**Feasibility of Optimizing Recovery and Reserves from a
Mature and Geological Complex Multiple Turbidite
Offshore California Reservoir Through the Drilling and
Completion of a Trilateral Horizontal Well**

**Quarterly Report
October 1 - December 31, 1996**

**By:
Steven F. Coombs**

Work Performed Under Contract No.: DE-FC22-95BC14935

For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
Pacific Operators Offshore Inc.
205 E. Carrillo Street
Suite 200
Santa Barbara, California 93101

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

FEASIBILITY OF OPTIMIZING RECOVERY AND RESERVES FROM A MATURE AND GEOLOGICAL COMPLEX MULTIPLE TURBIDITE OFFSHORE CALIFORNIA RESERVOIR THROUGH THE DRILLING AND COMPLETION OF A TRILATERAL HORIZONTAL WELL

Cooperative Agreement: DE-FC22-95BC14935

Institution: Pacific Operators Offshore, Inc.

Report Date: December 31, 1996

Award Date: September 1, 1995

Anticipated Completion Date:

Funding for FY 1995: \$814,718

Program Manager: Steven F. Coombs

Principal Investigator: Pacific Operators Offshore, Inc.

C0-Participants: University of Southern California/ Coombs and Associates

Contracting Officer's Representative: Edith Allison

Reporting Period: October 1, 1996- December 31, 1996

Objectives

The main objective of this project is to devise an effective redevelopment strategy to combat producibility problems related to the Repetto turbidite sequences of the Carpinteria Field. The lack of adequate reservoir characterization, high-water cut production, and scaling problems have in the past contributed to the field's low productivity.

To improve productivity and enhance recoverable reserves, the following specific goals are proposed:

- Develop an integrated database of all existing data from work done by the former ownership group.
- Expand reservoir drainage and reduce sand problems through horizontal well drilling and completion.
- Operate and validate reservoirs' conceptual model by incorporating new data from the proposed trilateral well.
- Transfer methodologies employed in geologic modeling and drilling multilateral wells to other operators with similar reservoirs.

Summary of Technical Progress

Pacific Operators Offshore, Inc. received pre-award authorization for this project effective May 9, 1995 and final approvals were obtained effective September 1, 1995. To date a significant amount of progress has been made on development of a database, which includes production data (project task 1.1.1), well log data (project task 1.1.2), well completion data (task 1.1.3) well test and PVT data (project task 1.1.4). Further, since the last progress report (July-September, 1996)

additional work has been completed in the various data analysis tasks, specifically Well log Data (task 1.1.2), stratigraphy and micro lamination (task 1.2.1) and reservoir performance (task 1.2.2).

Task 1.1.2 - Database: Well Log Data

Oil water contact picks were re-evaluated with sections representing true vertical depth logs. Quality control consisted of use of the data in Strata Model, comparing the data with top and bottom picks and plotting a number of computer cross sections which included the oil water contacts. The computer cross sections were also used to scrutinize the effect of production in the key areas. For these areas, studies have been started to assess the effect of production on logs for mapping swept and unswept oil, and to evaluate remaining reserves. Several potential remaining productive areas have been identified and additional evaluation is in progress.

Task 1.2.1 - Stratigraphy and Micro lamination

Lithology of cored sections has been investigated. A brief lithology description for each zone is given in Table 1. A detailed study of thin shales and silt stones in cored wells is in progress. This study will include comparisons of resistivity logs, continuity of thin shales and silts tones and their effect on past production. The three dimensional visual model, Earth vision (Dynamic Graphics Software) is now being used for visualization, comparison and posting data.

Task 1.2.2 - Reservoir Performance

PRODUCTION ALLOCATION

Three modifications have been incorporated in the production allocation program. Reservoir pressure history has been used to estimate the pressure at the end of each producing month. The water saturation at the end of each time interval was updated by replacing produced oil by water. The drainage volumes for individual wells in each sand were also updated at the end of a given time step. It was assumed that the drainage volumes of the wells in each sand are directly proportional to the well's cumulative oil production and inversely proportional to the initial hydrocarbon column.

REEVALUATION OF ORIGINAL OIL IN PLACE

Material Balance - Monte Carlo Simulation

A Monte Carlo Simulation approach was devised to estimate OOIP in lease OCS P-0166. The material balance equation was rearranged in the following form:

$$N_i = a \times N_{pi} + b$$

where N_i is an apparent estimate of initial oil in place at different time steps, i . Assuming no water influx, N_{pi} is cumulative oil production at different time steps and a and b are constants. For a reservoir with water influx, N_i tends to show mono-tonically increasing linear correlation with N_{pi} .

The true value of original oil in place may be obtained by plotting N_i versus N_{p_i} and extrapolating the straight line to $N_{p_i} = 0$. In this study a least squares approach was used to calculate the intercept of the straight line. Early time, data during which the reservoir was fully developed, were excluded. A correlation has been used to calculate the PVT data. Average initial fluid parameters have been assumed to produce bubble point pressure very close to initial reservoir pressure. Average porosity of normal distribution with a mean of 24.75 % and standard deviation of 2.48 was assumed. Also an average connate water saturation of normal distribution with a mean of 40 % and standard deviation of 3 was assumed. Initial reservoir pressure of triangular distribution with a most likely value of 1500 psig was assumed with a minimum and a maximum values of 1440 and 1560 psig respectively. Further triangular distribution of pressure values was made to cover a range of 95 to 125% of those shown in Table 2. Assumptions were also made for cumulative gas production to cover a minimum range of 80 to 90 % of those values given in Table 2 and a maximum range of 111 to 125%. Cumulative water and gas injection data is given in Table 3.

Monte Carlo Simulation results are given as follow. The OOIP distribution and estimates are shown in Figures 1 and 2.

Estimation of OOIP

Summary:

Display Range is from 50,000,000 to 325,000,000

Entire Range is from 63,000,000 to 323,000,000

After 1,000 Trials, the Std. Error of the Mean is 1,300,000

Statistics:	Value
Trials	1000
Mean	167,000,000
Median	162,000,000
Mode	---
Standard Deviation	41,994,564
Variance	2e+15
Skewness	0.53
Kurtosis	3.27
Coeff. of Variability	0.25
Range Minimum	63,218,309
Range Maximum	322,749,981
Range Width	259,531,672
Mean Std. Error	1,327,984.72

RESERVOIR DESCRIPTION

The geological structure of Lease P-0166 has been re-evaluated and the traces of normal faults have

been identified. A study of the fault blocks and their communication has been started. This study will include information about past measurements of reservoir pressure, measurement of new key point pressures, transient tests and production history.

1.3.1 Management and Administration

Monthly meetings were held with the participants in the project (USC, Coombs and Associates,.....) to review the progress of various tasks.

1.4.1 Tech Transfer

During this period we completed the following activities:

- September - October, 1996: Participated in brain-storming sessions related to the initial formation of the West Coast PTTC.
- Conducted sessions with the CSLC to demonstrate that the State portion of field has significant remaining reserves and that it should be included in the Class III study for potential drilling.
- Pacific Operators was invited to contribute its reservoir database as an example of slope and basin reservoir as a part of the on-line database under development between USC and LLNL.
- November 1, 1996: Pacific Operators became a member of the producers advisory group, known as PAG, that advises PTTC and works with CIPA.
- October 23, 1996: POOI participated in the planning committee for the design of the California Comprehensive database system.
- November 12-13, 1996: POOI co-sponsored the PTTC exhibit at the Pacific Coast Oil and Gas Show in Bakersfield, in Bakersfield, Ca.
- November 26, 1996: POOI co-Sponsored the West Coast PTTC Problem Identification workshop in Ventura, Ca.
- November 26, 1996: Steve Coombs presented a talk at the West Coast PTTC Problem Identification workshop titled "Problems and A Potential Solution to Excess Water Production From The Turbidite Sands, The Carpinteria Field".
- December 6, 1996: Co-sponsored the West Coast PTTC opening ceremonies and provided exhibits demonstrating progress on the Class III project.
- December, 1996: Provide data from the Carpinteria Class III project for the California reservoir database which will be exhibited on the ACTI database via the Internet.

TABLE 1
CORE ANALYSIS

Layer	Well	Depth: SSD (MD)	Description
E1	A-49	2629 - 2649 (2786 - 2806)	Interchanging areas of: 1. Sand, 2. Sand w/ traces of silt and shale, 3. Shale (small sections -- 2 - 3 ft total)
	A-9	2575 - 2615 (2792 - 2832)	All Sandstone
	B-45	2271 - 2309 (2418 - 2458)	Silty Sand throughout
E1A	B-45	2311 - 2327 (2459 - 2475)	Silty Sand throughout
F1	B-15	2688 - 2748 (2912 - 2972)	Mostly Sandstone with traces of Claystone
	B-45	2759 - 2815 (2910 - 2976)	Silty Sand throughout
	A-9	3014 - 3072 (3247 - 3305)	Sand for first 49 ft; then 7 scattered increments of shale (0.4-0.8 ft thick)
F2	B-15	2830 - 2850 (3070 - 3090)	Silts tone for first 3 - 4 ft then all Sandstone
F4	B-15	3105 - 3125 (3345 - 3365)	Silts tone for first 4 - 5 ft then Sandstone with thin streaks of silt
	B-45	3126 - 3143 (3277 - 3294)	Silty Sand throughout
G1	B-15	3346 - 3366 (3591 - 3611)	Mostly Sandstone with scattered traces of Silts tone (0.2 - 0.6 ft thick)
	B-35	3349 - 3369 (3445 - 3465)	Sandstone with consistent streaks of shale and silt
	B-45	3396 - 3412 (3547 - 3563)	Silty Sand throughout
G1B	B-15	3390 - 3410 (3636 - 3656)	Mostly Sand with traces of shale (streaks about .1' thick). About 5 - 6 streaks total
G2	A-9	3738 - 3754 (3986 - 4002)	Mostly Sandstone with scattered traces of Silts tone (each 1' thick)
G3	B-35	3496 - 3514 (3592 - 3610)	Sandstone with paper thin streaks of shale
	B-15	3483 - 3523 (3730 - 3770)	Sandstone with many traces of Silts tone (mostly 0.2' thick but 4 scattered occurrence of 1' thick)
	B-15	3556 - 3576 (3803 - 3823)	Top portion mixed with Sand and Clay Pebbles; bottom mostly Sand with 1' Silts tone at 3823'.
G3B	B-15	3646 - 3666 (3895 - 3915)	1 Ft Mudstone at top and the rest all Sandstone with 1 ft shale in middle
G6B	A-9	4315 - 4330 (4565 - 4580)	WATER SAND----->At top and middle, mostly Sand and Clay; at bottom all Sand
G6B (sub-thrust)	A-9	4939 - 5019 (5190 - 5270)	All Sandstone for first 35 ft. Traces of Silts tone appear (2 scattered increments of 1' thick). Bottom is Sandstone

TABLE 2

PRODUCTION DATA FOR MATERIAL BALANCE

Date	Pressure	Cum. Oil	Cum. Gas	Cum. Water
YYMM	psig	MSTB	MMSCF	Mbbbls
6912	1400.00	8850.15	5984.34	1224.79
7012	1150.00	14003.43	10545.15	3691.13
7112	840.00	17354.14	12914.52	7259.29
7212	800.00	19915.88	14515.57	11105.35
7312	790.00	22105.33	15989.57	14145.24
7412	775.00	23976.40	17264.05	17337.19
7512	765.00	25737.86	18226.75	20727.54
7612	757.50	27468.60	19154.33	23943.15
7712	750.00	28983.75	19907.36	26577.11
7812	742.50	30715.08	20913.56	29132.08
7912	735.00	32417.00	22296.50	31731.50
8012	727.50	34139.78	23888.16	33729.06
8112	720.00	35598.79	25383.18	35550.60
8212	712.50	36696.60	26784.73	37341.10
8312	705.00	37682.64	28063.91	39049.33
8412	697.50	38557.88	29083.95	40571.84
8512	690.00	39330.80	29685.85	42010.80
8612	682.50	39970.74	30154.10	43396.42
8712	675.00	40730.16	30737.70	44999.30
8812	667.50	41446.96	31576.55	46792.03
8912	660.00	42072.58	32552.92	48486.41
9012	652.50	42704.62	34102.98	50033.71
9112	645.00	43310.57	35891.20	51946.43
9212	637.50	43808.62	36791.94	53650.30
9312	630.00	44317.74	37428.98	55423.29
9412	622.50	44787.88	38023.90	57215.68
9512	615.00	45241.29	38505.80	58907.88

TABLE 3
INJECTION DATA FOR MATERIAL BALANCE

Date	Water Injection	Gas Injection
YYMM	Mbbls	MMSCF
6912	0.00	0.00
7012	0.00	0.00
7112	0.00	0.00
7212	0.00	0.00
7312	849.87	0.00
7412	2931.02	0.00
7512	6323.57	0.00
7612	9542.62	0.00
7712	12196.97	0.00
7812	12686.91	27.99
7912	12686.91	614.73
8012	12686.91	1162.53
8112	12686.91	1856.20
8212	12746.62	2694.61
8312	13139.91	3390.49
8412	13531.81	3854.32
8512	13818.95	3908.56
8612	14088.52	3921.19
8712	14327.30	4102.28
8812	14557.83	4546.91
8912	14779.69	5133.10
9012	15074.59	6344.21
9112	15103.12	7536.29
9212	15103.12	7670.01
9312	15103.12	7685.87
9412	15103.12	7710.05
9512	15103.12	7738.92

Figure 1

Figure 2