontal wellbore length providing four zones for stimulation may be more suitable for fractured Devonian Shale reservoirs than a longer wellbore length considering costs and efficiencies of operation.

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APPENDIX A

CASING TALLYS

13 3/8" CASING TALLY 12/2/89

JOINT NUMBER	LENGTH
1	30.40
2	30.58
3	43.47
4	42.95
5	43.35
6	43.26
7	41.74
8	42.02
9	36.63
10	43.27
11	42.48
12	42.73
13	42.53
14	42.00
15	43.33
16	43.34
TOTAL	654.08

9 5/8" CASING TALLY 12/9/89

JOINT NUMBER	LENGTH	JOINT NUMBER	LENGTH
1	15.10	41	44.25
2	43.90	42	43.70
3	44.00	43	43.95
4	43.55	44	43.85
5	43.75	45	43.60
6	43.80	46	43.80
7	43.75	47	43.75
8	43.80	48	43.75
9	44.00	49	43.85
10	43.40	50	43.70
11	43.40	51	43.35
12	43.65	52	43.90
13	43.80	53	44.05
14	43.60	54	43.90
15	44.00	55	43.70
16	44.00	56	43.90
17	43.65	57	42.75
18	43.40	58	43.95
19	43.70	59	43.80
20	43.70	60	43.60
21	43.75	61	43.85
22	43.70	62	15.00
23	43.90	63	
24	44.25	64	
25	44.10	65	
26	43.90	66	
27	43.70	67	
28	43.65	68	
29	43.55	69	
30	43.30	70	
31	44.00	71	
32	43.95	72	
33	43.55	73	
34	43.60	74	
35	43.65	75	
36	44.25	76	
37	43.90	77	
38	43.50	78	
39	43.85	79	
40	44.05	80	
SUBTOTAL	1722.05	SUBTOTAL	933.95
TOTAL	2656.00		

4 1/2" CASING TALLY 1-1-90

JOINT NUMBER	LENGTH	SETTING DEPTH	JOINT NUMBER	LENGTH	SETTING DEPTH	JOINT NUMBER	LENGTH	SETTING DEPTH	JOINT NUMBER	LENGTH	SETTING DEPTH
SET AT		6150.81									
1	44.52	6106.29	41	44.33	4625.65	81	44.54	3032.67	121	44.55	1255.30
2	44.33	6061.96	42	44.75	4580.90	82	44.40	2988.27	122	44.45	1210.85
3	44.36	6017.60	43	44.41	4536.49	83	44.59	2943.68	123	44.40	1166.45
4	7.20	6010.40	44	44.61	4491.88	84	44.52	2899.16	124	44.40	1122.05
5	44.50	5965.90	45	44.48	4447.40	85	44.47	2854.69	125	44.55	1077.50
6	44.62	5921.28	46	44.35	4403.05	86	44.38	2810.31	126	44.40	1033.10
7	2.40	5918.88	47	9.65	4393.40	87	44.64	2765.67	127	44.40	988.70
8	44.51	5874.37	48	7.20	4386.20	88	44.36	2721.31	128	44.65	944.05
9	44.40	5829.97	49	44.42	4341.78	89	44.70	2676.61	129	44.45	899.60
10	44.43	5785.54	50	44.09	4297.69	90	44.40	2632.21	130	44.30	855.30
11	44.46	5741.08	51	44.67	4253.02	91	44.47	2587.74	131	44.40	810.90
12	44.33	5696.75	52	44.32	4208.70	92	44.46	2543.28	132	44.40	766.50
13	44.61	5652.14	53	44.45	4164.25	93	44.36	2498.92	133	44.40	722.10
14	44.52	5607.62	54	44.46	4119.79	94	44.45	2454.47	134	44.40	677.70
15	44.42	5563.20	55	9.68	4110.11	95	44.47	2410.00	135	44.40	633.30
16	44.30	5518.90	56	7.20	4102.91	96	44.40	2365.60	136	44.40	588.90
17	7.20	5511.70	57	44.73	4058.18	97	44.45	2321.15	137	44.40	544.50
18	44.67	5467.03	58	2.40	4055.78	98	44.40	2276.75	138	44.35	500.15
19	44.43	5422.60	59	44.56	4011.22	99	44.50	2232.25	139	44.45	455.70
20	44.62	5377.98	60	44.67	3966.55	100	44.35	2187.90	140	44.40	411.30
21	44.47	5333.51	61	44.41	3922.14	101	44.40	2143.50	141	43.80	367.50
22	44.49	5289.02	62	44.49	3877.65	102	44.40	2099.10	142	44.50	323.00
23	44.54	5244.48	63	44.50	3833.15	103	44.35	2054.75	143	44.30	278.70
24	44.45	5200.03	64	44.60	3788.55	104	44.50	2010.25	144	44.40	234.30
25	44.47	5155.56	65	44.46	3744.09	105	44.45	1965.80	145	44.45	189.85
26	44.43	5111.13	66	44.40	3699.69	106	44.45	1921.35	146	44.40	145.45
27	44.54	5066.59	67	44.55	3655.14	107	44.40	1876.95	147	44.55	100.90
28	44.44	5022.15	68	44.53	3610.61	108	44.55	1832.40	148	44.45	56.45
29	44.41	4977.74	69	44.40	3566.21	109	44.45	1787.95	149	44.45	12.00 BELOW KB
30	44.39	4933.35	70	44.58	3521.63	110	44.40	1743.55	150	44.50	OUT
31	44.43	4888.92	71	44.52	3477.11	111	44.50	1699.05	151	44.50	OUT
32	44.52	4844.40	72	44.47	3432.64	112	44.45	1654.60	152	44.55	OUT
33	2.40	4842.00	73	44.45	3388.19	113	44.50	1610.10	153	44.35	OUT
34	44.44	4797.56	74	44.55	3343.64	114	44.35	1565.75	154	44.40	OUT
35	14.70	4782.86	75	44.39	3299.25	115	44.40	1521.35	155	44.35	OUT
36	14.50	4768.36	76	44.44	3254.81	116	43.70	1477.65	156	44.50	OUT
37	7.20	4761.16	77	44.30	3210.51	117	44.40	1433.25	157	44.40	OUT
38	44.38	4716.78	78	44.35	3166.16	118	44.45	1388.80	158	44.65	OUT
39	2.40	4714.38	79	44.40	3121.76	119	44.45	1344.35	159	44.35	OUT
40	44.40	4669.98	80	44.55	3077.21	120	44.50	1299.85	160		

PORT COLLARS ARE 2.40' LONG
EXTERNAL CASING PACKERS ARE 7.20' LONG

APPENDIX B

BOTTOM HOLE DRILLING

ASSEMBLIES (BHA'S)

BHA #1 - RUN 12-12-89	LENGTH, FT.	
BIT - 8 3/4", M84F, 3-16'S	1.00	
EASTMAN MOTOR, 6 3/4"	20.75	BEND SET AT 1.1
STABILIZER, 7 7/8"	5.67	
X-O SUB, 6.5 X 2 1/4"	1.47	
ORIENTING SUB 6.25 X 3.75"	2.18	
MONEL, 6 5/16 X 2 13/16"	31.18	
MONEL, 6 5/16 X 2 13/16"	30.75	
TOTAL	93.00	

BHA #2 - RUN 12-13-89		
BIT - 8 3/4", M84F, 3-16'S	1.00	
EASTMAN MOTOR, 6 3/4"	20.75	bend set at 1.3
X-O SUB, 6.5 X 2 1/4"	1.47	
ORIENTING SUB 6.25 X 3.75"	2.18	
MONEL, 6 5/16 X 2 13/16"	31.18	
MONEL, 6 5/16 X 2 13/16"	30.75	
TOTAL	87.33	

BHA #3 - RUN 12-14-89		
BIT - 8 3/4", M84F, 3-16'S	1.00	
EASTMAN MOTOR, 6 3/4"	20.75	bend set at 1.3
BENT SUB 1.5 6 1/2" X 2 1/4"	1.25	
ORIENTING SUB 6.25 X 3.75"	2.18	
MONEL, 6 5/16 X 2 13/16"	31.18	
MONEL, 6 5/16 X 2 13/16"	30.75	
TOTAL	87.11	

BHA #4 - RUN 12-14-89		
BIT - 8 1/2", M84F, open	1.00	
EASTMAN MOTOR, 6 3/4"	20.75	bend set at 1.3
BENT SUB 1.5 6 1/2" X 2 1/4"	1.25	
ORIENTING SUB 6.25 X 3.75"	2.18	
MONEL, 6 5/16 X 2 13/16"	31.18	
MONEL, 6 5/16 X 2 13/16"	30.75	
TOTAL	87.11	

BHA #5 - RUN 12-16-89	LENGTH, FT.		
BIT - 8 1/2", M84F, 11-14-14	1.00		
BAKER MOTOR, 6 3/4"	23.10	bend set at 2	
FLOAT SUB 5 3/4" X 2 1/4"	1.87		
X-0 6 1/2" X 2 1/4"	1.47		
ORIENTING SUB 6.25 X 3.75"	2.18		
MONEL, 6 5/16 X 2 13/16"	31.18		
MONEL, 6 5/16 X 2 13/16"	30.75		
TOTAL	91.55		

BHA #6 - RUN 12-20-89			
BIT - 7 7/8", M84F, 16-16-16	1.00		
FLOAT SUB 5 3/4" X 2 1/4"	1.87		
3 PT REAMER	4.72	2.35	1.75
X-0 6 1/4" X 2 1/2"	1.80	6.25	7.00
MONEL, 6 5/16 X 2 13/16"	31.18		
MONEL, 6 5/16 X 2 13/16"	30.75		
21 STANDS DRILL PIPE	1302.00		
X-0 6 1/4" X 3"	2.00		
6-6 1/4" DC'S	179.00		
X-0 6" X 3"	1.79		
TOTAL	1556.11		

BHA #7 - RUN 12-21-89			
BIT - 7 7/8", M84F, 16-16-16	1.00		
FLOAT SUB 5 3/4" X 2 1/4"	1.87		
3 PT REAMER	4.72		
X-0 6 1/4" X 2 1/2"	1.80		
MONEL, 6 5/16 X 2 13/16"	31.18		
3 PT REAMER	7.00	3.60	1.60
MONEL, 6 5/16 X 2 13/16"	30.75	6.25	7.00
30 STANDS DRILL PIPE	1860.00		
X-0 6 1/4" X 3"	2.00		
6-6 1/4" DC'S	179.00		
X-0 6" X 3"	1.79		
TOTAL	2121.11		

BHA #8 - RUN 12-21-89	LENGTH, FT.
BIT - 7 7/8", M84F, 16-16-16	1.00
BIT SUB 6' X 2 1/4"	1.92
SHORT DRILL COLLAR 6 1/4" X 2 1/4"	10.75
3 PT REAMER	7.00
X-0 6 1/4" X 2 1/2"	1.80
FLOAT SUB 5 3/4" X 2 1/4"	1.87
MONEL, 6 5/16 X 2 13/16"	31.18
MONEL, 6 5/16 X 2 13/16"	30.75
30 STANDS DRILL PIPE	1860.00
X-0 6 1/4" X 3"	2.00
6-6 1/4" DC'S	179.00
X-0 6" X 3"	1.79
TOTAL	2129.06

BHA #9 - RUN 12-28-89	
BIT - 7 7/8", M84F, 16-16-16	1.00
BIT SUB 6' X 2 1/4"	1.92
SHORT DRILL COLLAR 6 1/4" X 2 1/4"	10.75
3 PT REAMER	7.00
FLOAT SUB 6 1/8" X 2 3/8"	1.60
MONEL, 6 5/16 X 2 13/16"	30.75
40 STANDS DRILL PIPE	2480.00
X-0 6 1/4" X 3"	2.00
10-6 1/4" DC'S	300.05
X-0 6" X 3"	1.79
TOTAL	2836.86

APPENDIX C

BUILD AND WALK RATE

DATA FOR HARDY HW#1 WELL

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	BUILD RATE DEG/100	WALK RATE DEG/100	BOTTOMHOLE ASSEMBLY
0.00	0.00	252.00	0.00	0.00	0.00	
3194.00	0.75	252.00	3194.00	0.02	0.00	ROTARY
3256.00	1.50	288.00	62.00	1.21	58.06	ROTARY
3318.00	4.75	322.00	62.00	5.24	54.84	EASTMAN RUN 1
3379.00	8.75	328.00	61.00	6.56	9.84	EASTMAN RUN 1
3441.00	12.50	328.00	62.00	6.05	0.00	EASTMAN RUN 1
3503.00	16.25	326.00	62.00	6.05	-3.23	EASTMAN RUN 1 & 2
3565.00	20.50	325.00	62.00	6.85	-1.61	EASTMAN RUN 2
3627.00	24.25	327.00	62.00	6.05	3.23	EASTMAN RUN 2 & 3
3688.00	28.25	330.00	61.00	6.56	4.92	EASTMAN RUN 3
3750.00	32.25	330.00	62.00	6.45	0.00	EASTMAN RUN 3
3812.00	36.50	330.00	62.00	6.85	0.00	EASTMAN RUN 3
3874.00	41.75	330.00	62.00	8.47	0.00	EASTMAN RUN 4
3936.00	46.50	329.00	62.00	7.66	-1.61	EASTMAN RUN 4
3997.00	51.75	328.00	61.00	8.61	-1.64	EASTMAN RUN 4
4059.00	57.00	328.00	62.00	8.47	0.00	EASTMAN RUN 4
4121.00	62.00	330.00	62.00	8.06	3.23	EASTMAN RUN 4
4183.00	66.75	332.00	62.00	7.66	3.23	EASTMAN RUN 4
4244.00	70.25	330.00	61.00	5.74	-3.28	EASTMAN RUN 4
4306.00	72.75	324.00	62.00	4.03	-9.68	EASTMAN RUN 4
4368.00	77.50	323.00	62.00	7.66	-1.61	EASTMAN AND BAKER
4430.00	83.25	326.00	62.00	9.27	4.84	BAKER RUN 7
4491.00	84.25	333.00	61.00	1.64	11.48	BAKER RUN 7
4553.00	87.25	337.00	62.00	4.84	6.45	BAKER RUN 8
4615.00	90.50	338.00	62.00	5.24	1.61	BAKER RUN 8
4677.00	91.75	339.00	62.00	2.02	1.61	ROTARY BUILD
4739.00	92.25	338.00	62.00	0.81	-1.61	ROTARY BUILD
4800.00	93.00	338.00	61.00	1.23	0.00	ROTARY BUILD
4862.00	93.25	339.00	62.00	0.40	1.61	ROTARY BUILD
4924.00	93.75	338.00	62.00	0.81	-1.61	ROTARY BUILD
4986.00	94.00	339.00	62.00	0.40	1.61	ROTARY BUILD
5047.00	94.25	339.00	61.00	0.41	0.00	ROTARY BUILD
5109.00	94.75	339.00	62.00	0.81	0.00	ROTARY BUILD
5171.00	94.00	339.00	62.00	-1.21	0.00	ROTARY BUILD & DROP
5233.00	92.75	339.00	62.00	-2.02	0.00	ROTARY DROP
5294.00	91.75	339.00	61.00	-1.64	0.00	ROTARY DROP
5356.00	90.25	339.00	62.00	-2.42	0.00	ROTARY DROP
5418.00	89.00	339.00	62.00	-2.02	0.00	ROTARY DROP
5480.00	87.25	339.00	62.00	-2.82	0.00	ROTARY DROP
5542.00	85.50	339.00	62.00	-2.82	0.00	ROTARY DROP

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	BUILD RATE DEG/100	WALK RATE DEG/100	BOTTOMHOLE ASSEMBLY
5603.00	83.75	340.00	61.00	-2.87	1.64	ROTARY DROP
5665.00	82.75	340.00	62.00	-1.61	0.00	ROTARY DROP
5727.00	81.00	339.00	62.00	-2.82	-1.61	ROTARY DROP
5789.00	79.25	338.00	62.00	-2.82	-1.61	ROTARY DROP
5850.00	78.75	337.00	61.00	-0.82	-1.64	ROTARY DROP
5912.00	77.00	336.00	62.00	-2.82	-1.61	ROTARY DROP
5974.00	75.50	335.00	62.00	-2.42	-1.61	ROTARY DROP
6036.00	73.25	333.00	62.00	-3.63	-3.23	ROTARY DROP
6097.00	71.25	332.00	61.00	-3.28	-1.64	ROTARY DROP
6159.00	69.75	330.00	62.00	-2.42	-3.23	ROTARY DROP
6221.00	67.75	329.00	62.00	-3.23	-1.61	ROTARY DROP
6283.00	65.50	328.00	62.00	-3.63	-1.61	ROTARY DROP
6345.00	64.00	327.00	62.00	-2.42	-1.61	ROTARY DROP
6399.00	62.65	326.00	54.00	-2.50	-1.85	ROTARY DROP

APPENDIX D

MULTISHOT SURVEY

OF WELLBORE

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	TRUE VERTICAL DEPTH	RECTANGULAR COORDINATES NORTH	RECTANGULAR COORDINATES EAST	CLOSURE DISTANCE FEET	CLOSURE AZIMUTH DEGREES	DOGLEG SEVERITY DEG/100'
0.00	0.00	252.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3194.00	0.75	252.00	3194.00	3194.00	0.00	0.00	0.00	0.00	0.00
3256.00	1.50	288.00	62.00	3255.99	0.00	-1.20	1.20	270.00	1.61
3318.00	4.75	322.00	62.00	3317.89	1.91	-3.93	4.37	295.95	5.81
3379.00	8.75	328.00	61.00	3378.45	7.78	-8.03	11.18	314.07	6.65
3441.00	12.50	328.00	62.00	3439.38	17.47	-14.09	22.45	321.11	6.05
3503.00	16.25	326.00	62.00	3499.43	30.38	-22.47	37.79	323.51	6.10
3565.00	20.50	325.00	62.00	3558.25	46.48	-33.54	57.32	324.19	6.87
3627.00	24.25	327.00	62.00	3615.57	66.04	-46.74	80.91	324.72	6.17
3688.00	28.25	330.00	61.00	3670.27	89.04	-60.83	107.83	325.66	6.91
3750.00	32.25	330.00	62.00	3723.82	116.08	-76.44	138.99	326.64	6.45
3812.00	36.50	330.00	62.00	3774.98	146.39	-93.94	173.94	327.31	6.85
3874.00	41.75	330.00	62.00	3823.06	180.26	-113.49	213.02	327.81	8.47
3936.00	46.50	329.00	62.00	3867.55	217.45	-135.40	256.15	328.09	7.74
3997.00	51.75	328.00	61.00	3907.46	256.76	-159.49	302.26	328.15	8.70
4059.00	57.00	328.00	62.00	3943.56	299.48	-186.18	352.64	328.13	8.47
4121.00	62.00	330.00	62.00	3975.02	345.26	-213.69	406.04	328.25	8.53
4183.00	66.75	332.00	62.00	4001.82	394.13	-240.78	461.86	328.58	8.19
4244.00	70.25	330.00	61.00	4024.18	443.76	-268.29	518.56	328.84	6.50
4306.00	72.75	324.00	62.00	4043.85	493.05	-300.30	577.30	328.66	10.02
4368.00	77.50	323.00	62.00	4059.76	541.20	-335.93	636.98	328.17	7.82
4430.00	83.25	326.00	62.00	4070.12	590.94	-371.41	697.96	327.85	10.43
4491.00	84.25	333.00	61.00	4076.76	643.15	-402.16	758.54	327.98	11.52
4553.00	87.25	337.00	62.00	4081.35	699.17	-428.28	819.92	328.51	8.05
4615.00	90.50	338.00	62.00	4082.57	756.43	-452.00	881.19	329.14	5.48
4677.00	91.75	339.00	62.00	4081.35	814.11	-474.72	942.41	329.75	2.58
4739.00	92.25	338.00	62.00	4079.19	871.76	-497.43	1003.69	330.29	1.80
4800.00	93.00	338.00	61.00	4076.40	928.25	-520.26	1064.11	330.73	1.23
4862.00	93.25	339.00	62.00	4073.02	985.85	-542.95	1125.48	331.16	1.66
4924.00	93.75	338.00	62.00	4069.23	1043.43	-565.63	1186.88	331.54	1.80
4986.00	94.00	339.00	62.00	4065.04	1100.98	-588.30	1248.30	331.88	1.66
5047.00	94.25	339.00	61.00	4060.65	1157.79	-610.10	1308.70	332.21	0.41
5109.00	94.75	339.00	62.00	4055.79	1215.49	-632.25	1370.09	332.52	0.81
5171.00	94.00	339.00	62.00	4051.06	1273.20	-654.40	1431.53	332.80	1.21
5233.00	92.75	339.00	62.00	4047.41	1330.98	-676.58	1493.08	333.05	2.02
5294.00	91.75	339.00	61.00	4045.02	1387.89	-698.43	1553.71	333.29	1.64
5356.00	90.25	339.00	62.00	4043.93	1445.76	-720.64	1615.41	333.51	2.42
5418.00	89.00	339.00	62.00	4044.34	1503.64	-742.86	1677.13	333.71	2.02
5480.00	87.25	339.00	62.00	4046.37	1561.49	-765.07	1738.84	333.90	2.82
5542.00	85.50	339.00	62.00	4050.29	1619.25	-787.24	1800.48	334.07	2.82

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	TRUE VERTICAL DEPTH	RECTANGULAR COORDINATES NORTH	RECTANGULAR COORDINATES EAST	CLOSURE DISTANCE FEET	CLOSURE AZIMUTH DEGREES	DOGLEG SEVERITY DEG/100'
5603.00	83.75	340.00	61.00	4056.00	1676.13	-808.51	1860.94	334.25	3.30
5665.00	82.75	340.00	62.00	4063.29	1733.99	-829.56	1922.21	334.43	1.61
5727.00	81.00	339.00	62.00	4072.05	1791.48	-851.06	1983.35	334.59	3.24
5789.00	79.25	338.00	62.00	4082.68	1848.31	-873.44	2044.29	334.71	3.24
5850.00	78.75	337.00	61.00	4094.32	1903.63	-896.36	2104.10	334.79	1.81
5912.00	77.00	336.00	62.00	4107.35	1959.21	-920.53	2164.69	334.83	3.23
5974.00	75.50	335.00	62.00	4122.08	2014.01	-945.50	2224.91	334.85	2.88
6036.00	73.25	333.00	62.00	4138.78	2067.67	-971.67	2284.60	334.83	4.78
6097.00	71.25	332.00	61.00	4157.38	2119.20	-998.50	2342.65	334.77	3.63
6159.00	69.75	330.00	62.00	4178.07	2170.31	-1026.83	2400.96	334.68	3.89
6221.00	67.75	329.00	62.00	4200.54	2220.10	-1056.15	2458.52	334.56	3.56
6283.00	65.50	328.00	62.00	4225.14	2268.62	-1085.89	2515.11	334.42	3.92
6345.00	64.00	327.00	62.00	4251.58	2315.91	-1116.02	2570.79	334.27	2.83
6399.00	62.65	326.00	54.00	4275.83	2356.15	-1142.65	2618.60	334.13	3.00

APPENDIX E

DRILL PIPE TALLY

DRILL PIPE TALLY - 12-11-89

STAND NUMBER	LENGTH	STAND NUMBER	LENGTH
1	62.93	41	62.22
2	62.86	42	
3	62.65	43	
4	61.85	44	
5	62.15	45	
6	61.49	46	
7	61.24	47	
8	62.41	48	
9	62.20	49	
10	61.60	50	
11	59.61	51	
12	62.06	52	
13	61.96	53	
14	61.65	54	
15	62.30	55	
16	61.80	56	
17	61.53	57	
18	61.78	58	
19	62.17	59	
20	62.47	60	
21	61.75	61	
22	61.93	62	
23	62.10	63	
24	62.98	64	
25	61.30	65	
26	60.88	66	
27	62.37	67	
28	63.03	68	
29	61.80	69	
30	62.00	70	
31	61.48	71	
32	62.72	72	
33	61.95	73	
34	61.95	74	
35	61.93	75	
36	62.77	76	
37	62.52	77	
38	63.18	78	
39	62.70	79	
40	62.95	80	
SUBTOTAL	2483.00	SUBTOTAL	62.22

DRILL PIPE TOTAL	2545.22	2637.04
BHA	667.74	
KELLY	40	
TOTAL	3252.96	

DRILL PIPE TALLY - 12-29-89

STAND NUMBER	LENGTH	STAND NUMBER	LENGTH	STAND NUMBER	LENGTH	
1	62.55	41	61.17	81	62.25	
2	59.95	42	61.95	82	62.84	
3	61.95	43	62.54	83	60.30	
4	62.10	44	61.65	84	62.55	
5	62.20	45	61.40	85	62.74	
6	61.90	46	61.83	86	61.02	
7	61.55	47	62.47	87	60.58	
8	61.40	48	61.43	88	62.59	
9	62.10	49	60.79	89	62.83	
10	61.10	50	62.36	90	61.90	
11	61.90	51	61.27	91	61.98	
12	62.05	52	61.72	92	62.49	
13	62.15	53	62.30	93	61.72	
14	62.35	54	62.49	94	62.55	
15	62.20	55	61.20	95	60.21	
16	62.15	56	61.20	96	62.19	
17	62.15	57	62.01	97	62.60	
18	61.15	58	61.19	98	2.00	X-O
19	62.55	59	61.29	99	59.70	DC
20	61.50	60	61.97	100	61.11	DC
21	62.30	61	60.28	101	58.92	DC
22	62.80	62	61.87	102	57.97	DC
23	62.35	63	61.62	103	61.75	DC
24	61.05	64	61.40	104	1.79	X-O
25	60.50	65	62.06	105		
26	62.55	66	61.72	106		
27	61.70	67	60.69	107		
28	62.65	68	62.81	108		
29	60.55	69	62.80	109		
30	61.15	70	61.73	110		
31	62.25	71	61.23	111		
32	60.00	72	61.41	112		
33	61.70	73	61.72	113		
34	61.95	74	62.62	114		
35	61.95	75	61.37	115		
36	62.40	76	61.89	116		
37	62.65	77	59.20	117		
38	62.20	78	61.88	118		
39	62.10	79	62.26	119		
40	62.75	80	62.57	120		
SUBTOTAL	2474.50	SUBTOTAL	2467.36	SUBTOTAL	1356.58	

D P TOTAL	6298.44
BHA	53.02
KELLY	40.00
TOTAL	6391.46 KB

APPENDIX F

MULTISHOT PIPE TALLY

MULTISHOT PIPE TALLY 1-1-90

STAND NUMBER	LENGTH	STAND NUMBER	LENGTH	STAND NUMBER	LENGTH	
1	60.67	41	61.63	81	62.46	
2	61.54	42	62.51	82	61.21	
3	62.35	43	61.49	83	60.61	
4	60.05	44	61.62	84	62.69	
5	62.65	45	61.84	85	61.77	
6	61.40	46	62.27	86	62.59	
7	60.60	47	62.23	87	60.53	
8	62.65	48	62.02	88	61.18	
9	62.35	49	60.03	89	62.41	
10	61.95	50	62.71	90	62.83	
11	59.30	51	61.74	91	62.36	
12	61.97	52	62.57	92	61.62	
13	61.42	53	60.22	93	62.58	
14	62.67	54	62.19	94	61.31	
15	62.82	55	61.74	95	62.24	
16	61.48	56	62.78	96	62.25	
17	61.22	57	62.86	97	62.34	
18	62.61	58	60.88	98	62.45	
19	62.08	59	61.89	99	62.28	
20	61.37	60	62.31	100	62.14	
21	61.27	61	61.60	101	62.04	
22	62.11	62	61.88	102	31.55	
23	61.79	63	59.71	103	31.60	
24	61.29	64	61.36	104	1.79	DC X-0
25	62.61	65	58.05	105	2.00	DC X-0
26	62.34	66	58.81	106	31.09	
27	61.93	67	62.01	107		
28	61.29	68	62.36	108		
29	61.97	69	60.45	109		
30	62.91	70	61.96	110		
31	62.28	71	62.48	111		
32	62.33	72	60.83	112		
33	62.73	73	61.52	113		
34	62.54	74	62.59	114		
35	62.09	75	61.88	115		
36	62.06	76	61.47	116		
37	61.84	77	61.64	117		
38	60.16	78	62.58	118		
39	62.42	79	62.08	119		
40	62.03	80	61.20	120		
SUBTOTAL	2473.14	SUBTOTAL	2463.99	SUBTOTAL	1399.92	

D P TOTAL	6337.05
BHA	33.35
KELLY	29.00

TOTAL DEPTH 6399.40 KB

APPENDIX G

SINGLE SHOT SURVEYS

TAKEN DURING DRILLING OPERATIONS

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	TRUE VERTICAL DEPTH	R E C T A N G U L A R C O O R D I N A T E S NORTH	EAST	CLOSURE DISTANCE FEET	CLOSURE AZIMUTH DEGREES	DOGLEG SEVERITY DEG/100'
0.00	0.00	279.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3191.00	1.00	279.00	3191.00	3191.00	0.00	0.00	0.00	0.00	0.00
3246.00	1.20	290.00	55.00	3245.99	0.26	-1.02	1.05	284.50	0.53
3276.00	2.40	305.00	30.00	3275.97	0.70	-1.85	1.98	290.62	4.26
3307.00	3.80	317.00	31.00	3306.93	1.80	-3.12	3.60	299.95	4.95
3339.00	6.20	325.00	32.00	3338.80	3.96	-4.87	6.28	309.12	7.79
3401.00	9.50	328.00	62.00	3400.21	11.02	-9.54	14.58	319.11	5.36
3433.00	11.20	327.00	32.00	3431.69	15.87	-12.63	20.28	321.48	5.34
3461.00	13.40	326.00	28.00	3459.05	20.84	-15.02	26.23	322.62	7.89
3492.00	15.30	325.00	31.00	3489.08	27.17	-20.28	33.91	323.27	6.18
3525.00	17.00	325.00	33.00	3520.78	34.69	-25.54	43.08	323.64	5.15
3556.00	18.80	325.00	31.00	3550.27	42.50	-31.01	52.61	323.89	5.81
3587.00	20.20	325.00	31.00	3579.50	50.97	-36.94	62.95	324.07	4.52
3617.00	22.50	327.00	30.00	3607.44	60.03	-43.05	73.87	324.36	8.04
3648.00	24.20	327.00	31.00	3635.90	70.33	-49.74	86.14	324.73	5.48
3679.00	27.00	330.00	31.00	3663.85	81.75	-56.74	99.51	325.24	9.95
3739.00	30.70	331.00	60.00	3716.39	106.94	-70.99	128.36	326.42	6.22
3770.00	32.70	331.00	31.00	3742.77	121.19	-78.89	144.60	326.94	6.45
3833.00	36.60	330.00	63.00	3794.58	152.36	-96.52	180.36	327.65	6.26
3863.00	39.10	330.00	30.00	3818.27	168.30	-105.72	198.75	327.86	8.33
3894.00	42.10	330.00	31.00	3841.80	185.77	-115.81	218.91	328.06	9.68
3925.00	44.70	330.00	31.00	3864.33	204.21	-126.46	240.20	328.23	8.39
3957.00	46.80	330.00	32.00	3886.65	224.06	-137.92	263.11	328.39	6.56
3988.00	49.20	329.00	31.00	3907.40	243.91	-149.61	286.14	328.48	8.10
4049.00	54.50	329.00	61.00	3945.06	285.02	-174.31	334.09	328.55	8.69
4111.00	59.60	329.00	62.00	3978.78	329.60	-201.09	386.10	328.61	8.23
4171.00	64.10	332.00	60.00	4007.07	375.62	-227.14	438.96	328.84	8.70
4202.00	66.80	333.00	31.00	4019.95	400.63	-240.15	467.10	329.06	9.19
4325.00	72.50	324.00	123.00	4062.71	498.82	-300.32	582.25	328.95	8.27
4355.00	74.60	323.00	30.00	4071.20	521.95	-317.44	610.90	328.69	7.70
4386.00	77.40	325.00	31.00	4078.70	546.28	-335.11	640.88	328.47	10.99
4416.00	80.70	326.00	30.00	4084.40	570.55	-351.80	670.29	328.34	11.48
4448.00	83.70	327.00	32.00	4088.74	596.98	-369.29	701.97	328.26	9.87
4479.00	84.90	331.00	31.00	4091.82	623.42	-385.18	732.81	328.29	13.41
4511.00	84.10	335.00	32.00	4094.89	651.79	-399.63	764.55	328.49	12.69
4542.00	84.00	339.00	31.00	4098.10	680.17	-411.68	795.05	328.82	12.84
4655.00	91.50	340.00	113.00	4102.54	785.85	-451.19	906.17	330.14	6.70
4718.00	92.00	340.00	63.00	4100.61	845.03	-472.73	968.27	330.78	0.79
4904.00	93.00	340.00	186.00	4092.50	1019.64	-536.28	1152.07	332.26	0.54
5076.00	95.00	338.00	172.00	4080.50	1179.81	-597.77	1322.60	333.13	1.64

MEASURED DEPTH FEET	DRIFT ANGLE DEGREES	DRIFT AZIMUTH DEGREES	COURSE LENGTH FEET	TRUE VERTICAL DEPTH	RECTANGULAR COORDINATES NORTH	RECTANGULAR COORDINATES EAST	CLOSURE DISTANCE FEET	CLOSURE AZIMUTH DEGREES	DOGLEG SEVERITY DEG/100'
5247.00	93.00	338.00	171.00	4068.57	1337.97	-661.66	1492.63	333.69	1.17
5372.00	90.00	343.00	125.00	4065.30	1455.70	-703.36	1616.72	334.21	4.66

APPENDIX H

GAS SHOWS

AS DETERMINED FROM HYDROCARBON MUD LOG

OF DRILLING OPERATION

GAS SHOWS RECORDED IN THE HURON SHALE SECTION OF THE WELLBORE

MEASURED DEPTH feet	CALCULATED VOLUME mcfpd
3705	3
3777	4
3844	2.8
3868	2.8
3932	4
3943	9
3959	9
4038	2.8
4207	45
4210	114
4220	41
4251	11
4294	30
4303	25
4320	82
4349	32
4416	15
4448	16
4524	30
4547	18
4598	40
4608	17
4621	11
4628	16
4706	9
4728	21
4772	24
4782	27
4785	10
4794	22
4803	16
4880	28
4925	57
4931	21
5078	50
5180	50
5211	36
5231	102
5252	21
5338	28
5342	75
5378	16
5383	28
5412	43

MEASURED DEPTH feet	CALCULATED VOLUME mcfpd
5434	25
5484	7.2
5500	28
5564	79
5574	50
5588	64
5603	64
5616	178
5794	28
5800	21
6030	36
6121	10.8
6140	10
6149	10
6168	21.6

APPENDIX I

DAILY DRILLING REPORTS

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 11-30-89 REPORT TIME: 8:00 A.M.
DEPTH: 32 FOOTAGE: 32 ACTIVITY: TRIP
FORMATION: SAND HLU: 8000 HLD: TORQUE:
ROTATING WEIGHT: 8000

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOTAGE	FT/HR	WT	RPM	CONDITION
1	24										

AIR RATE: 2500 MIST RATE: BBLS/HR PRESSURE: 140
ADDITIVES:

BHA:
SURVEYS: o, o, @ o, @ ', o, o, o, @ o, @ ', '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
7:00	5:00	10	RIGGING UP DRILLING RIG AND AIR COMPRESSOR SYSTEM
5:00	7:00	2	DRILL RAT HOLE AND REPAIR RAT HOLE DIGGER
7:00	9:00	2	DRILL MOUSE HOLE
9:00	11:00	2	RIG UP TO DRILL CONDUCTOR HOLE
11:00	5:30	6.5	DRILLED CONDUCTOR HOLE TO 32' BELOW GL
5:30	6:30	1	CIRCULATE TO CLEAN HOLE
6:30	8:00	1.5	TRIP OUT AND BREAK OFF BIT

On November 29, 1989, hauled 720 bbls of water:

1-300 bbls hauled to the tanks (2 tanks at a capacity of 150 bbls each)

2-420 bbls to the pit

*estimated time 10 hours, load capacity 60 bbls

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-1-89 REPORT TIME: 8:00 A.M.
DEPTH: 258 FOOTAGE: 226 ACTIVITY: DRILLING
FORMATION: RED ROCK HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOTAGE	FT/HR	WT	RPM	CONDITION
2	17.5										

AIR RATE: 2550 SCFM MIST RATE: BBLS/HR PRESSURE: 180 PSI
ADDITIVES:

BHA:
SURVEYS: ° , ° , @ ' ° , @ ' ° , ° , @ ' ° , ° , @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:30	.5	Break off bit
8:30	10:00	1.5	Run and set conductor pipe
10:00	11:30	1.5	Unload 13 3/8" casing. Weld flange on to conductor casing
11:30	12:30	1	Unload mud products
12:30	3:00	2.5	Pick up 10" collars and trip in hole
3:00	5:00	2	Nipple up. Install flow line and air head
5:00	6:15	1.25	Drilling 17 1/2" hole
6:15	7:00	.75	Install air head and make connection. Depth 155'
7:00	11:00	4	Drilling
11:00	12:00	1	Service rig and air compressors
12:00	1:30	1.5	Circulate to clean hole. Put soap pump on hole
1:30	6:00	4.5	Drilling
6:00	7:00	1	Plugged bit
7:00	8:00	1	Work on air compressors. Circulate and clean hole. Service rig and air.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-2-89 REPORT TIME: 8:00 A.M.
DEPTH: 696 FOOTAGE: 438 ACTIVITY: DRILLING
FORMATION: RED SAND HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION
2	17.5										

AIR RATE: 3000 SCFM MIST RATE: BBLS/HR PRESSURE: 210 PSI
ADDITIVES:

BHA:
SURVEYS: ° , ° ° , @ ' ° , ° , ° , @ ° , @ ' '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	3:30	7.5	Drilling
3:30	4:00	.5	Service rig and air
4:00	11:00	7	Drilling
11:00	11:30	.5	Service rig and air
11:30	2:45	3.25	Drilling
2:45	3:30	.75	Work on soap pump. Freezing up
3:30	6:00	2.5	Drilling
6:00	7:00	1	Circulate to clean hole
7:00	8:00	1	Nipple down

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-3-89 REPORT TIME: 8:00 A.M.
DEPTH: 696 FOOTAGE: 0 ACTIVITY: Nippling Up
FORMATION: Sandstone HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS: o , o , @ ' o , o , @ ' o , o , @ ' o , o , @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:30	0.5	Back off kelly, pull air bowl
8:30	10:30	2	Trip out, lay down hammer
10:30	12:30	2	Run 16 joints 13-3/8" casing (654')
12:30	1:00	0.5	Rig up Dowell
1:00	2:30	1.5	Cement 13-3/8 casing w/ 460 sx
2:30	8:30	6	Wait on cement
8:30	11:30	3	Cut off 20" conductor, break out, nipple up
11:30	4:00	4.5	Pick up colars, trip in hole
4:00	6:00	2	Start air compressor, blow water
6:00	8:00	2	Nippling up

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-4-89 REPORT TIME: 8:00 A.M.
DEPTH: 1145 FOOTAGE: 449' ACTIVITY: DRILLING
FORMATION: SHALE AND SAND HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION
3	12.25	H33	HTC		696		449	40.8			

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS: O , O , @ ' O , O , @ ' O , O , @ ' O , O , @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:00	1	SERVICE RIG AND AIR
9:00	11:00	2	DRILL OUT OF 13 3/8" CASING
11:00	3:00	4	DRILLING
3:00	3:30	.5	SERVICE RIG
3:30	5:30	2	DRILLING WITH STIFF FOAM
5:30	11:00	5.5	TRIP OUT OF HOLE FOR PLUGGED PIPE. PIPE PLUGGED WITH METAL SHAVINGS
11:00	1:00	2	TRIP IN HOLE
1:00	2:00	1	REPAIR AIR AND CAT HEAD
2:00	3:00	1	WASH TO BOTTOM
3:00	8:00	5	DRILLING

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-5-89 REPORT TIME: 8:00 A.M.
DEPTH: 1981 FOOTAGE: 836 ACTIVITY: EMPTY RESERVE PIT
FORMATION: LIMESTONE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION
2	12.25	H33	HTC		696		1285	38.1	40	55	

AIR RATE: 934 SCFM MIST RATE: 12-15 BBLS/HR PRESSURE: 240 PSIG
ADDITIVES: SODA ASH, POLYPAC, GEL, AND KCl

BHA:
SURVEYS: o, o o , @ ' o, o, o , @ o , @ '

GAS: C1: 12u , C2: , C3: , C4: , C5: , C5+: , TOT: 12u
SHOWS: 1848 - 6u, 1859 - 9u, 1862 - 14u, 1921 - 18u, 1935 - 42u, 1959 - 28u, 1968 - 17u, 1976 - 14u
TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	3:00	7	Drilling
3:00	3:45	.75	Service rig
3:45	11:00	7.25	Drilling
11:00	11:30	.5	Service rig
11:30	7:00	8.5	Drilling. Hit 3" water flow in Maxton at 1860'
7:00	8:00	1	Pull 8 stands pipe. Pits full of water. Empty lower reserve pit to allow room for formation water.

Top of Big Lime 1896'

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-6-89 REPORT TIME: 8:00 A.M.
DEPTH: 2123 FOOTAGE: 142 ACTIVITY: RIGGING UP MUD PUMPS
FORMATION: LIMESTONE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	38.75 FT/HR	WT	RPM	CONDITION
2	12.25	H33	HTC		696	2123	1427	36.83	40	55	

AIR RATE: 1016 MIST RATE: 12-15 BBLS/HR PRESSURE: 200
ADDITIVES: SAME

BHA:
SURVEYS: ° , ° , @ ' ° , ° , @ ' ° , ° , @ ' ° , ° , @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	11:00	3	Mix foam and drain fresh water from second pit
11:00	12:00	1	Unload 9 5/8" casing
12:00	1:00	1	Try to blow water out of hole without success
1:00	2:00	1	Pull 8 more stands drill pipe
2:00	4:00	2	Blowing hole back to bottom
4:00	9:00	5	Drilling with foam, making a lot of water. Standpipe pressure increased to 500 psi on last connection
9:00	2:00	5	Trip out. Wait on cathead cable and mud pump. Third reserve pit 3/4 full
2:00	8:00	6	Rig up mud pump

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12-7-89 REPORT TIME: 8:00 A.M.
DEPTH: 2301 FOOTAGE: 178 ACTIVITY: WORK STUCK PIPE
FORMATION: HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOTAGE	10.25 FT/HR	WT	RPM	CONDITION
RR2	12.25	H33	HTC		2123		178	17.4	40	60	

FLOW RATE: 364 GPM ANNULAR VELOCITY: 80 AND 69 PRESSURE: 500 PSI
ADDITIVES: Drilling with water

BHA:
SURVEYS: o, o , @ ' o , @ ' o, o, o , @ ' o , @ ' '

GAS: C1: 0 u , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS: 250 u at 2105 dropped to 40 after a few minutes

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	4:00	8	Rigging up to drill with mud.
4:00	6:15	2.25	Establish circulation 7 stands off bottom. Partial returns. Losing approximately 40 bbls per hour.
6:15	11:00	4.75	Drilling
11:00	11:30	.5	Service Rig
11:30	5:00	5.5	Drilling
5:00	6:00	1	Work on water transfer pump
6:00	8:00	2	Drill pipe stuck. Work stuck pipe.

Top of Big Injun at 2105

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/8/89 REPORT TIME: 8:00 A.M.
DEPTH: 2382 FOOTAGE: 81 ACTIVITY: DRILLING
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	16.5 FOOT-AGE	FT/HR	WT	RPM	CONDITION
RR2	12.25	H33	HTC		2123		259	15.7	40	60	

FLOW RATE: 403 GPM ANNULAR VELOCITY: 89 & 79 FT/MIN PRESSURE: 600 PSI
ADDITIVES:

BHA: BIT, 21 DC'S, TOT: 635'
SURVEYS:

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 75u
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	5:00	9	Work stuck pipe. Would not come loose
5:00	7:00	2	Rig up Nowsco and pump 80 bbls of oil. Pipe came free
7:00	1:15	6.25	Work on mud pump. Clean pit and mix mud.
1:15	2:30	1.25	Drilling
2:30	3:00	.5	Service rig
3:00	8:00	5	Drilling

75 units of gas due to oil in mud system

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/9/89 REPORT TIME: 8:00 A.M.
DEPTH: 2635' FOOTAGE: 253' ACTIVITY: DRILLING
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	39.5 FT/HR	WT	RPM	CONDITION
RR2	12.25	H33	HTC		2123		512	13.0	40	55	

FLOW RATE: 429 GPM ANNULAR VELOCITY: 97 & 81 FPM PRESSURE: 600 PSI
MUD WT: 9.6, VIS: 47, PV: 10, YP: 17, GELS: 10/15, FILTRATE: 15, SOLIDS: 6%, OIL: 2%, WATER: 92%, SAND: .125%, PH: 7.5, CL: 80,000, CA: 4,000
BHA: SAME
SURVEYS: o, o , @ ' o, o , @ '
o , @ ' o, o , @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 20 u
SHOWS: 2561 - 25u, 2580 - 35u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:14	.25	Service rig
8:15	3:00	6.75	Drilling
3:00	3:15	.5	Service rig
3:15	11:45	8.25	Drilling
11:45	12:00	.25	Service rig
12:00	8:00	8	Drilling

Top of Berea at 2579', bottom at 2596'

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/10/89 REPORT TIME: 8:00 A.M.
DEPTH: 2657' FOOTAGE: 22' ACTIVITY: WAITING ON CEMENT
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	42 FT/HR	WT	RPM	CONDITION
RR2	12.25	H33	HTC		2123	2657	534	12.7	40	55	2-4-I

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS: o, o , @ o , @ ' o, o, o , @ o , @ ' '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	10:30	2.5	Drilling to 2657'
10:30	12:30	2	Circulate to clean hole.
12:30	6:00	5.5	Trip out of hole. Rig up to run casing
6:00	11:00	5	Rig up and run 9 5/8", 36#/ft, ST&C casing. Ran 62 joints and landed casing at 2654' KB.
11:00	1:30	2.5	Rig up Halliburton and cement casing as follows: Pump 15 barrels of fresh water, 330 sacks of Halliburton light mixed at 13.6 ppg and 1.54 cubic feet per sack followed by 100 sacks of class "A" cement containing 3% Calcium chloride, and 1/8 pps flocele mixed at 15.6 ppg and 1.18 cubic feet per sack. Displaced with 204 barrels of water. Bumped plug with 1200 psi. Plug down at 1:15 am. Full returns while cementing.
1:30	8:00	6.5	Wait on cement and rig down mud drilling equipment

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/11/89 REPORT TIME: 8:00 A.M.
DEPTH: 2661' FOOTAGE: 4' ACTIVITY: DRILLING
FORMATION: HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOTAGE	FT/HR	WT	RPM	CONDITION
3	8.75	M84CF	SEC	511602	2657		4				

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA: BIT, FLOAT SUB, 2-MONELS, X-O, 6 1/4" DC'S
SURVEYS: º, º, @ ', º, º, @ ', º, º, @ ', º, º, @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:30	1.5	Wait on cement. Weld 13 3/8" to 9 5/8"
9:30	3:00	5.5	Rig down mud pump and clean pit. Rig up boosters and air package. Run gamma ray correlation log in 9 5/8" casing
3:00	4:00	1	Break out 9 5/8" landing joint
4:00	10:00	6	Nipple up
10:00	5:30	7.5	Pick up monels and trip in hole. Blowing water from hole every 10 stands
5:30	7:00	1.5	Work on brake water system and soap pump
7:00	8:00	1	Drill out casing shoe and drill 8 3/4" hole to 2661'

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/12/89 REPORT TIME: 8:00 A.M.
DEPTH: 3253' FOOTAGE: 592' ACTIVITY: PICK UP DRILL PIPE
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	8 FT/HR	WT	RPM	CONDITION
3	8.75	M84CF	SEC	511602	2657	3253	596	74.5	25	60	1-4-I
4	8.75	M84F	SEC	511139	3253						

AIR RATE: 1700 scfm MIST RATE: 0 BBLS/HR PRESSURE: 180 psi
ADDITIVES:

BHA: BIT, EASTMAN MOTOR, X-O, MSS, 2-MONELS TOTAL 93'
SURVEYS: 1°, N81°W, @ 3191' °, °, @ ' °, °, @ ' °, °, @ '

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 1 u
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:30	.5	Circulate to dry hole
8:30	10:30	2	Drilling
10:30	11:00	.5	Service rig
11:00	3:45	4.75	Drilling
3:45	4:00	.25	Service rig
4:00	5:15	1.25	Drilling to KOP at 3248'
5:15	6:15	1	Survey
6:15	8:00	1.75	Trip out of hole strapping drill pipe. Change depth to strap depth 3253'.
8:00	10:30	2.5	Lay down drill collars
10:30	1:00	2.5	Pick up Eastman motor and adjust bend in motor to build 8°/100'. Test motor - motor runs OK. Rig up oil injection pump.
1:00	2:00	1	Rig down kelly bushing and rig install split kelly bushing. Rig up steering tool wireline.
2:00	3:45	1.75	Wait on Smith orienting sub.
3:45	4:15	.5	Make-up orienting sub and orient motor.
4:15	6:15	2	Trip in hole with drill pipe
6:15	6:30	.25	Work on drum clutch
6:30	8:00	1.5	Picing up drill pipe out of tubs to replace collars

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/13/89 REPORT TIME: 8:00 A.M.
DEPTH: 3539' FOOTAGE: 286' ACTIVITY: DRILLING
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	5,1.5 FT/HR	WT	RPM	CONDITION
4	8.75	M84F	SEC	511139	3253	3487	234	46.8	4-12	MTR	1-2-I
RR4	8.75	M84F	SEC	511139	3487		52	34.7	6	MTR	

AIR RATE: 1931 SCFM OIL RATE: 10 GALS/HR PRESSURE: 280 - 300 PSI
ADDITIVES:

BHA: BIT, EASTMAN MOTOR, X-O, MSS, 2-MONELS TOTAL 87.13

SURVEYS: 1.2°, N70W @ 3246'; 2.4°, N55W @ 3276'; 3.8°, N43W, @ 3307'; 6.2°, N35W @ 3339'; 9.5°, N32W, @ 3401; 11.2°, N33W, @ 3433'; 13.4°, N34W, @ 3461'; 15.3°, N35W, @ 3492'

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 1 u
SHOWS: NONE

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:00	1	Finish picking up drill pipe. Install new rotating head rubber
9:00	11:30	2.5	Run steering tool through side entry sub. Install string float.
11:30	12:30	.5	Drilling with motor. 1/2 hour connections.
12:30	3:00	2.5	Work on cathead and clear floor. Service rig
3:00	8:45	4.5	Drilling with motor. 1.25 hours connections. Motor is building inclination at only 5.5°/100'
8:45	9:30	.75	Chain out to side entry sub
9:30	10:00	.5	Pull steering tool
10:00	12:00	2	Trip out of hole. Bit in good shape
12:00	1:00	1	Set motor for maximum build. Lay down the stabilizer on top of the motor. Re-orient orientation sub
1:00	4:00	3	Trip in hole
4:00	6:00	2	Run steering tool through side entry sub. Install string float.
6:00	8:00	1.5	Drilling with Eastman motor. 1/2 hours connections.

Coordinates at last survey point - 3492'MD, 3489.08' TVD, 27.17' NORTH, 20.28' WEST

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/14/89 REPORT TIME: 8:00 A.M.
DEPTH: 3817' FOOTAGE: 278' ACTIVITY: TRIP
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOTAGE	9.5 FT/HR	WT	RPM	CONDITION
RR4	8.75	M84F	SEC	511139	3487		330	34.7	4-8	MTR	

AIR RATE: 2007 SCFM OIL RATE: 2 GALS/HR PRESSURE: 265 PSI
ADDITIVES:

BHA: BIT, EASTMAN MTR SET AT 1.3°, 1.5° BENT SUB, MSS, 2-MONELS, TOTAL 87.23'
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 2 u
SHOWS: 3502 - 8u, 3550 - 2u, 3559 - 2u, 3576 - 3u, 3704 - 6u, 3776 - 8u, 3808 - 4u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:30	.5	Service rig and compressors
8:30	10:00	1.25	Drilling. 1/4 hour connection
10:00	11:30	1.5	Pull steering tool and trip out of hole. Motor assembly building only 5.5°/100'. Theoretical build rate as calculated by Eastman is 9.5°/100'
11:30	4:30	5	Make up a 1.5° bent sub on top of the Eastman motor leaving the bent housing set at 1.3° (maximum). Trip in hole.
4:30	4:45	.25	Finish trip in hole. Found that the string float had accidently placed on top of the collars as a cross over sub. Could not run steering tool.
4:45	7:00	2.25	Chain out of hole. Remove string float
7:00	7:15	.25	Service rig.
7:15	8:45	1.5	Trip in hole.
8:45	9:30	.75	Run steering tool.
9:30	6:00	6.75	Drilling. 1.75 hours connections. Motor building at an average rate of 6.5°/100'.
6:00	8:00	2	Trip out of hole to change bit.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/15/89 REPORT TIME: 8:00 A.M.
DEPTH: 4280' FOOTAGE: 463' ACTIVITY: DRILLING
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOTAGE	9.75 FT/HR	WT	RPM	CONDITION
RR4	8.75	M84F	SEC	511139	3487	3817	330	34.7	4-8	MTR	1-2-I
5	8.5	M84F	SEC	399929	3817		463	47.5	6-8	MTR	

AIR RATE: 1738 SCFM OIL RATE: 1 GAL/HR PRESSURE: 185 PSI
ADDITIVES:

BHA: SAME
SURVEYS: SEE ATACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 30 u
SHOWS: 3826 5u, 3833 6u, 3840 5u, 3843 6u, 3844 10u, background increased to 8u. 3852 9u, 3861 9u, 3862 12u, background increased to 10u. 3932 16u, 3941 23u, 3758 23u, background increased to 14u. 4206 82u, background increased to 30u. 4212 250u, 4220 60u.

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:30	1.5	Trip out of hole.
9:30	10:15	.75	Change bit. Check motor.
10:15	12:15	2	Trip in hole
12:15	1:45	1.5	Run steering tool.
1:45	4:00	1.75	Drilling. 1/2 hour connections. Steering tool failed.
4:00	6:30	2.5	Pull steering tool. Change probe and run steering tool back in hole.
6:30	8:15	1.5	Drilling. 1/4 hour connections. Steering tool bouncing around a lot at the lower pressure.
8:15	10:30	2.25	Pull steering tool. Replaced standard probe with a probe encased in a fiberglass case. Supposedly this will make it less susceptible to vibration.
10:30	6:00	5.5	Drilling. 2 hours connections.
6:00	6:45	.75	Orienting motor. The motor had turned to 90^{O} right during a connection at the same time there was a 250 unit gas show. Work torque in drill string to get motor back to 20^{O} right.
6:45	8:00	1	Drilling. 1/4 hours connections.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/16/89 REPORT TIME: 8:00 A.M.
DEPTH: 4374' FOOTAGE: 94 ACTIVITY: STEERING TOOL FAILURE
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	1.25 FT/HR	WT	RPM	CONDITION
5	8.5	M84F	SEC	399929	3817	4324	507	47.2	6-8	MTR	1-2-I
RR5	8.5	M84F	SEC	399929	4324		50	33.3	8-10	MTR	

AIR RATE: 1848 SCFM OIL RATE: 1-5 GAL/HOUR PRESSURE: 350 PSI
ADDITIVES:

BHA: BIT, BAKER 2° BENT HOUSING MOTOR, FLOAT SUB, X-O, MSS, 2-MONELS
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 50u
SHOWS: 4250 40u, 4294 110u, 4303 90u, 4312 60u, 4319 200u, 4348 120u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:15	1	Drilling. 1/4 hour connection
9:15	9:45	.5	Steering tool problems. The well appears to be turning to the left; but can't get good information out of the steering tool. Will pull the steering tool to make sure it is still oriented properly. Take single shot survey with steering tool. No picture.
9:45	12:30	2.75	Pull out of hole to side entry sub. The hole was tight 2 stands off bottom. Had to wash out 8 joints until it pulled free. Hole cleaning is the problem.
12:30	1:30	1	Pull steering tool. The orienting stinger had pulled loose from the steering tool when the steering tool was pulled from the hole. Can't tell if the tool had been oriented properly.
1:30	5:00	3.5	Trip out of the hole. Orienting sub still properly positioned.
5:00	9:00	4	Lay down Eastman motor. Pick up Baker motors. Took shims out of second motor so that the first motor could be shimmed up to a 2° bent housing. Pick up rest of BHA and orient motor.
9:00	11:00	2	Trip in hole.
11:00	2:45	3.75	Ran steering tool. Tool would not fall past 60°. Pulled 4 stand from hole. Run and seat steering tool.
2:45	3:15	.5	Drilling. Steering tool still not working right.
3:15	4:15	1	Work on booster clutch.
4:15	7:00	2.75	Pull steering tool and change probes. Run steering tool.
7:00	7:45	.75	Drilling. Steering tool failed half way through kelly. Cannot tell which way the well has turned or what the inclination is. All four probes on location have failed.

7:45 8:00 .25 Attempt to take single shot. No picture.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/17/89 REPORT TIME: 8:00 A.M.
DEPTH: 4422' FOOTAGE: 48' ACTIVITY: STEERING TOOL FAILURE
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	2.25 FT/HR	WT	RPM	CONDITION
RR5	8.5	M84F	SEC	399929	4324		98	43.6	8-10	MTR	

AIR RATE: 1604 SCFM OIL RATE: 5-10 GAL/HOUR PRESSURE: 280 PSI
ADDITIVES:

BHA: SAME
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 80 u
SHOWS: NONE

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:15	.25	Steering tool failure
8:15	8:45	.5	Trip out to side entry sub.
8:45	9:15	.5	Pull steering tool.
9:15	10:30	.45	Pulled tight 4 1/2 stands off bottom (bit at 4095'). Circulated out 4 joints.
10:30	12:00	1.5	Trip out to casing.
12:00	8:15	8.25	Wait on Eastman steering tool. Rearrange compressors to run higher volume in the 7 7/8" hole. Cut drilling line.
8:15	8:30	.25	Trip in hole.
8:30	8:45	5	Water frozen in brake hydromatic. Let brakes cool.
8:45	9:00	.25	Trip in hole.
9:00	1:45	4.5	Rigging up Eastman steering tool to Smith truck. Build crossover to Smith latch in sub.
1:45	2:15	.5	Generator died. Repair same.
2:15	2:30	.25	Drum clutch frozen. Thaw same.
2:30	5:30	3	Steering tool failed when generator quit. Trip to side entry sub. Pull tool and run second probe.
5:30	6:30	1	Trip to bottom.
6:30	7:45	1	Drilling. 1/4 hour connections. Steering tool started failing almost immediately.
7:45	8:00	.25	Waiting for the steering tool to clear up and present a proper tool face.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/18/89 REPORT TIME: 8:00 A.M.
DEPTH: 4422' FOOTAGE: 0 ACTIVITY: TRIP IN HOLE
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION
RR5	8.5	M84F	SEC	399929	4324		98	43.6	8-10	MTR	

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA: BIT, BAKER 2º BENT HOUSING MOTOR, FLOAT SUB, X-O, MSS, 2-MONELS
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 80 u
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	8:45	.75	Trying to get a tool face. Steering tool won't settle down.
8:45	11:00	2.25	Trip out to side entry sub. Hole tight at the same place. Circulated out one joint. Pull steering tool.
11:00	3:00	4	Chain out of hole. Service rig.
3:00	5:00	2	Rig up geoscience MWD. Change jet nozzles from 11-14-14 to 11-11-14.
5:00	9:45	4.75	Trip in hole surveying with the MWD every 4 to 8 stands.
9:45	11:00	1.25	Tagged up approximately 70' off bottom. Tried to wash to bottom but it reamed hard. Quit washing to bottom because we could not get a tool face. Did not want to sidetrack. The electromagnetic MWD was unable to send signals back to the surface.
11:00	2:00	3	Trip out of the hole. Had to circulate out through the same tight spot. Checked the MWD on the way out of the hole. The tool is still working good, just could not get a signal from TD.
2:00	2:30	.5	Work on derrick lights.
2:30	4:30	2	Trip out of hole.
4:30	5:30	1	Lay down MWD equipment.
5:30	6:30	1	Check orientation of motor and orienting sub. Wait on Smith steering tool probes.
6:30	8:00	1.5	Trip in hole.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/19/89 REPORT TIME: 8:00 A.M.
DEPTH: 4512' FOOTAGE: 90' ACTIVITY: DRILLING
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	6.5 FT/HR	WT	RPM	CONDITION
RR5	8.5	M84F	SEC	399929	4324		272	41.9	10	MTR	

AIR RATE: 1652 SCFM OIL RATE: 5-10 GALS/HOUR PRESSURE: 320 PSI
ADDITIVES:

BHA: SAME
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: 1% , C2: TR , C3: , C4: , C5: , C5+: , TOT: 60 u
SHOWS: 4448' 122u, 4496' 70u, 4498' 80u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:15	.75	Trip in hole.
9:15	11:00	1.75	Run steering tool.
11:00	1:15	2.5	Blowing hole back to bottom. Could not get back to bottom. The well ended up sidetracked at 4338'.
1:15	6:30	4.25	Drilling. 1 hour connections. Probe failed.
6:30	6:45	.25	Service rig.
6:45	8:15	1.5	Trip out to side entry sub. Circulate out two joints.
8:15	9:00	.75	Pull steering tool. Tool had come apart. Left the bottom 2/3 rds in the hole.
9:00	1:00	4	Chain out of hole. Had to circulate several joints out of hole.
1:00	1:30	.5	Pull steering tool out of monel.
1:30	2:30	1	Check bit, motor and alignment of motor. All OK. Hook water line to brakes.
2:30	4:30	2	Trip in hole.
4:30	6:00	1.5	Run steering tool.
6:00	7:45	1.75	Blowing hole back to bottom.
7:45	8:00	.25	Drilling.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/20/89 REPORT TIME: 8:00 A.M.
DEPTH: 4750' FOOTAGE: 238' ACTIVITY: SURVEY
FORMATION: SHALE HLU: 82,000 HLD: 64,000 TORQUE: 2RDS
ROTATING WEIGHT: 72,000

BIT RECORD: 24-24-24

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	3 FT/ HR	WT	RPM	CONDITION
RR5	8.5	M84F	SEC	399929	4324	4610	370	39.0	10	MTR	2-3-I
6	7.875	M84F	SEC	388215	4610		140	46.7	20	60	

AIR RATE: 1936 SCFM MIST RATE: 0 BBLS/HR PRESSURE: 180 PSI
ADDITIVES:

BHA: BIT, FLOAT SUB, BOTTOMHOLE THREE POINT WITH FLAT CUTTERS, X-O, 2 MONELS.
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 100u
SHOWS: 4524 120u BG 70u, 4535 80u, 4542 75u, 4547 100u, 4576 90u, 4598, 180u BG 90u, 4606 130u BG 60u, 4621 100u, 4629 160u, BG 100u, 4704 125u, 4728 160u, 4730 140u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	11:45	3	Drilling. 3/4 hours connections.
11:45	12:00	.25	Circulate to clean hole.
12:00	1:45	1.75	Trip out to side entry sub. Circulate out 4 joints.
1:45	2:15	.5	Pull steering tool.
2:15	4:30	2.25	Trip out of hole.
4:30	6:45	2.25	Lay down motor assembly. Pick up rotary assembly.
6:45	8:00	1.25	Trip in hole 22 stands. Run three stands of collars.
8:00	9:00	1	Install kelly bushing back on kelly.
9:00	10:00	1	Trip in hole to tight spot.
10:00	10:15	.25	Change rotating head rubber.
10:15	1:00	2.75	Blow three joints in. Trip in and tag where the well sidetracked. Worked through.
1:00	2:45	1.75	Drilling
2:45	5:15	2.5	Trying to survey by pumping down the single shot. Tried the canvas umbrella first. Got to 4400'. Tried the pig second and got to 4450'. Not able to pump it down.
5:15	6:30	1.25	Drilling.
6:30	7:00	.5	Circulate to survey. Will run two surveys.
7:00	8:00	1	Surveying through side entry sub.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/21/89 REPORT TIME: 8:00 A.M.
DEPTH: 5126' FOOTAGE: 376' ACTIVITY: TRIP
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	11.25 FT/HR	WT	RPM	CONDITION
6	7.875	M84F	SEC	388215	4610	5126	516	45.8	25	55	

AIR RATE: 2174 SCFM MIST RATE: 0 BBLS/HR PRESSURE: 185 PSI
ADDITIVES:

BHA: SAME
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS: 4772 160u, 4781 140u, 4785 130u, 4796 150u, 4803 145u, 4880 140u, 4925 200u, 4931 200u, 5078 270u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	3:00	7	Surveying. Trip out 10 stands. Run singleshot through side entry sub. Trip to bottom and take survey. Trip out and pull singleshot. Run singleshot through side entry sub for second survey. Trip in 9 stands and take survey. Trip out and pull singleshot. Trip to bottom.
3:00	5:00	2	Drilling
5:00	5:15	.25	Service rig.
5:15	6:15	1	Work on booster.
6:15	8:00	1.75	Drilling.
8:00	1:00	5	Trip and survey through side entry sub. BHA is building 0.5°/100'.
1:00	5:30	4.5	Drilling.
5:30	8:00	2.5	Trip out of hole to change bottomhole assembly. Will have to drop approximately 1.5 °/100' to drill through the target.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/22/89 REPORT TIME: 8:00 A.M.
DEPTH: 5126 FOOTAGE: 0 ACTIVITY: Shutting down for holiday
FORMATION: SHALE HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION

AIR RATE: N/A MIST RATE: N/A BBLS/HR PRESSURE: N/A
ADDITIVES:

BHA: BIT, FLOAT SUB, 10.75-FOOT PONY COLLAR, BOTTOMHOLE 3-PT W/ FLAT CUTTERS, X-O, 2 MONELS
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
0800	0900	1	Tripping out.
0900	1230	3.5	Trip in with new BHA as follows: bit, near-bit 3-pt reamer, 30-ft collar, 3-pt string reamer, X-O, monel
1230	1300	0.5	Run single shot w/ timer set for 75 minuters on SMITH (ON COURSE) wire line through side entry sub.
1300	1400	1	Trip in; bit won't go down past sidetrack point (approx. 4338); worked string up and down, blew air but still wouldn't go.
1400	1500	1	Pull 3 stands. Pull side entry sub, wireline, and single shot.
1500	1545	0.75	Run in to sidetrack point; apply torque, drill string rolls into old hole, can't make it go.
1545	1845	3	trip out. Break out BHA.
1845	2000	1.25	Rig down loggers.
2000	2030	0.5	Pick up bit, subs, reamer; new BHA consists of bit, float sub, 10.75-ft pony collar, 3-pt reamer, X-O, collars
2030	2345	3.25	Run in hole.
2345	0215	2.5	Run single shot survey using Wilson Downhole's S.S.Tool, Smith's releasing overshot tool, and rig's slick line unit.
0215	0345	1.5	Pull 20 stands of pipe.
0345	0415	0.5	Fish out single shot w/ sl. line.
0415	0700	2.75	Trip out to casing point.
0700	0800	1	Shutting down; set "dry watch".

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1   DATE: 12/23/89   REPORT TIME: 8:00 A.M.
DEPTH: 5126   FOOTAGE: 0   ACTIVITY: Shut down for holiday
FORMATION: SHALE   HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION

AIR RATE: N/A   MIST RATE: N/A   BBLS/HR   PRESSURE: N/A
ADDITIVES:

BHA: BIT, FLOAT SUB, 10.75-FOOT PONY COLLAR, BOTTOMHOLE 3-PT W/ FLAT CUTTERS, 8-O, 3 MONELS
SURVEYS: NO CHANGE

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:
FROM TO HRS

Rig shut down -- 24-hour "dry watch" set.

12/23 - 12/26 - NO REPORT

RIG SHUT DOWN FOR HOLIDAYS

DRY WATCH ONLY

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/27/89 REPORT TIME: 8:00 A.M.
DEPTH: 5422' FOOTAGE: 296' ACTIVITY: ATTEMPT SURVEY
FORMATION: SHALE HLU: 95000 HLD: 40000 TORQUE:
ROTATING WEIGHT: 68000

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	7.25 FT/HR	WT	RPM	CONDITION
RR6	7.875	M84F	SEC	388215	5126		296	40.8	20-25	60	

AIR RATE: 2174 SCFM MIST RATE: 0 BBLS/HR PRESSURE: 185 PSI
ADDITIVES:

BHA: BIT, X-O, SHORT DRILL COLLAR, THREE POINT, X-O, FLOAT SUB, 2-MONELS, 30 STANDS DRILL PIPE, X-O, 6-DRILL COLLARS, X-O
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	11:00	3	Start up rig. Service rig and air.
11:00	1:30	2.5	Trip in hole. No problem getting into the right hole.
1:30	2:00	.5	Blow hole dry. Had a little water. Probably due to condensation from pipe.
2:00	5:15	3.25	Drilling.
5:15	5:30	.25	Service rig.
5:30	5:45	.25	Work on cathead.
5:45	7:00	1.25	Drilling to 5297'.
7:00	11:30	4.5	Trip out 19 stands. Run survey tool on Smith releasing overshot. Pull slick line and trip to bottom. Trip out and retrieve survey tool. Trip to bottom. Survey read 93° S10W. The direction change is probably due to the singleshot moving to the top of the monels or into the first joint of drill pipe causing magnetic interference. Actual survey depth is probably 40 to 70' higher than shown on the survey sheet.
11:30	12:00	.5	Service rig.
12:00	2:45	2.75	Drilling to 5422'.
2:45	8:00	5.25	Attempt survey. Pulled 21 stands pipe. Run survey tool on releasing overshot. Trip in hole. Got into the short hole. Would not go past 4423'. Made three attempts at getting into the long hole with no luck. Pull out and retrieve survey tool. Trip in to see if the pipe would go into the long hole and it did. Pull bit to 4390' (bit below sidetrack). Ran survey tool to see if it will go down and it did.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/28/89 REPORT TIME: 8:00 A.M.
DEPTH: 5763' FOOTAGE: 341' ACTIVITY: TRIP
FORMATION: SHALE HLU: 115000 HLD: 12000 TORQUE: 3RDS
ROTATING WEIGHT: 64000 BLOCKS AND KELLY WEIGH 12000

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	17.5 FT/HR	WT	RPM	CONDITION
RR6	7.875	M84F	SEC	388215	5126		637	36.4	20-25	60	

AIR RATE: 2068 SCFM MIST RATE: 0 BBLS/HR PRESSURE: 190 PSI
ADDITIVES:

BHA: BIT, X-O, SHORT DRILL COLLAR, THREE POINT REAMER, FLOAT SUB, 1-MONEL, 40 STANDS DRILL PIPE, X-O, 10-DRILL COLLARS, X-O
SURVEYS: SEE ATTACHED SURVEY SHEET

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 170u
SHOWS: 5145 110u, BG 100u, 5180 170u, BG 140u, 5209 190u, 5230 290u, BG 160u, 5253 190u, 5337 200u, 5341 280u, BG 190u, 5378 200u, 5383 220u, 5410 240u, 5432 220u, BG 160u, 5485 170u, 5500 200u, BG 170u, 5564 350u, BG 250u, 5574 320u, 5589 350u, BG 310u, 5603 400u, BG 340u, 5615 600u, BG 440u, BG DROPPED TO 170 UNITS WHEN AIR WAS INCREASED TO 2900 SCFM.

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	12:30	4.5	Trip in with survey tool and take survey. Trip out to 4390' and retrieve survey tool. Trip back to bottom.
12:30	8:30	8	Drilling. After the connection at 5670', the pipe will no longer fall into the hole. Increasd air rate from 2000 scfm to 2900 scfm on next two kellys down. Didn't make any difference. Not a hole cleaning problem. Now having to rotate the pipe to get it in the hole.
8:30	8:45	.25	Service rig.
8:45	11:00	2.25	Drilling. Rotating the pipe in after each connection. Connections taking 30 to 45 mins. Will not be able to take any more surveys by tripping in with pipe. The maximum time on the timer is not long enough to reach bottom.
11:00	11:45	.75	Tried pumping down a survey with the latest revision of the pump down equipment. Would not go through the collars at 3600'.
11:45	12:00	.25	Service rig.
12:00	4:15	4.25	Trip out to move the drill collars up the hole.
4:15	5:30	1.25	Lay down one monel drill collar to help reduce drag.
5:30	7:00	1.5	Trip in 40 stands drill pipe and 6 drill collars.
7:00	8:00	1	Pick up 4 more drill collars.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/29/89 REPORT TIME: 8:00 A.M.
DEPTH: 6406' FOOTAGE: 643' ACTIVITY: CIRCULATE
FORMATION: GREY SHALE HLU: 150000 HLD: 12000 TORQUE: 3.5RDS
ROTATING WEIGHT: 72000 BLOCKS AND KELLY WEIGH 12000

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	37 FT/HR	WT	RPM	CONDITION
RR6	7.875	M84F	SEC	388215	5126	6406	1280	34.6	20-25	60	

AIR RATE: 2012 SCFM MIST RATE: 0 BBLS/HR PRESSURE: 195 PSI
ADDITIVES:

BHA: SAME
SURVEYS: NONE

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT: 220u
SHOWS: 5794 280u, 5800 280u, BG 250u - 220u, 6030 270u, 6121 230u, 6140 240u, 6150 240u, 6168 260u, BG 250u - 220u

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	10:00	2	Trip in hole. Pipe went in with no problem.
10:00	10:30	.5	Service rig.
10:30	3:30	6	Drilling. Started having problems getting the pipe in the hole again at 5913'. Had to rotate the next few connections in. Then was able to work the pipe in to TD.
3:30	4:00	.5	Service rig.
4:00	6:30	2.5	Drilling.
6:30	7:15	.75	Change air head rubber.
7:15	11:00	3.75	Drilling.
11:00	11:30	a9w	Service rig and adjust brakes.
11:30	6:45	7.25	Drilling to TD of 6406'. Shale has been mostly grey since 6220'. Last show at 6168'.
6:45	8:00	1.25	Circulate to clean hole.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/30/89 REPORT TIME: 8:00 A.M.
DEPTH: 6406' FOOTAGE: 0 ACTIVITY: TRIP IN WITH VIDEO LOG
FORMATION: HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	37 FT/HR	WT	RPM	CONDITION
RR6	7.875	M84F	SEC	388215	5126	6406	1280	34.6	20-25	60	2-5-I

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS:

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:00	1	Circulate to clean hole before logging.
9:00	3:00	6	Trip out of hole. Strap drill pipe.
3:00	4:30	1.5	Rig up Hitwell video camera.
4:30	6:00	1.5	Run the camera free fall to 4100' before it stopped.
6:00	9:00	3	Rig up Schlumberger and run GR, Lithodensity, and Temperature log to 4325'.
9:00	5:15	6.25	Wait on Hitwell side door sub and Hot connect to run drill pipe conveyed log.
5:15	8:00	2.75	Trip in hole with camera.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 12/31/89 REPORT TIME: 8:00 A.M.
DEPTH: 6406' FOOTAGE: 0 ACTIVITY: LOGGING
FORMATION: HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS:

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	9:30	1.5	Trip in hole with video camera.
9:30	10:30	1	Hang wireline sheave and rig up side entry sub. Pull air head rubber.
10:30	4:00	5.5	The side entry sub that Hitwell brought out had ST&C connections. Did not know if the connections would take the compressive loads necessary to push the pipe in the hole. Wait on Schlumberger's side entry sub.
4:00	9:00	4	Rig up Schlumberger's side entry sub and run hot connect. Had trouble getting the tool to work. Did not make good contact.
9:00	11:00	2	Logging with the video camera. Kept losing connection to the tool. Could not log to TD.
11:00	12:00	1	Trip out to side entry sub.
12:00	1:15	1.25	Pull wire line and rig down side entry sub.
1:15	2:45	1.5	Trip out of hole.
2:45	4:30	1.75	Rig down the camera and rig up Schlumberger open hole logs.
4:30	6:00	1.5	Trip in hole with logging tools.
6:00	8:00	2	Pick up side entry sub and run wet connect. Start logging.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 1/1/89 REPORT TIME: 8:00 A.M.
DEPTH: 6406' FOOTAGE: 0 ACTIVITY: LAY DOWN DRILL PIPE
FORMATION: HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS:

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	3:00	7	Logging in the hole. Had to work the last 10 stands into the hole.
3:00	6:30	3.5	Logging out of hole.
6:30	9:30	3	The logger did not keep the line tight while pulling out of the hole. The line fell by the side entry sub and became tangled on the drill pipe. The logs coming out of the hole are off depth. Had to untangle the line from the pipe. Pull wire and rig down the side entry sub.
9:30	10:00	1.5	Trip out of hole.
10:00	10:30	.5	Repair fuel leak.
10:30	11:00	.5	Service rig.
11:00	12:15	1.25	Trip out of hole.
12:15	1:15	1	Rig down Schlumberger.
1:15	5:30	4.25	Rig up multishot and trip in hole. Start taking surveys at 3200'.
5:30	7:00	1.5	Rig up to lay down drill pipe.
7:00	8:00	1	Trip out of hole laying down drill pipe.

BDM DAILY REPORT

WELL NAME: BDM/DOE CABOT HW #1 DATE: 1/2/90 REPORT TIME: 8:00 A.M.
DEPTH: 6406' FOOTAGE: 0' ACTIVITY: RIG DOWN ROTARY TOOLS
FORMATION: HLU: HLD: TORQUE:
ROTATING WEIGHT:

BIT RECORD:

BIT #	SIZE	TYPE	MANUF	SERIAL #	DEPTH IN	DEPTH OUT	FOOT-AGE	FT/HR	WT	RPM	CONDITION

AIR RATE: MIST RATE: BBLS/HR PRESSURE:
ADDITIVES:

BHA:
SURVEYS: SEE ATTACHED SURVEY SHEET FOR MULTISHOT DATA

GAS: C1: , C2: , C3: , C4: , C5: , C5+: , TOT:
SHOWS:

TIME BREAKDOWN AND COMMENTS:

FROM	TO	HRS	
8:00	5:00	9	Lay down drill pipe and collars.
5:00	6:00	1	Nipple down BOP's and rig up power tongs.
6:00	7:15	1.25	Strap casing on racks and work out setting depth of external casing packers and port collars.
7:15	12:30	5.25	Ran 140 joints of 4 1/2", 10.5 ppf, K-55, ST&C casing (including 4 pup joints). Casing contained five external casing packers (Tam) and four port collars. Landed casing in wellhead slips.
12:30	8:00	7.5	Rigging down rotary tools.

APPENDIX J

DAILY COST REPORT

WELL NAME: HARDY HW #1 DATE: 11/30/89 SUPERV.: SALAMY

CODE	DESCRIPTION	TICKET NUMBER	COST
401	BUILD LOCATION *		2950
601	GREAT WESTERN - DRILLED 32'		416
	General and Administrative		63
	DAILY TOTAL		3429

COMMENTS: * ESTIMATED COST FROM PO

WELL NAME:HARDY HW #1 DATE: 12/1/89 SUPERV.: SALAMY

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 226'		2938
612	13 3/8" CASING - MCJUNKIN	67-62491	11575
615	13 3/8" CEMENTING EQUIP. - MCJUNKIN	67-62524-	553
	General and Administrative		282
	DAILY TOTAL		15347

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/2/89 SUPERV.: SALAMY

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 438'		5694
	General and Administrative		106
	DAILY TOTAL		5800

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/3/89 SUPERV.: LOCKE

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 0'		0
615	DOWELL - CEMENT 13 3/8"	01-18-240	4531
	General and Administrative		85
		DAILY TOTAL	4616

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/4/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 449'		5837
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		117
	DAILY TOTAL		6374

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/5/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 836'		10868
626	TELEPHONE - C&P BELL	N-1789493	342
606	GSM - WELLSITE CONSULTANT		450
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		226
	DAILY TOTAL		12306

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/6/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 142'		1846
606	GSM - WELLSITE CONSULTANT		450
801	MUD LOGGER - STRATAGRAPH		420
626	OFFICE TRAILER + DEL. AND SET UP - WACO		555
616	9 5/8" CEMENTING EQUIPMENT - MCJUNKIN	67-62881-	578
626	20" PIPE - MCJUNKIN	67-20588	500
	General and Administrative		81
	DAILY TOTAL		4430

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/7/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 178'		2314
606	GSM - WELLSITE CONSULTANT		450
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		60
	DAILY TOTAL		3244

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/8/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 81'		1053
606	GSM - WELLSITE CONSULTANT		450
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		36
	DAILY TOTAL		1959

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/9/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 253'		3289
606	GSM - WELLSITE CONSULTANT		450
606	GSM - PLANNING		3424
626	AIR METER - LAUGHLIN *		1000
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		161
	DAILY TOTAL		8744

COMMENTS: * 10 DAYS RENTAL

WELL NAME: HARDY HW #1 DATE: 12/10/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 22'		286
603	DIRECTIONAL DRILLER		425
603	DIRECTIONAL DRILLER MOBILIZATION		600
607	DIRECTIONAL DRILLING MOBILIZATION		3985
604	DIRECTIONAL EQUIPMENT		145
606	GSM - WELLSITE CONSULTANT		450
613	9 5/8" CASING	67-20827	34769
616	HALLIBURTON - CEMENT 9 5/8" CASING		5856
626	MCJUNKIN - FLOAT VALVES	67-34143	829
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		895
		DAILY TOTAL	48759

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/11/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN - DRILLED 4'		52
603	DIRECTIONAL DRILLER		425
604	DIRECTIONAL DRILLING EQUIPMENT RENTAL		255
604	EASTMAN MOBILIZATION *		1720
606	GSM - WELLSITE CONSULTANT		450
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER STANDBY - STRATAGRAPH		200
802	GAMMA RAY CORRELATION - ATLAS	38906	1270
626	VIDEO TAPE ROAD - SKIDMORE		495
	General and Administrative		93
	DAILY TOTAL		5060

COMMENTS: * ESTIMATED COST

WELL NAME: HARDY HW #1 DATE: 12/12/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
601	GREAT WESTERN DRILLED 592'		7696
602	GREAT WESTERN DAY WORK		3073
604	DIRECTIONAL DRILLING EQPT. RENTAL		215
603	DIRECTIONAL DRILLER		1105
604	STEERING TOOL MOB		1800
606	GSM- WELL SITE CONSULTANT		450
626	AIR METER- LAUGHLIN		100
626	CLEAN DRILL PIPE		250
801	MUD LOGGER- STRATAGRAPH		420
	General and Administrative		283
	DAILY TOTAL		15391

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/13/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - EAST. & WIL.		1130
604	DIRECTIONAL SERVICES		2808
605	STEERING TOOL - SMITH		1800
606	WELLSITE CONSULTANT - GSM & MILFORD		775
609	SECURITY - BIT #4 SN 511139		3074
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		282
		DAILY TOTAL	15389

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/14/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - EAST. & WIL.		1130
604	DIRECTIONAL SERVICES		2702
605	STEERING TOOL - SMITH		1800
606	WELLSITE CONSULTANT - GSM & MILFORD		775
608	FOAM ADDITIVES	38432	2201
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		264
	DAILY TOTAL		14392
	CUMULATIVE		172877

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/15/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLERS - EAST. AND WIL.		1130
604	DIRECTIONAL SERVICES		3955
605	STEERING TOOL - SMITH		1800
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		246

DAILY TOTAL	13426
CUMULATIVE	186303

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/16/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - EAST. AND WIL.		1130
604	DIRECTIONAL SERVICES	01952,090	4841
605	STEERING TOOL - SMITH		1800
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER		420
	General and Administrative		263

DAILY TOTAL	14329
CUMULATIVE	200632

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/17/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		779
605	STEERING TOOL - SMITH		1200
605	STEERING TOOL - EASTMAN		2530
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		210

DAILY TOTAL	11464
CUMULATIVE	212097

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/18/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		1161
605	STEERING TOOL - SMITH		1200
606606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		170
	DAILY TOTAL		9277
	CUMULATIVE		221373

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/19/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		2393
605	STEERING TOOL - SMITH *		2500
605	STEERING TOOL - SCIENTIFIC *		2000
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUID LOGGER - STRATAGRAPH		420
	General and Administrative		255
		DAILY TOTAL	13893
		CUMULATIVE	235266

COMMENTS: * INCLUDES TRANSPORTATION

WELL NAME: HARDY HW #1 DATE: 12/20/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		1768
605	STEERING TOOL - SMITH		1800
605	STEERING TOOL - SCIENTIFIC		2100
606	WELLSITE CONSULTANT - GSM & MILFORD		775
607	REAMER - WILSON		1075
609	BIT #6 - SN 388215 - SECURITY		2688
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		302
	DAILY TOTAL		16478
	CUMULATIVE		251745

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/21/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		405
605	STEERING TOOL - SMITH		1800
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
626	PUMP DOWN EQUIPMENT - RAY MAZZA	98615	536
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		177
	DAILY TOTAL		9663
	CUMULATIVE		261408

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/22/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		305
605	STEERING TOOL - SMITH		1800
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
626	DRILLING/LOGGING CONSULT- RAY MAZZA		85
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		167
	DAILY TOTAL		9102
	CUMULATIVE		270510

COMMENTS: COSTS FOR DEC 22 DO NOT INCLUDE THE USE OF SMITH INT'L RELEASING OVERSHOT TOOL @ $200/DAY, NOR THE COST OF SHIPPING THE TOOL SMITH MAY NOT START CHARGING UNTIL 26TH, BUT COULD START 22ND

WELL NAME: HARDY HW #1 DATE: 12/27/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		2250
604	DIRECTIONAL SERVICES		305
606	WELLSITE CONSULTANT - GSM & MILFORD		775
607	THREE POINT REAMER		775
626	AIR METER - LAUGHLIN		500
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		187
		DAILY TOTAL	10212
		CUMULATIVE	280723

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/28/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		405
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		134

DAILY TOTAL	7284
CUMULATIVE	288006

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/29/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		405
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		134
	DAILY TOTAL		7284
	CUMULATIVE		295290

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/30/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		405
606	WELLSITE CONSULTANT - GSM & MILFORD		775
626	AIR METER - LAUGHLIN		100
801	MUD LOGGER - STRATAGRAPH		420
	General and Administrative		134

DAILY TOTAL	7284
CUMULATIVE	302574

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 12/31/89 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
603	DIRECTIONAL DRILLER - WILSON		450
604	DIRECTIONAL SERVICES		295
606	WELLSITE CONSULTANT - GSM & MILFORD		775
606	WELLSITE CONSULTANT - RAY		400
	General and Administrative		129
	DAILY TOTAL		7049
	CUMULATIVE		309623

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 1/1/90 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
604	DIRECTIONAL SERVICES		295
606	WELLSITE CONSULTANT - GSM & MILFORD		775
606	WELLSITE CONSULTANT		400
802	SCHLUMBERGER - OPEN HOLE LOGS	555781	29786
802	HITWELL - VIDEO LOG	3790	20700
	General and Administrative		1065
	DAILY TOTAL		58021
	CUMULATIVE		367644

COMMENTS:

WELL NAME: HARDY HW #1 DATE: 1/2/90 SUPERV.: CARDEN

CODE	DESCRIPTION	TICKET NUMBER	COST
602	GREAT WESTERN - DAYWORK		5000
604	DIRECTIONAL SERVICES		295
606	WELLSITE CONSULTANT - GSM & MILFORD		775
606	WELLSITE CONSULTANT		400
606	WELLSITE CONSULTANT - GSM EXTRA DAYS		900
604	MULTISHOT SURVEY - EASTMAN	S09086	2770
614	4 1/2" CASING - MCJUNKIN	67-20827-	22039
619	9 5/8 X 4 1/2 WELLHEAD - MCJUNKIN	67-34137-	919
619	MISCELLANEOUS WELLHEAD EQUIP. - MCJUNKI	67-63167	500
614	4 1/2" PUP JOINTS - MCJUNKIN	67-20827	450
617	CENTRALIZERS FOR 4 1/2" - MCJUNKIN	67-62479	1000
626	POWER TONGS - AMERICAN POWER TONG	1496	1000
626	STANDYBY TO RUN RBP - ATLAS	38829	625
626	MISCELLANEOUS TRANSPORTATION		800
621	EXTERNAL CASING PACKERS - TAM		18780
622	PORT COLLARS AND SERVICE REP - TAM	1436	11589
	General and Administrative		1269
	DAILY TOTAL		69111
	CUMULATIVE		436755

COMMENTS:

WELL NAME: HARDY HW #1 YEAR: 1989

TASK CODE	DESCRIPTION	PREVIOUS WEEK	11/30	12/1	12/2	DATE 12/3	12/4	12/5	12/6	WEEKLY TOTAL	PO BUDGET	PO VARIANCE
401	ROADS AND LOCATION	0	2950							2950	2950	0
	SUBTOTAL TASK 4		2950	0	0	0	0	0	0	2950	2950	0
501	CONSULTING ENGINEERING	7494								7494	4743	2751
	SUBTOTAL TASK 5	7494	0	0	0	0	0	0	0	7494	4743	2751
601	FOOTAGE CONTRACT	0	416	2938	5694	0	5837	10868	1846	27599	42484	-14885
602	DAY WORK CONTRACT	0								0	85000	-85000
603	DIRECTIONAL DRILLER	0								0	0	0
604	DIRECTIONAL SERVICES	0								0	0	0
605	STEERING TOOL	0								0	23400	-23400
606	CONSULTING ENGINEER	0						450	450	900	0	900
607	RENTALS-REAMERS & STABILIZERS	0								0	7660	-7660
608	DRILLING FLUID ADDITIVES	0								0	2951	-2951
609	DRILL BITS	0								0	10316	-10316
610	WATER HAULING	0								0	1200	-1200
611	WATER TANK RENTAL	0								0	900	-900
612	13 3/8" CASING	0		11575						11575	11102	473
613	9 5/8" CASING	0								0	31189	-31189
614	4 1/2" CASING	0								0	21632	-21632
615	CEMENTING 13 3/8" CASING	0		553		4531				5084	5084	0
616	CEMENTING 9 5/8" CASING	0							578	578	6434	-5856
617	CEMENTING 4 1/2" CASING	0								0	4651	-4651
618	PRODUCTION TUBING 2 3/8"	0								0	0	0
619	WELLHEAD 9 5/8" X 4 1/2"	0								0	919	-919
620	WELLHEAD 13 3/8 X 9 5/8"	0								0	1678	-1678
621	EXTERNAL CASING PACKERS	0								0	11290	-11290
622	PORT COLLARS	0								0	0	0
623	COMPLETION RIG	0								0	0	0
624	NITROGEN-SERVICE-PACKERS	0								0	0	0
625	SET-TOOL RENTAL	0								0	0	0
626	MISCELLANEOUS	0						342	1055	1397	8501	-7104
	SUBTOTAL TASK 6		416	15066	5694	4531	5837	11660	3929	47133	276391	-229258
801	MUD LOGGER	0	0				420	420	420	1260	7110	-5850
802	WELL LOGGING	0	0							0	27341	-27341
	SUBTOTAL TASK 8		0	0	0	0	420	420	420	1260	34451	-33191
1101	FRAC JOB	0								0	0	0
1102	WORKOVER RIG	0								0	0	0
1103	PERFORATING	0								0	0	0
1104	WELLHEAD PLUMBING	0								0	0	0
1105	MISCELLANEOUS	0								0	0	0
1106	LOCATION RECLAMATION	0								0	0	0
	SUBTOTAL TASK 11		0	0	0	0	0	0	0	0	0	0
	TOTAL COST		3366	15066	5694	4531	6257	12080	4349	58837	318535	-259698
	OVERHEAD AND G&A (1.87%)		63	282	106	85	117	226	81	1100	5957	-4856
	TOTAL COSTS w/ OH/G&A		3429	15348	5800	4616	6374	12306	4430	59937	324492	-264554

WELL NAME: HARDY HW #1 YEAR: 1989

TASK CODE	DESCRIPTION	PREVIOUS WEEK	12/7	12/8	12/9	DATE 12/10	12/11	12/12	12/13	WEEKLY TOTAL	PO BUDGET	PO VARIANCE
200	ROADS AND LOCATION	2950								2950	2950	0
	SUBTOTAL TASK 4	2950	0	0	0	0	0	0	0	2950	2950	0
501	CONSULTING ENGINEERING	7494								7494	4743	2751
	SUBTOTAL TASK 5	7494	0	0	0	0	0	0	0	7494	4743	2751
601	FOOTAGE CONTRACT	27599	2314	1053	3289	286	52	7696		42289	42484	-195
602	DAY WORK CONTRACT	0						3073	5000	8073	85000	-76927
603	DIRECTIONAL DRILLER	0				1025	425	1105	1130	3685	0	3685
604	DIRECTIONAL SERVICES	0				145	1975	2015	2808	6943	0	6943
605	STEERING TOOL	0							1800	1800	23400	-21600
606	CONSULTING ENGINEER	900	450	450	3874	450	450	450	775	7799	0	7799
607	RENTALS-REAMERS & STABILIZERS	0				3985				3985	7660	-3675
608	DRILLING FLUID ADDITIVES	0								0	2951	-2951
609	DRILL BITS	0							3074	3074	10316	-7242
610	WATER HAULING	0								0	1200	-1200
611	WATER TANK RENTAL	0								0	900	-900
612	13 3/8" CASING	11575								11575	11102	473
613	9 5/8" CASING	0				34769				34769	31189	3580
614	4 1/2" CASING	0								0	21632	-21632
615	CEMENTING 13 3/8" CASING	5084								5084	5134	-50
616	CEMENTING 9 5/8" CASING	578				5856				6434	6585	-151
617	CEMENTING 4 1/2" CASING	0								0	4651	-4651
618	PRODUCTION TUBING 2 3/8"	0								0	0	0
619	WELLHEAD 9 5/8" X 4 1/2"	0								0	919	-919
620	WELLHEAD 13 3/8 X 9 5/8"	0								0	1678	-1678
621	EXTERNAL CASING PACKERS	0								0	11290	-11290
622	PORT COLLARS	0								0	0	0
623	COMPLETION RIG	0								0	0	0
624	NITROGEN-SERVICE-PACKERS	0								0	0	0
625	SET-TOOL RENTAL	0								0	0	0
626	MISCELLANEOUS	1397			1000	929	595	350	100	4371	8501	-4130
	SUBTOTAL TASK 6	47133	2764	1503	8163	47445	3497	14689	14687	139881	276592	-136711
801	MUD LOGGER	1260	420	420	420	420	200	420	420	3980	7110	-3130
802	WELL LOGGING						1270			1270	27341	-26071
	SUBTOTAL TASK 8	1260	420	420	420	420	1470	420	420	5250	34451	-29201
1101	FRAC JOB	0								0	0	0
1102	WORKOVER RIG	0								0	0	0
1103	PERFORATING	0								0	0	0
1104	WELLHEAD PLUMBING	0								0	0	0
1105	MISCELLANEOUS	0								0	0	0
1106	LOCATION RECLAMATION	0								0	0	0
	SUBTOTAL TASK 11	0	0	0	0	0	0	0	0	0	0	0
	TOTAL COST	58837	3184	1923	8583	47865	4967	15109	15107	155575	318736	-163161
	OVERHEAD AND G&A (1.87%)	1100	60	36	161	895	93	283	283	2909	5960	-3051
	TOTAL COSTS w/ OH/G&A	59937	3244	1959	8744	48760	5060	15392	15390	158485	324696	-166212

WELL NAME: HARDY HW #1 YEAR: 1989

TASK CODE	DESCRIPTION	PREVIOUS WEEK	DATE 12/14	12/15	12/16	12/17	12/18	12/19	12/20	WEEKLY TOTAL	PO BUDGET	PO VARIANCE
200	ROADS AND LOCATION	2950								2950	2950	0
	SUBTOTAL TASK 4	2950	0	0	0	0	0	0	0	2950	2950	0
501	CONSULTING ENGINEERING	7494								7494	4743	2751
	SUBTOTAL TASK 5	7494	0	0	0	0	0	0	0	7494	4743	2751
601	FOOTAGE CONTRACT	42289								42289	42484	-195
602	DAY WORK CONTRACT	8073	5000	5000	5000	5000	5000	5000	5000	43073	85000	-41927
603	DIRECTIONAL DRILLER	3685	1130	1130	1130	450	450	450	450	8875	0	8875
604	DIRECTIONAL SERVICES	6943	2702	3955	4841	779	1161	2393	1768	24542	0	24542
605	STEERING TOOL	1800	1800	1800	1800	3730	1200	4500	3900	20530	23400	-2870
606	CONSULTING ENGINEER	7799	775	775	775	775	775	775	775	13224	0	13224
607	RENTALS-REAMERS & STABILIZERS	3985							1075	5060	7660	-2600
608	DRILLING FLUID ADDITIVES	0	2201							2201	2951	-750
609	DRILL BITS	3074							2688	5762	10316	-4554
610	WATER HAULING	0								0	1200	-1200
611	WATER TANK RENTAL	0								0	900	-900
612	13 3/8" CASING	11575								11575	11102	473
613	9 5/8" CASING	34769								34769	31189	3580
614	4 1/2" CASING	0								0	21632	-21632
615	CEMENTING 13 3/8" CASING	5084								5084	5134	-50
616	CEMENTING 9 5/8" CASING	6434								6434	6585	-151
617	CEMENTING 4 1/2" CASING	0								0	4651	-4651
618	PRODUCTION TUBING 2 3/8"	0								0	0	0
619	WELLHEAD 9 5/8" X 4 1/2"	0								0	919	-919
620	WELLHEAD 13 3/8 X 9 5/8"	0								0	1678	-1678
621	EXTERNAL CASING PACKERS	0								0	11290	-11290
622	PORT COLLARS	0								0	0	0
623	COMPLETION RIG	0								0	0	0
624	NITROGEN-SERVICE-PACKERS	0								0	0	0
625	SET-TOOL RENTAL	0								0	0	0
626	MISCELLANEOUS	4371	100	100	100	100	100	100	100	5071	8501	-3430
	SUBTOTAL TASK 6	139881	13708	12760	13646	10834	8686	13218	15756	228489	276592	-48103
801	MUD LOGGER	3980	420	420	420	420	420	420	420	6920	7110	-190
802	WELL LOGGING	1270								1270	27341	-26071
	SUBTOTAL TASK 8	5250	420	420	420	420	420	420	420	8190	34451	-26261
1101	FRAC JOB	0								0	0	0
1102	WORKOVER RIG	0								0	0	0
1103	PERFORATING	0								0	0	0
1104	WELLHEAD PLUMBING	0								0	0	0
1105	MISCELLANEOUS	0								0	0	0
1106	LOCATION RECLAMATION	0								0	0	0
	SUBTOTAL TASK 11	0	0	0	0	0	0	0	0	0	0	0
	TOTAL COST	155575	14128	13180	14066	11254	9106	13638	16176	247123	318736	-71613
	OVERHEAD AND G&A (1.87%)	2909	264	246	263	210	170	255	302	4621	5960	-1339
	TOTAL COSTS w/ OH/G&A	158485	14392	13426	14329	11464	9276	13893	16478	251745	324696	-72952

WELL NAME: HARDY HW #1 YEAR: 1989

TASK CODE	DESCRIPTION	PREVIOUS WEEK	DATE 12/21	12/22	12/27	12/28	12/29	12/30	12/31	WEEKLY TOTAL	PO BUDGET	PO VARIANCE
200	ROADS AND LOCATION	2950								2950	2950	0
	SUBTOTAL TASK 4	2950	0	0	0	0	0	0	0	2950	2950	0
501	CONSULTING ENGINEERING	7494								7494	4743	2751
	SUBTOTAL TASK 5	7494	0	0	0	0	0	0	0	7494	4743	2751
601	FOOTAGE CONTRACT	42289								42289	42484	-195
602	DAY WORK CONTRACT	43073	5000	5000	5000	5000	5000	5000	5000	78073	85000	-6927
603	DIRECTIONAL DRILLER	8875	450	450	2250	450	450	450	450	13825	0	13825
604	DIRECTIONAL SERVICES	24542	405	305	305	405	405	405	295	27067	0	27067
605	STEERING TOOL	20530	1800	1800						24130	23400	730
606	CONSULTING ENGINEER	13224	775	775	775	775	775	775	1175	19049	0	19049
607	RENTALS-REAMERS & STABILIZERS	5060			775					5835	7660	-1825
608	DRILLING FLUID ADDITIVES	2201								2201	2951	-750
609	DRILL BITS	5762								5762	10316	-4554
610	WATER HAULING	0								0	1200	-1200
611	WATER TANK RENTAL	0								0	900	-900
612	13 3/8" CASING	11575								11575	11102	473
613	9 5/8" CASING	34769								34769	31189	3580
614	4 1/2" CASING	0								0	21632	-21632
615	CEMENTING 13 3/8" CASING	5084								5084	5134	-50
616	CEMENTING 9 5/8" CASING	6434								6434	6585	-151
617	CEMENTING 4 1/2" CASING	0								0	4651	-4651
618	PRODUCTION TUBING 2 3/8"	0								0	0	0
619	WELLHEAD 9 5/8" X 4 1/2"	0								0	919	-919
620	WELLHEAD 13 3/8 X 9 5/8"	0								0	1678	-1678
621	EXTERNAL CASING PACKERS	0								0	11290	-11290
622	PORT COLLARS	0								0	0	0
623	COMPLETION RIG	0								0	0	0
624	NITROGEN-SERVICE-PACKERS	0								0	0	0
625	SET-TOOL RENTAL	0								0	0	0
626	MISCELLANEOUS	5071	636	185	500	100	100	100		6692	8501	-1809
	SUBTOTAL TASK 6	228489	9066	8515	9605	6730	6730	6730	6920	282785	276592	6193
801	MUD LOGGER	6920	420	420	420	420	420	420		9440	7110	2330
802	WELL LOGGING	1270								1270	27341	-26071
	SUBTOTAL TASK 8	8190	420	420	420	420	420	420	0	10710	34451	-23741
1101	FRAC JOB	0								0	0	0
1102	WORKOVER RIG	0								0	0	0
1103	PERFORATING	0								0	0	0
1104	WELLHEAD PLUMBING	0								0	0	0
1105	MISCELLANEOUS	0								0	0	0
1106	LOCATION RECLAMATION	0								0	0	0
	SUBTOTAL TASK 11	0	0	0	0	0	0	0	0	0	0	0
	TOTAL COST	247123	9486	8935	10025	7150	7150	7150	6920	303939	318736	-14797
	OVERHEAD AND G&A (1.87%)	4621	177	167	187	134	134	134	129	5684	5960	-277
	TOTAL COSTS w/ OH/G&A	251745	9663	9102	10212	7284	7284	7284	7049	309623	324696	-15073

WELL NAME: HARDY HW #1 YEAR: 1990

TASK CODE	DESCRIPTION	PREVIOUS WEEK	1/1	1/2	1/3	DATE 1/4	1/5	1/6	1/7	WEEKLY TOTAL	PO BUDGET	PO VARIANCE
200	ROADS AND LOCATION	2950								2950	2950	0
	SUBTOTAL TASK 4	2950	0	0	0	0	0	0	0	2950	2950	0
501	CONSULTING ENGINEERING	7494								7494	4743	2751
	SUBTOTAL TASK 5	7494	0	0	0	0	0	0	0	7494	4743	2751
601	FOOTAGE CONTRACT	42289								42289	42484	-195
602	DAY WORK CONTRACT	78073	5000	5000						88073	85000	3073
603	DIRECTIONAL DRILLER	13825								13825	0	13825
604	DIRECTIONAL SERVICES	27067	295	3065						30427	0	30427
605	STEERING TOOL	24130								24130	23400	730
606	CONSULTING ENGINEER	19049	1175	2075						22299	0	22299
607	RENTALS-REAMERS & STABILIZERS	5835								5835	7660	-1825
608	DRILLING FLUID ADDITIVES	2201								2201	2951	-750
609	DRILL BITS	5762								5762	10316	-4554
610	WATER HAULING	0								0	1200	-1200
611	WATER TANK RENTAL	0								0	900	-900
612	13 3/8" CASING	11575								11575	11102	473
613	9 5/8" CASING	34769								34769	31189	3580
614	4 1/2" CASING	0		22489						22489	21632	857
615	CEMENTING 13 3/8" CASING	5084								5084	5134	-50
616	CEMENTING 9 5/8" CASING	6434								6434	6585	-151
617	CEMENTING 4 1/2" CASING	0		1000						1000	4651	-3651
618	PRODUCTION TUBING 2 3/8"	0								0	0	0
619	WELLHEAD 9 5/8" X 4 1/2"	0		1419						1419	919	500
620	WELLHEAD 13 3/8 X 9 5/8"	0								0	1678	-1678
621	EXTERNAL CASING PACKERS	0		18780						18780	11290	7490
622	PORT COLLARS	0		11589						11589	0	11589
623	COMPLETION RIG	0								0	0	0
624	NITROGEN-SERVICE-PACKERS	0								0	0	0
625	SET-TOOL RENTAL	0								0	0	0
626	MISCELLANEOUS	6692		2425						9117	8501	616
	SUBTOTAL TASK 6	282785	6470	67842	0	0	0	0	0	357097	276592	80505
801	MUD LOGGER	9440								9440	7110	2330
802	WELL LOGGING	1270	50486							51756	27341	24415
	SUBTOTAL TASK 8	10710	50486	0	0	0	0	0	0	61196	34451	26745
1101	FRAC JOB	0								0	0	0
1102	WORKOVER RIG	0								0	0	0
1103	PERFORATING	0								0	0	0
1104	WELLHEAD PLUMBING	0								0	0	0
1105	MISCELLANEOUS	0								0	0	0
1106	LOCATION RECLAMATION	0								0	0	0
	SUBTOTAL TASK 11	0	0	0	0	0	0	0	0	0	0	0
	TOTAL COST	303939	56956	67842	0	0	0	0	0	428737	318736	110001
	OVERHEAD AND G&A (1.87%)	5684	1065	1269	0	0	0	0	0	8017	5960	2057
	TOTAL COSTS w/ OH/G&A	309623	58021	69111	0	0	0	0	0	436755	324696	112058

WR-35

APPENDIX K

04-Oct-89
API # 47-079-01150

State of West Virginia
DEPARTMENT OF ENERGY
Division of Oil and Gas
Well Operator's Report of Well Work

Farm name: WALKER, CHARLEY   Operator Well No.: HARDY HW #1
Location: Elevation: 862.00   Quadrangle: ELMWOOD

District: UNION   County: PUTNAM
Latitude: 13600 Feet South of 38 Deg. 40 Min. 0 Sec.
Longitude: 3400 Feet West of 81 Deg. 50 Min. 0 Sec.

Company: CABOT OIL & GAS CORPORATION
P. O. Box 1473
Charleston, WV 25325

Agent: DAVID G. MCCLUSKEY

Inspector: JERRY TEPHABOCK
Permit Issued: 11/4/89
Well Work Commenced: 11/29/89
Well Work Completed: 5/16/90
Verbal Plugging
Permission granted on: ________
Rotary X Cable ____ Rig ____
Total Depth (feet) TVD 4276, MD 6399
Fresh water depths (ft) 705

Salt water depths (ft) 1790, 2109, 2118
Is coal being mined in area (Y/N): N
Coal Depths (ft): None Reported

Casing & Tubing	Used in Drilling	Left in Well	Cement Fill Up Cu. Ft.
20"	32'	32'	CTS
13-3/8"	668'	668'	460 sks CL-A w/ 3% CC
9-5/8"	2654'	2654'	330 sks Howco Lt 100 sks CL-A w/ CC
4-1/2"		6151' MD	130 sks CL-A BOC 4103' TOC 3560'
2-3/8"		5550' MD	N/A

OPEN FLOW DATA

Producing formation Lower Huron Shale Pay zone depth (ft) 4010 - TVD
Gas: Initial open flow 15 MCF/d Oil: Initial open flow 0 Bbl/d
Final open flow 582 MCF/d Final open flow 0 Bbl/d
Time of open flow between initial and final tests N/A Hours
Static rock Pressure 575 psig (surface pressure) after N/A Hours

Second Producing formation ________ Pay zone depth (ft) ________
Gas: Initial open flow ________ MCF/d Oil: Initial open flow ________ Bbl/d
Final open flow ________ MCF/d Final open flow ________ Bbl/d
Time of open flow between initial and final tests ________ Hours
Static rock Pressure ________ psig (surface pressure) after ________ Hours

NOTE: ON BACK OF THIS FORM PUT THE FOLLOWING: 1). DETAILS OF PERFORATED INTERVALS, FRACTURING OR STIMULATING, PHYSICAL CHANGE, ETC. 2). THE WELL LOG WHICH IS A SYSTEMATIC DETAILED GEOLOGICAL RECORD OF ALL FORMATIONS, INCLUDING COAL ENCOUNTERED BY THE WELLBORE.

For: CABOT OIL & GAS CORPORATION
By: David G McCluskey
Date: 8-2-90

DETAILS OF PERFORATED INTERVALS, FRACTURING OR STIMULATING, PHYSICAL CHANGE, ETC.

PORT COLLARS NUMBER	MD
1	5919
2	4842
3	4714
4	4056

ZONE	PERFORATIONS RANGE	NUMBER
1	5579-5585	12
2	4864-4880	30
3	4430-4475	10
4	4207-4370	32

ZONE	TABLE OF STIMULATION/TREATMENT
1	Treat w/ 140,000# 20/40 sand in 75Q foam.
2	Attempt to frac w/ no success.
3 & 4	Treated w/ approximately 29,000# 20/40 sand in 75Q foam.
3 & 4	Treat w/ 1.8 million scf N_2.

FORMATION	TOP	BOTTOM
Sandstone	0	700
Sandy Shale	700	1200
Sandstone	1200	1280
Sandy Shale	1280	1810
Sandstone	1810	1900
Limestone (Big Lime)	1900	2080
Shale	2080	2106
Sandstone (Injun)	2106	2166
Silty Shale	2166	2560
Sunburn Shale	2560	2580
Berea Sand	2576	2594
Devonian Shale	2596	4403

APPENDIX L

TABLE L-1

TABLE L-2

TABLE L-3

TABLE L-1

PRE-STIMULATION PRESSURE BUILD-UP DATA ANALYSIS FOR HARDY#1
DATA ARE CONVERTED TO ADJUSTED PRESSURES AND ADJUSTED EFFECTIVE TIME
TO ACCOUNT FOR GAS PROPERTIES SUCH AS VISCOSITY AND COMPRESSIBILITY

TIME-HRS	PRSS	PSUDP	PSUVIS	PSU--Z	PSUCOMP	P-AVG	ADJ-PRS	A-TIME	B-TIME	C-TIME	PSU-TIME	ADJ-TIME	TPA	ADJ EFF T
0	0					500.02517931				0	0	0	677.2278	0
0.017	20.938	39074.30	0.011507	0.996618	0.048598		0.436986	1788.061	894.0307	15.19852	15.1985233	0.000333		0.000333
0.034	20.938	39074.30	0.011507	0.996618	0.048598		0.436986	1788.061	1788.061	30.39704	45.5955700	0.001000		0.001000
0.051	23.134	48715.00	0.011507	0.996263	0.044938	VIS-AVG	0.544803	1933.686	1860.873	31.63485	77.2304271	0.001694		0.001694
0.068	23.134	48715.00	0.011507	0.996263	0.044938	0.012159812	0.544803	1933.686	1933.686	32.87266	110.103094	0.002415		0.002415
0.085	23.992	52481.73	0.011507	0.996124	0.043508		0.586928	1997.239	1965.462	33.41287	143.515965	0.003148		0.003148
0.102	23.992	52481.73	0.011507	0.996124	0.043508		0.586928	1997.239	1997.239	33.95307	177.469038	0.003893		0.003893
0.119	26.733	64515.05	0.011507	0.995682	0.038940	Z-AVG	0.721503	2231.543	2114.391	35.94465	213.413691	0.004682		0.004682
0.136	26.733	64515.05	0.011507	0.995682	0.038940	0.919754928	0.721503	2231.543	2231.543	37.93623	251.349925	0.005514		0.005514
0.153	23.653	50993.48	0.011507	0.996179	0.044073		0.570284	1971.636	2101.589	35.72702	287.076953	0.006298		0.006298
0.17	23.653	50993.48	0.011507	0.996179	0.044073	COMP-AVG	0.570284	1971.636	1971.636	33.51782	320.594775	0.007034		0.007034
0.187	23.781	51555.41	0.011507	0.996159	0.043860	0.001834389	0.576569	1981.226	1976.431	33.59933	354.194109	0.007771		0.007771
0.204	23.781	51555.41	0.011507	0.996159	0.043860		0.576569	1981.226	1981.226	33.68084	387.874956	0.008510		0.008510
0.221	23.845	51836.38	0.011507	0.996148	0.043753		0.579711	1986.056	1983.641	33.72190	421.596857	0.009250		0.009250
0.238	23.845	51836.38	0.011507	0.996148	0.043753	PRS-CONST	0.579711	1986.056	1986.056	33.76295	455.359813	0.009991		0.009990
0.255	24.606	55177.26	0.011507	0.996025	0.042485	0.0000111835	0.617074	2045.345	2015.700	34.26691	489.626729	0.010742		0.010742
0.272	24.606	55177.26	0.011507	0.996025	0.042485		0.617074	2045.345	2045.345	34.77087	524.397605	0.011505		0.011505
0.289	23.996	52499.29	0.011507	0.996124	0.043502		0.587124	1997.545	2021.445	34.36457	558.762181	0.012259		0.012259
0.306	23.996	52499.29	0.011507	0.996124	0.043502		0.587124	1997.545	1997.545	33.95827	592.720457	0.013004		0.013004
0.323	23.514	50383.25	0.011507	0.996202	0.044305		0.563460	1961.327	1979.436	33.65042	626.370878	0.013743		0.013742
0.34	23.514	50383.25	0.011507	0.996202	0.044305		0.563460	1961.327	1961.327	33.34256	659.713443	0.014474		0.014474
0.357	22.926	47801.86	0.011507	0.996297	0.045285		0.534591	1918.883	1940.105	32.98179	692.695239	0.015198		0.015198
0.374	22.926	47801.86	0.011507	0.996297	0.045285		0.534591	1918.883	1918.883	32.62102	725.316265	0.015914		0.015913
0.391	23.762	51472.00	0.011507	0.996162	0.043892		0.575636	1979.796	1949.340	33.13878	758.455053	0.016641		0.016640
0.408	23.762	51472.00	0.011507	0.996162	0.043892		0.575636	1979.796	1979.796	33.65654	792.111600	0.017379		0.017379
0.425	23.733	51344.69	0.011507	0.996166	0.043940		0.574212	1977.619	1978.708	33.63803	825.749638	0.018117		0.018117
0.442	23.733	51344.69	0.011507	0.996166	0.043940		0.574212	1977.619	1977.619	33.61952	859.369165	0.018855		0.018854
0.459	23.744	51392.98	0.011507	0.996165	0.043922		0.574752	1978.444	1978.031	33.62654	892.995708	0.019593		0.019592
0.476	23.744	51392.98	0.011507	0.996165	0.043922		0.574752	1978.444	1978.444	33.63355	926.629268	0.020331		0.020330
0.493	23.717	51274.44	0.011507	0.996169	0.043967		0.573426	1976.419	1977.432	33.61634	960.245616	0.021068		0.021068
0.51	23.717	51274.44	0.011507	0.996169	0.043967		0.573426	1976.419	1976.419	33.59913	993.844753	0.021805		0.021805
0.527	23.771	51511.51	0.011507	0.996160	0.043877		0.576078	1980.473	1978.446	33.63359	1027.47834	0.022543		0.022543
0.544	23.771	51511.51	0.011507	0.996160	0.043877		0.576078	1980.473	1980.473	33.66805	1061.14640	0.023282		0.023281
0.561	23.83	51770.53	0.011507	0.996151	0.043778		0.578974	1984.922	1982.697	33.70586	1094.85226	0.024022		0.024021
0.578	23.83	51770.53	0.011507	0.996151	0.043778		0.578974	1984.922	1984.922	33.74367	1128.59594	0.024762		0.024761
0.595	23.879	51985.64	0.011507	0.996143	0.043697		0.581380	1988.631	1986.776	33.77520	1162.37114	0.025503		0.025502
0.612	23.879	51985.64	0.011507	0.996143	0.043697		0.581380	1988.631	1988.631	33.80673	1196.17788	0.026245		0.026244
0.629	23.927	52196.37	0.011507	0.996135	0.043617		0.583737	1992.279	1990.455	33.83774	1230.01562	0.026987		0.026986
0.646	23.927	52196.37	0.011507	0.996135	0.043617		0.583737	1992.279	1992.279	33.86874	1263.88437	0.027730		0.027729
0.663	23.952	52306.12	0.011507	0.996131	0.043575		0.584964	1994.184	1993.231	33.88493	1297.76930	0.028474		0.028473
1.343	24.949	56683.07	0.011507	0.995970	0.041913		0.633914	2073.241	2033.712	1382.924	2680.69411	0.058817		0.058812
2.023	24.465	54558.26	0.011507	0.996048	0.042720		0.610151	2034.094	2053.668	1396.494	4077.18852	0.089457		0.089445
2.703	23.612	50813.48	0.011507	0.996186	0.044142		0.568271	1968.584	2001.339	1360.910	5438.09942	0.119317		0.119296
3.383	27.18	66477.43	0.011507	0.995610	0.038195		0.743449	2275.068	2121.826	1442.841	6880.94141	0.150974		0.150941
4.063	590.819	34314780	0.012418	0.905510	0.001864		383.7587	43184.87	22729.96	15456.37	22337.3206	0.490103		0.489749
4.743	595.498	34889816	0.012434	0.904781	0.001851		390.1897	43436.23	43310.55	29451.17	51788.4974	1.136293		1.134389
5.423	599.452	35375752	0.012447	0.904165	0.001840		395.6241	43651.58	43543.91	29609.85	81398.3570	1.785963		1.781266
6.103	603.042	35823853	0.012459	0.903607	0.001830		400.6354	43844.90	43748.24	29748.80	111147.163	2.438683		2.429933
6.783	606.422	36246913	0.012470	0.903081	0.001821		405.3667	44028.11	43936.51	29876.82	141023.990	3.094211		3.080138
7.463	609.629	36648319	0.012481	0.902582	0.001812		409.8558	44203.73	44115.92	29998.83	171022.821	3.752417		3.731740

8.143	612.684	37036829	0.012491	0.902108	0.001804	414.2007	44366.97	44285.35	30114.04	201136.864	4.413150	4.384578
8.823	615.585	37406559	0.012500	0.901658	0.001796	418.3356	44522.64	44444.81	30222.47	231359.336	5.076262	5.038495
9.503	618.379	37762652	0.012509	0.901224	0.001789	422.3180	44673.88	44598.26	30326.81	261686.155	5.741664	5.693394
10.183	621.06	38106774	0.012518	0.900808	0.001782	426.1665	44818.01	44745.94	30427.24	292113.400	6.409269	6.349180
10.863	623.621	38439045	0.012526	0.900411	0.001775	429.8824	44953.53	44885.77	30522.32	322635.728	7.078960	7.005730
11.543	626.088	38759119	0.012534	0.900029	0.001769	433.4619	45085.07	45019.30	30613.13	353248.858	7.750644	7.662944
12.223	628.458	39066609	0.012542	0.899661	0.001763	436.9007	45212.36	45148.72	30701.13	383949.990	8.424258	8.320754
12.903	630.744	39364910	0.012550	0.899307	0.001757	440.2368	45334.49	45273.43	30785.93	414735.923	9.099733	8.979084
13.583	632.958	39657251	0.012557	0.898965	0.001752	443.5062	45450.50	45392.49	30866.89	445602.823	9.776985	9.637845
14.263	635.096	39939555	0.012564	0.898634	0.001746	446.6633	45563.25	45506.88	30944.67	476547.502	10.45594	10.29696
14.943	637.164	40212618	0.012571	0.898314	0.001741	449.7171	45672.99	45618.12	31020.32	507567.829	11.13656	10.95639
15.623	639.167	40477097	0.012577	0.898004	0.001736	452.6749	45779.93	45726.46	31093.99	538661.824	11.81879	11.61607
16.303	641.092	40733797	0.012583	0.897707	0.001732	455.5457	45881.12	45830.52	31164.75	569826.583	12.50258	12.27595
16.983	642.965	40985433	0.012589	0.897417	0.001727	458.3599	45978.50	45929.81	31232.27	601058.856	13.18785	12.93594
17.663	644.783	41229680	0.012595	0.897137	0.001723	461.0914	46073.53	46026.02	31297.69	632356.550	13.87455	13.59600
18.343	646.546	41466537	0.012601	0.896865	0.001718	463.7403	46166.17	46119.85	31361.50	663718.051	14.56265	14.25610
19.023	648.261	41696946	0.012607	0.896600	0.001714	466.3171	46256.74	46211.45	31423.79	695141.843	15.25212	14.91619
19.703	649.93	41921175	0.012612	0.896342	0.001710	468.8247	46345.32	46301.03	31484.70	726626.547	15.94293	15.57624
20.383	651.537	42140635	0.012617	0.896094	0.001706	471.2791	46428.01	46386.67	31542.93	758169.483	16.63502	16.23620
21.063	653.098	42353970	0.012622	0.895854	0.001703	473.6649	46508.57	46468.29	3159[illegible].44	789767.923	17.32832	16.89600
21.743	654.602	42559515	0.012627	0.895622	0.001699	475.9636	46586.52	46547.54	31652.33	821420.257	18.02280	17.55560
22.423	656.076	42760960	0.012632	0.895395	0.001696	478.2165	46663.25	46624.89	31704.92	853125.183	18.71844	18.21498
23.103	657.502	42955845	0.012637	0.895175	0.001693	480.3960	46737.79	46700.52	31756.35	884881.538	19.41521	18.87411
23.783	658.883	43144580	0.012641	0.894962	0.001689	482.5067	46810.26	46774.02	31806.34	916687.878	20.11307	19.53296
26.258	663.615	43799745	0.012656	0.894234	0.001679	489.8337	47058.34	46934.30	116162.4	1032850.28	22.66180	21.92803
29.578	669.396	44603343	0.012672	0.893344	0.001665	498.8207	47364.97	47211.65	156742.6	1189592.98	26.10089	25.13227
32.898	674.55	45330744	0.012684	0.892553	0.001654	506.9556	47647.28	47506.13	157720.3	1347313.33	29.56144	28.32503
36.218	679.114	45976165	0.012694	0.891852	0.001644	514.1737	47901.16	47774.22	158610.4	1505923.77	33.04152	31.50443
39.538	683.262	46570775	0.012703	0.891216	0.001635	520.8235	48128.64	48014.90	159409.4	1665333.26	36.53912	34.66861
42.858	687.104	47123538	0.012711	0.890628	0.001627	527.0053	48340.08	48234.36	160138.0	1825471.36	40.05272	37.81619
46.178	690.597	47627563	0.012719	0.890093	0.001619	532.6420	48533.14	48436.61	160809.5	1986280.92	43.58105	40.94608
49.511	693.692	48080499	0.012725	0.889619	0.001613	537.7074	48701.07	48617.10	162040.8	2148321.74	47.13639	44.06909
52.831	696.658	48514557	0.012732	0.889166	0.001607	542.5617	48863.29	48782.18	161956.8	2310278.59	50.68989	47.16000
56.151	699.421	48918906	0.012737	0.888744	0.001601	547.0838	49015.55	48939.42	162478.8	2472757.48	54.25484	50.23070
59.471	701.947	49293404	0.012743	0.888358	0.001596	551.2719	49152.29	49083.92	162958.6	2635716.10	57.83032	53.28055
62.791	704.274	49639722	0.012748	0.888003	0.001591	555.1450	49278.11	49215.20	163394.4	2799110.58	61.41537	56.30891
66.111	706.523	49974431	0.012753	0.887660	0.001587	558.8882	49400.43	49339.27	163806.3	2962916.97	65.00945	59.31554
69.431	708.63	50288008	0.012757	0.887338	0.001583	562.3951	49515.68	49458.05	164200.7	3127117.72	68.61218	62.30033
72.751	710.572	50578454	0.012761	0.887042	0.001579	565.6433	49621.48	49568.58	164567.6	3291685.42	72.22297	65.26299
76.071	712.408	50856276	0.012765	0.886763	0.001575	568.7503	49719.75	49670.62	164906.4	3456591.88	75.84118	68.20326
79.391	714.23	51131980	0.012769	0.886485	0.001571	571.8336	49817.73	49768.74	165232.2	3621824.13	79.46655	71.12113
82.711	715.926	51388617	0.012773	0.886227	0.001568	574.7037	49909.35	49863.54	165546.9	3787371.09	83.09882	74.01665
86.031	717.486	51624675	0.012776	0.885990	0.001565	577.3437	49993.97	49951.66	165839.5	3953210.61	86.73751	76.88969
89.351	719.001	51853924	0.012780	0.885759	0.001562	579.9075	50076.47	50035.22	166116.9	4119327.55	90.38229	79.74022
92.671	720.49	52080464	0.012783	0.885533	0.001559	582.4410	50157.04	50116.76	166387.6	4285715.19	94.03301	82.56839
95.991	721.876	52293662	0.012786	0.885322	0.001556	584.8253	50230.74	50193.89	166643.7	4452358.93	97.68934	85.37421
99.337	723.117	52484555	0.012788	0.885134	0.001554	586.9601	50296.95	50263.85	168182.8	4620541.77	101.3794	88.17922
102.657	724.408	52683139	0.012791	0.884938	0.001552	589.1810	50366.04	50331.50	167100.5	4787642.36	105.0458	90.93997
105.977	725.678	52878493	0.012794	0.884745	0.001549	591.3657	50434.23	50400.14	167328.4	4954970.84	108.7171	93.67868
109.297	726.851	53058926	0.012796	0.884567	0.001547	593.3836	50497.41	50465.82	167546.5	5122517.38	112.3933	96.39544
112.617	727.998	53235360	0.012799	0.884392	0.001545	595.3567	50559.37	50528.39	167754.2	5290271.65	116.0740	99.09034
115.937	729.139	53410871	0.012801	0.884219	0.001543	597.3196	50621.18	50590.27	167959.7	5458231.37	119.7592	101.7636
119.257	730.241	53580989	0.012804	0.884052	0.001541	599.2221	50680.65	50650.91	168161.0	5626392.42	123.4488	104.4154
122.577	731.255	53739514	0.012806	0.883898	0.001539	600.9949	50734.20	50707.42	168348.6	5794741.08	127.1425	107.0458
125.897	732.253	53[illegible]5538	0.012808	0.883747	0.001537	602.7398	50787.04	50760.62	168525.2	5963266.35	130.8402	109.6549
129.217	733.251	54051562	0.012810	0.883596	0.001535	604.4847	50840.01	50813.52	168700.9	6131967.26	134.5416	112.2429

132.537	734.201	54200082	0.012812	0.883452	0.001533	606.1457	50890.55	50865.28	168872.7	6300840.00	138.2469		114.8100
135.857	735.104	54341255	0.012814	0.883315	0.001531	607.7245	50938.70	50914.63	169036.5	6469876.57	141.9557		117.3563
139.177	735.999	54481176	0.012816	0.883179	0.001530	609.2893	50986.54	50962.62	169195.9	6639072.48	145.6680		119.8820
142.497	736.862	54616095	0.012818	0.883049	0.001528	610.7982	51032.76	51009.65	169352.0	6808424.53	149.3838		122.3874
145.843	737.643	54738194	0.012820	0.882930	0.001527	612.1637	51074.68	51053.72	170825.7	6979250.29	153.1319		124.8919
149.163	738.411	54858260	0.012821	0.882814	0.001525	613.5064	51115.98	51095.33	169636.5	7148886.79	156.8539		127.3566
152.483	739.186	54979421	0.012823	0.882696	0.001524	614.8614	51157.73	51136.85	169774.3	7318661.16	160.5789		129.8014
155.803	739.979	55103396	0.012825	0.882576	0.001522	616.2479	51200.54	51179.14	169914.7	7488575.92	164.3070		132.2266
159.123	740.729	55222491	0.012826	0.882463	0.001521	617.5798	51239.92	51220.23	170051.1	7658627.11	168.0381		134.6323
162.443	741.449	55336872	0.012828	0.882354	0.001520	618.8590	51277.76	51258.84	170179.3	7828806.48	171.7720		137.0186
165.763	742.201	55456337	0.012829	0.882240	0.001518	620.1950	51317.36	51297.56	170307.9	7999114.40	175.5088		139.3858
169.083	742.92	55570560	0.012831	0.882132	0.001517	621.4724	51355.28	51336.32	170436.5	8169550.99	179.2483		141.7342
172.403	743.584	55676045	0.012832	0.882031	0.001516	622.6521	51390.36	51372.82	170557.7	8340108.77	182.9905		144.0637
175.723	744.255	55782642	0.012834	0.881930	0.001515	623.8442	51425.87	51408.12	170674.9	8510783.73	186.7353		146.3747
179.043	744.935	55890669	0.012835	0.881827	0.001513	625.0524	51461.92	51443.89	170793.7	8681577.47	190.4827		148.6673
182.363	745.601	55996472	0.012837	0.881726	0.001512	626.2356	51497.28	51479.60	170912.2	8852489.75	194.2327		150.9417
185.683	746.232	56096715	0.012838	0.881631	0.001511	627.3567	51530.83	51514.06	171026.6	9023516.43	197.9852		153.1982
189.003	746.825	56190921	0.012839	0.881541	0.001510	628.4102	51562.42	51546.63	171134.8	9194651.25	201.7401		155.4368
192.349	747.36	56275913	0.012840	0.881460	0.001509	629.3607	51590.95	51576.68	172575.6	9367226.85	205.5266		157.6750
195.669	747.874	56357568	0.012842	0.881383	0.001508	630.2739	51618.40	51604.68	171327.5	9538554.39	209.2857		159.8781
198.989	748.29	56423655	0.012842	0.881320	0.001507	631.0130	51640.64	51629.52	171410.0	9709964.42	213.0466		162.0636
202.309	748.722	56492284	0.012843	0.881255	0.001507	631.7805	51663.76	51652.20	171485.3	9881449.75	216.8091		164.2317
205.629	749.148	56559960	0.012844	0.881190	0.001506	632.5374	51686.59	51675.17	171561.5	10053011.3	220.5734		166.3825
208.949	749.571	56627159	0.012845	0.881126	0.001505	633.2889	51709.27	51697.93	171637.1	10224648.4	224.3393		168.5163
212.269	749.9	56679425	0.012846	0.881077	0.001504	633.8734	51726.93	51718.10	171704.1	10396352.6	228.1066		170.6332
215.589	750.157	56720651	0.012846	0.881038	0.001504	634.3344	51740.49	51733.71	171755.9	10568108.5	231.8751		172.7332
218.909	739.167	54976451	0.012823	0.882699	0.001524	614.8282	51156.71	51448.60	170809.3	10738917.9	235.6229		174.8044
222.229	744.731	55858261	0.012835	0.881858	0.001514	624.6899	51451.10	51303.90	170328.9	10909246.8	239.3601		176.8530
225.549	747.851	56353914	0.012842	0.881386	0.001508	630.2330	51617.17	51534.13	171093.3	11080340.2	243.1140		178.8939
228.869	750.013	56697410	0.012846	0.881059	0.001504	634.0745	51732.98	51675.08	171561.2	11251901.4	246.8783		180.9238
232.189	751.701	56969852	0.012850	0.880805	0.001501	637.1214	51821.15	51777.07	171899.8	11423801.3	250.6499		182.9412
235.509	753.048	57187257	0.012853	0.880602	0.001499	639.5527	51891.77	51856.46	172163.4	11595964.8	254.4274		184.9453
238.829	754.177	57369478	0.012855	0.880432	0.001497	641.5906	51951.14	51921.45	172379.2	11768344.0	258.2096		186.9357
242.175	755.177	57530877	0.012857	0.880281	0.001495	643.3956	52003.85	51977.50	173916.7	11942260.7	262.0255		188.9276
245.495	756.083	57677105	0.012859	0.880144	0.001493	645.0309	52051.73	52027.79	172732.2	12114993.0	265.8154		190.8900
248.815	756.86	57802513	0.012861	0.88002[illegible]	0.001492	646.4334	52092.87	52072.30	172880.0	12287873.1	269.6086		192.8384
252.135	757.574	57917752	0.012862	0.879919	0.001491	647.7222	52130.74	52111.80	173011.2	12460884.3	273.4046		194.7726
255.455	758.296	58034283	0.012864	0.879810	0.001490	649.0254	52169.10	52149.92	173137.7	12634022.0	277.2034		196.6929
258.775	759.001	58148069	0.012865	0.879704	0.001488	650.2979	52206.63	52187.87	173263.7	12807285.8	281.0050		198.5993
262.095	759.61	58246362	0.012867	0.879612	0.001487	651.3972	52239.10	52222.86	173379.9	12980665.7	284.8091		200.4919

TABLE L-2

POST-STIMULATION PRESSURE BUILD-UP DATA ANALYSIS FOR HARDY#1
DATA ARE CONVERTED TO ADJUSTED PRESSURES AND ADJUSTED EFFECTIVE TIME
TO ACCOUNT FOR GAS PROPERTIES SUCH AS VISCOSITY AND COMPRESSIBILITY

TIME-HRS	PRSS	PSUDP	PSUVIS	PSU--Z	PSUCOMP	P-AVG	ADJ-PRS	A-TIME	B-TIME	C-TIME	PSU-TIME	ADJ-TIM	TPA	ADJ EFF T
0						724.84056014				0	0	0.000	129.4114	0.000
1.75	115.35	1193379	0.011561	0.981370	0.008850		9.318	9773.469	4886.734	8551.786	8552	0.170		0.169
3.5	285.21	7547534	0.011792	0.954001	0.003675		58.935	23070.35	11535.17	20186.55	28738	0.570		0.568
5.25	379.98	13640810	0.011972	0.938820	0.002801	VIS-AVG	106.514	29810.33	14905.16	26084.04	54822	1.088		1.079
7	428.33	17490675	0.012051	0.931115	0.002505	0.0127926	136.576	33115.82	16557.91	28976.34	83799	1.663		1.642
8.75	473.23	21537071	0.012111	0.923990	0.002284		168.172	36138.14	18069.07	31620.87	115420	2.291		2.251
10.5	497.37	23901396	0.012155	0.920174	0.002182		186.634	37698.55	18849.27	32986.23	148406	2.945		2.880
12.25	530.28	27340856	0.012214	0.914989	0.002057	Z-AVG	213.491	39788.80	19894.40	34815.20	183221	3.636		3.537
14	546.73	29157378	0.012265	0.912405	0.002001	0.804872364	227.675	40742.32	20371.16	35649.57	218871	4.344		4.203
15.75	574.50	32355882	0.012361	0.908057	0.001912		252.651	42290.71	21145.35	37004.3	255875	5.078		4.886
17.5	585.69	33694302	0.012400	0.906309	0.001879	COMP-AVG	263.102	42904.12	21452.06	37541.10	293416	5.823		5.572
19.25	596.89	35060560	0.012439	0.904565	0.001847	0.001551326	273.770	43511.59	21755.79	38072.64	331489	6.579		6.260
21	608.08	36454842	0.012476	0.902823	0.001816		284.657	44118.87	22059.43	38604.01	370093	7.345		6.950
22.75	619.28	37877375	0.012512	0.901084	0.001786		295.765	44722.88	22361.44	39132.52	409225	8.121		7.642
24.5	624.88	38602014	0.012530	0.900216	0.001772	PRS-CONST	301.423	45020.39	22510.19	39392.84	448618	8.903		8.330
26.25	630.48	39329398	0.012549	0.899349	0.001758	0.0000078085	307.103	45320.45	22660.22	39655.39	488273	9.690		9.015
28	641.67	40811580	0.012585	0.897617	0.001730		318.677	45911.16	22955.58	40172.27	528446	10.487		9.701
29.75	645.03	41262829	0.012596	0.897099	0.001722		322.200	46086.47	23043.23	40325.66	568771	11.288		10.382
31.5	652.87	42322383	0.012622	0.895889	0.001703		330.174	46496.62	23248.31	40684.54	609456	12.095		11.061
33.25	656.23	42781411	0.012633	0.895372	0.00169		334.058	46671.06	23335.53	40837.17	650293	12.905		11.735
35	661.82	43550729	0.012650	0.894509	0.00168		340.065	46964.32	23482.16	41093.78	691387	13.721		12.406
36.75	664.06	43861990	0.012657	0.894165	0.001678		342.496	47081.91	23540.95	41196.67	732584	14.538		13.070
38.5	666.30	44173252	0.012663	0.893820	0.001672		344.926	47200.24	23600.12	41300.21	773884	15.358		13.729
40.25	666.30	44173252	0.012663	0.893820	0.001672		344.926	47200.24	23600.12	41300.21	815184	16.178		14.380
42	673.02	45114310	0.012681	0.892788	0.001657		352.275	47562.85	23781.42	41617.49	856802	17.004		15.029
43.75	675.26	45430965	0.012686	0.892444	0.001653		354.747	47686.50	23843.25	41725.69	898527	17.832		15.672
45.5	678.62	45905948	0.012693	0.891928	0.001645		358.456	47873.39	23936.69	41889.21	940416	18.663		16.311
47.25	680.86	46224709	0.012698	0.891585	0.001640		360.945	47997.36	23998.68	41997.69	982414	19.496		16.944
49	681.98	46385788	0.012700	0.891413	0.001638		362.203	48058.36	24029.18	42051.07	1024465	20.331		17.571
50.75	684.22	46707947	0.012705	0.891070	0.001633		364.718	48180.91	24090.45	42158.30	1066624	21.168		18.192
52.5	685.34	46869027	0.012707	0.890899	0.001631		365.976	48242.46	24121.23	42212.15	1108836	22.005		18.807
54.25	693.24	48014352	0.012724	0.889689	0.001614		374.920	48676.46	24338.23	42591.90	1151428	22.851		19.421
56	693.24	48014352	0.012724	0.889689	0.001614		374.920	48676.46	24338.23	42591.90	1194019	23.696		20.029
57.75	693.24	48014352	0.012724	0.889689	0.001614		374.920	48676.46	24338.23	42591.90	1236611	24.541		20.629
59.5	694.37	48179853	0.012727	0.889516	0.001612		376.212	48738.09	24369.04	42645.83	1279257	25.387		21.224
61.25	696.63	48510855	0.012731	0.889170	0.001607		378.796	48861.90	24430.95	42754.16	1322011	26.236		21.814
63	701.16	49175728	0.012741	0.888479	0.001598		383.988	49109.71	24554.85	42970.99	1364982	27.089		22.400
64.75	703.42	49512342	0.012746	0.888134	0.001593		386.617	49231.74	24615.87	43077.77	1408060	27.944		22.981
66.5	704.55	49680649	0.012749	0.887961	0.001591		387.931	49293.03	24646.51	43131.40	1451192	28.800		23.557
68.25	706.81	50017264	0.012753	0.887616	0.001586		390.559	49416.13	24708.06	43239.12	1494431	29.658		24.128
70	707.94	50185571	0.012756	0.887443	0.001584		391.873	49477.96	24738.98	43293.22	1537724	30.517		24.694
71.75	710.20	50522693	0.012761	0.887098	0.001579		394.506	49601.81	24800.90	43401.58	1581125	31.378		25.255
73.5	715.86	51378328	0.012773	0.886238	0.001568		401.187	49905.67	24952.83	43667.46	1624793	32.245		25.813
75.25	715.86	51378328	0.012773	0.886238	0.001568		401.187	49905.67	24952.83	43667.46	1668460	33.111		26.365
77	718.12	51720582	0.012778	0.885893	0.001564		403.860	50028.44	25014.22	43774.89	1712235	33.980		26.913
78.75	719.25	51891709	0.012780	0.885721	0.001562		405.196	50090.10	25045.05	43828.83	1756064	34.850		27.456
80.5	719.25	51891709	0.012780	0.885721	0.001562		405.196	50090.10	25045.05	43828.83	1799893	35.720		27.993
82.25	720.38	52063790	0.012783	0.885549	0.001559		406.540	50151.29	25075.64	43882.38	1843775	36.591		28.525
84	720.38	52063790	0.012783	0.885549	0.001559		406.540	50151.29	25075.64	43882.38	1887658	37.461		29.052
85.75	720.38	52063790	0.012783	0.885549	0.001559		406.540	50151.29	25075.64	43882.38	1931540	38.332		29.573

87.5	720.38	52063790	0.012783	0.885549	0.001559	406.540	50151.29	25075.64	43882.38	1975423	39.203	30.088
89.25	721.51	52237748	0.012785	0.885377	0.001557	407.898	50211.39	25105.69	43934.96	2019357	40.075	30.599
91	723.77	52585662	0.012790	0.885034	0.001553	410.615	50332.10	25166.05	44040.59	2063398	40.949	31.106
92.75	727.17	53107534	0.012797	0.884519	0.001546	414.690	50514.46	25257.23	44200.15	2107598	41.826	31.610
94.5	729.43	53455449	0.012802	0.884175	0.001542	417.406	50636.91	25318.45	44307.29	2151906	42.706	32.110
96.25	731.69	53807615	0.012807	0.883832	0.001538	420.156	50757.25	25378.62	44412.59	2196318	43.587	32.605
98	733.95	54161218	0.012812	0.883489	0.001534	422.917	50877.31	25438.65	44517.65	2240836	44.470	33.097
99.75	733.95	54161218	0.012812	0.883489	0.001534	422.917	50877.31	25438.65	44517.65	2285353	45.354	33.584
101.5	735.08	54338019	0.012814	0.883318	0.001531	424.298	50937.60	25468.80	44570.40	2329924	46.238	34.067
103.25	736.21	54514820	0.012817	0.883147	0.001529	425.678	50998.05	25499.02	44623.30	2374547	47.124	34.545
105	737.35	54691621	0.012819	0.882975	0.001527	427.059	51058.68	25529.34	44676.34	2419223	48.011	35.019
106.75	737.35	54691621	0.012819	0.882975	0.001527	427.059	51058.68	25529.34	44676.34	2463900	48.897	35.488
108.5	737.35	54691621	0.012819	0.882975	0.001527	427.059	51058.68	25529.34	44676.34	2508576	49.784	35.953
110.25	737.35	54691621	0.012819	0.882975	0.001527	427.059	51058.68	25529.34	44676.34	2553253	50.671	36.413
112	737.35	54691621	0.012819	0.882975	0.001527	427.059	51058.68	25529.34	44676.34	2597929	51.557	36.869
113.75	737.35	54691621	0.012819	0.882975	0.001527	427.059	51058.68	25529.34	44676.34	2642605	52.444	37.320
115.5	738.48	54868423	0.012821	0.882804	0.001525	428.439	51119.48	25559.74	44729.54	2687335	53.331	37.767
117.25	738.48	54868423	0.012821	0.882804	0.001525	428.439	51119.48	25559.74	44729.54	2732064	54.219	38.210
119	738.48	54868423	0.012821	0.882804	0.001525	428.439	51119.48	25559.74	44729.54	2776794	55.107	38.649
120.75	738.48	54868423	0.012821	0.882804	0.001525	428.439	51119.48	25559.74	44729.54	2821523	55.995	39.084
122.5	738.48	54868423	0.012821	0.882804	0.001525	428.439	51119.48	25559.74	44729.54	2866253	56.882	39.514
124.25	738.48	54868423	0.012821	0.882804	0.001525	428.439	51119.48	25559.74	44729.54	2910982	57.770	39.940
126	739.61	55045224	0.012824	0.882633	0.001523	429.820	51180.44	25590.22	44782.89	2955765	58.659	40.363
127.75	739.61	55045224	0.012824	0.882633	0.001523	429.820	51180.44	25590.22	44782.89	3000548	59.547	40.782
129.5	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3045384	60.437	41.197
131.25	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3090219	61.327	41.609
133	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3135054	62.217	42.017
134.75	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3179890	63.106	42.420
136.5	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3224725	63.996	42.821
138.25	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3269560	64.886	43.217
140	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3314396	65.776	43.610
141.75	740.74	55223889	0.012826	0.882462	0.001521	431.215	51240.38	25620.19	44835.34	3359231	66.666	43.999
143.5	741.87	55403548	0.012829	0.882291	0.001519	432.618	51299.85	25649.92	44887.37	3404118	67.556	44.386
145.25	741.87	55403548	0.012829	0.882291	0.001519	432.618	51299.85	25649.92	44887.37	3449006	68.447	44.769
147	741.87	55403548	0.012829	0.882291	0.001519	432.618	51299.85	25649.92	44887.37	3493893	69.338	45.148
148.75	741.87	55403548	0.012829	0.882291	0.001519	432.618	51299.85	25649.92	44887.37	3538781	70.229	45.524
150.5	744.13	55762864	0.012834	0.881949	0.001515	435.424	51419.28	25709.64	44991.87	3583772	71.122	45.897
152.25	745.26	55942523	0.012836	0.881778	0.001513	436.827	51479.24	25739.62	45044.33	3628817	72.016	46.268
154	746.39	56122181	0.012838	0.881607	0.001511	438.229	51539.37	25769.68	45096.95	3673914	72.911	46.636
155.75	747.52	56301840	0.012841	0.881436	0.001509	439.632	51599.66	25799.83	45149.70	3719063	73.807	47.001
157.5	748.65	56481498	0.012843	0.881265	0.001507	441.035	51660.13	25830.06	45202.61	3764266	74.704	47.363
159.25	749.79	56661156	0.012846	0.881094	0.001505	442.438	51720.76	25860.38	45255.66	3809522	75.602	47.722
161	753.18	57208192	0.012853	0.880582	0.001499	446.709	51898.58	25949.29	45411.26	3854933	76.503	48.080
162.75	754.31	57390718	0.012855	0.880412	0.001497	448.135	51958.07	25979.03	45463.31	3900396	77.405	48.435
164.5	755.44	57573245	0.012858	0.880241	0.001495	449.560	52017.71	26008.85	45515.50	3945912	78.309	48.787
166.25	755.44	57573245	0.012858	0.880241	0.001495	449.560	52017.71	26008.85	45515.50	3991427	79.212	49.136
168	756.57	57755772	0.012860	0.880071	0.001493	450.985	52077.52	26038.76	45567.83	4036995	80.116	49.482
169.75	756.57	57755772	0.012860	0.880071	0.001493	450.985	52077.52	26038.76	45567.83	4082563	81.020	49.826
171.5	757.70	57938299	0.012863	0.879900	0.001491	452.411	52137.50	26068.75	45620.31	4128183	81.926	50.167
173.25	758.83	58120826	0.012865	0.879730	0.001489	453.836	52197.64	26098.82	45672.93	4173856	82.832	50.505
175	758.83	58120826	0.012865	0.879730	0.001489	453.836	52197.64	26098.82	45672.93	4219529	83.739	50.841
176.75	758.83	58120826	0.012865	0.879730	0.001489	453.836	52197.64	26098.82	45672.93	4265202	84.645	51.174
178.5	759.96	58303352	0.012868	0.879559	0.001487	455.261	52257.94	26128.97	45725.70	4310928	85.552	51.504
180.25	759.96	58303352	0.012868	0.879559	0.001487	455.261	52257.94	26128.97	45725.70	4356653	86.460	51.831
182	759.96	58303352	0.012868	0.879559	0.001487	455.261	52257.94	26128.97	45725.70	4402379	87.367	52.156
183.75	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4448156	88.276	52.479

185.5	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4493933	89.184	52.798
187.25	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4539711	90.093	53.115
189	758.83	58120826	0.012865	0.879730	0.001489	453.836	52197.64	26098.82	45672.93	4585383	90.999	53.429
190.75	758.83	58120826	0.012865	0.879730	0.001489	453.836	52197.64	26098.82	45672.93	4631056	91.906	53.740
192.5	758.83	58120826	0.012865	0.879730	0.001489	453.836	52197.64	26098.82	45672.93	4676729	92.812	54.049
194.25	759.96	58303352	0.012868	0.879559	0.001487	455.261	52257.94	26128.97	45725.70	4722455	93.719	54.355
196	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4768232	94.628	54.660
197.75	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4814009	95.536	54.962
199.5	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4859786	96.445	55.261
201.25	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4905563	97.353	55.558
203	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4951341	98.262	55.853
204.75	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	4997118	99.170	56.145
206.5	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5042895	100.079	56.435
208.25	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5088723	100.988	56.723
210	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5134552	101.898	57.009
211.75	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5180329	102.806	57.292
213.5	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5226106	103.715	57.573
215.25	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5271883	104.623	57.852
217	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5317661	105.532	58.129
218.75	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5363438	106.440	58.404
220.5	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5409215	107.349	58.676
222.25	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5454992	108.257	58.946
224	761.09	58488667	0.012870	0.879389	0.001485	456.708	52316.70	26158.35	45777.11	5500769	109.165	59.215
225.75	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5546598	110.075	59.481
227.5	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5592426	110.984	59.746
229.25	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5638255	111.894	60.008
231	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5684083	112.803	60.269
232.75	762.22	58674075	0.012872	0.879219	0.001483	458.156	52375.56	26187.78	45828.61	5729912	113.713	60.528
234.5	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	5775792	114.623	60.785
236.25	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	5821673	115.534	61.040
238	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	5867553	116.444	61.293
239.75	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	5913433	117.355	61.544
241.5	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	5959313	118.266	61.794
243.25	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6005194	119.176	62.042
245	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6051074	120.087	62.287
246.75	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6096954	120.997	62.531
248.5	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6142834	121.908	62.774
250.25	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6188715	122.818	63.014
252	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6234595	123.729	63.253
253.75	763.36	58859483	0.012875	0.879049	0.001481	459.604	52434.57	26217.28	45880.25	6280475	124.639	63.490
255.5	764.49	59044892	0.012877	0.878879	0.001479	461.051	52493.75	26246.87	45932.03	6326407	125.551	63.726
257.25	764.49	59044892	0.012877	0.878879	0.001479	461.051	52493.75	26246.87	45932.03	6372339	126.462	63.960
259	764.49	59044892	0.012877	0.878879	0.001479	461.051	52493.75	26246.87	45932.03	6418271	127.374	64.192
260.75	765.62	59230300	0.012880	0.878709	0.001477	462.499	52553.08	26276.54	45983.95	6464255	128.286	64.423
262.5	766.75	59415708	0.012882	0.878538	0.001475	463.947	52612.58	26306.29	46036.01	6510291	129.200	64.653
264.25	766.75	59415708	0.012882	0.878538	0.001475	463.947	52612.58	26306.29	46036.01	6556327	130.114	64.881
266	766.75	59415708	0.012882	0.878538	0.001475	463.947	52612.58	26306.29	46036.01	6602363	131.027	65.107
267.75	766.75	59415708	0.012882	0.878538	0.001475	463.947	52612.58	26306.29	46036.01	6648399	131.941	65.332
269.5	767.88	59601117	0.012885	0.878368	0.001473	465.395	52672.24	26336.12	46088.21	6694487	132.855	65.555
271.25	767.88	59601117	0.012885	0.878368	0.001473	465.395	52672.24	26336.12	46088.21	6740576	133.770	65.777
273	769.01	59786525	0.012887	0.878198	0.001471	466.842	52732.05	26366.02	46140.55	6786716	134.686	65.998
274.75	769.01	59786525	0.012887	0.878198	0.001471	466.842	52732.05	26366.02	46140.55	6832857	135.601	66.217
276.5	770.14	59972294	0.012889	0.878028	0.001469	468.293	52791.82	26395.91	46192.84	6879050	136.518	66.435
278.25	770.14	59972294	0.012889	0.878028	0.001469	468.293	52791.82	26395.91	46192.84	6925242	137.435	66.651
280	770.14	59972294	0.012889	0.878028	0.001469	468.293	52791.82	26395.91	46192.84	6971435	138.352	66.866
281.75	770.14	59972294	0.012889	0.878028	0.001469	468.293	52791.82	26395.91	46192.84	7017628	139.268	67.080

283.5	771.27	60160593	0.012892	0.877858	0.001467	469.763	52850.23	26425.11	46243.95	7063872	140.186	67.292
285.25	771.27	60160593	0.012892	0.877858	0.001467	469.763	52850.23	26425.11	46243.95	7110116	141.104	67.502
287	771.27	60160593	0.012892	0.877858	0.001467	469.763	52850.23	26425.11	46243.95	7156360	142.021	67.712
288.75	771.27	60160593	0.012892	0.877858	0.001467	469.763	52850.23	26425.11	46243.95	7202604	142.939	67.920
290.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7248899	143.858	68.126
292.25	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7295194	144.777	68.332
294	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7341490	145.695	68.536
295.75	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7387785	146.614	68.738
297.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7434080	147.533	68.940
299.25	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7480375	148.452	69.140
301	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7526670	149.370	69.338
302.75	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7572966	150.289	69.536
304.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7619261	151.208	69.732
306.25	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7665556	152.127	69.926
308	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7711851	153.045	70.120
309.75	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7758146	153.964	70.312
311.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7804442	154.883	70.503
313.25	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7850737	155.802	70.693
315	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7897032	156.720	70.881
316.75	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7943327	157.639	71.069
318.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	7989622	158.558	71.255
320.25	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8035918	159.477	71.440
322	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8082213	160.395	71.624
323.75	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8128508	161.314	71.806
325.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8174803	162.233	71.988
327.25	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8221098	163.152	72.168
329	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8267393	164.070	72.347
330.75	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8313689	164.989	72.525
332.5	772.40	60348891	0.012894	0.877689	0.001465	471.234	52908.79	26454.39	46295.19	8359984	165.908	72.702

TABLE L-3

TWO RATE TEST ANALYSIS FOR HARDY #1 DURING PRODUCTION

t1,(hr) = 144 q1 = 61
q2 = 100

ADJUSTED PRESSURE A	ADJUSTED EFF-TIME B	ACTUAL TIME C
444.9944	0	0
429.0316	2.276799	1.742
421.2009	4.520595	3.484
421.2009	6.746407	5.226
421.2009	8.961824	6.968
421.2009	11.16692	8.71
421.2009	13.36176	10.452
421.2009	15.54643	12.194
421.2009	17.72099	13.936
421.2009	19.88551	15.678
421.2009	22.04006	17.42
413.3701	24.17766	19.162
405.6896	26.29125	20.904
401.0813	28.38385	22.646
405.6896	30.46705	24.388
390.4784	32.53094	26.13
390.4784	34.57154	27.872
394.9968	36.60739	29.614
401.0813	38.64408	31.356
405.6896	40.68148	33.098
405.6896	42.71396	34.84
408.7618	44.74018	36.582
408.7618	46.76017	38.324
413.3701	48.77535	40.066
425.8993	50.79644	41.808
413.3701	52.80853	43.55
398.0091	54.78766	45.292
390.4784	56.73794	47.034
382.9476	58.66635	48.776
375.5678	60.57282	50.518
375.5678	62.46418	52.26
382.9476	64.35456	54.002
390.4784	66.25046	55.744
398.0091	68.15147	57.486
402.6174	70.05482	59.228
402.6174	71.95386	60.97
405.6896	73.84734	62.712
405.6896	75.73527	64.454
405.6896	77.61514	66.196
394.9968	79.47808	67.938
390.4784	81.32043	69.68
382.9476	83.1449	71.422
371.1399	84.94488	73.164
365.2982	86.72143	74.906
363.8533	88.4839	76.648
372.6159	90.24594	78.39

375.5678	92.01149	80.132					
379.9957	93.77634	81.874					
382.9476	95.5405	83.616					
385.9599	97.30249	85.358					
390.4784	99.06334	87.1					
390.4784	100.8206	88.842					
390.4784	102.5707	90.584					
382.9476	104.3077	92.326					
375.5678	106.0252	94.068					
368.188	107.7233	95.81					
360.9634	109.4017	97.552					
360.9634	111.0668	99.294					
360.9634	112.7253	101.036					
360.9634	114.3774	102.778					
360.9634	116.0229	104.52					
360.9634	117.6621	106.262					
360.9634	119.2948	108.004					
360.9634	120.9212	109.746					
360.9634	122.5413	111.488					
360.9634	124.1551	113.23					
360.9634	125.7627	114.972					
360.9634	127.3641	116.714					
346.6717	128.9465	118.456					
339.6046	130.5039	120.198					
336.8404	132.0465	121.94					
336.8404	133.5808	123.682					
346.6717	135.1182	125.424					
353.7388	136.665	127.166					
358.0736	138.216	128.908					
363.8533	139.7697	130.65					
365.2982	141.3237	132.392					
371.1399	142.8778	134.134					
372.6159	144.4319	135.876					
375.5678	145.9834	137.618					
375.5678	147.5313	139.36			LOG(E)	LOG(D)	q1/q2 * G
368.188	149.0677	141.102	D	E	F	G	H
360.9634	150.5865	142.844	========	========	========	========	========
342.4314	152.0779	144.586	0.586	246.7338	2.392229	-0.2321	-0.3805
339.6046	153.5458	146.328	2.328	62.85567	1.798344	0.366983	0.601611
332.6941	154.9999	148.07	4.07	36.38084	1.560873	0.609594	0.999335
321.7307	156.433	149.812	5.812	25.77632	1.411221	0.764326	1.252993
320.3798	157.8502	151.554	7.554	20.06275	1.30239	0.878177	1.439634
319.0289	159.2599	153.296	9.296	16.49053	1.217235	0.968296	1.587371
314.976	160.6599	155.038	11.038	14.04584	1.147548	1.04289	1.709656
312.2741	162.0491	156.78	12.78	12.26761	1.08876	1.106531	1.813985
308.3143	163.4274	158.522	14.522	10.91599	1.038063	1.162026	1.904961
306.9943	164.7961	160.264	16.264	9.85391	0.993609	1.211227	1.985619
305.6743	166.1577	162.006	18.006	8.997334	0.954114	1.255417	2.058061
325.7836	167.7004	163.963	19.963	8.213345	0.91452	1.300226	2.131518
325.7836	169.257	165.92	21.92	7.569343	0.879058	1.340841	2.198099
325.7836	170.8074	167.877	23.877	7.030908	0.847011	1.37798	2.258983
319.0289	172.3451	169.834	25.834	6.57405	0.817833	1.412192	2.315068
312.2741	173.8637	171.791	27.791	6.181534	0.791096	1.443904	2.367056
312.2741	175.3701	173.748	29.748	5.840662	0.766462	1.473458	2.415505
305.6743	176.8641	175.705	31.705	5.54187	0.743656	1.501128	2.460865
303.0344	178.3433	177.662	33.662	5.277821	0.722455	1.52714	2.503508

299.0746	179.8104	179.619	35.619	5.042786	0.702671	1.551682	2.543741
299.0746	181.2683	181.576	37.576	4.832233	0.684148	1.574911	2.581821
295.2072	182.7167	183.533	39.533	4.642526	0.666754	1.59696	2.617967
299.0746	184.1597	185.49	41.49	4.470716	0.650377	1.617943	2.652366
299.0746	185.6013	187.447	43.447	4.314383	0.634919	1.63796	2.68518
299.0746	187.0375	189.404	45.404	4.171527	0.620295	1.657094	2.716548
299.0746	188.4683	191.361	47.361	4.040476	0.606433	1.675421	2.746592
299.0746	189.8938	193.318	49.318	3.919826	0.593267	1.693005	2.775419
299.0746	191.314	195.275	51.275	3.808386	0.580741	1.709906	2.803124
299.0746	192.7289	197.232	53.232	3.70514	0.568805	1.726173	2.829791
295.2072	194.1349	199.189	55.189	3.609216	0.557413	1.741853	2.855496
292.6289	195.5293	201.146	57.146	3.519861	0.546526	1.756986	2.880305
292.6289	196.9162	203.103	59.103	3.436425	0.536107	1.77161	2.904278
286.1833	198.2919	205.06	61.06	3.358336	0.526124	1.785757	2.92747
286.1833	199.6564	207.017	63.017	3.285098	0.516548	1.799458	2.949931
286.1833	201.0161	208.974	64.974	3.216271	0.507353	1.81274	2.971704
282.4085	202.3671	210.931	66.931	3.151469	0.498513	1.825627	2.992832
279.8919	203.707	212.888	68.888	3.09035	0.490008	1.838144	3.01335
279.8919	205.0396	214.845	70.845	3.032606	0.481816	1.850309	3.033294
279.8919	206.3675	216.802	72.802	2.977968	0.47392	1.862143	3.052694
279.8919	207.6907	218.759	74.759	2.926189	0.466302	1.873663	3.071579
277.3753	209.0068	220.716	76.716	2.877053	0.458948	1.884886	3.089977
276.117	210.3146	222.673	78.673	2.830361	0.451842	1.895826	3.107911
276.117	211.6166	224.63	80.63	2.785936	0.444971	1.906497	3.125404
274.8587	212.9129	226.587	82.587	2.743616	0.438323	1.916912	3.142478
273.6004	214.2022	228.544	84.544	2.703255	0.431887	1.927083	3.159152
273.6004	215.486	230.501	86.501	2.664721	0.425652	1.937021	3.175444
273.6004	216.7652	232.458	88.458	2.627891	0.419607	1.946737	3.191372
273.6004	218.0401	234.415	90.415	2.592656	0.413745	1.95624	3.206952
273.6004	219.3106	236.372	92.372	2.558914	0.408056	1.96554	3.222197
273.6004	220.5767	238.329	94.329	2.526572	0.402532	1.974645	3.237123
273.6004	221.8385	240.286	96.286	2.495545	0.397165	1.983563	3.251743
273.6004	223.0959	242.243	98.243	2.465753	0.39195	1.992302	3.266068
273.6004	224.349	244.2	100.2	2.437126	0.386878	2.000868	3.280111
273.6004	225.5979	246.157	102.157	2.409595	0.381944	2.009268	3.293882
272.373	226.8413	248.114	104.114	2.383099	0.377142	2.017509	3.307392
271.1456	228.078	250.071	106.071	2.357581	0.372467	2.025597	3.32065
267.4635	229.3058	252.028	108.028	2.332988	0.367912	2.033536	3.333666
265.0088	230.5236	253.985	109.985	2.309269	0.363475	2.041333	3.346448
261.3267	231.7315	255.942	111.942	2.28638	0.359148	2.048993	3.359005
261.3267	232.932	257.899	113.899	2.264278	0.35493	2.05652	3.371344
258.9335	234.126	259.856	115.856	2.242922	0.350814	2.063919	3.383473
255.3438	235.3103	261.813	117.813	2.222276	0.346798	2.071193	3.395399
255.3438	236.4872	263.77	119.77	2.202304	0.342877	2.078348	3.407128
252.9507	237.6579	265.727	121.727	2.182975	0.339049	2.085387	3.418667
261.3267	238.8306	267.684	123.684	2.164257	0.335309	2.092314	3.430022
267.4635	240.0133	269.641	125.641	2.146123	0.331655	2.099131	3.441199
267.4635	241.1977	271.598	127.598	2.128544	0.328083	2.105844	3.452203
267.4635	242.3783	273.555	129.555	2.111497	0.32459	2.112454	3.46304
267.4635	243.5549	275.512	131.512	2.094957	0.321175	2.118965	3.473714
267.4635	244.7276	277.469	133.469	2.078902	0.317834	2.12538	3.48423
261.3267	245.891	279.426	135.426	2.063311	0.314565	2.131702	3.494594
261.3267	247.0449	281.383	137.383	2.048165	0.311365	2.137933	3.504808
249.361	248.1839	283.34	139.34	2.033443	0.308232	2.144076	3.514878
255.3438	249.3136	285.297	141.297	2.01913	0.305164	2.150133	3.524808
255.3438	250.4451	287.254	143.254	2.005208	0.302159	2.156107	3.534601

252.9507	251.5709	289.211	145.211	1.99166	0.299215	2.162	3.544262
251.7541	252.6897	291.168	147.168	1.978474	0.29633	2.167813	3.553792
250.5576	253.8028	293.125	149.125	1.965633	0.293502	2.17355	3.563197
249.361	254.9102	295.082	151.082	1.953125	0.29073	2.179213	3.57248
249.361	256.0131	297.039	153.039	1.940937	0.288011	2.184802	3.581643
249.361	257.1125	298.996	154.996	1.929056	0.285345	2.19032	3.590689
249.361	258.2084	300.953	156.953	1.917472	0.282729	2.19577	3.599622
249.361	259.3009	302.91	158.91	1.906173	0.280162	2.201151	3.608445
249.361	260.39	304.867	160.867	1.895149	0.277643	2.206467	3.617159
249.361	261.4756	306.824	162.824	1.884391	0.275171	2.211718	3.625768
249.361	262.5579	308.781	164.781	1.873887	0.272743	2.216907	3.634274
249.361	263.6369	310.738	166.738	1.86363	0.27036	2.222035	3.64268
256.5404	264.7344	312.7233	168.7233	1.853468	0.267985	2.227175	3.651107
256.5404	265.835	314.7086	170.7086	1.843543	0.265653	2.232255	3.659435
258.9335	266.9342	316.6939	172.6939	1.833845	0.263363	2.237277	3.667667
261.3267	268.0343	318.6792	174.6792	1.824368	0.261113	2.242241	3.675805
261.3267	269.133	320.6645	176.6645	1.815104	0.258902	2.247149	3.683851
263.7814	270.2304	322.6498	178.6498	1.806046	0.256729	2.252003	3.691807
266.2362	271.3284	324.6351	180.6351	1.797187	0.254593	2.256802	3.699676
268.6909	272.4272	326.6204	182.6204	1.788521	0.252494	2.261549	3.707458
271.1456	273.5267	328.6057	184.6057	1.780041	0.25043	2.266245	3.715156
273.6004	274.6268	330.591	186.591	1.771741	0.2484	2.270891	3.722772
276.117	275.7276	332.5763	188.5763	1.763617	0.246404	2.275487	3.730307
279.8919	276.83	334.5616	190.5616	1.755661	0.244441	2.280035	3.737763
282.4085	277.9339	336.5469	192.5469	1.74787	0.242509	2.284537	3.745142
286.1833	279.0394	338.5322	194.5322	1.740237	0.240608	2.288991	3.752445
288.7616	280.1464	340.5175	196.5175	1.732759	0.238738	2.293401	3.759674
295.2072	281.2567	342.5028	198.5028	1.725431	0.236897	2.297767	3.766831
295.2072	282.3683	344.4881	200.4881	1.718247	0.235086	2.302089	3.773916
296.4963	283.4772	346.4734	202.4734	1.711205	0.233302	2.306368	3.780931
299.0746	284.5855	348.4587	204.4587	1.704299	0.231546	2.310606	3.787878
299.0746	285.6922	350.444	206.444	1.697526	0.229816	2.314802	3.794758
305.6743	286.8	352.4293	208.4293	1.690882	0.228113	2.318959	3.801572
312.2741	287.9138	354.4146	210.4146	1.684363	0.226436	2.323076	3.808321
316.327	289.0317	356.3999	212.3999	1.677966	0.224783	2.327154	3.815007
296.4963	290.1342	358.3852	214.3852	1.671688	0.223155	2.331195	3.821631
286.1833	291.211	360.3705	216.3705	1.665525	0.221551	2.335198	3.828194
279.8919	292.2717	362.3558	218.3558	1.659474	0.21997	2.339165	3.834696
272.373	293.3181	364.3411	220.3411	1.653532	0.218413	2.343096	3.84114
267.4635	294.3514	366.3264	222.3264	1.647696	0.216877	2.346991	3.847526
257.737	295.3696	368.3117	224.3117	1.641964	0.215364	2.350852	3.853856
251.7541	296.3718	370.297	226.297	1.636332	0.213871	2.354679	3.860129
249.361	297.3641	372.2823	228.2823	1.630798	0.2124	2.358472	3.866348
243.5313	298.3465	374.2676	230.2676	1.625359	0.210949	2.362233	3.872513
240.0335	299.318	376.2529	232.2529	1.620014	0.209519	2.365961	3.878625
243.5313	300.2867	378.2382	234.2382	1.614759	0.208108	2.369658	3.884685
243.5313	301.2554	380.2235	236.2235	1.609592	0.206716	2.373323	3.890694
243.5313	302.2213	382.2088	238.2088	1.604512	0.205343	2.376958	3.896652
243.5313	303.1843	384.1941	240.1941	1.599515	0.203988	2.380562	3.902561
243.5313	304.1445	386.1794	242.1794	1.594601	0.202652	2.384137	3.908422
237.7016	305.097	388.1647	244.1647	1.589766	0.201333	2.387683	3.914234
237.7016	306.042	390.15	246.15	1.585009	0.200032	2.3912	3.92
234.2951	306.9813	392.1353	248.1353	1.580329	0.198747	2.394689	3.925719
232.0241	307.913	394.1206	250.1206	1.575722	0.19748	2.398149	3.931393
228.6176	308.8372	396.1059	252.1059	1.571189	0.196228	2.401583	3.937021
226.3465	309.754	398.0912	254.0912	1.566726	0.194993	2.40499	3.942606

194.0852 355.4181 507.4425 363.4425 1.396211 0

226.3465	310.6664	400.0765	256.0765	1.562332	0.193773	2.40837	3.948147
226.3465	311.5762	402.0618	258.0618	1.558006	0.192569	2.411724	3.953645
226.3465	312.4834	404.0471	260.0471	1.553746	0.19138	2.415052	3.959102
226.3465	313.388	406.0324	262.0324	1.54955	0.190206	2.418355	3.964516
226.3465	314.2901	408.0177	264.0177	1.545418	0.189046	2.421633	3.96989
226.3465	315.1897	410.003	266.003	1.541347	0.1879	2.424887	3.975224
226.3465	316.0868	411.9883	267.9883	1.537337	0.186769	2.428116	3.980518
226.3465	316.9813	413.9736	269.9736	1.533385	0.185651	2.431321	3.985773
226.3465	317.8734	415.9589	271.9589	1.529492	0.184547	2.434503	3.990989
226.3465	318.7629	417.9442	273.9442	1.525654	0.183456	2.437662	3.996167
226.3465	319.65	419.9295	275.9295	1.521872	0.182378	2.440798	4.001308
226.3465	320.5346	421.9148	277.9148	1.518144	0.181313	2.443912	4.006413
226.3465	321.4168	423.9001	279.9001	1.514469	0.18026	2.447003	4.01148
223.0308	322.2936	425.8854	281.8854	1.510846	0.17922	2.450073	4.016512
223.0308	323.1653	427.8707	283.8707	1.507273	0.178192	2.453121	4.021509
223.0308	324.0345	429.856	285.856	1.50375	0.177176	2.456147	4.026471
220.8203	324.8995	431.8413	287.8413	1.500276	0.176171	2.459153	4.031399
223.0308	325.7621	433.8266	289.8266	1.496849	0.175178	2.462138	4.036292
224.136	326.6252	435.8119	291.8119	1.493469	0.174196	2.465103	4.041152
224.136	327.4868	437.7972	293.7972	1.490134	0.173225	2.468048	4.04598
224.136	328.346	439.7825	295.7825	1.486844	0.172265	2.470972	4.050775
225.2413	329.2038	441.7678	297.7678	1.483598	0.171316	2.473878	4.055537
225.2413	330.0602	443.7531	299.7531	1.480395	0.170378	2.476764	4.060268
223.0308	330.9124	445.7384	301.7384	1.477235	0.169449	2.479631	4.064968
220.8203	331.7587	447.7237	303.7237	1.474115	0.168531	2.482479	4.069637
217.5045	332.5982	449.709	305.709	1.471036	0.167623	2.485308	4.074276
215.294	333.431	451.6943	307.6943	1.467997	0.166725	2.488119	4.078884
215.294	334.2598	453.6796	309.6796	1.464997	0.165837	2.490913	4.083463
215.294	335.0864	455.6649	311.6649	1.462035	0.164958	2.493688	4.088013
215.294	335.9108	457.6502	313.6502	1.45911	0.164088	2.496446	4.092534
215.294	336.733	459.6355	315.6355	1.456222	0.163228	2.499186	4.097026
215.294	337.5531	461.6208	317.6208	1.453371	0.162376	2.501909	4.10149
212.0684	338.3682	463.6061	319.6061	1.450555	0.161534	2.504615	4.105926
209.918	339.1768	465.5914	321.5914	1.447773	0.160701	2.507304	4.110335
207.7676	339.9797	467.5767	323.5767	1.445026	0.159876	2.509977	4.114717
204.542	340.7761	469.562	325.562	1.442312	0.159059	2.512634	4.119072
204.542	341.5679	471.5473	327.5473	1.439631	0.158251	2.515274	4.1234
204.542	342.3577	473.5326	329.5326	1.436983	0.157451	2.517898	4.127702
204.542	343.1454	475.5179	331.5179	1.434366	0.15666	2.520507	4.131979
204.542	343.9311	477.5032	333.5032	1.43178	0.155876	2.5231	4.13623
204.542	344.7148	479.4885	335.4885	1.429225	0.155101	2.525678	4.140455
204.542	345.4487	481.3521	337.3521	1.426854	0.154379	2.528083	4.144399
204.542	346.1807	483.2157	339.2157	1.424509	0.153665	2.530476	4.148321
199.3136	346.907	485.0793	341.0793	1.422189	0.152957	2.532855	4.152222
201.405	347.6292	486.9429	342.9429	1.419895	0.152256	2.535222	4.156101
199.3136	348.3497	488.8065	344.8065	1.417626	0.151562	2.537575	4.15996
197.2223	349.0653	490.6701	346.6701	1.415381	0.150873	2.539916	4.163797
197.2223	349.7777	492.5337	348.5337	1.413159	0.150191	2.542245	4.167614
197.2223	350.4885	494.3973	350.3973	1.410962	0.149515	2.544561	4.171411
199.3136	351.1991	496.2609	352.2609	1.408788	0.148846	2.546864	4.175188
199.3136	351.9096	498.1245	354.1245	1.406637	0.148182	2.549156	4.178944
199.3136	352.6184	499.9881	355.9881	1.404508	0.147524	2.551435	4.182681
194.0852	353.3217	501.8517	357.8517	1.402401	0.146872	2.553703	4.186398
199.3136	354.0234	503.7153	359.7153	1.400317	0.146226	2.555959	4.190097
194.0852	354.7235	505.5789	361.5789	1.398253	0.145586	2.558203	4.193776
194.0852	355.4181	507.4425	363.4425	1.396211	0.144951	2.560436	4.197436

194.0852	356.1111	509.3061	365.3061	1.39419	0.144322	2.562657	4.201077
194.0852	356.8026	511.1697	367.1697	1.392189	0.143698	2.564867	4.2047
189.0018	357.4885	513.0333	369.0333	1.390209	0.14308	2.567066	4.208304
186.9685	358.1675	514.8969	370.8969	1.388248	0.142467	2.569253	4.21189
183.9184	358.8412	516.7605	372.7605	1.386307	0.141859	2.57143	4.215459
183.9184	359.5111	518.6241	374.6241	1.384385	0.141257	2.573596	4.219009
183.9184	360.1795	520.4877	376.4877	1.382483	0.14066	2.575751	4.222542
185.9518	360.8479	522.3513	378.3513	1.380599	0.140067	2.577895	4.226058
183.9184	361.5147	524.2149	380.2149	1.378733	0.13948	2.580029	4.229556
186.9685	362.1809	526.0785	382.0785	1.376886	0.138898	2.582153	4.233037
180.955	362.8432	527.9421	383.9421	1.375057	0.138321	2.584266	4.236501
183.9184	363.5019	529.8057	385.8057	1.373245	0.137748	2.586369	4.239949
183.9184	364.1613	531.6693	387.6693	1.371451	0.13718	2.588461	4.243379
183.9184	364.8193	533.5329	389.5329	1.369674	0.136617	2.590544	4.246794
183.9184	365.4759	535.3965	391.3965	1.367913	0.136059	2.592617	4.250192
183.9184	366.131	537.2601	393.2601	1.36617	0.135505	2.59468	4.253574
183.9184	366.7846	539.1237	395.1237	1.364443	0.134955	2.596733	4.256939
183.9184	367.4368	540.9873	396.9873	1.362732	0.13441	2.598777	4.26029
183.9184	368.0876	542.8509	398.8509	1.361037	0.13387	2.600811	4.263624
180.955	368.7346	544.7145	400.7145	1.359358	0.133334	2.602835	4.266943
183.9184	369.3802	546.5781	402.5781	1.357695	0.132802	2.60485	4.270246
183.9184	370.0267	548.4417	404.4417	1.356046	0.132275	2.606856	4.273534
183.9184	370.6717	550.3053	406.3053	1.354413	0.131751	2.608852	4.276807
183.9184	371.3153	552.1689	408.1689	1.352795	0.131232	2.61084	4.280065
186.9685	371.9597	554.0325	410.0325	1.351192	0.130717	2.612818	4.283309
184.9351	372.6033	555.8961	411.8961	1.349603	0.130206	2.614788	4.286537
183.9184	373.2434	557.7597	413.7597	1.348028	0.129699	2.616748	4.289751
178.9793	373.8777	559.6233	415.6233	1.346468	0.129196	2.6187	4.292951
177.0037	374.5054	561.4869	417.4869	1.344921	0.128697	2.620643	4.296136
174.0403	375.1282	563.3505	419.3505	1.343388	0.128202	2.622577	4.299307
174.0403	375.7475	565.2141	421.2141	1.341869	0.12771	2.624503	4.302464
169.2448	376.3618	567.0777	423.0777	1.340363	0.127222	2.62642	4.305607
174.0403	376.9748	568.9413	424.9413	1.33887	0.126739	2.628329	4.308736
174.0403	377.5902	570.8049	426.8049	1.337391	0.126258	2.630229	4.311851
174.0403	378.2042	572.6685	428.6685	1.335924	0.125782	2.632122	4.314953
174.0403	378.817	574.5321	430.5321	1.33447	0.125309	2.634006	4.318042
174.0403	379.4284	576.3957	432.3957	1.333028	0.124839	2.635881	4.321117
174.0403	380.0386	578.2593	434.2593	1.331599	0.124373	2.637749	4.324179
174.0403	380.6475	580.1229	436.1229	1.330182	0.123911	2.639609	4.327228
171.163	381.2529	581.9865	437.9865	1.328777	0.123452	2.641461	4.330263
171.163	381.8548	583.8501	439.8501	1.327384	0.122997	2.643305	4.333286
169.2448	382.4541	585.7137	441.7137	1.326003	0.122545	2.645141	4.336297
169.2448	383.0506	587.5773	443.5773	1.324633	0.122096	2.646969	4.339294
167.3266	383.6445	589.4409	445.4409	1.323275	0.12165	2.64879	4.342279
167.3266	384.2357	591.3045	447.3045	1.321928	0.121208	2.650603	4.345251
167.3266	384.8258	593.1681	449.1681	1.320593	0.120769	2.652409	4.348211
169.2448	385.416	595.0317	451.0317	1.319268	0.120333	2.654207	4.351159
174.0403	386.01	596.8953	452.8953	1.317954	0.1199	2.655998	4.354095
174.0403	386.6063	598.7589	454.7589	1.316651	0.119471	2.657781	4.357018
167.3266	387.1964	600.6225	456.6225	1.315359	0.119044	2.659557	4.35993
169.2448	387.7817	602.4861	458.4861	1.314077	0.118621	2.661326	4.36283
168.2857	388.3665	604.3497	460.3497	1.312806	0.1182	2.663088	4.365718
164.4492	388.9467	606.2133	462.2133	1.311544	0.117783	2.664842	4.368594
164.4492	389.5229	608.0769	464.0769	1.310293	0.117369	2.66659	4.371459
164.4492	390.098	609.9405	465.9405	1.309052	0.116957	2.66833	4.374312
164.4492	390.6719	611.8041	467.8041	1.307821	0.116548	2.670064	4.377154

164.4492	391.2446	613.6677	469.6677	1.3066	0.116143	2.671791	4.379985
164.4492	391.8161	615.5313	471.5313	1.305388	0.11574	2.673511	4.382804
164.4492	392.3865	617.3949	473.3949	1.304186	0.115339	2.675224	4.385612
164.4492	392.9558	619.2585	475.2585	1.302993	0.114942	2.67693	4.38841
164.4492	393.5239	621.1221	477.1221	1.30181	0.114547	2.67863	4.391196
164.4492	394.0909	622.9857	478.9857	1.300635	0.114156	2.680323	4.393971
164.4492	394.6567	624.8493	480.8493	1.29947	0.113766	2.682009	4.396736
164.4492	395.2214	626.7129	482.7129	1.298314	0.11338	2.683689	4.39949
167.3266	395.7869	628.5765	484.5765	1.297167	0.112996	2.685362	4.402233
166.3674	396.3527	630.4401	486.4401	1.296028	0.112614	2.687029	4.404966
164.4492	396.9153	632.3037	488.3037	1.294898	0.112236	2.68869	4.407689
164.4492	397.4754	634.1673	490.1673	1.293777	0.11186	2.690344	4.410401
161.6577	398.0323	636.0309	492.0309	1.292665	0.111486	2.691992	4.413102
161.6577	398.5661	637.8945	493.8945	1.29156	0.111115	2.693634	4.415794
162.5882	399.1394	639.7581	495.7581	1.290464	0.110746	2.69527	4.418475
164.4492	399.6937	641.6217	497.6217	1.289376	0.11038	2.696899	4.421146
169.2448	400.2754	643.565	499.565	1.288251	0.11	2.698592	4.423921
169.2448	400.8594	645.5083	501.5083	1.287134	0.109624	2.700278	4.426685
169.2448	401.4421	647.4516	503.4516	1.286026	0.10925	2.701958	4.429439
169.2448	402.0237	649.3949	505.3949	1.284926	0.108878	2.703631	4.432182
169.2448	402.604	651.3382	507.3382	1.283834	0.108509	2.705298	4.434914
167.3266	403.1817	653.2815	509.2815	1.282751	0.108142	2.706958	4.437636
167.3266	403.7568	655.2248	511.2248	1.281676	0.107778	2.708612	4.440347
166.3674	404.33	657.1681	513.1681	1.28061	0.107417	2.71026	4.443049
164.4492	404.9	659.1114	515.1114	1.279551	0.107058	2.711901	4.44574
164.4492	405.4675	661.0547	517.0547	1.278501	0.106701	2.713536	4.44842
164.4492	406.0339	662.998	518.998	1.277458	0.106347	2.715166	4.451091
164.4492	406.599	664.9413	520.9413	1.276423	0.105995	2.716789	4.453752
164.4492	407.163	666.8846	522.8846	1.275395	0.105645	2.718406	4.456403
164.4492	407.7259	668.8279	524.8279	1.274376	0.105297	2.720017	4.459044
164.4492	408.2876	670.7712	526.7712	1.273363	0.104952	2.721622	4.461675
164.4492	408.8481	672.7145	528.7145	1.272359	0.10461	2.723221	4.464297
164.4492	409.4075	674.6578	530.6578	1.271361	0.104269	2.724815	4.466909
166.3674	409.9671	676.6011	532.6011	1.270371	0.103931	2.726402	4.469512
166.3674	410.5269	678.5444	534.5444	1.269388	0.103594	2.727984	4.472105
164.4492	411.0841	680.4877	536.4877	1.268412	0.103261	2.72956	4.474688
164.4492	411.639	682.431	538.431	1.267444	0.102929	2.73113	4.477262
164.4492	412.1927	684.3743	540.3743	1.266482	0.102599	2.732695	4.479827
164.4492	412.7452	686.3176	542.3176	1.265527	0.102271	2.734254	4.482383
164.4492	413.2967	688.2609	544.2609	1.264579	0.101946	2.735807	4.48493
164.4492	413.847	690.2042	546.2042	1.263638	0.101623	2.737355	4.487467
164.4492	414.3962	692.1475	548.1475	1.262703	0.101301	2.738897	4.489996
164.4492	414.9444	694.0908	550.0908	1.261775	0.100982	2.740434	4.492515
164.4492	415.4913	696.0341	552.0341	1.260853	0.100665	2.741966	4.495026
164.4492	416.0372	697.9774	553.9774	1.259938	0.100349	2.743492	4.497528
164.4492	416.582	699.9207	555.9207	1.25903	0.100036	2.745013	4.500021
164.4492	417.1257	701.864	557.864	1.258127	0.099725	2.746528	4.502505
164.4492	417.6683	703.8073	559.8073	1.257231	0.099415	2.748039	4.504981
164.4492	418.2098	705.7506	561.7506	1.256342	0.099108	2.749544	4.507448
164.4492	418.7502	707.6939	563.6939	1.255458	0.098802	2.751043	4.509907
164.4492	419.2895	709.6372	565.6372	1.25458	0.098498	2.752538	4.512357
164.4492	419.8278	711.5805	567.5805	1.253709	0.098197	2.754027	4.514799
164.4492	420.3649	713.5238	569.5238	1.252843	0.097897	2.755512	4.517233
164.4492	420.901	715.4671	571.4671	1.251983	0.097598	2.756991	4.519658
164.4492	421.436	717.4104	573.4104	1.251129	0.097302	2.758466	4.522075
164.4492	421.97	719.3537	575.3537	1.250281	0.097008	2.759935	4.524487

164.4492	422.5028	721.297	577.297	1.249438	0.096715	2.761399	4.526884
164.4492	423.0347	723.2403	579.2403	1.248601	0.096424	2.762859	4.529277
164.4492	423.5654	725.1836	581.1836	1.24777	0.096135	2.764313	4.531661
164.4492	424.0951	727.1269	583.1269	1.246945	0.095847	2.765763	4.534038
164.4492	424.6237	729.0702	585.0702	1.246124	0.095561	2.767208	4.536407
164.4492	425.1513	731.0135	587.0135	1.24531	0.095277	2.768648	4.538767
164.4492	425.6779	732.9568	588.9568	1.2445	0.094995	2.770083	4.54112
164.4492	426.2034	734.9001	590.9001	1.243696	0.094714	2.771514	4.543466
164.4492	426.7278	736.8434	592.8434	1.242897	0.094435	2.77294	4.545803
164.4492	427.2513	738.7867	594.7867	1.242104	0.094158	2.774361	4.548133
164.4492	427.7736	740.73	596.73	1.241315	0.093882	2.775778	4.550456
164.4492	428.295	742.6733	598.6733	1.240532	0.093608	2.77719	4.55277
164.4492	428.8153	744.6166	600.6166	1.239754	0.093335	2.778597	4.555078
164.4492	429.3346	746.5599	602.5599	1.23898	0.093064	2.78	4.557377
164.4492	429.8529	748.5032	604.5032	1.238212	0.092795	2.781399	4.55967
164.4492	430.3701	750.4465	606.4465	1.237449	0.092527	2.782792	4.561955
164.4492	430.8864	752.3898	608.3898	1.23669	0.092261	2.784182	4.564233
164.4492	431.4016	754.3331	610.3331	1.235937	0.091996	2.785567	4.566503
164.4492	431.9158	756.2764	612.2764	1.235188	0.091733	2.786948	4.568766
164.4492	432.429	758.2197	614.2197	1.234444	0.091471	2.788324	4.571023
162.5882	432.9399	760.163	616.163	1.233704	0.091211	2.789696	4.573272
162.5882	433.4486	762.1063	618.1063	1.23297	0.090952	2.791063	4.575513
159.7966	433.9544	764.0496	620.0496	1.232239	0.090695	2.792426	4.577748
162.5882	434.4592	765.9929	621.9929	1.231514	0.090439	2.793785	4.579976
164.4492	434.9661	767.9362	623.9362	1.230793	0.090185	2.79514	4.582197
164.4492	435.4734	769.8795	625.8795	1.230076	0.089932	2.796491	4.584411
164.4492	435.9796	771.8228	627.8228	1.229364	0.089681	2.797837	4.586618
164.4492	436.4849	773.7661	629.7661	1.228656	0.08943	2.799179	4.588818
164.4492	436.9892	775.7094	631.7094	1.227953	0.089182	2.800517	4.591012
159.7966	437.4894	777.6527	633.6527	1.227254	0.088934	2.801851	4.593199
155.1439	437.9825	779.596	635.596	1.226559	0.088688	2.803181	4.595379
155.1439	438.4717	781.5393	637.5393	1.225868	0.088444	2.804507	4.597552
155.1439	438.9599	783.4826	639.4826	1.225182	0.088201	2.805829	4.599719
155.1439	439.4472	785.4259	641.4259	1.2245	0.087959	2.807146	4.601879
155.1439	439.9336	787.3692	643.3692	1.223822	0.087718	2.80846	4.604033
155.1439	440.4191	789.3125	645.3125	1.223148	0.087479	2.80977	4.60618
159.7966	440.9066	791.2558	647.2558	1.222478	0.087241	2.811076	4.608321
159.7966	441.3962	793.1991	649.1991	1.221812	0.087004	2.812378	4.610456
159.7966	441.8849	795.1424	651.1424	1.22115	0.086769	2.813676	4.612584
159.7966	442.3727	797.0857	653.0857	1.220492	0.086535	2.81497	4.614705
155.1439	442.8565	799.029	655.029	1.219838	0.086302	2.816261	4.616821
155.1439	443.3365	800.9723	656.9723	1.219187	0.08607	2.817547	4.61893
155.1439	443.8156	802.9156	658.9156	1.218541	0.08584	2.81883	4.621032
155.1439	444.2938	804.8589	660.8589	1.217898	0.085611	2.820109	4.623129
155.1439	444.7711	806.8022	662.8022	1.217259	0.085383	2.821384	4.62522
155.1439	445.2475	808.7455	664.7455	1.216624	0.085156	2.822655	4.627304
155.1439	445.723	810.6888	666.6888	1.215993	0.084931	2.823923	4.629382
157.9355	446.1994	812.6321	668.6321	1.215365	0.084707	2.825187	4.631454
157.9355	446.6766	814.5754	670.5754	1.214741	0.084484	2.826448	4.633521
159.7966	447.1542	816.5187	672.5187	1.21412	0.084262	2.827704	4.635581
159.7966	447.632	818.462	674.462	1.213504	0.084041	2.828957	4.637635
159.7966	448.1089	820.4053	676.4053	1.21289	0.083821	2.830207	4.639684
155.1439	448.582	822.3486	678.3486	1.21228	0.083603	2.831453	4.641726
155.1439	449.0513	824.2919	680.2919	1.211674	0.083386	2.832695	4.643763
155.1439	449.5198	826.2352	682.2352	1.211071	0.08317	2.833934	4.645794
155.1439	449.9874	828.1785	684.1785	1.210471	0.082955	2.835169	4.647819

155.1439	450.4123	829.9475	685.9475	1.209929	0.08276	2.836291	4.649657
155.1439	450.8365	831.7165	687.7165	1.209389	0.082566	2.837409	4.651491
150.6335	451.2572	833.4855	689.4855	1.208851	0.082373	2.838525	4.65332
150.6335	451.6746	835.2545	691.2545	1.208317	0.082181	2.839638	4.655144
155.1439	452.094	837.0235	693.0235	1.207785	0.08199	2.840748	4.656964
155.1439	452.5154	838.7925	694.7925	1.207256	0.081799	2.841855	4.658779
155.1439	452.936	840.5615	696.5615	1.20673	0.08161	2.842959	4.660589
155.1439	453.356	842.3305	698.3305	1.206206	0.081422	2.844061	4.662395
150.6335	453.7726	844.0995	700.0995	1.205685	0.081234	2.84516	4.664196
150.6335	454.1858	845.8685	701.8685	1.205167	0.081047	2.846256	4.665993
146.123	454.5958	847.6375	703.6375	1.204651	0.080861	2.847349	4.667785
150.6335	455.005	849.4065	705.4065	1.204138	0.080676	2.848439	4.669573
150.6335	455.4162	851.1755	707.1755	1.203627	0.080492	2.849527	4.671356
150.6335	455.8268	852.9445	708.9445	1.203119	0.080309	2.850612	4.673135
155.1439	456.2393	854.7135	710.7135	1.202613	0.080126	2.851695	4.674909
155.1439	456.6537	856.4825	712.4825	1.20211	0.079944	2.852774	4.676679
155.1439	457.0675	858.2515	714.2515	1.20161	0.079763	2.853851	4.678445
155.1439	457.4806	860.0205	716.0205	1.201112	0.079583	2.854925	4.680206
150.6335	457.8904	861.7895	717.7895	1.200616	0.079404	2.855997	4.681962
150.6335	458.2968	863.5585	719.5585	1.200123	0.079226	2.857066	4.683715
146.123	458.7001	865.3275	721.3275	1.199632	0.079048	2.858132	4.685463
146.123	459.1002	867.0965	723.0965	1.199144	0.078871	2.859196	4.687207
146.123	459.4996	868.8655	724.8655	1.198658	0.078695	2.860257	4.688947
146.123	459.8983	870.6345	726.6345	1.198174	0.07852	2.861316	4.690682
146.123	460.2965	872.4035	728.4035	1.197693	0.078345	2.862372	4.692413
146.123	460.6939	874.1725	730.1725	1.197214	0.078172	2.863425	4.69414
150.6335	461.0933	875.9415	731.9415	1.196737	0.077999	2.864476	4.695863
150.6335	461.4946	877.7105	733.7105	1.196263	0.077827	2.865525	4.697582
150.6335	461.8952	879.4795	735.4795	1.195791	0.077655	2.866571	4.699296
150.6335	462.2951	881.2485	737.2485	1.195321	0.077484	2.867614	4.701006
146.123	462.6919	883.0175	739.0175	1.194853	0.077315	2.868655	4.702713
146.123	463.0856	884.7865	740.7865	1.194388	0.077145	2.869693	4.704415
146.123	463.4786	886.5555	742.5555	1.193925	0.076977	2.870729	4.706113
146.123	463.871	888.3245	744.3245	1.193464	0.076809	2.871762	4.707807
146.123	464.2628	890.0935	746.0935	1.193005	0.076642	2.872793	4.709497
146.123	464.6539	891.8625	747.8625	1.192549	0.076476	2.873822	4.711183
146.123	465.0445	893.6315	749.6315	1.192094	0.076311	2.874848	4.712865
146.123	465.4344	895.4005	751.4005	1.191642	0.076146	2.875871	4.714543
146.123	465.8237	897.1695	753.1695	1.191192	0.075982	2.876893	4.716218
150.6335	466.2148	898.9385	754.9385	1.190744	0.075818	2.877912	4.717888
150.6335	466.6078	900.7075	756.7075	1.190298	0.075656	2.878928	4.719554
150.6335	467.0001	902.4765	758.4765	1.189854	0.075494	2.879942	4.721217
150.6335	467.3919	904.2455	760.2455	1.189412	0.075332	2.880954	4.722875
150.6335	467.783	906.0145	762.0145	1.188973	0.075172	2.881963	4.72453
150.6335	468.1735	907.7835	763.7835	1.188535	0.075012	2.88297	4.726181
150.6335	468.5633	909.5525	765.5525	1.188099	0.074853	2.883975	4.727828
146.123	468.9501	911.3215	767.3215	1.187666	0.074694	2.884977	4.729471
146.123	469.3338	913.0905	769.0905	1.187234	0.074536	2.885977	4.731111
146.123	469.7169	914.8595	770.8595	1.186804	0.074379	2.886975	4.732746
146.123	470.0995	916.6285	772.6285	1.186377	0.074223	2.887971	4.734378
146.123	470.4814	918.3975	774.3975	1.185951	0.074067	2.888964	4.736006
146.123	470.8627	920.1665	776.1665	1.185527	0.073912	2.889955	4.737631
146.123	471.2434	921.9355	777.9355	1.185105	0.073757	2.890944	4.739252
146.123	471.6235	923.7045	779.7045	1.184685	0.073603	2.89193	4.740869
150.6335	472.0054	925.4735	781.4735	1.184267	0.07345	2.892914	4.742482
150.6335	472.3892	927.2425	783.2425	1.183851	0.073297	2.893896	4.744092

146.123	472.7699	929.0115	785.0115	1.183437	0.073145	2.894876	4.745698
146.123	473.1476	930.7805	786.7805	1.183024	0.072994	2.895854	4.747301
146.123	473.5248	932.5495	788.5495	1.182614	0.072843	2.896829	4.7489
146.123	473.9013	934.3185	790.3185	1.182205	0.072693	2.897802	4.750495
146.123	474.2773	936.0875	792.0875	1.181798	0.072543	2.898773	4.752087
146.123	474.6526	937.8565	793.8565	1.181393	0.072394	2.899742	4.753675
146.123	475.0274	939.6255	795.6255	1.18099	0.072246	2.900709	4.75526
146.123	475.4016	941.3945	797.3945	1.180588	0.072098	2.901673	4.756841
146.123	475.7752	943.1635	799.1635	1.180188	0.071951	2.902636	4.758419
146.123	476.1483	944.9325	800.9325	1.17979	0.071805	2.903596	4.759993
146.123	476.5207	946.7015	802.7015	1.179394	0.071659	2.904554	4.761564
146.123	476.8926	948.4705	804.4705	1.179	0.071514	2.90551	4.763131
146.123	477.2639	950.2395	806.2395	1.178607	0.071369	2.906464	4.764695
146.123	477.6346	952.0085	808.0085	1.178216	0.071225	2.907416	4.766256
146.123	478.0048	953.7775	809.7775	1.177827	0.071081	2.908366	4.767813
146.123	478.3744	955.5465	811.5465	1.177439	0.070938	2.909313	4.769366
146.123	478.7434	957.3155	813.3155	1.177053	0.070796	2.910259	4.770916
146.123	479.1118	959.0845	815.0845	1.176669	0.070654	2.911203	4.772463
146.123	479.4797	960.8535	816.8535	1.176286	0.070513	2.912144	4.774007
146.123	479.847	962.6225	818.6225	1.175905	0.070372	2.913084	4.775547
146.123	480.2137	964.3915	820.3915	1.175526	0.070232	2.914021	4.777084
146.123	480.5799	966.1605	822.1605	1.175148	0.070093	2.914957	4.778617
146.123	480.9455	967.9295	823.9295	1.174772	0.069954	2.91589	4.780148
146.123	481.3105	969.6985	825.6985	1.174398	0.069815	2.916821	4.781675
146.123	481.675	971.4675	827.4675	1.174025	0.069677	2.917751	4.783198
146.123	482.0389	973.2365	829.2365	1.173654	0.06954	2.918678	4.784719
146.123	482.4023	975.0055	831.0055	1.173284	0.069403	2.919604	4.786236
141.7543	482.7627	976.7745	832.7745	1.172916	0.069267	2.920527	4.78775
141.7543	483.1201	978.5435	834.5435	1.172549	0.069131	2.921449	4.789261
141.7543	483.477	980.3125	836.3125	1.172184	0.068996	2.922369	4.790768
141.7543	483.8334	982.0815	838.0815	1.171821	0.068861	2.923286	4.792273
141.7543	484.1892	983.8505	839.8505	1.171459	0.068727	2.924202	4.793774
137.3855	484.5422	985.6195	841.6195	1.171099	0.068593	2.925116	4.795272
137.3855	484.8923	987.3885	843.3885	1.17074	0.06846	2.926028	4.796767
137.3855	485.2419	989.1575	845.1575	1.170382	0.068328	2.926938	4.798258

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