SURTEK

1511 Washington Avenue — Golden, Colorado 80401 — [303] 278-0877 — FAX: [303] 278-2245

RECEIVED

93 MAY 24 11:11:20

RECEIVED U.S. DEPARTMENT OF ENERGY

TECHNICAL PROGRESS REPORT

DOE Contract No DE-AC22-93BC14860

Detailed Evaluation of the West Kiehl
Alkaline-Surfactant-Polymer Field Project
and It's Application to Mature Minnelusa Waterfloods

submitted by
Surtek, Inc.

Contract date: January 7, 1993

Anticipated Completion Date: September 30, 1994

Government Award for Fiscal Year October 1, 1992 to September 30, 1993: \$165,148

Principle Investigator: Malcolm J. Pitts
Surtek Program Manager: Harry Surkalo

Contract Specialist: William R. Mundorf
Contract Officer's Representative: Tom Reid

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.

Report for the Period of
January to March 1993

RECEIVED

JUN 07 1993

OSTI

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

I. Objectives of Study

The objective of "Detailed Evaluation of the West Kiehl Alkaline-Surfactant-Polymer Field Project and It's Application to Mature Minnelusa Waterfloods" is to 1) quantify the incremental oil produced from the West Kiehl alkaline-surfactant-polymer project by classical engineering and numerical simulation techniques, 2) to quantify the effect of chemical slug volume injection on incremental oil in the two swept areas of the field, 3) to determine the economic ramifications of the application of the alkaline-surfactant-polymer technology, 4) to forecast the results of injecting an alkaline-surfactant-polymer solution to mature waterfloods and polymer floods, and 5) to provide the basis for independent operators to book additional oil reserves by using the alkaline-surfactant-polymer technology.

This report will document the initial geological and reservoir engineering data gathering. In addition, some of the initial laboratory results will be discussed. Some evaluation of the West Kiehl has been published.^{1,2}

II. Summary of Technical Progress

Milestone 1 - Geological and Reservoir Engineering - A study area around the West Kiehl Field, located in Sections 25 and 36, Twp 53N, Rge 68W of Crook County, Wyoming, was selected to encompass sufficient productive Minnelusa oil fields to accomplish the objectives of the study. The area selected includes

- Twp 51N - Rge 67W - Sections 4-9
- Twp 51N - Rge 68W - Sections 1-12
- Twp 51N - Rge 69W - Sections 1-3, 10-12
- Twp 52N - Rge 67W - Sections 4-9, 16-21, 28-33
- Twp 52N - Rge 68W - All Sections
- Twp 52N - Rge 68W - Sections 1-3, 10-15, 22-27-34-36
- Twp 53N - Rge 68W - All Sections
- Twp 53N - Rge 69W - Sections 1-3, 10-15, 22-27, 34-36
- Twp 54N - Rge 67W - Sections 4-9, 16-21, 28-33
- Twp 54N - Rge 68W - All Sections
- Twp 54N - Rge 69W - Sections-1-3, 10-15, 22-27, 34-36
- Twp 55N - Rge 67W - Sections 28-33
- Twp 55N - Rge 67.5W - Sections 25 & 36
- Twp 55N - Rge 68W - Sections 25-36
- Twp 55N - Rge 69W - Sections 25-27, 34-36

This area includes over 1,500 Minnelusa penetrations and 62 separate Minnelusa oil producing reservoirs with cumulative production ranging from 3,200 to 9,481,300 barrels. Table 1 list the Minnelusa fields being studied.

Logs and scout tickets were retrieved from the Denver Earth Resources Library on all of these wells. An east-to-west and north-to-south stratigraphic cross section grid of the Minnekahta and Minnelusa section was prepared on an approximate two-mile

grid (10 east-to-west and 4 north-to-south). Utilizing the correlation grid, tops and porous intervals in the Upper Minnelusa were determined for all of the wells within the study area. A data table was constructed listing a stratigraphic breakdown of the productive portion of the Minnelusa formation for all of the retrieved wells. This table includes the tops and bases of the sand units, their porous intervals, drill-stem tests and current oil production. The correlation and tabulation of this data is almost complete. The data table will be used to construct a series of geologic maps that will clearly define the geometry of the 62 producing Minnelusa reservoirs.

A series of geologic maps and cross sections were prepared for the West Kiehl Field. The cross sections were used to define three separate producing zones to be incorporated into the reservoir modeling. The structure and isopachus maps, constructed on a 1"=400' scale, provide the basis for determining pore volumes for each of the zones. Porosity and water saturations from the logs were utilized to calculate hydrocarbon pore volumes. Analysis of the West Kiehl Field has resulted in the following:

<u>Well Number</u>	<u>Layer 1</u>		<u>Layer 2</u>		<u>Layer 3</u>	
	H	oH	H	oH	H	oH

25-10	12	1.571	5	0.406	6	0.624
25-15	16	3.543	6	0.517	8	1.899
31-36	9	1.333	9	0.968	8	1.473
42-36	17	3.827	3	0.283	7	1.351
32-36	4	0.557	0		0	

A thorough search of available cores was conducted through the United States Geological Survey Core Repository in Denver and various industry sources. Since whole cores are preferable for laboratory analysis and general industry practice is to slab cores for analysis of sedimentary structure, the number of satisfactory cores available for the study is small. We were able to obtain three cores of productive Minnelusa reservoirs within the study area that we believe are representative of the West Kiehl reservoir and we are in the process of locating other whole cores.

As soon as the regional map suite is completed on a 1"=2000' scale, ten or more fields will be selected for more detailed analysis as proposed in the "Statement of Work". Two will be selected from this list for reservoir simulation. On the basis of work completed to date at least five suitable Minnelusa reservoirs have been identified. They are: Cambridge, Kiehl, Mellott Ranch, Prairie Creek South, and Semlek North

Milestone 2 - Laboratory and Numerical Simulation Study - The laboratory evaluations were initiated with collection of fluid and rock samples. Crude oil, injection water, and produced water were collected from the West Kiehl. Core

samples were collected from two analogous oil reservoirs: Wolf Draw - Twp 52N - Rge 68W - Section 18. and Guthery - Twp 51N - Rge 68W - Section 3.

Crude oil viscosity at 134°F was 16.9 cp and the API gravity was degree. Produced water is currently contains none of the injected chemicals. The total dissolved solids is 8,100 mg/l and the hardness is 486 mg/l as CaCO_3 . Injection water is from the Fox Hills formation. The total dissolved solids is 838 mg/l and the hardness is 5 mg/l as CaCO_3 .

The interfacial tension at 134°F between West Kiehl crude oil and 0.8 wt% Na_2CO_3 plus 0.1 wt% Petrostep B-100 plus 1050 mg/l Pusher 700 is 0.017 mN/m. Dilution with produced water decreased the interfacial tension. Dilution of the alkaline-surfactant-polymer solution with 20, 40, 60, and 80% produced water increased the interfacial tension 2.7, 3.9, 13.8, and 23.5 fold. These are consistent with previously published interfacial tension values.¹

III. References

1. Clark, S.R., Pitts, M.J. and Smith, S.M.: "Design and Application of an Alkaline-Surfactant-Polymer Recovery System to the West Kiehl Field," SPE Advanced Technology Series, Vol 1, Number 1, April 1993, pages 1-10.
2. Meyers, J.J., Pitts, M.J., and Wyatt, K.: "Alkaline-Surfactant-Polymer Flood of the West Kiehl, Minnelusa Unit," SPE/DOE 24144.

Table 1

MINNELUSA FIELD PRODUCTION – ASP STUDY

TWP 51N to 55N – RGE 67W to 69W

MNL–list

4/9/93

62 FIELDS

FIELD	SEC	LOCATION	
		TWP	RGE
ALPHA	1,2,11	51N	69W
AMERICAN	5,6	52N	68W
AMMO	16, 17	52N	68W
ASH	27,28	52N	69W
BERGER HILL	6	53N	69W
BRACKEN	12,13	52N	69W
BRACKEN SOUTH	13	52N	69W
BREAKS	26	52N	69W
BREAKS SOUTH	35	52N	69W
BRISLAWN		54N	68W
BROUSA DRAW	8	53N	67W
CAMBRIDGE	28	53N	68W
CARDINAL	3	51N	69W
COUNTY LINE	31	52N	68W
DEADMAN CREEK	18,19	53N	67W
EDSEL	25,26,35,36	53N	68W
GUTHERY	3	51N	68W
GUTHERY NORTH	34,35	52N	68W
HEATH	4,5,8,9	53N	68W
HILDA	36	52N	69W
HOOVER GULCH	24	52N	69W
J B	20	53N	68W
JEWEL	7	53N	67W
KIEHL	30,31	53N	67W
KIEHL WEST	25,36	53N	68W
LAD	17–19	54N	67W
LAD SE	20	54N	67W
LILY	27,34,35	54N	68W
LITTLE MISSOURI	5,31,32	54N,55N	67W
LITTLE MITCHELL CR	11,14	52N	69W
LITTLE MO	23,26	53N	68W
M D	6;1,31,36	52N,53N	68W,69W
M D NORTH	25	53N	68W
MELLOTT RANCH	2,10,11	52N	68W
MISSOURI	23	53N	68W
MOORCROFT	31,32	52N	67W
MOORCROFT NORTH	24	52N	68W
MOREL	17	53N	68W
MULE HERDER	32	53N	68W
OSHOTO	21,22	53N	68W
OSHOTO NORTH	22	53N	68W

Table 1

MINNELUSA FIELD PRODUCTION – ASP STUDY

TWP 51N to 55N – RGE 67W to 69W

MNL–list

4/9/93

62 FIELDS

FIELD	LOCATION		
	SEC	TWP	RGE
OSHOTO SOUTH	27	53N	68W
OSHOTO SOUTH–C	27	53N	68W
PONDEROSA RIDGE	21	53N	67W
PRAIRIE CREEK	6	53N	68W
PRAIRIE CREEK SO	16	53N	68W
REYNOLDS RANCH	6;1	52N	67W,68W
RULE	15	52N	69W
SCRIBNER	10	53N	69W
SEMLEK	27	52N	68W
SEMLEK NORTH	21	52N	68W
SEMLEK NW	21	52N	68W
SEMLEK WEST	28,29,33	52N	68W
SIDNER DRAW	17	53N	67W
SIMPSON NORTH	10	51N	69W
TERRACE	11,12	51N	69W
TERRY CRAW		54N	68W
TEXAS TRAIL	14,23	53N	68W
TRAVA	21	52N	67W
WAGONSPOKE	3;34	52N,53N	69W
WILDFIRE	21	53N	68W
WOLF DRAW	18	52N	68W

END

**DATE
FILMED**

7 / 8 / 93