Method for Appraising Results of Production Control of Oil Wells

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Introduction

Some of the factors that limit the ultimate recovery of oil sands are beyond the control of the operator, but other factors are to some extent subject to control. That the ultimate recovery from a well or group of wells is partially dependent upon the way in which the property is operated has been recognized, but just how wells should be operated to secure the greatest recovery is still largely a matter of opinion rather than of definite scientific knowledge.

This paper is the result of statistical research into a few of the almost infinite number of oil production problems that need investigation. It sets forth a convenient method of estimating the effect of changes in operation upon ultimate recovery, and shows the results of such changes in certain specific cases. It is found that in most of the cases investigated, an increase of operating back pressure with consequent reduction in daily rate of production has given indication of resulting in large increases in ultimate oil recovery. Such effects as the indicated reduction in ultimate oil recovery from an old well due to drainage from a new well nearby, are shown, as is the relation between gas-oil ratio and ultimate recovery for certain wells.

Factors Affecting Ultimate Recovery

The factors affecting the ultimate recovery of any well may be broadly grouped as those over which the operator has no control, and those which are at least partially, and in some cases, subject to control. Chief among the first class are the character of the geologic structure, the thickness, extent, porosity, grain size, and partitioning or lenticularity of the sands, and the contents of the structure as regards amount, physical characteristics, and distribution of oil, gas, and water. These factors will not be discussed.

Chief among the group of factors subject to control are the manner in which the well is drilled, cased and tubed for production, the way the well is operated, and the proximity and operation of other wells. While the first of these three, the drilling and casing of the well, is of great importance, it is generally necessary to talk about the back pressure. However, different methods of production may result in different back pressures, and different distributions of back pressure, and thus indirectly affect recovery. It is unfortunate that there is not yet available any practical method for measuring the pressure at the bottom of an oil well while the well is producing. In the absence of such a device, it is generally necessary to talk about the back pressure in terms of things that affect it and can be observed or measured, such as flow bean size, tubing size, tubing depth, tubing pressure, casing pressure, and production rate.

In the case of a well flowing through tubing, the pressure at the bottom of the tubing is substantially equal to the casinghead pressure. However, tubing is not always run to the bottom of a flowing well, so casing pressure is not a measure of the pressure at bottom. Where the producing zone is of considerable thickness, not only the pressure at some one level, but at a whole series of levels should be known. Therefore, casing pressure is not an entirely satisfactory indication of back pressure against the oil measures. It is important, however, to remember that recovery is controlled solely by amount and distribution of back pressure. An installation or device that is claimed to increase recovery should be judged by whether it is capable of giving a more suitable pressure or distribution of pressure than the installation with which it is competing.

A reasonable method for computing the back pressure at various levels in a flowing or gas lift well was outlined by F. W. Lake at the Fort Worth meeting of the American Institute of Mining and Metallurgical Engineers in October, 1927. His analysis is of value in understanding qualitatively the effect of various installations, but unfortunately all the factors necessary for evaluating his equations are not known.

Both theory and observation indicate that rate of production is some inverse function of back pressure—that is, decreasing back pressure tends to increase production. The corollary of this is that an increased production indicates decreased back pressure. Thus in cases where back pressure can not be measured, changes of pressure may be inferred from changes of production rate.

It is of course believed that drilling new wells is apt to reduce the recovery of old wells in the same zone, and there has been unlimited theoretical discussion of this subject, but little statistical evidence is available as to just how much the recovery of an old well is curtailed by new wells at various distances and completed at various dates. The wisdom of drilling late wells is therefore largely a matter of guess-
FIG. 1.

COMPARISON OF TWO FORMS OF DECLINE CURVES
(derived from same data, hypothetical case)
FIG. 2.

COMPARISON OF
ACTUAL AVERAGE DECLINE CURVE
AND STRAIGHT LINE APPROXIMATION
For East Side Coalinga Pool

Data from similar chart U.S.B.M. Bull. 228, p. 34, by Cutler.

Actual average recovery 3,619,000 bbl.
Recovery estimated by straight line approximation 3,563,000 bbl.
Discrepancy only 56,000 bbl. or 1 1/2 %

PRODUCTION PER WELL

YRS
work. It is believed that the method herein described will throw some light on this problem.

**Estimation of Ultimate Recovery**

In attempting to estimate the future production of a well, the life of the well should be divided into three periods.

First of these is the flowing period during which the rate of decline is a true measure of the decline of potential production rate, so long as no changes are made such as tubing size or depth, bean size, etc. Estimates of ultimate recovery may be based upon production data during this period. With the flowing period may perhaps be included the time the well is produced by gas lift, provided the installation remains unchanged, and the amount of gas circulated is constant. Sufficient data have not yet been analyzed to determine whether this is always allowable or not.

The second period is the early pumping life of a well, when the potential production rate is in excess of the capacity of the pump. During this period the rate of production is a measure of the capacity of the pumping equipment rather than of the capacity of the well. Estimates of the future production of a well based on this period are inaccurate. It should be noted that the displacement of a pump may be several times the production and its capacity be just equal to the actual production and much less than the potential production, because of low volumetric efficiency.

The third period is the later pumping life of a well, when the capacity of the pump is in excess of the potential production so that the actual production is the potential production. During this period estimates of future production are probably most accurate. However, estimates at this stage are of relative unimportance because the remaining production is generally only a small fraction of the total production.

So many different methods have been proposed for estimating the future production of oil wells that it may seem superfluous to bring forward another. Some of the past methods are unsatisfactory because they do not give a satisfactory degree of accuracy, or because they require production data over too long a period without changes in methods of handling wells, to make their application practicable. Many are too cumbersome or involve too much mathematics to be used extensively. Others, although mathematically correct, are liable to lead to erroneous conclusions. None of them is entirely satisfactory for all purposes.

The method about to be described seems superior to any others that have been used in the past for the purposes for which it is used in this paper. It is believed to be as accurate as the data justify in most cases, it is easy to apply, and the conclusions are apparent as soon as the data are plotted. No computations more difficult than addition and averaging are required.

Most methods have assumed that the ultimate recovery of a well is not under the control of the operator, or at least that the operator does not exercise such control. The method described in this report shows quite clearly that the ultimate recovery of a well is greatly affected by the manner in which it is operated, and that every little change in operating method that causes a change in back pressure is reflected in the estimated ultimate production. This new method of estimating ultimate production provides a convenient means of determining what method of control will lead to the greatest ultimate recovery.

**The Rate-Cumulative Production Curve**

It has been found that when the rate of production of a well is plotted against the cumulative production of that well, the decline curve so established is generally almost a straight line so long as conditions remain unchanged. Such a curve having been plotted for a period of a few weeks may be extrapolated until it intersects the cumulative production axis. The production rate will then be zero, or in other words the well will have reached its total ultimate production which will be the cumulative production to that point. For approximate purposes the extrapolation may be a straight line, but it may be curved if the data indicate that it should be. The value of the method is not solely dependent upon the curve being a straight line. This forms a convenient and apparently fairly reliable method of estimating the ultimate production to be expected from a well, assuming that conditions remain unchanged. Such curves will be called “rate-cumulative production curves,” the name describing the curve by abscissa and ordinate.

If conditions are changed, either in the operation of the well concerned or of a neighboring well, or if a new well is brought in nearby in the same horizon, then the slope of such a decline curve is apt to change. This indicates that the change of conditions has altered the expected ultimate recovery, and this change of expected recovery can be quickly estimated as the difference on the cumulative production axis between the points where projections of the new and old rate-cumulative production curves intersect it when extrapolated.

This form of decline curve is believed to be better than the customary curve of production rate plotted against time, for the purpose of estimating ultimate recovery and of observing the effects of changes in operating methods, because the ultimate recovery under any set of conditions is an intercept value which may be read directly, and also because changes are apparent at a glance. Ultimate recovery could only be estimated from the familiar rate-time decline curves by first extrapolating a curved line, which can only be done accurately by some mathematical method, and then integrating the area under the curve by an instrumental or mathematical method. Changes of rate of decline are not so apparent on the old type of curve as on the new because a change of slope is not so apparent on a sharply curved line as on an otherwise nearly straight line. Also rate-time curves are nearly vertical in the early life of the well, and nearly horizontal in the late life of the well, so that during these periods a large change of rate of decline causes only a small change of direction of the curve. On the contrary, rate-cumulative curves if properly drawn have a slope somewhere near forty-five degrees, at which angle any percentage change in rate of decline makes the greatest change of direction of the curve. On the average well in the latter stage of its history any change in rate quickly shows up; for example, old wells in Colorado. The production is so steady it is almost impossible to guess the future production.
FIG. 3.
RATE-CUMULATIVE CURVE FOR A FLOWING WELL WHERE CONDITIONS WERE NOT CHANGED (Practically a Straight Line)

August
September
October
Nov
Dec
Jan
Feb
Mar
Apr
May
1927

Rate of Production

Cumulative Production

Thousands of Barrels

0
50
100
150
200
250
300
350
400

Days per Day

Barrels

Ultimate Recovery Indicated
Figure I illustrates the differences between the old and new forms of decline curves, for an imaginary well. The first curve is the customary decline curve of production rate as a function of time or date. The second straight line decline curve is derived from the same data, daily rate of production being plotted against cumulative production. Such a curve is easily constructed by totaling the daily productions on an adding machine, taking off sub-totals once a week or at any other convenient interval, and plotting the rate of production against the corresponding sub-total.

For purposes of illustration, it was assumed that in November some change was made in the operation of the well that reduced the rate of decline to half of the previous rate. The upper branch on each of the charts shows this changed condition. The two differences previously described are apparent. Looking only at the first chart it would be difficult to tell even which branch of the curve was the smooth continuation and which represented a change of conditions. It is probable in fact that the change of decline rate would pass entirely unnoticed even though it were a fifty per cent change. With a curve showing the performance of an actual well it would be still more difficult to detect a general change because there would be many minor and temporary changes resulting in irregularities of the curve that would obscure the big change, and even a careful operator might change back to the original conditions without realizing that he was making a mistake. Estimating the difference between the ultimate recovery resulting from the two sets of conditions would be a task for a mathematician.

Looking now at the lower chart based on cumulative production, the same change is so striking that it could not possibly be overlooked. The improvement is marked and it would not be apt to change back to the original condition. Moreover, the ultimate recovery to be expected under either of the conditions of operation can be quickly estimated merely by continuing the curves as shown dotted. The expected ultimate recovery is the value of cumulative production where the dotted line hits the zero production rate line.

It is not expected that this method is infallible or absolutely accurate, but it is held to be as reliable and correct as the data justify; at the same time much more convenient; and to give results much more apparent than customary methods. Certainly rate of decline is a measure of efficiency that needs to be studied and made apparent.

It can be demonstrated mathematically that a rate-cumulative curve which is a straight line is equivalent to a constant percentage decline curve, which is a straight line on semi-logarithmic paper. The assumption that oil well production curves in which the rate of production is plotted against time on semi-log paper are straight lines, has been seriously criticized. By inference, the same condemnation applies to rate-cumulative curves if assumed as straight lines.

This criticism may be correct from a mathematical point but at the same time may be more theoretical than actual. Cutler\(^1\) in Bureau of Mines Bulletin 228, entitled “Estimation of Underground Oil Reserves by Oil Well Production Curves,” shows curves that are copied in Figure 2. The original is captioned: “Chart to illustrate inapplicability of semi-logarithmic paper to production decline curves.” Reading from the chart as carefully as possible the values of annual production by years and totaling them gives the following results:

- Average recovery ............... 3,619,000 barrels
- Recovery estimated by straight line....3,563,000 barrels
- Discrepancy ...................... Only 1\(\frac{1}{2}\)%

Anyone even casually acquainted with oil wells knows that all estimates of future performance are only approximate, so that differences of a few per cent are entirely negligible. Of two methods that agree as closely as this, the most convenient one should be used.

The example of Cutler's illustrates the erroneous conclusions that are apt to be drawn from theoretically good methods. A casual inspection of this chart would lead anyone to the conclusion that the straight line approximation of the true curve is seriously in error. The explanation is that the part of the chart where there is a wide divergence between the two lines is on a large scale, while the part of the chart where the two lines nearly coincide is on a small scale. Semi-logarithmic and logarithmic paper are useful tools for the experienced engineer, but they are not so well suited for a graphic portrayal of facts which is to be studied by a layman, as curves plotted to normal scales.

In order to illustrate how accurately the ultimate recovery of wells can be predicted from their early performance, a few actual examples will be given. Cutler\(^1\) on pages 64 to 68 of Bureau of Mines Bulletin 228 gives coordinates which he says establish the complete decline curve for wells in many fields. He says of them: “These average curves were made in 1921 by the mathematical method from the latest production records available from many thousands of individual wells and properties.”

Rate-time curves have been plotted from these data for a few cases, and transferred to a rate-cumulative basis. The actual recovery for ten years has been totaled, and compared with the recovery estimated from straight line extrapolation of the first year’s rate-cumulative curve. Results are as follows:

- Brea Canyon .................. 3% Discrepancy
- Buena Vista ................... 6% Discrepancy
- Whittier ...................... 5% Discrepancy

Certainly greater accuracy than this cannot be expected in estimating the future production of wells and in fact it is doubtful if either method is within any such accuracy of the actual ultimate production.

**Rate-Cumulative Curves of Actual Wells**

Figure 3 is the rate-cumulative production curve for a flowing well in the Ventura Avenue field. This is submitted as evidence that such a curve may be practically a straight line so long as conditions of handling the well remain unchanged.

\(^{1}\) Cutler, Willard, W., Jr., Estimates of Underground Oil Reserves by Oil Well Production Curves; Bulletin 228, Bureau of Mines.
FIG. 5.
A CASE WHERE INCREASING SIZE OF BEAN RESULTS IN INCREASING ULTIMATE RECOVERY (UNUSUAL)

<table>
<thead>
<tr>
<th>Month</th>
<th>Rate of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>100</td>
</tr>
<tr>
<td>July</td>
<td>120</td>
</tr>
<tr>
<td>Aug.</td>
<td>150</td>
</tr>
<tr>
<td>Sept.</td>
<td>180</td>
</tr>
<tr>
<td>Oct.</td>
<td>200</td>
</tr>
<tr>
<td>Nov.</td>
<td>220</td>
</tr>
<tr>
<td>Dec.</td>
<td>240</td>
</tr>
<tr>
<td>Jan.</td>
<td>260</td>
</tr>
<tr>
<td>Feb.</td>
<td>280</td>
</tr>
<tr>
<td>Mar.</td>
<td>300</td>
</tr>
</tbody>
</table>

Cumulative Production

- 5/8": 150,000 Bbl.
- 11/16": 365,000 Bbl.
- 25/32": 450,000 Bbl.
Assuming the rate-cumulative curve to be a straight line, it can be shown that the recovery to any date is to the ultimate recovery to be expected as the decline to the same date is to the initial production rate. Thus while this chart covers less than a year's time, it represents over 80 per cent of the life of the well in terms of recovery, as the rate of production has declined by over 80 per cent of the initial production.

The increase of indicated ultimate recovery effected by increasing back pressure is very marked in some cases as illustrated in Figure 4. Soon after being brought in this well was flowed through a 3/4 inch bean for several weeks. During this period the indicated ultimate recovery was only 108,000 barrels. The well was then pinched back with a 5/16 inch bean, and the decline rate decreased to such an extent that the indicated ultimate recovery became 270,000 barrels, about two and a half times as much as before. Opening up to 3/4-inch bean affected the well in such manner as to decrease the indicated recovery to 113,000 barrels, whereas pinching it again to 3/4-inch increased the indicated ultimate production to 132,000 barrels. In this case the smallest bean gave the highest indicated recovery. Many cases of this kind can be cited, and this one seems typical.

A few exceptions to this rule have been found, of which Figure 5 presents a typical case. This well after cleaning up was flowed through a 5/8-inch bean. The decline was very rapid, indicating an ultimate recovery of 160,000 barrels. When the bean size was increased to 11/16-inch, the indicated recovery was increased to 365,000 barrels. Further opening up, to a bean size of 25/32-inch further increased the indicated ultimate recovery to about 450,000 barrels. In this case the largest bean gave the lowest indicated recovery. A few other cases of this type might be cited but they are decidedly in the minority among those studied to date.

In a paper entitled “Methods of Effecting Gas Conservation and Increased Recovery Efficiency in Ventura Field, California,” T. E. Swigart gives several examples of the effect of back pressure on gas-oil ratio and ultimate recovery from wells in Ventura Field, California, with more complete discussion of the relations found in wells in that field.

The effect of the completion of a new well upon the recovery of a previous well is clearly shown by Figure 6. This well had an indicated recovery of 395,000 barrels, but completion of a new well nearby reduced it to 300,000 barrels, even though it occurred in the middle life of the older well. It is of interest to note the straightness of this curve both before and after the completion of the new well, and the sharpness of the break.

It should be noted that there was no sharp break in the daily production rate when the new well was completed—only a change in rate of decline. For this reason, curves of this sort are necessary to make such important effects apparent. Many similar cases have been observed.

Killing or pinching-back wells frequently results in increasing the production of a neighboring well, as is illustrated in Figure 7. This well had an indicated ultimate recovery of 113,000 barrels. The first of November some nearby wells were killed back to conserve gas, and as a result, the indicated ultimate recovery of this well was increased to 170,000 barrels. A few other cases of this kind are known, particularly in Ventura Field, California.

Relation Between Rate of Decline and Gas-Oil Ratio

Recently, gas-oil ratio has received much attention, and is generally conceded to be an important measure of production efficiency. It would perhaps be expected that there would be some fixed relation between the gas-oil ratio of a well and its rate of decline. Figure 8 illustrates an unsuccessful attempt to establish such a general relation. On it are plotted the monthly percentage declines of a number of wells against the corresponding gas-oil ratios. Data are all from one small group of wells within a period of a year. The most obvious conclusion is that the points not only do not fall along any line, but do not even fall in a band, or any regular pattern. It has been found further that the points for certain wells on different months do not always show any consistent tendency, and also that the points for different wells on any one month do not establish any logical relation.

It must be concluded, therefore, that other variables are so numerous as to completely mask the effect of gas-oil ratio when investigated in this statistical manner. A well’s rate of decline is dependent not only upon its gas-oil ratio, but also upon many other factors, previously outlined. While gas-oil ratio is only one of the many factors affecting recovery, it merits the attention it is receiving because it is one of the few factors over which the operator has any control.

That gas-oil ratio is at least one important factor affecting rate of decline can hardly be doubted after studying Figure 9. During the first period shown, the rate of decline was rapid, giving an indicated ultimate recovery of 250,000 barrels, and the gas-oil ratio was high and climbing. A pinch-back reduced the gas-oil ratio about 30 per cent and increased the indicated recovery to 340,000 barrels. Later, when the well was opened up again the gas-oil ratio increased 40 per cent, and the indicated recovery was reduced to 230,000 barrels. Another pinch-back again reduced the ratio and increased the recovery. In this field, flowing wells when undisturbed have a steadily rising ratio. It is important to bear this in mind while looking at Figure 9. Thus through four distinct periods, with three intervening changes, the relation was consistent,—increased ratio apparently caused reduction of ultimate recovery, and vice versa.

It would be unfair to omit saying that while numerous cases similar to that of Figure 9 might be cited, there are also some where this expected relation between ratio and rate of decline, is not apparent, or even contradictory. Swigart has given a rather complete discussion of this subject in his paper.

Conclusion

The most important thing that can be concluded from this research is that changes in the operation of wells affect such
FIG. 7.
ULTIMATE RECOVERY
OF THIS WELL INCREASED
BY
BEANING-BACK NEIGHBORING WELLS
FIG. 8.

RATE OF DECLINE
NOT SOLELY A FUNCTION OF
GAS-OIL RATIO

Data all from one small
group of wells for six
months of one year.
large changes in ultimate recovery that experimental changes should be made from time to time and the results carefully analyzed, so that the conditions leading to the greatest economic ultimate recovery can be known and maintained. Conditions that are best for one well are not necessarily best for a neighboring well, although experience may make possible intelligent guesses as to what will be best. Conditions that are best at one period in the life of a well may not be best later.

Rate-cumulative production charts form a convenient means of making the results of changes apparent.

The wisdom of drilling new wells in old leases should be considered in the light of the amount of production they are apt to rob from old wells. Analyzing with rate-cumulative curves the effect of new wells on old wells gives definite information upon which to base such estimates.

The relation between gas-oil ratio and ultimate recovery is not as simple as some have supposed, but the belief that gas-oil ratio should be kept as low as possible is not refuted or disputed.

Acknowledgments are made to those executives of the General Petroleum Corporation of California who made possible the preparation and presentation of this paper, to Mr. S. J. Dickey of the General Petroleum Corporation who first proposed the use of rate-cumulative curves, and to Mr. B. H. Robinson who assisted in developing the methods and conclusions herein presented.

DISCUSSION

Mr. Bennett: I would like to ask Mr. Swigart if he made any tests which would indicate the maximum range of pressure allowable or the proper amount of back pressure for any of these wells. The point I have in mind is, that as the back pressure is increased the gas-oil ratio will decrease to a certain point, and if the back pressure is increased further the gas-oil ratio will increase until finally with a very high gas-oil ratio, nothing but gas will be produced. I am curious to know whether any tests have been run on Ventura flowing wells to determine the back pressure at which maximum efficiency (or lowest gas-oil ratio) can be obtained.

Mr. Swigart: We have had occasion to do some experimenting of the kind Mr. Bennett refers to and the results on two wells are given in my paper on Figures 13 and 14 and the discussion in connection with those figures. It was found that without knowing it, we had increased back pressures so much on certain small flowing wells, that the gas-oil ratio had greatly increased. By reducing back pressures gradually we found pressures that resulted not only in lower gas-oil ratios, but a gas-oil ratio curve of declining slope. Our observations and conclusions on these tests are set forth rather fully in my paper. My present idea of the best method for determining the proper back pressure for a flowing well is to conduct experiments on the well, changing beans and then observing over a period of two or three weeks the effect on the gas-oil ratio, but more particularly on the trend of the gas-oil ratio curve. This implies of course, that the well be gaged daily and that gas productions also be measured daily. By now as a result of experience with many Ventura wells, we are frequently able to make an intelligent guess on the proper back pressure for a given well, but that back pressure probably will not be the same next month or the month after. In other words, almost continuous changing of back pressure is necessary if a well is to be flowed with minimum gas-oil ratio. It is undoubtedly true that every month or so, back pressures of Ventura flowing wells must be adjusted because the wells by virtue of producing during that period, lower the reservoir pressure and sort of "slip out" from under the effects of back pressure control. There is one point which I have not emphasized and which should be borne in mind by anyone making experiments of this nature. The first few days after making the change, and sometimes this period extends for two or three weeks, the gas-oil ratio may increase. If you become discouraged too soon and change the pressure or discontinue observations you may fail to recognize that the trend of the gas ratio has been changed from an upward trend to a downward trend. This was one error we made in conducting our first Ventura experiments. In making flow-bean changes there might be no immediate change in the gas-oil ratio or it might increase and we would become discouraged too soon. Another contributing factor to our unsuccessful results at that time was our failure to recognize that relatively great changes in back pressure were necessary before results could be obtained that would be really apparent. Success will not attend half hearted efforts or lack of persistence in experimental work of this kind.

Mr. Wood: I am very much interested in this question of decline curves and particularly in the so-called rate-cumulative curves advanced by Mr. Marsh. I would like to bring up one question that occurs to me in connection with interpreting these curves for wells that have been subjected to back pressure control as discussed in Mr. Swigart's paper. Assume, for example, that at the beginning of May you pinch a one-thousand barrel well down to two hundred barrels a day. That well might continue to produce at two hundred barrels a day or it might even increase in production until, let us say, August. Now, if a rate-cumulative curve is applied to this well, it is evident that an extension of the production curve between May and August would be absolutely flat and the ultimate recovery of that particular well, of course, would be infinity. If the well increased in production after proration, as did may of the Ventura wells, the extension of the rate-cumulative curve would lead to an absurdity. At the end of August, according to Mr. Swigart's hypothetical plan of controlling Ventura flowing wells, the well might start to decline and it might again be desirable to increase the back pressure. Let us say the well is pinched to a production of one hundred barrels per day and that it maintains a one-hundred barrel per day rate for several months. Another plotting of a rate-cumulative curve will give a new extension that will also extend to infinity. Thus, if we produce a well according to Mr. Swigart's method, which appears to be a very logical method, these rate-cumulative curves are going to give us a series of infinities. As a result, as the decline of the well is taking place, but by a series of jumps and the extensions of segments of the rate-cumulative curve would indicate each time, infinity. I would like to know how rate-cumulative curves would be applied to a well handled in this manner. Is one safe in
FIG. 9.

A CASE WHERE INCREASED ULTIMATE RECOVERY GOES WITH DECREASED GAS-OIL RATIO
using these curves to show the effect of different methods of handling wells on ultimate production?

Mr. Marsh: I can't answer that general question. I can simply say this regarding the cumulative curve—of course, you cannot use it during the "rebound" in production that results from a drastic pinch-back. Some judgment is required to know how long to wait after a drastic pinch before you start plotting your cumulative curve in order for it to be a true indication of the ultimate production. Of course, the production cannot be infinite. I know we have had occasional flat or upward sloping curves as shown by Mr. Swigart, but I believe he will agree in general that the upward tendency is not apt to continue for more than a few weeks at the most, and you simply have to wait until after the rebound has ended, after which the well will settle down to a normal decline curve, which in this particular case should be of flatter slope than the original curve.

Chairman Sumner: I think the answer to your question is that while that system may be applicable to Ventura, it might not be universally applicable. Consider for example, the Yates pool down in Texas; the wells have been on proration for about a year now, and there are no noticeable decreases in pressure or production, except as a result of water encroachment. The cuts in production are so drastic—we cut a twenty thousand barrel well down to as low as four hundred barrels per day, for example, that the four hundred barrel rate may continue for a period of a year and a half or two years. Thus, rate-cumulative curves in the Yates Pool under the present proration plan, would be flat and the indicated ultimate production would be infinite.

Mr. Marsh: I would like to cover this point—it is in the written paper, but I don't know whether I emphasized it sufficiently this morning; I wouldn't want anyone to try to use this method in every field and assume it will work. I only know that it seems to work out very well in the Ventura field and some other fields in southern California. So far, we haven't found any curve that would deviate from a straight line without there being some good and sufficient reason for it. I don't know whether that would work out in any other fields or not. You may try it out for yourself by taking the records of old wells and plotting them on this basis, and if the method doesn't work, discard it so far as that field is concerned.

Mr. Mills: I might mention, in connection with the curves Mr. Marsh has shown, that we are doing some work in the Bureau of Mines which should correlate closely with Mr. Marsh's work. However, we are attacking the problem from a somewhat different point of view—we are making an attempt to determine some practical method, and possibly in some measure, some accurate method of estimating what percentage of the oil originally present in the oil sands can be recovered with different initial gas pressures in a field.

Purposes of this work are to provide means to estimate what oil remains in a field after ordinary methods become unprofitable and what can be done toward recovering more oil by repressuring. We find, incidentally, from studies of actual field records, that a definite relationship exists between successful results of a repressuring project for example, and the degree of efficiency in recovery during the original operations. The relationships are usually inverse. So far, we feel we have had very satisfactory results experimentally, and we find that we are able to express the total ultimate percentage of recovery in relation to the initial gas pressures by simple straight-line log curves. However, we are only part way through our work, and I wouldn't wish to suggest that we have solved the problem. We have asked nearly all the large operators in the Mid-Continent field to give us field production data which we can use to correlate and compare with our laboratory work, and thus assist us in avoiding improper conclusions from our laboratory work. If any one present has information along the lines discussed, it would be useful to the Bureau and we would certainly appreciate receiving it.

Dr. Haseman: I would like to remark on the benefit of the engineers that Mr. Marsh's method is applicable only to cases where sand conditions are uniform. I mean by that such conditions as the gas factor remaining constant, the permeability of the sand around the well that is producing remaining constant, so that the gas pressure energy is free to be dissipated. Under those conditions, this method of interpretation is all right. In other words, with a fundamental solution of recovery from an oil well according to the dissipation of the energy, you can have at a solution which will be represented by this method, but if the sand conditions are not uniform, I might say don't go too far with it, or you might have to look for another job somewhere. Don't try to apply it too strictly to lease data where you have wells coming in for three thousand barrels at the same pressure on one part of your lease where you have another well coming in for five hundred barrels on the same lease.

Mr. Swigart: I am very much interested in Dr. Haseman's warnings. It occurs to me that the field which largely furnished Mr. Marsh his records for development of this method, is a conspicuous example of what Dr. Haseman warns us to look out for. Ventura has an oil zone of about thirty-five hundred feet in thickness, and we have wells that penetrate the top part of the zone, others that penetrate the middle part and still others that drain the lower part of the zone. The overlapping of penetrations is one of the interesting engineering features of the field. Certainly the sand and energy conditions are not uniform in this field, but despite this the rate-cumulative production curves prepared in accordance with Mr. Marsh's suggestions, are surprisingly constant, provided the part of the record obtained immediately after a bean change is eliminated and the history during a normal or settled production rate is considered.