SOME LABORATORY DATA RELATIVE TO DRAINAGE, FLOW, AND RECOVERY OF CRUDE OIL IN SAND AND SANDSTONES

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WHILE IT is practically impossible to reproduce underground oil field conditions in the petroleum laboratory, we can nevertheless, reproduce them to such an extent that the results and conclusions obtained are somewhat applicable to oil sands in general. Data obtained regarding gravity drainage of various crudes through unconsolidated sands of various grain sizes and compaction, capillary and surface tension effects, as well as repressuring and water flooding results, are all valuable when attacking more complete recovery problems on the average oil field property. Also, laboratory experiments will do much toward clarifying the student's mind as to what to expect in the field regarding the physical and chemical nature of crudes, oil sands, and reservoir rocks.

REPRESSURING SOLID SANDSTONES

Two students sawed a block of dry Permian sandstone to approximately 12" x 11" x 8" in size. Two 1½" holes were drilled in this block about 8 inches apart to a depth of 6½ inches. A ¼-inch steel nipple was placed in each of these holes, then tamped securely with lead, wool and tar. The block was then given two coats of hot tar, then set in 3 inches of cement.

The sandstone was then saturated with 40° A. P. I. crude. After saturation the in-put "well" was connected to an air compressor, and repressuring was begun. Pressures from one to ten pounds were applied over a period of three hours. The crude was recovered at the "flowing" well. The results were as follows:

Volume of Sandstone block	18336.8c.c.
Volume of Oil required to Saturate	5330 c.c.
Effective porosity of Block	28.9%
Percent recovered at 1 to 2½ lbs. pressure	38 %
Percent recovered at 2½ to 5 lbs. pressure	44 %
Percent recovered at 5 to 10 lbs. pressure	47 %

A similar block of the same sandstone, but containing only 3739 c.c. volume, was treated in the same manner; but the wells were only 5 inches apart. The results were as follows:

Volume of block	3739 c.c.
Amount of 40° A.P.I. crude to saturate	1211 c.c.
Effective porosity	32.3%
Percent recovered at 1 to 2½ lbs. pressure	41.3%
Percent recovered at 2½ to 5 lbs. pressure	50.6%
Percent recovered at 5 to 30 lbs. pressure	57 %

This proved that closer spacing of wells will more completely drain the sand. It also proved that more of the oil is recovered per cubic inch (or per acre-foot, if need be) in small pools than in large ones, especially if the porosity is higher, and there is sufficient gas present. It also showed that excessive pressures are not necessary, as pressures exceeding 10 lb. merely cause a "blowing-through' or channelling within the sandstone, little oil being recovered.

A 9-foot static head was built upon the input "well" of this smaller block, then the sandstone was "flooded" with clear tap water for two

hours. Only 15 additional c.c. of oil were recovered by this process. The flooding medium was then changed to a 2 percent Na_2CO_3 solution. After two hours more, 34 additional c.c. of crude were recovered. The carbonate solution was then forced through the sandstone under 3 to 5 lbs. air pressure. Very little more recovery was obtained. This oil was so badly emulsified by air, water, and Na_2CO_3 that it could not be measured accurately, but it was estimated at 15 c.c. Thus, by using all three methods of recovery, 62.5% of the total volume of oil was recovered. This high percent of recovery could not be expected in the field, however.

The small block was then split open with a chisel, to examine the sandstone. The oil was completely drained from the vicinity of the "flowing" well, but the tight or shaley streaks parallel to the bedding planes still contained appreciable amounts of crude oil.

EFFECTS OF EVAPORATION

On the 15th day of last May 500 c.c. of Cromwell crude was set aside in a graduate in order to note the effects of evaporation. The graduate was covered with a piece of rough surfaced cardboard, the top being only partially vapor tight. The A.P.I. gravity of this crude was 40.5° at 76° F. The viscosity was 39 seconds Saybolt.

On November 13, 1928, the original volume was reduced to 363 c.c., a loss of 27.5 percent. The gravity was reduced to 33.7° A.P.I. at 72° F., a reduction of 6.8 degrees, which at the present price represents a loss of 35 cents a barrel over a period of six months. The viscosity of this sample was increased to 50 seconds Saybolt.

CAPILLARITY AND SURFACE TENSION

(a) Two prisms of hard Permian sandstone, porosity 33 percent, were cut to 1"x1"x3" in size. One was stood in a beaker containing one half inch of 41° A.P.I. gravity crude at 86° F. The other was stood in a beaker containing one-half inch of distilled water at the same temperature. The prism in the water was saturated in 5 minutes. It required 12 minutes for the one in oil to become saturated.

(b) The oil-saturated prism mentioned above was placed in a beaker of distilled water at 86° F. All of the oil was driven out by the water in 1 hour and 57 min. A similar prism was saturated with the same crude for only half its length, then placed with the dry end down in water at 86° F. All of the oil was driven out in 42 minutes.

(c) A similar prism to those mentioned above was saturated in the same crude, then placed in a beaker of distilled water at 120° F. All of the oil was recovered in 26 minutes.

Another prism was saturated in crude for half its length, then placed in distilled water at 120° F. All of the oil was recovered in 9 minutes and 30 seconds.

(d) A prism 1"x1"x3" was saturated with water, then placed in a beaker of crude oil. No effect was noticed after 20 minutes. When the prism was broken, it could be clearly seen that the oil had not penetrated the sandstone at all.

CHARACTERISTICS OF GRAVITY DRAINAGE

(a) A glass percolator was filled with 209 c.c. of clean, spherical sand of 60-80 mesh (grain ranging between .0087" and .0069"). The sand was packed to approximately 31 percent porosity. Sixty-five c.c. of 39.5° A.P.I.

was poured upon the sand and permitted to percolate through it. Twenty-eight c.c. of the oil were recovered after two hours, after which drainage ceased. This represented 42 percent recovery. There was no change in the gravity or color of the crude.

An equal volume of 100-115 mesh (grains ranging from .0059" to .0049") sand was placed in a similar percolator, and packed in the same manner. This sand was very red, and contained an appreciable amount of clay, shale, and iron salts. Sixty-five c.c. of the same oil was percolated through the sand. It moved downward at the rate of one inch in approximately 3 minutes. After 5 days only 15 per cent of the oil had drained out. Two washings with Na_2CO_3 solution recovered only an additional 6 percent after a period of 3 days. The gravity of the oil used in this test was reduced approximately 1.5° A.P.I., and the filtered oil had an amber color.

POROSITY AND GRAIN SIZE

Thirty c.c. of 20-24 mesh rounded sand was placed in a test tube. An equal amount of 80-100 mesh Simpson sand was placed in a similar test tube. Thirty c.c. of Simpson that had passed through a 200 mesh screen was placed in a third test tube. Each quantity of sand was packed and compressed an equal amount and in the same manner. Warm distilled water (temp. 125° F.) was dropped slowly from a burette tube upon each quantity of sand until it was saturated. The amount of water necessary to fill the pore space in each tube was as follows:

20—24 = 9.7c.c.
80—100 Simpson = 9.9c.c.
200+ Simpson = 10.2c.c.

This small variation was due to experimental error. The conclusion is, porosity is independent of grain size, provided the shape of the grains is similar and the size uniform.