SPE 666

FIELD CASE HISTORY

The South Burbank Unit — A Comparison of Oil Recoveries by Various Type Drives

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Abstract

The South Burbank Unit of Osage County, Okla., produces from an offshore-bar-type reservoir which has been subjected to both intensive gas injection and to water flooding. The Unit was formed early in the primary life of the reservoir, and development involved only about one-half the well densities of nearby pools in the same-type reservoirs. Gas injection was started immediately after unitization, and was continued to near its economic limit. Ultimate recovery by gas injecton would have been about 34 per cent of the initial oil in place, compared to about 22 per cent recovery of the initial oil in place by primary depletion in nearby areas.

Initial waterflood development of the South Burbank Unit was made in 1951 on an irregular five-spot pattern with about 40 acres per producing well. Recoveries will be as high as nearby regular five-spot pattern on 20-acre spacing. The water flood will ultimately recover an additional 12.8 per cent of the initial oil in place over that which could have been recovered by gas injection. The combination of gas injection and water flooding will recover 46.8 per cent of the original oil in place. However, early application of water injection, without the intervening period of gas injection, would have recovered as much total oil in a much shorter total operating life.

Introduction

The South Burbank Unit, in Osage County, Okla., affords an opportunity to compare the recovery of oil by each of the three most common energy mechanisms: solution gas, gas injection and water flooding. Since the Unit was formed and gas injection started some 17 months after discovery of the field, performance of the field under primary solution-gas drive can only be determined on the basis of the performance in nearby, similar reservoirs. Early unitization permitted development with about one-half the well density of nearby areas.

Geology

The South Burbank pool was discovered on Jan. 5, 1934, with completion of the Mead Oil Co., *et al*, No. 1 De Noya in the NE-NE-SW part of Section 10-25N-6E, at a total dept of 2,857 ft. in the Burbank sand. Other publications have discussed the geology of the pool,[1,2] and the information presented here is but a brief summary.

The South Burbank field is located off the southeast flank of the North Burbank field and, like the latter field, is a sand lens within the Cherokee shale formation which immediately overlies the Mississippi lime. Following post-Mississippian erosion, the general area of southern Kansas and eastern Oklahoma was covered by the Cherokee Sea in which shales were deposited upon the eroded surface of the Mississippi lime. As the Cherokee Sea advanced and receded upon land, offshore sand bars were formed. Major sand bodies such as North and South Burbank were laid down over an extended period of time. As conditions were altered by shifting currents, severe wind and wave action, and changes in the shore line, there were periods of deposition of silt and mud, resulting in inhomogeneities in the sand bars.

The general attitude of the base of the sand in the South Burbank pool is that of an irregular plane dipping at the rate of about 40 ft/mile toward the west. The productive sand thins to the south and west as it is pinched-out by sandy shales.

Permeability of the Burbank sand ranges from less than 1 md to about 2 darcies, and porosity ranges from 11 to about 29.5 per cent. Estimated average reservoir physical properties are tabulated in Table 1.

Reservoir Oil Properties

Fig. 1 presents the gas solubility and shrinkage curves for a sample of the reservoir oil. The gas in solution at the estimated original reservoir pressure of 1,200 psi was 380 cu ft/bbl, and the original formation volume factor was 1.2. Gravity of the produced oil is about 39° to 40° API.

[1]References given at end of paper.

TABLE 1—PHYSICAL PROPERTIES OF THE BURBANK SAND RESERVOIR, SOUTH BURBANK UNIT, OSAGE COUNTY, OKLA.

Average Sand Thickness, ft	53.3
Total Volume of Saturated Oil Sand, acre-ft	128,000
Average Porosity, per cent	16.8
Connate-Water Saturation, per cent	26.0
Estimated Average Permeability, md	50-100
Reservoir Volume Factor	1.2

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Initial Oil In Place

Fig. 2 is an isopachous map of net oil sand. Sand volume within the South Burbank Unit area is 128,000 acre-ft. From the physical properties summarized in Table 1, initial stock-tank oil in place was calculated to be 130 million bbl within the Unit area. This volume of oil in place was also determined by material-balance calculations, and is the basis of the recovery efficiency estimates reported in this paper.

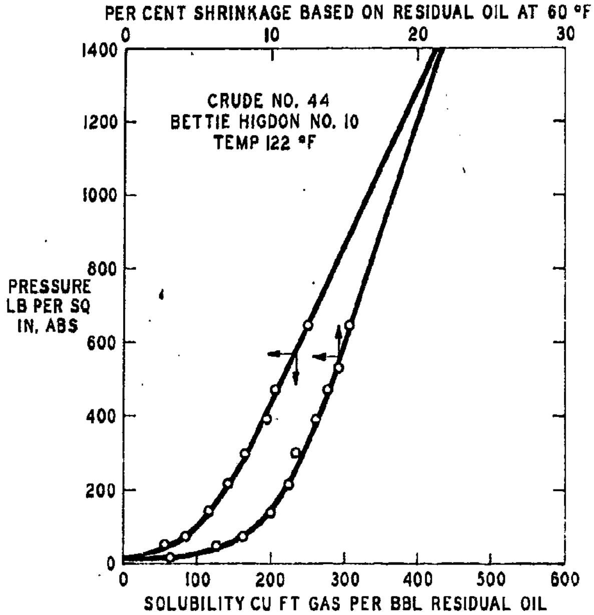

Fig. 1—Solubility and shrinkage curves, South Burbank crude.

History of Gas Injection

McWilliams[3] has reported the history of the gas-injection operations of the South Burbank Unit through the year 1945. The Unit was formed in June, 1935, only 17 months after discovery of the pool, and gas injection was started the same month, with four wells being utilized for gas injection. An additional four wells were converted to gas injection during 1936, with all the injection wells being in the area of the thickest sand along the eastern side of the Unit in an effort to create an expanding gas cap. The produced gas-oil ratio increased from about 800 to 5,500 cu ft/bbl by the end of 1940, during which period an average of about 55 per cent of the produced gas was returned to the reservoir.

In 1941 the program of gas injection was changed from a "gas-cap-type" injection to a "dispersed-type" injection with 29 wells used to return gas to the formation. The volume of gas injected was increased to about 80 per cent of the produced gas, and producing wells were deepened and cleaned out to increase capacity. As a result, the capacity to produce was sustained, and the Unit was able

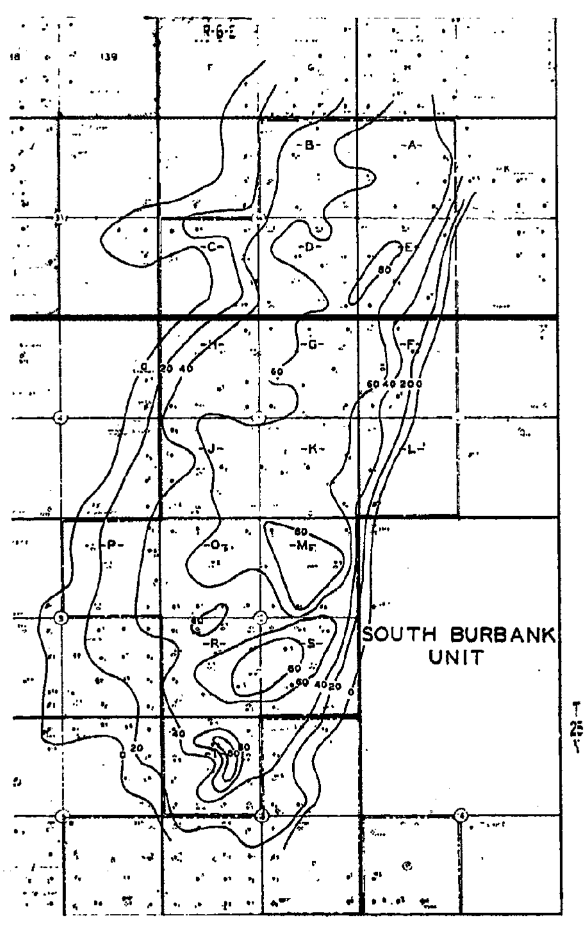

Fig. 2—Sand thickness map.

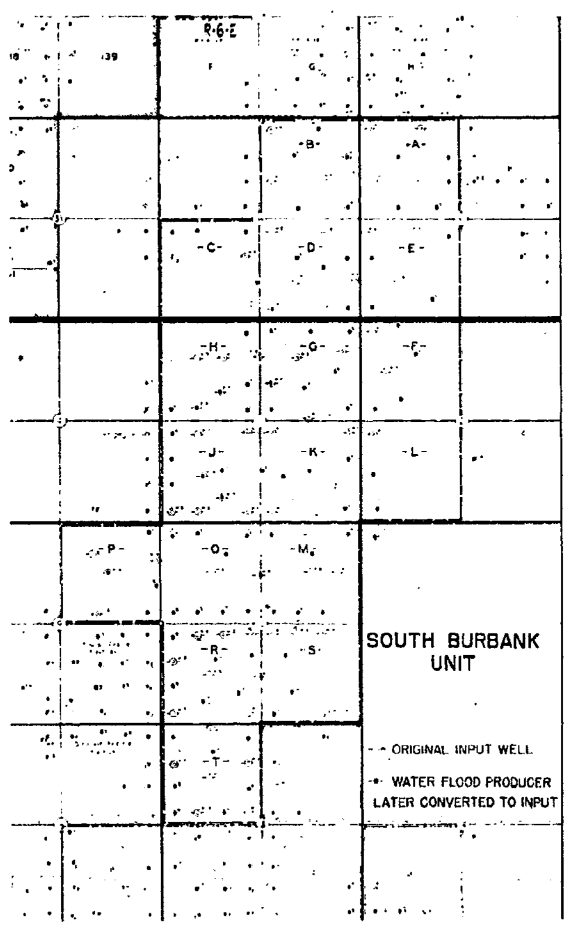

Fig. 3—Water injection pattern.

to produce at maximum allowable rate until 1945, at which time capacity to produce became the limiting factor. Production declined about 3,300 B/D between 1945 and 1951, when the initial waterflood development was made.

History of Water Flooding

The waterflood development pattern for the South Burbank Unit is shown in Fig. 3. The area first placed under water flood was the north five quarter-sections which were developed in 1951. The central six quarter-sections were placed under flood in 1955, and the remainder of the Unit was developed in 1958. The existing wells were utilized to achieve, as nearly as possible, an irregular five-spot pattern. A minimum number of new wells was drilled to fill out the pattern.

High producing water-oil ratios were anticipated for the South Burbank Unit water flood because of zones of high permeability and the high gas saturation of the reservoir at the start of the flood. Flood performance has generally followed the anticipated behavior. Produced water-oil ratio has generally been above 10:1, even from initial response. However, there was a period of about 2½ years, beginning in early 1954, when the produced water-oil ratio of the initial flood development was below 10:1, ranging as low as 6:1.

Oil Recoveries

Fig. 4 is a graphical representation of the entire producing history of the South Burbank Unit. The dashed-line extrapolations of the oil-production curve represent the anticipated ultimate depletion under the various producing mechanisms: solution-gas drive, gas injection and water flooding. Since gas injection was started early in the primary life of the reservoir, the curve for production under solution-gas depletion was estimated from the behavior of the nearby North Burbank field. The South Burbank field is, in reality, an extension of the system of off-shore bars which comprise the North Burbank field and Stanley Stringer, and the reservoir oils are identical. The North Burbank field was produced to an advanced stage of depletion before gas injection was initiated, and primary depletion performance can be estimated accurately from the production decline curve. On this basis, it is estimated that 22.7 million bbl of oil, or 22 per cent of the 103 million bbl initially in-place, would have been recovered by solution-gas expansion during an approximate 40-year life.

The South Burbank Unit gas-injection program had reached a state of depletion by 1951 that permitted a fairly accurate estimate of ultimate recovery by gas injection. Extrapolation of the production decline curve under gas injection indicates an ultimate recovery of 35 million bbl, or 34 per cent of the initial oil in place, during a 32-year life.

Oil production under water flood has reached a peak and is declining. The rate of decline of the total Unit has been estimated from the rate of decline in the earliest-developed area of the Unit. Final ultimate recovery from the reservoir, after flooding, is estimated to be 48.2 million bbl, or 46.8 per cent of the initial oil in place during a 43-year life.

Comparison of the waterflood recovery of the irregular five-spot pattern of the South Burbank Unit, having

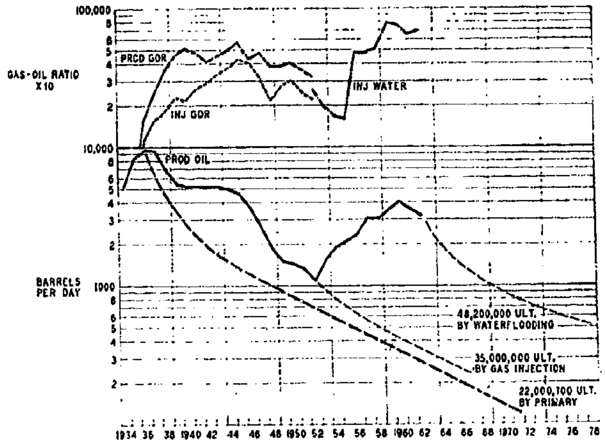

Fig. 4—South Burbank unit production history.

about 40-acre spacing, with the 20-acre regular five-spot patterns of the other floods in the area, indicates that the flood recoveries per acre-foot will be the same.

Conclusions

An effective gas-injection pressure-maintenance program in the South Burbank Unit would have ultimately recovered 54 per cent more oil than could have been recovered by primary pressure depletion in about the same operating life. It is estimated that the average residual oil saturation of the Burbank sand reservoir pore space at ultimate depletion by gas injection would have been 41 per cent.

Early application of water injection, without the intervening period of gas injection, would have recovered as much total oil as will be ultimately recovered by water flooding following the gas injection, and total operating life would have been shortened. It is estimated that early application of water flooding would have recovered 112 per cent more oil than primary pressure depletion alone, and total operating life would not have exceeded 30 years.

The estimated average residual oil saturation of the Burbank sand reservoir pore space following depletion by water flooding will be 33 per cent.

References

1. Markham and Lamar: "Geology of the South Burbank Pool", *Oil and Gas Jour.* (1937) **35**, No. 45, 64.
2. Bass, Leathercock, Dillard and Kennedy: *Bull.*, AAPG (1937) **21**, No. 1, 30.
3. McWilliams: "Unitization and Gas Injection in South Burbank", *Drill. and Prod. Prac., API* (1946) 175. ★★★

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