ADVANCED CORE ANALYSIS STUDY

Mako Chemicals & Services LLC
Berea Sandstone
Waterflood Chemical Tests

FINAL REPORT

Submitted to:

Mako Chemicals & Services LLC

September 15, 2017

Performed by:

Core Laboratories
Petroleum Services Division
6316 Windfern
Houston, Texas 77040

HOU-1702633

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September 15, 2017

Mako Chemicals & Services LLC
3338 Old Yoakum Road
Cuero, Texas 77954

Attention: Shawn Kurtz

Subject: Berea Sandstone
Waterflood Chemical Tests
File: HOU-1702633

Dear Mr. Kurtz,

Presented in this report are the final results of the chemical flood tests performed on berea core plug samples. The study comprises Routine Rock Properties measurements and Basic Water Flood measurements using two chemicals.

We appreciate the opportunity to be of service to Mako Chemicals & Services LLC with this study and look forward to working with you on future projects. If you have any questions concerning this report, please do not hesitate to contact us.

Sincerely,

Jasmine Langston
Project Coordinator
Petroleum Services Division
Houston, Texas
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Mako Chemicals & Services LLC
Berea Sandstone
Waterflood Chemical Tests

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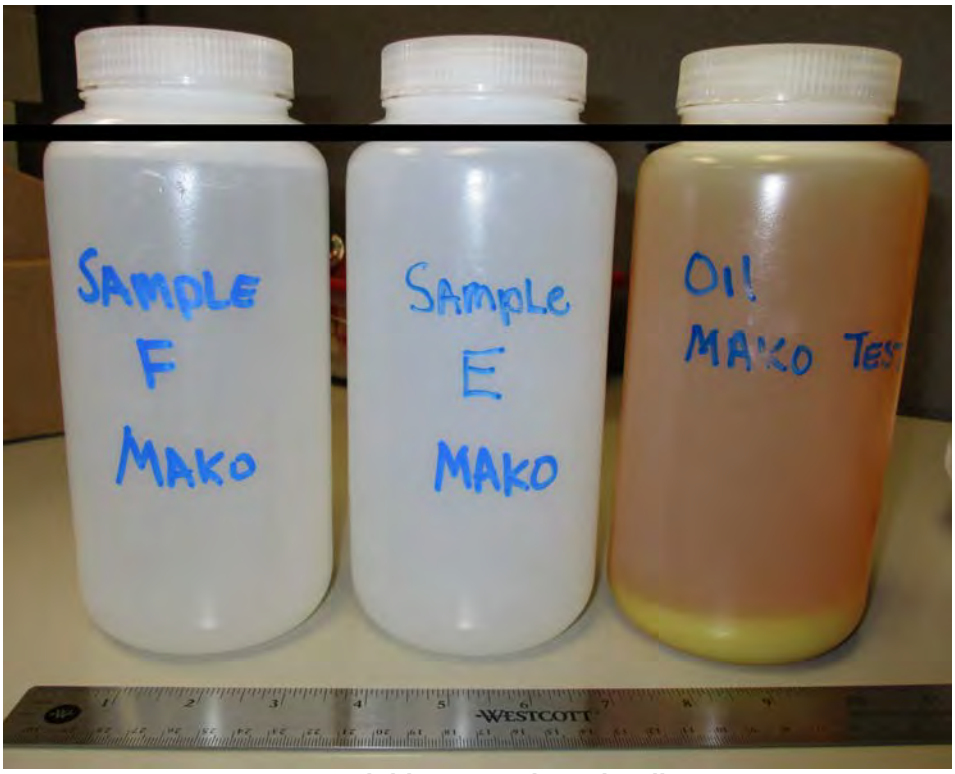
SUMMARY OF RESULTS

The Advanced Technology Center of Core Laboratories received two fluid samples, labeled “E” and “F” and a crude oil sample for a basic waterflood analysis using Berea sandstone samples.



Test Fluids F, E and Crude Oil

The Berea samples were dried in a convection oven at 220°F until weight stabilized. Following drying, basic properties (permeability and porosity) were measured at 800 and 1200 psi net confining stress. The Klinkenberg permeabilities were 144 and 192 millidarcies (md) at 800 psi and 142 and 189 md at 1200 psi. The porosities ranged from 20.1 to 20.5 percent. Grain density measurements for these samples were 2.65 and 2.66 g/cm^3.

After the basic properties measurements, Sample 1 was pressure saturated with sample Fluid E and Sample 2 was pressure saturated with sample Fluid F. The samples were then desaturated to initial water saturation (Swi) in a high speed centrifuge in a gas-displacing-brine configuration. The samples were then vacuum saturated with crude oil. The samples were loaded into a core holder at 1200 psi net confining stress for testing. At these initial conditions, effective permeability to oil was measured at Swi. During the permeability to oil measurement, an instantaneous reaction occurred between Fluid E and the crude oil that caused a significant reduction in the effective permeability. This would seem to indicate the presence of polymers in Fluid E which would influence final oil recovery. The effective permeability to oil for Sample 1 was 6.94 md and for Sample 2 was 148 md.

Fluid-displacing-oil flood endpoints were performed at ambient temperature and at 1200 psi net confining stress, using Fluid E for Sample 1 and Fluid F for Sample 2. The test fluids were injected (flooded) into the samples at a constant rate.

After the fluid floods, the relative permeabilities to water were 4.15 percent for Sample 1 and 11.1 percent for Sample 2 (relative to the effective oil permeability at initial water saturation). Fluid E showed a final oil recovery for 37.0 percent of the original oil in place (Free Oil). Fluid F showed a final oil recovery for 55.8 percent of the original oil in place (Free Oil). The first tube of effluent collected from each sample was photographed for comparison.

Sample Fluid E

Sample Fluid F

An emulsion was observed during two phase flow (after water breakthrough) for Fluid E. See tube photographs in this report for further comparison.

Fluid E had a higher recovery of original-oil-in place compared to Fluid F *(However, that was concluded by calculating emulsified fluids as oil recovery), but Fluid E reduced the terminal permeability by 96 percent of the initial effective permeability in Sample 1. Fluid F reduced the terminal permeability by 89 percent in Sample 2.

After the fluid flood endpoints, basic properties (permeability and porosity) were re-measured at 800 and 1200 psi net confining stress. The Klinkenberg permeabilities were 132 and 184 md at 800 psi and 131 and 182 md at 1200 psi. The porosities ranged from 19.8 to 20.3 percent. Grain density measurements for these samples were 2.65 g/cm^3.

TEST SCHEDULE SUMMARY

Company: Mako Chemicals & Services LLC File: HOU-140890
Well: Berea Sandstone

Berea Sample Number	Basic Properties - Permeability and Porosity	Basic Water Flood with Fluid Sample E	Basic Water Flood with Fluid Sample F	Basic Properties - Permeability and Porosity
1	X	X		X
2	X		X	X

Basic Rock Properties

Basic Rock Properties - Permeability and Porosity

LABORATORY PROCEDURES

Basic Properties

1. The samples were dried to a stable dry weight in a vacuum oven at 220°F and then were cooled to room temperature.
2. Grain volume was determined for each sample by placing it into a stainless steel matrix cup. It was injected with helium from reference cells of known volume and pressure using the Core Lab AutoPorosimeter. Grain volume was calculated using Boyle's Law of gas expansion. Grain density was calculated by dividing sample dry weight by grain volume.
3. The samples were loaded into the CMS-300™ for determination of permeability and porosity. Net confining pressures of 800 and 1200 psi were applied.
4. Each sample in turn was placed into a rubber sleeve between stainless steel end pieces and confining pressure applied. Helium was injected into the sample from reference cells of known volume and pressure. A direct pore volume was determined using Boyle's Law of gas expansion, then pressure was vented at a known rate and unsteady-state Klinkenberg permeability was determined by pressure decay.
5. Porosity was calculated for each sample as the pore volume fraction of the summation (grain volume + pore volume) bulk volume.

Company: Mako Chemicals & Services LLC
Well: Berea Sandstone

File: HOU-1702633
Date: 31-Aug-2017

CMS-300™ CONVENTIONAL PLUG ANALYSIS – SCAL REPORT

Before the Waterflood Tests

Sample Number	Depth (ft)	Confining Stress (psi)	Pore Volume (cm^3)	Porosity fraction	Permeability, millidarcies		Grain Volume (cm^3)	Grain Density (g/cm^3)	Dry Weight (g)	Length (cm)	Diameter (cm)
					Klinkenberg	Kair					
1	n/a	800	11.165	0.201	144.	151.	44.267	2.65	117.492	5.044	3.737
		1200	11.117	0.201	142.	149.					
2	n/a	800	11.146	0.205	192.	199.	43.287	2.66	115.174	4.852	3.781
		1200	11.093	0.204	189.	197.					

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Well: Berea Sandstone

File: HOU-1702633
Date: 15-Sep-2017
Analyst(s): AP, TV

After BWF

CMS-300™ CONVENTIONAL PLUG ANALYSIS – SCAL REPORT

Sample Number	Depth (ft)	Confining Stress (psi)	Pore Volume (cm^3)	Porosity fraction	Permeability, millidarcies		Grain Volume (cm^3)	Grain Density (g/cm^3)	Dry Weight (g)	Length (cm)	Diameter (cm)
					Klinkenberg	Kair					
1	n/a	800	11.054	0.199	132.	136.	44.468	2.65	117.639	5.002	3.742
		1200	11.013	0.198	131.	135.					
2	n/a	800	11.049	0.203	184.	192.	43.462	2.65	115.124	4.868	3.788
		1200	11.039	0.203	182.	190.					

Flow Studies

Basic Water Flood

LABORATORY PROCEDURES

Basic Waterflood with Fluids E and F

1. The received test fluids, E and F were filtered to 0.45 microns and degassed. Fluid parameters including viscosity and density were measured at ambient temperature. The received crude oil was filtered to 0.45 microns and dewatered prior to use.
2. The clean and dry samples were weighed and vacuum-pressure saturated with the test fluids, Berea sample 1 was saturated with Fluid E and Berea Sample 2 was saturated with Fluid F. The saturated samples were then weighed and loaded into a high speed centrifuge in a gas-displacing-water configuration and centrifuged at an equivalent capillary pressure of 200 psi to establish irreducible water saturation.
1. The desaturated samples were vacuum saturated with crude oil. Differential pressure was monitored, and effective permeability to oil at initial water saturation was determined at two injection rates.
3. The specific test fluid for each sample (E or F) was injected through the samples at a constant rate, while collecting produced volumes of test fluid and oil, until an incremental water cut of 99.95 percent was achieved. Effective permeability to brine at residual oil saturation was determined at two injection rates.
4. Each sample was unloaded and weighed then loaded into a Dean-Stark apparatus for determination of final fluid volumes.

ENDPOINT BASIC WATER FLOOD

Unsteady State Method Extracted State Samples
Net Confining Stress: 1200 psi Temperature: 68°F

Company: Mako Chemicals
Well: Berea Sandstone

HOU-1702633

Sample Number	Sample Fluid	Sample Depth, feet	Klinkenberg Permeability millidarcies	Porosity, fraction	Initial Conditions		Terminal Conditions			Oil Recovery, fraction	
					Water Saturation, fraction pore space	Effective Permeability to Oil, millidarcies	Oil Saturation, fraction pore space	Effective Permeability to Water, millidarcies	Relative Permeability to Water*, fraction	Pore space	Oil in place
1	Fluid E (Nissan Corp)	Berea	142.	0.201	0.191	6.94	0.340	0.288	0.0415	0.469	**0.360
2	Fluid F (Mako)	Berea	189.	0.204	0.134	148.	0.383	16.5	0.111	0.483	0.56

* Relative to the Effective Oil Permeability at Initial Water Saturation

** Free oil extracted during testing. Fluid F had no emulsification tendencies

SUMMARY OF SAMPLE PARAMETERS

Company: Mako Chemicals
Well: Berea Sandstone HOU-1702633

Sample Number	Depth, feet	Net Confining Stress, psi	Length, cm	Area, cm^2	Pore Volume, cm^3
1	N/A	1200	5.04	10.97	11.117
2	N/A	1200	4.85	11.23	11.093

SUMMARY OF FLUID PARAMETERS

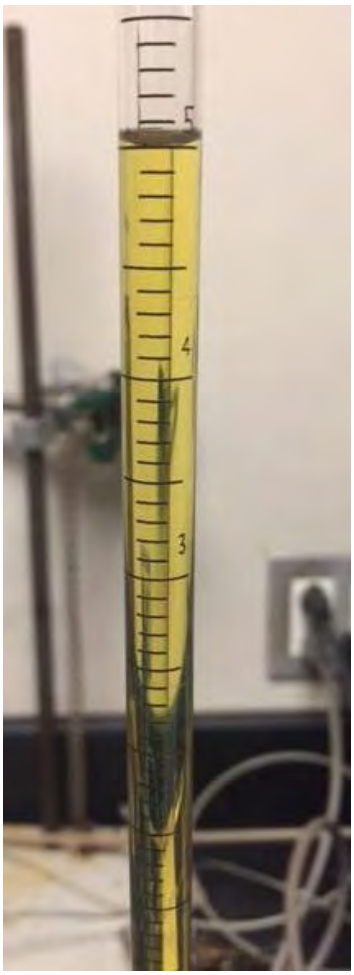
Company: Mako Chemicals
Well: Berea Sandstone HOU-1702633

Fluid	Temperature, °F	Viscosity, centipoise	Density, g/cm^3
Crude Oil	68.0	3.19	0.793
Fluid E	68.0	1.31	1.030
Fluid F	68.0	1.12	1.004

INITIAL TUBE PHOTOS

Company: Mako Chemicals
Well: Berea Sandstone File: HOU-1702633

Fluid "E"



Fluid "F"

Initial Effluent Tubes

TUBE PHOTOS

Company: Mako Chemicals
Well: Berea Sandstone File: HOU-1702633

Sample 1, Fluid E

TUBE PHOTOS

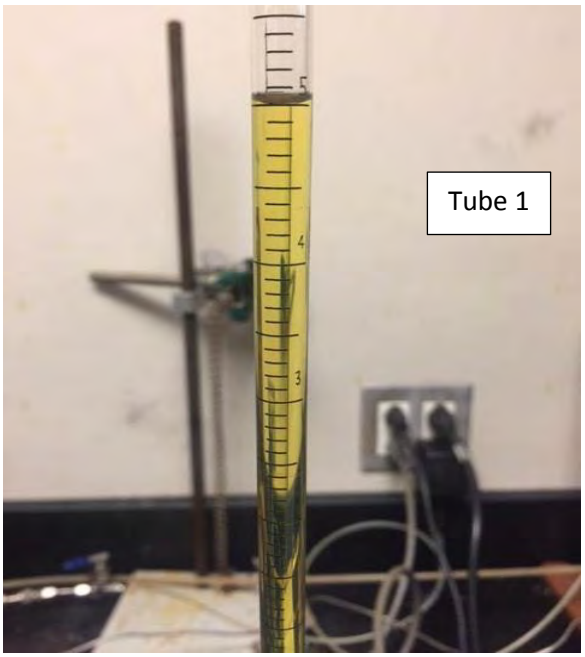
Company: Mako Chemicals
Well: Berea Sandstone File: HOU-1702633

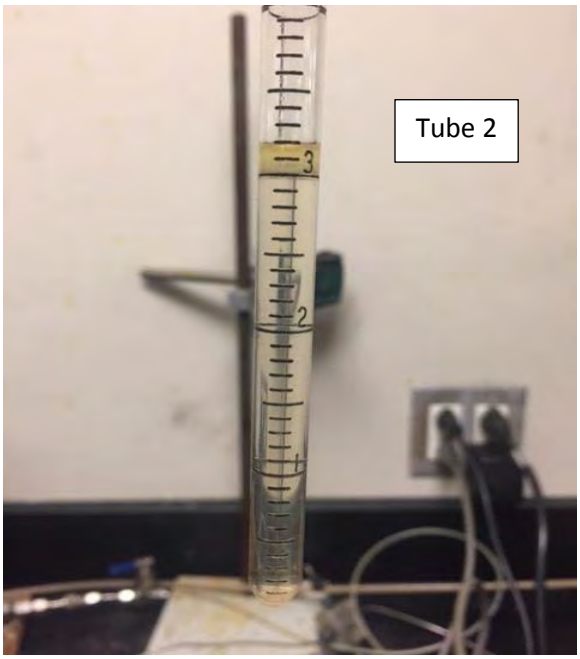
Sample 1, Fluid E

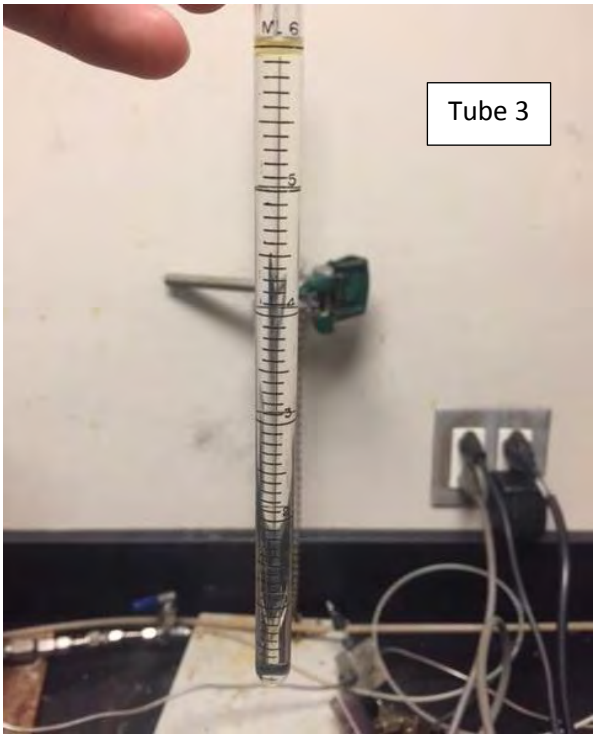
TUBE PHOTOS

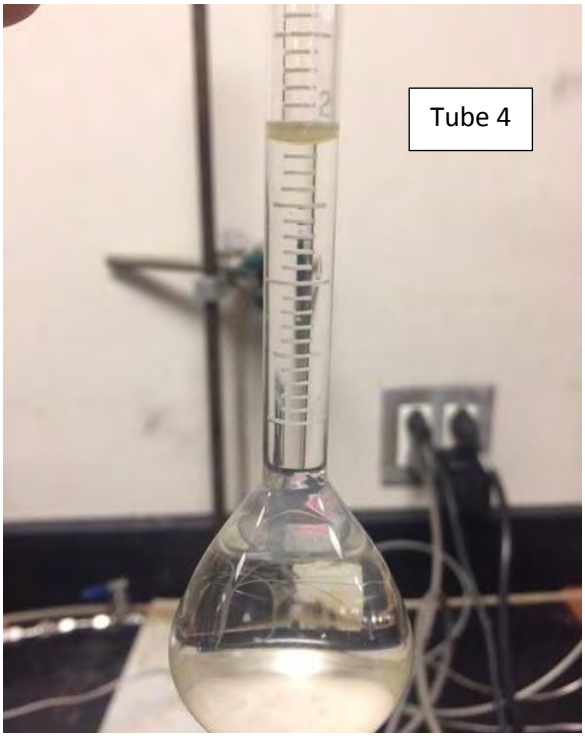
Company: Mako Chemicals
Well: Berea Sandstone File: HOU-1702633

Sample 2, Fluid F









TUBE PHOTOS

Company: Mako Chemicals
Well: Berea Sandstone File: HOU-1702633

Sample 2, Fluid F