DOE/BC/14963--9

QUARTERLY TECHNICAL PROGRESS REPORT
7/1/95-9/30/95

WEST HACKBERRY TERTIARY PROJECT

Cooperative Agreement No. DE-FC22-93BC14963

Amoco Exploration and Production Sector

Date of Report: 10/11/95
Award Date: 9/3/93
Anticipated Completion Date: 4/2/97(Budget Period 1)
Government Award: $6,017,500(Budget Period 1)
Program Manager: Travis Gillham
Principal Investigators: Travis Gillham, Bruce Cerveny(facilities), Ed Turek(research)
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Reporting Period: 7/1/95-9/30/95(8th Quarter of Budget Period 1)

Objectives

The goal of the West Hackberry Tertiary Project is to demonstrate the technical and economic feasibility of combining air injection with the Double Displacement Process for tertiary oil recovery. The Double Displacement Process is the gas displacement of a water invaded oil column for the purpose of recovering oil through gravity drainage. The novel aspect of this project is the use of air as the injection fluid. The target reservoir for the project is the Camerina C-1,2,3 Sand located on the West Flank of West Hackberry Field in Cameron Parish, Louisiana. If successful, this project will demonstrate that the use of air injection in the Double Displacement Process can economically recover oil in reservoirs where tertiary oil recovery is presently uneconomic.

Summary of Technical Progress

Air injection was initiated on November 17, 1994. During this quarter, the West Hackberry Tertiary Project completed the first ten months of air injection operations. Plots of air injection rates and cumulative air injected are included in this report as attachments. The following events are reviewed in this quarter's technical progress report: 1)successful workovers on the Gulf Land D Nos.44, 45 and 51 and the Watkins No.3, 2)the unsuccessful repair attempt on the Watkins No.16, 3)gathering of additional bottom hole pressure data, 4)air compressor operations and repairs, 5)technology transfer activities.

1)Successful Workovers on the Gulf Land D Nos.44, 45 and 51 and Watkins No.3

In the Gulf Land D No.51(air injector), corrosion in the tubing caused pressure communication between the tubing and the tubing/casing annulus. During July, 1995, the well was pulled and the tubing was replaced with coated tubing. The source of the corrosion was the mixture of KCl purge water and oxygen or carbon dioxide downhole in the well. The KCl purge water had been injected each time air injection stopped to cool the injector wellbore and to prevent downhole explosions due to mixing hydrocarbons with heated air in the wellbore. To alleviate corrosion, the use of the KCl purge water system was stopped in June of 1995 with no apparent negative consequences.

At this point in time, the poor run time seen for the air compression system has resulted in much less air injection volumes than originally predicted. To compensate for lower than expected air injection volumes, the flood pattern was modified by recompleting two wells which were higher on structure and closer to the air injector in Fault Block IV than the wells in the original project design. These two wells are the Gulf Land D Nos.44 and 45. A structure map for the top of the Cam C-1 is included as an attachment. In August of 1995, the Gulf Land D No.45 was recompleted back to the Cam C-1,2 Sand after previously watering out in the identical completion interval in December of 1990. On August 17,1995, the Gulf Land D No.45 tested gas lifting at a rate of 190 BOPD, 451

BWPD and 25 MSCFD with no evidence of nitrogen production. After one month of production, the Gulf Land D No.45 had declined to a rate of 60 BOPD and 450 BWPD. The source of the oil production in the Gulf Land D No.45 is either due to response to air injection or due to zones now producing through a gravel pack which had previously sanded up. Although the oil cut has declined in the Gulf Land D No.45, the oil cut declined during a time frame when air injection operations were suspended due to ongoing compressor repairs. Of particular interest will be the trend of the oil cut in the Gulf Land D No.45 after air injection is restarted. A production plot for the project reservoir is included as an attachment.

Slightly upstructure to the Gulf Land D No.45 in Fault Block IV, the Gulf Land D No.44 was recompleted to the Cam C-1,2 Sand in an attempt to validate that the oil production seen in the Gulf Land D No.45 resulted from the air injection project. This was a difficult recompletion which involved fishing a packer and a perforating gun out of the well while cleaning the well out to the Cam C-1,2 Sand. During October of 1989, a recompletion to the Cam C-1,2 in the Gulf Land D No.44 tested at a rate of 0 BOPD, 500 MSCFD and 275 BWPD and was shut in awaiting a recompletion to the Cam B-1 Sand. On October 8, 1995, the Gulf Land D No.44 tested gas lifting at a rate of 0 BOPD, 0 MSCFD and 413 BWPD with no evidence of nitrogen production. A total of 411 MSCFD of air has been injected into the Gulf Land D No.51 in Fault Block IV since the start of air injection on November 17, 1994. After additional air injection in Fault Block IV, the oil cut in the Gulf Land D No.44 should increase.

In Fault Block II, the Watkins No.3 produced nitrogen contaminated gas from suspected communication between the well's completion interval and the project sand, the Cam C-1,2,3 Sand. The Watkins No.3 was squeezed with cement to prevent crossflow between the two zones and temporarily abandoned.

2)Unsuccessful Repair Attempt in the Watkins No.16

On March 27, 1995, the Watkins No.16(air injector) developed pressure communication between the tubing and the tubing/casing annulus. Air injection into the Watkins No.16 was immediately stopped due to concerns regarding corrosion and casing integrity. A repair was initiated during August of 1995 to replace the highly corroded tubing in the Watkins No.16. While attempting to squeeze cement into a high permeability interval in the upper portion of the Cam C-1, 371' of tubing was cemented in the wellbore. Subsequent fishing operations to recover the tubing proved to be unsuccessful and the well was temporarily abandoned.

The unsuccessful repair of the Watkins No.16 left Fault Block II without an air injector. Fortunately, an earlier air injection workover had prepared the nearby Watkins No.18 for service as a producer and with a minimal amount of work the Watkins No.18 can be converted to an air injector. The Watkins No.18 conversion will only require replacing the tubing, tree and packer. From a surface facilities perspective, only 400' of air injection line will be needed to carry the air from the Watkins No.16 surface location to the Watkins No.18 surface location. Before the line can be installed, flowline permits will be required. In addition, the air injection wellsite control skid and RTU will be moved from the Watkins No.16 surface location to the Watkins No.18 surface location. Before air injection in the Watkins No.18 can begin, an Underground Injection Committee(UIC) permit is also needed.

3)Gathering of Additional Bottom Hole Pressure Data

A minimum of three bottom hole pressure surveys are taken every quarter to assess the effect of air injection on reservoir pressure. The most recent series of bottom hole pressure surveys were taken in August of 1995. A plot of bottom hole pressures is included as an attachment. In Fault Block II, pressure data collected since the start of air injection indicates that reservoir pressure had increased by 50 psi to 3350 psi and then had fallen to 3311 psi over a prolonged period of production without injection. In Fault Block IV, bottom hole pressure surveys show that the reservoir pressure had increased by over 200 psi since the start of air injection. The pressure response seen thus far is the result of air injection and confirms the original geologic picture.

4)Air Compressor Operations and Repairs

Air compressor mechanical failures have continued to be a significant cause of air injection downtime. Discussed below are the significant mechanical failures that occurred this quarter and a follow up on two failures that occurred the previous quarter to the turbochargers on the reciprocating compressor engine and the screw compressor cooler. All repairs have been covered under warranty by the equipment manufacturers except for the turbochargers.

The mechanical failure which occurred during the previous quarter to both turbochargers on the Waukesha 9390 GL engine which drives the reciprocating compressor was diagnosed to be caused by insufficient lubrication due to hot shutdowns. This occurs when the turbos, which operate at high temperature and rpm's, continue to spin(due to momentum) in the turbine wheel after the engine oil pressure has dropped due to the shutdown. A post lube shutdown system has been installed which should prevent future turbo failures. When the engine shuts down, the prelube pump starts automatically and lubricates the engine for 3-5 minutes after shutdown allowing the turbos to coast down while being lubricated. In addition, the engine oil pump was adjusted from the previous setting of 45 psi to 55 psi and the oil pressure shut down switch was set to 35 psi from the previous setting of 25 psi. This post lube system will be tested on the 9390 engine and later installed on the 5108 engine driving the screw compressor.

The mechanical failure which occurred to the oil cooler of the Atlas Copco ZR-6 screw compressor during the previous quarter was caused by a defective casting end plate which allowed communication between the oil and water. The cooler was replaced by Atlas Copco and should be a one-time occurrence.

Rod packing failures have continued to be a problem on the Ariel JGK-4 reciprocating compressor. The failures have occurred on throws 1 and 3 which are the rods for the higher pressure stages 3, 4, and 5. Stages 4 and 5 are a tandem cylinder sharing the same rod and will be referred to only as stage 4 for the remainder of this discussion. Examination of the failed parts indicated a heat related failure. New packing cases were designed and installed for the 3rd and 4th stages. The new packing cases are water cooled for heat dissipation, have two lube points instead of one for better lubricant distribution, have 4 seal ring assemblies instead of 5 to reduce friction, use polymer filled Teflon rings instead of carbon filled Teflon to reduce friction and use bronze back up rings instead of cast iron for better heat dissipation. This resulted in a rod temperature reduction from 300+ degrees Fahrenheit(°F) which was causing failures to an acceptable 187 °F. The rod temperatures were 201, 203, 181 and 187 °F on stages 1, 2, 3, and 4, respectively, on 8/14/95 utilizing Anderol 555 (SAE 30 wt.) as the lubricant. The rod temperatures were 226, 238, 182 and 189 °F on stages 1, 2, 3, and 4, respectively, on 10/10/95 utilizing Mobil Rarus 829 (SAE 40 wt.) as the lubricant. The higher rod temperatures recorded on 10/10/95 on the 1st and 2nd stage rods could be caused by additional friction due to the more viscous SAE 40 weight oil. However, the constancy of the temperatures on the 3rd and 4th stage rods shows that the water cooled packing assemblies are dissipating heat effectively. This appears to have solved the problem and we expect reasonable rod packing life in the future. In future installations, water cooled packing assemblies should be installed for stages where the discharge pressure exceeds 1000 psig or where high compression ratios are causing discharge temperatures in excess of 300 °F.

Compressor valve failures have been a recurring problem on the Ariel JGK-4 reciprocating compressor. The failures have occurred mostly on the 3rd and 4th stages. The failures have been caused by improper valve springing for actual operating conditions, incorrect valve springs installed by a non-authorized valve service center and excessive heat caused by other mechanical and lubrication failures. New Hoerbiger valves have been installed with the latest recommended springing for actual operating conditions. All replacement valves in our inventory have been serviced by Hoerbiger and updated with the new springing. Future valve repairs will be performed by only Hoerbiger authorized service centers to prevent incorrect springs from being installed.

In late August, a mechanical failure occurred to the piston and rings on the 4th stage of the reciprocating compressor. The rings were found to be disintegrated and extruded due to high heat and the cylinder and piston were scored due to metal to metal contact. The failure appeared to be due to lack of lubrication. Ariel has designed, manufactured and installed a new piston and rod assembly for the 4th and 5th stages. The new piston design incorporates rider bands to reduce friction and adds piston to cylinder clearance to improve lubrication flow around the piston and rings. New 4th and 5th stage cylinders were also replaced due to scoring. The lubrication distribution system was modified to improve lubrication to the 4th and 5th stage cylinders. A larger force feed lubricator pump was installed for the 3rd, 4th and 5th stages to increase capacity and the metering valves for the 4th and 5th stage cylinders were changed to double the lubrication rate. The lubricant was also changed to Mobil Rarus 829 synthetic diester (SAE 40 wt.) based on successful experience in Ariel's high pressure seismic air compressors.

The compressors are currently running and we are injecting 4.2 MMSCFD into the Gulf Land D No.51 with a wellhead surface injection pressure of 2200 psig. With the repairs and modifications completed this quarter, improved run time is expected throughout the remainder of the project.

5)Technology Transfer Activities

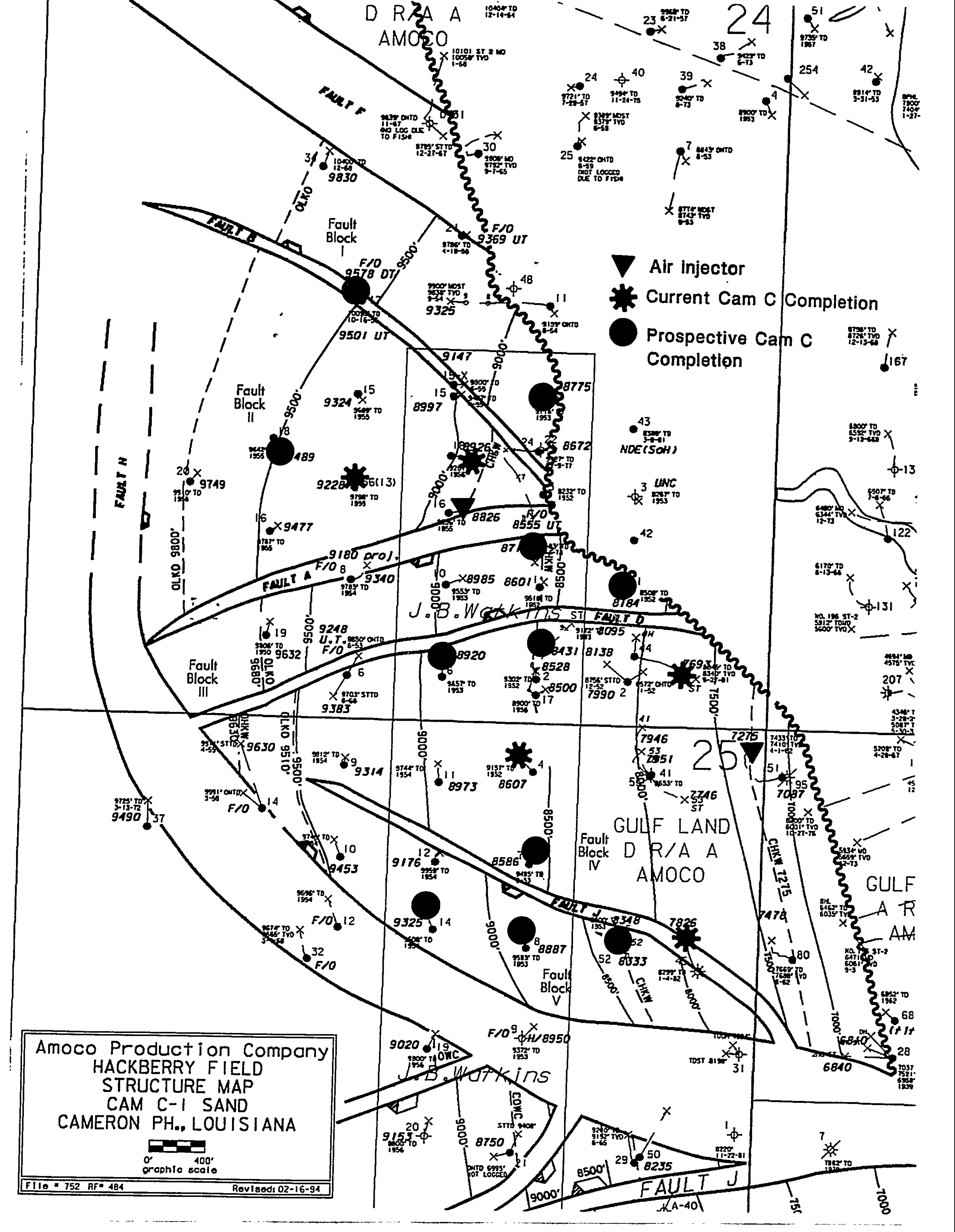
On September 19, 1995, Amoco gave a presentation on the West Hackberry Tertiary Project to an oil industry fluid imaging workshop at the BP Plaza in Houston, Texas. In addition, both Amoco and LSU have submitted abstracts to an improved oil recovery symposium scheduled for April 21-24, 1996, in Tulsa, Oklahoma. While Amoco's paper will discuss the economic aspects of light oil air injection projects, the LSU paper will review the results of LSU's core tests. As additional experience is gained from operating the West Hackberry project, more technology transfer activities will be planned to share key learnings.

Upcoming Workovers

As noted earlier, the unsuccessful repair on the Watkins No.16 leaves Fault Block II without an air injector and the upcoming conversion of the Watkins No.18 to an air injector will fill that void. Over the next 12 months, production performance of the Gulf Land D Nos.44 and 45 will dictate the timing of recompleting the Gulf Land D No.1 to the Cam C-1,2 Sand. The recompletion of the Gulf Land D No.1 was included in the original project design.

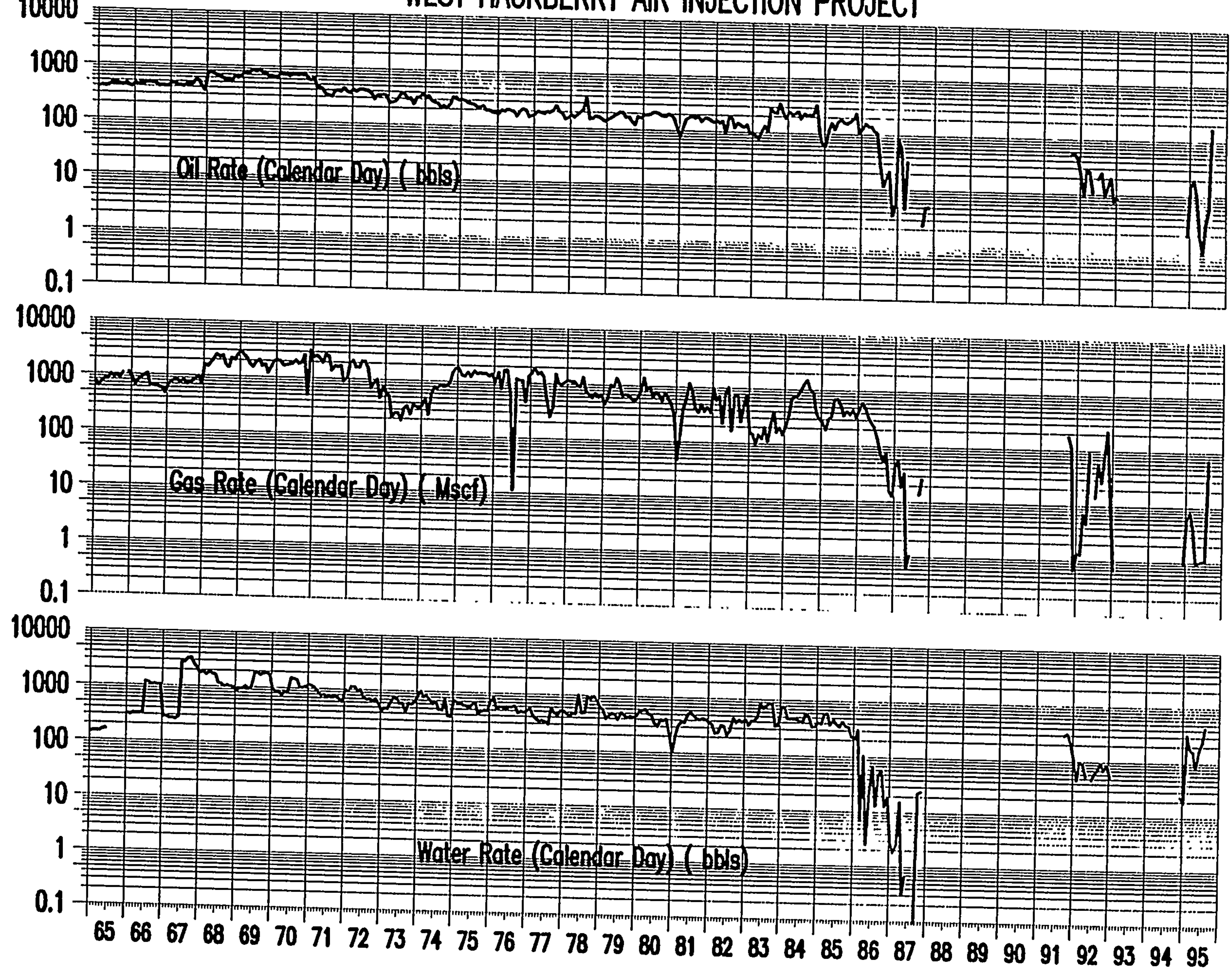
Attachments:

1) Structure Map for the Cam C-1 Sand
2) Production Plot for the Cam C-1,2,3 Sand
3) Plot of Bottom Hole Pressures vs. Time
4) Plot of Air Injection Rate and Air Injection Wellhead Pressure vs. Time
5) Plot of Cumulative Air Injected vs. Time


Amoco Production Company
HACKBERRY FIELD
STRUCTURE MAP
CAM C-1 SAND
CAMERON PH., LOUISIANA
0' 400'
graphic scale
File # 752 RF# 484
Revised: 02-16-94
Air Injector
Current Cam C Completion
Prospective Cam C Completion
24
25
D R/A A
AMOCO
GULF LAND
D R/A A
AMOCO
J.B.Watkins
J.B.Watkins
Fault Block I
Fault Block II
Fault Block III
Fault Block IV
Fault Block V
FAULT F
FAULT B
FAULT A
FAULT D
FAULT J
FAULT J
FAULT H
OLKO 9800'
OLKO 9510'
CHKW 7275
F/O 9578 DT
F/O 9369 UT
9501 UT
9180 proj.
F/O 8555 UT
9248 U.T.
NDE(SoH)
UNC
OWC
A-40

WH CAM C RI SU

WEST HACKBERRY AIR INJECTION PROJECT



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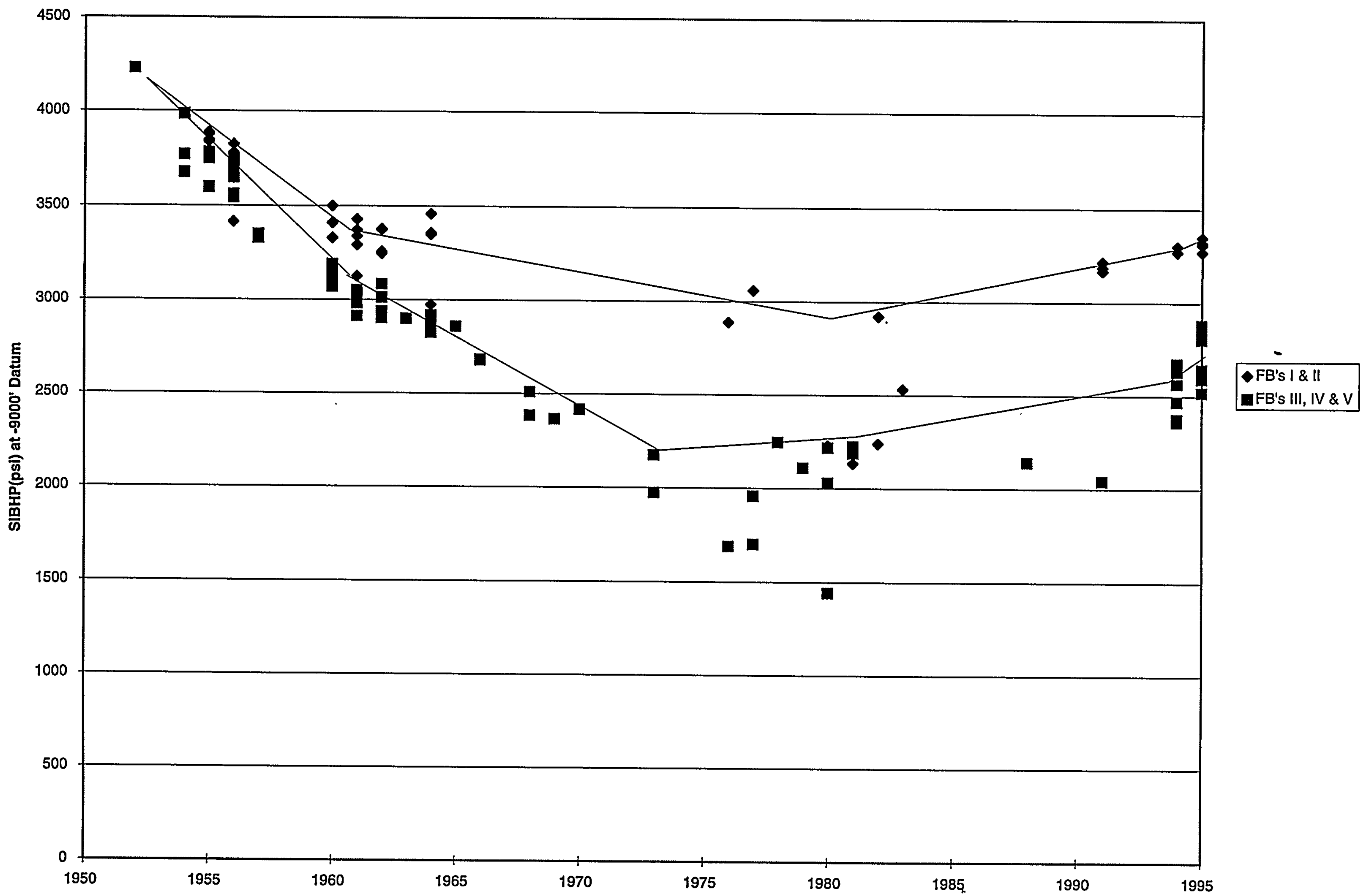
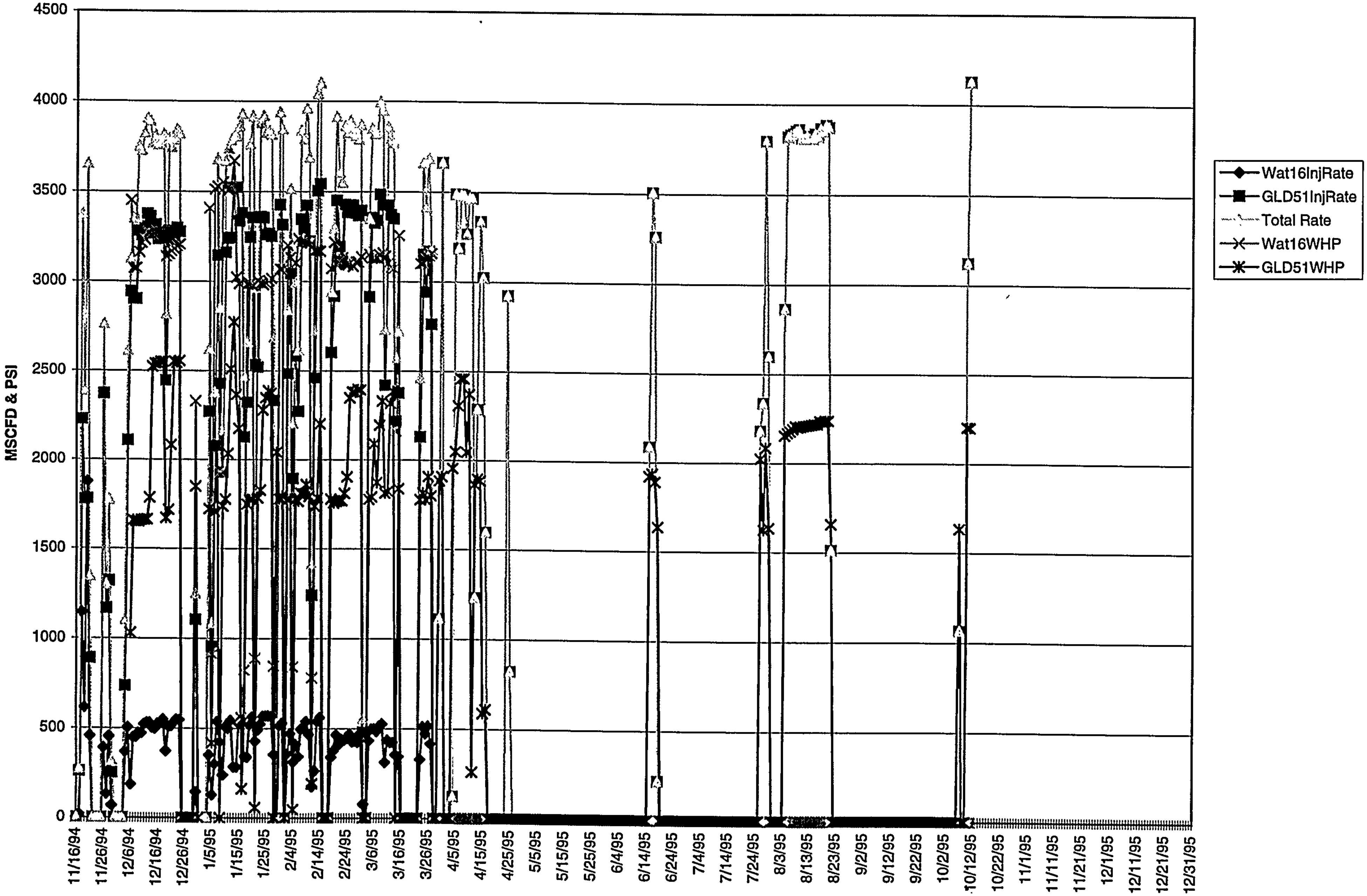
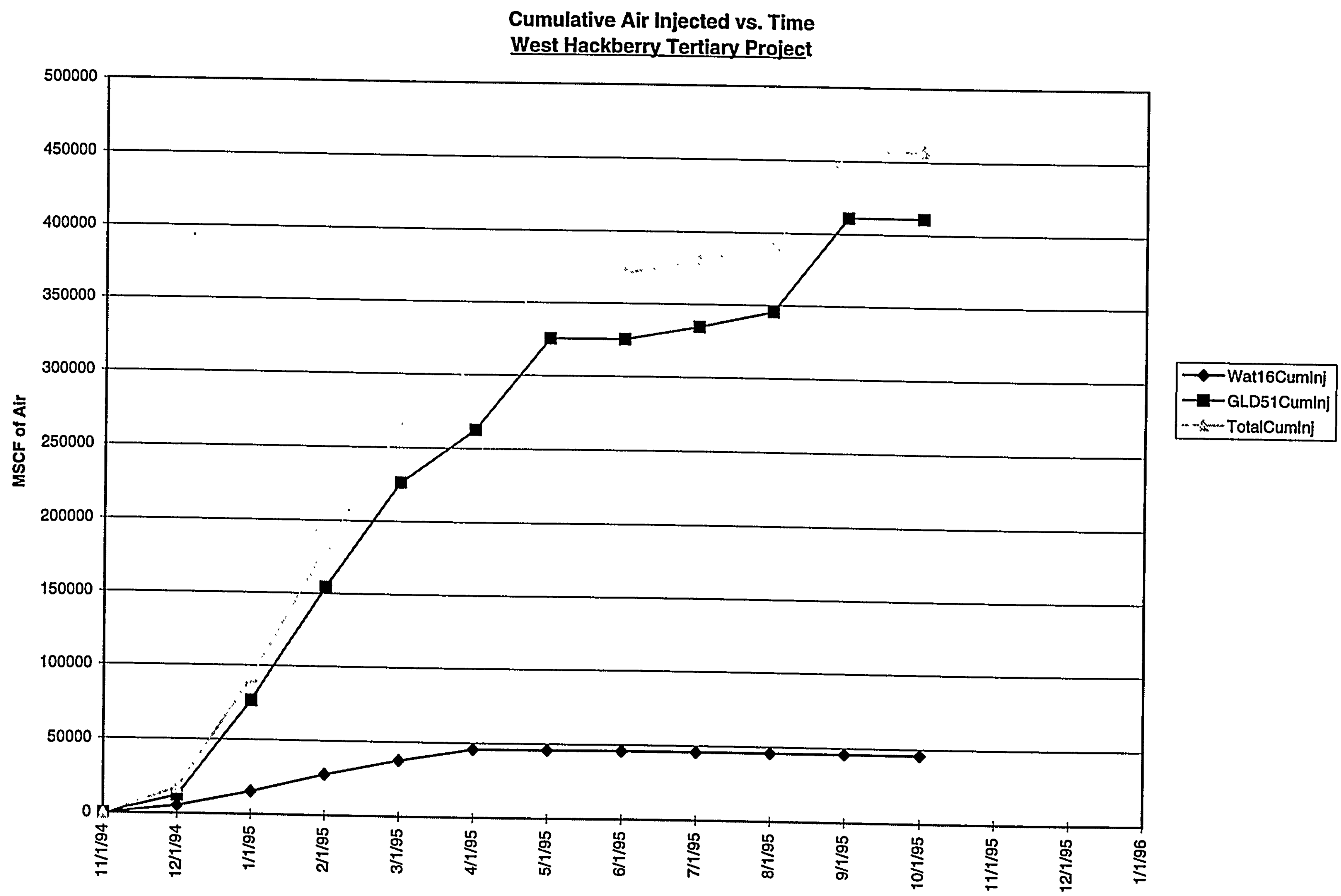
BHP vs. Time(W. Hackberry Air Injection Project)



Air Injection Rate and Wellhead Pressure
West Hackberry Tertiary Project




Cumulative Air Injected vs. Time
West Hackberry Tertiary Project
MSCF of Air
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
11/1/94
12/1/94
1/1/95
2/1/95
3/1/95
4/1/95
5/1/95
6/1/95
7/1/95
8/1/95
9/1/95
10/1/95
11/1/95
12/1/95
1/1/96
Wat16CumInj
GLD51CumInj
TotalCumInj