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RESATURATE WHILE REPRESSURING

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Resaturate While Repressuring—A Wartime Suggestion

by Frederick Squires

GAS - REPRESSURED properties are apt to develop the undesirable characteristic that certain input wells may provide too ready a passage for gas to neighboring output wells to the detriment of their oil production.

The writer long ago came to the conclusion that the cause of this phenomenon lay in the reduction of the percentage of the liquid content of the sand between such input and output wells and this belief has been fortified by recent laboratory investigations.[1]

The present paper is intended to show how the rules developed for the relation between the degree of liquid saturation and the amount of liquid movement may be applied to improve oil production in repressured areas. "Blowing through" may be reduced by adding water through the gas input wells in quantities sufficient to increase the liquid content of the sand to the point at which, when gas injection is resumed, the permeability of the sand to gas is reduced and gas reacquires its ability to move oil.

Laboratory Investigations

Experiments have proved in laboratory tests that when a gas and a liquid flow simultaneously through a sand, the permeability to gas increases as the liquid saturation decreases and vice versa. As interpreted by Parke A. Dickey [ref. 1 (d)] the experiments indicate:

"That injected gas-oil ratio varies geometrically with gas-liquid saturation ratio of the sand. At a liquid saturation of about 80 per cent, the gas-oil ratio will be about 5 cu. ft. per barrel, whereas at a liquid saturation of about 60 per cent, the gas-oil ratio will be about 5,000 cu. ft. per barrel.

"It makes very little difference whether the liquid is water or oil. Consequently, if the liquid were all oil, practically none would be recovered even if the saturation were 30 per cent. If the liquid saturation was 60 per cent, of which 30 per cent was oil and 30 per cent was water, considerable quantities (of oil) could be recovered at reasonable injected gas-oil ratios. If the liquid was 70 per cent, of which 40 per cent was water and 30 per cent was oil, the oil could be recovered at still better gas-oil ratios."

Application of Laboratory Findings to Correction of Blowing Through

Many sands, such as the Cow Run in southeastern Ohio and the adjoining fields in West Virginia, have high but irregular permeabilities and produce little water. They are vulnerable to the well-known evil of "blowing through" or "bypassing" wherein gas finds the easiest channel between an input and one but not all of its surrounding output wells, quickly reduces the intervening saturation to submarginal proportions and no longer moves oil to any of the surrounding output wells, even with enormous gas throughput. The pressure medium has followed an excessively permeable channel which was, of course, quickly flushed of most of its oil and has therefore become tremendously permeable to

1. (a) Wyckoff, R. D., and Botset, H. D., The Flow of Gas-Liquid Mixtures Through Unconsolidated Sands.
(b) Leverett, M. C., and Lewis, W. B., Steady Flow of Gas-Oil-Liquid Mixtures Through Unconsolidated Sands. Trans. A.I.M.E. (Petroleum Development and Technology) vol. 142, 1941, p. 107.
(c) Dickey, Parke A., and Bossler, Robert B., Role of Connate Water in Secondary Recovery of Oil. Trans. A.I.M.E. (Petroleum Development and Technology) vol. 155, 1944, p. 175.
(d) Dickey, Parke A., Influence of Fluid Saturation in Secondary Recovery of Oil: (Pt. II, sec. 4), Proceedings Am. Petr. Inst., vol. 24 (IV) 1944, p. 158.

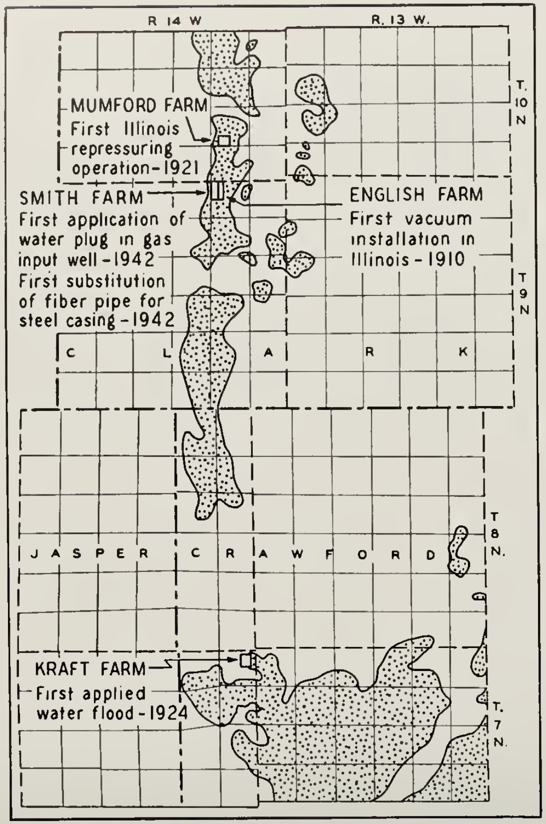

Fig. 1: Map showing location of resaturating experiment. It also shows the initial applications in the state of repressuring, flooding, and nonferrous well casing, these being the work of the author

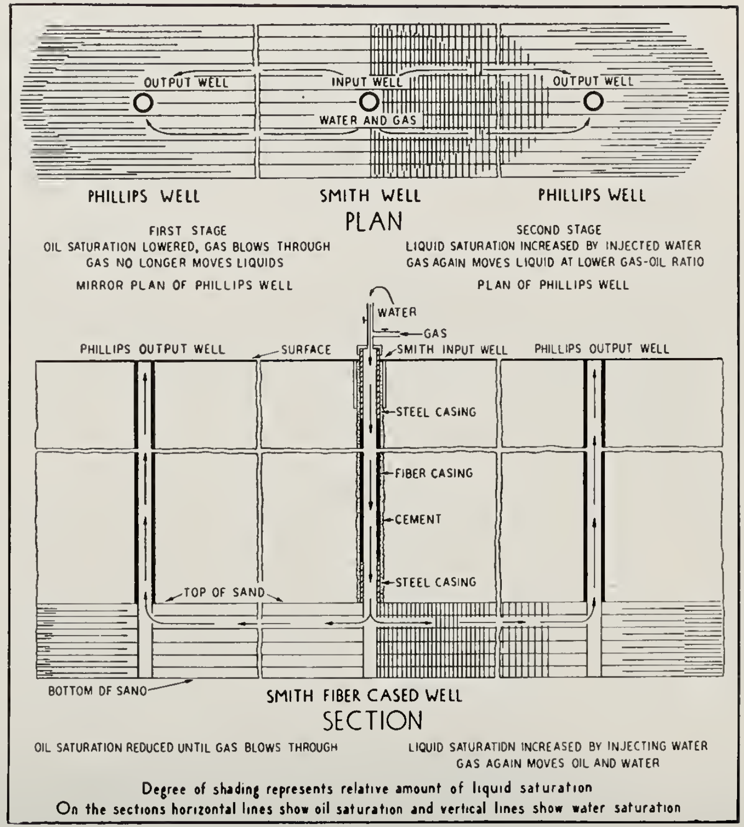

Fig. 2: Diagram illustrating the process of resaturating to correct the evil of blowing through. Smith-Phillips wells in W½ NW 2-9n-12w, Johnson Township, Clark County, Illinois

gas. To correct this, water may be injected through the gas-input well from which most of it will occupy the most permeable sand. The result is an increase in the fluid saturation to the point at which it is less permeable to gas, the degree being determined by the amount of water. Some of the injected gas then moves to others of the surrounding outputs as well as through normally less permeable horizons of sand between the wells formerly blowing through. This is the simplest form of selective plugging. It may be, but does not often need to be, refined by adding any of the well-known plugging agents. The process is cheap and can do the well no harm. The Dinsmoor brothers were the first to practice this water plug.

Application of Laboratory Findings to Oil Production in the Field

On many properties, especially those that produce little water, after repressuring operations have been carried on for a long time, the percentage of liquid saturation between many input and output wells scattered throughout the area falls to a point at which little oil is moved, even by constantly increasing volumes of injected gas. The liquid content in the area traversed by the gas has fallen below Dickey's critical per cent of the sand-pore space. Its permeability to gas has been so increased that in effect the whole field is "blowing through" even though some of the wells still offer resistance. Since no more oil can be moved by injected gas at the existing liquid saturation of the depleted areas and since oil would be moved elsewhere if the liquid saturation was raised in the too permeable horizons, then both laboratory experiment and field experience dictate that water should be introduced from the surface into the offending wells to provide enough resistance for oil to be again gas movable. This was recognized by the writer as a rule of thumb rather than a law of science in 1917 in patent No. 1,249,232, claim 3 of which reads: "The method of recovering oil and gas which consists in introducing into the oil-bearing stratum a gas under pressure and introducing, simultaneously with the gas, a liquid under pressure."

A Field Test in Illinois

Fig. 1 is a map of an area in Illinois which is historic ground because here is located the English farm, Illinois' first vacuum application; the Mumford farm, the first Illinois repressuring operation: the Kraft, the first intentional water flooding in the state; and the Smith farm, the first property in Illinois on which water injection intermittent with gas was used to correct blowing through, and the first installation of fiber pipe as a substitute for steel casing.

Vacuum was applied by Harry Werts on the English farm and accomplished large oil-production increase. The magnitude of the results caused operators to adopt the process generally, although many applications were not profitable.

The first successful repressuring operation in the state was applied on the Mumford farm in 1921 using an existing gasoline plant. It is unfortunate that the spread of this very generally profitable process has not extended into the rich Lawrence County fields, especially on the Kirkwood sand. It would be a good war effort now.

Water injected from the surface on the Kraft farm in 1924 was the forerunner of the process of flooding which has recently been applied with marked success in the Siggins, Patoka, and Noble pools and promises to be very valuable in many other areas of the state.

Pioneer Work

The Smith farm was chosen for experiments with fiber casing and for correction of blowing through. The Mumford repressuring, Kraft flooding, and Smith fiber-casing operations were pioneer work done by the writer.

Fig. 2 shows the Smith well and the adjoining Phillips well. Gas introduced through the Smith well soon blew through to the Phillips. To correct this, water was injected into the Smith well to increase the liquid saturation and reduce the permeability to gas between the of-

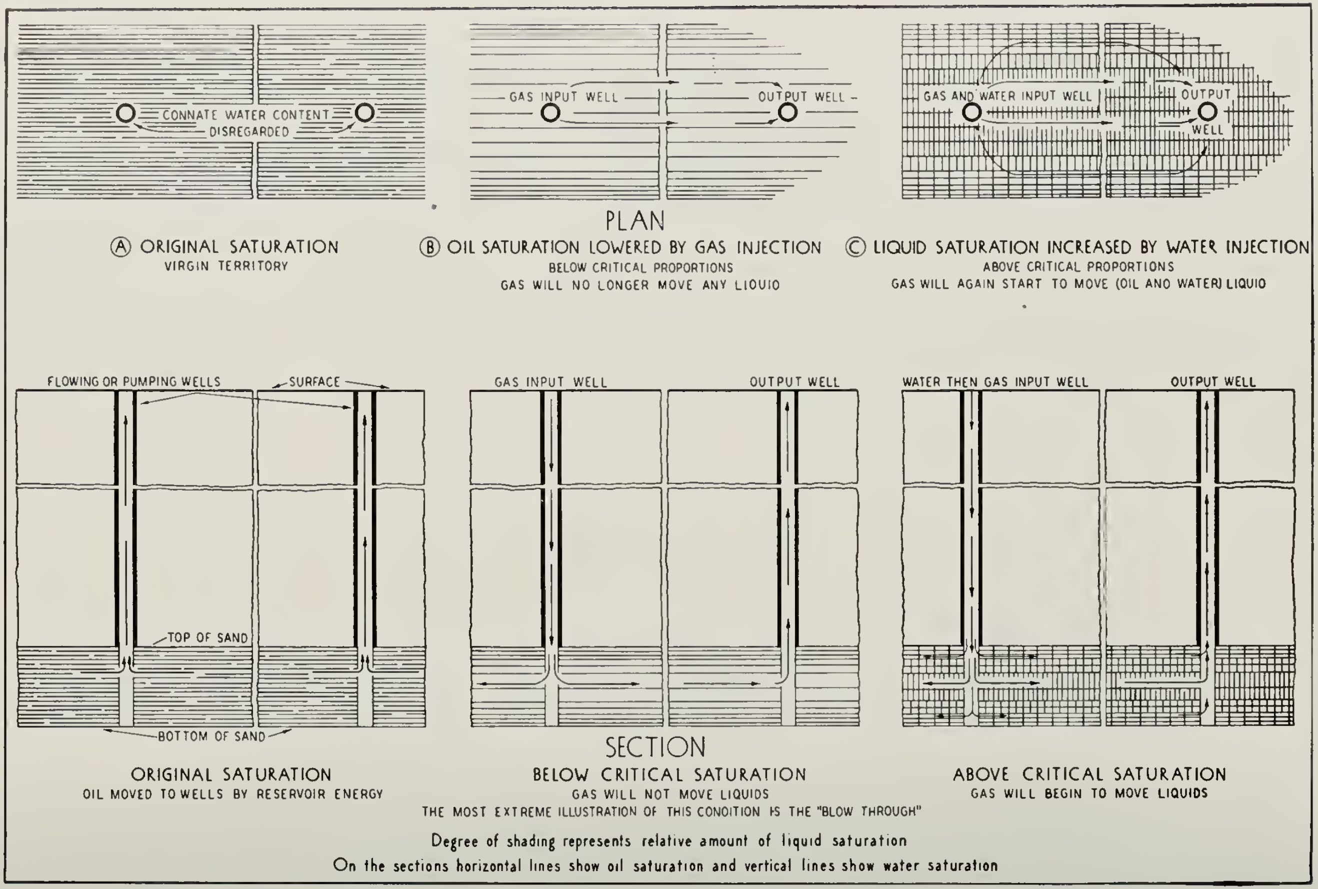

Fig. 3: Diagram in plan and section indicating relative saturations. It illustrates the process of resaturating in order to increase the liquid content of a sand from the point at which gas ceases to move liquid to a proportion at which gas is again effective

fending wells and this resulted in a reduction of the gas-oil ratio of the Phillips output well. After the water plug was placed, gas pressure was gradually rebuilt. When the gas-liquid ratio at the Phillips well again increased more water was turned in with a like result. The operation requires a considerable water supply.

The same principle is applicable to any parts of whole properties which have had their sand-pore liquid saturations reduced below the critical limit so that wells blow through. The correction for this condition is illustrated in Fig. 3.

This drawing shows three stages in the liquid saturation of a repressured property between any two adjoining input and output wells where blowing through occurs. (A) The condition in the virgin sand; (B) The blowing-through condition after prolonged passage of gas through the sand from any input to any output well, and (C) the improved state of liquid saturation between offending wells after water has been injected through the gas pressure wells. In the drawing (Fig. 2) the sand is shown as if it were homogeneous. It is to be understood that there would always be variations in vertical and horizontal permeabilities. This would act to make gas move oil in the less-permeable strata after water had increased resistance to it in the most permeable horizon.

Acknowledgments

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