FOSSIL ENERGY

172
10-4-83 JS (11)
I. 11426

Dr. 1800-7

DOE/ET/12059-6

THE "200" SAND STEAMFLOOD DEMONSTRATION PROJECT Sixth Annual Report, June 1981-June 1982

Work Performed for the Department of Energy
Under Contract No. DE-AC03-79ET12059
6

Date Published—August 1983

DO NOT MICROFILM
THIS PAGE

Santa Fe Energy Company—Western Division
Santa Fe Springs, California

U. S. DEPARTMENT OF ENERGY

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DO NOT MICROFILM
THIS PAGE

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.

Printed in the United States of America. Available from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes

Paper copy:	\$7.00
Microfiche copy:	\$4.50

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.

DISCLAIMER

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

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.

DOE/ET/12059--6

DE84 000576

THE "200" SAND STEAMFLOOD DEMONSTRATION PROJECT Sixth Annual Report, June 1981-June 1982

Willie O. Alford, *Principal Investigator*
Santa Fe Energy Company—Western Division
10737 Shoemaker Avenue
Santa Fe Springs, California 90670

H. J. Lechtenberg, *Technical Project Officer*
San Francisco Operations Office
Fossil Energy Division
1333 Broadway
Oakland, California 94612

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE.

It has been reproduced from the best available copy to permit the broadest possible availability.

Work Performed for the Department of Energy
Under Contract No. DE-AC03-79ET12059

Date Published—August 1983

MASTER

UNITED STATES DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION	1
SCOPE OF WORK	3
PROJECT DESCRIPTION	6
a. Reservoir and Geological Data	6
b. Well Completions	7
c. Surface Facilities	8
PROJECT PERFORMANCE	10
a. Steam Injection	10
b. Production	11
FUTURE PLANS	12

LIST OF FIGURES

FIGURE I-1	Map of California Showing Midway-Sunset Field	13
FIGURE I-2	200 Sand Contours	14
FIGURE I-3	Viscosity Reduction Curve	15
FIGURE I-4	Cross Section	16
FIGURE II-1	Total Steam Injection	18
FIGURE II-2	Production and Injection History	19
FIGURE II-3	Total Production	20

LIST OF TABLES

TABLE I-1	Summary of Reservoir Data	17
-----------	---------------------------	----

INTRODUCTION

The "200" Sand Steamflood Demonstration Project, a jointly funded venture between Santa Fe Energy Company - Western Division (SFE) and the United States Department of Energy (DOE), is testing an enhanced steamflooding technique in the Midway-Sunset Field, Kern County, California (Figure I-1). The project was initiated in July, 1975, by Santa Fe Energy Company - Western Division (SFE) and was followed by the DOE Cost - Sharing Contract which commenced on June 16, 1976. Estimated time required for the field trial is seven years.

Steamflooding generally has been conducted in Midway-Sunset Field reservoirs which have responded favorably to cyclic steam stimulation in order to increase recovery and accelerate cyclic production. Numerous heavy oil pools in this field as well as other fields have not been adequately developed because of poor cyclic steam performance. The Demonstration Project was initiated in the "200" Sand Pool to demonstrate the operational, recovery, and economic aspects of steamflooding a typical heavy oil reservoir which had unfavorable response to cyclic stimulation. This pool, designated the "200" Sand, contains approximately 50 million barrels of oil-in-place in a structure that lies between 400 and 700 feet in depth. The reservoir produced very little primary oil production and responded poorly to cyclic steam stimulation.

The project is being conducted in two major phases. The first phase was a pilot test consisting of four (4) 2.35 acre inverted seven-spot steam drive patterns, which were not fully developed with producers (Figure I-2). As a result of the response shown by the pilot, the second phase was implemented in 1980-81 by expanding the pilot area to a total of fourteen (14) fully developed 2.35 acre inverted seven-spot patterns (Figure I-2). The steamflood project consist of 42 producing wells and 14 injection wells. Based on prediction and actual performance here and in other heavy oil reservoirs, steamflooding is considered the most promising thermal recovery technique for this reservoir.

SCOPE OF WORK

The scope of the "200" Sand Steamflood Demonstration Project is being done in five phases, which are: (1) pilot site monitoring and evaluation, (2) pilot area expansion, (3) site selection for expansion to full-scale project, (4) expansion to full-scale steamflood, and (5) production monitoring.

The pilot site monitoring and evaluation phase consisted of a comprehensive evaluation of all available reservoir and production data such as well logs, sidewall cores, radioactive surveys, temperature surveys, and production and injection data. Two enclosed producers were key wells in the evaluation of the pilot project. The two interior wells are completed with two types of completion techniques, a conventional gravel-pack slotted liner and a cemented cased-through-zone completion with only the steam drive interval being jet perforated. The purpose of the jet perforated completion was to determine if the steam injection can be restricted to the drive interval. This is accomplished by restricting production to the steam drive interval only. All other producers in the pilot are conventional gravel-pack slotted liner completions. The logs run in the producers and injectors were the formation density compensated log (FDC), compensated neutron log (CNL) and the dual induction log (DIL). Sidewall cores were taken and tested for permeability, porosity, saturation along with lithological description of samples. A minimum of two radioactive surveys are run in each of the injection wells, and a minimum of three temperature surveys are run in each of the producing wells each year. Surface equipment was installed including automatic gauging of production and injection data.

The pilot area expansion phase consisted of two step-out wells and two observation (information) wells. The step-out producers were drilled and completed in February, 1977, and in January, 1979, the information wells were drilled and completed. The step-out wells helped delineate and define the limits of the reservoir. The information wells were drilled to determine the degree of channeling, sweep efficiency, and to evaluate advancement of the flood front from an injector. The suite of logs run in the four wells were DIL, FDC, and CNL. A minimum of twenty (20) sidewall core samples were taken from each step-out well and analyzed for permeability, porosity, saturations and description of samples. Each information well was conventionally cored through the entire producing zone with a minimum of ten (10) sidewall core samples taken from each well.

The site selection for expansion to full-scale project was based on data obtained during Phase 1 and Phase 2. A pilot evaluation report was prepared in September, 1979, and after it was reviewed by SFE and DOE, both parties agreed that the pilot merited expansion. The expansion area was selected from the economics, production, and reservoir data.

The expansion to a full-scale steamflood phase, which took place in 1980-81, consisted of drilling and completing 10 continuous steam injection wells and 30 producing wells. Concurrent with this development drilling program, the surface equipment and facilities were designed and constructed. A minimum of twenty sidewall cores per well were taken in twelve of the wells drilled, with permeability, porosity, and saturation being obtained. Two producers were conventionally cored. A suite of logs consisting of DIL, FDC

and CNL was obtained in twelve wells drilled during this phase. The remaining wells were logged with DIL as a minimum. Mud logs were run on all wells. The expansion wells will have steam injected continuously in the injection wells and steam injected intermittently, as needed, in the production wells until there is a response to the steam drive process. The reason for the cyclic injection is to remove any wellbore's viscous oil preventing steam breakthrough and production. Response of all ten patterns is expected by late 1982.

The production monitoring phase will consist of three years of data gathering and reporting to complete the demonstration project. The project area will be monitored and evaluated monthly. During this phase of the project, two information wells will be drilled to determine sweep efficiency and permit evaluation of the advancement of the flood front in one of the ten expansion patterns. Each well will be conventionally cored through the entire producing zone, and DIL, FDC, and CNL logs will be run. A final report containing an evaluation of the total project will be prepared at the completion of the project.

Estimated steamflood and cyclic recovery for the total demonstration area is 4.5 million barrels of oil for the 200 foot sand reservoir. If the "200" Sand Steamflood Demonstration Project, which covers 32.9 acres, proves to be economically feasible, steamflooding can be expanded to the entire "200" Sand reservoir, which is approximately 250 acres and contains approximately 50 million barrels of oil-in-place. Likewise, methods and economics could be applied to other reservoirs in the Midway-Sunset Field as well as other fields with similar characteristics.

PROJECT DESCRIPTION

Reservoir and Geological Data

The reservoir is located in Section 17, T32S, R23E, Midway-Sunset Field, Kern County, California. The Spellacy formation, designated the "200" Sand of Upper Miocene Age, contains approximately 50 million barrels of oil-in-place. The crude oil is very viscous with ambient viscosities in the range of 6500 centipoise. Figure I-3 shows as the temperature increases from 90°F (reservoir temp.) to approximately 200°F, the 12° API oil has an approximately 110-fold reduction in viscosity. With the same increased temperature, the oil-water viscosity ratio has a 35-fold reduction and an 18-fold mobility ratio reduction at original saturations.

The reservoir pressure in the "200" pool is very low, in the range of 20-60 psi. This pressure range does not provide sufficient energy for a producing mechanism. Most of the project area is located on top of a monoclinical structure where dips range from 5 to 15 degrees. With the low dips, gravity drainage does not provide an effective mechanism to obtain economical production rates and effectively deplete the reservoir. Herein lies the necessity of steamflooding, to not only reduce the oil viscosity, but also increase the displacement process.

The reservoir, which consists of interbedded sands, conglomerates, silts, and diatomites, is a series of submarine fan-channels with the source area to the northwest of the project area. Figure I-4 is a south-north

cross-sections map of the project. These lower permeability layers of silts, diatomites, or conglomerates, are not laterally continuous and therefore allow gravity override and little control of steam drive profile. However, lateral transmissiblity is better than vertical transmissibility because of the lower permeability layers randomly distributed throughout the reservoir.

The sand is fine to medium grained, with scattered coarse to very coarse grains and pebbles. Usually the sand is clean and extremely friable with the grain held together by the heavy viscous crude.

The average petrophysical properties for all productive sands are 2,250 millidarcies permeability, 30 percent porosity, and an oil saturation before steamflooding of 59 percent, equivalent to an average oil content of 1,373 barrels per acre foot. Table I-1 has a summary of reservoir data.

Well Completions

All 14 injection wells are completed with 5-1/2" O.D. casing strings cemented to total depth. The steam drive interval is jet perforated with 1/2" holes every 2 feet. Steam is injected through an open-ended tubing string with a thermal packer. The tubing and packer is set at the lower 10 feet of perforated interval and approximately 20 feet above perforated interval, respectively.

All, except one, of the 42 producing wells are completed with 7" O.D. casing cemented from surface to top of producing sand, and 5-1/2" O.D. slotted liner from top of producing sand to total depth. The liners are

gravel packed for sand control. One producing well (well 225) had a limited perforated cased-through completion to determine if steam injection could be confined to the drive interval by restricting production in the producer to the steam drive interval. Since discontinuous barriers did not allow steam to be confined to the drive interval, Well 255 was reperforated over the entire sand.

Surface Facilities

The steamflood project receives its steam from two 50-million BTU/hr. and two 20-million BTU/hr. steam generators. The units provide approximately 7,000 B/D steam to the project. One of the 20's has been shut down temporarily for remodification. All the generators are grouped together, approximately one-half mile from the project area, as part of a central steam plant for the area.

In order to comply with the local air pollution requirements, 95% efficient SO₂ scrubber systems were installed on the two 50-million BTU/hr and one 20-million BTU/hr steam generators. To make operation easier, each generator has its own scrubbing system. The non-regenerative sulphur dioxide removal system can use aqueous solutions of sodium carbonate, sodium hydroxide or sodium sulfite as the scrubbing agent. At this time sodium hydroxide is the chemical being used. The disposal material will consist of sodium sulfite, sodium bisulfite and sodium carbonate. Design of the scrubber system do allow for expansion to accommodate more steam generators.

The project is supplied with fresh water from the West Kern Water District. Water with total dissolved solids of 246 parts per million (ppm) is treated at Santa Fe Energy's South Midway soft water plant located on Section 8, T32S, R23E, approximately 1-1/2 miles northeast of the project. This plant is capable of handling approximately 20,000 barrels of water per day. The water system services numerous oil production areas and has operated with only minor problems. The system allows the steam generators to be operated without any appreciable scaling problem.

The oil treating plant, located 1-3/4 miles northeast of the project on Section 9, T32S, R23E, has operated with minor problems throughout the project life. However, treating the fluid production is a major problem because an estimated 90% or greater of all Midway heavy oil is produced as an emulsion. Between 5 and 10 percent of the oil is rejected and has to be pumped back through the treating system with emulsion breaking chemicals.

PROJECT PERFORMANCE

Steam Injection

Continuous injection was initiated in October, 1975. As of July 1, 1982, 3.9 million cumulative barrels of steam have been injected into the project area. Each injector receives steam at an average sand face injection temperature and quality of 350°F and 72%, respectively. Steam at the generator outlets is 420°F with 80% quality. The total project injection is shown in Figure II-1.

With a larger project area, oil displacement and oil viscosity reduction from steam injection is expected to improve. The reason being that a larger heat flux can be obtained in the 33 acres project because of minimum heat losses outside the project area. In the small pilot area the effects of steam leaving was observed when several expansion wells had elevated temperatures which resulted in production above primary level. The larger heat flux with more steam vapor will put more energy in the steamflood by increasing drive pressure which will drive oil more effectively to the producing wells. Furthermore, the heat flux will cause sustained oil viscosity to be less than 60 centipoise. In this viscosity range oil flows much more freely.

This reservoir is rate sensitive therefore, the higher the injection rate, the higher the production. Sensitivity can be expected in a steam drive area where the reservoir with very little dip does not allow for gravity drainage. With the low reservoir pressure, flat formation, and heavy viscous oil, the burden of displacing the crude oil to the producing wells lies primarily with the continuous injected steam. Realizing this, the

initial objectives are getting the producing formation hot and observing maximum production rate potential then optimize the injection rate later. Continuous injection rate is presently at 450 B/D per injector. Rates will eventually be at 500 B/D per injector.

Production

Presented in Figures II-2 and II-3 are the production performance curves for the total project. As shown in these graphs, after expansion and steam injection for one (1) year, the wells are averaging eight (8) B/D oil and 29 B/D water per well. This rate is above the five (5) BOPD for cyclic stimulation. Most of the producing wells are steam stimulated about twice a year to enhance steam breakthrough from the continuous steam. The total area has average 319 B/D oil and 1,233 B/D water the last year.

As mentioned before, the steamflood is rate sensitive, but the production response to changes in injection rate isn't that obvious at this stage because many wells don't have steamflood response. Often, response is hindered by failure to keep wells' pumped-off or wellbore viscous oil plugging slots/perforations. To make this a successful steamflood operation, SFEC steam producing wells often enough to keep wellbores clean and also maintain good mechanically conditions where wellbores are at complete drawdown.

After one year of continuous steam, most of the response is still occurring in the original four (4) patterns. Calculations indicate that a significant amount of oil has been displaced in the expansion area but not produced. Experience with this steamflood indicate the need for future cycling steaming in many of the expansion producing wells to enhance steamflood response and increase recovery efficiency.

The steam-oil ratio is one of the most, if not the most, important economic parameter in steamflood operations. In June, 1982, the instantaneous steam-oil ratio was 19.5, and the cumulative ratio had increased to 12.9. As response takes place and oil production starts increasing while steam volume is being reduced, the steam-oil ratio is predicted to approach the 2.0 to 3.0 range. The breakeven point to operate the project is near the steam-oil ratio of 11.0.

As shown in Figure II-3, production was a little more than 30 B/D oil or 3 B/D oil per producer at the end of 1975. Cumulative additional oil since the start of continuous steam injection totalled more than 330,000 barrels, approximately seven (7) percent of the estimated total recovery from the tota project area. Total recovery is estimated at 4.5 million barrels of oil. This is based on results from the pilot area in terms of recovery efficiency, but at a reduced steam-oil ratio. The reduced steam-oil ratio will result in decreased operating expenses thereby improving significantly overall profitability.

FUTURE PLANS

Continue with high steam injection volume until production and temperature response improve in the area. However, put most of steam in the expanded area where the reservoir is cooler. Most of the cyclic stimulation will be concentrated in the expanded producing wells. When response is significant in the project, steam volume will be reduced carefully to an optimum rate.

Project performance will be monitored through production/ injection data, temperature profiles, injection profiles, and neutron (depletion) logs run in the two (2) observation wells located in the pilot area. Two information wells will be drilled and conventionally cored after sufficient breakthrough and response in the expansion area.

FIGURE I-1

FIGURE I-2

200 SAND CONTOURS
SW / 4 SEC. 17X 32 / 23 MDB&M

□ PILOT DRIVE AREA
□ EXPANSION AREA
⊙ OBSERVATION WELLS

FIGURE I-3

FIGURE I-4

91

TABLE I-1

SUMMARY OF RESERVOIR DATA

DEPTH, FEET	400-700
AREAL EXTENT, ACRES (EST.)	250
OIL GRAVITY, °API	12
RESERVOIR PRESSURE, PSI (EST.)	40
RESERVOIR TEMPERATURE, °F	90
AVERAGE FORMATION DIP, DEGREES	12
AVERAGE GROSS THICKNESS, FEET	200
AVERAGE NET THICKNESS, FEET	150
PERMEABILITY TO AIR, MD	1,050-3,440
AVERAGE POROSITY, PERCENT	30
AVERAGE OIL SATURATION, PERCENT	59
AVERAGE OIL CONTENT, BBL/ACRE-FT.	1,373
OIL VISCOSITY @ 90° F, CP	6,500
OIL VISCOSITY @ 212° F, CP	60

SEC 17 200 SAND STEAM INJECTION

FIGURE II-2

"200" SAND STEAMFLOOD DEMONSTRATION PROJECT

PRODUCTION AND INJECTION HISTORY

FIGURE II-3

UNITED STATES DEPARTMENT OF ENERGY
BARTLESVILLE ENERGY TECHNOLOGY CENTER

P.O. BOX 1398
BARTLESVILLE, OKLAHOMA 74005

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, \$300

DO NOT MICROFILM
THIS PAGE

FIRST-CLASS MAIL
POSTAGE & FEES PAID
U.S. DEPT. OF ENERGY
PERMIT NO. G-20

FIRST CLASS MAIL

Return this sheet to above address, if you
do NOT wish to receive this material ☐,
or if change of address is needed ☐ (indi-
cate change, including ZIP code).