Case 391

Proposed Testimony For Fowler Field Spacing Hearing

The object of the testimony to be offered at this hearing is to present an analysis of the relationship between well density and ultimate oil recovery in the Fowler Field, Lea County, New Mexico. Specifically, we will consider the variation in recovery to be expected between 40 acre and 80 acre development programs.

To accomplish this objective it is necessary that we present certain exhibits setting forth basic engineering and geological data on the field. With this information available it is possible, through the use of well known and accepted basic principles which govern the flow of fluids through permeable rock, to calculate the effect of well density on ultimate recovery. On the basis of an investigation of this type it will be shown that there is no appreciable variation in ultimate recovery for well densities of 40 and 80 acres.

The procedure followed in arriving at this conclusion is based on the assumption that continuous permeability development exists throughout the reservoir. The validity of this assumption can be established only by conducting a well planned and properly executed interference test in the field in question. Such a test has been conducted in the Fowler Field and, as will be shown later, the results obtained furnish positive proof of continuous permeability development within the Ellenburger reservoir. Accordingly, we will take the position that the theoretical approach employed in analyzing the effect of well spacing on ultimate recovery is completely justified and thereby satisfactorily demonstrates the adequacy of 80 acre spacing in the Fowler Field.

Exhibits 1 through 4 -

Geological exhibits to be presented by Mr. Tom Ingram.

Exhibit No. 5 - Cross Section A-A':

As indicated on the index map in the lower left hand corner of the exhibit, this cross section extends through unit wells Nos. 6, 2, 3, and 5. The electric log and available core data are shown for each of these wells from which it will be observed that the pay characteristics are such that it is impossible to correlate porosity and permeability development from one well to another. This is a characteristic feature of Ellenburger reservoirs where the bulk of the oil is contained in fractures and vugs. It will be further noted that the porosity development is of a low order of magnitude, averaging between 1 and 3 percent of the total rock volume. The low porosity development is characteristic of the majority of the Ellenburger reservoirs in New Mexico and West Texas. Permeability development is erratic; however, it compares favorably with other Ellenburger reservoirs in the West Texas-New Mexico area.

Exhibit No. 6 - Cross Section B-B':

A trace of this cross section is shown on the index map in the lower left hand corner of the Exhibit. It will be observed that this section extends from well No. 4 on the Northwest flank of the Ellenburger structure, through the discovery well which to date is the highest well in the field, down structure through well No. 3 which is approximately 400' lower than South Mattix Unit Well No. 1.

From observation of the logs and core data on this cross section and the preceeding exhibit, it will be noted that dense intervals are present at various points throughout the pay. If these dense sections could be correlated from one well to another there would, of course, be good reason to expect poor vertical communication within the reservoir; however, since these intervals obviously are not correlatable from one well to another, communication in a vertical direction is to be expected. The validity of this observation is borne out by field test data which will be presented in a subsequent exhibit.

<u>Exhibit No. 7 - Fowler Field Performance History:</u>

This graph indicates data which have been accumulated since the discovery of the Fowler Field in May, 1949. The upper curve indicates the number of wells as a function of time from which it will be noted that there are presently six producing wells in the field. The seventh well is currently drilling at a depth of approximately _______ feet. The next curve indicates cumulative oil production up to July 1, 1952, at which time 587,000 barrels of oil had been produced from the field. From the pressure-time relationship it will be observed that the bottom hole pressure has declined from an initial value of 4300 psia., to 3670 psia. in May, 1952. Attention is called to the fact, however, that the pressure is still well above the bubble point of 2450 psia., which accounts for the rapid decline observed to date.

While the type of reservoir control has not yet been determined, the pressure history suggests the absence of a water drive, in which case the bottom hole pressure may be expected to decline along the presently established trend until the bubble point is reached. At this time a pronounced flattening may be expected to occur. Inasmuch as the pressure is still well above the bubble point, no increase in gas-oil ratio has been observed. As indicated on the graph, the solution gas-oil ratio, as determined from bottom hole sample analyses, is on the order of 1,020 cubic feet per barrel. The lowermost curve shows monthly oil production as a function of time. With continued development the monthly withdrawals have, of course, increased and reached a peak value of 31,000 barrels during the month of March, 1952. The sharp reduction in withdrawals indicated for the month of May, 1952, was occasioned by the oil strike.

Exhibit No. 8 - Fowler Field Crude Characteristics:

This Exhibit indicates the volume of gas in solution in the crude, oil viscosity, and the reservoir volume factor, all as a function of pressure and at a temperature of 144°F. As indicated on the graph, the bubble point pressure is approximately 2450 psia., with a solution gas-oil ratio of 1,020 cubic feet per barrel. The reservoir volume factor initially was 1.5110 and increases gradually with the reduction in pressure to a maximum value of 1.5625 at the bubble point. This means simply that at a pressure of 2482 psia. a barrel of stock tank oil on the surface occupies a volume of 1.562 barrels in the reservoir. From the viscosity pressure relationship, it will be observed that the oil viscosity initially was approximately 0.37 centipoise and is reduced to a value of 0.31 at the bubble point. Attention is called to the fact that this is an unusually low crude viscosity and is a characteristic which will enable higher recoveries than would be possible if the viscosity were substantially higher. This will be the case regardless of whether the reservoir developes a water drive or operates essentially under volumetric control.

Exhibit No. 9 - Summary of Productivity Index Tests, Fowler Fields:

During the course of developing the Fowler Field, Stanolind has conducted carefully planned productivity index tests on all wells in the field with the exception of Unit Well No. 3, which is being used as the control well in an interference test.

Results of these tests are summarized on this exhibit. It will be observed that the measured psi varied from the minimum of 0.4 on South Mattix Unit No. 5 to 10 on Unit Well No. 4. It should be noted, however, that the full Ellenburger section is not exposed in any of the wells. Taking this into consideration and applying a simple correction factor, it is possible to determine the true productivity capacity of the total section in each of these wells, from which the average permeability for the total section may be determined.

Unfortunately all wells were not cored, however, in the two wells (Unit Well Nos. 4 and 5) where P.I. tests and representative core data are available, it will be observed that the calculated permeabilities agree remarkably well with the values measured on cores in the laboratory. Since the calculated permeability values were determined by assuming that the full Ellenburger section was contributing production, it necessarily follows that good vertical communication exists throughout the formation. This bears out a previous statement that tight intervals observed in a particular well should not be regarded as reflecting poor vertical communications throughout the reservoir.

Exhibit No. 10 - Calculated Differences in Recovery, 40 versus 80 acre Spacing:

As stated previously, the type of reservoir control has not been definitely established from the performance history observed to date; however, the data suggest a volumetric reservoir. Accordingly, we have made certain calculations which assume that solution gas will be the principle source of energy contributing to the expulsion of oil from the reservoir. The method of attack is general and is not limited to any particular volumetric reservoir, however, pertinent variables used in the calculations have been selected so as to be of the order of magnitude of those found in the Fowler Field. Accordingly, the quantitative values exhibited will apply only to a field in which the reservoir and fluid characteristics are similar to those in the Fowler Field.

Calculations have been worked out for well densities of 40 and 80 acres per well and for PI values of 1 and 10 barrels/day/psi. The problem considered is represented by the key map on the left hand side of this exhibit, on which are shown locations of the six wells completed to date. Shown in red in between wells No. 1 and No. 6 is a regular 40 acre location.

The graph to the right shows calculated oil saturation distribution in the area surrounding the three wells. It is apparent that the only effect with regard to recovery efficiency, of drilling the 40 acre location, would be to develop a small saturation sink in the immediate vicinity of that well. This effect is perhaps more clearly demonstrated by the tabulation shown on the exhibit which compares recovery efficiency expressed as a percent of the oil initially in place for 40 and 80 acre densities and for PI values of 1 and 10. It will be observed that for a PI of 1 barrel/day/psi., recovery for a 40 acre location would be 31.82 percent as compared to 31.18 percent for an 80 acre location. This represents an increase of only 0.64 percent as a result of doubling the well density. For a PI of 10 the recoveries are 35.42 and 35.34 percent respectively, an increase of only 0.06 percent.

While we have considered the effect of well density on ultimate recovery in a reservoir in which the solution gas is the principle source of energy, it should be pointed out that even if the reservoir develops a water drive or if gravity drainage plays an important part in the recovery mechanism, the effect of well spacing on ultimate recovery would be essentially the same as we have indicated on this exhibit. For example, the statistical analyses of Craze and Buckley,* which considered the performance data of approximately 70 water drive fields, failed to indicate any pronounced variation in recovery efficiency with well density.

Exhibit No. 11 - Interference Test Data, Fowler Field:

Up to this point we have considered the effect of well density on ultimate recovery as determined from the application of certain basic physical principles which govern the flow of fluids in a reservoir having continuous permeability development. Opponents of wide spacing frequently point to the assumption of continuous permeability in an oil reservoir as being unrealistic. They take the position that as a result of lenticularity within the producing horizon whereby segments of pores and permeable oil saturated rock are completely isolated from other permeable beds, the method of analysis utilized in calculating ultimate recovery is not valid. It should be pointed out, however, that situations of this type are not to be anticipated in dolomite limestone beds due to the manner in which porosity was developed in these formations. This has proved to be the case in every carbonate reservoir which we have investigated in the New Mexico-West Texas area, including the Fowler Field.

The validity of the assumption of continuous permeability development is borne out by interference test data accumulated over a period of 16 months in this field, the results of which are shown on this exhibit. As indicated on the time scale this test was initiated on March 15, 1951, and is still in progress. In conducting this test, permission was obtained to transfer the allowable from Unit Well No. 3 to the remaining wells in the field. The location of the control well with respect to

*R. C. Craze and S. C. Buckley, "A Factual Analysis of the Effect of Well Spacing on Oil Recovery", API Drlg. and Prod. Prac., (1945), 144-59.

other wells on the lease is shown on the key map. Since initiating the test, pressure measurements have been made with a calibrated bottom-hole pressure bomb as often as deemed necessary in order to accurately establish the pressure decline relationship as a function of time. It will be observed that after shutting in well No. 3, pressure remains constant at approximately 3955 psia. over a period of approximately 45 days, after which the pressure began to decline. During the 16 months that this interference test has been in progress a pressure decline of around 300 psi. has been observed, thus furnishing positive proof of continuous permeability development within the reservoir and demonstrating the adequacy of the 80 acre spacing pattern.

Attention is also called to the pressure value measured in South Mattix Unit No. 6, immediately after completion and before the well had produced any oil. This well was completed on April 28, 1952, with a pressure of 3650 psia., which is 650 pounds below the original reservoir pressure. This is further indication of continuous permeability development within the reservoir.