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BODCAU IN SITU COMBUSTION PROJECT—IGNITION

Topical Report of May 1977

MASTER

Date Published—February 1980

**Work Performed for the Department of Energy
Under Contract EY-76-C-03-1189**

**Cities Service Company
Jackson, Mississippi**

U. S. DEPARTMENT OF ENERGY

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BODCAU IN SITU COMBUSTION PROJECT—IGNITION

Topical Report
May 1977

by

Conrad Joseph

John W. Haggard
Principal Investigator
Cities Service Company
Jackson, Mississippi

Alan J. Leighton
Technical Project Officer
Fossil Energy Division
San Francisco Operations Office
Oakland, California

Date Published—February 1980

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SUMMARY

The five patterns of the Bodcau In Situ Combustion Project were successfully ignited between August 7 and September 24, 1976. Electric heaters were used to ignite the formation. Cities Service Company personnel operated the equipment and monitored the process to ignition confirmation. Operational problems encountered were handled in an expeditious manner enabling operations to continue without appreciable delays.

INTRODUCTION

The Bodcau In Situ Combustion Project consists of five inverted nine-spot patterns located on the Cities Service Bodcau Fee lease in the Bellevue Field, Section 11-T19N-R11W, Bossier Parish, Louisiana.¹ The project makes use of the forward combustion process, which requires formation ignition at a central injection well within each pattern (Figure 1). All five injectors were successfully ignited between August 7 and September 24, 1976. This report will describe the ignition process used by Cities Service Company. The equipment used, general procedure and individual well specifics will be discussed in detail. Figures and field data are provided for reference.

DISCUSSION

Equipment:

The electric ignition procedure was chosen because of the relative simplicity and safety, compared with gas burner ignitions used in the past. The repeatability of the process is much higher. Electricity was available, and there is no hazard from gas or other explosive compounds.

¹Little, Tracy P., *Bodcau In Situ Combustion Project Pre-Contract Work & Plan for Project Development*, Cities Service Oil Company Topical Report.

The five patterns were ignited using a 30-kw, 440-volt, three-phase electric heater having 86 inches of heating length for each of six elements delivering 30 watts per square inch of surface area. Power to the heater was supplied through a three-conductor armored cable of 0.800-inch outside diameter. This cable was also used to position the heater as required (Figure 2).

Control and monitoring equipment was housed in a trailer, enabling Company personnel to watch all aspects of the ignition process closely. Panel-mounted charts recorded air injection rates and wellhead pressure continuously. A thermostat connected to a thermocouple inside a one-inch thermowell within the seven-inch casing of the well was used to control heater temperatures. Manipulation of the heater temperature and air rate allowed control of injected air temperatures. Temperature profiles of the formation interval using the downhole thermocouple were periodically recorded.

Confirmation of formation ignition was by analysis of produced gases at offset production wells. The Orsat method for analysis of oxygen, carbon dioxide and carbon monoxide was the primary consideration. Fyrite method of analysis for oxygen and carbon dioxide was done at regular four-hour intervals and was found to compare well with the Orsat method which was taken only once or twice each day. The injection well temperature profiles were also used as backup for confirming ignition though it was not the primary function.

General Procedure:

Before igniting, the injection wells were cleaned internally by circulating air to remove any water or oil inside the well. A string of one-inch diameter pipe was run inside the casing to a depth not less than 10 feet below the base of the perforated interval. A thermocouple was run inside the one-inch pipe for monitoring downhole temperatures.

Air injection was begun at a rate of 200 MCFPD and maintained until offset producing wells began to vent the injected air. Rates near 200 MCFPD would be required during the ignition procedure in order to develop high enough temperatures for ignition, so this rate was used during pre-ignition injection. Pressure falloff tests were conducted to determine average pattern permeability. (Falloff tests will be discussed in a future topical report on Pressure Testing.) Background gas analyses at offset producers were gathered to establish a base line prior to any heating.

Ignition equipment was then moved to the well. The heater was lowered through a lubricator into the well and positioned above the perforated interval. The heater was turned on and air was injected past the heater at 200 MCFPD and heated to 300°F for preheating the formation.

After the pay interval had been heated to 300°F and maintained at that temperature for several hours, the thermostat setting was increased to the maximum safe operating temperature of 1000°F, and the air was heated to 600°F and held as nearly constant as possible throughout the remainder of the ignition operation. Temperature profiles were recorded periodically and

gas analyses at offset producers were taken regularly to monitor the process.

Ignition was indicated by drastic reductions in oxygen content and increases in carbon dioxide content in the produced gases. Generally, Orsat oxygen levels of 1.0% or less were considered confirmation of efficient burning conditions.

Ignition of Well 12-1:

Ignition equipment was rigged up at Well 12-1 on August 7, 1976. Background Orsat gas analyses at surrounding producers were taken, as follows:

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
2-4	7.4	5.4	0.0
12-2	3.8	10.6	0.0
12-3	5.2	9.6	0.1
12-4	6.0	7.2	0.0

Wells 2-4 and 12-2 were chosen as the key wells for confirming ignition since Wells 12-3 and 12-4 would probably continue to show some oxygen even after ignition of pattern 12 due to pre-ignition air in pattern 13.

The heater was positioned at 406 feet, four feet above the perforations (410 to 425 feet) and was turned on at 4:30 p.m. At 5:00 p.m. a dramatic increase in temperature down hole was recorded near the heater. The heater was switched off, but high temperatures persisted and the heater was raised to prevent damage. Apparently some oil had entered the well during the rig-up time, and this had ignited inside

the pipe (Figure 3). Air injection was stopped for two hours to allow the burning oil to either starve or smother itself. At 7:30 p.m. injection was restarted at 165 MCFPD and combustion within the well resumed. The temperatures were not thought to be high enough at that air rate to severely damage the casing and thermowell, so the oil was allowed to burn itself off. By 8:00 a.m. the oil had burned off to the base of the perforations (Figure 3), and the heater was removed from the well to inspect for damage. No evidence of damage was found and the heater was rerun to 350 feet and turned on.

Since the casing and surrounding formation had been heated by the combustion within the well, no significant heat losses were noticed through the 60 feet separating the heater and the perforations (Figure 4). Heating was continued until gas analyses at Wells 2-4 and 12-2 confirmed ignition. Confirming Orsat analyses on these wells were taken on August 9 at 7:00 a.m. (Figure 5).

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
2-4	9.2	0.4	0.8
12-2	8.5	0.9	0.8

Heating was continued for one day until on August 10, cumulative heat input had reached 3.6 million BTU (Table 1).

Ignition of Well 13-1:

Ignition equipment was moved from Well 12-1 to 13-1 on August 11, 1976. Perforations in this well are 410 to 426 feet. The heater was initially set at 350 feet as a safety measure, in case any oil remained in the casing of this well

as it had at 12-1. This proved to be unnecessary, but the position was all right for preheating. Background gas analyses were taken at three wells on August 11.

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
12-3	9.0	4.0	1.6
12-4	8.8	4.0	1.0
13-6	11.2	2.8	0.2

Preheating to 300°F was done from a depth of 350 feet, but on August 12 at 12:30 p.m., the heater was lowered to 375 feet for ignition.

The heater temperature was raised to 1000°F and generated 700°F air at 200 MCFD (Figure 6). Heating was continued and on August 13 confirming Orsats were obtained (Figure 7).

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
12-3	11.2	0.2	0.8
12-4	10.6	0.3	0.7
13-6	10.8	1.4	1.2

Heating was continued until 7:00 a.m. August 14 with 3.5 million BTU's having been delivered (Table 2).

Ignition of Well 14-1:

On August 16 equipment was set up at Well 14-1. Background Orsat analyses were obtained.

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
13-3	6.6	2.4	0.1
13-5	3.6	5.8	0.2

Once again, west side producers in the pattern were selected for monitoring since east side wells would be picking up oxygen from pattern 15.

At 9:00 a.m. on August 17 the heater was lowered to 360 feet for preheating the formation. By 5:00 p.m. the interval had been sufficiently preheated. The heater was lowered to 390 feet (perforations from 412 to 425 feet) and the thermostat was set to 1000°F. Temperatures of 800°F were observed at the perforations within 14 hours (Figure 8).

At noon on August 18 the compressor shut down for 20 minutes. During this time, because of a slight surface leak, hot air moved up the hole and melted the insulation in the armored cable, shorting out the heater. Temperature profiles of the formation continued to indicate combustion (Figure 8) and gas analyses had improved, indicating ignition (Figure 9).

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
13-3	6.8	0.1	0.4
13-5	12.6	0.2	0.6

More problems were encountered when the heater was pulled up the hole to remove and inspect it for damages. As the heater was raised, the cable and heater coiled around the one-inch thermowell and became wedged between the casing and thermowell just below the wellhead connections. Rotating the wellhead and repeated jarring could not free the stuck heater. In order to free the heater, the one-inch pipe was cut from the surface and allowed to drop. This enabled the heater to be pulled up into the lubricator. The procedure was to bleed off pressure at the well, pump water down hole to kill the well and cut the thermowell while killing. A plate was welded over the hole left where the one-inch was cut.

Gas analyses were watched closely afterwards and continued to indicate ignition. Cumulative heat input was 1.3 million BTU (Table 3).

Ignition of Well 15-1:

The heater and cable were inspected and 40 feet of cable was cut off, which had been subjected to elevated temperatures. The connection from cable to heater was respliced and the heater was checked thoroughly before moving to Well 15-1 on September 1.

Background Orsats were obtained.

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
14-3	8.0	0.4	0.4
14-4	8.0	1.0	0.0
14-5	7.0	1.0	0.0

The heater was set at 385 feet (perforations from 410 to 423 feet), and preheating was begun at 6:00 p.m. At 11:00 a.m. on September 2 the compressor shut down once again for about 10 minutes. The temperature at the top of the heater was watched, and it was observed to rise quite rapidly, indicating some back flow of air possibly through a leaking valve or poor seal in the lubricator. The heater was raised 35 feet in an effort to outrun the escaping hot gases but the heat still reached the cable and damaged the insulation on the connections inside the heater.

The heater was pulled from the well at 3:00 p.m. on September 2. Temperature profiles taken after the heater had

been off for several hours showed surprisingly warm temperatures remaining in the perforations (Figure 10).

Orsat gas analyses taken on September 2 indicated that combustion was occurring in the formation (Figure 11).

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
14-3	10.0	0.0	0.8
14-4	8.8	0.6	0.2
14-5	7.0	0.5	0.0

A short test was conducted on September 3 to confirm the ignition. The air injection rate was cut from 180 MCFPD to 90 MCFPD and the temperature at 410 feet (corresponding to the top perforation in the well) was monitored. The temperature was seen to rise from 400°F to 483°F in 40 minutes, indicating greater heat feedback from the formation at the reduced air rate (Figure 12). Since the combustion zone would be at a temperature of about 1000°F, it was felt that at low air injection rates some of the heat from this combustion might be seen in the wellbore. Routine temperature profiles were also continued for several days, hoping to see more elevated temperatures. On September 7 temperatures ranging from 600°F to 845°F were seen at the base of the zone (Figure 13).

Gas analyses at two other wells also confirmed the ignition.

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
15-3	11.4	1.4	0.0
15-4	12.5	0.3	0.0

Cumulative heat input to Well 15-1 was only 0.6 million BTU (Table 4).

Ignition of Well 16-1:

Extensive damage to the heater was sustained at Well 15-1. Four of the six elements had deformed after the supports which held them straight snapped off. This was corrected by banding the elements into a small enough bundle to fit the lubricator dimensions. There was no apparent internal damage to the elements; however, all three couplings for attaching the heater to the cable leads had to be cut off and remade in a machine shop. After reassembling the heater, it was tested above ground before lowering it into Well 16-1.

Background gas analyses were obtained on the following wells on September 21 and 22:

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
15-3	12.2	0.0	0.0
15-4	12.4	0.8	0.0
15-5	8.0	2.4	0.0
16-2	7.4	5.0	0.2
16-3	7.0	4.2	0.0
16-4	6.2	7.8	0.0
16-5	10.0	1.2	0.2
16-6	7.6	3.4	0.0

Wells 16-2, 16-3 and 16-6 were selected as key wells for confirming ignition because of the high oxygen content and higher flow rates than other pattern producers. The heater was lowered to 386 feet (perforations from 411 to 421 feet) and heating began at 6:00 a.m. on September 22. The formation was slowly heated until at 6:00 a.m. on September 23 the air temperatures at the top perforation had reached 600°F (Figure 14).

Gas analyses at the surrounding producers showed good response, and on September 24, confirming Orsats were obtained (Figure 15).

<u>Well</u>	<u>%CO₂</u>	<u>%O₂</u>	<u>%CO</u>
16-2	10.2	0.4	1.2
16-3	9.6	0.2	0.8
16-6	13.0	0.0	0.4

Cumulative heat input to pattern 16 was 3.95 million BTU (Table 5).

The heater was turned off on September 24, but when it was raised to 300 feet, further upward movement was blocked. The heater could be lowered but not raised, so it remained in the well for one month until the well could be blown down for pulling the thermowell safely.

On November 2 the well was blown down, the wellhead backed off, and the one-inch was pulled. The heater was pulled up into the lubricator and air was started back in the well. The well was off for approximately four hours with no harm to the combustion front, as evidenced by continued gas analyses.

FIGURE 1

FIGURE 2
IGNITION WELL EQUIPMENT SCHEMATIC

FIGURE 3
WELL #12-1
DOWNHOLE SCHEMATIC AND
TEMPERATURE PROFILES

FIGURE 4
WELL # 12-1
TEMPERATURE PROFILES

HEATER

DEPTH-FT.

PERFORATIONS

○—PROFILE AT 12:00 PM, 8/8/76
●—PROFILE AT 9:00 AM, 8/9/76

FIGURE 5
PATTERN 12 IGNITION
ORSAT GAS ANALYSES

○ - OXYGEN
△ - CARBON DIOXIDE
□ - CARBON MONOXIDE

TIME ZERO = 8:00 AM, 8/7/76

FIGURE 6
WELL #13-1
TEMPERATURE PROFILES

FIGURE 7
**PATTERN 13 IGNITION
ORSAT GAS ANALYSES**

○ - OXYGEN
△ - CARBON DIOXIDE
□ - CARBON MONOXIDE

TIME ZERO = 9:00 AM, 8/11/76

FIGURE 8
WELL #14-1
TEMPERATURE PROFILES

- - PROFILE AT 5:30 PM, 8/17/76
- - PROFILE AT 7:00 AM, 8/18/76
- - PROFILE AT 6:00 PM, 8/18/76
WITH HEATER OFF SINCE
12:00 NOON

FIGURE 9
**PATTERN 14 IGNITION
ORSAT GAS ANALYSES**

○ - OXYGEN
△ - CARBON DIOXIDE
□ - CARBON MONOXIDE

TIME ZERO = 3:00 PM, 8/16/76

FIGURE 10
WELL #15-1
TEMPERATURE PROFILES

FIGURE II
PATTERN 15 IGNITION
ORSAT GAS ANALYSES

○ - OXYGEN
 △ - CARBON DIOXIDE
 □ - CARBON MONOXIDE

TIME ZERO = 1:00 PM, 9/1/76

FIGURE 12
WELL # 15 - I
TEST FOR INDICATION
OF BURNING

AIR RATE = 94 MCFD
PRESSURE = 120 PSIG
DEPTH = 410 FEET

FIGURE 13
WELL #15-1
TEMPERATURE PROFILES

PROFILE AT 9:30 AM, 9/7/76

FIGURE 14
WELL #16-1
TEMPERATURE PROFILES

HEATER
DEPTH - FT.
PERFORATIONS

- - PROFILE AT 8:30 PM, 9/22/76
- - PROFILE AT 8:00 PM, 9/23/76
- ◇ - PROFILE AT 12:00 PM, 9/24/76

TEMPERATURE - °F

FIGURE 15
PATTERN 16 IGNITION
ORSAT GAS ANALYSES

○ - OXYGEN
△ - CARBON DIOXIDE
□ - CARBON MONOXIDE

TIME ZERO = 9:00 AM, 9/21/76

WELL # 12-1 IGNITION DATA

TABLE 1

DATE	TIME	DEPTH	METER RUN READINGS				Q MCFD	T _M @ 408'	H BTU/hr	ΣH	WELL #21		WELL #12-2		WELL #12-3		WELL #12-4		WELL #2-4	
			T _g	P _g	Δ _h	P _{wh}					O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂
8-8	1130	351	94°F	212 psi	20" H ₂ O	90 psi	178	665°F	81.36	81.36										
	1300	351	100	210	21	102	180	665	81.36	162.72	3.0	10.5	3.5	6.0	4.0	7.5	3.5	6.0	3.0	8.0
	1400	351	100	210	21	102	180	665	81.36	244.08										
	1500	351	100	210	21	103	180	622	75.17	319.25										
	1600	351	100	210	27	108	205	622	85.61	404.86	0.5	9.0	1.5	7.0	4.0	7.2	3.5	6.5	1.0	8.5
	1700	351	93	210	28	109	210	622	85.61	490.47										
	1800	351	92	210	28	110	210	633	90.89	581.36	0.7	9.5	1.0	7.7	3.5	7.2	2.7	6.5	0.7	7.8
	1900	351	86	210	28	112	210	633	91.90	673.26										
	2000	351	82	210	28	112	210	633	92.57	765.83										
	2100	351	79	210	28	113	210	932	143.30	909.13										
	2150	Decreased Air Rate to Cool Off inside pipe.																		
	2200	351	79	210	9	102	120	932	81.89	991.02	1.0	9.8	0.5	7.7	2.2	7.7	2.5	7.0	0.3	7.7
	2300	351	79	210	8	98	118	930	80.33	1071.35										
	2400	351	78	210	8	95	118	880	75.61	1146.96										
8-9	0100	351	76	210	8	95	118	880	75.90	1222.86										
	0200	351	74	210	8	95	118	880	76.09	1298.95	0.5	10.5	0.5	7.5	2.0	8.8	2.2	7.5	0.2	8.2
	0300	351	72	210	8	93	118	775	66.36	1365.31										
	0400	351	70	210	8	90	118	775	66.55	1431.86										
	0430	Increased Air Rate - Heater Off 44% of Time & Heating up.																		
	0500	351	70	210	13	93	140	775	78.96	1510.82										
	0600	351	70	209	13	96	141	687	69.60	1580.42										
	0700	351	70	209	13	94	141	687	69.60	1650.02	0.3	10.8	0.8	7.5	1.2	8.0	2.0	7.5	0.1	8.4
	0800	351	73	209	13	93	141	687	69.60	1719.62										
	0900	351	82	208	20	103	179	645	79.90	1799.52										
	1000	351	87	208	20	105	179	645	79.90	1879.42										
	1100	351	90	208	20	105	180	645	79.90	1959.32										
	1200	351	95	210	20	105	180	630	77.04	2036.36										
	1300	351	96	210	20	106	180	630	76.90	2113.26	1.6	11.0	1.5	9.0	1.6	9.0	1.5	8.0	0.6	7.0
	1400	351	100	200	21	106	177	630	75.05	2188.31										
	1500	351	98	200	23	103	185	638	79.92	2268.23										
	1600	351	98	210	24	105	193	638	83.38	2351.61										
	1700	351	98	212	24	107	195	636	83.93	2435.54										
	1800	351	98	212	24	107	195	638	84.24	2519.78	2.5	11.5	1.0	9.0	1.0	10.0	2.5	8.5	3.5	12.5
	1900	351	90	216	19	105	173	638	75.84	2595.62										
	2000	351	82	218	21	105	181	638	80.51	2676.13										
	2100	351	80	219	21	107	181	631	79.78	2755.91										
	2200	351	76	220	22	107	184	631	81.70	2837.61	0.7	10.5	0.6	8.6	1.0	9.5	1.0	9.0	0.6	12.6
	2300	351	74	220	22	107	184	631	81.99	2919.60										
	2400	351	72	220	22	108	184	633	82.87	3002.47										
8-10	0100	351	70	220	22	108	184	633	82.87	3085.34										
	0200	351	70	220	22	108	184	633	82.87	3168.21	0.6	10.6	0.5	9.5	2.0	9.7	1.7	8.8	0.5	14.5
	0300	351	70	222	22	108	188	635	84.98	3253.19										
	0400	351	70	222	22	108	188	635	84.98	3338.17										
	0500	351	72	222	22	108	188	635	84.68	3422.85										
	0600	351	72	222	22	108	188	630	83.92	3506.77										
	0700	351	72	222	22	108	188	630	83.92	3590.69										

WELL * 13-1 IGNITION DATA

TABLE 2

DATE	TIME	DEPTH	METER RUN READINGS				Q MCFD	T _h @ 410'	H BTU/hr	ΣH	WELL * O ₂ CO ₂		WELL * O ₂ CO ₂		WELL *12-3 O ₂ CO ₂		WELL *12-4 O ₂ CO ₂		WELL *13-6 O ₂ CO ₂	
			T _a	P _s	Δ _h	P _{WH}														
8-11	0800	350	80°F	210 psi	17" H ₂ O	173 psi	160													
	0900	350	80	200	30	186	210	95°F	2.5	2.5										
	1000	350	85	190	10	165	120	95	1.4	3.9										
	1100	350	95	160	20	165	165	97	0.3	4.2										
	1200	Compressor Down - High Bearing Temperature - Off for 40 minutes																		
	1300	350	98	175	20	164	162	102	0.4	4.6										
	1400	350	100	165	16	162	140	110	0.8	5.4					2.0	10.6	3.5	9.2	2.5	11.0
	1500	350	97	164	17	165	147	123	3.0	8.4										
	1600	350	97	167	23	170	170	128	4.2	12.6										
	1700	350	97	195	24	175	187	146	7.3	19.9										
	1730	Increased Thermostat Setting from 600°F to 800°F																		
	1800	350	97	190	28	181	200	163	10.6	30.5										
	1900	350	97	200	30	182	205	180	13.6	44.1										
	2000	350	86	210	36	195	231	189	19.0	63.1										
	2100	350	76	210	34	199	229	197	22.2	85.3										
	2200	350	76	210	33	200	223	205	23.0	108.3										
	2300	350	76	212	33	201	225	213	24.7	133.0										
	2400	350	74	212	33	202	225	221	26.5	159.5										
8-12	0100	350	74	212	33	202	225	229	27.9	187.4										
	0130	Increased Thermostat Settings from 800°F to 900°F. Decreased Air Rate																		
	0200	350	74	212	22	195	185	232	23.4	210.8										
	0300	350	74	214	27	193	205	235	26.4	237.2										
	0400	350	74	214	27	192	205	238	26.9	264.1										
	0500	350	76	214	27	192	205	244	27.6	291.7										
	0600	350	80	214	32	230	225	250	31.3	323.0										
	0700	350	82	212	31	230	225	255	31.1	354.1										
	0800	350	85	212	32	197	228	255	31.2	385.3										
	0830	Increased Thermostat Setting from 900°F to 1000°F																		
	0900	350	85	210	30	190	218	255	29.7	415.0					4.0	10.2	3.5	10.0	3.8	11.0
	1000	350	90	210	32	193	228	256	30.3	445.3										
	1100	350	90	210	30	193	218	256	29.7	475.0										
	1130	Shut heater off. Will lower to 375' when cool enough for cable.																		
	1300	375	90	220	29	178	220	256	20.0	495.0					2.5	9.0	3.0	9.0	3.6	10.5
	1400	375	102	210	22	173	187	279	26.5	521.5										
	1500	375	102	210	28	182	210	302	33.6	555.1										
	1600	375	102	208	26	182	205	324	36.4	591.5										
	1700	375	102	210	22	184	185	352	37.0	628.5										
	1800	375	97	209	19	187	172	380	38.9	667.4										
	1900	375	95	210	17	190	165	410	41.6	709.0					2.5	9.5	2.0	9.0	1.5	10.0
	2000	375	86	210	16	199	160	462	48.1	757.1										
	2100	375	80	210	16	200	160	514	55.6	812.7										
	2200	375	78	210	16	201	160	566	62.2	874.9										
	2300	375	74	212	16	202	160	597	66.9	941.8										
	2400	375	72	212	15	202	155	628	68.9	1010.7					1.0	9.5	1.0	9.7	1.8	11.0

WELL # 13-1

IGNITION DATA

TABLE 2 (CONT'D)

DATE	TIME	DEPTH	METER RUN READINGS				Q MCFD	T _M @ 410'	H BTU/hr	ΣH	WELL #		WELL #		WELL #12-3		WELL #12-4		WELL #13-6		
			T _o	P _o	Δ _h	P _{WH}					O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂
8-13	0100	375	72	212	14	202	150	660	70.6	1081.3											
	0200	375	72	212	13	202	145	664	68.7	1150.0											
	0300	375	72	212	13	202	145	668	69.1	1219.1											
	0400	375	72	216	15	205	155	672	74.4	1293.5					1.0	9.5	0.6	10.0	2.0	10.8	
	0500	375	74	215	14	205	150	673	72.0	1365.5											
	0600	375	74	212	13	201	145	674	69.6	1435.1											
	0700	375	74	211	13	201	145	676	69.8	1504.9											
	0800	375	80	211	13	202	145	676	69.6	1574.7											
	0900	375	83	210	13	198	146	676	69.3	1644.0											
	1000	375	86	209	13	197	145	664	67.0	1711.0					0.2	11.0	0.5	10.6	0.6	12.2	
	1100	375	90	206	12	195	137	670	62.9	1773.9											
	1200	375	96	210	17	200	163	664	74.1	1848.0											
	1300	375	100	210	16	199	161	668	73.2	1921.2											
	1400	375	105	210	16	199	161	668	73.2	1994.4					1.0	12.0	0.3	11.5	0.8	12.6	
	1500	375	108	210	17	199	163	675	73.9	2068.3											
	1600	375	110	210	17	199	163	675	73.9	2142.2											
	1700	375	110	210	17	198	163	675	73.9	2216.1											
	1800	Raised Heater to 850° to prevent overheating.																			
	1900	350	90	210	17	197	160	774	87.6	2303.7											
	2000	350	80	210	18	197	165	770	91.6	2395.3											
	2100	350	78	210	19	198	172	756	95.8	2491.1											
	2200	350	76	210	20	200	175	743	93.4	2584.5					0.8	11.6	0.3	11.0	0.5	12.0	
	2300	350	76	210	20	199	175	743	93.4	2677.9											
	2400	350	74	210	20	199	175	743	93.7	2771.6											
8-14	0100	350	74	210	20	199	175	751	94.8	2866.4											
	0200	350	72	210	21	200	180	751	97.8	2964.2											
	0300	350	72	210	21	200	180	751	97.8	3062.0											
	0400	350	74	212	21	200	180	760	98.8	3160.8											
	0500	350	74	212	21	200	180	760	98.8	3259.6											
	0600	350	74	212	21	200	180	760	98.8	3358.4					0.4	11.0	0.7	11.5	0.5	11.7	
	0700	350	74	212	21	200	180	790	103.1	3461.5											

WELL * 14-1 IGNITION DATA

TABLE 3

DATE	TIME	DEPTH	METER RUN READINGS				Q MCFD	T @ 412'	H BTU/hr	IH	WELL #12-3		WELL #12-4		WELL #12-5		WELL #12-6		WELL #12-7	
			T _o	P _o	Δ _h	P _{WH}					O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂
8-17	0900	360	95°F	200psi	27 H ₂ O	148psi	202	90°F	—			1.5	7.0	Down	6.0	3.2				
	1000	360	98	200	24	157	193	128	4.63	4.63										
	1100	360	102	200	38	174	238	190	10.69	15.32										
	1200	360	105	200	36	176	230	170	11.96	27.28										
	1300	360	105	200	35	176	230	198	18.11	44.39										
		Increased Thermostat Setting from 500°F to 800°F																		
	1400	360	105	200	34	176	225	198	16.74	61.13										
	1500	360	100	200	34	176	225	218	21.24	82.37	3.0	5.5	Down	7.0	2.5					
	1600	360	100	200	35	176	230	218	21.71	104.08										
		Perforated Interval Preheated to 200°F - Lowered Heater to 390' - Set @ 1000°F																		
	1700	390	90	200	32	179	220	235	25.52	129.60										
	1800	390	90	200	32	178	220	292	35.55	165.15										
	1900	390	90	200	24	182	190	350	39.52	204.67										
	2000	390	84	200	22	180	189	455	56.09	260.77										
	2100	390	80	200	16	187	160	445	46.72	307.49	2.5	5.5	Down	7.0	2.5					
	2200	390	80	200	13	190	145	505	49.30	356.79										
	2300	390	80	203	10	192	126	505	44.35	401.14										
		Losing Injectivity Rapidly - Fluid Blockage from Heating & Coking.																		
8-18	2400	390	78	203	9	195	122	505	41.68	442.82										
	0100	390	76	203	9	195	122	612	52.31	495.13	1.0	5.5	Down	6.3	4.2					
	0200	390	76	203	9	195	122	665	57.49	552.62										
	0300	390	76	203	9	195	122	620	53.09	605.71										
	0400	390	75	203	9	195	122	740	64.90	670.61	1.5	6.5	Down	6.1	4.6					
	0500	390	75	204	9	195	122	770	67.83	738.44										
	0600	390	72	205	10	195	128	770	71.48	809.92										
	0700	390	75	204	10	196	125	878	80.30	890.22	0.5	5.0	Down	3.5	3.0					
	0800	375	80	208	12	197	140	844	85.57	975.79										
	0900	375	86	208	12	197	140	847	85.23	1061.02										
	1000	375	90	208	12	196	140	847	84.78	1145.80										
	1100	375	94	208	12	196	140	847	84.33	1230.13	1.0	7.5	Down	1.5	3.5					
	1200	375	98	200	11	190	129	790	71.41	1301.54										
		Compressor went down 20 minutes - Flow back from well shorted heater out (Burned cable?).																		
	1300		98	200	11	190	128	790												
	1400		98	200	11	188	128	790												
	1500		98	195	27	186	200	790												
	1600		98	198	22	186	178	686												
1700		98	198	19	186	169	686													
1800		98	198	19	186	169	641			1.0	7.5	11.5	4.5	1.5	4.5					
1900		93	198	18	186	160	641													
2000		82	201	20	192	180	641													
2100		78	202	22	192	190	605			1.3	8.0	1.0	5.0	1.5	4.5					
2200		78	202	22	193	190	605													
2300		77	203	20	195	180	605													
2400		76	203	22	195	190	505			0.5	5.0	0.5	6.0	2.0	6.0					

WELL #15-1 IGNITION DATA

TABLE 4

DATE	TIME	DEPTH	METER RUN READINGS				Q MCFD	T _M @ 410'	H BTU/hr	ΣH	WELL #14-3		WELL #14-4		WELL #14-5		WELL #15-3		WELL #15-5		
			T _g	P _g	Δ _h	P _{WH}					O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	
9-1	1800	385	86°F	182 psi	27 H ₂ O	92 psi	200	101°F				0.2	7.5	1.0	8.0	0.5	6.5	1.5	3.0		
	1900	385	80	182	30	95	207	176	15.9	15.9											
	2000	385	79	182	31	95	210	233	25.9	41.8											
	2100	385	78	182	31	95	210	250	28.9	70.7											
	2200	385	78	182	31	95	210	232	25.9	96.6	0.5	8.0	0.7	7.5	0.5	7.0	1.5	3.0			
	2300	385	78	182	24	95	185	245	24.7	121.3											
	2400	385	78	182	20	95	170	252	23.7	145.0											
9-2	0100	385	78	182	20	95	170	276	26.9	171.9	0.5	7.5	1.0	8.0	0.5	7.0	1.5	3.0			
	0200	385	78	180	20	95	170	276	26.9	198.8											
	0300	385	78	180	20	95	170	276	26.9	225.7											
	0400	385	78	180	20	95	170	275	26.8	252.5											
	0500	385	78	180	20	95	170	280	27.5	280.0											
	0600	385	78	180	26	95	196	290	31.5	311.5	0.5	8.0	1.0	8.0	0.5	7.5	1.5	3.0			
	0700	385	77	180	23	97	180	290	30.7	342.2											
	0800	385	78	185	27	105	200	290	33.9	376.1											
	0900	385	82	182	27	107	200	340	41.3	417.4											
	1000	385	86	185	28	110	205	388	49.5	466.9	1.2	10.0	0.5	9.0	0.5	7.5	2.5	5.5	0.5	6.5	
	1100	385	85	186	28	115	200	405	51.2	518.1											
	1108	Compressor down 10 minutes. Raised heater but had 275°F on cable @ 340' after moving. Heater off.																			
	1200	350	85	185	27	112	200	—	—	518.1	Lowered back to 385'. Heater on.										
	1300	385	88	185	26	125	191	381	44.8	562.9	0.2	10.0	0.0	7.5	0.0	7.0	—	—	0.5	7.0	
	1400	385	93	185	27	135	195	385	45.6	608.5											
		Maximum heater temp = 630°F. Checked current draw - found one log out on heater.																			
	1500	Compressor down 15 minutes. Heater off.																			
	1530	Turned heater on - shorted out. Pulled heater out.																			
	1600		90	180	22	136	180	372													
	1700		87	180	21	140	174	380													
	1800		86	180	19	144	165	380													
	1900		85	182	17	147	159	388													

WELL * 16-1 IGNITION DATA

TABLE 5

DATE	TIME	DEPTH	METER RUN READINGS				Q MCFD	T _M @ 411'	H BTU/hr	ΣH	WELL #5-4		WELL #5-5		WELL #5-2		WELL #5-4		WELL #5-6		
			T ₀	P ₀	Δ _H	P _{WH}					O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	
9-22	0600	386	62°F	200 psi	26" H2O	73 psi	208														
	0700	386	66	200	27	75	212	188°F	20.69	20.69											
	0800	386	67	200	27	75	212	207	23.74	44.43											
	0900	386	76	195	26	75	208	222	24.29	68.72											
	1000	386	80	197	26	75	205	242	26.57	95.29											
	1100	386	82	193	26	76	205	257	28.70	123.99											
	1200	386	84	195	26	76	208	295	35.11	159.10	1.5	12.5	3.0	8.0	5.5	7.0	10.0	4.0	3.0	12.5	
	1300	386	86	196	27	78	208	334	41.27	200.37											
	1400	386	89	195	27	85	208	322	38.77	239.14											
	1500	386	90	195	27	97	208	354	43.93	283.07											
	1600	386	90	198	25	107	196	378	45.16	328.23	3.0	11.0	4.0	6.0	7.0	6.5	10.0	4.0	0.5	10.0	
	1700	386	90	197	24	110	190	407	48.18	376.41											
	1800	386	90	195	24	113	189	413	48.84	425.25											
	1900	386	90	197	23	115	190	432	51.98	477.23											
	2000	386	69	197	23	116	190	432	55.18	532.41											
	2100	386	67	197	23	117	190	460	59.74	592.15											
	2200	386	67	197	22	121	187	480	61.78	653.93	1.0	12.0	1.4	12.0	6.0	7.4	9.0	0.0	5.8	6.4	
	2300	386	65	199	22	124	188	493	64.37	718.30											
	2400	386	63	199	21	126	182	515	65.81	784.11											
9-23	0100	386	62	199	21	127	182	545	70.32	854.43											
	0200	386	62	199	21	127	182	570	73.96	928.39	1.5	13.0	1.0	6.5	5.2	8.0	8.0	6.5	5.5	7.0	
	0248	No current to heater - 2 fuses blown - shorted at plug. Cut & reconnected back on at 0346.																			
	0400	386	62	199	21	126	182	455	57.22	985.61											
	0500	386	62	199	21	126	182	576	74.83	1060.45											
	0600	386	62	199	21	125	182	610	79.79	1140.24											
	0700	386	62	199	21	125	182	628	82.41	1222.65											
	0800	386	65	198	21	123	182	641	83.86	1306.51	2.5	11.0	4.0	6.5	4.5	7.0	6.0	5.5	0.5	12.0	
	0900	386	70	198	21	122	182	649	84.30	1390.81											
	1000	386	78	198	22	121	185	658	85.83	1476.64											
	1100	386	84	198	22	120	185	663	85.69	1562.33											
	1200	386	88	195	22	120	182	610	76.00	1638.33											
	1300	386	90	195	22	118	182	656	82.41	1720.74											
	1400	386	92	195	22	118	182	681	85.76	1806.50	1.0	10.0	3.5	6.0	3.5	8.0	5.5	4.0	0.5	11.5	
	1500	386	93	195	22	117	182	681	85.76	1892.26											
	1600	386	92	195	22	115	182	672	84.45	1976.71											
	1700	386	90	195	22	115	182	691	87.50	2064.21											
	1800	386	88	195	22	115	182	696	88.52	2152.73	0.5	11.5	1.0	7.0	4.5	6.0	4.0	4.0	0.0	11.0	
	1900	386	75	197	22	114	182	693	89.98	2242.71											
	2000	386	70	198	22	113	184	685	90.53	2333.24											
	2100	386	68	198	22	113	186	681	91.21	2424.45											
	2200	386	66	198	22	112	186	681	91.51	2515.96											
	2300	386	64	198	22	111	186	681	91.81	2607.77											
	2400	386	62	198	22	111	186	685	92.70	2700.47											
9-24	0100	386	60	198	22	111	186	685	93.00	2793.47											

WELL * 16-1 IGNITION DATA

TABLE 5 (CONT'D)

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UNITED STATES DEPARTMENT OF ENERGY
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