Influence of Production Practices on Gravity of Produced Oil

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(Los Angeles Meeting, October, 1937)

The gravity discussed here is that of the clean oil produced. Gravities of fluids containing water, free or in the form of emulsion, sand, drilling mud or mineral salts of a nonbituminous nature do not represent the gravity of crude oil as considered in this paper.

During recent years it has become a frequent occurrence for operators to be called upon to explain to landowners the reasons for variations in gravity on shipments of oil from wells in which they are interested as royalty owners. In regard to single well leases it has been noted that marked changes in gravity frequently have occurred for no apparent reason. Data collected on the subject and correlated with production methods reveal interesting facts. It is the purpose of this paper to present some of the highlights on the subject.

These gravity changes in the natural crude oil are with a few exceptions the result of the liberation under varying conditions of the volatile hydrocarbons from the natural oil-gas solution contained within the pool. The subject of the liberation of gases from natural oil-gas solution has been investigated by Ben E. Lindsly, of the U. S. Bureau of Mines, and the observations recorded here are in the main consistent with his conclusions.

Investigators have recognized two methods of liberation of gas from solution—flash and differential. In the latter method the vapors are removed from the liquid as rapidly as formed and have no opportunity to come to a condition of equilibrium with the oil. In flash liberation an equilibrium condition between the oil and the gas exists at the pressure of separation. Mr. Lindsly has found that the method of liberating the gas from the oil has a pronounced effect on the final gravity and that differential liberation results in a higher A.P.I. gravity due to the higher ratio of gasoline producing hydrocarbons left in the oil.

Under actual production practices with high velocities in flow strings, it is our contention that conditions of perfect equilibrium between gas and the oil rarely exist, and that gas separation is made under varying conditions, sometimes approaching that of equilibrium and at other times departing from it.

Manuscript received at the office of the Institute Oct. 13, 1936.

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It has been pointed out that the gravity of the oil-gas solution in a natural reservoir under pressure is much lighter, because of the dissolved gas, than is the gravity of the oil as delivered to the production tanks. From a production standpoint it is desirable to distinguish between the gravity of the oil-gas solution in the reservoir and that of the oil component. As the gravity of the residual oil will vary with the changing conditions under which the gas component is liberated, we may define the gravity of the oil within the reservoir as the gravity of the liquid hydrocarbon content of the reservoir when reduced to atmospheric pressure under conditions of differential liberation. We may not be able to measure this gravity accurately unless we get a bottom-hole sample under static conditions, nevertheless we shall adopt the definition.

A discussion covering the changes in gravity of crude oil brought about through methods of production involves two separate phases:

1. The gravity changes of the fluid within the reservoir.
2. Gravity changes brought about in the wells, lines and traps, by the methods of operation.

Gravity Changes within the Reservoir

Gravity changes within the reservoir may be brought about by migration. A decrease in the gravity of the oil in an old field under water drive is a common phenomenon. Occasionally an increase in gravity has been noted after prolonged periods of pumping, which may be ascribed to a downward migration of lighter oil originally accumulated on the top of the structure, the downward migration having been caused by edge withdrawals.

The method of gas liberation in the reservoir naturally has a bearing on the gravity of the oil entering the well. Without arguing whether or not this method more nearly approaches flash liberation or is approximately differential liberation, we can admit that it varies between the two methods, and also that it is influenced by the position of the well on the structure, the presence or absence of a free gas cap, and the method of pressure control on the well.

Gravity Changes Caused by Producing Operations

It is obvious that an increase in casinghead gasoline from the well must result in the lowering of the gravity of the oil produced, except when such gasoline is recovered from a product that previously was lost, or when it is drawn from oil still left in the ground. In the first instance the economic gain is clear. In the second, an ultimate loss is indicated as casinghead gasoline produced from the oil left in the ground necessarily lowers the gravity of the oil remaining, thus lowering its value and making its recovery more difficult.

It often happens that a justification of a change in production is based on an increased gasoline recovery from the gas produced with the oil. Except as noted above, increased production of casinghead gasoline can occur only when such gasoline is taken directly from the oil produced, thus lowering the gravity and its value, the net results to the operator remaining substantially the same. Changes in gravity of as much as 4° A.P.I. on 30° oil have been brought about by operating practices within the control of the operator. The changes in gravity were accompanied by an equalizing change in natural gasoline production. The producer is primarily interested in producing the maximum amount of oil at a minimum cost, and is not greatly concerned with the effect of his production method on the gravity of the oil as long as the gasoline-producing fractions are all recovered in the gasoline plant.

There are some reasons, however, why we should have a better understanding of the causes of these gravity fluctuations, among them the following:

1. Gasoline production may be erroneously credited to an operation that has merely resulted in extracting the gasoline from the oil produced.
2. Geologists may err when using gravity data as an aid in determining the horizon from which the production originates.
3. Claims have arisen for the improper accounting of royalties, based on the theory that the gravity of the produced oil varies uniformly with the time the well has been on production.
4. A knowledge of the subject may enable the producer to use the gravity data as an aid in solving production problems, including those which have to do with reservoir withdrawals.

The following data are presented covering changes in gravity that have resulted from changes in well operations. The gravity figure used is that of the average of all tank gravities for each month and, unless otherwise noted, represents the gravity of oil cutting 1 per cent or less in water and sediment.

Effect of Release of Pressure on Well Head.—Fig. 1 shows the result of a sudden drop in well-head pressure. On this chart, in addition to the gravity range, has been platted oil production in barrels per day and the back pressure on the flow string. Through the first 21 months of the life of the well, the tubing pressure dropped from 290 lb. per sq. in. to 70 lb. with little change in the gravity of the oil. The gas was separated in a trap carrying 5 to 10 lb. The gas-oil ratio varied considerably, gradually making two complete cycles between 1500 and 2300 cu. ft. per barrel. With 60 lb. carried in the tubing, the well ceased to flow. The choke was removed and the well was placed on production by means of the gas-lift, which was immediately discontinued. The well continued to flow against 5 to 10 lb. pressure carried on the trap. The results were as given in Table 1.

In the fourth year, the absorption plant was shut down and wet gas instead of dry gas was recycled. This was followed by an immediate increase in the gravity of the oil to a point equal to or in excess of the initial observed gravity. The effects of the change are shown in Table 2.

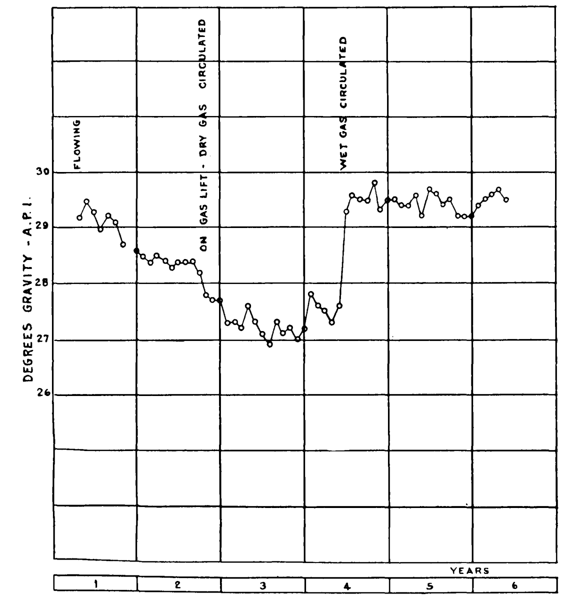

FIG. 3.—EFFECT OF SUBSTITUTING WET GAS CIRCULATION FOR DRY GAS IN GAS-LIFT OPERATIONS.

Wax trouble in the upper 1000 ft. of the flow string ceased entirely under wet gas circulation.

TABLE 2.—*Wet Gas versus Dry Gas*

Production under dry gas circulation:	
Barrels oil per day	129.4
Barrels natural gasoline	13.4
Total	142.8
Average gravity of crude oil	27.4° A.P.I.
Production under wet gas circulation:	
Barrels oil per day	146.5
Barrels natural gasoline	6.9
Total	153.4
Average gravity of crude oil	29.6° A.P.I.

Effect of Periodic Intervals of Idleness.—Fig. 4 shows the effect on gravity of shutting in a well and allowing the fluid level to build up on the pump. The oil from this well had a slight cut, which has been indicated at the bottom of the chart. The days on production each month are also indicated. The practice on this well was to allow it to produce its allotment each month. This was done by producing for a sufficient number of days at the end of one month and continuing on into the next month. The well was then closed in for a period of perhaps 20 or 30 days. There are periods, however, of several consecutive months when no curtailment was taken. After each shut-in period, there were high points on gravity followed by low points after the well had been on production a few weeks. Where there was continuous production there was continuous low. This well was shut in at one time while producing 23.8° oil.

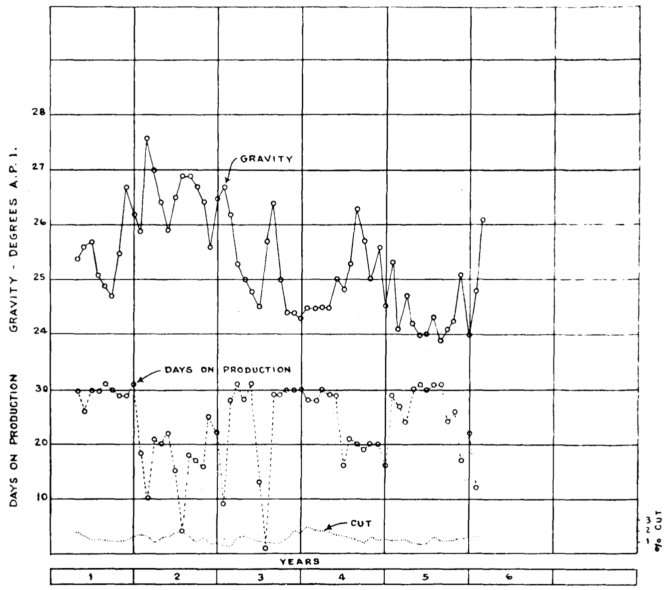

FIG. 4.—EFFECT OF PRODUCING WELLS WITH PERIODIC INTERVALS OF IDLENESS.

After being closed in for one month, on being placed on production, successive tanks during the next month had the following gravities: 26.7°, 26.3°, 25.6°, 24.7°, 24.7°, 24.0°.

In contrast to this graph, some pumping wells that are producing continuously show a close approximation to a straight-line decline in gravity. One record covering several years of a Brown zone well, at Long Beach, shows a drop of 1.3° A.P.I. in that time, with only 10 months where the gravity falls more than 0.2° above or below a straight line drawn between the beginning and end of the record. The extremes in variation are 0.5° above the line and 0.3° below the line.

Effect of Vacuum on the Casinghead.—On Fig. 5 are plotted the gravity by months, the oil production by months in barrels, and the natural gasoline production by months in gallons. Roughly, the relation throughout is one gallon of natural gasoline per barrel of oil.

The irregularities of the production curve are caused by curtailment. During the period of high fluid levels, the ratio of gasoline to oil drops and the gravity increases.

Production methods of the offsets involved the use of a vacuum, which caused the same method to be used here. As no appreciable improvement was noted in the oil production, the practice was stopped, with the result that gas production dropped to zero with no improvement in the oil gravity. The practice was then resumed increasing the amount of vacuum, resulting in the production from the gas of 11 gal. of gasoline per barrel of oil, a quantity far in excess of the amount drawn from the oil produced indicating the extraction of gasoline from oil still left in

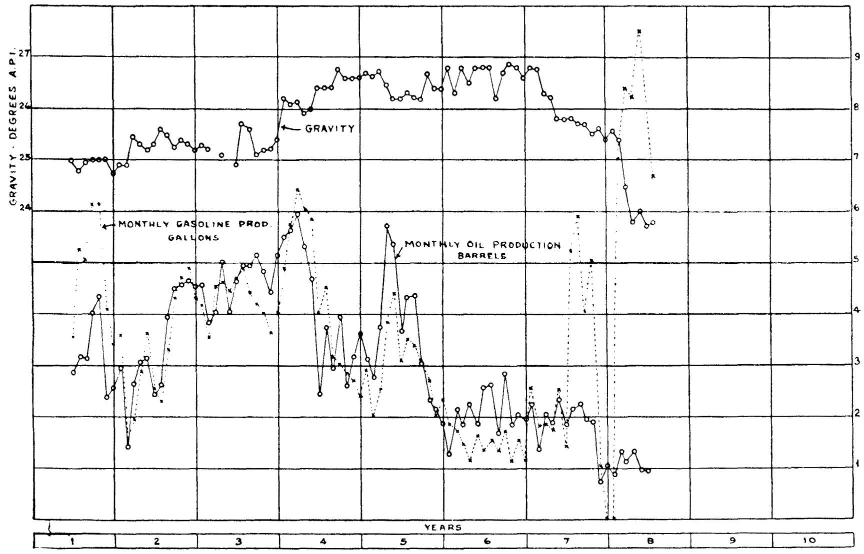

FIG. 5.—EFFECT OF A VACUUM ON THE CASINGHEAD.

the ground. The evil effects are appearing at the end of the graph, with a decreasing gasoline production and no improvement in the quantity or quality of the oil produced, which has already been bled of a considerable part of its gasoline content before it enters the well.

EFFECT OF HIGH-PRESSURE TRAPS

If the primary separation of gas is made at high pressure, we may expect to conserve the gravity of the oil. Mr. Lindsly has discussed this matter at length, so we will merely submit some data on a well that had been producing for some months previous to the installation of the high-pressure trap (Table 3).

CONCLUSIONS

As a result of the data we have accumulated, we can conclude that the following operating conditions help to retain the heavier vapor in the oil and therefore conserve its gravity: (1) carefully regulated pressure control at the well head; (2) primary separation of gas at high pressure; (3) use of wet gas in gas-lift work; (4) high fluid levels; (5) smooth pumping motion.

TABLE 3.—*Effect of High-pressure Trap*

	A.P.I. Gravity of Oil	Gasoline Produced, Gal. per Bbl. Oil
Before high-pressure trap was used	29.2°	7.38
During use of 360-lb. trap	30.6°	4.56
On gas-lift[a]	26.6°	11.8

[a] There are no gravity data for the later stages of the flowing period, therefore the gas-lift figures cover a period some two years longer than the others. When the well was pumped later the gravity of the oil was around 30.0° A.P.I.

Some of the causes of abrupt drop in gravity are as follows: (1) marked drops in well-head or trap pressures; (2) circulation of dry gas for gas-lift work; (3) low fluid levels; (4) poor pump operations.

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DISCUSSION

(*A. H. Bell presiding*)

S. C. HEROLD,* Glendale, Calif.—This paper seems to me to illustrate the principle that when we are producing oil and gas we are dealing with something very closely related to events taking place in an absorption plant. If we change the conditions of production in any way whatever we alter the amount of gas that comes with the oil from the well. We have, in fact, a choice in producing gasoline from the well—we can take it either with the oil or with the gas. This paper illustrates the fact that each change in production causes a change in the gasoline content of the gas and that of the oil. Naturally, if a greater amount of gasoline is allowed to come with the gas, a smaller amount is allowed to come with the oil, and because of this smaller amount the gravity of the oil itself is decreased.

The author says that geologists may err when using gravity data. I suppose it would be true that if we could produce our wells without manipulating them in any way whatever the gravity of the oil would decrease throughout production. If we are trying to picture the situation existing within a reservoir or a structure, we know that the gas tends to accumulate on the crest and that water surrounds the pool. We may expect, before the first well is drilled, that there is a gas cap or something of

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the nature of the gas cap on the top, that there is more free gas there than elsewhere in the reservoir, and that there is more gasoline on the crest per acre-foot of formation than there is on the edge of the pool near the water. But this does not mean that since the gas in the gas cap has a greater amount of gasoline the oil to the extent that it exists on the crest has less gasoline. We may, in fact, expect on the crest a high gasoline content of gas and a light gravity of oil, because of dissolved lighter fractions in such oil.

It is not as simple to regulate production of gas in California as it is in some other fields. In fact, it is not easy to conserve gas in this state. We often regulate well performances for the purpose of controlling encroachment of water in the vicinity of the well. Gas production, water production, water encroachment, rather than oil production itself, are all very sensitive to manipulation of wells in California. Necessarily, then, there will be erratic changes in gravity at times in our fields; we cannot hope to produce oil in the ideal way, in a way in which we are led to believe it is being produced in the Mid-Continent field.

It is impossible for the Mid-Continent field to have the variations in gravity that exist in California. Every well there has its own drainage area while every well in California is producing from one large reservoir. Gas cannot shoot from one well location to another in that area, whereas here it does so, carrying gasoline with it. As a consequence it is obvious that the gravity of oil can change almost daily in California, whereas it cannot do so to the same degree in the Mid-Continent. The approach of water to a well seems to mean a change in the gravity of oil. In the Mid-Continent field there is no such approach of water. In the Cushing field of Oklahoma, the water line surrounding the pool was located soon after discovery of the field in 1915. Now over five hundred million barrels of oil has been taken out of that field, and yet the water line is today where it was in 1915.

There is no field in California like the Cushing field. Encroachment here is sometimes very difficult to measure but we can at least measure some movement towards definitely located edge wells. These wells respond by increasing the proportional production of water. In view of the fact that there is more trouble with water here than in the Mid-Continent, I do not believe we deserve some of the criticism we have had in the past regarding the manner in which we handle our wells, especially with respect to the amount of water itself, changes in the gravity of the oil and the changes in the gasoline content of the gas.

Concerning the maintenance of pressure in the reservoir, when we in California get a sufficient number of wells to satisfy demand with a prorated production of 25 or 50 bbl. per well, then we too can maintain the pressure in our reservoirs; and when we finish our Pliocene and Miocene production and drill down to the Permian, Pennsylvanian, Mississippian, Devonian, and Silurian formations, provided they exist, then we too can do as well as they do in the Mid-Continent field.