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TITLE: REACTIVATION OF AN IDLE LEASE TO INCREASE HEAVY OIL RECOVERY THROUGH APPLICATION OF CONVENTIONAL STEAM DRIVE TECHNOLOGY IN A LOW DIP SLOPE AND BASIN RESERVOIR IN THE MIDWAY-SUNSET FIELD, SAN JAOQUIN BASIN, CALIFORNIA

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Contractor Name and Address: Energy & Geoscience Institute at the University of Utah, 423 Wakara Way, Salt Lake City, UT 84108

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Principal Investigator: Steven Schamel

Project Manager: Jerry Castille, Bartlesville Project Office

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Objective

This project reactivates ARCO's idle Pru Fee lease in the Midway-Sunset field, California and conducts a continuous steamflood enhanced oil recovery demonstration aided by an integration of modern reservoir characterization and simulation methods. Cyclic steaming is being used to reestablish baseline production within the *reservoir characterization phase* of the project. During the *demonstration phase* scheduled to begin in January 1997, a continuous steamflood enhanced oil recovery will be initiated to test the incremental value of this method as an alternative to cyclic steaming. Other economically marginal Class III reservoirs having similar producibility problems will benefit from insight gained in this project. The objectives of the project are: (1) to return the shut-in portion of the reservoir to optimal commercial production; (2) to accurately describe the reservoir and recovery process; and (3) to convey the details of this activity to the domestic petroleum industry, especially to other producers in California, through an aggressive technology transfer program.

The 40 ac Pru Fee property is located in the super-giant Midway-Sunset field (Figure 1) and produces from the late Miocene Monarch Sand, part of the Monterey Formation. The Midway-Sunset Field was drilled prior to 1890. In 1991 cumulative production from the field reached two billion barrels, with remaining reserves estimated to exceed 695 MMBO. In the Pru Fee property, now held by ARCO Western Energy, cyclic steaming

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was used to produce 13° API oil. However, the previous operator was unable to develop profitably this marginal portion of the Midway-Sunset field using standard enhanced oil recovery technologies and chose rather to leave more than 3.0 MMBO of oil in the ground that otherwise might have been produced from the 40 ac property. Only 927 MBO had been produced from the property when it was shut-in in 1987. This is less than 15% of the original oil-in-place, which is insignificant compared to typical heavy oil recoveries in the Midway-Sunset field of 40 to 70%. Target additional recoverable oil reserves from the 40 ac property are 2.9 MMBO or greater. The objective of the demonstration project is to encourage a similar incremental increase in production in all other marginal properties in the Midway-Sunset and adjacent fields in the southern San Joaquin Basin.

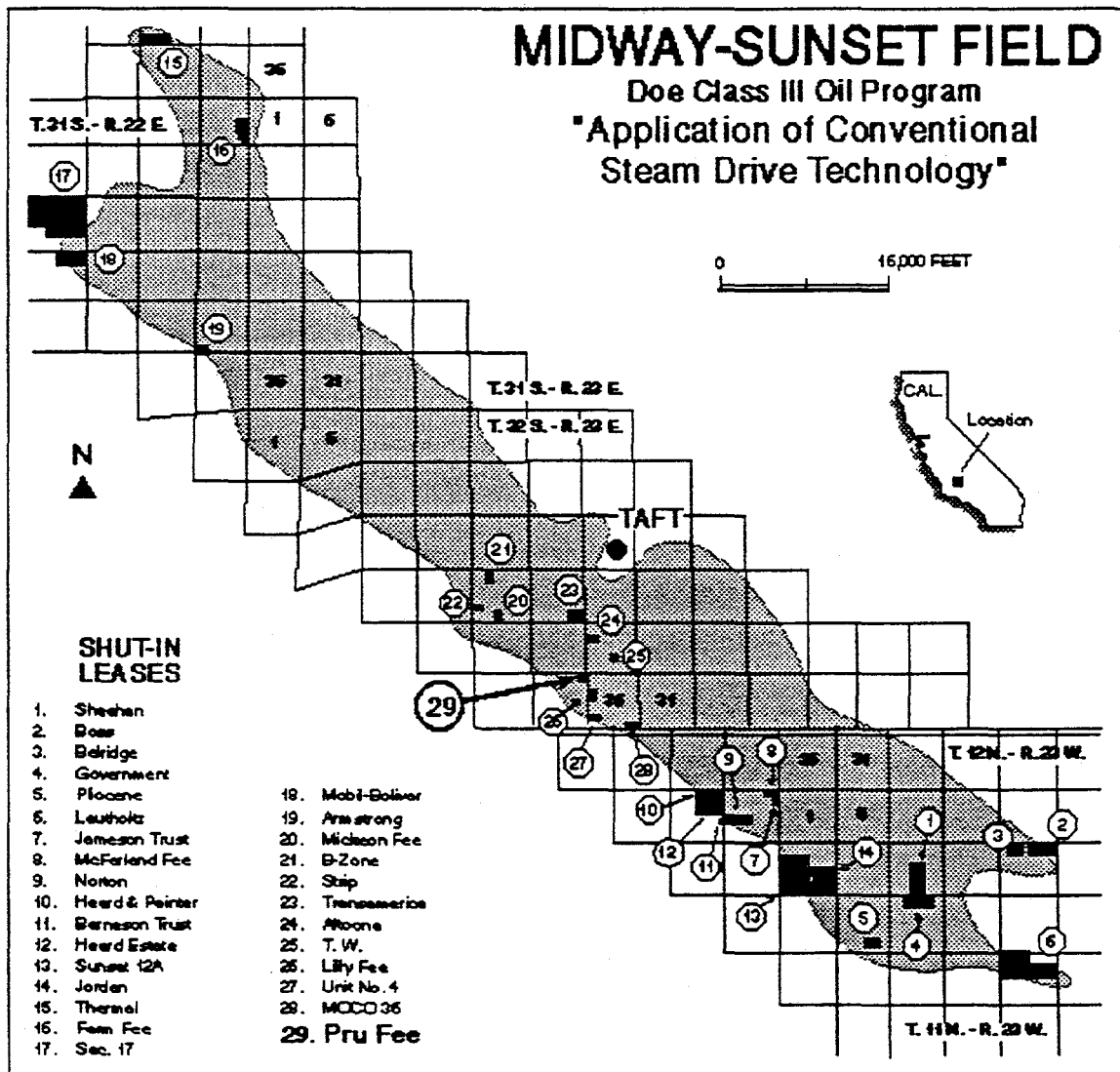


Figure 1: Index map of the Midway-Sunset field showing location of the Pru Fee property and other shut-in leases.

A previously idle portion of the Midway-Sunset field, the ARCO Western Energy Pru Fee property, is being brought back into commercial production through tight integration of geologic characterization, geostatistical modeling, reservoir simulation, and petroleum engineering. This property, shut-in over a decade ago as economically marginal using conventional cyclic steaming methods, has a 200-300 foot thick oil column in the Monarch Sand. However, the sand lacks effective steam barriers and has a thick water-saturation zone above the oil-water contact. These factors require an innovative approach to steam flood production design that will balance optimal total oil production against economically viable steam-oil ratios and production rates. The methods used in the Class III demonstration are accessible to most operators in the Midway-Sunset field and could be used to revitalize declining production of heavy oils throughout the region.

Summary of Technical Progress

Cyclic Steaming Baseline Tests

One of the main objectives of Budget Period 1 was to return the Pru Fee property to economic production and establish a baseline productivity with cyclic steaming. By the end of the second quarter 1996, all Pru producers except well 101 had been cyclic steamed two times. Each steam cycle was around 10,000 barrels of steam (BS) per well. No mechanical problems were found in the existing old wellbores.

After the first round of steam cycles it was readily apparent that the new Pru 101 well was producing much better than the old existing Pru wells. In fact two of the old producers had no response at all to the first steam cycle. There were several possible explanations for the difference in performance, including (1) error in steam measurement/allocation, (2) misplacement of steam in the reservoir and (3) formation damage in the older wells.

In each of the second steam cycles, we steamed only one well at a time using one dedicated steam generator to make sure that the measured volume of steam was accurate. We also ran injection tracer surveys in each well during the cycle to determine the vertical profile of steam entry into the reservoir. The surveys indicated some variability of vertical profiles from well to well. However, none of the profiles appeared to be particularly unfavorable from the standpoint of heat distribution. There were no obvious small thief zones taking all the steam, leaving the rest of the interval unheated. Attached is a typical vertical profile (Figure 2) that indicates all of the steam is being confined to the Monarch reservoir, with most of the heat distributed above the tubing tail, as expected.

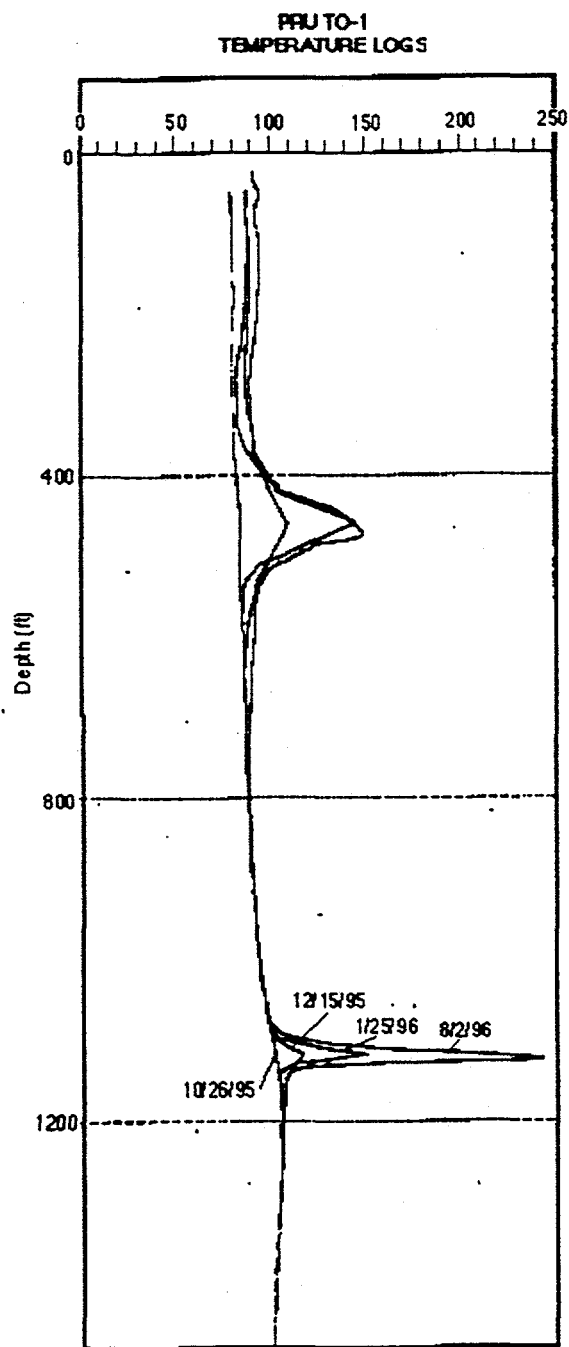


Figure 3: Temperature observation well 1 near the center of the Pru Fee property with recordings during the period of first-cycle steam injection showing steam migration upward into in the Tulare Formation and the upper, depleted zone of the Monarch Sand reservoir.

Production: Total Pru Fee production following the first steam cycle was about 70 BOPD and 300 BWPD, as shown on the attached lease production plot (Figure 4). Due to the concerns about steam placement and measurement, the second round of steam cycles were started before production had stabilized from the first cycle. The drop in production during the second cycle is primarily due to producers being taken off line to inject the second steam cycle.

The total lease production resulting from the first steam cycle was lower than expected. As mentioned previously this is due to poor performance in the old existing wells. As seen in the attached bubble map (Figure 5), post steam oil rates in the older wells were less than 10 BOPD, as compared to the post steam oil rate in new Pru 101 well of 30 BOPD.

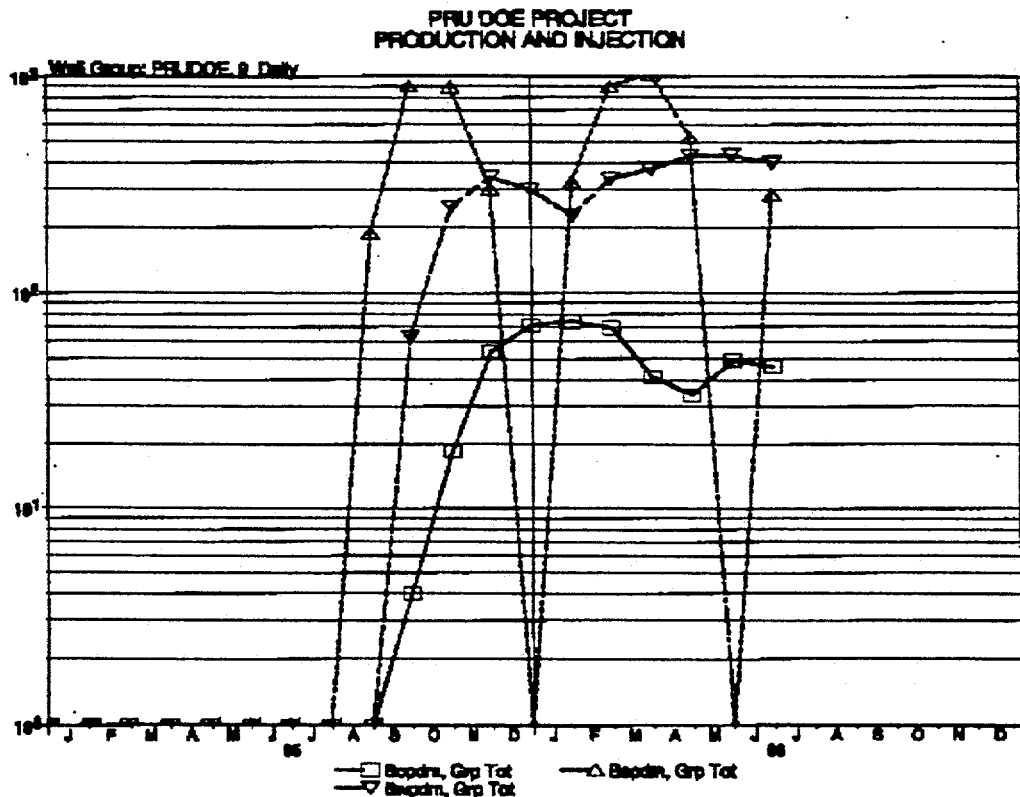


Figure 4: Plot of steam injection and oil production during the first cycle steam injection of the cyclic baseline test. Total for all wells in test is shown.

However, early production results following the second steam cycle are encouraging. Some wells such as producer D-1 shown in the attached production graph (Figure 6), are responding better to the second steam cycle. Time will tell whether this trend will continue. If it does, this may indicate that although the old wells may have a high near wellbore skin as compared to a new well, they may still have the potential to be economic producers as the reservoir heats up with continued injection.

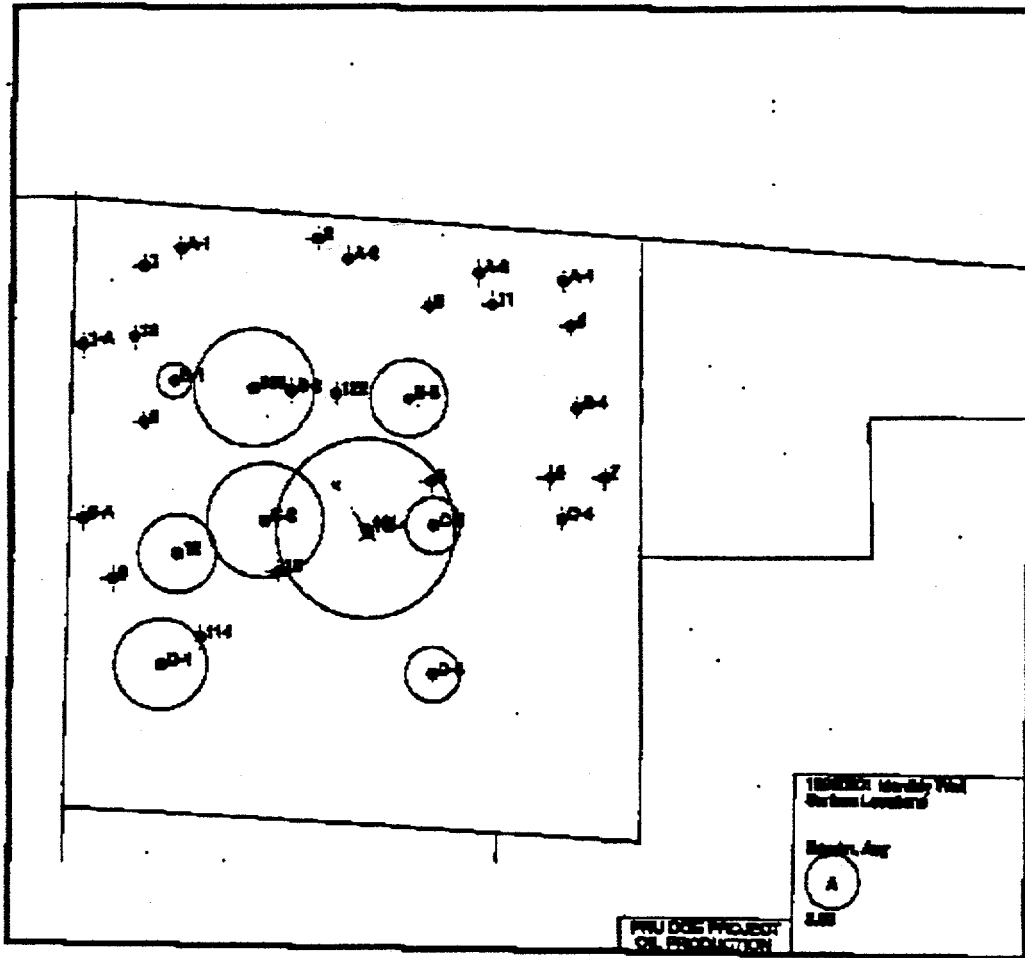


Figure 5: Bubble map of the Pru Fee property showing relative rates of oil production for the operating wells during the first cycle baseline test. Wells with no bubbles were not included in the test.

Conclusion: After several years of being shut-in, the existing producers on the Pru lease are in reasonable mechanical condition, and can therefore be utilized as viable producers in whatever development plan we determine is optimum. Production response to cyclic steam is very encouraging in the new producer, however productivity in the old producers appears to be limited in comparison.

Effectively heating the entire reservoir will be the key challenge in the economically developing the Pru lease.

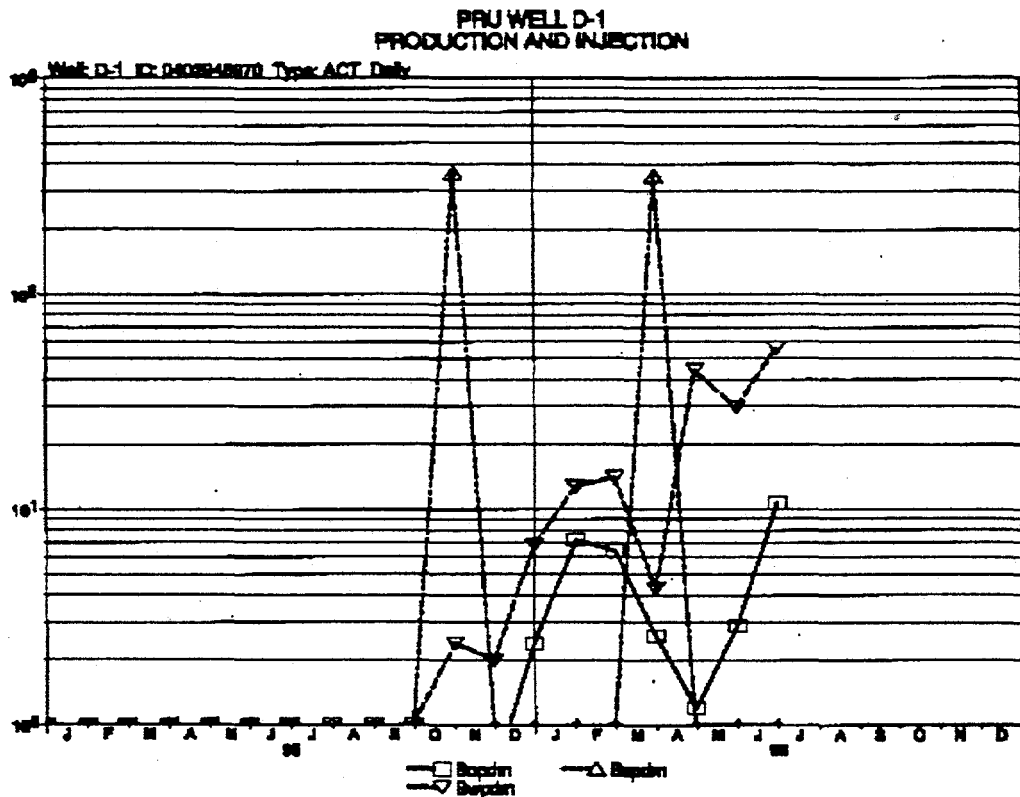


Figure 6: Plot of steam injection and oil production for the D-1 well during the first and second cycles. Note the increase in production rates after the second cycle.

Reservoir Simulation

Effects of reservoir characteristics, such as presence of bottomwater, dip, thinning pay and reservoir heterogeneities on three different thermal processes - cyclic, "pure" steamflood, and "cyclic" steamflood - have been evaluated using two and three dimensional simulations. Results of preliminary three dimensional modeling were described in the fourth quarterly report for 1995.

Conventional practice in the Midway-Sunset field is to complete the injectors over the bottom third of the reservoir pay zone and the producers over the complete pay interval. Using a generic two-well homogeneous model, three different completion scenarios were investigated:

1. injection and production over the entire pay interval
2. injection over the bottom third of the pay interval and production over the entire interval; this is the current standard production mode.

3. injection and production over just the lower and upper third of the pay interval, respectively.

These completion practices were evaluated in a homogeneous reservoir dipping at 30°; both updip and downdip injection strategies were investigated.

In addition to completion and dip evaluations, a 11-layer two-dimensional model with eight wells (four injectors, four producers) was used to perform additional sensitivity studies. Preliminary geologic analysis of the reservoir had revealed that the pay zone consisted of thick uniform layers separated by thin lower permeability layers. The production response was evaluated as the permeability contrast between the high and the low permeability zones and the thickness of the lower permeability layers were varied. Once again, the three different processes were studied. Comprehensive results of the 2-D sensitivity studies will be presented in a forthcoming quarterly report.

Technology Transfer

At the 1996 annual convention of the American Association of Petroleum Geologists (AAPG) in San Diego, California, May 19-22, the project team presented an invited paper in the session *Application of New Technologies to Enhance Oil Recovery*. The paper entitled "Integrated, multidisciplinary reservoir characterization, modeling and engineering leading to enhanced oil recovery from the Midway-Sunset field, California" summarized the purpose of the project and the technical results to date.

References

1. Schamel, S., C. Forster, M. Deo, R. Swain, M. Simmons, D. Sprinkel and R. Adams, 1996, *Integrated, multidisciplinary reservoir characterization, modeling and engineering leading to enhanced oil recovery from the Midway-Sunset field, California*. Presented at 1996 annual AAPG convention, May 19-22, 1996, San Diego, California.