The Estimation of Petroleum Reserves*

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INTRODUCTION

SOONER or later in the development of any natural resource it becomes highly desirable to know the quantity of this resource in the country as a whole, as well as of the part that is being developed, for the general course and conduct of the development work must be governed, to some extent, by the total supply available. An accurate estimate of the quantity of any natural resource is difficult to make; yet if one is diligent enough one can obtain a pretty accurate idea of the quantity of marketable timber, the acreage of tillable land, or the horsepower that may be developed from the streams, for these are things that may be measured. But any attempt to estimate the quantity of some mineral in the ground appears to enter the realm of imagination and it seems that the estimate can be nothing more than a blind guess. It may appear to be especially futile to attempt to determine the quantity of oil and gas that is available in the ground, for these minerals are so vagrant that even if the quantity now available should be known quite exactly, the quantity that will eventually be obtained may be much less, for certain losses in the extraction of both oil and gas are unavoidable, and just what these losses will be cannot be predicted.

Though necessarily inaccurate, estimates of such mineral reserves are, however, of distinct value, for they summarize the existing knowledge of the deposits of the mineral and thus enable those who are interested in some industry that depends in one way or another on this mineral to formulate a rational commercial policy.

Some time ago, when the price of gasoline suddenly rose in a rather spectacular manner, the writer was one of the U. S. Geological Survey geologists called upon to help to estimate the quantity of oil that could be obtained in the United States, for the fear had become widespread that perhaps the rate of increase in the price of gasoline was a measure of the rate of depletion of the supply of petroleum. It thus became his

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official duty to make some sort of an estimate of the quantity of oil that still remained available in the ground in California. In making this estimate the writer attempted to predict the future output by a study of the past output of the productive fields, for such a mode of prediction is generally by far the most satisfactory one that can be used and has been employed, in one form or another, a great many times. There are, however, various ways in which historical and statistical data may be used, some being best suited for one set of conditions, some for another. The writer believes that the particular methods which he used in handling the data, and which are described below, are peculiarly adapted to the conditions in California, and that they are in considerable part new.

It is the purpose of this paper (1) to outline briefly one or two of the methods that have been used by others in estimating the available supply of oil, and (2) to describe somewhat more in detail the methods used by the writer, and to state why such methods were chosen and what degree of accuracy can be attained by using them. The general method followed might be applied to any oil field, provided the necessary data are available.

GENERAL METHODS

There are two general methods of estimating the quantity of oil and gas in the ground. The first of these to be described is what is commonly known as the saturation method; the second has been termed the production curve method. The two methods are not quite comparable, for the first is used to determine the quantity of oil in the ground, and the second the quantity of oil recoverable, assuming that the conditions governing production will continue to be about the same as they have been in the past. The two methods likewise have separate applications, for the saturation method may be used to determine roughly the quantity of oil or gas in an area that has not been tested, whereas the production curve method is applicable to a partly developed field but only indirectly to an undrilled area.

SATURATION METHOD

The saturation method consists essentially of a determination: (1) of the volume of the strata that serve as reservoirs for the oil; (2) of the porosity of these strata—that is, of the “voids” in them—and thus of the maximum volume of the space that may be occupied by the various fluids; and (3) of the percentage of the “voids” that is occupied by oil. This method is the one that has commonly been used ever since estimates of the oil reserves of the country were first attempted. The method has recently been described in some detail by Washburne.¹

The saturation method obviously involves the consideration of several

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¹C. W. Washburne: *Trans.* (1915), 51, 645.

factors that cannot be measured directly. The first factor to be considered—the volume of the sand that serves as a reservoir—is the factor that may be determined most accurately, and in fields where the strata show relatively little variation in lithology and thickness over large areas, such as the Appalachian fields, it may be possible to calculate the volume with considerable accuracy from measurements made on the outcrops of the oil- or gas-bearing sand, or from those given by a few scattered wells. In a very great many areas, however, and of these the California fields are fairly typical, the formations are so lenticular and the reservoir sands so inconstant both in thickness and in lithology that no reliance can be placed on the calculations of the volume of the reservoir made in this manner, even if the points at which the measurements were made lie fairly close together.

The second factor, the porosity of the reservoir sand, is even more difficult to estimate. In making an estimate of the oil, it is clearly useless to determine the porosity of the oil-bearing sands in areas where the total volume of the strata cannot be determined with some degree of precision; but even in areas in which the thickness of the formations is fairly constant, and in which the volume of the beds acting as reservoirs may be calculated with fair precision, the porosity may vary greatly, either because of variation from place to place in the grain of the rock or because of the local introduction of a secondary cement that occupies a considerable part of the original void space of the rock; and the variation may be so great that the space which may be occupied by fluids cannot be calculated. In these areas the porosity of the oil-bearing bed as determined from samples of rock taken on the outcrop, or from a few samples obtained in drill holes, is apt to be very different from the average porosity of the stratum over a large area.

The third factor, the percentage of the void space that is occupied by oil, is, of course, not directly measurable, so that it is necessary to assume either that the voids are all so occupied or that some arbitrarily chosen proportion of them are.

Should all these different factors be correctly determined, the resulting figures will record the total quantity of oil in the field. Not all this oil is recoverable, however, and the figures so obtained must be multiplied by an "extraction factor" in order to obtain figures that will represent the available oil.

Even under the most favorable conditions, then, the saturation method is capable of giving only a rough approximation of the recoverable oil in any area; but rough as it is, this method has a distinct value, for it will give directly a first approximation of the maximum amount of oil to be expected from an untested or very sparsely drilled area in which the formations are fairly constant in thickness and lithology. This method is not, however, applicable to areas where oil is held in solution

cavities or in fracture zones, nor is it of any very great value in the consideration of pools that occur in the variable Tertiary strata of California.

PRODUCTION CURVE METHODS

The production curve method is a mode of predicting the future production of an area and is based on a study of the past production of that area. The method is largely graphic, and although various modifications of it have been used all are essentially extrapolations of one or more curves that show the production or development of the field. The advantages of this method over the saturation method are: (1) it is concerned with actual production, so that the assumption of any "production factor" is unnecessary; (2) the factors that must be estimated or assumed are fewer, and on the whole less liable to great variation, than those that must be estimated or assumed for the saturation method.

Two general methods of using production figures are employed in estimating the reserves of oil in a given area. One uses figures showing the production per unit of time of the whole field or of a group of fields within a given area; the other concerns itself only with the production of certain small areas, which are considered as types, the results obtained in their study being applied to the field as a whole.

In support of the first method, it has been urged that a consideration of the combined production of a large number of wells, and of wells distributed over a large area, automatically takes account of various irregularities in the production of individual wells—of irregularities due to variation in demand, to increased drilling, and to the discovery of new pools—it being always assumed, of course, that the conditions in the future will vary about as they have varied in the past. But in the very fact that the curve incorporates these factors lies its weakness, for in the nature of things drilling cannot continue indefinitely into the future, nor is it reasonable to expect the continuous discovery of new pools. These two factors should therefore be taken into account separately, and their effect should be eliminated from the curve showing total production.

The second method—that of studying the history of a small group of wells—has an advantage in that it permits a more intensive study, but it has a disadvantage in that the data necessary for this study are much more numerous and are seldom available. Moreover, in applying to the whole field the results obtained in the study of a small part of it, it is necessary to estimate the degree in which this area represents the conditions that exist throughout the field.

Method Using the Record of the Production of the Entire Field

Projection of Curve Showing Quantity of Oil Produced.—Probably the simplest method of predicting the future of a field is to project the curve that represents the field production per unit of time. Such a method

will give reasonably correct results only for an old field in which the production of oil per unit of time has been constantly decreasing. When applied to the Appalachian fields it gives fairly satisfactory results. The method of representation shown in Fig. 1, in which the shaded area below the line *ABC* represents the volume of oil that has been produced to date from an old field, that has long been producing a constantly decreasing quantity of oil in a given length of time. Assuming that this rate of decrease will continue until the field is completely drained, the amount of oil now remaining in the field is represented by the unshaded area below the line *CD*.

This method of prediction is open to the criticism that it does not discount the effect of new wells but that it tacitly assumes that new wells will continue to be drilled up to the very moment that the pool is drained,

FIG. 1.—ESTIMATION OF RESERVE OF PETROLEUM BY EXTRAPOLATION OF CURVE SHOWING FIELD PRODUCTION IN UNIT TIME.

or, if the curve represents the production of a large area rather than of a single pool, that new pools will continue to be discovered up to the moment when the oil in the region is exhausted.

Curve Showing Percentage of Decrease in Production.—A variation of the graphic method of estimating reserves just described is to plot, not the figure showing the actual quantity of oil produced, but a figure showing the relation between this quantity and the maximum quantity of oil that the field has produced during some unit of time. The curve so obtained—the so-called percentage curve—was used by Arnold, and Fig. 2 is adapted from his plate.²

This mode of estimating oil reserves, like that just described, is applicable only to those fields that have passed the zenith of their productivity and are producing in any unit of time a constantly decreasing quantity of oil. The curve in Fig. 2 represents the life of the field after the time when the maximum yield per unit of time was obtained. It is so constructed as to show the quantity of oil obtained during each unit of time that followed the period of maximum yield, the quantities being expressed in percentages of that maximum. This method is also open to the objections that have just been raised against the method of projecting the curve that shows the total production directly, particularly to the objec-

² Ralph Arnold: The Petroleum Resources of the United States. *Economic Geology* (December, 1915), 10, 695-712.

tion that it in no way takes account of the effect of new wells. The sole object of plotting the statistics of production in this form was to obtain a curve that would serve as a type to show decline in production for any and all fields. The rate of decrease in production, however, is so different for different fields that it seems very doubtful whether a single curve can express the decline for more than a single field, or perhaps for a group of fields, in rock of the same general type or of the same general geologic structure.

This method of plotting production in terms of percentages of total production is essentially an attempt to apply to the country as a whole

FIG. 2.—ESTIMATION OF RESERVE OF PETROLEUM BY USE OF "THEORETICAL CURVE OF FINAL DECREASE."

the methods employed by the California evaluation committee, whose work is explained below. That committee, however, concerned itself with small areas for which a mass of detailed information was available and constructed a number of curves, each showing the rate of decline for a certain particular field. An inspection of these curves, all of which were prepared for fields in California, shows that even within that State the decline is different for different fields. It is evident that similar curves constructed for fields in Oklahoma and Pennsylvania would show still greater differences. Moreover, the production curves of the evaluating committee were so constructed that the effect of continued drilling is to a measure discounted. The "theoretical curve of final decrease" used by Arnold does not in any way consider the effect of drilling new wells, but, like the method shown in Fig. 1, assumes that drilling will continue up to the very moment that the field is totally drained. This method, therefore, has less to recommend it than the method of projecting the curve showing the exact quantity of oil produced in some unit of time.

Method Using Record of the Production of Small Areas

Curve Showing Production of the Average Well.—Some time ago, when a plan was on foot to combine certain producing properties in California, it became necessary to determine the relative value of the different properties, and especially the reserves of oil contained in each. A committee, of which M. L. Requa was the moving spirit, attempted to determine the reserves by making a detailed study of the history of the wells. The method that they followed was essentially the study of a small area in great detail, and the application of the results of this study to the field as a whole. The immediate problem was not to determine the reserve

FIG. 3.—ESTIMATION OF RESERVE OF PETROLEUM BY USE OF CURVE SHOWING PRODUCTION OF AVERAGE WELL EXPRESSED IN PERCENTAGES OF PRODUCTION OF WELL DURING FIRST YEAR OF ITS LIFE.

of oil in the whole field, for that was of only incidental interest, but the amount remaining in certain parts of the field. The areas studied, however, were regarded as types of the fields or of the parts of the fields in which they lay, and the curves showing the predicted production for the small parts were applied to the whole field.

Then, too, the manner in which they used the record of the production of the wells was unique. Instead of plotting a curve that showed the rate at which oil had actually been taken from the area—that is, instead of constructing what might be termed a chronologic curve—the figures showing the production of the wells were so grouped that the quantity of oil obtained from a well during each year of its life was grouped with the quantity of oil obtained from all the other wells during the corresponding years of their lives, irrespective of the actual time at which the wells were drilled. Thus, although well B may have been

drilled 10 years later than well A, the oil that well B produced during each year of its life was grouped with the oil that well A produced 10 years before. The figures showing the production of the wells as thus grouped were then expressed in percentages of the production of the first year, and this curve was taken to represent the production of the average well in the area. To get a figure representing the quantity of oil that the average well will produce, it is necessary only to determine what the average production during the first year of their lives has been for the wells that have been drilled, and to substitute this number in the curve. The oil produced during the following years is then expressed in percentages of this number.

In order to obtain a figure representing the total production of an area, it is necessary to determine the number of wells that would be necessary to drill the area completely, and to multiply this number of wells by the figure showing the total quantity of oil obtainable from the average well, as shown by the curve. A curve constructed for one of the California fields is shown in Fig. 3.

This method has the distinct advantage over the methods hitherto described in that it attempts to determine the effect upon production of the rate at which new wells are drilled. The degree to which this discounting is really effected is, of course, dependent in large part upon the degree to which the property is drilled, for the mutual interference of wells increases as wells are multiplied.

METHODS USED BY THE WRITER

In casting about for some way in which to estimate the oil reserves in California, the writer, after considering the methods just described, concluded (1) that the production curve rather than the saturation method should be used in estimating the reserves in the producing fields, and (2) that the untested areas should be estimated by comparing them with the producing areas that they most closely resembled geologically, after the reserves in these areas had been estimated by the production curve method. The best way of handling the production record did not seem to be quite so clear, for none of the methods appeared quite to fit the requirements. It seemed better to use a method that considers the production of the whole field rather than one that considers only a small part of it, both because the data necessary for the detailed study of a small area are seldom available and because of the difficulty in choosing areas that might fairly represent the whole field. It appeared, however, that in dealing with the record of the total production some way should be found to discount the effect of the new wells.

METHODS USING FIGURES SHOWING FIELD PRODUCTION

In order to fulfil approximately these requirements, the method

described below was devised. Fig. 4 shows the application of the method to a California field:

1. The field production per unit of time was plotted and a curve, *ABCF*, similar to that in Fig. 1 was obtained.

2. Two points, *B* and *C*, which represented dates when the field production was the same, were selected. These points were as far apart as possible and corresponded to the general level of the curve about them—that is, they represented dates when the field production was fairly constant.

3. The number of the new wells drilled between the two dates represented by points *B* and *C* was then determined, this, of course, being a matter of record, and,

4. The number of new wells required to drill the field completely was then estimated from a knowledge of the geology of the field, it being

FIG. 4.—ESTIMATION OF RESERVE OF PETROLEUM BY USE OF CURVE SHOWING FIELD PRODUCTION IN UNIT TIME ASSUMING THAT DRILLING MAINTAINS PRODUCTION AT CONSTANT FIGURE.

assumed that the manner of locating wells would in the future be about the same as it had been in the past.

These factors having been determined, the supposition was made that, if new wells were drilled after the time represented by the point *C* at the same rate as they had been drilled during the period represented by the line *BC*, the production of the field would be maintained at a constant figure. This is not precisely correct, for the initial production of the wells that are drilled late in the life of the field is not nearly so great as that of the wells drilled while the field is new. The number of new wells necessary to maintain production will therefore increase as the field grows older. An idea as to what this rate of increase is in the number of wells necessary, may be obtained from a study of a cumulative curve showing the time at which new wells have been drilled, and a curve showing the production of the field. The correction may be neglected in making the first approximation of the reserve of petroleum in a field, for other factors which enter into the calculation are liable to so great error that such a refinement seems insignificant, but in making a detailed study of a small area where a considerable number of reliable data are available, such a correction should be made. When the rate has been

determined at which the drilling of new wells must progress in order to keep the output of the field constant, the time at which the field would under these conditions be completely drilled is calculated. This time is represented on the diagram by the point *D*. The quantity of oil which under these conditions would be produced between the time represented by point *C* and the time represented by point *D*—the time at which the field would be completely drilled—may be calculated or may be measured directly from the diagram. After the field is completely drilled a considerable quantity of oil will still remain in the ground and the field will continue to produce at a constantly decreasing rate. The rate of decrease may, however, be estimated fairly well, for it is unaffected by the flush production of new wells.

The most satisfactory method of making this estimate is to choose some small area containing a number of fairly old wells, preferably one

FIG. 5.—ESTIMATION OF RESERVE OF PETROLEUM BY USE OF CURVE SHOWING FIELD PRODUCTION IN UNIT TIME, ASSUMING THAT DRILLING MAINTAINS PRODUCTION AT A UNIFORMLY DECREASING RATE.

in which all the wells were drilled at about the same time, and to plot the production per unit of time of this group of wells after the date at which the last well was completed. The resulting curve may be taken as typical of the last period of the life of the average well in the field and it may be applied directly to the curve *ABCD* at the point *D*, which represents the time at which the field is completely drilled.

It may so happen that the field has produced a constantly decreasing quantity of oil since almost the first year of its life and that it is not possible to find two dates far enough apart at which the total production was the same. It may be possible, however, that for a considerable time the decrease in production was fairly constant. If so, a calculation similar to that required in the preceding method may be made, with the difference that drilling is theoretically continued at a rate sufficient to maintain not a constant production but a regular decrease similar to that which takes place during the period chosen. Then, in a manner like that just described, the date at which the field would theoretically be completely drilled may be calculated and the production up to this time estimated. The oil remaining in the field after the completion of drilling

could then, as before, be estimated by assuming that the rate of decrease of production would be like that shown by a typical group of old wells.

An application of this method is shown in Fig. 5. Here the shaded area below the line $ABCF$ represents the volume of oil produced to date from the field. On the curve $ABCF$ a section BC is chosen during which the decrease in production is fairly constant; the number of new wells drilled during this time is ascertained and, on the assumption that this rate of drilling will be continued from the time represented by point C until the field is completely drilled, the time at which the field will be completely drilled is calculated. This time is represented on the diagram by point D . The quantity of oil that will be produced between the time represented by point C and the time at which the field is completely drilled is represented by the area inclosed by the lines CD , DD' , $D'C'$, $C'C$. The oil that is contained in the field after drilling has been completed is represented by the area lying below the line DE .

In this method, as in the preceding one, the assumption that if new wells are drilled after the time represented by the point C at the same rate as they had been drilled during the period represented by the line BC , production would decrease at the rate at which it decreased during the line BC , is not quite correct. Because of the smaller initial production of wells drilled late in the life of the field, the number of wells necessary to maintain this rate of decrease in production of the field will gradually increase as the field is drilled up. A correction similar to that suggested in the method just described may be made here.

METHOD USING FIGURES SHOWING FIELD PRODUCTION EXPRESSED IN TERMS OF PRODUCTION PER WELL PER UNIT OF TIME

During the first few years of the life of a field, drilling is usually so actively carried on that the quantity of oil produced in the field as a whole during a given unit of time is constantly increasing. It is obviously impossible to apply either of the methods just described to this early period in the life of a field, for they are applicable only to a period when the field production per unit of time is decreasing. For many fields, however, a fairly satisfactory estimate may be made by expressing the production of the field per unit of time in terms of the production per well per unit of time, for although the production of oil obtained during a given length of time from the field as a whole is increasing, the production of the average well during equal intervals of time is the same or is decreasing. This method of estimating the petroleum reserves is not so accurate as either of the preceding methods, because it is based upon fewer data. It should not be used, therefore, if either of the other methods is applicable.

Fig. 6 shows the application of this method. The production of the field is represented by the line AB . This curve shows a constantly increasing value for the production of the field during a unit of time, so that the methods represented by Figs. 4 and 5 are not applicable. The production per well per unit of time is therefore determined, and the curve CD , showing these values, is plotted. On the curve CD the points E and F are chosen as representing dates at which the production of the average well—the production per well per unit of time—is the same. The rate at which new wells were drilled during the time EF is ascertained and, as before, the length of time necessary to drill the field completely is

FIG. 6.—ESTIMATION OF RESERVE OF PETROLEUM BY USE OF CURVE SHOWING PRODUCTION PER WELL PER UNIT TIME ASSUMING THAT DRILLING MAINTAINS PRODUCTION OF AVERAGE WELL AT CONSTANT FIGURE.

determined, it being assumed that drilling will be continued at a rate that will maintain the production of the average well at a constant figure—a figure equal to that of the average well at the dates represented by points E and F . A first approximation of this date at which the field would be completely drilled may be obtained by assuming that production would be maintained at a constant figure if drilling be carried on after the date represented by point F , at the same rate as it had been carried on during the period represented by the line EF . To be accurate, this assumption as to the rate of drilling after the time represented by point F should be corrected to take into account the smaller initial output of the wells that are drilled late in the life of the field. The time at which the field would be completely drilled is represented on the diagram (Fig. 6) by the point G . Then if

a = the number of wells producing at E —the first date,

- b = the number of new wells drilled during a unit of time in the period between E and F —the two dates chosen,
 c = production of the average well in a unit of time during the period EF ,
 d = the number of wells necessary to drill the field completely, (This number may be estimated from a knowledge of the geology of the field and of the field practice in spacing wells),
 S = the total amount of oil that would be produced between dates E and G .

And assuming that new wells are drilled after the time represented by the point F at the same rate as they had been drilled during the period represented by the line EF , the total quantity of oil produced by the field from the date E until the field has been completely drilled would be given by the formula:

$$\begin{aligned}
 S &= ac + (a + b)c + (a + 2b)c + (a + 3b)c + \dots + dc \\
 &= \frac{n}{2}(ac + dc), \text{ where } n = \text{the number of terms in the series.}
 \end{aligned}$$

but:

$$n = \frac{d - a}{b} + 1$$

therefore:

$$S = \frac{d - a + b}{2b} (a + d)c.$$

The total quantity of oil produced before the time represented by E should be a matter of record. The oil remaining in the field after it had been completely drilled under the conditions stated may be estimated, as in the two methods just described, by assuming that the rate of decrease in production will be the same for the field as it is for a small group of old wells.

If the smaller initial production of the wells drilled late in the life of the field is considered and the rate of drilling of new wells corrected to show this factor, the formula given above will not apply. The curve shown in Fig. 6 may, however, be projected in a manner similar to that in which the curve in Fig. 4 was projected. This curve will show the total amount of oil that the average well will produce, from which the total reserve in the field may be calculated.

Should the field production be increasing, but the production of the average well decreasing, the size of the available reserve may be estimated by a method similar to that shown in Fig. 5, but with the difference that the production figures plotted express the production of the average well, and not of the field as a whole.

PROBABLE DEGREE OF ACCURACY OF ESTIMATES

All the methods of estimating petroleum reserves described above involve the consideration of facts that, in the very nature of things, cannot be determined precisely, and the results obtained, therefore, cannot be precisely accurate. The results obtained by the methods that take into account the greater number of the variable factors are probably the more accurate. The writer believes that the methods he used in estimating the reserves in California express correctly the order of magnitude of the reserve, but he would not claim for them greater accuracy than that.

DISCUSSION

C. W. WASHBURN, New York, N. Y. (communication to the Secretary*).—We are indebted to Mr. Pack for his detailed description of a rapid method of estimating the oil reserves in large fields. Although his method will give only a rough approximation of the reserves, nevertheless it is much more reliable than the saturation method. The saturation method should not be used when any other method is available.

The paper describes a generalized method, which is especially useful in estimating the total resources of a Nation or State.

Properly, it is a method of estimating the oil that can be extracted by common methods within a given period of time. It does not account for the additional amount of oil which some day will be extracted by new methods, such as water-flooding, the use of compressed gas, etc. These limitations can be overcome only by future investigation.

In valuation work it is customary to estimate the future production in a given number of years, by using decline curves. These may be expressed either in percentage of the average daily production of the first active well or in percentage of mean daily production during the first year.

Requa's method of finding an average decline curve for a typical well (see Mr. Pack's paper, page 974) is the one I have been using in appraising properties. It is the best way to develop a control curve for estimating future production.

In valuing a property, the ideal method is to estimate the future production of each well and to add the total. In recent work involving many hundred wells, I found this impossible within the time available. Accordingly, I devised the following scheme by which the curve may be applied to the entire production of a property.

Having determined a typical decline curve for each field, it was necessary to determine the position on the curve occupied by the present pro-

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* Received Aug. 8, 1917.

duction of a lease. It would be wrong to use the average age of the wells in determining that point, because of the variation in size of wells. The percentage of flush production on a property with one large new well among many old wells, is much larger than would appear from finding the point on the decline curve corresponding to the average age of the wells. It is necessary to find the point corresponding to the average age of a barrel of production. Commonly this is much less than the average age of the wells.

The average age of a barrel of production is determined by tabulating (a) the daily production and (b) the age of each well, and by finding (c) the sum of the products of (a) times (b) and dividing by the sum of (b). It is necessary to consider production from drilling deeper as though it were from a different well. The following table is not an actual case, but it illustrates the method of determining the average age of the production on a property.

Well No.	(a) Barrels	(b) Age, Months	(c) Product of Terms
1	10	18	180
2	12	14	168
2-b	25	5	125
3	15	8	120
	—		—
Totals	62		593

The oil 2-b is that estimated to result from the deeper drilling of well No. 2, 5 months ago.

Dividing the totals of columns (c) and (a) we find the average age of a barrel of production to be only 9.6 months, although the average age of the three wells is 13.3 months, and the average age of the four drillings including 2-b, is 11.2 months. The first figure, 9.6 months, is the one to be used in finding the point on the decline curve represented by the present production of the property. Having found that point, the curve gives the daily production at future dates from which it is easy to calculate the total production to any required date.

This method saves much time where there are many wells on a property. Where there are few wells, it is best to estimate the future production of each well.

Experience has shown that it is best to separate wells on young properties into two groups, one group including all wells whose age places their production on the steep part of the curve and the second group including all wells that lie on the flatter part of the curve. Calculate the average age of production and the future production of each group separately.

The future production of undrilled locations may be estimated from the same curve by estimating the probable initial production of the locations that are geologically favorable. No others should be considered. If the probable future production is the basis of an appraisal, a large factor of safety must be applied to reduce the estimated production of undrilled locations, because of the uncertainty of geological inferences. The method is not justified except on producing properties.

The publication of more decline curves will be of great assistance to petroleum engineers. I greatly regret that the curves I have collected must be treated as confidential information. If any of the older companies would publish the decline of production on their leases, and if they would keep better records of the individual capacity of wells, it would be a boon to engineering science. Incidentally, it would enable them to make more accurate estimates of the value of a barrel of present production of given age in any field, and also of the value of their own properties.