BC/14963-15

DOE/BC/14963--15

# QUARTERLY TECHNICAL PROGRESS REPORT
**4/1/96-6/30/96**

## WEST HACKBERRY TERTIARY PROJECT

**Cooperative Agreement No. DE-FC22-93BC14963**

**Amoco Exploration and Production Sector**



**Date of Report:** 7/11/96
**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)
**Technical Project Officer:** Edith C. Allison
**Reporting Period:** 4/1/96-6/30/96(11th Quarter of Budget Period 1)

## DISCLAIMER

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

## DISCLAIMER

## 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 reservoirs for the project are the Camerina sands located on the west and north flanks 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

During the second quarter of 1996, air injection continued on the west flank of the field while construction of a pipeline was underway to allow air injection to begin on the north flank of the field. A discussion of the following topics are contained herein: 1)performance summary for air injection on the west flank, 2)air compressor operations, 3)an introduction to the next air injection reservoir(north flank), 4)construction of surface facilities to bring air injection to the north flank and 5)plans for the upcoming quarter.

## 1)Performance Summary for Air Injection on the West Flank

Throughout the second quarter, all of the air available for injection, 232 million standard cubic feet(MMSCF), was injected into the Gulf Land D No.51 in Fault Block IV. Wellhead injection pressure remained relatively stable at approximately 2100 pounds per square inch(psi) for the whole quarter. A plot of injection rates and pressures is included as Figure No.2. A total of 1159 MMSCF of air has been injected since the start of injection on November 17, 1994. Out of the 1159 MMSCF injected, 1080 MMSCF were injected into the Gulf Land D No.51 in Fault Block IV. A plot of cumulative air injected versus time is included as Figure No.3.

Neither of the closest producing wells, the Gulf Land D Nos.44 and 45, have exhibited any evidence of production response or nitrogen breakthrough. A structure map denoting the location of key wells is included as Figure No.1. Reservoir modeling based upon a nominal injection rate of 4 million standard cubic feet per day(MMSCFD) had predicted that the Gulf Land D No.44, the structurally highest producing well in Fault Block IV, would see production response during the first half of 1996. Water samples taken in the Gulf Land D Nos.44 and 45 exhibited an unusual difference in chlorides content with the analysis of the water sample from the Gulf Land D No.44 displaying 32,000 parts per million(ppm) greater chlorides(131,000 ppm vs. 99,000 ppm). To confirm that the difference in chlorides is not due to a casing leak in the Gulf Land D No.44, a workover rig will be moved to the well during early July, tubing will be pulled and the casing will be tested. If there is no evidence of a casing leak, production logs will be run to confirm that there is no channeling occurring behind pipe. If there is evidence of channeling or a casing leak, steps will be taken to repair the well and to eliminate the problem.

Reservoir pressure has continued to increase significantly as a result of air injection. The most recent bottom hole pressures were measured in June of 1996. A plot of bottom hole pressure versus time is included as Figure No.4. As noted on the plot, reservoir pressure in Fault Block IV has increased by approximately 350 psi since the start of injection.

**2)Air Compressor Operations**

During the second quarter of 1996, a total of 232 MMSCF of air was injected into the Gulf Land D No.51. Even though a typical daily injection rate was about 4 MMSCFD, compressor downtime resulted in an average injection rate of 2.6 MMSCFD or about 64% of 4 MMSCFD. Most of this lost injection volume was due to three weeks of downtime between May 19th and June 10th caused by a failure of the coupling on the screw compressor package that transmits the power from the engine to the compressor. A new floating tube assembly center section was machined to new tolerances to prevent future failures. Downtime also occurred during the tie in of new injection facilities to serve the north flank injection wells.

**3)An Introduction to the Next Air Injection Reservoir(North Flank)**

On the west flank of West Hackberry Field, air injection is combined with the Double Displacement Process in a reservoir with high reservoir pressure resulting from relatively strong water influx and little or no gas cap. In contrast, the north flank of West Hackberry contains several good size Oligocene reservoirs that are: 1)low pressure, 2)have large gas caps, 3)possess thin oil rims and 4)exhibit extremely slow water influx. The West Hackberry Tertiary Project presents the opportunity to demonstrate that air injection can generate economic tertiary oil recovery in both the high pressure reservoirs on the west flank and the low pressure reservoirs on the north flank. Both types of reservoirs can be found in salt dome fields throughout the Gulf Coast.

The original project design authorized the installation of a flowline from the west flank to the north flank of the field to carry produced flue gas for injection and disposal into low pressure oil reservoirs on the north flank. In low pressure oil reservoirs, the oil rim can become trapped between downstructure wells which have watered out and upstructure wells which have gassed out. Implementing a waterflood by injecting into the downstructure well risks the possibility of dissipating the remainder of the oil rim in the gas cap before the oil rim reaches the upstructure well. Injecting a gas in the upstructure well pushes the oil rim to the downstructure well while gaining the dual benefit of increasing reservoir pressure and increasing the volume of reservoir available for double displacement generated gravity drainage.

The Cam C-1 sand in the West Hackberry Cam C Reservoir B Sand Unit(WH Cam C RB SU) is the first low pressure reservoir targeted for air injection on the north flank of West Hackberry Field. Reservoir pressure is approximately 335 psi at -7700' subsea. A schematic of the reservoir is included as Figure No.5. Between May of 1992 and March of 1993, Amoco injected 136 MMSCF of natural gas into the Cam C-1 Sand in the SL 42 No.98. Prior to gas injection, the nearest producing well, the SL 42 No.220 had watered out. Shortly after gas injection commenced, the SL 42 No.220 began producing oil again and has averaged 45 barrels of oil per day(BOPD) and 70 barrels of water per day(BWPD) since gas injection. A production plot for the SL 42 No.220 is included as Figure No.6. The results of this gas injection pilot were documented in SPE Paper No.35393, "Economics of Light Oil Air Injection Projects."

Plans are to follow the original gas injection in the WH Cam C RB SU with air injection. Injecting into the same reservoir that already responded successfully to gas injection provides a low risk opportunity to prove that air injection works and for significantly less cost than gas injection.

Although using the SL 42 No.98 as an air injector was planned, a recent workover to convert the well to air injection discovered collapsed casing. As an alternative, the SL 42 No.155 is available to serve as an air injector and encounters the Cam C-1 slightly upstructure to the SL 42 No.98. Accordingly, the SL 42 No.155 was converted to an air injector and air injection is expected to begin during the first half of July. Initially, air injection capacity will be split between the Gulf Land D No.51 at 2 MMSCFD and the SL 42 No.155 at 2 MMSCFD. Reservoir performance will dictate future injection rates. At least four additional low pressure reservoirs on the north flank have been identified as future air injection candidates.

**4)Construction of Surface Facilities to Bring Air Injection to the North Flank**

Facilities are presently being installed to transport air from the Gulf Land D No.51 wellsite to the four air injection candidates on the north flank. At the Gulf Land D No.51 the air flow is split downstream of the wellhead scrubber and choked through a control valve to an existing pipeline which flows to Amoco's Central Facility No.2. A scrubber, measurement, and automation monitoring equipment is installed at CF No.2. From CF No.2 approximately 18,000' of new pipeline is being installed as a trunkline across Black Lake on an existing pipe rack. Spurs off of this trunkline will run to each of the four injection wells.

**5)Plans for the Upcoming Quarter**

The upcoming quarter will provide the opportunity to: 1)monitor the west flank and north flank reservoirs for production response, 2)determine if the water production in the Gulf Land D No.44 is from an external source, 3)monitor reservoir pressures in both reservoirs for evidence of pressure response, 4)prepare the injector and the surface facilities for injection into the West Hackberry Cam D North Flank Sand Unit(WH Cam D NF SU) which is intended to be the next air injection reservoir following the WH Cam C RB SU.

Although injecting 2 MMSCFD into a reservoir on the north flank is expected to produce north flank production response during the third quarter of 1996, the reduction in injection rate on the west flank from 4 MMSCFD to 2 MMSCFD will defer production response on the west flank. According to the reservoir model, production response on the west flank is controlled to a large extent by the air injection rate, not just by the cumulative volume of air injected. That is, at high injection rates the gas-oil contact and water-oil contacts are forced downstructure more on the north end of Fault Block IV(near the Gulf Land D No.44) than on the south end. At lower air injection rates, say 2 MMSCFD, the gas-oil and water-oil contacts tend to be flatter across the reservoir. In the model, the response of contacts to changes in injection rate occurs within a couple of weeks. For example, when compression is shut-in, the gas-oil and water-oil contacts retreat upstructure and away from the Gulf Land D No.44 as the contacts level out across the fault block. A 1996 production response in the Gulf Land D No.44 is dependent upon the contacts being forced downstructure due to the higher pressure around the injection well resulting from a higher injection rate.

Although reducing the injection rate in Fault Block IV will most certainly defer production response, the lower injection rate should allow more time for effective gravity segregation thereby reducing the negative impact of permeability variations and resulting in improved vertical sweep efficiency. In addition, studies published by Exxon assessing the performance of the Double Displacement Process in Hawkins Field(SPE Paper No.28603) suggested that slowing the rate of advancement of the oil rim improved the gravity drainage performance of the reservoir. Even though lowering the injection rate to 2 MMSCFD will defer the arrival of the oil rim at the Gulf Land D No.44, better vertical sweep efficiency and more time allowed for gravity drainage should increase the size of the oil bank thereby increasing the volume of oil produced by the Gulf Land D No.44 when the oil bank does arrive.

Hopefully, evidence of production response will be found in both the north flank and west flank reservoirs during the last half of 1996. This would provide the opportunity to work with LSU to push forward with an aggressive technology transfer program based upon proven production response rather than reservoir model predictions. Without seeing barrels of oil in the tank as a result of air injection, the domestic oil industry can be expected to give little heed to air injection technology transfer activities.

**Figures:**

1) Structure Map for the Cam C-1 Sand
2) Plot of Air Injection Rate and Air Injection Wellhead Pressure vs. Time
3) Plot of Cumulative Air Injected vs. Time
4) Plot of Bottom Hole Pressures vs. Time(west flank)
5) Schematic Drawing of the WH Cam C RB SU on the North Flank
6) Production Plot for the SL 42 No.220(north flank)

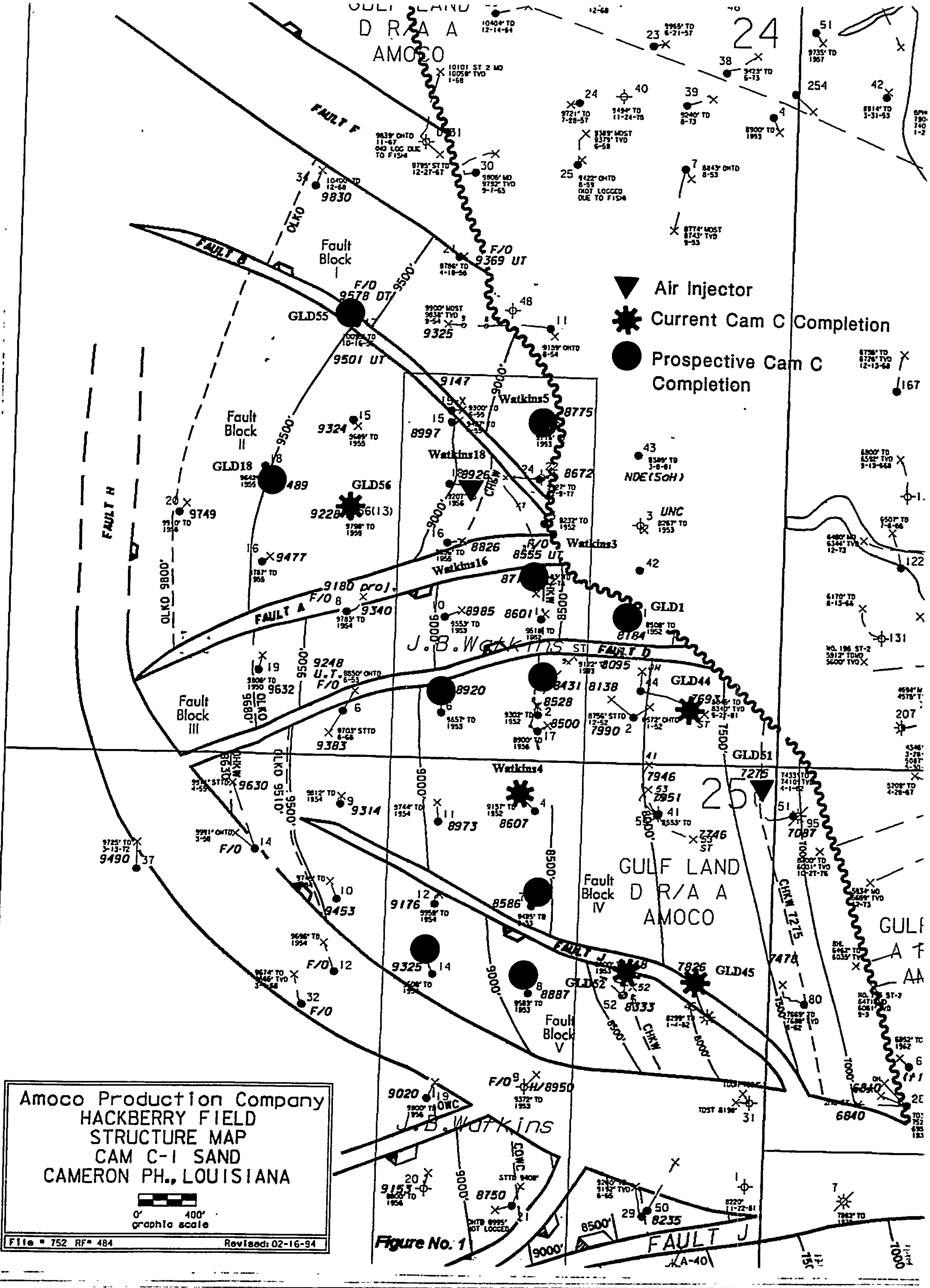
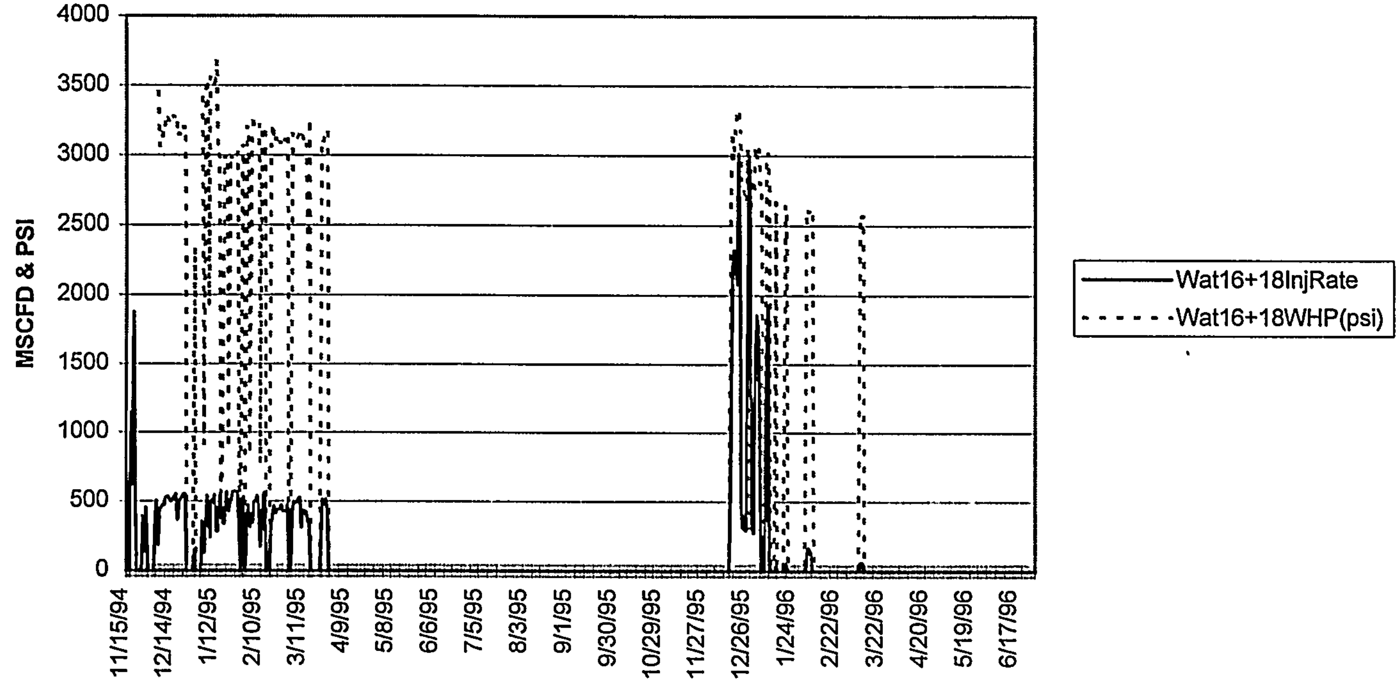

Amoco Production Company
HACKBERRY FIELD
STRUCTURE MAP
CAM C-1 SAND
CAMERON PH., LOUISIANA
0' 400'
graphic scale
File # 752 RF# 484
Revised: 02-16-94
Air Injector
Current Cam C Completion
Prospective Cam C Completion
FAULT F
FAULT B
FAULT A
FAULT D
FAULT J
FAULT H
Fault Block I
Fault Block II
Fault Block III
Fault Block IV
Fault Block V
GULF LAND
D R/A A
AMOCO
J. B. Watkins
24
25
GLD55
GLD18
GLD56
GLD1
GLD44
GLD51
GLD52
GLD45
Watkins5
Watkins18
Watkins16
Watkins3
Watkins4

Figure No. 1

## Air Injection Rate & Wellhead Pressure
### Watkins No.16(11/94-3/95) + Watkins No.18(12/95-6/96)




## Air Injection Rate & Wellhead Pressure
### Gulf Land D No.51

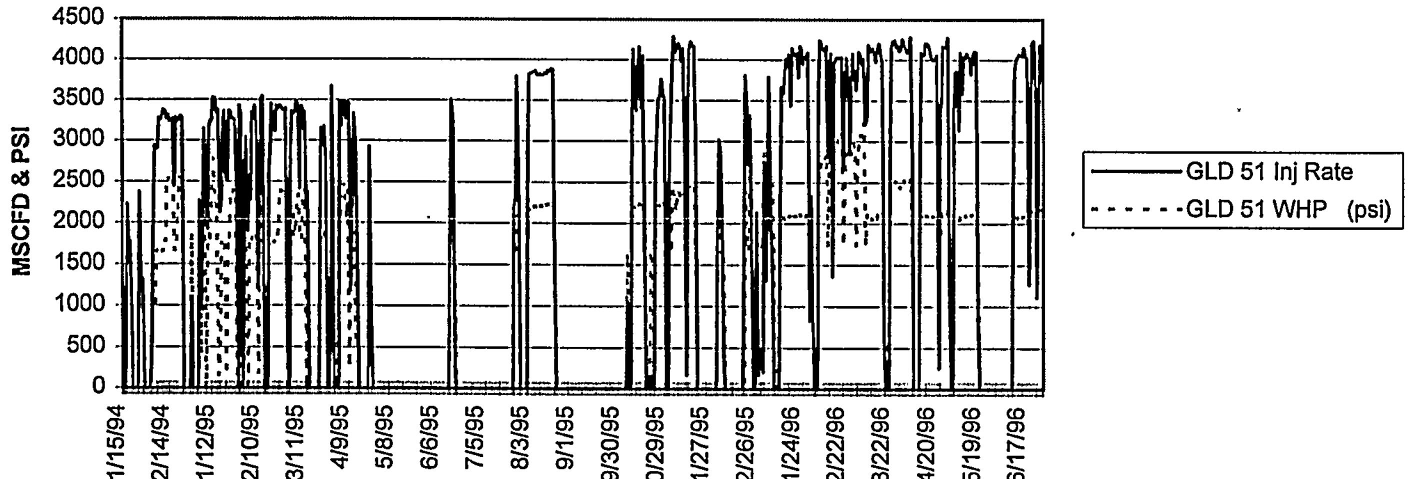



Figure No.2

**Cumulative Air Injected vs. Time**
**West Hackberry Tertiary Project**

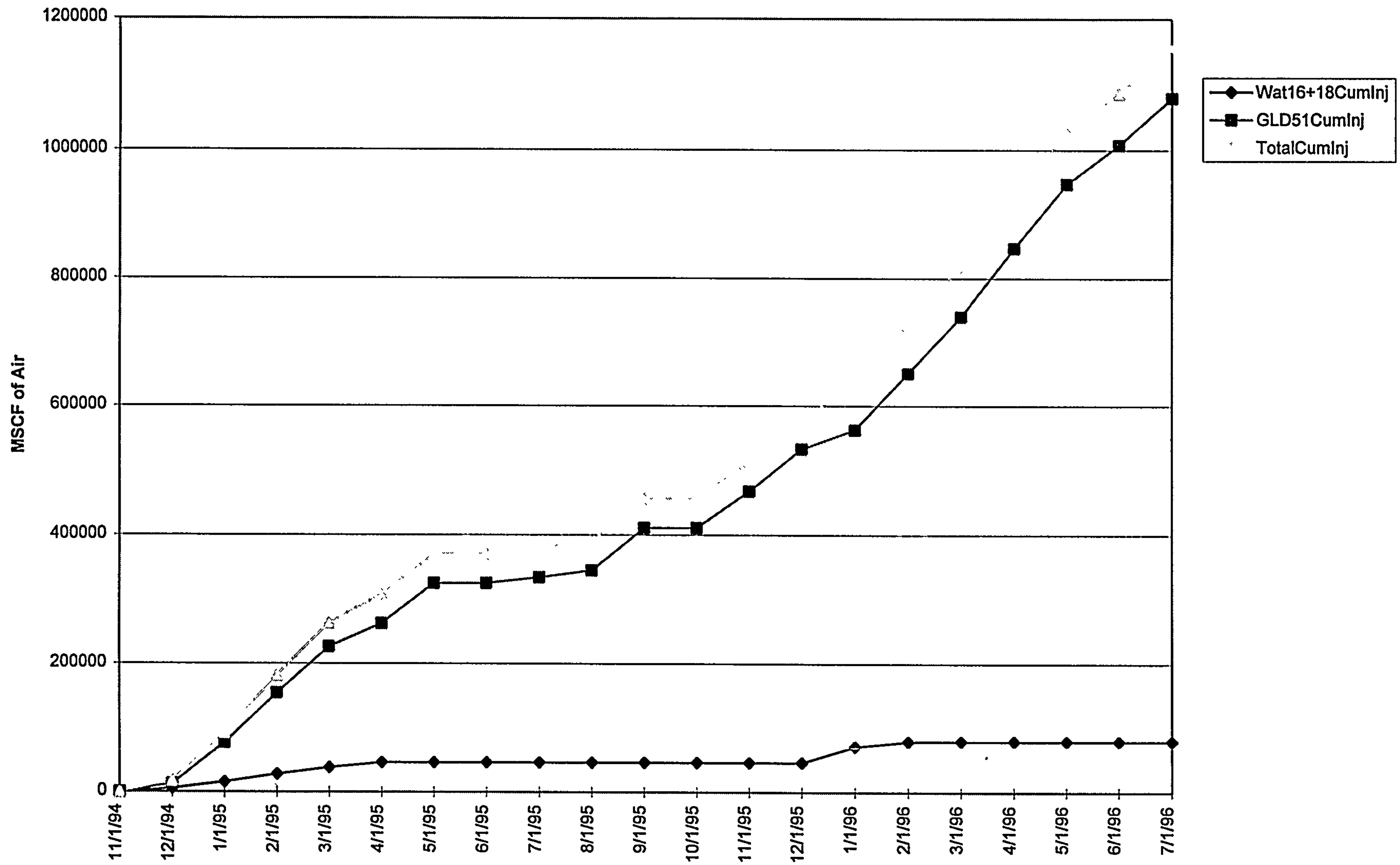



Figure No.3

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

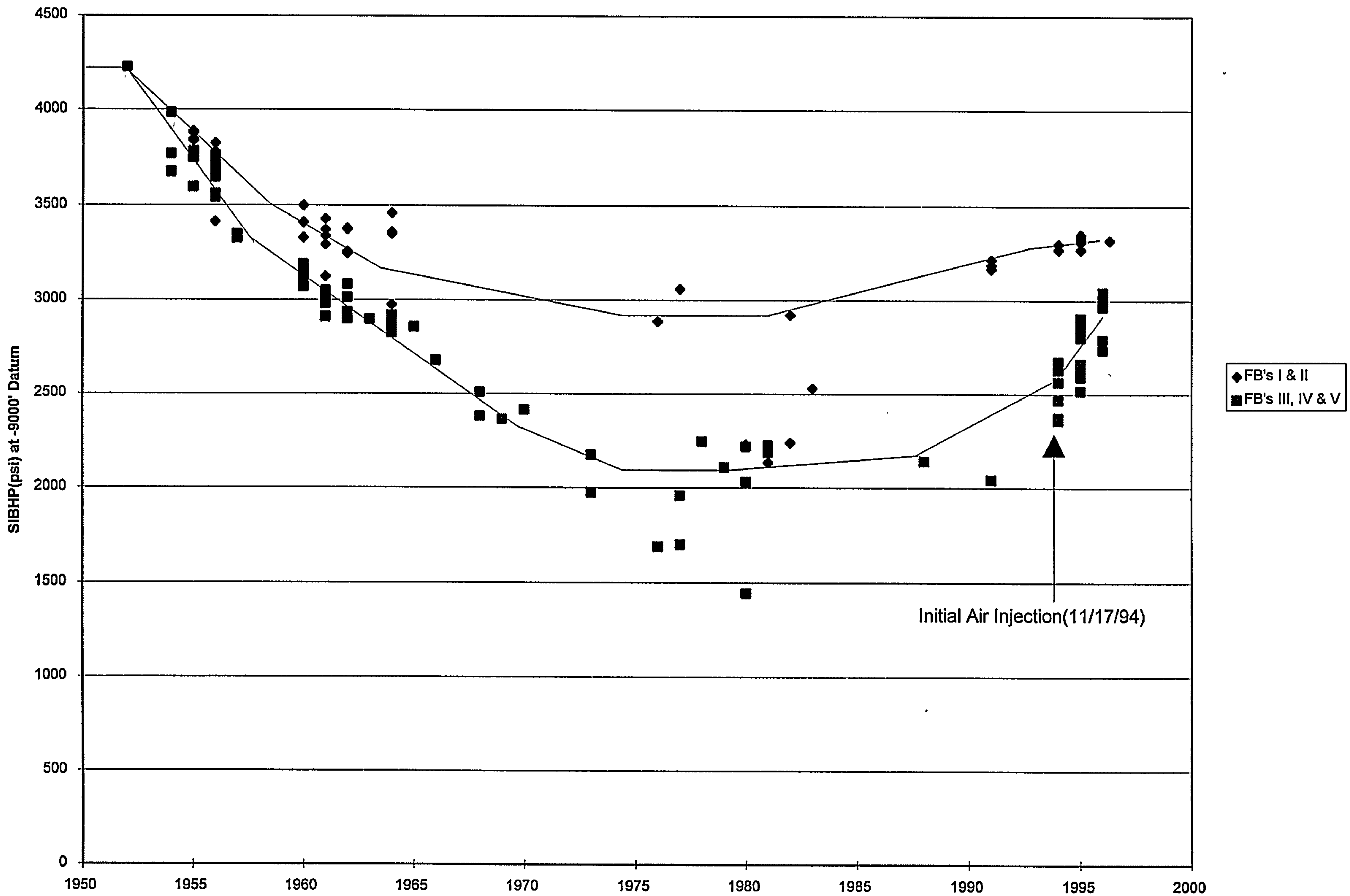



Figure No.4

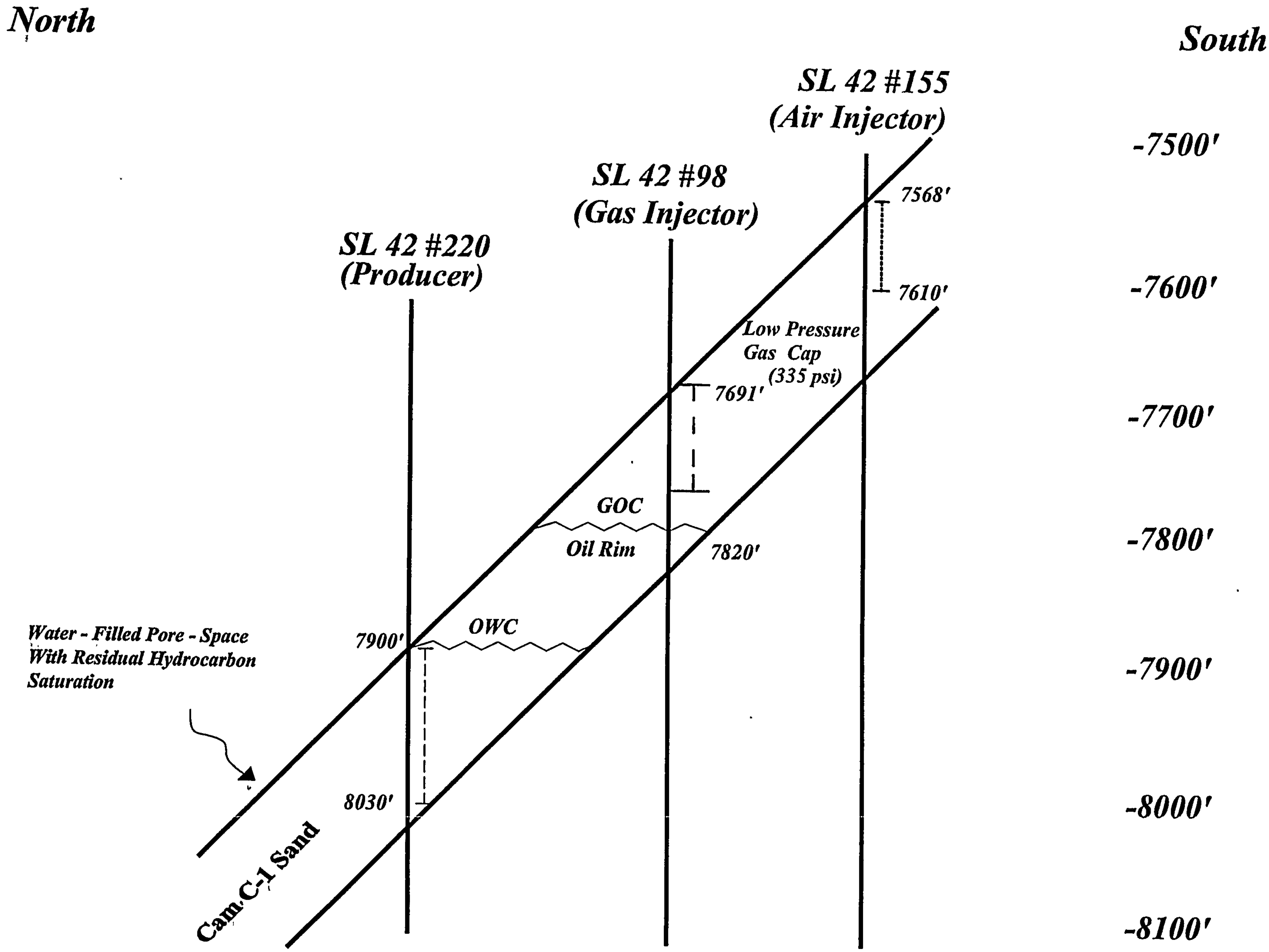



**Figure 5 - Reservoir Schematic of Cam C-1 (located on the north flank of the West Hackberry Field) as of May 1992 and prior to Natural Gas Injection**

## SL 42 No.220(Gas Injection Pilot)