16-3

Dr # 1151

BERC/TPR-77/2

**COMMERCIAL SCALE DEMONSTRATION
ENHANCED OIL RECOVERY BY MICELLAR-POLYMER FLOODING
M-1 PROJECT—FACILITIES REPORT**

By

Marathon Oil Company
Prepared for ERDA Under Contract No. E(49-18)-2242

Date Published—April 1977

Bartlesville Energy Research Center
Energy Research and Development Administration
Bartlesville, Oklahoma

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

MASTER

TECHNICAL INFORMATION CENTER
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

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.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

NATIONAL TECHNICAL INFORMATION SERVICE PAPER COPY PRICES EFFECTIVE JAN. 1, 1976

Page range	Domestic price	Page range	Domestic price	Page range	Domestic price	Page range	Domestic price	Page range	Domestic price	Page range	Domestic price
001-025	\$3.50	126-150	\$6.00	251-275	\$ 9.00	376-400	\$10.75	501-525	\$12.75	701- 800	\$18.75
026-050	\$4.00	151-175	\$6.75	276-300	\$ 9.25	401-425	\$11.00	526-550	\$13.00	801- 900	\$21.25
051-075	\$4.50	176-200	\$7.50	301-325	\$ 9.75	426-450	\$11.75	551-575	\$13.50	901-1000	\$23.75
076-100	\$5.00	201-225	\$7.75	326-350	\$10.00	451-475	\$12.00	576-600	\$13.75	1001-1100	\$28.25
101-125	\$5.50	226-250	\$8.00	351-375	\$10.50	476-500	\$12.50	601-700	\$16.25	1101-1200	\$32.75

For additional pages, add \$4.50 for each beginning 100 pages. Add \$2.50 per copy for foreign price.

Microfiche \$3.00 (domestic) \$4.50 (foreign).

COMMERCIAL SCALE DEMONSTRATION
ENHANCED OIL RECOVERY BY MICELLAR-POLYMER FLOODING

M-1 PROJECT
FACILITIES REPORT

By

Bruce L. Knight, *Editor*
Bruce D. Thomas, *Principal Author*

Marathon Oil Company
Findlay, Ohio 45840

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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.

Prepared for the Energy Research and Development
Administration Under Contract No. E(49-18)-2242

Bruce L. Knight, *Project Coordinator*
Marathon Oil Company

William D. Howell, *Technical Project Officer*
Bartlesville Energy Research Center
Energy Research and Development Administration

Date Published—April 1977

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
TECHNICAL INFORMATION CENTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

PREFACE

A contract was executed between the United States Energy Research and Development Administration (ERDA) and Marathon Oil Company, Findlay, Ohio, on September 30, 1976, for the purpose of a commercial scale demonstration of enhanced oil recovery by the MarafloodTM oil recovery process.

This commercial scale demonstration is known as the M-1 Project; it is located within Sections 15, 16, 21 and 22, T6N, R13W, Crawford County, Illinois. The M-1 Project area encompasses approximately 407 acres of Robinson Sand reservoir developed in the first decade of the century. The area covers portions of several waterfloods developed on 10-acre spacing in the 1950's that were approaching their economic limit.

The Robinson Sand reservoir is a stream channel sandstone deposition of Pennsylvanian age at a depth of approximately 950 feet. Extensive reservoir studies were conducted to define the area and to determine flooding patterns to be developed to conduct the micellar-polymer project. Ultimately, a five-spot pattern configuration was selected using patterns of 2.5-acre spacing and 5.0-acre spacing to analyze relative system performance and economics.

M-1 Project development was begun in October, 1974, with a total of 246 wells being prepared for utilization as process injection or production wells.

TM Trademark of Marathon Oil Company, Findlay, Ohio

Project development also included construction of all facilities necessary for handling injected and produced fluids. Preparation of project wells and injection-production facilities was nearing completion when the contract between Marathon Oil Company and ERDA was executed. In order that information concerning this work be made available to ERDA and the public, Marathon Oil Company proposed a special report be prepared to document the work. This report, the Facilities Report, is the result of this proposal.

This report, then, describes all M-1 Project facilities, how they were prepared or constructed, their purpose and how they operate. These facilities include: 1) wells - drilling and completion; 2) production facility; 3) injection facility; and 4) various service systems required during project development and/or operation. The material is presented in more general form in the report body. An appendix provides additional detail for various systems and specific equipment items.

This report was prepared by Marathon Oil Company's Northeastern District, located in Bridgeport, Illinois. Efforts of the NED staff are gratefully acknowledged. Special acknowledgement is made to Bruce D. Thomas, the principal author.

Bruce L. Knight
Project Coordinator

TABLE OF CONTENTS

	<u>Page</u>
PREFACE.	i
WELL DRILLING AND COMPLETION	1
Injection Wells	1
Production Wells.	3
Abandonments, Reabandonments and Inactive Oil Wells	4
Salt Water Disposal Wells	5
FLUID PRODUCTION	6
Lead Lines.	6
Production Facility	7
FLUID INJECTION.	10
Injection Facility.	10
Supply Water System.	11
Slug System.	13
Polymer System	14
Injection Pump System.	18
Injection Lines	19
Peripheral Water Injection.	20
STAGING AREAS.	22
Roads	22
Pipeyards	22
Miscellaneous Buildings	22
Electrification	23
APPENDIX	26
Production Facility	26
Chem Electric Treaters	26
Catch Boxes.	28
Control System	28
Injection Facility.	31
Water Filters.	31
Water Softeners.	33
Slug Filters	35
Polymer Skids.	37
Control System	40
Triplex Pumps.	43
Quality Control.	45

TABLE OF FIGURES

<u>Figure</u>		<u>Page</u>
A	Production System.	8
B	Water Processing System.	12
C	Slug System.	15
D	Polymer System	16
1	Field Location	49
2	M-1 Project.	50
3	Injection Wells.	51
4	Typical Injection Well Completion.	52
5	Typical Injection Well Hookup (w/Shear Relief Tubing).	53
6	Oil Wells.	54
7	Typical Production Well Completion	55
8	Production Well Hookup	56
9	Abandonments, Reabandonments and Inactive Oil Wells.	57
10	Abandonment Procedure.	58
11	Fluid Disposal System.	59
12	Lead Lines	60
13	Production Facility.	61
14	Produced Fluid Retention Tank.	62
15	Disposal Fluid Treatment System.	63
16	Fluid Disposal Lines and Wells	64
17	Injection Plant.	65
18	Project Injection Facility	66
19	West Side Injection Tank Battery	67
20	East Side Injection Tank Battery	68
21	Heat Exchanger Schematic	69
22	Injection Pump Installation.	70
23	Injection Lines.	71
24	Perimeter Water Injection Wells.	72
25	Access Roads	73
26	Miscellaneous Buildings and Pipeyards.	74
27	Surface Facility Plan.	75
28	Electrical System.	76
29	Production Facility and Electrical Circuit Diagram	77
30	Electrostatic Oil Processing Unit.	78
31	Production Facility Catch Boxes.	79
32	2.5-Acre Hold Tank	80
33	5.0-Acre Hold Tank	81
34	Sell Tank.	82
35	Water Softener - Operating Cycles.	83
36	Water Softener	84
37	Polymer Mixing Skid.	85
38	Injection Facility Air Control System.	86
39	Fluid Injection Control System	87
40	Injection Control Panel.	88
41	Alcohol Blending System.	89

TABLE OF TABLES

<u>Table</u>		<u>Page</u>
1	Conversions and Recompletions.	90
2	Casing and Cementing Data - Injection Wells.	91
3	Injection Well Stimulation	96
4	Casing and Cementing Data - Oil Wells.	97
5	Oil Well Stimulation	102
6	Abandonments, Reabandonments and Inactive Oil Wells.	103
7	Injection System Monitoring and Control Equipment.	104

WELL DRILLING AND COMPLETION

The initial section of this report describes drilling and completion techniques used in preparation of M-1 Project wells for injection of Maraflood process fluids and production of oil and water. Abandonment and reabandonment of existing wells and use of salt water disposal wells are also discussed.

The project location is indicated on Figure 1. Figure 2 illustrates all field well locations. Examination of Figure 2 reveals a shift of well spacing that divides the M-1 Project into two separate areas. The project has 176 wells drilled on 2.5-acre five-spot patterns. These wells are in the southwest portion of the project and are all designated with a single letter and number (e.g., B-6), with the exception of E. C. Burch No. 5, XA-10, XA-12, XA-14 and AA-11, all of which are also included in the 2.5-acre wells. The 70 wells drilled on 5.0-acre five-spot patterns are located to the north and east of the 2.5-acre wells and are designated with two letters and a number (e.g., CC-15). The XA row is part of the 2.5-acre project area, but wells Sally Carlisle No. 14, A. R. Smith Nos. 35 and 36 and Brubaker-Prier Fee No. 18 are also included in the 5.0-acre patterns. These wells are all reconditioned perimeter producers and merely retain their waterflood designations.

Injection Wells

Injection wells for both 2.5-acre and 5.0-acre patterns are designated on Figure 3. The project has 85 injectors for 2.5-acre patterns and 29 injectors for 5.0-acre patterns. Of the 114 total M-1 Project injectors, 101 were newly drilled for the project, nine are oil well conversions, and four are reconditioned waterflood injectors. All recompletions and conversions are highlighted

on Figure 3 and listed in Table 1.

New project wells were generally drilled with contract tools using foam as drilling fluid. These wells typically have 140-160 feet of surface casing cemented in the hole; in every case, an attempt was made to circulate cement to the surface. Drilling to total depth was then completed and the casing long string was set and cemented at the top of the Robinson Sand using either a cement basket or formation packer shoe to protect the zone from cement contamination. The long string was also cemented to surface in most cases. (Casing and cement utilization for injection wells is shown in Table 2.) Injection wells were then completed by drilling out the cement plug and bailing or circulating the hole clean. Various stimulation programs were then implemented to improve injectivity in certain wells. Some injectors were stimulated by open hole shooting with a solid explosive; some wells were acidized; and some were sand fractured. Wells completed using these different stimulation procedures are listed in Table 3.

All injection wells were equipped with epoxy-coated tubing. Tubing was set with a tension packer immediately above the casing shoe of the long string. Figure 4 is a schematic of a typical injection well completion. Figure 5 shows a typical injection well surface hookup. This drawing illustrates the wellhead hookup during polymer injection. During this phase of fluid injection, copper coils of varying lengths regulate flow rate to the well. Copper coils are absent during micellar solution (slug) injection and flow is adjusted by pinching a ball valve. This procedure is not feasible during polymer injection, because the resulting abrupt pressure drop causes severe polymer degradation. However, by installing 1/4-inch I.D. copper tubing, flow control is maintained by the gradual pressure loss due to fluid friction within the coil. The length of

copper coil controls pressure loss so that, by varying the length (and pressure drop), a desired rate can be obtained. Experiments with polymer solution at various concentrations are necessary to determine length of tubing required to achieve required injection rates.

Production Wells

The M-1 Project utilizes 132 oil wells. These wells are contained in the 2.5-acre and 5.0-acre portions of the project as indicated on Figure 6. There are 91 producers in the 2.5-acre spacing and 41 producers in the 5.0-acre spacing. Five wells in the 2.5-acre spacing are reconditioned oil wells. The 5.0-acre spacing also has five such recompletions. All other oil wells were newly drilled

General drilling practice for new oil wells was similar to that for injectors. New oil wells were drilled with foam through the Robinson zone, casing was set above the formation and cement was circulated (in most wells) to surface. Cement quantity and casing size and amount are indicated in Table 4 for all oil wells. Oil well completions also required stimulation in some cases. These are listed in Table 5.

Following stimulation and/or cleanout, all oil wells were equipped with tubing, rods and a pumping unit. In most wells, tubing was run so that the bottom of the pump barrel would be at the base of the casing shoe. Enough tubing was added below the pump barrel to make a mud anchor that extends to approximately 2 feet above T.D. The mud anchor was run open-ended and perforated over an 18-24-inch interval, starting 2 feet below the bottom of the pump barrel. Down-hole pumps used in the M-1 Project are 1-25/32-inch traveling valve-standing valve pumps with a 5-1/2-foot stainless steel pump barrel. The traveling valve

is connected directly to the end of the string of 5/8-inch rods. A typical down-hole installation is illustrated on Figure 7. Figure 8 shows the surface hook-up for a typical oil well.

Abandonments, Reabandonments and Inactive Oil Wells

In addition to developmental drilling and conversions for both injection wells and oil wells, 98 wells have been abandoned or reabandoned during project development. These wells are listed in Table 6 and are shown on Figure 9.

Abandonments reflect those wells either in need of extensive workover or located so as not to lend themselves to use in the M-1 Project. Reabandonments are previously abandoned wells determined to be inadequately plugged for Maraflood process application. Abandonments and reabandonments will prevent migration of injected fluids from the reservoir.

Two general procedures were used for old well abandonment. If casing was cemented to the surface: 1) rods and/or tubing were pulled; 2) the hole was cleaned out to below the base of the Robinson Sand or T.D.; and 3) the hole was filled with cement to 3 feet below surface, where the casing was cut and capped. If casing was not cemented in the hole, intermediate and long strings were pulled from the hole to the extent possible and the hole was abandoned as indicated on Figure 10. All abandonments were executed in accordance with state regulations.

A rotary rig equipped with a mud pump was required for reabandonments. The general procedure for reabandonments was to re-enter the old hole, clean out to T.D. and fill with cement to 3 feet below surface. This procedure was often complicated by poor abandonment practice in years past. Miscellaneous junk was

frequently encountered in the hole during reabandonment activities. In addition, some wells were abandoned more than 50 years ago and no surface casing was left in the hole. Exact well location sometimes required excavating the expected location to find the wellbore prior to moving a rig on site. Seven inactive waterflood producers are located in the M-1 Project near its perimeter. These wells, scheduled for abandonment, are shown in Table 6 and on Figure 9.

Salt Water Disposal Wells

Development of the M-1 Project included drilling two salt water disposal wells - SWDW #1 and #2. These wells are located near wells K-5A and A-15, respectively. Each of these disposal wells had 140-150 feet of surface casing cemented to surface. A 7-7/8-inch hole was then drilled, using mud, to below the Salem formation and a long string of 5-1/2-inch casing was set through the formation and cemented in two stages. Total depths for SWDW #1 and SWDW #2 are 1,960 and 1,949 feet, respectively. SWDW #1 was completed in the Salem zone and also in the McClosky, Cypress and Basal Pennsylvanian zones. SWDW #2 was completed only in the Salem formation. Two and seven-eighths inch O.D. EUE tubing was then run to above the Salem zone in each well and set with a tension packer. Salt water disposal well surface installation is shown on Figure 11.

FLUID PRODUCTION

The dual-pattern nature of the M-1 Project dictated that the fluid production system be designed to allow independent operation and evaluation of the two project segments. Produced fluid lead lines from oil wells to the production facility are designed so that the 2.5-acre and 5.0-acre systems are independent and two distinct produced fluid streams enter the production facility. Similarly, the overall production facility is two completely independent facilities - one for 2.5-acre pattern fluids and one for 5.0-acre pattern fluids. Salt water disposal does not require segregated facilities and produced water streams from the production facility are piped to a common disposal system.

Lead Lines

To maintain the dual nature of the M-1 Project's spacing scheme, two distinct lead line systems are incorporated into the production system - one for all 2.5-acre patterns, the other for all 5.0-acre patterns. The entire produced fluid lead line system was laid underground from the oil wells to the production facility. Most of the system was fabricated from plastic line pipe and laid in a common ditch with the electrical distribution system. This was an economy measure that also resulted in a more maintenance-free electrical supply due to the absence of damage-prone overhead lines and utility poles. Also, presence of electrical lines in a common ditch facilitates location of plastic lead lines and results in more usable land for the surface owner. While lead lines are plastic, each wellhead is hooked up with a single joint of 2-inch diameter steel line. Steel was used to minimize damage to the gathering line from jolting of the surface hookup during well servicing operations. The joint of steel line pipe is connected to the 2-inch diameter plastic line used for the lead line

from each well and for many smaller gathering lines. Line diameter increases to 3 inches and finally to 4 inches for the primary produced fluid line for 5.0-acre patterns. The 2.5-acre patterns also used graduated line sizes. The primary line diameter is 6 inches.

Line locations and sizing information are indicated on Figure 12. Check valves are used throughout the system at main gathering system junctions to prevent backflow in the event a leak develops in any of the lead lines. Each oil well is also equipped with a combination check-and-plug valve to prevent lead line pressure from causing backflow into any well.

Production Facility

Produced fluids enter the production facility in two separate streams. Throughout the facility, dual separation processes are maintained so that produced fluids from the 2.5-acre and 5.0-acre patterns are never commingled, assuring independent data collection and project analysis. A production facility schematic is presented on Figure A (following page); Figure 13 is a more detailed illustration.

Each fluid stream is piped to a battery of retention tanks. The 2.5-acre battery is comprised of three 880-barrel vertical tanks; four standard 300-barrel tanks are utilized in the 5.0-acre system. Figure 14 illustrates operation of a typical retention tank. Fluid enters the retention tanks at the bottom under gathering line pressure, filling the tank and displacing any free oil. The first tank fills until a capacitance probe near the top senses high water content fluid, at which time fluid is diverted into a second retention tank. The first tank is then allowed a predetermined quiescent period for free water separation.

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

PRODUCTION SYSTEM
FIGURE A

After separation, a clock mechanism actuates an air-operated valve that opens, allowing the tank to drain. Draining continues until a second capacitance probe, located near the tank bottom, detects increased oil content in the fluid. The valve is then automatically closed, permitting the filling-water separation cycle to be repeated. The retention tanks, then, have two products - separated oil and high water content waste material. The free oil is piped to hold tanks while waste material is transported to the disposal system catch boxes. From the hold tank, free oil is pumped to either the 5.0-acre chem electric treater or to either of two chem electrics for 2.5-acre patterns. At the treater, final separation occurs and clean, dry oil is scanned by a BS&W monitor and routed to the sell tank for retention prior to LACT unit runs. If its quality is inadequate, oil is diverted to the inlet side of the retention tanks, where the separation procedure is repeated.

Water and other waste material, including emulsion, are transferred to a catch box. The catch box serves as a surge tank to maintain constant suction head to the transfer pump that moves fluid to the produced water pits at the Dewey treating system (Figure 15). Here, produced water is retained for settling and further treatment prior to disposal in the two salt water disposal wells (Figure 16).

FLUID INJECTION

The high cost and unique characteristics of micellar-polymer fluids dictate that their quality and distribution in the reservoir be carefully controlled. These considerations are reflected in special design features in the fluid injection system that distinguish it from a normal waterflood operation.

The M-1 Project injection system is divided into two parts - the injection facility and the injection lines. The injection facility section of this report is divided to separately analyze individual systems comprising the facility. Additional discussion describes operation of wells exterior to the project for peripheral water injection and pressure maintenance.

Injection Facility

The M-1 Project injection facility is housed in and around a 100 x 70-foot all-weather building designed and constructed specifically for this project. It is an insulated, all-metal building with concrete floor and of suitable size to house all project injection equipment. The only unusual design aspect is a pipeline trench running its entire length. The trench contains all lines necessary to operate the injection system. All injection equipment is located adjacent this trench so lines simply run from individual units into the trench.

To facilitate injection of the different micellar-polymer fluids, injection plant design was based on integration of several sub-systems, each designed to operate during one or more phases of fluid injection. These sub-systems include: 1) supply water system; 2) slug filtering and blending system; 3) polymer mixing system; and 4) an injection pump and manifold system. These systems, plus

necessary support equipment, make up the injection facility. Dual pattern spacing within the project allows injection of micellar solution (slug) and polymer solution to occur simultaneously into the two spacings during part of the project. Simultaneous injection of two different polymer solution concentrations will also occur in the 2.5- and 5.0-acre portions of the project. Figure 17 is an overall illustration of the facility. Figure 18 illustrates tank battery locations with respect to the injection building. Figures 19 and 20 are piping layout diagrams for these batteries. Operation of the injection facility will vary considerably depending on which phase(s) of injection is(are) occurring at any given time. Description of the overall facility is presented on a segment by segment basis to facilitate understanding.

Supply Water System. The supply water system will be operated throughout the project life. It is designed to supply water for several purposes. The most important function is to provide supply water of adequate quality for polymer solution and drive water makeup (Figure B).

Project supply water comes from a fresh water pit near Palestine, Illinois, approximately 13 miles east of the facility. It is transported to the project via pipeline. At the project, it is controlled by a pressure regulator and is piped to twin 600 sq. ft. diatomaceous earth (D.E.) filters. Although two filters are discussed here and illustrated on Figure 17, only one filter is in operation throughout part of the project life. During slug injection and the early phase of polymer injection, fluid requirements are such that only one filter will be used. The second filter will be purchased and installed when required. A second line connects the supply to a 300-barrel backup storage tank to be utilized in the event of a short duration loss in flow from the supply line.

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

WATER PROCESSING SYSTEM
FIGURE B

The filters are connected so that filtered water is piped to dual hold tanks. Waste products from the filter backwash cycle are expelled through a 6-inch drain line to a catch box and then to a pit at the Dewey treating system.

From the hold tanks, filtered water can be either piped directly to triplex pumps for injection or routed to the water softener for further treatment. With additional plumbing, water may be routed directly from the filter to the softener. Water for polymer solution makeup is proportioned through the softener to polymer skids. Waste from softener regeneration operations goes into the drain common to the water filter.

Softening is the final water treatment step. However, several auxiliary operations take place that warrant discussion. One auxiliary line connects unfiltered, unsoftened Palestine water to a brine tank. In the brine tank, water flows through a bed of rock salt, becomes saturated and is piped to the softener brine storage tank to be used during the regeneration cycle. Another auxiliary line connects the Palestine fresh water line to the slug filters. It transports water to the D.E. slurry tank so small quantities of diatomaceous earth can be added to the stream of unfiltered slug. A final auxiliary water line connects the softener and the steam generator water supply tank. This system uses a float valve to supply softened water for the steam generator as required. In addition, taps exist throughout the facility for sampling and/or cleaning purposes. Cleaning requires little more than hosing equipment and concrete floors. Quality control sampling requires more planning and is discussed in the Appendix.

Slug System. Crude oil sulfonate slug (COSS) is produced in Marathon's Robinson Refinery and pipelined to the injection facility (Figure 1). At the facility,

slug is treated to improve quality and to adjust certain physical properties by chemical addition prior to injection (Figure C). At the injection facility, slug is heated to 95-100° F using a heat exchanger (Figure 21). Heating improves filter run time by reducing fluid viscosity and ensuring stable micellar solution. It also provides some measure of protection against paraffin precipitation during cold weather injection. From the heat exchanger, slug is transported to two 300-barrel hold tanks for temporary storage. Slug is pumped from hold tanks to the slug filters. These filters are dual 900 sq. ft. D.E. units, connected in parallel. They can be operated one at a time so that the idle unit can be backwashed and made operational; this guarantees uninterrupted filtration, even during changeover operations. After filtration, slug is piped to the alcohol blending system, where alcohol is pumped from storage tanks and mixed with the slug. Alcohol is a cosurfactant and is necessary to control slug viscosity. Following alcohol addition, COSS is transferred to filtered slug hold tanks and piped directly to the main triplex pump for injection.

Polymer System. This system is comprised of the Dow mixing skids (with hoppers), large bulk storage silos and peripheral equipment used to operate and connect skids and storage silos (Figure D). Much of this equipment will not be purchased and installed until slug injection nears completion. Only the three bulk storage silos were constructed during project development. These units were erected at that time because their large size required the use of certain construction equipment that would be on site only during early development work.

The fundamental unit within the polymer system is the Dow mixing skid. This project will use three such skids - one for the 5.0-acre pattern area and two in parallel for the 2.5-acre pattern area. This arrangement reflects the polymer

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
 Contract No. E (49-18)-2242
 Facilities Report

SLUG SYSTEM
FIGURE C

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

POLYMER SYSTEM
FIGURE D

requirement for the project and the fact that different concentration solutions may be required for the 2.5-acre pattern area and the 5.0-acre pattern area at a given time. Each mixing skid is an "off the shelf" purchase from The Dow Chemical Company. The mixers are identical. Their operation is straightforward; the units are highly automated and require little operator attendance and/or maintenance.

Each mixer is equipped with an overhead hopper capable of holding 150 pounds of dry polymer. Polymer is fed via a vibrating auger screw into a fast-moving sheet of water swirling down a funnel-shaped vessel. The auger can be accurately adjusted to feed polymer at a desired rate, while water flow rate can be varied to allow proper mixing. Water flow rate is regulated by diverting some water around the mixing funnel. This diverted water is added to the polymer solution downstream of the mixer to ensure proper concentration of polymer at the wellhead. The unit is also equipped with emergency shutdown devices that will shut down the power auger in the event of a water flow stoppage, and return it to operation 30 seconds after flow is restored. The entire unit can also be shut down if either insufficient water is available for polymer makeup or if water level in the mixing funnel becomes excessive.

The other primary component of the polymer system is the dry polymer storage and handling system. The conventional method for handling dry polymer is to store the material in 50-pound bags and manually load it into a large floor hopper, which in turn automatically auger feeds it to the overhead 150-pound capacity storage bin. This system will be used at the M-1 Project facility only as a backup. The primary system is to be a bulk loading arrangement with powdered polymer being transported, using vacuum, from storage into the mixing skids.

The facility is equipped with three 25-foot silos, each capable of storing 40,000 pounds of dry polymer. Storage units are designed to accept bulk shipments. During operation, each silo will be connected by a line to the overhead hoppers. A vacuum system will be used to transport polymer through this line. This system will be automatically controlled to keep the hoppers constantly supplied with polymer.

Once dry polymer and water are mixed, the resulting slurry is piped to a tank battery (Figure 20) for the retention required to ensure complete solution of the powder. There are two tank batteries - one for the 2.5-acre pattern area and one for the 5.0-acre pattern area. Each battery is comprised of three 300-barrel tanks in series. Four tanks are equipped with low speed agitators to ensure adequate mixing while minimizing mechanical shear to the solution. Slurry from the skid is introduced into the first tank near the bottom. As the tank fills, solution overflows into the second and third tanks, respectively. Fluid is piped from the third surge tank to the suction side of the main triplex pumps for injection. Formaldehyde is added to the polymer stream for both pattern areas in the first retention tank. Formaldehyde eliminates oxygen-induced polymer degradation. It also functions as a biocide. A concentration of approximately 200 ppm will be delivered using a small chemical feed pump.

Injection Pump System. The M-1 Project injection facility uses three Oilwell 346-P triplex pumps to inject fluids into the two project segments. One pump is used for 5.0-acre patterns. The 2.5-acre spacing area is divided into a north and a south portion, each with a separate pump. The pumps used for 2.5-acre pattern injection are piped so that the same fluid will be injected into both portions while a different fluid can be injected into the 5.0-acre patterns.

Figure 22 shows the three injection pumps with installation lines on both suction and discharge sides of the pumps. This diagram illustrates that the system is designed to permit injection of dissimilar fluids into the two different spacing areas. For example, slug or water can be injected into the entire project. In addition, since the facility has two polymer mixing and retention systems, injection of polymer at equal or different concentrations into the two project areas is possible. Finally, it is possible to inject either slug or water into one area while injecting polymer of any concentration into the other. This installation uses minimal equipment, yet results in a highly versatile system that can be changed from one fluid to another with little effort.

Injection Lines

The dual spacing scheme in the project dictates the use of dual injection systems so that dissimilar fluids can be injected into the two different areas simultaneously. The injection line system is shown on Figure 23. Line sizes are indicated on this figure.

Line sizing for the injection system is important in a micellar-polymer flood. Care must be taken when an acrylamide polymer is used. To minimize polymer shear degradation, steps were taken to eliminate all line constrictions or other flow restrictions imposing an abrupt pressure drop. In addition, lines were sized to minimize shear degradation during all phases of polymer solution injection.

Line size determinations, to minimize polymer shear degradation, were based on field data. Lines were sized so that an experimentally determined maximum flow rate would not be exceeded in any line. A 1-inch line has a maximum rate of

400 BPD. A 2-inch line 1,600 BPD, etc. A 4-inch line is the largest used in the system; its design maximum is 6,400 BPD. In general, this means that a 1-inch line can service from one to three injection wells, depending on net reservoir thickness and injectivity characteristics (all individual injection well lines are 1-inch in diameter). A 2-inch line will supply two to nine injection wells. A 3-inch line can service up to 29 wells. On this basis, a series of three 4-inch lines was laid from the three injection pumps as the main injection lines to the field.

In addition to sizing lines for polymer injection, consideration was given to metallurgy. Problems can arise if slug is exposed to mild steel. If this occurs, iron contamination can be detrimental to the slug. Several alternatives exist for solving this problem. Some stainless steel alloys, for example, minimize the damaging chemical reaction. Use of high pressure fiberglass line pipe is another alternative. It was determined that the best approach was to use epoxy-coated mild steel line pipe. This alternative gives necessary strength while assuring chemical resistance. The entire injection line system was constructed from internally coated line pipe.

Peripheral Water Injection

Reservoir engineering studies indicate off-pattern slug migration can be minimized if waterflood injectors surrounding the project area are activated and used to maintain reservoir pressure at the project perimeter. Although the impact of this fluid migration is small compared to overall project performance, the low cost required to activate existing waterflood injectors justifies the measure economically.

The wells of interest are highlighted on Figure 24. This figure also indicates injection line locations for these wells. All of the wells except P-12, Q-12, R-12 and X-88 are part of the Dewey Plant injection system. Wells P-12, Q-12 and R-12 are in the Brubaker Plant area, while well X-88 is connected to the Bond treating system.

In addition, the possibility exists of utilizing one or more of the UU row wells for water injection. Since the area north of this row was deleted from development and perimeter slug injection is economically unfeasible, three wells (UU-1, UU-3, UU-5) were drilled but never completed. The disposition of UU-1, UU-3 and UU-5 is currently under consideration.

STAGING AREAS

Project facilities include several items not directly related to wells or the injection and production of fluids. These facilities were constructed during field development to support drilling and/or subsequent operations. They include roads, pipeyards, miscellaneous buildings and field electrification.

Roads

Project lease roads were designed to give access to all wells, as indicated on Figure 25. Where possible, layout was designed to best utilize existing public and lease roads. Roads were constructed to maximize pumping operation efficiency while using as little surface as possible. Excluding the public road, approximately 9 miles of lease roads were built for the M-1 Project.

Pipeyards

During developmental drilling, existing pipeyards were supplemented with additional new facilities to expedite movement of pipe. Pipeyards were located both in the field and near the facility, as indicated on Figures 26 and 27, respectively.

Miscellaneous Buildings

Existing buildings are shown on Figures 26 and 27. Several buildings in addition to the main injection building are located near the injection-production facilities. A large garage and maintenance building is located adjacent the production facility. A storage shed is located immediately north of the garage. Three trailers are located near the road and just west of the garage. They include a construction office trailer, a drilling department trailer and a meeting trailer.

Electrification

Electric power is purchased for the project from Central Illinois Public Service. Power is metered and connected to Company primary lines 4-1/2 miles south of Stoy, Illinois. From the meter, overhead primary electric lines run north to the eastern project boundary, then west through the project to the injection facility. Three main transformer banks (150 kva) along this east-west overhead line step the 12,470-volt, 3-phase primary supply down to usable field requirements of 831 volts. All primary and secondary electric lines are illustrated on Figure 28. From the transformers, direct-burial electric lines, in a common ditch with plastic lead lines, carry power to individual wells. Four wires are laid throughout the underground secondary system - three to supply required 3-phase electricity plus a fourth that acts as a grounded neutral. Wire size of direct-burial electric lines is dictated by expected load on the line and the distance it must traverse. The entire secondary system is either #2 or #4 aluminum direct-burial wire, as shown on Figure 28. Although conductor size varies with location, all neutral wires are #4 aluminum. In addition to the 831-volt secondary distribution system, certain areas within the project are connected to a separate 480-volt secondary power supply. Parts of the H. Martin and S. Tohill A/C 3 leases, for example, were added to the project after construction of the electrical system had begun. This meant that an additional 12 pumping units had to be added to the electrical system. The partially completed secondary system, however, was inadequately sized to allow expansion of this magnitude. It was, therefore, necessary to modify the electric system to handle the increased power requirements by tying into the existing primary system at an existing transformer bank located near well G-11. Although this bank steps the 12,470-volt primary down to 480 volts and not 831 volts, its proximity to the wells makes its use advantageous. These 12 wells are, therefore,

equipped with 480-volt, 3-phase motors on the pumping units. The secondary distribution system in this area is also run underground, below the lead line, from the transformer bank to each individual well.

Several other wells were also connected to the existing 480-volt secondary power system. These wells are all perimeter wells that were also added after construction had begun on the distribution system. Perimeter wells connected to the existing 480-volt secondary system are: all wells in the row from B-0 north to V-0; B-4, B-6, B-8, E. C. Burch No. 5, Sally Carlisle No. 14, A. R. Smith Nos. 35 and 36 and Brubaker-Prier Fee No. 18. Each of these wells is supplied with 480-volt, 3-phase power from an overhead line connected to the existing secondary system servicing the nearby waterflood.

Two additional primary lines were built during construction of the electrical system. These overhead lines branch from the main east-west line to each salt water disposal well where transformers step primary voltage down to 480 volts for the disposal pumps and controls. The only remaining aspect of the field electric system is the wellhead hookup and control system. At each oil well pumping unit, whether it is a 480-volt or 831-volt application, the secondary line is connected to the unit motor through a motor controller. A small control transformer inside the control box at each well provides single-phase 120 volts for control circuits. These motor controllers include both a conventional timer so the unit can pump intermittently and a sequence timer so all wells in the field do not start simultaneously after a power interruption. There is an adjustable high pressure shutdown device at each well to protect plastic lead lines from excessive pressure. This shutdown mechanism has a direct high pressure connection from the lead line to a switchgauge that closes a contact at a

predetermined pressure, which in turn opens a "tattle-tale" relay in the control circuit of the motor controller, stopping the motor. The relay must then be manually reset to restart pumping.

Electrical supply for the production facility is illustrated on Figure 29. Power comes from a 480-volt transformer and is delivered to an electrical breaker panel between the sell tanks and the chem electric treaters. From this panel, electricity is supplied to equipment such as chem electrics, pumps and the air compressor. In addition, power is stepped down to 120 volts for use in various control circuits that turn on pumps and activate solenoid valves that open air lines, which in turn control inlet valves or dump valves on various tanks.

APPENDIX

Production Facility

Chem Electric Treaters. The production facility is equipped with three identical treaters (Figure 30). These units are manufactured by C. E. Natco and marketed under the designation "VFH-CWW" Electrostatic Oil Processing Unit. However, the unit is more often referred to as a chem electric heater treater, or simply a chem electric.

Each chem electric is a horizontal vessel 8 feet in diameter and 20 feet long, designed for a working pressure of 50 psig. The unit is designed to process high oil content product from the retention tanks. Fluid enters the top of the vessel near one end over fired tubes. Each unit is equipped with two 18-inch burners fueled by atomized crude oil and air that is drawn by convection into the tubes. These tubes extend about 8 feet into one end of the vessel. At the inlet, fluid is diverted around a shroud that forms an annular space within the vessel shell. Entering fluid impinges on the shroud. Flow becomes turbulent as fluid traverses the annular region. Turbulent flow separates any gas, allowing it to flow back to the inlet for venting. Location of the shroud around the tubes utilizes the heat source to improve gas separation. As fluid passes through the separating section, it flows downward through a network of distributors located beneath the tubes. Open bottoms on these distributors allow free water and sediments to gravity separate, while oil and suspended water are forced upward. The free water level in this section is controlled by a float valve that monitors the level of the interface between the free water and oil phases. As this level rises, the float control sends

a pneumatic signal, which opens a valve to discharge water until the level is sufficiently lowered.

As oil and suspended water move upward, fluid temperature is increased due to contact with the hot tubes and additional gas is released. Gas from this section is vented back to the initial separation area and liquid spills over a baffle to a differential oil control chamber. This area acts as surge to absorb effects of incoming rate variations so that flow through the remainder of the treater will be more uniform. The fluid level is controlled in the differential control chamber by a float-actuated valve. As the fluid level reaches a certain point, a valve is opened and gas pressure within the system forces fluids from the control chamber through a series of orifices into a coalescing chamber. The distribution system in this chamber forces oil and entrained water upward allowing free water and solid particles to migrate to the bottom of the vessel. Flow from this section is also controlled by an interface-type float linked via pneumatic control to a water drain valve.

While free water and solids move out of the system, oil and suspended water flow upward to the electrostatic coalescing area. An electrically charged grid coalesces water droplets, improving gravity separation and allowing removal of oil from the top of the unit. Oil passes a BS&W monitor and is piped to a sell tank for delivery to the pipeline.

Each chem electric treater is also equipped with several other operating and safety controls. For example, each crude oil burner is equipped with a propane-fired pilot. In addition, operation of the heating system is controlled by a temperature controller that operates a float control valve ahead of the fired tubes. Each unit is also equipped with a low level shutdown switch. This is

a safety device designed to stop the burners if fluid flow through the heating section is interrupted.

Catch Boxes. Produced water from both production systems (2.5-acre and 5.0-acre) enters the catch boxes illustrated on Figure 31. Catch boxes provide a constant suction head for the fluid transfer pumps. Each catch box is equipped with a float-actuated switch to control the pump motor permitting it to start automatically when the fluid level increases and stop when the catch box has been adequately drained. Both catch boxes are equipped with field shutdown switches that shut down pumping units in the appropriate area of the field if the pumps encounter an overflow situation. The catch boxes are also equipped with meters and with a common sump pump designed to drain the pump compartments.

Control System. An elaborate control system regulates flow of all produced fluid streams through the production facility.

Individual high pressure pumping unit shutdown switches are located at the lead line near each oil well. The two primary produced fluid lines from the 2.5-acre and 5.0-acre patterns are also equipped with high pressure shutdown switches. These switches are designed to throw circuit breakers at the main transformers, cutting off power to all areas of the field that feed the main lines. If one of the shutdown devices is actuated, a warning light in the plant control room identifies the problem.

Fluid entering the retention tank battery is controlled from a panel adjoining each battery. As fluid separates, it is allowed a pre-determined period

of total quiescence that is regulated by an adjustable timer at the control panel. Following static separation, the timer sends an electrical signal to a solenoid valve on an air line that is connected to a dump valve. The dump valve opens and allows the vessel contents to exit under gravity flow. A capacitance probe located 2 feet from the tank bottom continuously monitors fluid quality at that point. During quiescent separation, free oil accumulates at the top of the tank, and as the fluid level drops sufficiently, this oil layer falls until it is detected by the capacitance probe. When the probe signal reaches a certain level, circuitry within the control panel cancels the signal from the timer to the solenoid valve, control air flow is stopped and the dump valve closes. At this point the tank is still partially filled, mostly with free oil. The capacitance probes can be adjusted to close the dump valve when oil of any quality is detected. This allows product control compatibility with the other fluid separation systems. The tank sits idle for a short period until the control panel opens another air-actuated valve and diverts produced fluid into the tank. Fluid enters the tank at the top, where free gas is separated. Liquids are piped to the tank bottom and released below the oil layer to fill the tank. When the tank is full, produced fluids continue to enter and displace oil from the tank at the top. A second capacitance probe, 1 foot below the top of the tank, monitors fluid until it senses fluid of high water content. The control panel then interrupts the electrical signal to the solenoid valve on the air line to the incoming fluid valve, and fluid entry into the tank stops. At this point the quiescent period begins again and the cycle is repeated.

From the retention tanks, high water content fluid enters the catch boxes and high oil content fluid enters hold tanks. Hold tanks maintain a constant

suction to the three centrifugal pumps feeding the chem electrics. Hold tanks are equipped with head switches that control pump operation. The 2.5-acre hold tank supplies suction to both pumps for the two associated chem electrics. The tank is equipped with five control switches: 1) stop center pump; 2) stop west pump; 3) start center pump; 4) start west pump; and 5) field shutdown. Figure 32 shows the switch arrangement controlling the level in the 2.5-acre hold tank. Orientation of these switches indicates that if the fluid level is above 6-1/2 feet, both transfer pumps will be operating. If the level falls below 3 feet, neither pump will be operating. Between these two points, either (both) pump(s) can be operating, depending upon the situation. The west pump (north chem electric) will only operate when the center pump (center chem electric) cannot handle the entire flow. The center pump is the primary pump, while the west pump is a backup unit.

The 5.0-acre hold tank feeds a single chem electric and has three control switches: 1) stop treater pump; 2) start treater pump; and 3) field shutdown switch. Figure 33 shows the orientation of these switches.

From the chem electrics, pipeline quality oil is piped to the 2.5-acre and 5.0-acre sell tanks awaiting pipeline runs through the LACT unit. Both tanks feed a common LACT unit that intermittently scans both sell tanks. The LACT unit is operated automatically by level controls on the two sell tanks.

Each sell tank (Figure 34) is equipped with three level switches: 1) LACT pump shutdown; 2) LACT pump start; and 3) field shutdown. In addition, the stop and start switches on each tank operate a solenoid valve on the air line

to the tank dump valve. When the LACT unit pump is started by the level control in a particular tank, an electrical signal opens an air line and the dump valve. When the level drops and the pump stops, the electrical signal stops and the dump valve closes. When one tank is emptying, the start control on the other tank is inoperative. This tank will not empty until the level of the first tank actuates the pump shutdown. At this time, control of the pump and the LACT unit is transferred to the other sell tank, which starts the pump if its level is above the pump start level. If the other sell tank has not achieved this level, either tank reaching the required level will be the next to empty.

The compressed air supply that feeds the production facility control system is equipped with self regulating controls and another field shutdown switch. The air supplied to the various valves in the system is furnished by a 75 hp Rollair compressor. Compressor operation is controlled automatically to operate when pressure in the volume tank and air line system falls below 100 psig. Shutdown pressure is 115 psig. Various control elements within the system are supplied with air at 20-25 psig. Instrument air supply is equipped with a field shutdown switch that is actuated if pressure drops below 16 psig. The field is automatically restarted when pressure reaches 19 psig.

Injection Facility

Water Filters. Water filtration at the injection facility is carried out with diatomaceous earth filter equipment (Figure 17). Although dual water filters are shown on this illustration, only one filter will be needed throughout much of the project. Purchase and installation of the second filter will be postponed until low concentration polymer injection is at such a rate as to

require increased filtered makeup water. When the second filter is installed it will operate in parallel with the existing filter and will utilize existing pre-coat and slurry addition tanks, as shown on Figure 17.

Each of the two filters is a 600 sq. ft. unit capable of throughputs up to 10,000 BPD, depending upon source water clarity. The filters are designed to operate independently so that backwashing operations can be staggered, allowing one filter to be backwashed during the other's duty cycle. Backwashing times are very small compared to filter run time. This ensures an uninterrupted supply of filtered water.

Pressures are monitored on both sides of the filter cake during operation of the unit. As the differential pressure increases to 35-40 psi, flow rate across the cake is substantially reduced. Therefore, each filter is backwashed before the differential pressure reaches 40 psi. When a filter reaches the end of a cycle, it is shut down by closing the inlet and outlet valves. The top vent and drain are opened, allowing the tank to empty. After the tank is drained, the cluster of filter leaves is mechanically rotated while water jets spray the screens, displacing the filter cake. The entire operation is done inside the filter shell without opening it. Following backwashing, the drain is closed and other valves are adjusted to allow circulation from the pre-coat tank to the filter shell, through the leaves and back to the pre-coat tank. The vent remains open to displace air as the chamber fills with water, after which it is closed. Pre-coat material is then added to water in the pre-coat tank, agitated to ensure suspension and circulated through the filter. Circulation continues until all of the fibrous filter aid is applied to the filter screens and outlet water is visually clear. At

this point, diatomaceous earth is added to the pre-coat tank and applied in a similar manner to the screens on top of the fibrous pre-coat filter aid. When output water appears clear and passes a Millipore filter test, the filter is ready for operation. The outlet valve is then opened and flow is diverted on stream. The main inlet valve is opened, the filter is isolated from the pre-coat tank and the filter is again ready for routine operation.

Located on the primary filter skid next to the pre-coat tank is a second, smaller tank used for slurry addition to the primary body feed. A diatomaceous earth slurry is maintained in this tank and added to the input stream to the filter. Diatomaceous earth mixes with insoluble impurities in the water and both are collected on the filter cake. In this application, D. E. body feed prevents particulate matter from prematurely plugging the filter.

Water filters are piped to allow input water to be used from two different sources. Water can either be taken from the Palestine water line and put through the filter under line pressure, or water can be pumped from the fresh water hold tank (Q) through the filter. Produced water can be introduced into Tank Q and filtered using these units. Necessary pumps are located on each filter skid and are also used for pre-coat purposes. Another transfer pump is located on the main skid and is used for low rate slurry addition.

Water Softeners. Fresh water used for polymer makeup requires softening to give designed mineral characteristics. However, all water for mixing polymer is not softened. Laboratory data indicate that softened and unsoftened Palestine water mixed in a ratio of 4:1 for polymer makeup gives improved oil recovery in the Maraflood process as applied to Robinson Sand reservoirs.

One-fifth of the water stream is, therefore, bypassed around the softener to be remixed upstream of the polymer skids.

The water softener in use at the injection facility is a Kisco Model TDV 72-4; it is located inside the injection building as indicated on Figure 17. It is actually a dual softener, using an ion exchange treating process and making it in essence an industrial-sized version of the common home water softener. Since it is a dual system, uninterrupted operation can be maintained by staggering the operation sequence so one tower is operating as the other is being regenerated. The unit is designed to operate at 720 GPM (25,000 BPD) with a maximum exchange of 6,000,000 grains per duty cycle. Calculations indicate that at the highest expected injection rate, each tower will require regeneration at 16-hour intervals, with cycle throughput of 4,500 barrels for each tower. The softener skid is equipped with a master control, referred to as the stager, which is used to time individual operations and adjust valves to proceed automatically through the sequence. The four operating cycles are described graphically on Figure 35. Experience indicates that regeneration and rinse cycles last about 1.25 hours, while the duty cycle should last a minimum of 14.5 hours at peak rates. Each softener tower operates during the service cycle by ion exchange using 100 cu. ft. of resin as exchange medium. As illustrated on Figure 35, water flows down through the resin, is softened and exits from the bottom of the vessel. As the duty cycle continues, operating capacity of the resin becomes progressively exhausted until the system will no longer function at the desired rate. At a predetermined time (approximately 3,000,000 grains of ion exchange), the tower automatically terminates the service cycle and begins regeneration. To regenerate, appropriate valves are opened and closed to allow hardened water to flow upward through the

vessel, exactly opposite to flow during the duty cycle. Regeneration acts to clean the resin bed of foreign particulate matter and to maintain bed permeability by preventing compaction due to constant downward flow. Next, brine is circulated from the top of the vessel to react with the resin, regenerating the system and preparing it for operation. Finally, the system is purged of brine during the fast rinse cycle so no dissolved salt remains in the system when it is put on stream.

The installation of twin softener tanks in this system is shown on Figure 36, along with hookup and location of the brine tank. As indicated, the brine tank is connected to both softeners and also to the brine makeup and storage pit located just east of the injection building. This pit contains rock salt through which water flows, providing saturated brine for the softeners. A float control on the brine tank controls a pump timer at the brine pit. When the float lowers sufficiently, the timer actuates the pump long enough to fill the tank. The entire system, from operating to regeneration and finally to fluid level maintenance in the brine tank, is automated and operator time is required only to check the system periodically and to monitor quality control.

Slug Filters. The injection facility utilizes twin 900 sq. ft. D. E. filters designed to filter slug at maximum project injection rates. The twin filters are equipped with a common accessory skid containing one pre-coat tank and one slurry tank with all additional pumping, mixing and other auxiliary equipment necessary for operation. The equipment is located as indicated on Figure 17. During filtration, fluid enters each filter shell from centrifugal pump No. 1, which has the two 300-barrel hot slug hold tanks for suction. Filtrate

is then piped from each filter through the alcohol blending system to twin slug hold tanks. Filters can be operated simultaneously or individually, with the backwash cycle of one filter occurring during the filtration cycle of the other. This ensures constant filtration and prevents injection shutdown due to insufficient filtered slug. Backwashing of these units is different from the water filters. To backwash a slug filter, it is first necessary to shut down the unit and to open the drain from the filter shell to the pre-coat tank. Air is then injected into the top of the unit displacing slug from the filter and back to the pre-coat tank. After the tank is emptied, air circulation continues for about 30 minutes while filter cake is being dried. When drying is complete, the shell is hydraulically opened and the filter leaves with the dried diatomaceous earth cake are withdrawn from the shell. An air-operated vibrator is used to shake the cluster of leaves, dropping the dry cake into a metal pan. Cleaning is frequently supplemented by washing with water. Screens are run back into the filter, the shell is closed and sealed and the unit is ready to be pre-coated and put back on line.

Pre-coating is essentially the same as for water filters. First, a slurry is made up of slug and a fibrous filter aid. The slurry is then pumped through the filter screens, where fibers are deposited. Slurry is circulated until slug appears clean at which time fine grade D. E. is added to the pre-coat tank. The D. E. is deposited onto the fiber layer as slurry is circulated. When slug again appears clear, samples are taken and a Millipore filter test is run to determine slug quality. If the sample passes the Millipore test, the filtrate stream can be put on line for injection. If Millipore quality is inadequate, circulation continues until quality is sufficiently improved.

Polymer Skids. The fluid injection system is designed to use three polymer mixers, manufactured by The Dow Chemical Company, for mixing dry polymer and water. The mixer, referred to by Dow as a polymer dispersing unit, was specifically designed to blend the polymer used in this project.

Use of these units is dictated by two inherent problem characteristics of dry acrylamide polymer. The first problem is associated with the fact that partially wetted polymer particles tend to stick together and become difficult to dissolve. This problem is solved by introducing powder into a fast-moving water stream in a fine spray, thereby effectively dispersing the particles.

The second problem is that oxygen can severely degrade polymer solution quality. This is partially alleviated by designing flow at the point where powder is introduced to be a smooth, non-turbulent sheet of water that minimizes atmospheric contact. This effect can be further reduced by using a nitrogen blanket over the entire system, to prevent exposure to oxygen. However, as a practical matter, it is not possible to completely exclude oxygen from an oilfield fluid injection system. The use of chemical addition to eliminate harmful effects of oxygen on polymer was chosen. Field and laboratory experience have shown that formaldehyde at a concentration of 200 ppm minimizes or eliminates detrimental effects of oxygen on polymer solution. Formaldehyde is added via a chemical pump to the polymer as it enters the first mixing tank.

Use of the Dow polymer dispersing unit, in conjunction with adequate retention tankage and sufficient chemical addition, should assure high quality

polymer solution at the wellhead. This combination has resulted in high quality mobility buffer solution in both of Marathon's intermediate and large scale micellar-polymer projects. The dispersing unit itself is a skid-mounted, self-contained unit with sufficient control mechanisms to allow automatic operation with virtually no operator attendance. A flow line schematic is presented on Figure 37. Water enters the system under line pressure and is pumped through a meter to a tee in the line. At this tee, water flow is broken into an upper stream and a lower stream. The upper stream is piped through a control valve and a visual flow rate indicator and finally to the mixing funnel, where it is mixed with dry polymer. The purpose of the lower stream is to provide flow control. It maintains a constant fluid level in the mixing funnel and ensures uniform and adequate mixing of dry polymer particles with water. The control mechanism for this system is a float-actuated control valve, which varies water flow through the lower flow system. When the fluid level rises the float valve closes, reducing flow through the lower line and allowing the fluid level to drop and normal flow to occur through the lower line. As indicated on the schematic, the upper and lower flow paths meet downstream of the mixing funnel, and the total fluid stream is pumped via Moyno progressing cavity pump to retention tanks for necessary mixing time.

Dry polymer is introduced at the mixing funnel. The funnel is fed by a vibrating auger-type screw feeder. Feed rate is adjusted by regulating the drive motor speed. Larger magnitude adjustments can be accomplished by changing the diameter of the screw feeder. For example, a 1/2-inch screw operates at 25-240 lb/day, while a 1-inch screw can operate at rates as high as 2,800 lb/day.

Each polymer skid is equipped with an extensive control system. There are many controls designed to regulate operation, prevent malfunctions and shut down the feeder or the entire unit under certain conditions. The first shutdown device is a pressure-activated low water supply switch, located on the discharge side of the first centrifugal pump. It is intended to shut down the entire unit if the water supply drops below any pre-determined level. Used in conjunction with this and other shutdown systems is the solenoid valve, indicated in the schematic diagram. This valve is tied into operation of the aforementioned centrifugal pump and is automatically closed if the pump shuts down. The shutdown switch on the centrifugal pump, when activated, will also turn on a warning light on the control panel to call operator attention to the problem. The unit will automatically restart once water supply has been restored and pressure has surpassed the pre-determined minimum level.

The next control device is an integral part of the rota-meter (visual flow rate indicator). It is a shutdown switch designed to affect only the screw feeder. The switch is activated by a reduced flow situation and is accompanied by a warning light on the control panel. This unit is also designed to restart automatically, about 30 seconds after adequate water flow is restored. This ensures complete mixing of the dry polymer from the first instant of blending.

The final automated control is integrated into the float control system. It is activated when the float valve is raised, but the water level continues to increase. This causes an overflow into a stand pipe, which in turn causes a pressure activated switch to shut down the entire unit. As in other systems, a warning light on the control panel calls attention to the problem.

To resume operation, the stand pipe must be manually drained, after which the mixing unit will automatically restart.

Control System. The injection facility uses an elaborate system of air lines designed to transmit pressure signals to monitor tank levels and control diaphragm valves. The system was designed as a failsafe mechanism to prevent spills and damage to lines and equipment. Figure 38 is an illustration of the injection facility air control system. Figure 39 illustrates control installation and operation. Figure 40 illustrates the control panel for the entire system. Injection system monitoring and control equipment is listed in Table 7.

The air control system is comprised of various types of equipment. The basic units include level transmitters, level controllers and monitors and various air-controlled diaphragm valves. The entire control system is operated with compressed air at 20 psig. The air compressor for this system is a Worthington 5 ED 8 located immediately adjacent the injection facility. The compressed air is filtered and dried to -40° F dew point prior to introduction into the system through a regulator. The distribution network for air at this pressure is referred to simply as "supply air". Supply air is delivered through the system to all level transmitters and controllers. It is also piped to the slug divert valve. The distribution network for this system is comprised of 1/2-inch rigid, color coded, Schedule 40 PVC plastic line with a length of flexible 1/4-inch line with NPT fittings on each end to facilitate hookup to individual equipment.

Ten 300-barrel tanks in the injection facility (Figure 38) are equipped with

level transmitters (D,F,G,I,J,K,N,Q,R,S). Each transmitter has 20 psi supply air piped to it. Fluid level in each tank (measured by the hydrostatic head) regulates output pressure of each level transmitter by bleeding a variable amount of supply air to the atmosphere. The output pressure from any level transmitter is referred to as "instrument air". Instrument air can be transmitted to either a level monitor or a level control. A level monitor is a visual level indicator that transforms instrument air pressure back into a display of fluid level. The project is equipped with five such monitors for various tanks (D,I,J,R,S). One of these units also incorporates a recording device on the level monitor (Tank J). This is included to provide plant operators with a permanent record of slug hold tank contents. Instrument air from the remaining five level transmitters (F,G,K,N,Q) goes to the five level controllers illustrated on Figure 40. Each of these controllers incorporates a level monitor similar to those described above. In addition, each controller is tied to an air-actuated diaphragm valve. Any controller can be adjusted from within the injection building to maintain a desired fluid level in any of the associated tanks. Any required fluid level is set by adjusting a control within the injection building to indicate desired level. The level controller then compares actual level (sent from the tank's level transmitter) to desired level. The difference in these two levels is converted to another pressure signal that acts directly on a control valve. If the fluid is at the desired level, the controller will output air at 50 percent pressure (9 psig). This means that the diaphragm valve in question will be 50 percent open. If the tank level is above the desired point, the controller produces a reduced air signal that allows the valve to close further. Since each of the five control valves is on the inlet side of the particular tank, closing the valve restricts flow into the system while injection

operations lower the level to the desired point. If the level is lower than desired, output control pressure is increased above 9 psig and the air-controlled valve is opened further, allowing the tank to fill to the desired level.

A proportioning mechanism is built into each level controller. This proportioner can be adjusted over a wide range of operation. For example, if the proportioner is adjusted so that a 4-foot range is selected, the maximum amount of variation from the desired fluid level will be 2 feet in either direction. If the level is at the desired point, the controller outputs 9 psig and the valve is 50 percent opened. However, if the proportioner is set to the 4-foot range, an increase in fluid level will gradually change the control valve from 50 percent open to completely closed (3 psig) when fluid reaches 2 feet or more above the set point. On the other hand, the valve is completely open (15 psig) when the fluid level drops 2 feet or more below the desired point. A trial and error setting usually generates the best operating conditions. If too broad a range is selected, fluid level will fluctuate over a great distance and system control will be inadequate. If too narrow a range is selected, the system will act "nervous" and the valve will open and close too frequently due to overcontrol. It has been determined that the best way to adjust a controller is to input the required fluid level and then adjust the proportioner until the valve starts to fluctuate excessively. If the proportioner is backed off slightly at this point, cyclic action of the valve should be greatly reduced and the controller will operate more satisfactorily.

Injection pumps are also equipped with an adjustable control for a pressure relief bypass valve. This protects the formation and injection lines without

stopping the pumps. If the discharge pressure exceeds a preset value, enough flow is diverted from the system to reduce injection line pressure. Controls are located on the monitoring panel and are operated by adjusting a dial to the desired pressure. Actual pump discharge pressure is transmitted to the controller through a 1/8-inch high pressure line while supply air is also brought to each controller. Operation of these controllers is similar to that previously described: actual and desired pressures are compared and the difference is converted to a low pressure control signal that acts on a pressure relief valve at the triplex. The only difference in this system is that its incoming signal is a direct high pressure source and not a low pressure pneumatic signal.

The injection facility is equipped with one additional air control system. This is an adjustable control within the plant that regulates alcohol addition to filtered slug. This unit is connected to supply air; it also receives an instrument air signal from a target flow meter in the slug line. The mechanism within the controller is designed so that output control air is proportional to the product of the signal from the target flow meter and the input concentration percentage. This regulates the drive speed of the pump used for alcohol addition. The control unit for this system also uses a low pressure shutdown switch that will turn off the motor to the blending pump if slug flow stops. The alcohol blending system, including associated controls, is illustrated on Figure 41.

Triplex Pumps. The M-1 Project uses five Oilwell 346-P triplex pumps for injection of Maraflood process fluids and salt water disposal. The three pumps used for Maraflood process fluid injection are identical but differ slightly

from the two disposal pumps. Pump applications vary only in that a higher rate and pressure can be tolerated in the disposal wells compared to project injection wells. Therefore, disposal pumps are equipped with 100 hp motors while injection pumps have only 60 hp motors. Also, while all pumps have a 6-inch stroke, the plunger diameter of injection pumps is 3-1/2 inches while disposal pumps are supplied with 3-1/4-inch plungers. Maximum rates for the injection and disposal pumps are 8,228 BPD and 7,095 BPD, respectively. Any of the Oilwell triplex pumps used in the project can be operated from 100 rpm to the maximum rate by changing the ratio of the diameter of the belt driven sheaves on the electric motor and the pump crankcase. If very large rate adjustments are required, the fluid end of the pump can be altered to use larger or smaller diameter plungers. The versatility of this pump is a primary reason for its use in both Maraflood process fluid injection and disposal. It is a common oilfield pump and has the added benefit of part interchangeability with equipment used in other projects.

The fluid end of these pumps is constructed of aluminum bronze to prevent iron contamination during slug injection. The rest of the unit is fabricated from ordinary carbon or stainless steel as strength requirements dictate. Ceramic plungers are used for injection. Installation of disposal pumps differs from that of the injection pumps. The injection pumps are each equipped with a suction stabilizer that uses compressed air on variable-sized chambers to maintain constant pressure at each pump suction. These pumps also use a variable, remote-controlled pressure bypass and high-low pressure shutdown, all of which are adjusted within the control room. All five pumps are equipped with a low oil pressure shutdown to protect the pump in case oil pressure drops severely. Each injection triplex is equipped with a multiple cartridge

final filter on the discharge line. The output fluid is pumped through this filter to remove any contamination picked up within the injection system or, in the case of polymer, to hold undissolved particles until they completely dissolve.

Quality Control. All Maraflood process fluids injected throughout the project life are subjected to continual quality control testing to ensure that only specification materials enter the reservoir. Proper quality control is essential to adequate injectivity and acceptable oil recovery.

Project injection water undergoes two tests. The first test determines the presence of suspended solids, while the second measures dissolved mineral content (hardness) of the water. A filtration test, known as the "Millipore Ratio Test" (MPR) is made several times daily on injection and polymer makeup water from the diatomaceous earth filters. The test is also run on wellhead water samples to ensure that no contamination is picked up in the injection lines.

The Millipore Ratio Test is conducted by passing a 1-liter fluid sample through a Millipore filter paper under constant differential pressure. A 0.45-micron filter paper is used for the test. Results are analyzed by adding the flow times for the 50-100 ml, 150-200 ml and 250-300 ml increments and comparing them to the sum of the 700-750 ml, 800-850 ml and 900-950 ml increments. As fluid flows through the filter paper, filtered particles tend to plug the filter. When this occurs, flow rate is reduced. If the ratio of the sum of the last three time increments to the sum of the first three increments is greater than 2.0, the fluid sample fails the test and the water is

considered unsatisfactory for injection. Millipore tests are run routinely to monitor project water quality. They offer a quick, reliable, semi-quantitative measure of fluid quality. In the event of significant contamination, filter paper residue can sometimes be analyzed by laboratory methods to identify the source of contamination.

A hardness test is made on water from the softener several times daily to ensure that the unit is operating properly. Excessive hardness adversely affects polymer solution properties and can ultimately affect performance and oil recovery of the Maraflood process. Hardness is determined by a simple titration run at the injection plant.

Filtered slug is subjected to a Millipore test similar to that described for injection water. Slug samples are normally taken either immediately downstream of the filter or at the triplex discharge. Millipore testing is conducted at filter discharge temperature (95-100° F) or at ambient temperature using 0.8-micron paper. A flow time ratio no greater than 2.0 indicates product acceptable for injection.

A second filtration test is conducted using filtered slug to be injected during cold weather. This test is commonly referred to as the "winter cool-down" test. Its purpose is to assess the impact of cold weather conditions on filtration (injection) characteristics of micellar solution. A sample of hot, filtered slug is mixed with the prescribed amount of cosurfactant. Fluid temperature is then quickly lowered to 40° F for 1.5 hours, followed by agitation for an additional 1.5 hours at 65° F. The normal Millipore test is then conducted at 65° F using 0.8-micron paper. A flow time ratio of 2.0 or less

indicates acceptable fluid quality.

This test simulates the temperature history of slug during cold weather injection. The 40° F and 65° F temperatures and 1.5-hour times represent ground (or wellhead) and bottomhole fluid temperatures and representative fluid residence times in the field. Acceptable filtration results using the normal Millipore test coupled with unacceptable winter cooldown test results are an indication of paraffin precipitation in the slug at reduced temperatures.

In addition to filtration tests, slug received from the refinery unit is tested daily for stability after alcohol addition. Alcohol is added to the slug at various levels and a viscosity-alcohol range curve is generated. The shape and alcohol range of this curve determine the level of cosurfactant addition required to impart necessary slug viscosity and stability prior to injection.

Polymer solution quality is monitored regularly by fluid viscosity and screen factor determinations. Comparison of results obtained in the plant and at various wellhead locations is an indication of deterioration in solution quality. Small volumes of solution are secured using a special sampler that prevents shear degradation during sampling. Viscosity is measured using a Brookfield viscometer, usually at a low shear rate (8 sec^{-1}). A conventional screen factor determination, as prescribed by The Dow Chemical Company, is also made on the samples.

Fluid viscosity is a direct measure of polymer concentration and/or mineral

content of makeup water. It is not the most reliable indication of mechanical or chemical degradation. Screen factor reductions are a more sensitive measure of loss in polymer quality due to mechanical or chemical factors. Screen factor is much less sensitive than viscosity to changes in polymer concentration and water quality.

LEGEND

- CRUDE OIL LINE
- . - . - . SLUG LINE
- ALCOHOL LINE
- PALESTINE WATER LINE

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E (M-1)-2242
 Facilities Report

R. 13 W.

M-1 PROJECT
 FIGURE 2

LEGEND

- OIL WELL
- + ABANDONED OIL WELL
- ⊗ INJECTION WELL
- ⊗ ABANDONED INJECTION WELL
- ⊗ OIL WELL CONVERTED TO INJECTION WELL
- ⊗ SALT WATER DISPOSAL WELL
- ◇ DRY HOLE

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E (49-18)-2242
 Facilities Report

R. 13 W.

INJECTION WELLS
 FIGURE 3

LEGEND

- ⊗ - NEW INJECTION WELL
- ⊠ - OLD INJECTION WELL RECONDITIONED
- ⊡ - OIL WELL CONVERTED TO INJECTION WELL

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

TYPICAL INJECTION WELL COMPLETION
FIGURE 4

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

TYPICAL INJECTION WELL HOOKUP
(WITH SHEAR RELIEF TUBING)

FIGURE 5

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E M9-181-2242
 Facilities Report

R. 13 W.

OIL WELLS
 FIGURE 6

LEGEND
 ● - OIL WELL
 ▲ - OIL WELL RECOMPLETED

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

TYPICAL PRODUCTION WELL COMPLETION
FIGURE 7

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

PRODUCTION WELL HOOKUP
FIGURE 8

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E M9-181-2242
 Facilities Report

**ABANDONMENTS, REABANDONMENTS AND
 INACTIVE OIL WELLS**
FIGURE 9

R.13 W.

T.6 N.

ABANDONMENT PROCEDURE
FIGURE 10

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

FLUID DISPOSAL SYSTEM
FIGURE 11

R.13 W.

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

LEAD LINES
FIGURE 12

NOTE: All lines are plastic
All main lines run approx. 11.5' from well, at rear of unit.
All well conn. lines run approx 9' from left side of unit, when at rear facing well
■ - Pumping Unit Location

T.6 N.

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E M3-18)-2242
 Facilities Report

PRODUCTION FACILITY
FIGURE 13

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

PRODUCED FLUID RETENTION TANK
FIGURE 14

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

DISPOSAL FLUID TREATMENT SYSTEM
FIGURE 15

MARATHON OIL COMPANY
WATERFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Oilfield No. E (N9-10)-2242
 Facilities Report

R.13 W.

FLUID DISPOSAL LINES AND WELLS
FIGURE 16

LEGEND

- OIL WELL
- + ABANDONED OIL WELL
- INJECTION WELL
- ⊗ ABANDONED INJECTION WELL
- ⊙ OIL WELL CONVERTED TO INJECTION WELL
- ◇ DRY HOLE
- ⊖ SALT WATER DISPOSAL WELL

T. 6 N.

MARATHON CIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E 449-101-2242
Facilities Report

INJECTION PLANT
FIGURE 17

LEGEND

- ⊗ Hand Operated Valve
- ⊕ Control Valve
- ⊖ Check Valve
- ⊙ Pressure Relief Valve
- ⊕ Pressure Regulator
- ⊙ Meter
- ① Drain Line (6" Plastic)
- ② Slug Line To Heat Exchanger (4" Plastic)
- ③ From Slug Filters To A.B.S. (3" Steel)
- ④ From Slug Line To Slug Hold Tank (3" Plastic)
- ⑤ From Slug Hold To Centrifugal Pump 1 (3" Plastic)
- ⑥ From Water Filter To Filter Fluid Water Tank (4" Plastic)
- ⑦ From Filter Fluid Water And/or Slug Tank To Tripless (6" Plastic)
- ⑧ From Filter Fluid Water Tanks To Water Softener (4" Plastic)
- ⑨ From Backup Slug Hold Tank To Centrifugal Pump 2 (3" Plastic)
- ⑩ From Heat Exchanger To Slug Hold Tank (3" Steel)
- ⑪ From Tripless To Filter Fluid Tanks Slug & Water (2" Steel)
- ⑫ Fresh Water For DE Slurry Make Up (1" Steel)
- ⑬ From Palestine Water Line To Water Filter (4" Steel)
- ⑭ To Palestine Water Hold Tank (Q) (4" Plastic)
- ⑮ From Palestine Water Hold Tank (Q) To Water Filter (4" Plastic)
- ⑯ From 2.5-Acre Polymer Surge Tank (K) To Tripless Pumps 2 And 3 (4" Plastic)
- ⑰ From 5.0-Acre Polymer Surge Tank (N) To Tripless Pump 1 (6" Plastic)
- ⑱ From 2.5-Acre Dow Slides To Polymer Mixed Tanks (L And M) (4" Plastic)
- ⑲ From 5.0-Acre Dow Slides To Polymer Mixed Tanks (O And P) (4" Plastic)
- ⑳ From Brine Pit To Water Softener (2" Plastic)
- ㉑ From Tripless 3 To North 2.5-Acre Injection Wells (4" Steel)
- ㉒ From Tripless 2 To South 2.5-Acre Injection Wells (4" Steel)
- ㉓ From Tripless 1 To South 5.0-Acre Injection Wells (4" Steel)
- ㉔ Condenser Return (2" Insulated Steel)
- ㉕ Steam Line (2" Insulated Steel)

TRIPLEX PUMPS

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E M9-101-2242
Facilities Report

PROJECT INJECTION FACILITY
FIGURE 18

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

WEST SIDE INJECTION TANK BATTERY
FIGURE 19

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

EAST SIDE INJECTION TANK BATTERY
FIGURE 20

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18) - 2242
Facilities Report

HEAT EXCHANGER SCHEMATIC
FIGURE 21

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

INJECTION PUMP INSTALLATION
FIGURE 22

R. 13 W.

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18) - 2242
Facilities Report

INJECTION LINES
FIGURE 23

PERIMETER WATER INJECTION WELLS
FIGURE 24

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E 49-181-2242
 Facilities Report

R. 13 W.

ACCESS ROADS
 FIGURE 25

- LEGEND**
- OIL WELL
 - + ABANDONED OIL WELL
 - INJECTION WELL
 - ABANDONED INJECTION WELL
 - OIL WELL CONVERTED TO INJECTION WELL
 - SALT WATER DISPOSAL WELL
 - DRY HOLE
 - ACCESS ROADS

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E M9-181-2242
Facilities Report

R. 13 W.

MISCELLANEOUS BUILDINGS AND PIPE YARDS
FIGURE 26

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E (49-18)-2242
 Facilities Report

SURFACE FACILITY PLAN
FIGURE 27

-75-

LEGEND

PRODUCTION FACILITY

Tank 1 3.0-Acre Sill
 Tank 2 3.0-Acre Hold
 Tank 3 2.5-Acre Sill
 Tank 4 2.5-Acre Hold
 Tanks 5 thru 8 3.0-Acre Retention
 Tanks 9 thru 11 2.5-Acre Retention

INJECTION FACILITY

Tanks A, E, C, D Alcohol Storage
 Tanks E & F Filtered Water Storage
 Tanks G & H Filtered Slag Storage
 Tank I Slag Hold
 Tank J Slag Hold
 Tank K 2.5-Acre Polymer Surge
 Tanks L & M 2.5-Acre Polymer Blend
 Tank N 3.0-Acre Polymer Surge
 Tanks O & P 3.0-Acre Polymer Blend
 Tank Q Rejection Water
 Tank R Fuel Oil Supply
 Tank S Formaldehyde Storage

ELECTRICAL SYSTEM
FIGURE 28

- Oil well
- Salt water disposal well
- 2 AL USE conductors in common ditch with gathering line
- 2 AL USE conductors in new separate ditch
- 4 AL USE conductors in common ditch with gathering line
- Existing primary line (Overhead)
- Overhead line (480 Volts)
- Existing transformer bank
- New transformer bank

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-10)-2242
Facilities Report

PRODUCTION FACILITY AND ELECTRICAL CIRCUIT DIAGRAM
FIGURE 29

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

ELECTROSTATIC OIL PROCESSING UNIT
FIGURE 30

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

PRODUCTION FACILITY CATCH BOXES
FIGURE 31

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

2.5-ACRE HOLD TANK
FIGURE 32

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

5.0-ACRE HOLD TANK
FIGURE 33

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

SELL TANK
FIGURE 34

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

WATER SOFTENER - OPERATING CYCLES
FIGURE 35

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

WATER SOFTENER
FIGURE 36

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

POLYMER MIXING SKID
FIGURE 37

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E M9-101-2242
 Facilities Report

INJECTION FACILITY AIR CONTROL SYSTEM
 FIGURE 3B

LEGEND

- Supply Air
- - - Instrument Air
- - - Control Air
- Level Transmitter
- Misc. Controller
- Level Monitor
- ⊕ Control Valve
- △ Level Controller

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 Crawford County, Illinois
 Contract No. E (49-18)-2242
 Facilities Report

FLUID INJECTION CONTROL SYSTEM
FIGURE 39

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

INJECTION CONTROL PANEL
FIGURE 40

MARATHON OIL COMPANY
MARAFLOOD PROCESS — M-1 PROJECT
Crawford County, Illinois
Contract No. E (49-18)-2242
Facilities Report

ALCOHOL BLENDING SYSTEM
FIGURE 41

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
CRAWFORD COUNTY, ILLINOIS
CONTRACT NO. E(49-18)-2242
FACILITIES REPORT

TABLE 1

Conversions and Completions

CONVERSIONS (Oil Well to Injector)

New Designation

U-15
S-15
Q-15
M-11
M-15
I-7
I-11
I-15
GG-13

Old Designation

W. Mann #17
W. Mann #16-K
W. Mann #28
C. I. Weirich #7
C. I. Weirich #8
J. N. Burch #9
H. Martin #11
H. Martin #12
Wakefield-Martin Comm. #11

RECOMPLETIONS (Injectors)

S-13
O-13
CC-15
CC-17

W. Mann #K-94
W. Mann #K-97
A. R. Smith #P-11
Wakefield-Martin Comm. #Q-11

RECOMPLETIONS (Oil Wells)

D-8
D-10
J-2
P-2
JJ-16
5
14
18
35
36

J. N. Burch #2
H. Martin #7
J. N. Burch #10
R. A. Siler #1
Wakefield Heirs #20
E. C. Burch #5
Sally Carlisle #14
Brubaker-Prier Fee #18
A. R. Smith #35
A. R. Smith #36

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
CRAWFORD COUNTY, ILLINOIS
CONTRACT NO. E(49-18)-2242
FACILITIES REPORT

TABLE 2
Casing and Cementing Data - Injection Wells
(All measurements from ground level)
2.5-ACRE PATTERNS

Well No.	G.L. Elev. ft	TD or PBTD ft	Surface Casing				Long String					Formation Packer (F.P.) or Cement Basket (C.B.)
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate		
A-11	473	930	8-5/8	139	72	Yes	4-1/2	895	120	Yes	F.P.	
A-13	477	923	8-5/8	140	114	Yes	4-1/2	900	120	Yes	F.P.	
A-15	479	940	8-5/8	143	113	Yes	4-1/2	887	120	Yes	F.P.	
C-1	470	926	8-5/8	139	113	Yes	4-1/2	886	120	Yes	F.P.	
C-3	459	919	8-5/8	140	96	Yes	4-1/2	907	130	Yes	F.P.	
C-5	455	913	8-5/8	141	100	Yes	4-1/2	900	120	Yes	F.P.	
C-7	455	914	8-5/8	139	108	Yes	4-1/2	901	120	No	F.P.	
C-9	460	940	8-5/8	139	140	Yes	4-1/2	902	120	Yes	F.P.	
C-13	473	935	8-5/8	140	90	Yes	4-1/2	892	120	Yes	F.P.	
E-1	476	950	8-5/8	141	97	Yes	4-1/2	905	120	Yes	F.P.	
E-3	465	930	8-5/8	141	126	Yes	4-1/2	906	140	Yes	F.P.	
E-5	455	917	8-5/8	141	102	Yes	4-1/2	899	120	Yes	F.P.	
E-7	455	925	8-5/8	144	150	Yes	4-1/2	882	130	Yes	F.P.	
E-9	471	945	8-5/8	144	126	Yes	4-1/2	903	120	Yes	F.P.	
G-1	475	436	8-5/8	141	88	Yes	4-1/2	893	130	Yes	F.P.	
G-3	473	935	8-5/8	141	105	Yes	4-1/2	897	130	Yes	F.P.	
G-5	455	932	8-5/8	141	105	Yes	4-1/2	880	130	Yes	F.P.	
G-7	456	930	8-5/8	140	106	Yes	4-1/2	900	140	Yes	F.P.	
G-9	464	940	8-5/8	144	90	Yes	4-1/2	893	120	Yes	F.P.	
G-11	477	950	8-5/8	141	142	Yes	4-1/2	912	120	Yes	F.P.	
G-13	466	935	8-5/8	140	120	Yes	4-1/2	905	120	Yes	F.P.	
I-1	474	912	8-5/8	142	130	Yes	4-1/2	885	120	Yes	F.P.	
I-3	473	935	8-5/8	140	115	Yes	4-1/2	891	130	Yes	F.P.	
I-5	456	940	8-5/8	140	105	Yes	4-1/2	878	130	Yes	F.P.	
I-7	457	925	N/A	N/A	N/A	N/A	7	885	175	No	N/A	
I-9	457	920	8-5/8	142	120	Yes	4-1/2	882	120	Yes	F.P.	
I-11	458	925	N/A	N/A	N/A	N/A	7	884	150	Yes	N/A	
I-13	468	921	8-5/8	140	112	Yes	4-1/2	904	130	Yes	F.P.	

TABLE 2 - 2.5-ACRE PATTERNS (continued)

Well No.	G.L. Elev. ft	TD or PBTD ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
I-15	482	926	N/A	N/A	N/A	N/A	7	886	175	Yes	N/A
K-1	467	915	8-5/8	159	130	Yes	4-1/2	874	20	No	C.B.
K-3	467	901	8-5/8	160	142	Yes	4-1/2	855	20	No	C.B.
K-5A	469	935	10-3/4	173	66	No	4-1/2	936	295	No	F.P.
K-7	470	930	8-5/8	159	84	Yes	4-1/2	885	30	No	C.B.
K-9	464	940	8-5/8	161	151	Yes	4-1/2	889	20	No	F.P.
K-11	455	910	7	161	80	Yes	4-1/2	881	30	No	C.B.
K-13	468	930	8-5/8	140	135	Yes	4-1/2	901	140	Yes	F.P.
K-15	479	946	8-5/8	160	120	Yes	4-1/2	893	20	No	C.B.
M-1	461	910	8-5/8	160	115	Yes	4-1/2	866	20	No	F.P.
M-3	462	889	8-5/8	160	112	Yes	4-1/2	863	20	No	F.P.
M-5	470	914	8-5/8	160	108	Yes	4-1/2	862	20	No	C.B.
M-7	472	925	8-5/8	159	85	Yes	4-1/2	873	20	No	C.B.
M-9	464	930	8-5/8	160	96	Yes	4-1/2	863	20	No	C.B.
M-11	457	907	N/A	N/A	N/A	N/A	7	855	150	Yes	N/A
M-13	456	935	7	151	78	Yes	4-1/2	861	110	Yes	F.P.
M-15	475	937	N/A	N/A	N/A	N/A	7	882	150	Yes	N/A
O-1	464	915	8-5/8	140	100	Yes	4-1/2	885	140	Yes	F.P.
O-3	470	920	8-5/8	160	112	Yes	4-1/2	880	140	Yes	F.P.
O-5	476	928	8-5/8	160	100	Yes	4-1/2	872	124	Yes	F.P.
O-7	477	940	8-5/8	160	108	Yes	4-1/2	872	20	No	C.B.
O-9	475	935	8-5/8	120	94	Yes	4-1/2	877	140	Yes	F.P.
O-11	458	925	8-5/8	160	85	Yes	4-1/2	859	26	No	C.B.
O-13	459	916	N/A	N/A	N/A	N/A	4-1/2	859	175	No	N/A
O-15	474	945	8-5/8	160	96	Yes	4-1/2	882	20	No	C.B.
Q-1	468	945	7	144	67	Yes	4-1/2	877	120	Yes	F.P.
Q-3	475	945	7	148	63	Yes	4-1/2	898	110	Yes	F.P.
Q-5	477	940	8-5/8	160	120	Yes	4-1/2	891	100	No	F.P.
Q-7	479	940	8-5/8	120	99	Yes	4-1/2	878	130	Yes	F.P.
Q-9	479	940	7	160	117	Yes	4-1/2	874	20	No	F.P.
Q-11	464	924	8-5/8	142	100	Yes	4-1/2	858	120	Yes	F.P.
Q-13	459	915	8-5/8	161	70	No	4-1/2	869	26	No	C.B.
Q-15	477	929	N/A	N/A	N/A	N/A	7	877	170	Yes	N/A
S-1	466	945	7	143	68	Yes	4-1/2	897	120	Yes	F.P.
S-3	475	955	7	145	84	Yes	4-1/2	903	120	Yes	F.P.
S-5	477	940	8-5/8	120	104	Yes	4-1/2	904	134	Yes	F.P.
S-7	479	940	7	120	73	Yes	4-1/2	894	120	Yes	F.P.
S-9	481	930	7	160	84	Yes	4-1/2	878	20	No	C.B.

TABLE 2 - 2.5-ACRE PATTERNS (continued)

Well No.	G.L. Elev. ft	TD or PBTD ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
S-11	472	930	7	161	117	Yes	4-1/2	868	20	No	F.P.
S-13	458	911	8-5/8	60	50	Yes	4-1/2	871	175	Yes	F.P.
S-15	460	922	10	94	N/A	N/A	4-1/2	870	105	Yes	F.P.
U-1	473	950	7	146	87	Yes	4-1/2	903	120	No	F.P.
U-3	474	943	7	140	82	Yes	4-1/2	903	140	Yes	F.P.
U-5	477	924	7	140	84	Yes	4-1/2	908	140	Yes	F.P.
U-7	480	940	7	118	56	Yes	4-1/2	904	140	No	F.P.
U-9	479	938	7	101	70	Yes	4-1/2	872	20	No	F.P.
U-11	464	930	7	160	40	Yes	4-1/2	862	20	No	C.B.
U-13	459	913	7	142	60	Yes	4-1/2	867	120	Yes	F.P.
U-15	458	930	8	424	N/A	N/A	4-1/2	885	230	Yes	N/A
W-1	473	950	8-5/8	143	122	Yes	4-1/2	903	120	Yes	F.P.
W-3	476	940	8-5/8	140	118	Yes	4-1/2	904	140	Yes	F.P.
W-5	478	937	8-5/8	140	105	Yes	4-1/2	901	140	Yes	F.P.
W-7	483	931	8-5/8	140	134	Yes	4-1/2	915	140	Yes	F.P.
W-9	475	945	8-5/8	161	90	Yes	4-1/2	904	130	No	F.P.
W-11	479	941	7	159	112	Yes	4-1/2	888	20	No	C.B.
W-13	459	950	7	160	80	Yes	4-1/2	893	20	No	C.B.
W-15	460	937	7	163	136	Yes	4-1/2	889	20	No	C.B.

MARATHON OIL COMPANY
 MARAFLOOD PROCESS - M-1 PROJECT
 CRAWFORD COUNTY, ILLINOIS
 CONTRACT NO. E(49-18)-2242
 FACILITIES REPORT

TABLE 2

Casing and Cementing Data - Injection Wells
 (All measurements from ground level)
 5.0-ACRE PATTERNS

Well No.	G.L. Elev. ft	TD or PBDT ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
CC-11	480	932	8-5/8	144	110	Yes	4-1/2	899	120	Yes	F.P.
CC-13	477	940	8-5/8	146	80	Yes	4-1/2	886	110	Yes	F.P.
CC-15	480	925	8-5/8	82	100	Yes	4-1/2	895	200	Yes	F.P.
CC-17	477	911	N/A	N/A	N/A	N/A	4-1/2	891	160	Yes	N/A
EE-11	477	940	8-5/8	141	125	Yes	4-1/2	883	120	Yes	F.P.
EE-13	487	950	8-5/8	140	86	Yes	4-1/2	892	120	Yes	F.P.
EE-15	482	955	8-5/8	141	112	Yes	4-1/2	891	130	Yes	F.P.
EE-17	481	925	7	140	108	Yes	4-1/2	876	110	Yes	F.P.
GG-13	482	935	N/A	N/A	N/A	N/A	7	895	190	Yes	N/A
GG-15	482	955	8-5/8	142	103	Yes	4-1/2	892	160	Yes	C.B.
GG-17	486	950	7	143	76	Yes	4-1/2	892	110	Yes	F.P.
GG-19	474	914	7	147	67	Yes	4-1/2	876	110	Yes	F.P.
II-13	485	924	7	140	70	Yes	4-1/2	901	120	Yes	F.P.
II-15	485	940	8-5/8	142	110	Yes	4-1/2	907	130	Yes	F.P.
II-17	486	925	7	144	68	Yes	4-1/2	910	120	Yes	F.P.
KK-13	486	945	8-5/8	142	104	Yes	4-1/2	924	130	Yes	F.P.
KK-15	486	932	7	143	60	Yes	4-1/2	901	120	Yes	F.P.
MM-13	486	941	7	146	68	Yes	4-1/2	921	120	Yes	F.P.
MM-15	485	931	7	147	86	Yes	4-1/2	909	130	Yes	F.P.
OO-13	478	940	7	148	76	Yes	4-1/2	912	120	Yes	F.P.
OO-15	481	932	7	141	92	Yes	4-1/2	904	120	Yes	F.P.
QQ-13	477	943	7	146	78	Yes	4-1/2	909	120	Yes	F.P.
QQ-15	481	952	7	140	95	Yes	4-1/2	913	130	Yes	F.P.
SS-1	478	955	7	143	78	Yes	4-1/2	921	68	No	F.P.
SS-3	479	948	7	140	84	Yes	4-1/2	918	140	Yes	F.P.
SS-5	480	938	8-5/8	140	95	Yes	4-1/2	923	140	Yes	F.P.
SS-7	482	950	8-5/8	140	115	Yes	4-1/2	916	140	Yes	F.P.
SS-9	482	932	7	141	90	Yes	4-1/2	888	140	Yes	F.P.
SS-11	462	915	7	141	82	Yes	4-1/2	884	130	Yes	F.P.

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
CRAWFORD COUNTY, ILLINOIS
CONTRACT NO. E(49-18)-2242
FACILITIES REPORT

TABLE 2

Casing and Cementing Data - Injection Wells
(All measurements from ground level)
PERIMETER WATER INJECTION WELLS

Well No.	G.L. Elev. ft	TD or PBTD ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
A-12	474	933	N/A	N/A	N/A	N/A	4-1/2	875	170	Yes	N/A
P-12	466	971	N/A	N/A	N/A	N/A	4-1/2	948	200	No	N/A
Q-12	467	912	N/A	N/A	N/A	N/A	4-1/2	883	200	No	N/A
R-12	480	980	N/A	N/A	N/A	N/A	4-1/2	956	200	No	N/A
X-3	476	933	N/A	N/A	N/A	N/A	4-1/2	893	175	No	N/A
X-6	475	945	N/A	N/A	N/A	N/A	4-1/2	905	175	Yes	N/A
X-9	475	932	N/A	N/A	N/A	N/A	4-1/2	906	175	Yes	N/A
X-12	475	931	N/A	N/A	N/A	N/A	4-1/2	896	175	Yes	N/A
X-88	475	925	8	120	N/A	N/A	4-1/2	900	50	No	N/A
X-91	474	940	8-1/4	387	N/A	N/A	4-1/2	895	225	Yes	N/A
X-94	472	929	N/A	N/A	N/A	N/A	4-1/2	903	175	Yes	N/A
X-97	472	925	N/A	N/A	N/A	N/A	4-1/2	883	175	Yes	N/A

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 CRAWFORD COUNTY, ILLINOIS
 CONTRACT NO. E(49-18)-2242
 FACILITIES REPORT

TABLE 3

Injection Well Stimulation

OPEN HOLE SHOT

2.5-Acre Pattern Wells

A-11	C-9	G-1	I-1	I-15	K-15	M-13	O-11	Q-9	S-7	U-5	W-3
A-13	C-13	G-3	I-3	K-1	M-1	M-15	O-13	Q-11	S-9	U-7	W-5
A-15	E-1	G-5	I-5	K-3	M-3	O-1	O-15	Q-13	S-11	U-9	W-7
C-1	E-3	G-7	I-7	K-7	M-5	O-3	Q-1	Q-15	S-13	U-11	W-9
C-3	E-5	G-9	I-9	K-9	M-7	O-5	Q-3	S-1	S-15	U-13	W-11
C-5	E-7	G-11	I-11	K-11	M-9	O-7	Q-5	S-3	U-1	U-15	W-13
C-7	E-9	G-13	I-13	K-13	M-11	O-9	Q-7	S-5	U-3	W-1	W-15

5.0-Acre Pattern Wells

Perimeter Water Injection Wells*

CC-13 EE-17
 CC-15 GG-13
 CC-17 GG-15
 EE-13 GG-17
 EE-15 QQ-15

A-12 X-6
 P-12 X-9
 Q-12 X-12
 R-12 X-94
 X-3 X-97

ACIDIZED

2.5-Acre Pattern Wells

5.0-Acre Pattern Wells

Perimeter Water Injection Wells*

A-11 K-5A
 C-5 O-13*
 C-7 W-3

CC-15* QQ-15
 GG-13* SS-7
 GG-17

A-12 X-3 X-12 X-94
 P-12 X-6 X-88 X-97
 Q-12 X-9 X-91

FRACTURED

2.5-Acre Pattern Wells

A-11	C-5	E-3	G-3	G-13	I-7	K-3	K-11	O-3	U-5
A-13	C-7	E-5	G-5	I-1	I-9	K-5A	M-1	Q-13	U-7
C-1	C-9	E-9	G-9	I-3	I-11	K-7	M-5	S-5	W-3
C-3	E-1	G-1	G-11	I-5	I-13	K-9	M-7	S-7	W-7

5.0-Acre Pattern Wells

Perimeter Water Injection Wells*

CC-11 II-13 MM-13 QQ-13
 CC-15* II-17 MM-15 SS-3
 EE-13 KK-13 OO-13 SS-5
 GG-19 KK-15 OO-15 SS-9
 SS-11

P-12
 Q-12
 R-12
 X-9

*Stimulation done prior to Maraflood development

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
CRAWFORD COUNTY, ILLINOIS
CONTRACT NO. E(49-18)-2242
FACILITIES REPORT

TABLE 4

Casing and Cementing Data - Oil Wells
(All measurements from ground level)
2.5-ACRE PATTERNS

Well No.	G.L. Elev. ft	TD or PBTD ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
XA-10	468	940	8-5/8	139	80	Yes	4-1/2	906	120	Yes	F.P.
XA-12	476	935	8-5/8	140	108	Yes	4-1/2	896	120	Yes	F.P.
XA-14	474	945	8-5/8	141	106	Yes	4-1/2	880	110	Yes	F.P.
AA-11	480	934	7	139	68	Yes	4-1/2	885	130	Yes	F.P.
B-0	472	945	7	152	72	Yes	4-1/2	883	120	Yes	F.P.
EB-5*	475	931	N/A	N/A	N/A	N/A	7	909	170	Yes	N/A
B-4	454	930	8-5/8	142	82	Yes	4-1/2	906	120	Yes	F.P.
B-6	455	930	8-5/8	140	80	Yes	4-1/2	904	120	Yes	F.P.
B-8	455	935	8-5/8	141	80	Yes	4-1/2	902	120	Yes	F.P.
B-10	468	945	8-5/8	140	80	Yes	4-1/2	910	120	Yes	F.P.
B-12	475	940	8-5/8	141	99	Yes	4-1/2	902	120	Yes	F.P.
B-14	476	955	8-5/8	141	121	Yes	4-1/2	880	120	Yes	F.P.
B-16	483	955	8-5/8	140	110	Yes	4-1/2	897	120	Yes	F.P.
D-0	476	945	7	144	85	Yes	4-1/2	904	120	Yes	F.P.
D-2	471	930	8-5/8	142	113	Yes	4-1/2	918	140	Yes	F.P.
D-4	457	930	8-5/8	140	108	Yes	4-1/2	903	130	Yes	F.P.
D-6	455	916	7	151	110	Yes	4-1/2	882	110	Yes	F.P.
D-8	471	942	8-1/4	430	N/A	N/A	6-1/4	860	120	Yes	N/A
D-10	468	928	8-1/4	380	N/A	N/A	6-1/4	865	N/A	N/A	N/A
F-0	476	935	7	142	87	Yes	4-1/2	912	120	Yes	F.P.
F-2	472	935	8-5/8	140	117	Yes	4-1/2	904	140	Yes	F.P.
F-4	459	925	8-5/8	141	105	Yes	4-1/2	901	130	Yes	F.P.
F-6	455	915	8-5/8	144	100	Yes	4-1/2	880	120	Yes	F.P.
F-8	456	930	8-5/8	140	112	Yes	4-1/2	886	120	Yes	F.P.
F-10	474	950	8-5/8	145	103	Yes	4-1/2	906	120	Yes	F.P.
F-12	478	945	8-5/8	146	147	Yes	4-1/2	914	120	Yes	F.P.
F-14	472	935	8-5/8	142	114	Yes	4-1/2	892	120	Yes	F.P.
H-0	476	940	7	141	92	Yes	4-1/2	891	120	Yes	F.P.

TABLE 4 - 2.5-ACRE PATTERNS (continued)

Well No.	G.L. Elev. ft	TD or PBD ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Bucket (C.B.)
H-2	471	926	7	150	72	Yes	4-1/2	863	115	Yes	F.P.
H-4	465	925	8-5/8	141	126	Yes	4-1/2	888	140	Yes	F.P.
H-6	455	930	8-5/8	141	86	Yes	4-1/2	880	130	Yes	F.P.
H-8	456	930	8-5/8	141	101	Yes	4-1/2	895	140	Yes	F.P.
H-10	456	930	8-5/8	140	98	Yes	4-1/2	899	130	Yes	F.P.
H-12	461	930	8-5/8	140	150	Yes	4-1/2	902	130	Yes	F.P.
H-14	471	930	8-5/8	148	112	Yes	4-1/2	892	130	Yes	F.P.
J-0	475	930	7	145	80	Yes	4-1/2	877	120	Yes	F.P.
J-2	472	920	8-1/4	377	N/A	N/A	4-1/2	874	N/A	N/A	N/A
J-4	457	916	8-5/8	140	135	Yes	4-1/2	873	140	Yes	F.P.
J-6	465	933	8-5/8	138	112	Yes	4-1/2	898	130	Yes	C.B.
J-8	458	925	8-5/8	140	92	Yes	4-1/2	888	140	Yes	F.P.
J-10	457	930	7	152	63	Yes	4-1/2	885	110	No	F.P.
J-12	457	930	7	149	99	Yes	4-1/2	892	120	Yes	F.P.
J-14	477	940	8-5/8	140	113	Yes	4-1/2	889	140	Yes	F.P.
L-0	476	940	8-5/8	146	98	Yes	4-1/2	892	110	Yes	F.P.
L-2	459	930	8-5/8	160	108	Yes	4-1/2	863	20	No	C.B.
L-4	459	915	8-5/8	160	93	Yes	4-1/2	862	20	No	F.P.
L-6	470	935	8-5/8	160	96	Yes	4-1/2	868	20	No	C.B.
L-8	469	935	8-5/8	160	75	Yes	4-1/2	876	20	No	C.B.
L-10	457	925	8-5/8	159	75	Yes	4-1/2	859	16	No	C.B.
L-12	456	940	7	140	76	Yes	4-1/2	883	110	Yes	F.P.
L-14	475	940	8-5/8	160	75	Yes	4-1/2	882	16	No	C.B.
N-0	464	940	7	149	74	Yes	4-1/2	885	120	Yes	F.P.
N-2	464	920	8-5/8	160	151	Yes	4-1/2	866	20	Yes	F.P.
N-4	469	926	8-5/8	161	144	Yes	4-1/2	864	132	Yes	F.P.
N-6	475	940	8-5/8	160	75	No	4-1/2	869	20	No	C.B.
N-8	464	937	8-5/8	160	92	Yes	4-1/2	874	20	No	C.B.
N-10	464	930	8-5/8	160	75	Yes	4-1/2	860	16	No	C.B.
N-12	458	925	8-5/8	160	96	Yes	4-1/2	854	26	No	C.B.
N-14	471	940	8-5/8	160	96	Yes	4-1/2	876	20	No	C.B.
P-0	463	945	7	152	87	Yes	4-1/2	887	120	Yes	F.P.
P-2	469	1000	8-1/4	460	N/A	N/A	4-1/2	882	N/A	N/A	N/A
P-4	475	940	8-5/8	160	142	Yes	4-1/2	830	100	Yes	F.P.
P-6	477	940	8-5/8	160	108	Yes	4-1/2	875	20	No	C.B.
P-8	475	935	8-5/8	160	100	Yes	4-1/2	875	20	No	C.B.
P-10	476	945	8-5/8	146	65	Yes	4-1/2	874	16	No	C.B.
P-12	459	930	8-5/8	160	80	No	4-1/2	864	26	No	C.B.

TABLE 4 - 2.5-ACRE PATTERNS (continued)

Well No.	G.L. Elev. ft	TD or PBDT ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
P-14	463	935	8-5/8	160	95	Yes	4-1/2	874	20	No	C.B.
R-0	463	945	7	155	87	Yes	4-1/2	889	120	Yes	F.P.
R-2	474	912	7	149	100	Yes	4-1/2	897	110	Yes	F.P.
R-4	477	921	7	150	113	Yes	4-1/2	905	110	Yes	F.P.
R-6	478	935	8-5/8	120	124	Yes	4-1/2	894	140	Yes	F.P.
R-8	479	942	7	160	95	Yes	4-1/2	889	20	No	F.P.
R-10	482	940	7	160	108	Yes	4-1/2	879	20	No	C.B.
R-12	459	920	8-5/8	140	104	Yes	4-1/2	861	120	No	F.P.
R-14	457	925	8-5/8	160	96	Yes	4-1/2	877	16	No	C.B.
T-0	472	955	7	139	78	Yes	4-1/2	899	120	Yes	F.P.
T-2	470	950	7	140	72	Yes	4-1/2	935	90	Yes	F.P.
T-4	475	929	8-5/8	140	100	Yes	4-1/2	905	140	Yes	F.P.
T-6	478	940	7	142	78	Yes	4-1/2	887	140	Yes	F.P.
T-8	480	940	7	121	116	Yes	4-1/2	885	140	Yes	F.P.
T-10	478	945	7	160	70	Yes	4-1/2	865	20	No	C.B.
T-12	464	944	7	160	93	Yes	4-1/2	877	20	No	F.P.
T-14	459	935	8-5/8	160	90	Yes	4-1/2	862	110	Yes	F.P.
V-0	474	955	7	154	74	Yes	4-1/2	912	120	Yes	F.P.
V-2	472	930	7	140	95	Yes	4-1/2	903	140	Yes	F.P.
V-4	476	931	7	140	82	Yes	4-1/2	912	140	Yes	F.P.
V-6	479	927	8-5/8	140	90	Yes	4-1/2	908	140	Yes	F.P.
V-8	482	940	7	161	80	Yes	4-1/2	909	92	No	F.P.
V-10	469	935	7	167	90	Yes	4-1/2	872	20	No	C.B.
V-12	464	935	7	160	116	Yes	4-1/2	874	20	No	C.B.
V-14	460	935	7	160	100	Yes	4-1/2	865	20	No	C.B.

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
CRAWFORD COUNTY, ILLINOIS
CONTRACT NO. E(49-18)-2242
FACILITIES REPORT

TABLE 4

Casing and Cementing Data - Oil Wells
(All measurements from ground level)
5.0-ACRE PATTERNS

Well No.	G.L. Elev. ft	TD or PBDT ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
DD-10	474	935	8-5/8	140	113	Yes	4-1/2	904	120	Yes	F.P.
DD-12	485	940	8-5/8	140	112	Yes	4-1/2	886	130	Yes	F.P.
DD-14	473	950	8-5/8	141	112	Yes	4-1/2	872	110	Yes	F.P.
DD-16	481	945	8-5/8	141	108	Yes	4-1/2	889	130	Yes	F.P.
DD-18	473	930	7	148	77	Yes	4-1/2	877	110	Yes	F.P.
FF-12	491	950	8-5/8	140	104	Yes	4-1/2	903	130	Yes	F.P.
FF-14	481	945	8-5/8	142	120	Yes	4-1/2	894	120	Yes	F.P.
FF-16	484	935	7	145	68	Yes	4-1/2	890	110	Yes	F.P.
FF-18	480	940	7	145	51	Yes	4-1/2	879	120	Yes	F.P.
FF-20	478	935	7	142	72	Yes	4-1/2	879	110	Yes	F.P.
HH-12	487	955	7	142	62	Yes	4-1/2	899	120	Yes	F.P.
HH-14	484	945	7	144	90	Yes	4-1/2	890	100	No	F.P.
HH-16	485	950	7	140	68	Yes	4-1/2	905	110	Yes	F.P.
HH-18	484	950	7	140	68	Yes	4-1/2	892	120	Yes	F.P.
HH-20	477	945	7	140	81	Yes	4-1/2	893	110	Yes	F.P.
JJ-12	487	955	8-5/8	142	105	Yes	4-1/2	915	120	Yes	F.P.
JJ-14	485	960	7	144	68	Yes	4-1/2	912	120	Yes	F.P.
JJ-16	485	958	8-5/8	59	50	Yes	4-1/2	984	200	Yes	C.B.
LL-12	486	964	7	140	71	Yes	4-1/2	911	120	Yes	F.P.
LL-14	487	955	8-5/8	140	113	Yes	4-1/2	927	130	Yes	F.P.
NN-12	475	950	7	150	82	Yes	4-1/2	902	120	Yes	F.P.
NN-14	480	950	8-5/8	141	115	Yes	4-1/2	901	130	Yes	F.P.
PP-12	462	950	7	148	90	Yes	4-1/2	899	120	Yes	F.P.
PP-14	476	955	7	149	105	Yes	4-1/2	902	120	Yes	F.P.
PP-16	485	965	8-5/8	144	117	Yes	4-1/2	910	120	Yes	F.P.
RR-2	474	942	7	140	92	Yes	4-1/2	919	140	Yes	F.P.
RR-4	478	942	8-5/8	141	84	Yes	4-1/2	906	140	Yes	F.P.
RR-6	480	934	8-5/8	140	86	Yes	4-1/2	918	140	Yes	F.P.

TABLE 4 - 5.0-ACRE PATTERNS (continued)

Well No.	G.L. Elev. ft	TD or PBTD ft	Surface Casing				Long String				
			O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	O.D. in	Setting Depth ft	Cement Sks	Did Cement Circulate	Formation Packer (F.P.) or Cement Basket (C.B.)
RR-8	481	960	7	141	72	Yes	4-1/2	901	140	Yes	F.P.
RR-10	476	945	8-5/8	140	122	Yes	4-1/2	896	140	Yes	F.P.
RR-12	460	950	7	143	82	Yes	4-1/2	892	115	Yes	F.P.
RR-14	479	955	7	145	81	Yes	4-1/2	921	120	Yes	F.P.
TT-2	478	938	7	141	95	Yes	4-1/2	869	100	Yes	F.P.
TT-4	479	944	7	143	68	Yes	4-1/2	913	140	Yes	F.P.
TT-6	481	946	7	142	78	Yes	4-1/2	922	140	Yes	F.P.
TT-8	483	960	7	143	68	Yes	4-1/2	916	120	Yes	F.P.
TT-10	475	929	7	141	85	Yes	4-1/2	898	110	No	F.P.
SC-14*	478	934	N/A	N/A	N/A	N/A	5-1/2	905	105	No	N/A
AS-35*	466	924	N/A	N/A	N/A	N/A	5-1/2	879	150	No	N/A
AS-36*	477	925	N/A	N/A	N/A	N/A	5-1/2	885	150	No	N/A
BP-18*	480	945	N/A	N/A	N/A	N/A	6-5/8	945	250	No	N/A

*E. C. Burch #5
 Sally Carlisle #14
 A. R. Smith #35
 A. R. Smith #36
 Brubaker-Prier Fee #18

MARATHON OIL COMPANY
 MARAFLOOD PROCESS - M-1 PROJECT
 CRAWFORD COUNTY, ILLINOIS
 CONTRACT NO. E(49-18)-2242
 FACILITIES REPORT

TABLE 5

Oil Well Stimulation

OPEN HOLE SHOT

<u>2.5-Acre Pattern Wells</u>				
D-8	L-6	N-8	P-6	R-10
D-10	L-8	N-10	P-8	R-14
EB-5*	L-10	N-12	P-10	T-10
J-2*	L-14	N-14	P-12	V-10
L-2	N-6	P-2	P-14	V-12
				V-14

5.0-Acre Pattern Wells

AS-35*
 AS-36*
 BP-18*
 LL-12
 SC-14*

ACIDIZED

2.5-Acre Pattern Wells

D-10*
 T-2

5.0-Acre Pattern Wells

JJ-16*

FRACTURED

2.5-Acre Pattern Wells

EB-5*

5.0-Acre Pattern Wells

JJ-16*
 SC-14*

*Stimulation done prior to Maraflood development

MARATHON OIL COMPANY
MARAFLOOD PROCESS - M-1 PROJECT
 CRAWFORD COUNTY, ILLINOIS
 CONTRACT NO. E(49-18)-2242
 FACILITIES REPORT

TABLE 6

Abandonments, Reabandonments and Inactive Oil Wells

LEASE	WELL NO.											
ABANDONMENTS												
Bassom & Siler	5	8	12	A-88	A-94	G-91						
J. N. Burch	1	A-9	D-3	D-6	G-6							
Sally Carlisle	A-91											
F. L. Dewey	A-98											
W. Mann	9	10	26	27	29	G-84	G-88	G-94	K-90	N-90	N-94	N-97
E. E. Martin	R-11											
H. Martin	13	K-3	K-6	L-11	N-6							
Mitchel A/C 2	A-86											
A. Riker	5	9	A-84	C-88	D-85							
R. A. Siler	13	18	A-3	D-97	G-97							
S. Tohill A/C 3	N-12											
Wakefield Heirs	4	10	12	18	19	N-3	N-88	N-92	P-92	P-97		
Wakefield-Martin Comm.	12	13	14	N-11	P-3	P-6	Q-6					
C. I. Weirich	G-3											
REABANDONMENTS												
Bassom & Siler	3	4	6	7	9	10	11					
J. N. Burch	3	4	6	7	11							
W. Mann	5											
E. E. Martin	1	3	5	13	14	16-K	17					
H. Martin	9											
R. A. Siler	2											
S. Tohill A/C 3	1	3										
Wakefield Heirs	2	3	5	7	8	15						
Wakefield-Martin Comm.	3	4	5	10								
C. I. Weirich	4	6	5-K									
INACTIVE												
Sally Carlisle	16											
F. L. Dewey, et al	13	17										
R. A. Siler	16	17										
A. R. Smith	1											
J. H. Wasson	24											

MARATHON OIL COMPANY
 MARAFLOOD PROCESS - M-1 PROCESS
 CRAWFORD COUNTY, ILLINOIS
 CONTRACT NO. E(49-18)-2242
 FACILITIES REPORT

TABLE 7

Injection System Monitoring and Control Equipment

<u>Control Equipment</u>			<u>Transmitter</u>			<u>Valve</u>	<u>Mfr.</u>	<u>Model</u>
<u>Type</u>	<u>Mfr.</u>	<u>Model</u>	<u>Location</u>	<u>Mfr.</u>	<u>Model</u>			
Monitor	Foxboro	P-105-ZA	Tank D (A,B,C)	Major	685P	N/A		
Control	Foxboro	43AP	Tank F	Foxboro	13FA1	F	Foxboro	V1C/P110 4"
Control	Foxboro	43AP	Tank G	Foxboro	13FA1	G	Foxboro	V1S/P110 3"
Monitor	Foxboro	P-105-ZA	Tank I	Major	685P	N/A		
Monitor	Foxboro	40	Tank J	Foxboro	13FA1	N/A		
Control	Foxboro	43AP	Tank K	Foxboro	13FA1	K	Foxboro	V1C/P110 4"
Control	Foxboro	43AP	Tank N	Foxboro	13FA1	N	Foxboro	V1C/P110 4"
Control	Foxboro	43AP	Tank Q	Foxboro	13FA1	Q	Foxboro	V1C/P110 4"
Monitor	Foxboro	P-105-ZA	Tank R	Major	685P	N/A		
Monitor	Foxboro	P-105-ZA	Tank S	Major	685P	N/A		
Control	Foxboro	57ZSR	Target Flow Meter-A.B.S.	Foxboro	13T	**	**	**
Control	Fisher	4150R	*	N/A	N/A	By-pass - Triplex 1	Fisher	657ED
Control	Fisher	4150R	*	N/A	N/A	By-pass - Triplex 2	Fisher	657ED

* Direct High Pressure Connection

** Controls Speed of Pump on Alcohol Blending System