BEFORE THE
OIL CONSERVATION COMMISSION

In the matter of.

Case 1324

TRANSCRIPT OF PROCEEDINGS

VOLUME I

DEARNLEY - MEIER & ASSOCIATES
INCORPORATED
GENERAL LAW REPORTERS
ALBUQUERQUE, NEW MEXICO
3-6691 5-9546

NEW MEXICO OIL CONSERVATION COMMISSION

Mabry Hall

Santa Fe, NEW MEXICO

REGISTER

HEARING DATE Special Commission Meeting October 28, 1957 TIME: 9:00 a.m.

NAME:	REPRESENTING:	LOCATION:
Sam A. Snyder	Union Oil Co of Calif.	Midland, Tex
Ralph L. Gray	Buffalo Oil Co	Artesia, N. Mex.
Bill McCombs	Malco	Roswell, N.M.
P M Badger	Moore Drilling Co Vex Exploration Charles A Stein	Abilene Texas
D.R. Cameron	Pan American Pet Corp	Roswell, N. Mex
C.E. Springer	- - - -	- -
Wayne Royal	N M State Land Off. Service	Santa Fe
Kenneth M. Oliver	John M. Kelly	Hobbs
[illegible]	Cities Service Oil Co	Hobbs
Jack M Campbell	Campbell & Russell	Roswell N M
Frank E. Irby	State Engr Office	Santa Fe
[illegible]	Humble	Midland
J.B. [illegible]	Chief	Ft Worth
John F. Burleson	Skelly	Wichita Falls, Tex
W.B. Wofford Jr.	Skelly	Roswell, N.M.
[illegible]	Buffalo Oil Co.	Artesia N.M.
R C McGinnis	Humble	[illegible]
[illegible]	[illegible]	Roswell N.M.

ILLEGIBLE

NEW MEXICO OIL CONSERVATION COMMISSION

Mabry Hall

Santa Fe, NEW MEXICO

REGISTER

HEARING DATE Special Commission Hearing, October 28, [illegible] TIME: 9:00 a.m.

NAME:	REPRESENTING:	LOCATION:
[illegible]	Humble Oil & Refg Co	[illegible]
S.R. Hoott	Humble Oil & Refg Co	[illegible]
M. W. Keathley	[illegible]	Midland
V.L. Hammel	Walter W. DeFord	Abilene
T. Hampton	Great Western Drlg	[illegible]
J. Kellenberger	Ambassador Oil Corp	Ft. Worth
[illegible]	OCC	[illegible]
W. V. [illegible]	Gulf Oil Co	Roswell
[illegible]	[illegible] Corp	Breckenridge, Tex
[illegible] Miller	Kan. Amer. Oil & Gas Co.	Artesia N.M.
Geo S. Cichowicz	Continental Oil Co.	Roswell N.M.
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible], Tex
[illegible]	[illegible]	[illegible]

ILLEGIBLE

Docket No. 1324

BEFORE THE OIL CONSERVATION COMMISSION

OF NEW MEXICO

IN THE MATTER - of the application of Graridge Corporation for an order authorizing capacity production for its pilot water flood project in the Caprock-Queen Pool, Lea County, New Mexico. Applicant, in the above-styled cause, seeks an order authroizing capacity production of all its wells in its pilot water flood project authorized by Order R-972 in Section 31, Township 12 South, Range 32 East, Caprock-Queen Pool, Lea County, New Mexico.

TRANSCRIPT
OF TESTIMONY

Hearing at Oil Conservation Commission

on October 28, 29, and 30th 19 57

Ada Dearnley-Marianna Meier
REPORTER.

I N D E X

TRANSCRIPT OF PROCEEDINGS

MR. PORTER: Good morning. The meeting will come to order, please. Case 1324 was advertised to be heard on October the 17th, but due to the order of the docket, it didn't come on until late in the day on the 17th. At that time it was determined that it would take more time than was left during that week to complete the case, and it was felt that we should have an uninterrupted hearing, so counsel moved for a continuance to October 28th and for an interim order to grant relief in the form of increased allowables to wells in the pilot water flood; and after brief testimony the Commission announced that the hearing would be continued to October 28th and an interim order would be entered granting that relief.

The order has been issued, so at this time we will continue with the case, and I know that this is a very important case, a case of tremendous interest to the entire industry and it's going to take some time for us to hear all the facts in the case; but I know, too, that you realize that there are other demands on the time of the Land Commissioner and the Governor which have to be met, too, so the Commission will appreciate any effort on your part to keep the case going and expedite it in any way that you can.

Mr. Campbell.

MR. CAMPBELL: If the Commission please, I'm Jack M. Campbell, Campbell and Russell, Roswell, New Mexico, appearing on behalf of the applicant. I shall not make an extensive preliminary statement, but perhaps it would clarify the matter if I would explain briefly to the Commission our position and what we intend to prove by the testimony that we will offer in this hearing. I would first like to express on behalf of the applicant appreciation for the Commission's indulgence in this special hearing date to hear what we consider to be a very important matter in the future of secondary recovery in New Mexico.

It is our position that unless the application is granted, there will be waste of this valuable natural resource by virtue of the facts that in the first instance, there will be physical waste resultant; in the second instance, there will be an economic factor enter the picture which will result in economic limits of these ventures being reached before all the possible ultimate recovery is obtained, which obviously would result in waste.

We recognize that the Commission and some in the industry apparently are concerned about the possible impact of this type of approach on market demand. We will face this, as I say, and offer testimony to show that in our opinion there is no serious impact and would be no serious impact on market demand with this application or future applications of similar nature granted; and we certainly feel while market demand is a factor, that the possibility of losing some ultimate recovery of oil from under the lands of New Mexico is the prime consideration of this Commission.

We also realize that there is some concern about the amount of water that might be required and that is, of course, always a matter of prime importance in New Mexico. We will offer some testimony to indicate the amount of water that might be required with regard to this particular pool to indicate to the Commission that in our judgment the amount of water required in the project of this nature, as compared to other beneficial uses of water, is not particularly significant.

I would like to call as our first witness Mr. John Buckwalter.

MR. HINKLE: If the Commission please, before proceeding with the witnesses, I would like -- Clarence Hinkle, Roswell -- I would like to enter appearance at this time, on behalf of the Humble Oil and Refining Company, by Mr. R. C. McGinnis, an attorney of Austin, Texas, Mr. Howard Bratton, and myself.

In view of the importance of this case, I believe it's only fair that the Humble make known to the Commission at this time, and to the applicant, the position of the Humble, inasmuch as it intends taking an active part in this case.

Humble Oil and Refining Company does not own an interest in the Caprock-Queen Field. However, Humble feels that it and all operators owning proratable wells in New Mexico have an interest in the result of this case.

Should unlimited allowable be granted in this case, the production of this field may be increased substantially beyond the amount it would be permitted to produce were it subjected to the same proration formula as are all other prorated fields in the State.

The State of New Mexico has a producing capacity far in excess of the present market demand for New Mexico crude; and capable wells are being limited to 37 barrels as the base proration unit. Therefore, should unlimited allowables be granted in this field, the allowable of all other proratable wells in the State must be reduced in order to make room in the market for the increased production from the field, and the operators owning such other wells must relinquish part of their share of the State's market for crude to the flood properties.

Humble believes that the Commission should follow the precedent set by the order in case 1300 involving General America Oil Company's unit G flood, and limit the allowable in the Caprock-Queen field to the well capabilities not to exceed the top well allowable as fixed for the base proration unit in the State times the number of injection and production wells on the lease. This is necessary to prevent discrimination against the proratable wells in the State.

Humble has a considerable number of water flood operations and it recognizes flooding as one of the principal oil recovery methods and is in favor of its use wherever practicable. Historically, where unlimited allowables are granted water floods, production therefrom often increases to the point that rates exceed the highest peak during primary production. It is reasonable to expect similar results should capacity flooding of New Mexico fields occur. This problem goes far beyond the effect of granting unlimited allowables to this pilot flood in this particular field. Should such unlimited allowables be granted in this case and a precedent set for New Mexico in the future water flood programs, the effect will be far reaching and of great magnitude.

Because of the general effect this case will have on State-wide allowables, Humble desires to participate fully in this case and to cross examine any witness offered in support of the application. Humble is prepared to offer testimony based upon an intensive study it has made to the effect upon ultimate recovery of the rate of production in water flood operations.

Humble believes the basic question involved in this case is of great importance to the Conservation Commission, to every royalty owner, and to every operator in the State of New Mexico, and should therefore be given the most careful and detailed study possible by the Commission.

MR. WEBB: Layton Webb, representing Sinclair Oil and Gas Company from Midland. I would like to enter an appearance for Mr. James McGowan from Tulsa, and myself.

We, too, feel that this case is a very important case. Sinclair is the operator of three leases in the Caprock-Queen area, none of which are immediately effected. One of the leases is still a top allowable lease. The other two have not reached their economic limit on primary yet. However, we have operated numerous floods and we plan to offer engineering testimony in support of the applicant's application at this hearing.

MR. ERREBO: Burns Errebo, Tulsa, Oklahoma, representing Sunray-Midcontinent Oil Company. We would like to enter an appearance in this case. We have no witnesses that we plan to offer at this time. We do feel that this matter is of critical importance to the State of New Mexico and to all operators, and we would like to observe the case and to cross examine whatever witnesses may be offered.

MR. PORTER: Anyone else?

MR. KERNS: Carlos P. Kerns, representing the Sun Oil Company. We do not plan to put on any testimony or cross examination; however, we would like to make a statement of policy later in the hearing.

MR. SNYDER: Sam Snyder representing the Union Oil Company of California, from Midland. We don't plan to put on any testimony; however, we would like to state our beliefs on this thing later on.

MR. MOTTER: E. F. Motter with Cities Service. We have a statement we will make later in the hearing.

MR. KEATHLEY: Marshal Keathley, Midland, Texas, for Forest Oil Corporation. We do not plan to enter any testimony at this hearing, but we would like to make a policy statement at a later time.

MR. PORTER: Mr. Cooley, would you like to swear all the witnesses for this hearing that will testify in the case at this time?

MR. COOLEY: I think I had better swear the applicant's witnesses.

MR. CAMPBELL: Or could we swear just a witness at a time?

MR. PORTER: It won't take long.

(Witnesses sworn.)

JOHN BUCKWALTER

a witness, of lawful age, having been first duly sworn on oath, testified as follows:

DIRECT EXAMINATION

By MR. CAMPBELL:

Q Will you state your name, please?

A John Buckwalter.

Q Where do you live, Mr. Buckwalter?

A Wichita Falls, Texas.

Q What is your profession?

A I'm a consulting petroleum engineer.

Q And what is the name of the consulting firm with which you are associated?

A A partner of Ryder Scott Company.

Q Have you ever testified previously before this Commission?

A No, I have not.

Q Have you testified previously before other regulatory agencies of other States?

A I have.

Q Would you state where you have previously testified?

A In Austin before the Texas Railroad Commission.

Q. Would you give the New Mexico Commission an outline of your educational and professional background, please?

A Yes, sir. My first contact with the oil business was in 1929 when, at the age of 17, I was hired to run production tests on water flood oil wells in Bradford, Pennsylvania. In 1931 I did laboratory work on fluid flow experiments under the direction of Harry Ryder. This was a summer job, both of these were summer jobs. In 1935 I graduated from Pennsylvania State College, and my formal education also includes some advanced studies in reservoir engineering under Dr. Terhune and Dr. Stall of Penn State; and I have also attended a short summer course at M.I.T. In 1939 I accepted a position with the Ryder Scott Company of Bradford, Pennsylvania, as a field engineer.

I first worked at field work where I was experimentally injecting air into water intake wells in a water flood project. From this field work I went into laboratory work for the same company and gradually became interested and worked in reservoir engineering in water flood projects. In 1943 I became a member of the Ryder Scott Company as a partner. At this time I started consultation work with clients of the firm. In 1946 I became a member of the A.I.M.E, and also a registered professional engineer.

I have been chairman of Eastern District A.P.I. on production technology and recently a citation, given a citation by the

A.P.I. for this kind of service to them. I have been a member of the Secondary Recovery Committee of the Interstate Oil Compact Commission, Pennsylvania Chairman, now a Texas member of that Commission's committee.

In 1949 the company opened an office in Wichita Falls, Texas, and I have been working on water floods in Texas since that time; not all of my work was with Texas floods since 1949, because I didn't move my residence here until 1955.

I have been consultant to the Forest Oil Corporation on a continuous basis since 1952. My consulting career has been devoted to the services of independent oil producers, primarily, and I have worked on water flood problems almost exclusively. I have worked on the planning phases of water floods, evaluation of results, reserve evaluations, and various other engineering problems.

I have written approximately fifteen papers which have been published in the industry literature. I have taught production practices in secondary recovery at night school courses as a part of the extension division of the Pennsylvania University.

I would say in all I have made engineering decisions on water flood projects on over five hundred different water floods throughout this country, worked on flood projects in Canada and also South America.

I would like to say, too, that I have never owned a barrel of oil nor any royalty. Our company has a policy not to enter into production but to stay completely on a consulting basis for a fee.

Q Are you at this time employed by Graridge Corporation as a consultant in connection with the Caprock-Queen pilot water flood program in Lea and Chaves Counties, New Mexico?

A I am.

Q Have you made a study of areas of this pool in which this pilot program is now working?

A I have made studies.

(Applicant's Exhibit No. 1 marked for identification.)

Q Yes, Mr. Buckwalter. I am handing you what has been identified as Applicant's Exhibit No. 1 in Case No. 1324, and ask you to state what that is.

A This is a brief report about the cooperative pilot water-flood project in the Caprock Pool and in Lea County, New Mexico. The cooperative project is carried on by Graridge, Gulf, and Great Western.

Q I presume you answered my question?

A I think I did, yes.

Q Will you refer now to that Exhibit No. 1 and commencing with the map shown on page 1 of that exhibit, will you in your own manner go through that exhibit and explain to the Commission what it reflects with reference to the present status of the pilot waterflood program in the Caprock-Queen Field, please?

A The first map is a map of the entire Caprock-Queen Field in Lea and Chaves Counties, New Mexico. The second map is an area map of part of the Field known as the old part of the Caprock Field. Also on the second map we show the location of the pilot waterflood project, shown in red, as well as an area outlined on that map in red which delineates a seventeen hundred and sixty acre area of the Caprock Field. I have made more specific studies of that area of the field than other parts of the field.

Q Is the area you refer to there on page 2 as the old Caprock Pool the area which is essentially in a stripper stage?

A Yes. Now that area also includes, I think in the south-west portion of the map, some of the area which is not stripper state but practically all of the area shown on the map is of low production at the present time, with the exception of the waterflood wells.

Q And is all the area outlined in the seventeen hundred sixty acres with the red on page 2 in the stripper state of development?

A That is, except for the results of waterfloods.

Q And referring again to that particular page 2, what does that reflect generally with reference to the ownership of lands, of minerals or royalties within that entire area?

A Well, most of that area, the minerals are owned by the State of New Mexico. For their eighth royalty, except for one Section, I believe, which is Williams, which is in fee. That apparently covers about one section.

Q All right, now will you proceed with the data on page 3, please?

A A brief summary of the present status and some historical data on the pilot waterflood are shown on that page. We have given data by months. You will notice the water was started injecting in 1957 on April 15th. The month of April we show the average pressure at the injection wells and the daily average injection barrels per well; the monthly injection total; the accumulated injection in barrels; the number of producing wells in the pilot area which have been pumping; and the daily average production from those wells, and the water production; the total producing wells from the leases in the pilot area; and the monthly production total from leases in the pilot area.

April, May, June, July, August, and September. I think the data there speaks for itself.

Then in the lower part of that sheet, we have some notes about recent well tests. We have listed individual daily well production tests taken the last half of September, 1957 on the wells affected in the area.

Then we show in red numbers, additional tests which were taken as of October 24, 1957. This shown that some wells have been affected by the injection of water and are now producing oil at larger quantities than they had been prior to the establishment of the flood. For example, there is a Great Western State "Q" No. 1 which is now at recent tests producing at about forty-four barrels per day and no water.

The Gulf Lea State "B" No. 1 is producing at the rate of about ninety barrels per day. This well is pumping at a fluid level of 1750 feet; they are unable to completely test the well because of, well, not allowable today, this was prepared for the previous section, but because we don't have a large enough equipment installed at the well at this time.

Another well which is affected, Graridge's Levermore State "G" No. 6, and that's now producing about a hundred and ten barrels per day on recent tests.

You will notice that several wells are being reworked. We don't have tests on those because of that. One is temporarily shut in.

Q In connection with that data on page 3, and based upon your experience in waterflood operations, do you consider this particular pilot waterflood is progressing in a satisfactory manner from the point of view of the recovery of the oil in the reservoir?

A I would say at this stage in this particular waterflood, it looks like a normal response to waterflood, compared to other waterfloods that I have worked with. It's normal in the sense there are exceptions and variations in the response. It is not a uniform response, but that is to be expected, particularly in pilot flood work.

Q Now will you go ahead and advise the Commission as to the balance of the data contained in this status report, Exhibit No. 1, please?

A The balance of the information is composed of sheets of curves which are prepared to show the production history of the various leases in the pilot area. The production on a monthly per well basis is plotted as of this time. Also listed are the number of wells which were producing at the time. This is monthly average data. You will notice a small arrow is shown on each of the curves indicating the time that water was first injected into the pilot area.

In looking through the curves, you will notice that some of them show response on the last month in particular, being the month of September. October is not yet completed, so we have data through September plotted.

Q In other words, the data contained in the balance of the report is the individual well history showing the current status as reflected on page 3 of the report, is that correct, except for the addition of the most recent production tests?

A Yes, but it isn't individual well history, it's really the average of the well history in the various leases.

Q In your opinion does the information contained in applicant's Exhibit No. 1 reflect the current status of the pilot project, Mr. Buckwalter?

A Yes, it does.

Q Was this information prepared and compiled by you or at your request and under your supervision?

A Yes, sir.

MR. CAMPBELL: I would like to offer Applicant's Exhibit No. 1 in evidence.

MR. PORTER: Are there any objections to the admission of Exhibit No. 1, Graridge Exhibit No. 1? It will be admitted.

Q Mr. Buckwalter, based upon your previous field experience that you have referred to in your introductory remarks in waterfloods, do you have any general opinion as to a relationship between the rate of injection and rate of production and the ultimate recovery of oil in waterfloods?

A Yes, I do.

Q Would you state for the Commission your analysis of that particular relationship, please?

A Well, I believe that there are several aspects to this rate question, there is the economic aspect, and there is the physical recovery aspect. I think we should consider those separately, although in the field they of course work together. I have found in my experience that first of all, in the matter of the effect of the rate of injection on the rate of production, there is a definite relationship between the two. That is the reason we have high or low producing rates in a waterflood, is because we inject water at a high or low rate.

Now my experience has been that the highest rates of water injection that we can attain in the field, below what we consider a breakthrough rate, is the best for waterflooding in terms of ultimate oil to be produced from any given project. Early in the flood, the water injection rates are usually considerably higher than they are later in a flood. This is due, of course, to the buildup of reservoir pressure as more water is injected into the reservoir.

I would say in addition, we always experience problems in the water itself, plugging some of the sand face, all that water has to be in a sense filtered through the sands, and so if the water isn't absolutely pure, it will cause plugging of that sand, that's one of our problems in waterflood operations.

Statistically speaking, over many waterfloods, I would like to state what I consider a high and a low rate of water injection. I think it's fairly vague if we don't get some numbers into the picture. In most floods that we work with and I personally worked with, we try to attain a rate of approximately one barrel per day per acre foot of reservoir served by an injection well.

Now to bring that into numbers that we can think about a little bit in this particular case, we are talking here in the pilot flood about eighty-acre five spots, and each injection well, if you will look at it on the map, really serves about eighty acres. So if we have ten feet of sand on an average well, and we are serving eighty acres, if we were to inject one barrel per day per acre foot, we would have to let that well inject eight hundred barrels of water per day.

Now I must say that I do not believe that we can attain that here throughout the life of the flood operation. It is attainable today, but I question it can be attained throughout the flooding history in this particular area. I do believe that it is possible to attain an average rate of approximately half that much. I believe that a half a barrel per day per acre foot is attainable here, just based on my own observations of the present results and compared to experiences in other places.

Now, I believe we can have successful waterflooding, by our terms of successful waterflooding, I mean equal waterflooding without excessive losses, at the half barrel per day per foot, but I believe you have losses of oil because you will not be able to attain the full barrel per day per foot injection rate. However, I think to be practical about it, in my own thinking about it, we will have to accept that as the attainable injection rate,

in my opinion, on an average in this particular field, so when we get below, in my opinion, approximately a third of a barrel per day per acre foot, we have serious trouble in waterflooding; and we believe that we can show cases where there are losses of large magnitude when those rates are exceptionally low, and I mean below a third of a barrel per day per acre foot, I believe that I would like to premise my work here on the basis that we can attain this half barrel per day per acre foot as a minimum. I would like to feel that that's possible.

Q Referring first, Mr. Buckwalter, to your statement that economic factors which affect ultimate recovery or prevention of waste, would you please refer to the exhibits on this board here, and particularly to Applicant's Exhibit No. 2, and state to the Commission what that is and explain it to them.

(Applicant's Exhibit No. 2 marked for identification)

A Well, in my work I'm called upon to make predictions as to what type of recovery will be obtained on waterflood projects before projects are initiated, and I have done the same thing in the Caprock area.

Now to do that, I have referred to a particular area which is about seventeen hundred and sixty acres of the Caprock Field, as shown in Exhibit 1 outlined in red previously. I have taken that area and I have felt that the average footage of sand there is approximately ten feet of pay; and I have studied core analysis data, some in that area, some nearby it; and I have concluded that the permeability characteristics of the rock are such if we inject water at certain rates, we will obtain certain types of characteristic oil production response.

I have arrived at a five-spot prediction, what one five-spot would recover in oil at two different rates of water injection into the intake wells. I have presented in this Exhibit No. 2 the data which I arrived at. This is an estimated future waterflood oil production for one eighty acre five-spot; and in this work I have assumed that the same efficiency of displacement will hold in each case.

Now in doing this I am not bringing into consideration losses of oil from a physical sense, because I am assuming immediately that there is no difference in the displacement efficiency at either rate which I am presenting. I am doing this in order to bring out the point of the economic effect of rate in waterfloods.

I have shown here with four hundred barrels per day intake rate per injection well, and there is the half barrel per day per foot which I believe is attainable and can be maintained in this area. I show what I expected in the way of barrels of oil per year, and primitively for a period of ten years of operation.

I then also show that if one-fifty of this amount of water were injected, now, of course, I believe this is a satisfactory rate here, and I believe this would be a definitely unsatisfactory or very low rate of water injection, butthis one-fifth factor, I then show what the oil production response might be by years, based on my own calculations.

I would like to call your attention to one or two things; particularly, you will notice in the high injection rates that we have the highest producing rate the first year of water injection, fifty-six thousand barrels in that first year on this projected study I have made. Now you see if we inject water for five years at the low rate of water injection, we will have injected the same amount of water as if we injected one year at the high rate of water injection; so with my assumption of the same displacement efficiency, I believe that at the end of five years at low rates we would accumulate about fifty-six thousand barrels of oil at this injection rate.

Now you will notice also that at two years I cumulatively expect to have at high rates ninety-nine thousand eight hundred barrels, and that that amount is similar to what would be recovered in ten years at the low rate. I think this explains the way in which I arrived at the second rate of injection response compared to the first one.

Q You stated in connection, I believe, with that exhibit, that while you have assumed the same displacement efficiency, you are doing that for the purpose of this calculation and do not consider that there is the same displacement?

A No, I don't. I have calculated this on the basis of our, you might say, usual method of calculation. I find a much different expected recover.

Q And this is a basis, or part of the basis for an ultimate conclusion you are going to draw with regard to the ultimate recovery in this reservoir?

A Yes, as the economic aspects of this question I brought out.

(Applicant's Exhibit No. 3 marked for identification.)

Q Referring now to the next exhibit there, which has been identified as Applicant's Exhibit No. 3, will you please state what it is and explain it to the Commission in relation to this question of economic factors as related to ultimate recovery?

A On the former exhibit I was speaking of eighty acres only. In this exhibit I'm showing production rate curves which I have estimated based on a development of the seventeen hundred and sixty acre area that I have studied. Now in these two curves on the upper part of the exhibit, you will find we have plotted a rate curve and a cumulative production curve. The units on that scale range from zero on the rate to 5,000 barrels per day, and on the cumulative scale -- no, on the horizontal, or across, I have "Years from the start of flood", and on the right side I have shown cumulative oil production in millions of barrels, starting from zero and reaching five million at the upper scale.

On the lower curve I have the same scales plotted, except the years extend beyond the first curve. Everything else is in the same proportion.

Now, we have in the upper part of this exhibit shown what we estimate would be the average, would be the production response in barrels of oil per day if seventeen hundred and sixty acres were developed, and the development rate here is all developed in the first year, and the injection wells would take water at four hundred barrels per well per day on an average.

On the lower part of the exhibit I show the expected oil production rates and cumulative production if eighty barrels of watter per day were injected on an average into the intake wells, at the same rate of development. That is, all development occurs generally in the first year.

Q Where you have lines on there indicating economic limits, would you state what that is?

A Yes. Although I have calculated the production for ten years, I do not believe that the production can continue that length of time in the upper curve because of an economic limit, which I arrived at on the next exhibit, which shows that the cost of operating would be too high to continue the operation beyond eight years.

On the second exhibit, or second part of this exhibit, the lower part, that economic limit is shown at thirteen years.

Q And that economic limit is what you will make reference to subsequently in your testimony, is that correct?

A I shall.

(Applicant's Exhibit No. 4 marked for identification.)

Q Referring now, Mr. Buckwalter, to what has been marked as Applicant's Exhibit No. 4, will you please state what that is?

A Exhibit No. 4 is a tabular set of data that I prepared to show valuation of the projected reserves for this seventeen hundred and sixty acre area that we spoke about on the previous exhibit. I have again shown, based on an average injection rate of four hundred barrels per injection well per day, the economic aspects of this projected flood; and then I have also, in the lower part of the exhibit, shown the economic aspects of injecting water at a rate of eighty barrels per injection well per day.

Now this is a type of valuation of these reserves, in my work I'm called upon to make this type of valuation regularly. I feel that this points up particularly the economic aspects based on my predicted waterflood recovery curves.

You will notice that this table does not include such things as acquisition costs, depletion, income taxes, or salvage values. Those factors are left out of both of these particular calculations. Now in valuation schedules of this type, which is, I believe, familiar to those working in production in the industry, we show gross barrels each year and barrels per day just for reference, and then our estimated future oil production also shows the net barrels to the operator. In this case it's approximately eighty-two percent of the gross barrels of oil. Then we have the income from sales shown in the next column, that income in this case is based on $2.90 a barrel, current prices.

Then of course we have to deduct from these incomes cost figures, and those cost figures I have separated into such costs as production tax, direct lease expense and overhead, development costs. The next column I show a total of these costs.

The next last three columns are the net value at each year, first to the value not discounted of these particular reserves; then I have entered a six percent discount factor which I think is in line with current interest rates, to show a present worth value. We all know that a barrel today is worth more than a barrel ten years from now, because of the interest rates that occurred in the time we would have to wait to obtain the barrel ten years from now, so I have carried this valuation schedule through year by year for each of these floods.

Now I found at the end of, if I went to the ninth year, on the first sheet, I couldn't end up with a profit, so I had to eliminate the years from that time on, so this really defines my economic limit and it's approximately eight years as shown on this exhibit.

Now in the lower half of the exhibit we have exactly the same type of data. It's presented, however, for the case where we have low injection rates, being eighty barrels per injection well per day. I would like you to note that there's a difference in the cost values on each of these projected projects. For example, my direct lease and overhead is higher on the high rate floods, simply because we do have to handle more water. We have to put more water into the flood. We have got to produce more water from the flood at any given time so the cost of doing that is taken into consideration.

The other thing I would like to point out in the matter of cost here is that the development costs are going to be higher if an operator injects at a higher rate, the reason being he has to have, for example, larger equipment to produce his wells, so that amounts to approximately $200,000.00 difference in the projected example for the seventeen hundred and sixty acres.

Q Where do you reach your economic limits insofar as the lower rate of injection is concerned?

A Well, I calculate that we can inject, or we can produce for thirteen years before we reach economic limits on the second or lower rate example.

Q And those are the points which were shown on the previous exhibits, the line reflecting the economic limits?

A That's right.

Q What do you mean by economic limits?

A Well, economic limit of a waterflood operation is reached at the time that profit can no longer be obtained from continuing the operation of the flood.

(Applicant's Exhibit No. 5 marked for identification.)

Q Now, Mr. Buckwalter, refer to what has been marked Applicant's Exhibit No. 5 and explain that exhibit, please.

A Exhibit No. 5 is simply a summary of values from the previous exhibit. I have entered this in order to point out differences. You will note that we have two columns entered in this exhibit, the faster flood, the four hundred barrel water injection rate, and the slower eighty-barrel injection rate; and I have shown such things as cumulative production to be obtained. All this oil has to be obtained before that economic limit, and that shows about two million nine hundred thousand to be produced at the fast rate, versus two million four hundred thousand at the slow rates.

Q So that on your calculations there would be a loss of fivehundred thousand barrels of oil cumulatively if the slower rate of injection were used, is that correct?

A Yes, and this takes into consideration only the economic limit aspect of this problem, and does not bring into consideration the physical waste due to the low rates themselves.

Q Well, isn't there a relationship, though, between the economic aspects and the loss of that oil?

A Definitely. I believe the five hundred thousand barrels of oil on this projected case is entirely due to the economic aspect.

Q Would that oil ever be recovered under that same situation?

A No, sir.

Q Go ahead with your testimony.

A This shows the cumulative oil production, on the next line, in barrels per acre, sixteen hundred sixty versus thirteen hundred and fifty. The economic life we have stated in years, eight and thirteen; the cumulative net oil production in barrels, two million four hundred thousand versus one million nine hundred thousand; and then we show the operating costs to show the differences. Yearly operating costs at peak rates, $132,000 per year for yearly operation on the first rate, and $106,000 on the slow rate.

Total development costs are compared; in addition, I show the average cost of operating at the two rates. Notice that even though our operating costs per year are lower at the slow rates, we have a higher average on a per barrel basis for the low rate of operation. You can see why that is, because it takes more years of operation in order to recover the oil. Total development costs run $400 versus $280 per acre.

The average of the total costs overall, eighty-five cents in the first rate versus a dollar at the slow rate.

Now our cash realization at economic limit, and of course that's what the oil producer is interested in, he wants to see what he is going to end up with in the way of a profit from his investment; you will notice in one case at the high rate, four million nine hundred thousand, and the slow rate, three million seven hundred thousand.

Now when we discount these figures for a present worth value, which takes into consideration interest rates, four million four hundred thousand value at fast rate versus two million six hundred thousand at the slow rate.

The average cash realization, $2.05 versus $1.90. The average present worth, $1.84 versus $1.34. This shows the loss in present worth value if operated at the slower rates instead of faster rate is one million eight hundred thousand dollars, or fifty cents per net barrel.

The five hundred thousand barrels of oil would never be obtained, the operator would lose in money, by going to the slow rate of operation.

Q Mr. Buckwalter, is this the type of calculations or estimates of values of these properties that an operator uses in order to determine whether to enter into the project in the first instance?

A Yes, we prepare these valuation schedules to show the economics of his projected operation. I would like to say that in this particular case we haven't proved, of course, exactly what the waterflood oil recovery is going to be, but we do know that if there is any serious reduction in the recoverable oil, and that reduction would, say, be half of what I have shown here, we could not recommend a waterflood in this particular reservoir at the low rate, because the operator would not make sufficient return on his invested dollars to recover the capital he invests.

At the faster rate, at half the recoveries, I believe he could still make a reasonable profit. It wouldn't be anything as much as this, of course, but he could still go into the business.

I think that is a very important point here, we have yet to prove the results by waterflooding in the Caprock Field. These are based on my best estimates of what I think is going to be produced from all of the factors I have taken into consideration; so I want to point out that if the operators do not get recoveries in this order it is seriously questioned whether they can go into business at lower rates of water injection.

Q And again that takes into consideration the loss, potential loss, of five hundred thousand barrels of oil from the reservoir on the slow rate?

A That's correct, it does.

Q Now, Mr. Buckwalter, in connection with this matter of capacity allowables, there's been considerable comment, and the statement of Humble Company this morning seems to indicate one of their principal concerns is with regard to the impact of this secondary recovery production upon the general market situation. Have you made any studies in connection with this particular phase of the case?

A Yes, I have looked into this phase of the problem here, and I have arrived at some conclusions.

(Applicant's Exhibit No. 6 marked for identification.)

Q In connection with the impact of secondary recovery oil on the general market situation, Mr. Buckwalter, I refer you to what has been identified as Applicant's Exhibit No. 6, and ask you to explain that to the Commission.

A Before I do that I would like to say something else.

Q All right, go right ahead.

A I don't believe there is any real problem in this connection. I do not believe that this development of the Caprock Field is going to cause any serious problem on the market situation, over and above what other oil production would cost. I base that opinion on historical facts. Waterfloods just aren't developed all at one time. That is just absolutely out of the question. It has never been done any place that I know of, and I don't believe it will be done here.

Particularly where you have problems of different ownerships, where you have problems of arriving at unitization groups within a reservoir, you delay the complete development of a reservoir, and I'm quite sure that history of oil reservoirs, States, and all figures you look at will show that same thing.

On this exhibit here I have simply shown --

Q (Interrupting) Exhibit 6?

A Exhibit 6. I simply have shown the relationship between primary oil production and secondary recovery oil production for one of the states, or the state in which it has been carried on for the longest period of time. This waterflooding has been done in Pennsylvania longer than any place else, and it's still going on. Profits are still being developed in Pennsylvania by waterflooding, and in particular, I would like to call your attention to the Bradford Field.

Now the Bradford Field data here is shown in a cross-hatched manner and is shaded, which shows the primary peak was reached at the year about 1980, and it was a peak --

Q You mean 1890?

A Did I say 1980?

Q You sure did.

A 1880. The peak in the Bradford Field in terms of millions of barrels in the year was about twenty-three million barrels of oil production. Now, waterflooding started in Bradford in the early 1920's. There's a little bit of illegal well flooding that shouldn't have taken place earlier than 1921, but the effect is shown here, by 1921 it was legalized in the State, and we reached a production peak in the year 1937, and that peak is approximately, or seventeen million barrels in that year, 1937.

Now, in no instance was there any restriction of producing rates in this particular Bradford Field. The operators have just as much right to develop this at high rates of development, and they just, by the natural course of events and by their own choices and by the problems involved of getting started, it didn't all develop at the same time, it didn't all produce at the same time; so the secondary recovery on it, the waterflooding peak is lower than the primary peak.

I believe this same thing is true other places, and for that reason I think this same type of thing will be true in the Caprock Field and also in the State of New Mexico.

Q Mr. Buckwalter, do you see any essential difference between what you anticipate with regard to the secondary recovery production, any distinction present between that and the discovery, say, of a new field, a new reservoir, say, in this State?

A No, I think you can imagine right here from this curve, it's possible this never would have been a secondary recovery, but just a discovery of another field, at which it would reach a peak on the development of that field as it did previously.

Q Have you made any studies or estimates of the impact of this secondary oil with regard to the Caprock Queen area?

A Yes, I did.

Q What portions, particularly?

A Well, I worked specifically first of all on the old Caprock Field.

Q What do you mean by the old Caprock Field?

A I think we have another exhibit there we should bring in at this time.

Q All right.

(Applicant's Exhibit No. 7 marked for identification.)

Q I refer you, Mr. Buckwalter, to what has been identified as Applicant's Exhibit No. 7, and ask you if you will please state what that is?

A This is a base map of the Caprock Queen Field in Lea and Chaves Counties, New Mexico, and on that map are shown the wells which have been drilled at this time; and each of the forty-acre surrounding each well drilled is shown a red color, or shown a color. There are five different colors, those which are so marked in red are wells, indicate wells which are producing at less than eight barrels per well per day, as of current time, being August, 1957.

Q Do you consider those wells to be stripper wells at that rate of production at this time?

A Yes, I do.

Q And do you recall the areas indicated in red to be depleted areas?

A Yes, I would say they are pressure depleted.

Q. All right, go ahead.

A The green indicates wells producing between nine and sixteen barrels per day, as of August, '57. The brown, seventeen to twenty-four barrels per day per well. The yellow, twenty-five to thirty-two barrels per well per day; and those in blue are producing at a rate of greater than thirty-three barrels per well per day.

Now to summarize the types of wells that were shown here, first of all, we show 612 wells, and of those wells, 185 are colored red, and that's about thirty percent of the total. Those that are colored green, 87 wells, about fourteen percent of the total; and those in brown, 72 wells, representing approximately twelve percent; those in yellow, 82 wells, and about thirteen percent of the Field; those above thirty-three represent about 30 percent of the field. Those wells that are producing above, who have capacities to produce above thirty-seven barrels per day, known as top allowable wells here, represent 96 different wells, and that's around sixteen percent of the total.

Q Now, when you referred a while ago to the old Caprock Pool or old Caprock area, will you point out on Exhibit 7 the area which you had reference to?

A The area to which I had reference is the area which is marked generally in red on the northern part of the major Caprock Field.

Q Was that area developed earlier in the stages of development than the balance of the field?

A Yes, it was.

Q And the studies which you have made and are going to refer to now with reference to market impact relate to that particular area, do they?

A Yes, and parts of it.

(Applicant's Exhibit No. 8 marked for identification.)

Q Mr. Buckwalter, will you please look at what has been identified as Applicant's Exhibit No. 8 and state what that is, please?

A This is an oil production rate plot as of this time in years, and it was prepared to show my estimate of the effect of developing six thousand seven hundred and twenty acre waterflood project which would encompass the old Caprock Field as shown on the previous exhibit. This is --

Q (Interrupting) Go ahead.

A This particular exhibit shows two curves. One is shown in red on the exhibit, and I arrived at this particular curve by making the assumption that the development rate per year would be two thousand two hundred and forty acres until the six thousand seven hundred twenty acres were completely developed. That would take three years time.

Q Is that a relatively fast rate of development insofar as that size project is concerned?

A Yes, it is. In addition, I show in, that curve, by the way, was arrived at by using my former data which I presented back in Exhibit 1, basically, and the injection rate was then calculated at four hundred barrels per injection well per day; and that shows a peak expectancy of about eight thousand six hundred barrels in the third year after development starts, eight thousand six hundred barrels of waterflood oil per day.

Now if we consider the case of injecting at rates of eighty barrels per injection well per day, we find we have a lower peak upon this amount of development. The same rate of development was used, taking three years to develop, but developing with an injection rate one-fifth of the former or red curve. Anyway, the peak then in the lower rate injection is reached in the fourth year and -- excuse me, the fifty year, and the rate shown here is four thousand three hundred barrels per day, or about half the rate in the high injection type operation.

Now you see we are injecting at a rate of only one-fifth but the peak reached is one-half of the former peak. I think that can be understood when we think of the high peak curves, they reach a peak but then they drop off more rapidly. If you recall my former exhibits, the low rate curves reach a peak but do not drop off as fast, so these low rate curves build up one upon another, more in the form of buildup of a base production rate, which adds up to be much larger than you might consider when you think of just one well's behaviour or one group of wells' behaviour.

The high rate curves drop off rapidly and another one comes along on a development program and it picks up its high peak, then it drops off, so in a sense you have a series, at the high rates, of peaks which follow one another.

That does not add up to as high a peak as you might anticipate unless you go into this type of calculation.

Q So that the raise of injection of water and the result in rate of production is not in direct proportion insofar as the peaks are concerned?

A That's right.

Q On a development program?

A Yes.

Q Now as I understood your Exhibit 8, it was predicated on the development of 6720 acres over a period of three years time.

(Applicant's Exhibit No. 9 marked for identification.)

Now would you look at what's been identified as Applicant's Exhibit No. 9 and state what that is and explain it to the Commission?

A Well, this is an exhibit to show the effect in waterflood oil production rate for a development which goes beyond the original

6720 acres that I spoke of, and shows that as continuous development continues, and we are assuming the same rate that we had previously. We reach a maximum peak above which we'll never go, because any time that 15,680 acres is reached, from then on additional development of the reservoir at the same rate and with my same assumptions do not create a higher peak in the overall production from the field.

Now of course that might also say for the entire State of New Mexico, if you want to look at it that way, because any time you are developing at a rate which then exceeds 15,680 acres, the peaks will not be increased higher by further development. Now at the high rate of injection, that amounts to around 10,300 barrels per day. At the low rates of injection, that amounts to around 8,300 barrels per day. Now there's about a twenty-three percent difference in these two peak rates, and that is just the difference in the expected ultimate reserves. Of course, if it could be argued, I don't think it can, but if it could be argued that the low rates and the high rates would recover the same amount of oil, there would be no difference in these peak rates at this particular amount of development.

I think we see here that the rate of development is an important consideration in the behaviour of this on a market situation.

(Applicant's Exhibit No. 10
marked for identification)

Q Mr. Buckwalter, you have considered the whole Caprock area as you referred to it, 6720 acres, and you have analyzed the ultimate effect of these rates of development on market situation. Would you look at what has been identified as Applicant's Exhibit No. 10, which appears to refer to the entire Caprock field, and explain that to the Commission?

A Well, on Exhibit 10 we have first of all an oil production rate plotting which shows the history of production for the entire field, starting, this plat starts in 1944, I believe. There may have been a little production prior to that; it is not shown on here; it would be insignificant. You'll notice that the old Caprock Field area peak production curve shows that the field reached about 3,000 barrels of oil production rate per day in the year 1947 and then sustained itself above 2,000 barrels per day for most of 1948 and '49 and then declined. Well, this shows me that the old area reached a stripper state in a normal fashion so that this old Caprock area had pretty well recovered its primary oil by the end of 1952, the wells being lower and lower in producing rate.

New development of the area, which has been in more recent years, starting in the year 1954 in particular, has lifted the production curve to considerably higher rate, reaching a peak of about 15,000 barrels per day during a period of 1956. Since that time there has been a decline in the rate for the field so that, I believe August is plotted on here as the last month, and it's around 12,000 barrels per day at this time.

Now I have made an assumption that we would develop this Caprock Field at just the fastest rate that I can personally imagine, I mean if we could do it and develop it at the fastest rate, to my mind five years would be the fastest that that could be developed. I considered that figure carefully. I considered that that would be a very rapid rate, so for that very rapid rate of development, I then investigated what the effect would be on the total production for the waterflood part of the field by arriving at a calculated curve which is shown to reach a peak on this exhibit at the end of 1962 of around 19,000 barrels of waterflood production per day.

Now we know that we have primary oil to produce at the same time, but we also believe that this primary production itself will be declining, and as it declines, the same principle that we spoke of previously will be in effect, as this declines and this picks up it will serve to maintain the production level.

Now I'm not able to predict the actual primary history here because we haven't gone far enough along in the history of this particular reservoir to arrive at a good extrapolation of the data. Oh, it could be done, I could do it, but I don't believe that I could say that I would have a good basis to extrapolate the entire field production.

We know there are several wells being drilled now, so it isn't possible to do that, but I do believe it will decline.

The other dashed curve shown on this exhibit shows what the water flood production peak would be if this five years of development would carry out for the entire field, and that would result in a little over 12,000 barrels per day. The peak would come later, it would come at the end of 1964, and I show what I would believe to be the type of production that would be experienced at these two rates of water injection, assuming the same development rate, the same area, but at different rates of water injection.

Q Now, based upon your studies of the market impact in the event capacity allowables are granted in this pool, what is your opinion as to that possible, general opinion as to that possible effect, based on these studies and this analysis?

A I believe that in general it would be just a case of picking up the oil production, but I don't believe it would get out of hand. I believe the production would be such that the rate of development would be spread over five years of time as a maximum rate, and that wouldn't give us a tremendous peak.

It's very similar to discovering another Caprock Field alongside the present one. You get another oil production rate curve which is not out of line with this.

Now you'll notice we here considered the entire Caprock Field in this calculation, and this really was not the entire field as the base curve is shown, so just to show, guessing what it would look like if the entire field under primary conditions were developed at about the same time, I have listed the oil production rates for the years 1949 and '48 and placed them above, in a dashed curve above the peak rate for the years 1956 and half of '57, just to show what I believe it would look like if this thing were all developed at one time.

Q In doing that do you see any marked difference between the primary oil production and the possible secondary oil production?

A I don't see any marked difference, no, sir. Maybe two thousand barrels per day, no, it isn't even two thousand -- yes, about two thousand barrels per day difference.

Q Now, Mr. Buckwalter, have you made any calculations in this reservoir with regard to the possible or approximate amount of water that might be required to accomplish a waterflood, say in the 1760 acres that you have referred to?

A Yes, I have.

Q Would you state to the Commission what your approximate result was of your analysis of that situation?

A Yes. I considered this development in the 1760 acres by the use of re-cycling of produced water. That is a customary method of handling waterflood operations where produced water is reduced. I think it is a good conservation practice.

I believe that the operators would want to use it and would use it in this particular field. Now when you consider then how much water is required to displace the oil that we are talking about under waterflooding, since we are reusing water year after year we do not have to have as much water as might be first considered.

To arrive at some calculation of this quantity in this case, I have arrived at my answer in this way. I have said that, well, the reservoir has produced its primary oil, certainly we are going to have to put back into the reservoir that amount of water that was produced in the form of oil. We also know that the oil in place under primary conditions occupied more space than it did at the surface, so we have the shrinkage of the oil. I have allowed for that factor. Then I have considered that we are going to produce secondary oil and we are certainly going to have to leave water behind for the secondary oil we produce.

We are also going to have losses, we get leaks in lines and things like that occasionally, and we have evaporation losses, depending on how it is handled.

I arrive at a calculation of six million six hundred thousand barrels of oil required --

Q (Interrupting) Barrels of water required?

A I am sorry, to recover the oil by waterflooding 1760 acres at the high injection rates.

Q Have you made any effort to convert that to acre feet?

A Yes, I believe that would calculate to be about eight hundred fifty acre feet.

Q Assuming three acre feet per annum is required for irrigating lands, how many acres of irrigated lands would that involve?

A About two hundred eighty acres.

Q Now, Mr. Buckwalter, first let me do this. Did you prepare or have prepared under your supervision Exhibits 2 through 10 that you have referred to and identified?

A Yes.

MR. CAMPBELL: I would like to offer those exhibits in evidence.

MR. PORTER: Any objections to the admission of the Exhibits 2 through 10? They will be admitted.

Q Now, Mr. Buckwalter, you have testified as to certain economic factors in this picture as related to ultimate recovery of oil from this project and the effect of capacity allowables upon the market. Do you have an opinion as to whether physical waste would result if well production were restricted in this waterflood project?

A Yes, I do have an opinion.

Q Will you state to the Commission first what the basis of your opinion is. What have you used as a basis of arriving at an opinion?

A Well, my basis is my life's work in waterflooding. I have operated in waterflood projects for clients; I have examined the results on the field; I have looked at many, many waterfloods that were not operated by us or where we made engineering decisions, but my sum total opinion in the whole work that I have done is that if you are restricting rates in waterflood operations, you are losing ultimate oil and causing physical waste of the natural resource.

Q Have you made any studies or have you seen any studies relating to possible examination of the situation following an initial waterflood, say in the Bradford area?

A Yes. Part of my experience consists of working in Bradford, a good part of it does, as a matter of fact, in Bradford, and we did core analysis work in the Bradford area.

The Bradford field, by the way, is about 100,000 acres in area. We cored and analyzed the cores of approximately 6,000 different wells in that field. We feel that we have got a pretty good insight into the reservoir characteristics where we were preparing to flood and subsequent to flooding.

The reason is, subsequent to flooding, is this: Bradford Field was operated for a long enough period of time that we have found out there have been mistakes made by the original development in that field. Many of the mistakes that were made had to do with low injection rates, poor well completions on there, impure waters were used resulting in low injection rates. Many errors were made in the original development plans, but we discovered that we could go back into the Bradford Field and redrill the field all over again on the same spacing and recover a third crop of oil economically by redeveloping in the areas where we prior had poor results.

Now, in this process of redevelopment, we cored many wells, many different positions in five spots in old waterflooded areas. Examinations of those cores led us to some conclusions as to the losses of oil in various parts of the sand layers in that reservoir.

We found that there was a difference in the saturation conditions in cores that were drilled, for example, near old injection wells. We found variations which we believe help support the basic conclusion that there are losses because of low rates.

Then in addition, besides the operations themselves being failures, we know that places where redrilling has not taken place that we have by comparative data showing the results in one property as against another, in what we consider to be similar conditions, and there are many variables in these reservoirs and it is very hard to arrive at average values which will properly delineate all the variables, but to the best of our ability we found that low rate flooding did not recover as much oil for the operator as high rate flooding.

Now that basically Bradford experience, moving out here into the Midwest and the Southwest, we at first didn't know whether we were going to find the same conditions out here as we found in Bradford or not. We of course were wondering and watching, but we hadn't made up our minds. It isn't until recent year or two at the most that I've come to the conclusion, based on looking at comparative results in the Permian Basin floods, that a similar condition exists, that the low rates are not recovering the ultimate recovery as the high rates; and so I have, out of my experience and working with floods, have firmly decided that the rate is a very critical question. Low rates are harmful and fast rates are beneficial in flooding.

(Applicant's Exhibit No. 11 marked for identification.)

Q Now you stated that you had made some studies in the Permian area with regard to the effect of rates upon the ultimate recovery. I would like to refer you to your last exhibit here, which is Applicant's Exhibit No. 11, and ask you if you will refer to that, state what it is, and explain to the Commission how it affects your decision with regard to the relationship of rate of injection and rate of production to the ultimate recovery of oil in the Permian Basin area?

A Well, I have made a study in the South Ward Field, Ward County, Texas. The reason that field was chosen is because it is one of the fields that has been in operation for waterflooding the longest in Texas, and more data was available there, and I wanted to see if I could satisfy myself as to whether the rate of production in that field had any relationship to the ultimate recovery, so I made a study.

Now in that study, I found, like in other places where I have made studies, that immediately you hit a multitude of variables in the reservoir itself. We know that is true, properties vary from one property to another; they are not all alike. I don't think there are any two wells alike, not a lot, nor any properties alike.

In our business we would like to be able to take it all back and do it a second time a different way, but that isn't possible, so we're not in a position to directly say that these figures are absolute proof of my contention. They're simply my way of finding out for myself what I think the relationship is.

Now I have prepared other data, some has been published in the literature from this same South Ward Field, and I have been criticized by people for presenting it and I suppose that's to be understood. I don't think any two of us engineers agree a hundred percent on anything. I know that it's not likely that operators will agree on many important matters, but at least this is my approach to it.

In former exhibits I presented the data to show the effect of the rate of production in barrels per acre foot versus the cumulative water flood production in barrels per acre foot. I'm used to thinking in terms of barrels per acre foot. That's the reason that I go to those terms in particular. I think of rates in terms of barrels per acre foot. I think of cumulative recoveries in the same terms. That is the reason I chose that method.

Then having been criticezed, my own admission that there are these variables in the reservoir, I decided to look at it a little different way and so I prepared another plot and this time I referred the production to the primary production from the same property; now these curves, each one represents a different waterflood operation in the South Ward Field, and you will notice on the vertical scale is water flood oil production rate. That is what it is, it's the rate of production of this property, and each point represents a rate of production for a year, average rate for a year, so we have a lot of data here.

We have a whole lot of data when we consider that each of these represents a year's data and there are ten different projections so shown on this chart.

Well, I referred the rate to the cumulative as a fraction or ratio to the total primary produced. You see my barrels per barrel of total primary is simply the percent of waterflood that is obtained in relation to the total amount of primary that was obtained; so if we have a property that obtains a million barrels of primary oil on my curve, if we show a point at point one, or one point zero on the horizontal scale, it means that the water flood has equalled the primary and some of these curves will show that the cumulative has reached even greater than twice primary production.

Well, prior to my prior study on this, I had used barrels per acre foot as a rate versus cumulative barrels per acre foot. So I chose to use the same type of relationship here where I show barrel per primary production, so this is the fraction of the part produced in the year of the total primary produced in the same property. The reason for choosing this relationship is because one serious criticism I received in prior work was that the quality of the pay varied from property to property, and so I figured, well, if we can somehow get over the problem of quality, maybe we can show this relationship a different way, so I figured that if we had a good primary producing property, we had some measure of the quality of pay on that property.

So I thought, I'll relate this to the primary production, then if we have a property you see that has good primary and good secondary both, we would have a case that the quality of the pay would be taken care of, so I'm presenting this and showing these points here.

This year, taking Flood C for example, I have one, two, three, four, four years of data presented here, and you will notice that the rate of production on this basis is the highest in flood C of any of the floods that I studied. You will notice that at the present time the cumulative recovery as percent of primary is the greatest, and I show a dashed line on here which is my extrapolation of the data production rate data, to show what I think will happen in the future.

I don't think my argument changes whether you consider this particular dashed portion of the curve or not. I still think my same conclusion would be arrived at.

Now if we drop down to some of these other floods which show low rates of production, we find that at four years, for example, in the case of Flood G, that it hasn't produced more than about seven-tenths of the primary production and that was also a low rate of production property by water flooding.

Well, now, this is not worked out to be a perfect example, this is not one of these that points out absolutely that this curve, for example, on I, at low rate falls directly, cumulatively, to where it does under the rate measurement, that is, these don't all fall in the, exactly in the same order, but the general tendency is here, and that general tendency of those with high rate to show better results is the only thing I'm trying to illustrate.

I believe this is a realistic approach. I believe that I satisfied myself that this means something. I'm presenting it for that purpose, to help substantiate my reasons in the Permian Basin area, in Permian sand production by water flood.

Q Now, Mr. Buckwalter, it is true, is it not, that there are certain of the wells that are reflected, or properties reflected on that Exhibit 11 where there may be more than one producing formation involved, is that correct?

A That's correct. In the South Ward the Yates formation there is divided into two members, basically, the Grand Falls and the Penn Bennett. Basically the Penn Bennett has been better producing formation than the Grand Falls. The production here is taken for the properties under primary and secondary from both formations.

Q Are all of the formations showing the lowest ultimate recovery ones that are completed in both, or are there some completed only in the one that is apparently better for water flood?

A Well, we have property G, that's the Forest Oil Corporation Johnson, that shows a pretty low relative rate here on this plot, and that is in the Penn Bennett formation, developed in the Penn Bennett formation; and J and K, however, I'm sure, have both formations exposed to water flooding, and there's not too much difference between G, K and J as far as their rate or their predictions are concerned.

Q Now, based upon your statements and your opinions and your analyses that you have given here, is it your opinion that if the application here is not granted, that it will result in waste of oil?

A Yes, it is.

MR. CAMPBELL: I believe that's all at this time. May the record show that I offered Exhibit 11 in evidence?

MR. PORTER: Any objection to the admission of Exhibit 11? It will be admitted. We'll take a short recess.

(Recess.)

MR. PORTER: The meeting will come to order, please. Does anyone have any questions of Mr. Buckwalter?

MR. McGINNIS: Robert McGinnis from Austin, Texas. I would like to ask some questions, if I may.

MR. PORTER: You may proceed.

CROSS EXAMINATION

By MR. McGINNIS:

Q Mr. Buckwalter, I understood you to say that you had found in your experience in water flooding that an injection rate of one barrel of water per acre foot to be flooded is desirable, is that correct?

A That is correct.

Q I understood also that you said that the optimum rate for flooding was the highest rate possible without causing breakthrough or fracturing the sand, is that correct?

A That's correct.

Q And that it is undesirable to flood at a rate less than one-third barrel per day per acre foot to be flooded?

A That's correct.

Q What physical factors caused you to reach the conclusion that the optimum rate or best rate for water flooding to recover the most oil is the highest rate possible without causing fracturing and breakthrough?

A You asked for the physical factors involved?

Q Yes, sir.

A I don't know. I wish I did.

Q What physical factors, if any, cause there to be loss or severe loss, as I believe possibly you put it, where the rate is less than one-third a barrel per day? What physical factors cause that to be true?

A I'm sorry. I again don't know. I wish I did.

Q As I understand it, you base your opinion that flooding at the rate you mentioned is more desirable than flooding at lower rates, based on the great amount of experience that you have had in practicing water flooding throughout the years, both in Pennsylvania and elsewhere, is that correct?

A That's correct.

Q Now during this experience that you had over the last twenty, twenty-five years or so, have you given thought to the question from a point of view of physical principles as to why, in your opinion, high rate water flooding results in greater recovery? Have you delved into that question and given consideration to it?

A I have thought about it, but I can't come to any conclusion.

Q Do I understand, then, that from the study that you have made in this long period of time that you have been unable to reach any physical explanation for why it is necessary to flood at fast rates, rather than at normal rates or somewhat reduced rates?

A In a physical recovery sense, yes.

Q You have no explanation?

A I have no explanation.

Q When you suggested as a rate for water flooding the rate of one barrel injection for each acre foot to be flooded per day, does that rate hold, regardless of the reservoir conditions, or does that rate vary with the reservoir conditions?

A Well, the reservoirs themselves vary and they vary in proportion quite a bit; therefore I believe that that one barrel, that is my thinking about it, varies, too. I don't believe that is a fixed number by any means. That's just the realm of values that I think about in this connection. You have rules of thumb, you know, that develop through the years, you are bound to have them. I think that the one barrel is just about where it comes out in most of the reservoirs in cases that I have worked with.

I believe that there are probably some that may have been different from a barrel per day per foot, if I really wanted to go into it.

Q What would you say, the reservoirs that you have experienced, would be the range of proper flooding rates?

A I would say the range would run in the order of a half barrel to a barrel. That's the general range.

Q In other words, you have not seen a field where you think it would be desirable from a point of view of recovering greater amounts of oil to inject in excess of a barrel per acre foot per day?

A Well, I certainly think we should clear up a point here which has been maybe confusing me a little. That is this injection rate varies over the life of the flood. To answer your question specifically, you know that during fill-up period after a flood operation, I am sure you know that you inject more than a barrel, considerably more than a barrel per day per foot.

When I talk about a barrel per day injection rate per acre foot, I'm thinking of the settled-down rate, after the reservoir is pressured up. During the flood life, that can vary many times. We can't accomplish what we would like to do, we do the best we can. When you start a flood your injection may be in the order of two barrels per foot per day; then as the flood progresses, you find the injection rates decreasing with constant pressure, so the operations are usually conducted by increasing the pressure at the well bore in order to maintain the injection rates at as high a level as possible without fracturing the formation, but the history of most water floods will show that same condition.

Now we don't every minute and every hour, we aren't capable of keeping that injection rate at a fixed number in satisfactory flooding the way I know it.

Q If I understand you correctly, the range that you have mentioned here from half a barrel to a barrel a day --

A (Interrupting) Yes.

Q --might be chosen in one reservoir, that is, the half barrel might be chosen in one reservoir and a barrel a day in another reservoir. What particular reservoir conditions in the reservoir would cause you to choose a barrel rate in one and a half-barrel rate in another?

A I don't choose these rates.

Q In your opinion are there any physical conditions in the reservoir which would make it more desirable to flood at fast rate in one reservoir and slow rate in another?

A I don't know of any instances in that case, no.

Q Do I understand, then, that in naming your range of half a barrel to a barrel a day, it would be immaterial to you what the permeabilities were in the reservoir, or how thick the reservoir was, or how continuous it was, whether it was heterogeneous or homogeneous, those things would be immaterial to you in choosing that rate?

A I don't choose the rates, I told you that previously, so I can't answer your question, I'm afraid.

Q Let me use the word "recommend", "select" the rate which would be most desirable to ultimately get the best recovery.

A I don't select a rate on that basis.

Q Do you recommend a rate when you are serving as a consultant to people who are going into the water flooding business? Do you recommend that they inject a half-barrel or barrel, or do you have anything to say about that matter, when they consult you about that matter?

A No, I do not recommend it on that basis. I do not recommend it on the basis of a half-barrel or a barrel. I don't use those numbers in a case. What I do, I recommend what pressures would be required to operate the flood to get the best results.

I do not like to regulate the injection of water into injection wells. I like to maintain the regulation on the pressure of the water which is injected into those wells so I do not regulate those rates or recommend that they be regulated in that sense.

Q Then with regard to the pressures at which you believe it is desirable to inject in a waterflood to get the optimum recovery, what is the range of pressure that you feel it is desirable to inject at?

A Well, that's a large range. There is a place where the permeability and the reservoir characteristics come into play very definitely. There are reservoirs that you can inject water at what I would call high rates at low pressure, and there are reservoirs that you can inject high rates at higher pressures.

Many of the reservoirs, it turns out that after the reservoir is pressured up, that the highest rate that we can put in those wells still does not reach my completely desired rate that I would like to have, but I do not put it on the basis of control of the rate but control of the pressure.

Now I also know that there are times in the operation of a water flood that you can inject at higher rates without breakthrough, than other times, so you can't be tied down specifically on that particular type of question. It just doesn't work out that way.

Q Now, in selecting or recommending a pressure at which a particular reservoir is to be flooded, do you take into consideration the reservoir conditions and recommend one pressure for one flood and another pressure for another flood?

A What I do is I consider first of all the economics of the situation, which I think is very important. If I find that we have a very high permeability type reservoir, first of all I think of spacing, I think of such things as how much water might be injected into that reservoir, and I certainly don't recommend starting a flood with a pressure which will be one whichwould overtake the capacity of pumping equipment that might be installed in that particular operation. So I keep the economies and the reservoir itself in mind when I make that decision.

Q Now with respect to this Graridge application pending here now, and with reference to your opinion that the optimum rate to flood a reservoir is the highest rate, fastest rate short of fracturing the reservoir so as to cause breakthrough, in your opinion wouldn't injection rate here of a barrel per day per acre foot result in breakthrough in this reservoir?

A I don't have data to answer that question at this time.

Q You've made no determination, then, as to what rate would be the best rate for this particular reservoir?

A I believe that based on my general background experience that it would fall in the same range as other water floods where I have worked.

Q Which would be around a barrel a day?

A I would say a half to a barrel, which is the range I have been talking about.

Q Well, now, do I understand that it is your opinion that in any water flood, that that point at which the greatest ultimate recovery will be obtained is the highest rate that can be flooded short of breakthrough? Now in this particular case that we have here, why would you recommend a half-barrel injection, instead of a barrel, unless you have some reason to believe that a barrel would cause breakthrough in the reservoir?

A I didn't recommend a half-barrel here.

Q Did you recommend certain injection pressures which would result in a four hundred barrel a day injection rate, which figures out to be half a barrel?

A No, I didn't do it that way. In this case my opinion is that it is going to be very difficult to maintain a high injection rate at this particular spacing in this particular reservoir under the conditions that I believe are present here.

Q What are those conditions that are present in this reservoir that cause you to have that opinion?

A Well, I have examined core analysis data from wells drilled in this reservoir, and our company has analyzed some core material from this reservoir. That, stacked alongside of experience in other reservoirs where I have seen what I consider to be similar type conditions.

Q What does this core analysis that you have examined or made, as the case may be, show to you with respect to this reservoir, which causes you to think that the particular rate that's been chosen is the proper rate?

A I haven't chosen a rate. Can I clear that up once? You see, it seems to me if I answer your question I'm assuming that

I have chosen that rate, the way you ask it. Can you ask it in a way that it wouldn't assume that?

Q Yes, sir, I'm sorry. You have told me that you have not chosen a rate, but as I understand it, you told me that you have examined certain core analyses in this field which made you feel that this field should not be flooded at a higher rate than a half-barrel. What I'm asking you, what did you see in this core analysis that caused you to reach that conclusion?

A Well, I believe it will be difficult to maintain the injection rate of a half-barrel per day per acre foot in this reservoir because I have examined the core analysis data at a number of wells, and it shows conditions similar to other reservoirs where it has been difficult to maintain a high rate of injection on an average basis.

Q What are those conditions that are similar to other reservoirs?

A Basically, the type of rock, porosity, permeability, saturation conditions.

Q What permeabilities did you find from an examination of these cores in this Caprock Queen?

A Well, in the entire Caprock area, which is the full reservoir and not just the old Caprock area which I have so designated, I found a very wide range of permeability. I would say from impermeable or zero, which is practically impermeable, to over twenty-five hundred millidarcies.

Q Now, in the area which is included in this application, the sixty seven hundred twenty acres, immediate area around this particular pilot flood, what was the range of permeabilities which you found?

A In this old area we are hampered by the lack of core information relative to the other areas, but what I have seen shows that the permeability is not quite as high a range as the figures I just mentioned.

Q What did you find the range to be in this flood area?

A Oh, in the order of impermeable to over five hundred millidarcies.

Q Now, what relationship is there between those permeabilities which you found in these cores and your flooding rate, or your pressure rate?

A The more permeable sand will take water at a higher rate than the less permeable sand for the same pressure imposed upon it.

Q Now, you said, I believe, that because this field had similar permeabilities and saturations to other fields in which you had experience, that you did not believe that this field could be flooded or should be or could be flooded at a faster rate. What is there about these par ticular permeabilities you found in this field that would prevent it from being flooded at a faster rate?

A Permeability is one factor and I believe that spacing enters into this consideration, too. Therefore I believe that at the eighty-acre five-spot size chosen that it will be more difficult to maintain the rate over and above a permeability relation similar to another reservoir where the five-spot size is smaller.

Q Is there any opinion onyour part with respect to whether a reservoir with high permeability should be flooded at a faster rate than a reservoir with low permeability, or do you think that makes any difference?

A I don't know that it does. I believe that the rate, in the sense of rate itself, through high permeability is important just the same as I think rate through low permeability is important.

One of the things that we must think about, I think, in this connection, if I may say so, is when we talk about rates we're talking about average rates, really. The well bore we find, we have permeabilities of various sizes, therefore we know that the difference in permeability in the well bore is a factor in the average rate at which we inject. I think that should be taken into consideration in this type of discussion.

Q Now, in connection with the core analysis data that you said you had studied on this Caprock field, you mentioned that in addition to permeability, you mentioned oil saturation, or saturation, I believe you said you were referring to?

A Yes.

Q You were referring to saturation of oil and water in the reservoir, I assume. What relationship is there, if any, between the oil and water saturations that you find in a particular reservoir with respect to the rate at which that reservoir should be flooded or the pressure at which it should be flooded?

A Well, there are various oil saturations and water saturation conditions as related to permeability in reservoirs that vary from foot to foot on a vertical basis, and from acre to acre on an areal basis. These variations in all of these factors seem to enter into the rate.

I can't myself keep all of these independently, apparently independent variables separated one from another, and arrive at any conclusion as to which of the variables are the most and greatest importance in all cases.

Q Do you have an opinion as to whether or not, for instance in a reservoir where you had forty percent oil saturation, you should have a faster or slower rate than in a reservoir where you had fifteen percent oil saturation?

A I think there are other factors that come into that that separate that particular one out, just as I have said, and depend on it alone in this matter of rate.

Q Now, if you are unable to separate out the factor of permeability in the reservoir and unable to separate out the factor of saturations in the reservoir, what other factors are there in the reservoir which in your opinion would make it desirable to flood the reservoir at a fast or slow rate, other than permeability and saturation?

A Well, rocks have different porosities, different texture, we say. Some rocks are clean rocks, other are dirty, that's general terms. I think those are the principal ones other than the ones mentioned.

Q All right. Now, where you find the clean rocks as distinguished from dirty rocks, does the finding of clean rocks indicate to you the desirability of injecting, rather, injecting or producing at a rapid rate or slow rate?

A I don't think I could make a distinction on that basis.

Q In other words, you find clean rocks in some reservoirs and dirty rocks in others, but you can't make any distinction as to whether it should be flooded fast or slow?

A I haven't found a case in my experience where I feel that the slow rate would be beneficial in the production of the oil or in the ultimate recovery obtainable thereby.

Q In other words, the slow rate wouldn't be beneficial regardless of whether you have clean or dirty rocks?

A In my opinion, no.

Q It wouldn't be beneficial whether you had high or low permeability?

A I don't think on that basis alone, no.

Q It wouldn't be beneficial whether you had variations in saturation, different percentages of oil in saturation in the reservoir?

A I think that when you come to the oil saturation you are into something there that is a distinct difference. On the basis of a low oil saturation in a reservoir, we know that you could interpret a poor result at a higher rate of injection if you had a low oil saturation to start with, and that might lead you to the conclusion that it's been a bad flood because of the high rate of injection. I don't believe that slowing the rate of injection would cure the problem of low oil saturation in that particular reservoir.

Q Is there anything about the saturation itself which would make it desirable to flood at a high or low rate?

A I can't think of anything specifically to answer that, no.

Q Is it a fair statement, then, Mr. Buckwalter, that your opinion that one barrel per acre per day is a good rate at which to flood and that anything less than a third of a barrel per day is a bad rate to flood, is sort of a rule of thumb based on your experience, and not based on information known to you about the physical properties of the particular reservoir, is that correct? Is that a fair statement, that it is based on a rule of thumb and not on physical facts?

A It is based on my experience in flooding, working with many different operations in many different places. I realize I haven't had all the experience by a long shot, and it wouldn't surprise me tremendously to find out there are some places where the rate might not make too much difference, but it seems that if it were so, I would have been able to detect that somewhere by this time, but I haven't been able to really do that, if that answers your question.

Q Now, Mr. Buckwalter, referring to your Exhibit No. 2 --

A Exhibit No. 2.

Q -- as I understand that exhibit in the case, on the left-hand side of the exhibit you were injecting at the rate of four hundred barrels per day per injection well, whereas on the right-hand side, you were injecting at the rate of eighty barrels per day per injection well, is that correct? Do I interpret that correctly?

A I was assuming those injection rates, yes.

Q Now, in this particular reservoir, since this is related to the present application in the Caprock Queen Field, what were your estimated injection pressures at the four hundred barrel rate, wellhead injection pressures?

A I estimate that it will be approximately a thousand pounds at the wellhead for an injection rate of four hundred barrels per well on an average after this reservoir is pressured up.

Q Now, at your eighty barrel rate, what would your wellhead injection pressure be?

A I would estimate that it would be, for most of the life of the flood, and that's what I'm speaking about in the first case, approximately three hundred pounds surface pressure.

Q Have you calculated approximately what the bottom hole injection pressure would be at the depth in this reservoir in the two cases?

A No, I haven't got that calculation but I think we can arrive at it.

Q Have you calculated what the production rate would be in terms of barrels per well per day in the first instance, and in the second instance?

A Approximately, yes.

Q What would it be?

A Speaking of the production rate at the peak of the --

Q (Interrupting) Take it, if you will, year by year.

A Five-spot?

Q Yes, sir, for your center well.

A Well, you can arrive at that answer by dividing barrels per year by the number of days in the year.

Q What would that be, if you know, if you have already done that, what would it be for the first year in your four hundred barrel rate?

A Well, I'll have to calculate it now. I don't recall. That's about one hundred fifty-three barrels per day.

Q One hundred fifty-three barrels a day?

A Yes.

Q As I understand it, that is just oil, not oil plus water?

A That's oil.

Q Oil alone?

A Yes.

Q Now, on the map attached to your Exhibit No. 1 you show a number of wells, which I presume are proposed injection wells, some forty-five of them around this area?

A That's right. I think it works out, yes, those are injection wells shown as a double circle.

Q Do you propose or is it proposed in the overall here, to inject in all forty-five of these wells at a rate of some four hundred barrels a day?

A I don't believe that that's possible. I don't believe that that's possible. I believe that the average will be the four hundred barrels per day.

Q It will vary a little bit from well to well, is that right?

A I think that it certainly will vary from well to well.

Q What is it that will cause it to vary from well to well?

A I beg your pardon?

Q What is it that will cause it to vary from well to well?

A Well, the thickness of the pay, the permeability conditions, possibly saturation conditions, different reservoir conditions that we have previously mentioned.

Q In other words, do you expect to use uniform wellhead injection pressure at all of these injection wells, or do you expect to vary that also?

A Insofar as that is possible, I would like to use a constant wellhead pressure at all the wells.

Q It would be possible, would it not, to get a uniform injection rate if you varied the wellhead pressure?

A I'm sorry, I didn't quite get that.

Q It would be possible, would it not, to inject approximately four hundred barrels per well for each of the injection wells if you varied the wellhead injection pressure at the wells so as to cause each of the wells to take four hundred barrels per day? That would be possible, would it not?

A No, I don't think it would be possible because I believe that some of these wells will not take four hundred barrels a day at a constant pressure relative to other wells.

Q Then your four hundred barrel figure is an average figure for all of the forty-five wells?

A That's right.

Q And you would expect the average producing rate for the producing wells to be a hundred fifty-three barrels?

A Average.

Q Do you have any estimate of what the range would be in production from those producing wells at the peak period of the flood?

A Well, the one hundred fifty-three barrels is not at the peak period. It's at the peak year.

Q All right, excuse me, at the peak year.

A At the peak year, I would say that the range would be in the order of twenty barrels to the order of two hundred fifty barrels.

Q Have you calculated the water-oil ratio which would be produced; in other words, the amount of water plus oil which would be produced in each of the years for each of the two calculations that you have made there, each of the two examples you have given?

A No, I didn't calculate that.

Q You made no determination on water-oil ratio at all?

A Well, I know how the water-oil ratio will behave according to the way that I have calculated it.

Q How will it behave according to the way you calculated it?

A When you reach a peak in the water flood operation, the peak is principally oil, we speak of the peak producing rate, and then as the peak, from the peak rate the oil production declines, the water production increases, but in general it is usually found that the total producing rate from the peak rate does not change very much; so that the approximate peak oil producing rate that you would obtain is indicative of the total producing rate that you would have for the remaining life of the operation.

Q For instance, in the tenth year after the start of the flood, on your exhibit, where you are injecting four hundred barrels a day, how much water would you be producing along with the nineteen hundred barrels of oil recovered?

A Well, on the basis of working with the yearly averages as shown on this exhibit, the difference between fifty-six thousand one hundred, and nineteen hundred would be the amount of water that you would expect to produce.

Q In other words, you would expect to produce fifty-four thousand two hundred barrels of water along with that nineteen hundred barrels of oil, is that correct?

A That sounds correct, yes.

Q Now, in the case of your eighty barrel per day injection rate, where you show a production in the fifteenth year after the start of the flood of twelve hundred barrels, what would your water production be in that year?

A Well, subtracting the peak year oil production rate of twenty thousand eight hundred, subtracting twelve hundred from that figure, that would be nineteen thousand six hundred.

Q This would mean, would it not, that you would have a substantially lower water-oil ratio from the producing well in the fifteenth year after the start of the flood in the eighty barrel case, than you would in the tenth year in the four hundred barrel case?

A That is correct.

Q Have you calculated what those water-oil ratios are?

A No, I haven't.

Q Isn't the water-oil ratio one of the important factors which causes an operator to abandon or not to abandon a particular water flood project?

A In some cases.

Q Why is water-oil ratio important?

A The cost of producing the water is a factor in the operation of the flood; therefore, if you have to produce large quantities of water your costs are higher.

Q So that it might be entirely possible to produce twelve hundred barrels of oil at a given water-oil ratio, whereas you could not produce twelve hundred barrels of oil if the water-oil ratio were much higher than that?

A That's correct.

Q Now, have you taken that factor into consideration in establishing the economic limit periods which you have used in your presentation here?

A Yes, I have.

Q In what manner did you take that water-oil ratio into consideration?

A If I may refer to Exhibit 4, in direct testimony I stated that I arrived at the economic limit by this method of evaluation, so that I consider one hundred thirty-two thousand dollars the cost of operating to obtain the one hundred seventy-two barrel per day production at the eighth year in the case of the fast rate.

Now, as against that, I arrived at the economic limit in the low rates by taking one hundred five thousand dollars as the operating costs to produce a hundred forty-eight barrels per day, in the thirteenth year of the operation.

In this manner, I have taken into consideration the cost of lifting the water at the different water-oil ratios which are current at these economic periods.

Q Have you taken into consideration the effect of increasing your water injection rate in the eighty barrel case so as to maintain production at the twelve hundred barrel figure which you showed on your Exhibit 2, or have you assumed that the injection rate will be held throughout the life of the project to eighty barrels?

A For the purposes of this example, I assumed that the injection rate would be held constant throughout the life of the operation.

Q In your opinion, in this reservoir, would it be possible to increase the injection rate in excess of eighty barrels after you had reached the twelve hundred barrel yearly oil production rate?

A After you reached the twelve hundred barrel -- I'm sorry, I don't know which barrels you are referring to.

Q Twelve hundred barrels of oil yearly production rate that you showed on Exhibit 2.

A I never reached that point in this particular flood, Mr. McGinnis.

Q You cut that off at the thirteenth year, did you?

A Yes, sir. At that time it is one hundred forty-eight barrels per day average for the year.

Q What is that on a yearly basis, according to your exhibit 2?

A Fifty-three thousand nine hundred barrels of oil.

Q Now, if you are producing, in other words, when you abandoned your eighty acre project, how much oil were you producing out of an eighty acre five-spot, according to your previous Exhibit No. 2?

A Number 2 Exhibit showed the production rates as though you could go beyond the economic limit of operation. It did not take into consideration the economic limit. I brought that in later on the next exhibit.

Q I understand that. What I was asking was, what was the production rate in barrels of oil when you reached economic limit, pursuant to Exhibit 2? I realize that you don't show economic limit on there, but based on the economic limit that you have chosen for that project, how much oil was being produced in that last year, at the time of abandonment, on the eighty barrel takes?

A One hundred forty-eight barrels a day for the twenty-two five-spots, I think will probably get that figure the best.

Q You have the exact figure on your other exhibit, do you not?

A Would you like to refer to that?

Q On Exhibit 2.

A In the thirteenth year under the single five-spot case, I show twenty-two hundred barrels per year of oil production for a single five-spot.

Q And it was your assumption that abandonment would occur when there was twenty-two hundred barrels being produced, is that correct?

A No, that is not the case. I took the date from this exhibit and then progressively developed an operation, of which I then applied operating costs. So you lose this comparison that you are talking about on the basis of this particular single five-spot. I did not work economics on this particular exhibit 2, so I don't think that I can answer that question on an economic basis.

MR. PORTER: At this time we will recess the hearing until 1:30.

(Recess.)

AFTERNOON SESSION
October 28, 1957

MR. PORTER: The meeting will come to order, please. Mr. McGinnis, would you proceed with your questioning?

CROSS EXAMINATION (Continued)

By Mr. McGINNIS:

Q Mr. Buckwalter, this morning I understood you to say that after fill-up that you produced fifty-six thousand one hundred barrels of fluid each year at the four hundred barrel case you have here, that was correct, was it not?

A No, I don't believe that's quite right, not each year. I said that in the first year of the flooding at the four hundred barrel rate, the average oil production was fifty-six thousand one hundred barrels.

Q Then I believe you said that, in the tenth year down there, when I asked you how much water was produced along with the ninteen hundred barrels, you said that would be arrived at by deducting the nineteen hundred barrels from the fifty-six thousand one hundred barrels?

A That is correct.

Q Which would result in fifty-four thousand eight hundred some odd barrels, is that right?

A That's right.

Q So that would mean, then, that the total fluid production in the tenth year would be fifty-six thousand one hundred barrels?

A That's correct.

Q I understood you to say also that the total fluid production each year would be that amount; for instance, in the ninth year you would deduct twenty-three hundred barrels of oil from the total of fifty-six thousand one hundred, and you would get the amount of water produced in that particular year?

A That's correct, yes, sir.

Q So after fill-up, each year, you would have production of fluid in the amount of fifty-six thousand one hundred barrels in your four hundred barrel rate?

A That is correct.

Q Now in your eighty barrel rate case, similarly, I bel you said that there the top figure was twenty thousand eight hundred barrels, so that your total production of fluid, both and water each year after fill-up would be twenty thousand eight hundred barrels at the eighty barrel rate?

A That is approximately correct.

Q Now, your annual injection rate at your four hundred barrel case would be obtained by multiplying four hundred barrels times three hundred sixty-five days, would it not?

A Times the number of wells.

Q Well, in this case here, you have one eighty-acre five-spot, do you not?

A Yes.

Q That would give you an injection of one hundred forty-six thousand barrels per year?

A That sounds approximately correct.

Q By multiplying four hundred by three hundred sixty-five, it would give you one hundred forty-six thousand?

A That sounds approximately correct, yes.

Q In your four hundred barrel injection rate case, you are withdrawing each year fifty-six thousand one hundred barrels; you are injecting one hundred forty-six thousand barrels. You are injecting one hundred forty-six thousand barrels of water and you are withdrawing fifty-six thousand one hundred barrels of total fluid?

A That's correct.

Q That would give you a ratio of production to injection after fill-up of 38.5 percent?

A I think your fill-up is the problem here, in this way that you are presenting this, because this fifty-six thousand one hundred is in the first year and quite a bit of the fill-up, I believe, would occur in that first year, but I don't think it would necessarily all occur in the first year, so when you -- the way I understand it, when you bring in after fill-up, then I think that doesn't quite work out that way.

Q Well, now, take your eighth year, for instance. In your eighth year, according to your table there you have one hundred forty-six thousand barrels of water put into the reservoir that year, and you have taken out fifty-six thousand one hundred barrels of total water and oil that year, so that in the eighty year then, we'll say for instance, which is long after fill-up, you would have a ratio of production to injection of 38.5 percent. In other words, you are taking out of the reservoir 38.5 percent of the volume that went into it, approximately?

A That's approximately correct in that calculation, yes.

Q That same thing would be true, based on your exhibit, in the ninth year, the tenth, the seventh, the sixth, and the fifth and so forth?

A Essentially, deducting this fill-up that we are not discussing in this case.

Q Of course, fill-up's occurred long before your fifth year there, hadn't it?

A Well, I don't know for sure whether it has or not.

Q Do you have an opinion as to when in this illustration here your fill-up would occur?

A Well, I believe that in some of the tight parts of this reservoir it may take, it may take five years to obtain some fill-up.

Q By your eighth year you certainly would have fill-up, though, wouldn't you?

A I would think a good, the best percentage of it would sure be filled up in eight years, I would think so.

Q Let's go to your eighty barrel case over here. In that case you are injecting into the reservoir eighty barrels times three hundred sixty-five, or approximately twenty-nine thousand one hundred barrels per year, are you not?

A That sounds right, yes.

Q And you've already established that your withdrawals of oil and water each year after fill-up is twenty thousand eight hundred barrels?

A That's right.

Q So in that case you have a ratio of withdrawals to injections of the fraction of twenty thousand eight hundred over twenty-nine thousand one hundred, do you not?

A That sounds correct.

Q That would be a ratio in that case of 71.5 percent, would it not, approximately?

A I think your calculation is right.

Q in other words, you are withdrawing from the reservoir, according to your tabulation and figures, 71.5 percent as much volume as you put into it in your eighty barrel case, whereas in your four hundred barrel case you are withdrawing 38.5 percent?

A Yes.

Q There is a substantial difference between 71.5 percent and 38.5 percent, is there not?

A There is, yes, sir.

Q If these floods are assumed to be of equal displacement efficiency, which is part of the heading of your exhibit up there, "assuming same displacement efficiency in each case", can you explain, please, why there is such a drastic difference in ratio of production to injection in the two cases?

A Well, I believe that what I have taken here is an analogy to a practical case, and I think that in a practical case that you have that sort of thing where you have low rates and where you have high rates.

Q In other words, in a high rate case, where you are injecting water at high rates, you actually recover out of the well bores drastically smaller percentages of the fluid injected than in a low rate case? From a practical standpoint, that is the way it would seem to be?

A That is what it seems to be.

Q That is the way it works?

A Yes.

Q In each year during the ten years shown on your chart there, you inject one hundred forty-six thousand barrels of water and produce fifty-six thousand one hundred barrels of oil and water each of those years. Where does that some ninety thousand, eighty-nine thousand difference go?

A Well, in the case of an individual five-spot, it can go into other areas around the five-spot. It doesn't necessarily have to go into the five-spot itself.

Q You mean it migrates off the five-spot, is that right?

A It can do that, yes.

Q Well, now in your high rate case you were losing a much larger percentage of your injection than in your low rate case?

A Yes.

Q Do you mean to say that much more of it migrates off the lease in the high rate case than the low rate case?

A I would say it depends on what is happening in other areas around the particular five-spot that you are speaking of, or the lease.

Q On the particular assumption that you have made here in your exhibit which you have presented here as Exhibit 2, what assumptions did you make in regard to that, in connection with this particular exhibit?

A I didn't make any assumptions in regard to that in this particular exhibit.

Q In other words, it's your opinion that as a practical matter, that under high rate flooding a much greater percentage of what you inject in the ground goes on off of the tract, than occurs in the low rate case, is that what this shows, is that your opinion?

A If you don't have other wells in an array which will change that condition.

Q That is what is shown by your exhibit at any rate, is it not?

A That's right.

Q If your greater percentage of the injected water goes off the lease, does it carry any oil with it when it goes off the lease?

A Oh, I think if you had an individual five-spot, it certainly can carry oil with it as it goes away from the five-spot that is set into production, that's correct.

Q Now if you have a bigger percentage of the injected water moving off of the lease in the high rate case than you do in the low rate case, does it also follow that you have a greater percentage of the oil being moved off the tract in the high rate case than the low rate case?

A Can we clear up a little case, when you say "tract", just what do you mean there?

Q Your eighty acre.

A I'm speaking of eighty acre, one unit of the five-spot. Are we clear on that?

Q I am talking about the tract that you considered in connection with this particular exhibit.

A Yes, that's right.

Q So that you would have more oil migrating and moving off of the lease at the high rate flooding in the four hundred barrel case than you would in the eighty barrel case, is that correct?

A As long as the lease is an eighty acre five-spot, yes.

Q Do you think that if that be true, that you are going to have a greater disruption of correlative rights where you have fast rate, high rate flooding than flooding at normal rates?

A No, I don't think necessarily, in a water flood where you have an array of injection and producing wells as compared to the case where you have a single unit.

Q Now if you just had the single unit there, you think there would be a disruption of correlative rights?

A I think that is possible, yes.

Q The disruption would be greater at the high rate than the low?

A Because you are moving larger volumes of water into the reservoir. There are other factors that come in there, and we haven't talked about those specifically. We're talking about injection rates, basically, but I think that the rate of production would have a bearing on it, too.

Q Now, in your Exhibit 4, you used this information obtained from your Exhibit 2, did you not, in calculating the economics for a number of five-spots together?

A Yes, I did.

Q Do you think that you can properly do that if you say that you aren't actually operating at field conditions on one eighty acre five-spot, and then transfer the same data over to Exhibit 4?

A Well, I believe that as far as the oil production is concerned, I think that is fairly representative.

Q Do you have any explanation from a scientific point of view, or based on the laws of physics and the laws of reservoir operation, to explain why it is that you get so much greater percentage of the injected water moving off of the lease and carrying oil with it in the high rate case than you do in the low rate case? Why it was 71.5 percent in one instance as against 38.5 in the other?

A Well, I think I stated previously this morning that I couldn't explain why some of these things take place. I think that is one of the sixty-four dollar questions, I really do.

Q Now in connection with the tabulation, Exhibit 2 there, do you have any proof or any field experience that shows you, of any sort, any information of any sort which shows you that you are going to have a greater percentage of your injected fluids, both oil and water, moving off the lease at the high rate case than at the low rate case? Do you have any proof, other than just a feeling based on experience?

A Well, in that case I would have to go back to the pilot flood experience, because that is what we are speaking of here, where you inject water into a single element of a reservoir, usually consisting of four injection wells and one producing well, with surrounding producing wells. I believe that I do have experience which shows that you do produce more fluids at surrounding wells on high injection rates than you do at low injection rates, yes.

Q In this particular field have you run such experiments?

A No, I have not run such experiments here.

Q Have you run such experiments in any other field?

A Well, I don't know that I have, any experiments that I have run that I can particularly point to, but I have that general information.

Q Is it correct, then, that what you are saying, Mr. Buckwalter is that you simply can't verify and prove water flooding rate matters by means of engineering principles, that engineering principles just simply can't be applied to this matter of water flooding and rate of water flooding?

A It pretty much depends on what you mean by engineering principles. I would say that I know that many experiments have been done in laboratories and many field cases have been examined, and my particular opinion on that matter is this, that I have distinct difficulty in reconciling what might be considered the classical engineering approach, which comes out of laboratory data, to apply that in my field of practice, sure do. I have not been able to do much with that.

Q I hate to trouble you with this Exhibit 2 again. I wonder if we could turn back to that for just a moment. Now at your peak rate of production in your eighty acre case, you would have an individual well production of 57.2 barrels, would you not?

A They are both eighty acre cases, I think you meant to say --

Q I meant to say the eighty barrel case.

A You mean in the eighty barrel per day case?

Q Yes, that's the one that I mean.

A Now I'm sorry, I forgot the rest of your question.

Q In connection with that particular illustration, you would have a 57.2 barrel maximum producing rate at peak, would you not?

A For the peak year, yes, average.

Q For the peak year. Have you calculated or attempted to calculate what water injection rate would be required to maintain the production rate at or near 57.2 barrels per well and when abandonment would be reached, if you injected enough water to keep the wells producing at 57.2 barrels?

A No, I haven't made that kind of a calculation.

Q There would be no reason why, would there, the injection rate could not be increased over eighty barrels per day?

A It could be increased over eighty barrels per day, yes.

Q And after the oil production began to decrease, oil production could be maintained by increasing the rate of injection of water, could it not?

A It couldn't be maintained very long.

Q But for instance, suppose at the point on your chart when oil production had fallen to forty barrels per well per day, could you not at that time increase that injection? You could, couldn't you?

A It's possible, if you had the equipment in place to do it and if you had sufficient remaining pressure available that wasn't used in the form of capacities and so on.

Q If you increased your injection rate from eighty barrels to some higher figure, that would tend to hold your oil production rate up, would it not?

A For a short period of time it would increase the oil production rate, but only for a short period of time.

Q That injection of water could be increased above eighty barrels a day at any time during the course of the flood, could it not?

A I'm not sure of that completely, and I know you want my reasoning on this, so I'll go ahead and talk about it.

It seems that my experience shows that as you go along and operate floods, that if you inject at low rates that you are limited on how much additional pressure you can put on that reservoir late in the operation to increase the rates to any substantial degree. Therefore, it just seems to me that it is some question as to whether you can, upon slow flooding rates, increase your injection rates later on to accomplish what you are talking about.

I think you could do it to a degree, but I don't think you could do it in proportion to your pressure increase, that's the problem.

Q Do you mean to say that you might not have the physical facilities at the surface to inject this additional water, that is the reason you might not be able to do it?

A That is one factor. The other factor seems to be inherent in the reservoir itself.

Q We could take care of the injection at the surface?

A If you put in the equipment to do it, I think it could be done, up to a breakthrough pressure, we're always assuming that in our discussions, I think.

Q What is the condition in the reservoir which might prevent or prohibit you from increasing injection rates from eighty barrels to two hundred barrels?

A It seems to be part of the question I can't answer. I don't know what it is, and I wish I knew. It may be associated with some of the losses that we spoke about, but I am not sure.

Q If the reservoir is taking the water at eighty barrel it could certainly take it at a somewhat increased pressure and increased rate, could it not?

A To some degree, but not -- it couldn't make it up, the point, to where you would have a comparable case here, that is the whole problem.

Q You have assumed the same reservoir in these two examples, have you not?

A Yes.

Q You have assumed that the reservoir would take the water at a four hundred barrel injection rate in the four hundred barrel case, have you not?

A I sure have.

Q Is there anything about the reservoir -- assuming that you started out at the four hundred barrel rate, that it would have taken it, which is your assumption?

A Yes.

Q Is there anything about the reservoir that would keep you from increasing the injection rate from eighty barrels up to four hundred barrels at some point during rhe course of the flood?

A Yes, there is something about the reservoir, and that is the part I don't understand.

Q Do you have any examples where that has been tried, not exactly with those same figures, but a parallel situation where it has been tried and the reservoir wouldn't take the additional injection?

A I have examples, I didn't bring anything like that with me. I do have some examples that I can show that, yes.

Q Where the reservoir simply wouldn't take the additional water?

A It does not take the additional water in proportion to your increase in pressure. In other words, you have a point here that, for a given bottom hole pressure, according to Darcy's law, we all know that the injection rate should be in proportion to that particular pressure imposed upon it, but I have cases where it doesn't do that in a water flood operation, where you try to increase injection rates later in the operation.

Q Are there any published examples of that type of phenomena in the literature that has been written in connection with the various committees that you have served on?

A I don't know that that has ever been presented in just that way. I think it can be derived from material that has been published. I am not prepared to go into that without doing some work on it or thinking about it.

Q You don't offhand --

A (Interrupting) I can't offhand point you to a place where that can be shown, no.

Q Mr. Buckwalter, in your testimony this morning I believe you stated that there were certain conditions under which you could not recommend or would not recommend that an operator enter into a water flood project at a low rate, and that was based on the economics of the picture, economics of the situation?

A It was.

Q Could you please, -- and I believe you further said that it was a question of just not an adequate rate of return, is what it would amount to?

A That's right.

Q Just would not get enough return on the investment?

A That's right.

Q Could you tell us, please, what criteria you would use for determining what the rate of return is at which an operator, you couldn't recommend or would not recommend that he go into a project? What is that point and how do you determine it?

A My various measures of profitably, I think is the term used, and I know that each case it may be a little different consideration, depending upon the individual operator and his financial structure, tax structure, situation of the individual operator, but I would say the rate of return on a cash flow basis, I think has been referred to in the literature as one measure; there is a pay-out time is another measure; there are other methods which have been used, and I have looked at a number of propositions of water flood on various yardsticks for measuring profitably.

Q Do you have a percentage figure to give, or one which, you say you would not recommend that they go into it under certain conditions -- what is your criteria of that?

A I would certainly say if you were in a position where you can no more than return the amount that you have invested without loss, it would certainly be foolish to go into the investment. We all know that there are various types of investments open to various operators. Some of them have good openings they can make, they are going to choose between two investments. Others may have a narrow range of investments.

I don't think you can narrow it on that point at all. It depends on the situation at hand. I felt in this case here that if you got half as much oil, that certainly on my calculations at the slow rate that I don't believe anybody would like to venture into the water flood in this particular case.

Q In your Exhibit 4 you show pay out in one year on the fast rate flood, and in two years on the normal rate of flood. That is correct, is it not?

A Approximately so, yes.

Q You mean to indicate, or would you set it up as your criterion, that unless a water flood project would pay out in two years that it should not be entered into?

A No, sir, I wouldn't take that as a criterion, not that alone, I'm certain. It may be of distinct importance to certain people at certain times as to how fast their capital is returned. That wouldn't be true of all our clients or all the oil producers.

Q Do you have any percentage rate of return or figure on pay out which you think would be reasonable or reasonably accepted by the industry?

A Rate of return on pay out?

Q There were two questions, eigher phrased in terms of a rate of return percentage or in terms of pay out in years, any way you would like to present it?

A I believe that on the basis -- by George, that varies from operators to operators. What is good for one might be bad for another. I would say generally on rate of return a ten percent rate of return isn't bad. I wouldn't like to have my feet held to the fire by everybody for that figure.

Q Mr. Buckwalter, have you calculated what the rate of return on this particular project at the four hundred barrel rate would be, and what it would be at the eighty barrel rate?

A No, I didn't calculate that specifically.

Q You have not calculated it?

A Not specifically, no.

Q In your opinion, in connection with this particular project under consideration here, what would be an acceptable rate of return on this project, in order for you to be able to recommend it?

A In this particular case, if I had to choose a rate of return, well, for whom, you mean for Graridge Corporation?

Q Well, as a consultant advising Graridge Corporation, yes, and one which you think would be reasonable in the industry.

A Well, I don't think that ten per cent is too bad in this case.

Q I recognize that you testified a moment ago that it was your belief that in certain cases, at lease, that the injection rate could not be increased from eighty up to four hundred barrels to one hundred sixty barrels as the oil production began to fall off, that there was something in the reservoir, you didn't know actually what it was, but there was something in the reservoir that prevented you from doing that in certain cases; but now, make the assumption for me for a moment that you could increase the injection rate after the project was started and after you ran along in a year or two at eighty barrels, you decided that you wanted to increase it so as to maintain your oil production somewhere around the fifty-seven barrel level. If you did that, it would follow, would it not, from your own exhibits here, that the same amount of oil would be recovered, assuming that you were able to increase the injection rate --

A (Interrupting) No.

Q -- as would be recovered in the four hundred barrel case?

A No, I don't believe so.

Q From an economic standpoint, I'm talking about, leaving out your belief about the waste.

A I believe you would still have this problem, because you would not be injecting through the entire life of the operation at the high rate. You are losing the benefit of your injection and production in the early part of the operation before you have increased your pressure on your rate, and according to your hypothetical example, so I don't believe that you would come out with the same recovery on an economic basis.

Q What you are saying is that you simply make a greater rate of return and make more money at the high rate of injection, high rate of production, but assuming the same displacement efficiency which you have assumed in your exhibit and assuming further that you could increase your injection rate from eighty barrels on up as the case required, then while you might make more money in the four hundred barrel injection case, you would still recover the same amount of oil, whether you injected at four hundred barrels per day all along, or whether you started at eighty and then increased it, would you not?

A No, I don't think so. As long as we talk about economic limit, I think economic limit comes into this picture here, and therefore I don't believe that that case would hold.

Q Even if you increased your injection rate to four hundred barrels of water per day, you will would not reach the same amount of production at the same water-oil ratio that you did in the four hundred barrel case, is that what you are saying?

A I think it is the same water-oil ratio. I don't want to be misunderstood in that connection, but I do believe that is not the same as the economic limit.

Q Now then, Mr. Buckwalter, in connection with your Exhibit No. 6, which is your Bradford Field exhibit, isn't it true, Mr. Buckwalter, that voluntary proration of the Bradford water flood was instituted sometime around 1935 or '36?

A For a short period of time.

Q How long did that proration continue?

A I think a matter of months, a few months.

Q There has been no proration, voluntary or otherwise, of the Bradford Field flood since that time, is that true?

A Not to my knowledge.

Q Now the Bradford Field, at least during this water flooding period in the field, has served to furnish some roughly ninety percent of the market demand for oil in Pennsylvania, has it not?

A I think that Exhibit 6 will show that during a specific period of time, yes.

Q If the Bradford Field had been permitted to produce unrestricted and, as you say, perhaps it was for a period of a few months, if that is the situation and if you had had a substantial amount of additional production in Pennsylvania other than the Bradford Field production, then your peak or what would have been required by way of market demand in Pennsylvania would have been substantially higher in the 1945 period than is shown by your chart, would it not?

A Certainly the peak for Pennsylvania would have been higher, but I have shown the Bradford peak here under water flooding related to Bradford peak here under the primary. I certainly agree with you that if water flood had been practiced in other parts of the State at the same time as in the Bradford Field, that this total Pennsylvanian curve could have been substantially higher.

Q Or if there had been substantial quantities of primary production in Pennsylvania at that time, you would have a much higher peak, would you not?

A Sure, that is true.

Q Thus, in order for the Bradford Field to produce without proration on its water flood, and in order for additional Pennsylvania production, if there had been any, to reach the market, it would have been necessary to have a substantially greater market demand in Pennsylvania than actually existed at that time?

A Gee, I don't know. I think from 1937 to 1948, in that particular period, why, we had a good demand for Pennsylvania grade crude, and that we couldn't supply what we could really use.

Q Now the situation in Pennsylvania at that period and the situation in New Mexico today are quite different, are they not?

A I would say in that connection they sure aren't.

Q In other words, at present, water flood production represents a very small production of the State's production in this State?

A I believe it does, yes.

Q There is a very substantial quantity of flush or primary production in New Mexico today, is there not?

A I think there is nice production in New Mexico, yes.

Q New fields are being discovered from time to time in New Mexico, bringing in new and additional primary production, too?

A That's true.

Q In that regard, the situation is vastly different in New Mexico today from what it was in Pennsylvania during the period portrayed by your chart there?

A In percentage-wise, yes, although I would like to say that a new field was discovered in Pennsylvania there around 1937.

Q In the period from 1915 to 1925, your Bradford Field production accounter for perhaps a third to a half of your total State production, did it not?

A Yes, that's correct.

Q And then when the water flood went into effect, that Bradford Field production increased some three or four fold, perhaps four or five fold?

A That's correct, with time and development.

Q If production from the Caprock Queen Field were to increase some four or five or six fold at this time, and considering that there is a substantial amount of prorated primary production in New Mexico, would that not have an effect on that primary prorated production if the Caprock Queen Field acted like the Bradford Field?

A I don't think -- I think that would be up to others to decide, than myself, as to what effect that would have on the picture. I do believe that your figure there of five or six times increase for the Caprock Field is too high a figure for me to imagine, but if I take your premise that if it would happen, that it be four or five or six times in the Caprock Field, that it would have a very definite effect on the State's production. No question about that in my mind.

Q I believe it was Exhibit 7 that was your colored map that shows the various stages of depletion of the tracts of this field, is that 7? I believe it was.

A Yes.

Q On one of your exhibits you assumed it would take three years to develop the northern third of the field by water flood, six thousand seven hundred twenty acres, I believe?

A I calculated development at that rate, yes.

Q There's a substantial amount of red acreage or stripper acreage in other parts of the field, too, is there not?

A There are some spotty areas, yes, throughout the field of stripper production.

Q The assumption on that graph dealing with the six thousand seven hundred twenty acres, I suppose, was that you would not get any water flood development anywhere except in that portion of the field?

A Oh, I don't think I assumed that. I just chose the six thousand seven hundred twenty acres as an example of what would happen, which I talked about in the northern part of the field. I didn't mean to make any further assumptions that would have any bearing on the rest of it.

Q It is perfectly reasonable that the water flooding may not be restricted in the next three years to the top one-third of the field, but may extend to some of the red tracts scattered throughout the rest of the field, and to other tracts that may become red within the next three years?

A I think that is right, but my calculation was based on a constant development rate up to the six thousand seven hundred twenty acres, and I don't think it matters for this particular question just where that six thousand seven hundred twenty acres might be located.

Q Now then, if capacity water flooding, unlimited allowables were granted to water floods in this field, it would be reasonable, would it not, to grant that privilege or that allowable to other tracts in the field, other than just to the northern one-third of the field? In other words, if it were to be adopted for the northern one-third of the field, it would be reasonable for it to be adopted elsewhere in the field?

A I think that is entirely up to others than myself to decide. I think that would be up to the Conservation Commission to decide.

Q There's no reason, is there, for making a distinction between a red tract in the north end of the field and a red tract in the south end or the center part of the field?

A No, they're all red, that's right.

Q You wouldn't recommend that the tracts be treated differently from a proration point of view, would you, just because some fall in the top part of the field and some in the center and some in the south?

A No, I don't think I would make that recommendation.

Q Now, if capacity or unlimited water floods were started on some of the red leases which offset leases of another color, that is to say, where you have some substantial primary production left, would you recommend to the Commission that it prorate the wells on the offsetting leases, the leases offsetting those in which the floods were being conducted?

A I think each case would have to be worked out on its own merits at the time that that particular case would come up. I think that if water flooding is granted in a situation where you have this stripper areas and higher productivity areas adjacent to it, that that problem would have to be faced and solved. I don't think that we could generalize on that at this point of the situation.

Q Well, if you granted your unlimited water flood allowables to those areas down in the central part of the field where water floods were started, but prorated the areas adjacent to them which were still in primary stage of depletion, you would have a certain amount of disruption of correlative rights, would you not?

A I believe you could have, yes, sir. I believe you could have.

Q Isn't that a serious problem to be considered in connection with this overall problem of water flood rates?

A I think it is a problem to be faced in a situation like the Caprock Field, yes, sir, I sure do.

Q Actually, in effect, it is being faced any time unlimited water floods are adopted in any part of a field, you are virtually facing that problem elsewhere in the field immediately, aren't you, as a practical matter?

A It depends somewhat what you mean by "immediately". I think there is a time there until you would face it in certain areas, and you must also, I think, recall with me that you would have declining production in some parts of the field while you would be in the process of developing other parts, so I don't think that you could come to an definite conclusion about what that picture would look like at some time in the future without a lot of decline curve work and other studies that might be made.

Q Your Exhibit 9, where you showed a prospective peak for production from the Caprock Queen Field, is based on an assumption of what length of time for development?

A Well, about eight years in the case of the high rate, and about thirteen years in the case of the low injection rate.

Q If you had used, instead of using the eight years, if you had used the five-year figure which you used in connection with your other exhibits, you would have shown a substantially higher peak rate of production under your high rate water flooding, would you not?

A I think maybe I must have misunderstood your former question. I think that actually the assumption that I have made here is that we would have twenty-two hundred forty acres per year developed at a constant rate in each case. Now twenty-two hundred forty acres per year for three years would be sixty-seven hundred and twenty; for twenty-two hundred and forty, that is not what I stated. The development rate there is considerably slower than I stated in my former question. I misunderstood it.

Q Now, on one of your exhibits you stated that you felt that five years was a fast period of time for this entire field to be placed under water flood?

A I sure did.

Q Now, if that rate of time were used instead of the rate of time that you used here of twenty-two hundred forty acres, or some eight years, you would have had a substantially higher peak for the Caprock Queen production, wouldn't you?

A Yes, I believe you would.

Q In other words, the unlimited allowables from the Caprock Queen Field, based on water flooding, would be taking up the larger proportion of the State's market demand, if you assumed a five-year development for the field instead of an eight year development for the field?

A I think my other exhibit worked it out for five years, and so I think that speaks for itself.

Q On your Exhibit 10 you showed the estimated peak of water flood production for the Caprock Queen Field. I believe you gave a figure of a little over eighteen thousand barrels --

A Nineteen thousand.

Q Nineteen thousand barrels?

A Yes.

Q That is water flood production alone, is it not?

A That is correct.

Q Under the assumption that you have made about the length of time it would take to put this whole field under flood, you would also have some primary production at the same time, would you not?

A I think I said that this morning, yes, sir.

Q Which would substantially further increase your total outlet from this field or total production from this field, above the peak of the water flood curve at nineteen thousand barrels?

A Well, I don't know what that "substantially", how do you define "substantially"? In my thinking, I don't believe it would be too terrific.

Q It would do this, wouldn't it, it would add the primary production to the water flood production?

A That would be the primary production at that time. That would be in nineteen -- the end of 1962, which would be five years from now, and five years from now I believe that the primary production will be at a considerably lower level than it is at the present, of course.

Q If this field were unitized in whole or in part, that would substantially speed up the peaks, would it not?

A Well, I would say that it is conceivable it could, if it were unitized in large areas, it could do that after it is unitized. My experience has been that it takes a little time to get these things unitized.

Q The flooding wouldn't presumably be going on before it was unitized?

A No, that is true.

Q So once it is unitized the flooding would commence simultaneously, so that instead of spreading out your rate of development over some eight years, you might condense it into one year?

A I don't believe that that could be done. That's too fast.

Q Now, referring to your last exhibit, Mr. Buckwalter, which was the exhibit relating to the South Ward Field, the ten floods that you haveconsidered there, were there differences in sand thickness between the flooded properties?

A Yes, sir.

Q What is the range of differences in sand thicknesses between the flooded properties, if you know?

A Well, I don't remember exactly.

Q Well, just approximately.

A I'll make a guess. I would say somewhere in the order of say, eighteen to twenty-seven feet, something like that, I mean just from memory.

Q Would there be, is it reasonable in your opinion to compare the recoveries from a tract having eighteen feet of sand with one having twenty-seven feet of sand?

A Unless you take other things into consideration, I think it would be reasonable.

Q Have you taken that into consideration in connection with this exhibit?

A In connection with this exhibit, I did not take it into consideration except in this way, I have made a comparison between what these tracts have actually produced, regardless of the footage under primary was and what they produced under secondary.

Q Now, it is true, is it not, that there is a gas cap in connection with some of the properties that you considered here and no gas cap in others?

A Well, the more I look into the gas cap and have looked into it, I would say that the more I see of gas cap conditions in this field; I wouldn't say that you could completely eliminate it in any one spot or any one property.

Q In your opinion, do you have the same amount of gas cap on each one of these tracts?

A No.

Q The same amount of gas saturated acre foot?

A No, I don't think you do.

Q You wouldn't expect to get oil recovery on either primary or water flood on acreage saturated with gas, would you?

A No, I wouldn't.

Q Have you considered in making this exhibit the dates at which primary production was commenced on various tracts in the field?

A No, I took the primary production for the total life of the primary in that particular property, regardless of when the property was developed.

Q If primary had started on one of your tracts a substantial length of time before it started from other tracts, that would make a considerable difference, would it not?

A Oh, I think there could be some difference there. I'm not too sure it would be tremendous or be even too significant.

Q You have not taken that factor into consideration?

A No, I have not taken that factor into consideration.

Q Have you made a study to determine whether or not there's been any migration from one of these flooded tracts to another, either during the primary stage or during the stage of water flooding?

A I did look into that under particularly the water flooding stage of the operations. I did conclude that there is movement of fluids from some of these properties to other properties, and I did conclude, however, that for the most part that movement is through this gas sand and the movement is water rather than oil.

Q Now, if you have had movement from one tract to another, that would make a difference in your expected recoveries from that tract and your actual recoveries from it under water flooding, irregardless of rate?

A It could make a difference if that were a large volume, it sure could.

Q Mr. Buckwalter, you mentioned earlier that part of your belief that high rate water flooding prevented physical waste was due to an examination that you had made of a number of cores that were taken in the Bradford Field after flooding operations had been completed, is that correct?

A Yes, though I don't think I ever said that the water flooding at any rate would completely prevent some waste. I believe that there are losses, some losses, at any rate that we achieved in the field.

Q But I believe you used these cores as part of your basis for believing that high rates were more effective than low rates, is that correct?

A Yes, I did say that.

Q Do you have the data or any tabulation in connection with these cores or has any information been published with respect to them, to show why you concluded from your study of these cores that a high rate water flooding is more desirable than low rate water flooding?

A I think that some material has been published in that connection, yes. As I recall, in approximately 1950, I believe a paper was published by Mr. Harry Ryder in which he presented data on the results of core wells subsequent to water flooding in the Bradford Field.

Q What did that data show which indicates to you that high rate flooding is more desirable than low rate flooding?

A Well, as I recall, the reduction in oil saturation was the principal point made, that where you have higher rates of water movement through Bradford sands in that area, the lower residual saturation resulting from those high rates, I thought was evident from the core material.

Q Now, if you reached the conclusion that high rate flooding will yield a greater ultimate recovery than would low rate flooding, can you explain how you isolate the rate effect, how you isolate the factors by which you determine that that is true?

A I'm sorry, we are going to have to go over that one again.

Q As I understand it, you reached the conclusion that by flooding through fast injection and fast production, you get more oil out of the sand than you do by low injection and low production. What I am asking you is how do you isolate the factors from which you reach that conclusion, and what are the factors from which you reach that conclusion?

A Well, I have a tough problem there, and I think I stated previously that I am in trouble on that particular problem. There are so many different factors that it is difficult to isolate them, and the saturation relationship we talked about just a minute ago is an indication, and I think it has to be taken that way.

MR. McGINNIS: Thank you. I believe that's all the questions I have, thank you.

MR. PORTER: Mr. McGowan.

MR. McGOWAN: I have just a few questions I would like to ask.

By MR. McGOWAN:

Q Mr. Buckwalter, when you were talking about the peak of water flood production in connection with your exhibit 10, you need not turn to it, your peak was reached, I believe, at the time that the entire field was developed, is that correct?

A In -- oh, I'm sorry, I am thinking about 11.

Q We were talking about your peak, the top peak is around 1961, 1962, that is when the entire field would be developed on that exhibit?

A That is correct.

Q There would be no primary oil production at that time, would there, except insofar as it might be a part of the water flood oil, because if your whole field is developed as a secondary recovery project, there would be no primary production left?

A Of course, the way I have arrived at the secondary recovery peak there, I have not considered the remaining primary that might be above stripper stages.

Q If the entire field is under water flood, all the oil would be water flood?

A I think technically you are right, it would be water flood. I suppose you would have to call it that.

Q In connection with Exhibit 9, we were talking about correlative rights, that is,the problem that it -- I think you stated that the Commission always has, the Commission has to approve particular acreage for water flood operation before it can be water flooded, does it not?

A That's correct, yes, I think it does.

Q I do wish you would turn to Exhibit No. 2 for just a moment. Now in your response to questions by Mr. McGinnis concerning the amount of fluid injected and the amount of fluid produced at any given time on either of those rates, with particular attention to the four hundred barrel per day rate, you said that the peak production was fifty-six thousand one hundred barrels. Now, that was on a yearly average, as I understood you?

A That's correct.

Q That is one hundred fifty-three barrels per day?

A On that average.

Q For a year's average?

A Yes.

Q Would not your particular peak on the highest day in that year be much higher than the one hundred fifty-three barrels a day?

A It certainly would.

Q Would not your produced fluid level be the peak of the highest day's production, rather than the yearly average of fifty-six thousand one hundred?

A It certainly would.

Q Then that would reduce considerably, if not almost eliminate, the water for which you made no accounting in response to Mr. McGinnis's question, is that not correct?

A That's correct.

Q Now, in connection with the economics that you have on your Exhibits 4 and 5, you need not turn to them, they essentially express the same things in different manner. Now I gathered from your testimony that you are of the opinion that a high rate of injection as opposed to a low rate of injection, using the terms relatively, will recover a greater amount of oil from the same reservoir space than will the low rate?

A Yes, sir.

Q However, in making your comparisons of recoveries against your four hundred barrel a day injection to your eighty barrel injection, for the purpose of that example alone, I understand that you assumed that the efficiency per injected well of water would be the same in recovery, is that correct?

A That's correct. That's correct.

Q And even under that assumption, as I read your exhibit, you would leave about five hundred thousand barrels of oil in the ground on the eighty barrel injection rate that would be recovered on the four hundred barrel injection rate?

A That's correct.

Q That would mean, then, some sixty-one thousand dollars less money paid the State of New Mexico on gross production tax, wouldn't it?

A I hadn't calculated that.

Q That is the difference in the two figures on your Exhibit

4. It would also mean approximately three times less that was paid the State of New Mexico in royalties, since they are the proper royalty owners?

A I suppose so.

Q If we drop the assumption that you made for the purpose of this exhibit and went to your stated opinion that the efficiency of recovery per barrel of injected water is not as great on the low rate as the high rate, then the amount of oil wasted would be increased, would it not?

A Yes, sir.

Q The amount of money in taxes to the State and royalty to the State, in money to the operator, and all other phases of the operation would be increased proportionately, would it not?

A Yes, sir.

MR. McGOWAN: Thank you. That's all I have.

MR. PORTER: Anyone else have a question? Mr. Cooley.

By MR. COOLEY:

Q In response to a question a short while ago concerning the problem of correlative rights with respect to one area in Caprock Queen Pool being water flooded while an adjacent area is not being water flooded, I believe you answered there was a possibility of violation of correlative rights. I would like to ask you whose correlative rights? Is there a possibility, even the remotest possibility, assuming that you have a tract of land adjacent to mine, that you are injecting water on yours and I'm not on mine, that you could withdraw any oil from my land through your producing well?

A I don't think you could, no.

MR. COOLEY: Thank you very much. That's all I have.

MR. PORTER: Anyone else have a question of Mr. Buckwalter? The witness may be excused.

(Witness excused.)

MR. PORTER: Call your next witness.

MR. CAMPBELL: Call Mr. Stiles. If the Commission please, this witness hasn't been sworn.

(Witness sworn.)

W. E. STILES

a witness, of lawful age, having been first duly sworn on oath, testified as follows:

DIRECT EXAMINATION

By MR. CAMPBELL:

Q Will you state your name, please?

A W. E. Stiles.

MR. PORTER: How do you spell that Stiles, please?

A S-t-i-l-e-s.

Q Where do you live, Mr. Stiles?

A Tulsa, Oklahoma.

Q By whom are you employed?

A Buffalo Oil Company.

Q In what capacity?

A Vice president in charge of production and engineering.

Q How long have you been with the Buffalo Oil Company?

A Six years.

Q Is Buffalo Oil Company engaged in any water flood projects, Mr. Stiles?

A Yes, we have interest in ten water flood projects in four States, and we operate seven of those projects.

Q Would you give the Commission a brief statement of your educational and professional background, Mr. Stiles?

A I am a petroleum engineering graduate, Texas A. & M., and during about the first four years of my business experience after college, I engaged in well testing work. The next eight years I was with Core Laboratories, Inc., in various capacities, most of which dealt with reservoir engineering, and principally with secondary recovery engineering; and for the last six years I have been with Buffalo Oil Company.

Q During the time that you have been with Buffalo Oil Company, have you had occasion to observe the operation of a waterflood which your company was interested in?

A Yes, sir, directly.

Q And have you had occasion to observe the operations and histories of water floods in which other companies were engaged in the areas in which you have worked?

A Yes, yes, in many of them.

Q Now, based upon your experience both in the work you did with Core Laboratories and your experience in the field with Buffalo Oil Company, in the field of secondary recovery, have you formed an opinion as to the relationship between the rate of injection or rate of production in water flood projects and the ultimate recovery of oil from those projects?

A Yes, I believe all the data I have seen of successful floods were floods in which the water was injected at a high rate. Many of the unsuccessful floods that I have examined have been floods in which the injection rate was low for one or more reasons.

Q Does your company, in the areas in which you operate water floods, follow that procedure in their operations?

A Yes, we inject as fast as possible in all of our floods in order to gain more recovery.

Q And is it your opinion that that results in a greater ultimate recovery of oil?

A Very definitely.

Q In connection with your operation of water floods in the State of Oklahoma, Mr. Stiles, have you had occasion to examine any records with regard to the possible effect of unrestricted water flood allowables in that State upon the general market picture in Oklahoma?

A Yes. In the State of Oklahoma, each water flood operator is required monthly to submit an affidavit type of report on each of his water flood projects, which report sets forth the number of injection wells, the number of producing wells, and the average daily rate of oil production, the average daily rate of water production, and average daily rate of water injection.

Early this year we asked the Oklahoma Corporation Commission to make a tabulation of one month's reporting of such information, and I have here a tabulation made by the Oklahoma Corporation Commission of all, I presume all of the flood projects in the State.

There are four hundred forty-nine projects reported in this tabulation by two hundred and nine different operators. There are fifteen thousand four hundred and fifty-six oil wells, and ten thousand and ninety-five input wells recorded in this tabulation.

Furthermore, the tabulation shows the amount of secondary oil production by months in the State, for the months of July, 1956, through January, 1957. The average monthly water flood production for that seven months period of time is a hundred and thirteen thousand two hundred and ninety-one barrels of water flood oil. During this seven months period, the State's allowable varied somewhat each month, but generally it was in the range of about six hundred twenty-five thousand barrels per day, so that the water flood production in the State averaged, over the seven months period of time,represented about eighteen percent of the State's total daily production.

The total amount of water flood oil produced per month, or per day, excuse me, when divided by the total number of producing wells shown in this tabulation, gives an average daily production rate per producing well of only 8.26 barrels. Now if we add into the number of producing wells the number of input wells, then the water flood production in the State averages only five barrels per day per well, counting both producing and input wells.

Now, of all these projects tabulated, there's quite a number of them that show no input wells, so that obviously something is wrong with those projects. There are also projects which show only one input well on the entire project. I surmise that that one input well project is truly a salt water disposal project and not a water flood project, because some of the operators in Oklahoma are prone to obtain a water flooding permit when really they want to dispose of salt water.

I have knocked out all the projects, which have less than two input wells. On the remaining projects, there are thirty-six in which the oil wells are averaging more than twenty-five barrels per day per well. I use the twenty-five barrels because that usually is the minimum allowable for any well in the State of Oklahoma, and I'm trying to show here that there are, that in these thirty-six projects in which the producing wells are averaging more than twenty-five barrels per well per day, there is a total production from these projects in excess of twenty-five barrels allowable of only twelve thousand one hundred and sixty-one barrels per day.

In effect, what I am saying, if you regulated a water flood in the State of Oklahoma to only twenty-five barrels per day per producing well, you would knock off only twelve thousand one hundred and sixty-one barrels a day of water flood production in the entire State, and that represents about 1.9 percent of the total State's production.

Now the highest producing water flood reported in this tabulation is one owned by Gulf Oil Company, in which they have nine input wells and fifteen producing wells. That water flood was producing during April of 1957 78.9 barrels per day per producing well. That is the highest producing water flood reported in this on a per well basis, reported in this tabulation. Now if you add in the nine inputs along with the fifteen producers, then per well you are producing fifty-four barrels per day, so in my opinion this tabulation indicates first, in the State of Oklahoma there is no need for proration, and that if you prorated wells that you still wouldn't reduce the amount of waterflood production in the State.

Q In other words, is it your opinion that the impact of secondary oil or water flood oil in the State of Oklahoma is negligible insofar as the State's market picture is concerned?

A Right.

Q Has Oklahoma been engaged in water flood operations, secondary recovery operations, for a number of years?

A Many years.

Q You consider in Oklahoma there are a substantial number of water flood projects in operation as compared to other States?

A I would say more than any other State.

Q Now, have you had any experience with regard to any particular field in Oklahoma which has, or pool which has reached a decline stage in water flood production, which would indicate the relationship of the impact of water flood production as related to primary production?

A Yes. Buffalo Oil Company owns and operates the Olympic Pool in Oklahoma, and the primary and the secondary production peaks of the Oklahoma Pool is shown on this exhibit.

(Applicant's Exhibit No. 12 marked for identification.)

Q I will refer you, for the record here, to what has been identified as Applicant's Exhibit No. 12, and ask you to go ahead and state what that is and explain it, please.

A There are about thirty-two hundred acres, thirty-two hundred acres developed for water flooding in the pool. The pool was discovered about nineteen -- early 1935, and it reached its peak of primary production in 1937, and what I have plotted here is the average daily rate of production during the peak year of 1937, and that average daily rate is about eleven thousand four hundred fifty barrels, roughly. During that year, the average number of producing wells in the field, and this is during the time we had no curtailment of production at all, the average number of producing wells during the 1937 year period was two hundred and ten wells, so that we have an average production per well per day of fifty-seven barrels, during the peak primary year.

The field was started under a pilot water flood in late 1948, and we expanded out of that pilot flood on about the first of 1950. Olympic was developed about as fast as any water flood has ever or will ever be developed. The field was originally drilled for ten-acre spacing, and two-thirds of the field was developed on water flooding on ten-acre five-spot basis which required that we drill all new input wells in field-type wells, and most of the time we had about three rigs busy drilling the input wells, and each rig completed a well in six or seven days, so that is pretty fast development.

Also, in Olympic we set our injection at one well per day per acre foot, and tried to hold it as close to that as possible, and the field has always been operated as close to one barrel per day per foot as natural factors would let us operate.

The secondary peak of production was reached in 1953, and we have produced about eleven thousand two hundred barrels a day on the average, during that year. That's strictly water flood oil. During that time we had under development an average of two hundred and sixteen producing wells that were within the developed area, and being subjected to water injection. Those two hundred and sixteen producers averaged during the year fifty-two barrels per day per well, which is about five barrels per day per well less than primary peak. Now if we add in, into the two hundred sixteen producing wells, the two hundred and sixteen input wells that we had also drilled and had in operation, then the average production per well including both input and producers was only twenty-six barrels per day per well. This in a water flood which was developed as fast as almost humanly possible, and in which the injection was maintained at a high rate, what we consider in this hearing as a high rate.

Q Now, what conclusion does that lead you to, with regard to the impact of that particular water flood project on the market situation in the State of Oklahoma?

A I don't think it had much of an impact on the total State's production. At least, when you look at it from a per well per day basis.

Q During the time the Olympic Pool was at its depth there in 1950, I assume there were other water flood projects in the State of Oklahoma that were perhaps at their peak, is that correct?

A Oh, yes, no doubt.

Q Would that tend to level out the impact of any particular water flood effort at a particular time?

A Yes, sir, yes, sir.

Q Now, your company does not operate any secondary recovery projects in the State of New Mexico, does it?

A Not at the moment, no. We have a vital interest in it, in that we are owners of many leases in the Maljamar and other fields, too.

Q You are engaged in production in the State of New Mexico?

A Very definitely. This Commission has recently given to us and other operators in New Mexico a pilot water flood permit.

Q Based upon your operations in New Mexico and your knowledge of the potential water flood areas in the State of New Mexico, do you anticipate there will be any marked difference between the effect of a secondary or water flood production in New Mexico than you experienced in the State of Oklahoma as secondary recovery developed there?

A No, I don't think so. I think secondary development in the State of New Mexico will probably go along about the same pace it is in Oklahoma, for instance, wherein it hasn't drastically affected the State's allowable, State's market.

MR. CAMPBELL: I believe that's all.

MR. PORTER: Mr. McGinnis.

CROSS EXAMINATION

By MR. McGINNIS:

Q Mr. Stiles, I believe you said you thought the progress of water flood in New Mexico would be similar to that in Oklahoma, and there are a good many more water floods in Oklahoma at the present time than there are in New Mexico, are there not?

A Correct, definitely.

Q I believe you said the biggest producing flood in Oklahoma today, from the point of view of production per well, per producing well, was a Gulf project in which there were nine producing wells, making an average of 78.9 barrels per producing well?

A That's right. I said according to this tabulation.

Q Yes, according to this tabulation you have there. Now, Mr. Stiles, you heard, I presume, the testimony of and the exhibits of Mr. Buckwalter here today?

A Yes, sir.

Q He's presented, and you heard him state, I believe, that he would have, in this project out here, an average of a hundred and fifty-three barrels per well per day at the peak?

A Yes.

Q And then on some cross examination by the attorney with Sinclair, it was developed the production rate might even go higher at the peak day than a hundred fifty-three barrels, which was the average for the peak year?

A Right.

Q Well, now, do you agree with the calculations that Mr. Buckwalter has made here, that a hundred fifty-three barrels will probably be the producing rate in this New Mexico flood?

A Mr. McGinnis, I don't recall that he made any actual calculations. I did not testify to that to start with, and I don't know I am qualified to answer that question.

Q Well, you saw the exhibit?

A Yes, sir.

Q That he had made or he was testifying from, and it was his statement that those were his estimates of what would happen at a four hundred barrel rate which he was recommending for this field, that it would reach a hundred fifty-three barrels as an average for a peak year, and substantially over a hundred fifty-three at the peak rate?

A I have seen no data on the same conditions in the Caprock Field. There's no calculations of my own.

Q On this same point, if Mr. Buckwalter's estimates of production for this particular Caprock Queen flood be correct, then right out of the box, the very first thing, New Mexico is going to have a flood that's producing substantially more than, and in fact just about double what the biggest flood in Oklahoma is producing per well, isn't that true from these figures, 78.9 barrels for your biggest Oklahoma flood, one hundred fifty-three barrels for New Mexico floods?

A Yes.

Q What is the basis, then, in view of this evidence, that you think the condition is going to be the same here in New Mexico that they are in Oklahoma?

A Conditions, you mean the effect upon State's allowable?

Q Yes, sir.

A How many barrels per day is this flood you are talking about going to produce, total barrels? One well at a hundred fifty-three barrels per day is not going to hurt anyone.

Q Mr. Stiles, I believe there's testimony there's six hundred -- excuse me, six thousand some-odd acres in one-third of this field.

That would mean about 18,000 acres in the field as a whole, and I believe some six hundred seventeen wells in the field.

A Yes.

Q Now, I can't answer you that question. He estimated five years, but he said if it was unitized it might be faster than that?

A As I recall, he was talking about a typical eighty-acre five-spot, wherein we would hit a hundred fifty-three barrels per day maybe, maybe get up to three hundred on some of them. All of these five-spots under development don't hit that peak estimate because you can't develop all these five-spots at the same time; so these peaks are going to be staggered out over a several years period of time, not all cumulative.

Q Now, you have had considerable experience in water flooding, have you not, sir?

A Well, I have had some, yes, sir.

Q Now, you have heard Mr. Buckwalter testify that he thought there were certain conditions in some reservoirs, at least, which would prevent increasing an injection rate from eighty barrels up to four hundred barrels, even though in that same reservoir you might have started out at four hundred barrels injection rate. Do you agree with his opinion on that?

A Yes, to a degree I will have to agree with that.

Q What is your reason for believing that from a scientific point of view, that that is true?

A I can't tell you from a scientific point of view, Mr.

McGinnis, I can tell you from experience, though, it does happen.

Q Do you know of fields which you could have flooded, for instance, at a four hundred barrel injection rate to begin with, but you could not start out at a lower rate and increase it to the higher rate?

MR. ERREBO: If it please the Commission, it seems to me this line of testimony is going far beyond the direct testimony offered by this witness, and we'll object to it.

MR. HINKLE: I would like to ask if Mr. Campbell is objecting?

MR. CAMPBELL: Sure, I join in the objection.

MR. HINKLE: If the Commission please, in order to save time, we are willing to withdraw the question.

MR. CAMPBELL: I believe the question was answered anyway.

Q Mr. Stiles, on your direct examination, did you express an opinion as to whether the low rate flooding would not recover as much oil as the high rate flooding? Did you express an opinion on that in your testimony?

A I think I expressed an opinion; high rate flood would produce more oil than low rate, yes.

Q Would you please state why this is true, in your opinion?

A Again based upon experience -- excuse me for interrupting -- based on experience.

Q Is there anything other than experience that causes you to have this belief?

A No, sir, I'll have to say it's almost entirely experience, because all the laboratory and theoretical data I see is sometimes in conflict; I can't always add them together and come up with the right answer.

Q What has your experience been that led you to believe that high rate flooding will recover more oil, what specific experience have you had that leads you to that belief?

A Within our own company, we have had no experience with low rate floods because we have never operated a low rate flood. The experience I have with the low recoveries in the low rate flood is based upon other people's results, data that I have seen over the years.

Q You had nothing to do with the operation of those particular floods?

A No, sir. No, sir.

Q When you use the term "high rate" as compared with "low rate", what do you mean by high rate and what do you mean by low rate?

A Well, I think I'll have to go along with Mr. Buckwalter this morning, that a high rate injection is somewhere between a half barrel per acre foot and a barrel per acre foot per day. Anything under that I would consider low rate injection.

Q Have you had any experience which indicates to you that the property cannot be flooded at less than a half barrel per well per acre foot, be flooded?

A Oh, definitely can be flooded, yes, but I think with poor results and poor economics at the low rates.

Q Are there any specific floods that you know of that lead you to that belief?

A Oh, I can't call them offhand, Mr. McGinnis, but I have seen quite a number of them in the past.

MR. McGINNIS: I have no further questions.

MR. PORTER: Anyone else have a question?

MR. McGOWAN: I have one question.

By MR. McGOWAN:

Q Mr. Stiles, when you were giving the total water flood oil in Oklahoma for the period, I believe, July, '56, to January, '57, you gave an average of a hundred thirteen thousand two hundred ninety-one barrels per day. Now that included, did it not, the oil that would have been produced as stripper primary oil from those properties had they not been under water flood order?

A Yes, yes.

Q So actually that entire 113,291 barrels was not oil, not all oil that would not have been produced if it weren't water flood?

A That's right.

Q So the impact on the market demand was actually less than a hundred thirteen thousand as a result of water flood?

A Right.

MR. PORTER: Anyone else have a question?

MR. CAMPBELL: I have one, please.

REDIRECT EXAMINATION

By MR. CAMPBELL:

Q In connection with Mr. McGinnis's cross examination relative to the comparison between the Gulf project in Oklahoma and the figures that Mr. Buckwalter gave on this proposed project, I believe you stated that some, or most of the areas in Oklahoma are developed on ten-acre five-spots, did you not?

A No, sir, I don't think I said that.

Q Well, are a number of them or not?

A Quite a number of them are, yes, sir.

Q And the proposal here is an eighty-acre five-spot, isn't it?

A Yes.

Q On a per acre basis, the allocation of secondary or water flood production to that particular project would be adjusted in that respect, would it not?

A That's right, it sure would.

MR. CAMPBELL: That's all.

MR. PORTER: Anyone else have a question of the witness, Mr. Stiles? Mr. Nutter.

RECROSS EXAMINATION

By MR. NUTTER:

Q Mr. Stiles, as an operator in the State of New Mexico, are you familiar with the current rate of production of the State of New Mexico?

A Total State's production?

Q Yes, sir.

A No, sir, I'm not.

Q Would somewhere in the neighborhood of two hundred fifty thousand barrels per day be about right, do you think?

A I don't know. I haven't the slightest idea what would be right for the State.

Q If I told you it's in the neighborhood of two hundred fifty thousand, would you believe me?

A I would agree with that, yes.

Q You are also aware that New Mexico is a growing State as far as new oil fields and the rate of production is on the upswing in the State?

A Yes, sir. Yes, sir.

Q Do you think it would be feasible, then, to project the rate of production to a period five years hence and say it would be in the neighborhood of three hundred thousand a day?

A That sounds reasonable, yes, sir.

Q Mr. Buckwalter's Exhibit No. 10 showed that five years from now estimated water flood oil production from this Caprock Queen Pool would be in the neighborhood of nineteen thousand barrels per day. If the total New Mexico production were three hundred thousand barrels a day, that would be approximately six percent of the total production, is that correct?

A Yes, sir.

Q Oklahoma with four hundred forty-nine water flood projects currently has a total of eighteen percent of its production allocated to water floods?

A In April of this year, or during that seven months period, yes, sir.

Q At the rate we are anticipating New Mexico water floods would go, one pool would account for six percent of the total allocation, whereas in Oklahoma --

A (Interrupting) That's a pretty sizeable pool.

Q Yes, sir, but four hundred forty-nine pools account for eighteen percent?

A Yes. Yes, well, now it's not very probable that there are going to be two or three fields like Caprock all developed at the same time for water flooding. It may happen, but I would doubt it, so these peaks of the various fields are not going to fall at the same time.

Q But one pool would be accounting for a larger percentage of the total allocation than any pool is in Oklahoma?

A That's correct, yes.

Q Now, Mr. Stiles, you have quite a bit of experience with water floods, does a water flood on the general rule, when you have capacity operations, deliver quicker payout or slower payout than primary production?

A I would say it is either the same or a little quicker, perhaps.

Q The water flood does yield a quicker payout?

A With unrestricted allowables, yes.

MR. McGOWAN: If the Commission please, that makes me want to ask one or two.

By MR. McGOWAN:

Q Mr. Stiles, referring to Exhibit 10 of Mr. Buckwalter, you need not look at it, the exhibit shows currently the production from Caprock Pool under consideration here is a little in excess of twelve thousand barrels a day. The exhibit also shows that the estimated peak of that pool under water flood, if it were all developed within five years, in 1962 would reach nineteen thousand. Would not the water flood impact on New Mexico market be only the difference between twelve and nineteen, rather than nineteen?

A Yes, would be the difference.

Q And that would be on the assumption that the entire pool, even the portions --

A (Interrupting) That's right.

Q -- that now have very top allowables on them would be water flooded effectively within five years?

A Right.

MR. McGOWAN: Thank you.

MR. PORTER: Any more questions of this witness? Mr. Campbell, I don't believe you offered your exhibit.

MR. CAMPBELL: I would like to offer Exhibit No. 12, Applicant's Exhibit No. 12, in evidence.

MR. PORTER: Without objection it will be admitted. The witness may be excused.

(Witness excused.)

MR. PORTER: We will take a short recess.

MR. CAMPBELL: Before you take the recess, you might consider this while you are recessing. At this point there are some questions about the procedure here. I believe there may be some other parties that desire to put on some testimony, and we may have one more witness in our principal case. I would like to ask if there are any others present who intend to put on any testimony?

MR. McGOWAN: In that connection, Sinclair does desire to put on some testimony. We are not necessarily supporting or opposing the application, in the sense we are not concerned with this particular application. We do have testimony we wish to put on in connection with water floods which will be applicable to the extent it is to this application.

It was our thought it would be proper procedure for the parties who are actively supporting or opposing the particular application as such, rather than in the broader sense we are, to proceed first, and let us follow with our testimony; and I wonder if at this time that procedure will be agreeable with the Commission?

My suggested procedure would be, following the closing of the applicant's case, those opposing the granting of the application proceed, and we be allowed after that to put on our testimony. Ours will not go to the application itself, but more to the water flood picture as a whole, and will be applicable to this application insofar as it applies. It would be more in the sense of general information illustrated by particular information we have that we feel would be of benefit or hope, at least, would be some benefit to the Commission.

MR. HINKLE: If the Commission please, the Humble intends to offer testimony in this case. At the outset it was my understanding in the statement of Sinclair they were supporting the application. In the interest of orderly presentation of this whole matter, I think all of those who are supporting the principle that's involved in this case, whether they have any interest in this particular case or not, should be required to put on their case first, and then followed by the opposition. We are in somewhat the same situation.

MR. McGOWAN: Our position, sir. He is correct, our general theory will support the theory under which the applicant is proceeding; to that extent he is correct. However, we do feel it is in the nature of general information rather than going directly to the application.

MR. HINKLE: Ours is certainly general, too, but I think all of those who are supporting the principle ought to put on first and be followed by the opposition.

MR. McGOWAN: Mr. Porter, I might further say we are not insisting on any particular procedure. We will gladly abide by any procedure the Commission desires. We would like to know.

however, so we can be prepared at the proper time.

MR. PORTER: Anyone else going to put on testimony?

MR. CAMPBELL: I haven't closed yet, of course. I may want to.

MR. PORTER: The Commission prefers to hear the components of the application first, and those who oppose to follow.

MR. McGOWAN: I presume that means you desire us to follow the applicant?

MR. PORTER: Yes, sir.

MR. CAMPBELL: I would like it made clear I may on the basis of their testimony want to call one more witness before we close the proponent's case, even though they are not appearing as proponents here, and their exhibits will be their own, is that agreeable?

MR. McGOWAN: Under this procedure, I'm assuming all those who proceed under the theory of proponents of the application, which we are not necessarily except a general aspect, will be treated as one; in other words, the applicant's case will not be closed until we both have closed?

MR. CAMPBELL: I have no objection to Sinclair putting their testimony in at this time, if I be permitted then to put on additional witnesses before I close.

MR. PORTER: That will be permitted, Mr. Campbell. We'll have a short recess.

(Recess.)

MR. PORTER: The meeting will come to order. Mr. McGowan.

F. F. W R I G H T

a witness, of lawful age, having been first duly sworn on oath, testified as follows:

DIRECT EXAMINATION

By MR. McGOWAN:

Q Will you state your name, by whom you are employed, and in what capacity, please?

A F. F. Wright is my name. I am employed by Sinclair Oil and Gas Company as assistant chief petroleum engineer.

Q Have you previously testified before this Commission as as expert?

A I have not.

Q Will you briefly advise the Commission of your education and background in engineering?

A I have a degree in Chemistry and I started to work for Sinclair in 1934. I received a B. S. in Petroleum Engineering, degree from the University of Oklahoma in 1940, while I was working with Sinclair. I worked with Sinclair --

MR. HINKLE: (Interrupting) Can the witness talk a little louder? We can't hear.

A I am sorry.

Q Go ahead.

A I have a B. S. in Petroleum Engineering, degree from the University of Oklahoma, I obtained while I was working with

Sinclair. I have worked as an engineer with Sinclair since 1940.

Q Now, in your work with Sinclair, Mr. Wright, have you been primarily concerned with the water flood properties of Sinclair and their operation?

A Yes, I have.

Q You in that capacity are and have been familiar with all water flood projects operated by Sinclair or in which Sinclair owns an interest, wherever they may be located, is that correct?

A Yes, sir.

Q Approximately how many water flood projects does Sinclair have an interest in at the present time?

A Something in excess of one hundred.

Q Approximately how many of those is Sinclair the actual operator of?

A Thirty.

Q Approximately what percentage of Sinclair's total production is water production?

A Ten percent.

Q Would it be correct to say that water flooding is considered to be an important segment of Sinclair's activities?

A It is, definitely.

Q Therefore we have not only you, but various members of our engineering staff have spent much time in trying to develop the best possible water flood techniques?

A We have.

Q You have heard the testimony that has been given here today. Do you have an opinion as to whether or not in the average water flood pool or the majority of water flood pools, or all of them, as to whether or not more possible recoverable oil will be recovered by a high rate of injection, as opposed to a low rate of injection?

A It's been my experience from observation of floods that we operate and from floods in which we own an interest, that the best successes are obtained with the higher rates.

Q Has that been a result of experiments in the field, to some extent, by Sinclair?

A I wouldn't call it deliberate experiment. We have, of necessity, when you handle a number of projects, some of them will be at different rates, and we have naturally and normally compared the results that are obtained at different rates.

Q I gather, then, that it's your opinion that to take any particular pool and water flood it at, oh, say seven-tenths of a barrel per day per acre foot, as opposed to three-tenths of a barrel per acre foot per day of injected water, that on the seven-tenths injection rate you would recover more oil out of that reservoir?

A In my opinion that is true.

Q You feel that opinion has been borne out by the numerous projects that Sinclair owns an interest in or has operated, is that correct?

A Yes, sir.

Q Have you picked a particular project of which Sinclair is the operator, and prepared data concerning that project which you think illustrates the conclusive proof of that opinion?

A Yes, I have an example here. It is a flood that Sinclair operates in Kansas. It's called the Browning Unit. It is located in Greenwood County, Kansas. It's Bartlesville sand solution gas drive reservoir. We have had a history of performance on this reservoir since 1924. The reservoir has produced approximately seven million barrels of primary production. It produced additionally a little over three million barrels by gas repressuring and in 1949 a water flood project was started on this Unit.

MR. McGOWAN: At this time, Mr. Porter, we have a series of nine exhibits that will be used collectively. Do you want them numbered consecutively from the applicant's number, or do you want them numbered Sinclair 1, 2, 3?

MR. PORTER: Yes, I believe it will be better, Sinclair's Exhibit 1, 2, 3.

(Sinclair's Exhibits Nos. 1, 2, 3, 4, 5, 6, 7, 8, and 9 marked for identification.)

Q Mr. Wright, I would like to ask you if all these exhibits that have been marked Exhibits 1 through 9 have been prepared by you or under your supervision?

A They have.

Q They have been taken from the actual history of the Browning Unit?

A Yes.

Q It is located in Kansas?

A Yes.

Q It is composed of some thousand acres or so, is it not?

A That's right.

Q About seven hundred eighty to eight hundred of which are now under effective water flood?

A That's right.

Q Will you advise the Commission briefly what type of reservoir the Browning Unit Bartlesville reservoir is and with reference to Exhibit 1, explain what it shows in connection therewith, and in connection with the history of this unit?

A Well, as I said, the Browning Unit produces from the Bartlesville sand. It's a typical Bartlesville sand, is typical to a lot of reservoirs you find in northeastern Oklahoma and eastern Kansas. It is about twenty-three hundred feet deep. As I stated, it was the first primary production, was in 1924, I believe the primary period lasted until, well, in 1928 gas injection was started on this, but the ultimate primary was estimated a little over seven million barrels. The gas injection period produced an additional three million, three million one hundred thousand barrels; in 1949 water injection was started on the Browning Unit area.

Now this, the purpose of this first Sinclair exhibit is just to give a kind of quick view of the history of the pool to give you a little background.

Q Just a minute, before we leave that exhibit. Am I correct I believe as I recall there was approximately thirty million barrels of oil in place in this reservoir initially?

A Yes, a little over thirty million barrels.

Q And Exhibit 1, then, would show that a little in excess of seven million of that thirty million would have been recovered by normal primary conditions?

A That's our opinion.

Q By starting gas injection in 1928, approximately, an additional three million barrels in addition to the normal primary oil was produced?

A That is our opinion.

Q In 1949 it was then placed under water flood production and that water flood production has to date produced an additional, what was it, about --

A Oh, about a million, a little over a million.

Q You estimate from this exhibit it will recover before water flood depletion an additional four million barrels of oil?

A Yes.

Q Operated at its present rates?

A Present rates.

Q While we have this exhibit, this water flood was started, I believe you said, in 1949?

A Injection was started in '49.

Q Approximately what rate -- well, I believe if you will go to Exhibit 2 you'll cover the point I want.

A Exhibit 2 is a typical secondary recovery performance curve which shows, it's divided in three parts. The top part shows the water production and barrels per day and the cumulative water production from the Browning Unit area. The middle section shows the water injection in barrels per day, the cumulative water injection in million barrels and the number of injection wells. The bottom third shows the oil production performance of the reservoir, shows the daily oil production and the cumulative oil production and the number of producing oil wells.

Q Now is there any other point you want to make in connection with Exhibit 2?

A The only thing that I would like to point out here on Exhibit 2 was that for the first six years of this Unit's life, from 1949, the middle of 1949 when we started it, to the middle of 1955, injection rates were relatively slow and low, with no apparent effect upon the oil production rates.

Q When we say "low", low can mean anything in relation to other figures. Approximately what portion of a barrel per day per acre foot was the injection rate?

A This would average about two-tenths a barrel per foot.

Q Am I correct in understanding you, then, that in this Unit from 1949 until early in '55, the average rate of injected water was two-tenths per barrel per day per acre foot?

A Yes.

Q The only effect upon the oil production during that six year period was for it to decline, is that correct?

A That's correct.

Q Now will you turn to Exhibit 3 and advise the Commission what that shows?

A Exhibit 3 shows three of the same factors that were depicted on Exhibit 2, except we have them blown up on Exhibit 3 so that you can tell a little more in detail what has happened. It shows for example in 1949 that we had around three hundred barrels per day of oil production on the Browning Unit, and that it had reached a low, it looks like, of about a hundred and eighty barrels per day in March of 1955.

Q During all that period of time water was continuously injected into the reservoir at approximately two-tenths per barrel per day per acre foot?

A That is the average figure, yes, sir. During that time our produced water increased from, started, it looks like, at about one hundred sixty barrels per day, it reached a low here of possibly a hundred and twenty barrels per day, and in March of 1955, we had about, it looks like, four hundred thirty barrels of water per day.

Q Wouldn't a logical conclusion from that, Mr. Wright, be that at this low rate of injection, even though the oil production was decreasing, the water production was increasing, and therefore you were producing water, flood water, without getting any additional oil and even getting less oil?

A That was our opinion. The third curve on this sheet is the injected water. It's very erratic. We started our injection the latter part of '49 and it looks like this would be February of '55, our water injection was about, oh, twenty-three, twenty-four hundred barrels per day.

Q Now at that point, Mr. Wright, to answer questions that maybe in some people's minds, why had the rate of injected water been low to that point?

A Well, it was not deliberate. We started out on this Unit and it was a Unit with other people, other parties, owning an interest in it. Sinclair owns roughly fifty-five percent of this Unit. We started out for our water supply; we planned to get it from the Douglas sand, which is a common water supply in Greenwood County; however, we drilled a number of wells to the Douglas sand on the Browning Unit and it was not a satisfactory water supply. We would try to stimulate them and fracture them and shoot them, and do all we could, but we couldn't get enough water to maintain the rate of injection which we desired, and with the Unit, even after Units are formed, it takes a little time to get approval for actions. We considered another source of water. We decided we would try to pick up some surface water on the Unit. We tried to dam up some little streams and build some ponds, and along at this time, as most of you know, Kansas, Oklahoma, Texas, and

New Mexico, we hit a period of prolonged drouth, and we just didn't have any surface water, so that source was disappointing.

We finally got together with the members of the Unit and decided that we would go about eight miles over to the head waters of the Vertigo River. There was a little water we thought we could get. By the time we built our line over there and built our station, that source dried up. Very frustrating all during this period we were trying to get water.

Q Early in 1955 you did succeed in getting an adequate supply of water from the Arbuckle formation?

A Yes, finally drilled to the Arbuckle formation and got enough water to start a water flood.

Q Will you go ahead and explain? I interrupted you.

A As you can tell, then, early in 1955, after that time we stepped up our injection of water, and as we stepped up the injected volume, that reached here during the middle of '55, it looks like, around seven or eight thousand barrels per day;in the early part of '56 it was above, oh, fifteen, sixteen, seventeen thousand barrels per day, and here in '57, the last month that is on this graph is July, is around twenty-four thousand barrels per day.

Of course, while we were stepping up that injected water we also received an increase in our produced water, as you can tell, from this March point in 1955 of four hundred and twenty-five barrels a day, up to about thirteen thousand barrels per day. All the while our oil production was increasing, too. It increased from this low of one hundred eighty barrels per day to here, it was between thirty-two and thirty-three hundred barrels per day.

Q Did this exhibit in effect show that six years of injection rate of approximately two-tenths per barrel per day per acre foot resulted in increased water production, decreased oil production, and a financial loss, but that now approximately two years or two and a half years of increased injection, which, as I recall, reaches about an average of seven-tenths per barrel per day per acre foot, has resulted in increase in oil production from less than two hundred barrels a day to in excess of thirty-two hundred barrels a day, and they hope for some profit?

A That is correct, that is the result.

Q Now then, will you go to Exhibit 4, and I believe it will be of benefit to discuss 4, 5, and 6 together, as I believe they each reflect a certain condition of the reservoir at a given time, is that correct?

A That's right. Exhibits 4, 5, and 6 show graphically the circumstances in the Browning Unit on March the 1st, 1955, at the end of this six years of slow injection. They will be followed by the final three exhibits 7, 8, and 9, which show graphically the conditions on the Browning Unit on August 1st, 1957.

Now Exhibit 4 is a fill-up map, you might call it, in which we have some circles drawn around injection wells. The radius of these circles gives the fill-up in feet of cumulative water injection as of March 1st, 1955.

Q Now would that indicate, Mr. Wright, that at that time, even at the low injection rate, you had reached a fill-up in the affected area?

A Yes, we had.

Q But you had not experienced any increase in oil production?

A Well, not for the Unit as a whole; on Exhibit 5, which depicts the oil production rate for producing wells in the Browning Unit as of March 1, 1955, we have circles on it which are in proportion to the daily oil production per well; in the lower right hand corner, the size circle there is a fifteen barrel per day circle. From that you can gauge the size of the other circles on the map. You'll see that we only had an increase in oil production from one well. There's one well there that made sixty-three barrels per day. It sticks out like a sore thumb.

Q In other words, that is the only effect then that you could find, production-wise, from the obvious fill-up of injection water at a low rate?

A Only oil effect.

Q The only production of oil?

A Yes.

Q Go to Exhibit 6.

A Exhibit 6 is of the same date, March, 1955. It is like the preceding plat; instead of showing oil production rate it shows water production rate. As is obvious, there are a number of wells in and near the pilot area where our injection was showing large volumes of, relatively large volumes of that produced water.

Q In the immediate vicinity of the pilot area, the slow injection did materially increase the water production?

A That's right.

Q But showed no effect except as to the one well on oil production?

A That's right.

Q Go to Exhibit 7, 8, and 9. Do they not show the same conditions as the previous three exhibits as of August 1, 1957?

A They do. We made these exhibits in an attempt to give a quick picture of Unit conditions on these two dates. We thought we could do it better this way than we could by just reeling off tables of statistics.

Q Will you discuss Exhibit 7?

A Exhibit 7 shows the fill-up, our interpretation of the fill-up from the accumulative water injection since 1949 in the injection wells on the Browning Unit, and it is obvious there is a lot of overlapping, particularly there in the center of the unit.

If there is more water than you have space for, it has to spill out elsewhere. Exhibit 8 shows the current oil production as of August 1st, 1957, also by the same scale that was used on Exhibit No. 5.

Q In connection with that exhibit, Mr. Wright, I notice that the circles representing oil production around the wells in the pilot area are not a great deal larger than the circles around those same wells in March of '55, but that the circles around outlying wells in areas that had not been affected by the low rate of flood showed a tremendous increase in production. Do you draw anything significant from that?

A Well, the significance that we drew from it was that this slow injection in this pilot area had not enabled us to recover any water flood oil and furthermore that we might have moved some out of the pilot area, but that there was also some that was locked in there that we had never moved. We think we had lost ultimate recovery on this project by this six years of slow injection.

Q In other words, the increase in injection rate has increased from the Unit the production from less than two hundred barrels to more than thirty-two hundred barrels, but as I gather from your statement in this exhibit, it has not, even the increased rate at that late date did not recover the oil from the pilot area that had been subjected to low rate of production in the proportions it did at the other areas?

A It did not, no, sir.

Q Would that lead you to the conclusion that the sustained low rate of injection did damage to the reservoir and doomed otherwise recoverable oil to be lost?

A We feel we had lost oil.

Q You would have recovered more oil if you had been able to inject water at six to eight tenths per acre foot at the beginning?

A That is our conclusion, yes.

Q Will you go to Exhibit 9?

A Exhibit 9 is a map showing the relative water production as of August 1, 1957, from the wells on the Browning Unit. It looks like a surrealistic or modernistic picture, there are so many circles, but it is indicative of the large amounts of water we are having to handle to produce the oil.

Q Even though you are not producing the oil from the original pilot area in comparison to the other areas, it would appear you are producing water from it?

A Yes, we are.

Q Would you conclude that the low injection rate in the pilot area increased permanently the water production and decreased permanently the oil production, whatever might be done thereafter?

A We certainly lost production in the pilot area. We lost ultimate recovery by having to flood that at slow rates for the six years.

Q I gather by your continued search for water in your attempt to have a high rate of injection in this Unit earlier than you did, you were of the opinion that the recovery would be at a low rate until you improved it?

A Yes.

Q You had such an opinion, for instance, five years ago?

A Yes.

Q You feel that the performance of this Unit has proved beyond doubt that that theory was correct?

A It is a good example.

Q We talk about, recognizing that this is a Bartlesville sand reservoir in Kansas and today we are in New Mexico talking about a different range and different type and, possibly a different type reservoir, do you feel that any general rule of thumb or general principle can be applicable to most all or possibly all water flood projects?

A Well, it's difficult to apply a yardstick to all, but certainly all good water flood projects have certain similar characteristics whether you find them in New Mexico or Kansas or Illinois.

Q Would that be because, Mr. Wright, certain types of reservoirs are susceptible to water floods and other types aren't?

A It has been our experience that certain reservoirs respond better to water flood than others.

Q Wherever you are, you choose those types of reservoirs to instigate water flood?

A We try to take advantage of all the experience we can in that regard.

Q Therefore, except in isolated instances, there will be a realm of good comparison between successful water flooding reservoirs in certain parts of the country?

A They will have similarities.

Q Is Sinclair operating in the State of New Mexico?

A Yes, sir.

Q We have considerable production?

A We have close to fifteen thousand barrels a day.

Q Do we have any water flood production?

A We have no water flood production.

Q To the extent that the granting of this application under consideration would have any impact on the primary production of the State, we would feel it, would we not?

A If it had any impact appreciable, we would feel it.

Q Was that matter considered by our company before deciding to come down here?

A It was.

Q The feeling of our company was that the high injection rate was the method of recovering the most oil, and if there was an impact on the market, we should stand it?

A We felt that the recovery of the highest amount of oil was the paramount consideration.

Q We are not entirely selfish in that we look forward in years to come to have water floods?

A Yes.

Q At that time we hope to be able to finish them on the most efficient method?

A As approved by the Commission.

Q Based on your testimony before the Commission and the other information that has been made available in connection with the area covered by the application, do you see any reason why your opinion that a high rate of injection will recover the greatest amount of oil should not apply to the area under consideration today?

A In my opinion it applies.

Q You feel in the interest of conservation and the greatest ultimate recovery of oil, the application should be granted, is that correct?

A Yes.

MR. McGOWAN: You may cross examine.

MR. PORTER: Any questions of the witness? Mr. Hinkle.

MR. HINKLE: If the Commission please, the exhibits offered by Sinclair seem to be complicated. We would like to see them and go over them this evening before we offer our cross examination. I understand that they have another witness, and we would like to have the privilege of calling Mr. Wright back in the morning, if we may do so, before we start cross examination.

MR. CAMPBELL: I am not going to object to that. It has to work both ways. If I need a day or two to think over Doctor Hocott's testimony, I will want it.

MR. McGOWAN: I have no objection to their cross examining Mr. Wright at any time they desire. The witness that we intend to follow Mr. Wright with, to some extent the testimony would depend upon the possible cross examination, and it puts us in a little awkward position. We could proceed, I believe, if the Commission desires, in that respect. It's a little early to quit, I could possibly put Mr. Earlougher on, but I almost would feel compelled to reserve the right to recall him, following the cross examination of Mr. Wright, if I deemed it advisable.

MR. HINKLE: We have no objection to that.

MR. CAMPBELL: With the reservation I made, that's agreeable with me.

MR. PORTER: Does anyone else want to question the witness at this time?

MR. CAMPBELL: I planned to call Earlougher here as a witness for the applicant on some matters that are not related to this particular unit. I don't think my direct examination will take very long. Perhaps we can dispose of that before the recess this evening, if it is agreeable.

MR. PORTER: May the record show that the witness is excused subject to recall.

MR. McGOWAN: I might at this time move the introduction of Sinclair's Exhibits 1 through 9.

MR. PORTER: Any objection to the introduction of Sinclair's Exhibits 1 through 9? They will be admitted.

(Applicant's Exhibits Nos. 13, 14, and 15 marked for identification.)

MR.CAMPBELL: This witness has not been sworn.

(Witness sworn.)

R. C. EARLOUGHER

a witness, of lawful age, having been first duly sworn on oath, testified as follows:

DIRECT EXAMINATION

By MR. CAMPBELL:

Q Will you state your name, please?

A R. C. Earlougher.

Q Where do you live, Mr. Earlougher?

A Tulsa, Oklahoma.

Q What profession are you in?

A I'm a consulting petroleum engineer and owner of Earlougher Engineering.

Q Would you please give the Commission a brief history of your educational and professional background?

A I graduated from the Colorado School of Mines in 1936 with a degree of petroleum engineer. For the next two years I was in Bradford, Pennsylvania, employed by the Sloan and Zucht Company. In the spring of 1938 I moved to Tulsa, went into business for myself with a partner. We bought out the oldest core analysis laboratory in Tulsa, and since that time I have been engaged principally in engineering work pertaining to secondary recovery operations, principally water injection, and we have also continued to operate the core analysis laboratory.

Q Are you presently engaged in the study of any potential water flood projects in the State of New Mexico?

A We are.

Q And what project is that and to whom are you a consultant in connection with it?

A In this connection, it's for Ashton Franklin & Farr, Inc., and the Loco Hills secondary recovery committee.

Q That possible project is in the Loco Hills area of New Mexico?

A Yes.

Q Have you made any study of the relationship between the rate of injection, the economic limits and ultimate recovery in connection with water flood projects, Mr. Earlougher?

A Yes, we have.

Q I'm going to refer you to what have been put up on the wall there and marked Applicant's Exhibits 13, 14, and 15. Those represent the graphical results of the study that you referred to of the relationship between rate of injection, economic limits, and ultimate recovery, is that correct?

A Yes, it is.

Q Those, of course, were prepared by you?

A They were prepared under my direction.

Q Referring to those exhibits as you see fit, explain to the Commission how they were prepared and what they reflect in relation to the matter that you mentioned.

A Exhibit 13 presents relationship of water flood operating costs on depth of wells versus the operating cost per well per month, and then on this well per month basis that includes both producing wells and water injection wells. The vertical scale is for thousand foot depth, two thousand, three thousand, four thousand feet. The horizontal scale, one hundred dollars per well per month, two hundred per well per month, three hundred dollars per well per month. The points colored in solidly in black represent actual operating costs from independent operators which were available to us in our files. The open symbols represent operating costs for major operators which were furnished to us.

It is to be noted that the floods involved here are delegated Indiana, Kansas, Oklahoma and Texas, so that it gives a pretty wide range of operating conditions. There you'll notice on the graph, we have a wavy line separating the points, in effect dividing the data into two parts. Everything below the wavy line represents floods in which the well spacing has been its five-spot pattern, ten acres per five-spot. The open circles above the line represent operating costs for floods which were developed on a twenty-acre five-spot spacing.

Now we will refer to this lower group of points. We have drawn an average line through here to try to pick an average operating cost per well per month in relation to the depth. While these points give a scatter-gram, it is obvious that the operating cost increases with the depth of the wells.

At this time I would also like to remark that these water flood operating costs, we have found in general, are about three to four times the cost for primary operations. That again is on a per well per month basis.

Q What is your reason there for showing the differentiation between what you have designated as small independent and major operator?

A The purpose is to show that on the ten-acre spacing that it apparently doesn't make much difference whether it is a major company operator or an active independent water flood operator, the costs are still, still fall within the similar range.

Now the second curve, which is based upon actual field performance, relates cumulative water injection, expressed as a percent of the total pore space of the sand being flooded, versus cumulative oil recovery as a percent of the possible ultimate oil recovery. I would like to explain the vertical scale here, which as I state is a cumulative water injection as percent of pore space. We have presented the water injection data in this form because several years ago we determined that for the majority of floods by the time they are abandoned, the majority of successful floods, the cumulative water injection is equivalent to between one hundred fifty to one hundred seventy percent of the total pore volume in the flood area.

The horizontal scale represents the cumulative oil production as percent of possible ultimate. Now this average curve is based upon the history of actually seven floods which we have followed since inception at the current, I mean currently each of these floods is, I think, within one to two years of the economic limit, so that the bulk of the history is behind us.

From the average curve it is to be noted that at the time the cumulative water injection is equal to one hundred percent of the pore volume, that is equivalent to one pore volume, there is about ninety percent of the possible ultimate recovery by water flooding has been obtained; by the time the cumulative injection reaches one hundred seventy percent of the pore volume, these particular projects will be at their economic limit, and the one hundred percent possible recovery will have been obtained.

We have shown in dashed lines the range of data for these individual floods. Again, these floods were located in Oklahoma, one in West Texas. For the most part they are fair sized floods, anywhere from one hundred sixty to about four hundred acres each.

We have identified the lower curve here as a peripheral flood, which was really a water injection pressure maintenance peripheral program in Oklahoma. We have so identified that because it is to be noted that a relatively high percentage of the total possible recovery was obtained with a relatively low cumulative water injection. However, it is again indicated that to obtain the maximum possible economic recovery, the cumulative water injection is going to be about one hundred thirty percent of the pore volume.

Now I would like to go to the third curve, which actually is based on these first two curves. This third curve presents graphically the effect of water injection on the ultimate recovery which can be produced by the time a given project reaches the economic limit and has to be abandoned.

For the purpose of illustration here, we will assume an eighty-acre lease with a ten-acre five-spot development, eighteen percent porosity. The operating costs for sixteen wells, taken from Figure I, for a fifteen hundred foot depth, would be $27,000.00 per year; for a three thousand foot depth would be $57,500.00 per year. We have further used a crude value of $2.50 per barrel, after deducting five percent gross production tax and one-eighth royalty. Now the reason we have deducted the five percent gross production tax is that the tax was deducted from the operating cost there.

Also these curves are based upon an ultimate water input of one hundred seventy percent pore space, which from Exhibit 14 indicates one hundred percent of the possible ultimate recovery.

Then we have constructed four different production rate curves based on, first, as shown in red, an average settled injection rate, that is, injection rate after fill-up of one barrel per day per acre foot, of three-quarters of a barrel per day per acre foot, of half a barrel per day per acre foot, and 0.35 barrels per day per acre foot.

Again, in the construction of these curves, we have not taken into consideration any physical oil recovery which might be lost by too low an injection rate, because this problem is dealing solely with the effect of the economic limit.

Horizontally on this graph we have presented the economic limit for a depth of three thousand feet, which in this case would represent about sixty-two barrels per day, gross barrels per day. This lower line is economic limit for fifteen hundred foot wells, for a production rate of thirty barrels per day. Now on the production rate you'll notice ten barrels, one hundred barrels per day, and thousand barrels per day. Now for example, we look at the red line for one barrel per day per acre foot for three thousand foot well, three thousand foot flood, by the time the production rate declines to sixty-two barrels per day -- excuse me, here is the red line coming down here -- by the time the production rate declines to sixty-two barrels per day, the economic limits will have been reached and the property abandoned.

For a fifteen hundred foot flood, the property can be operated until the production rate is thirty barrels per day.

Now you will notice that we have colored in under these curves the amount of lost oil, or the oil that will not be recovered because of the limiting economic factors of production. The green curve, which represents .75 barrels per day per acre foot represents a much bigger area than the red curve. We go out to the blue curve which is .50 barrels per day per acre foot, you have more loss; and you go down to .35 barrels per day per acre foot, there is still a greater loss.

Now to summarize, the loss for fifteen, a depth of fifteen hundred feet with the injection rate of one barrel per day per acre foot, there is an indicated loss of three thousand barrels, or one percent, which is actually the reason that we show a loss here, is that we have used average cost data which may be slightly higher than the actual operating cost for the floods used for our base curves.

Coming on along across to three-quarters of a barrel per day per acre foot, there's an indicated twelve thousand barrel loss, or three percent of the ultimate possible. At half a barrel per day per acre foot, the indicated loss is twenty-seven thousand barrels, or seven percent; and you get down to a third of a barrel per day per acre foot, the loss is forty-one thousand barrels, or ten percent of ultimate recovery.

For a depth of three thousand feet, the losses amount to about eight percent with a high rate, thirty-two thousand barrels, up to twenty-seven percent or one hundred eight thousand barrels for the very low injection rate.

I think that for any given lease or set of conditions there will be some variations of an economic limit or factor, but this certainly serves to illustrate one very important factor which any sound water flooder has to consider. Generally, I might say, on economic limit the most important factor in determining that is barrels of oil per day per well being produced, because large volumes of water can be handled at relatively little additional expense.

Q Are you acquainted in general with the Caprock Queen Pool in New Mexico, as to depth and so on?

A I'm familiar with the testimony that was presented here today.

Q Assuming it is in the three thousand foot depth range, the calculations that you have made on the upper right-hand portion of the exhibit numbered Applicant's Exhibit No. 15 would be related to this particular application, would they not?

A In general, yes.

Q And those calculations indicate a differential loss of eight percent on one barrel per day per acre foot, as related to twenty-seven percent on approximately a third of a barrel per day per acre foot, is that not correct?

A Yes, using the data on this third exhibit.

MR. CAMPBELL: I believe that's all.

MR. PORTER: Are there any questions of Mr. Earlougher at this time?

MR. HINKLE: I understand that Mr. Earlougher is going to be a witness for Sinclair. We would like to reserve our cross examination until he has finished all his testimony.

MR. McGOWAN: We will continue, then.

By MR. McGOWAN:

Q Mr. Earlougher, before we start in effect on the Sinclair testimony, a portion of your testimony, let me ask you about this, one question about the exhibit up there. When you talk about lost oil, in comparing between a barrel per day of injected rate to, I think it is .35?

A Yes, .35.

Q Is what you are saying from the facts you have here of actual water floods in the field; in other words, actual productive history of these water floods shows to you, and that your conclusion therefrom is that a particular flood would have recovered twenty-seven percent more ultimate oil at an injection rate of one barrel per day per acre foot than at three five point per day?

A Than it would have at point three five per acre foot, yes.

Q Now you have heard the testimony here today, Mr. Earlougher. Am I correct in assuming that it is also your opinion that a high injection rate in water flooding will recover more ultimate oil from the same reservoir than would a low injection rate?

A Yes, in general I think that is true.

Q Have you always been of that opinion, Mr. Earlougher?

A No, sir.

Q What changed your mind?

A Working with a lot of water floods. In fact, I know at least approximately ten years ago, upon one or two occasions, we made recommendations to reduce injection rates, and subsequent performance proved to me that we were wrong in doing so.

Q You testified, I believe, that you had been in the consulting business with primary attention to secondary recovery for some twenty years, is that correct?

A That is correct.

Q How many water flood projects would you estimate in that twenty years that you studied and obtained the performance data from, Mr. Earlougher?

A We have worked with several hundred different water floods. We have done a major part of the engineering work and preliminary investigation through development and operating on approximately a hundred floods. We currently are actively following on a week to week basis some thirty-five to forty floods throughout the United States.

Q Now, Mr. Earlougher, in connection with a hearing before the Kansas Corporation Commission concerning the Browning Unit, about which Mr. Wright has heretofore testified, were you requested by Sinclair to make an independent study and evaluation of that Unit?

A I was.

Q The information that you felt necessary to allow you to form opinions about it was made available to you?

A It was.

Q Including all the information on the exhibits heretofore introduced by Mr. Wright?

A Yes, it was.

Q You heard Mr. Wright's testimony in connection with that Unit here today?

A I did.

Q Do you in general concur with his conclusions and opinions from that information in connection with that Unit?

A Yes, I very definitely do.

Q Have you had your mind changed about the desirable injection rate for ultimate recovery prior to the Browning Unit?

A Yes.

Q Had you not had your mind changed by then, do you think it would not have done so?

A Yes.

Q You think that was the proof of the pudding?

A To me that is one of the most clearcut cases that I have ever seen to prove the effects and the very poor effects of very low injection rates.

Q I gather then that you would feel that if we at this time reduced the injection rate in the Browning Unit, we wouldn't recover the amount of oil that we will recover if we continue the high rate of injection?

A That is my opinion.

Q That any oil that we did not recover at that reduced rate would be wasted oil, would it not?

A Yes.

Q Now then, in connection with that same problem, did you take a particular Unit about which you, on which you were the consultant and on which you, in effect, operated and guided and prepared an exhibit to in effect display the same theory?

A Yes.

(Sinclair's Exhibit No. 10 marked for identification.)

Q Was this exhibit prepared by you or under your supervision?

A Yes, it was.

Q You know the correctness of the information reflected thereon?

A I do.

Q Will you briefly advise the Commission of what this exhibit relates to and what it in your opinion shows, and the conclusions you have drawn therefrom?

A This exhibit presents the water flood performance history of an eighty-acre lease in Northeastern Oklahoma. The lease was developed on a ten-acre five-spot pattern, as is shown by the little plat in the upper right-hand part of the exhibit.

The right-hand scale represents cumulative oil production and cumulative water input in barrels. The left-hand scale at the left-hand side of the exhibit represents gross oil production and water input in barrels per day. The horizontal scale is a time scale in years by months. Starting at the top of the graph, we have a curve which is marked as water input in barrels per day.

We also have a scale showing the number of oil and water injection wells which are depicted here on the graph.

In the lower portion of the graph, the heavy solid line represents the oil production rate average as barrels per day by months. Then lower on the graph in the stippled area with solid black lines for each year, we have shown the average operating cost as gross barrels of oil per day, during the period represented here, from about August, 1950, through 1956 -- well, strike that for a minute, it was for the period 1954 to 1956; the price of oil was constant, so that oil price has no effect, I mean there's no change of oil price to affect the operating cost data.

Now it is to be noted that by the end of 1954, in fact, in November of 1954, the oil production rate had declined to approximately one hundred twenty-eight barrels per day. An extrapolation of the production decline indicated that the production under existing conditions would reach the economic limit of approximately eighty-four barrels per day in early 1956.

The conditions on this lease were this: Each of these injection wells and producing wells had been newly drilled, the entire sand section was cored and analyzed, the indicated water flood oil recovery from all of these core data was approximately ten thousand barrels per acre.

At the end of 1954 we had similar information on another eighty-acre lease in this same general area, in which the estimated recovery, based upon core data, was about, I think it was eighty-five hundred barrels per acre, and the flood recovery had actually exceeded that volume,so late in 1954 when it was indicated that the ultimate recovery under existing operating conditions was only going to be about four hundred ninety thousand eight hundred barrels as is represented by the area colored in yellow on the graph, which would represent an average recovery of only about six thousand barrels per acre. It was evident to us that there was something wrong with the operations of this flood and with the results, in view of the fact that we felt there was a very large amount of additional oil to be recovered if we could improve the methods. We were finally able to convince the operator that it was worthwhile spending an appreciable amount of money to try to get this additional oil; so, in effect starting at the end of 1954 and the early 1955, steps were made to greatly increase the flooding rates both on the producing side in the way of fluid production, and also on the injection side. The fluid production rates were increased by sand fracing and installation of high volume pumping equipment. Injection rates were also increased appreciably from about fifty-five hundred barrels a day to nine thousand barrels a day by the end of 1955.

Now it is to be noted from the oil production curve that significant additional oil has been recovered from this eighty-acre lease as a result of this big increase in producing rates and injection rates. For example, on the producing side, the water injection late in 1954 was only about thirteen hundred, excuse me, about sixteen hundred barrels a day. By the end of 1955, the water production rate had increased to about fifty-five hundred barrels per day.

Now it is interesting to note, to go back and refer to this gross operating cost in gross barrels per day, that for the last year prior to increased rates, the operating costs amounted to about eighty-five gross barrels per day. The two years after that with the much higher rates, the operating costs were still practically the same.

Q You did have, however, an added capital investment at the time that you stepped up the injection rate, did you not?

A That's right. There was an additional investment of very nearly fifty thousand dollars.

Q From your previous testimony about this, I would assume that this is a very rich lease, thinking in terms of oil in place?

A Yes, it was an extremely rich lease.

Q Would the added capital expenditure have resulted in extra profit had this not been such a rich lease?

A No, it wouldn't have and in that connection I would just like to mention that we're working with several other floods in which we would like to increase the rates, both the injection and the producing rates, but the quality of the floods are so thin and the additional oil recovery which we think reasonably could be anticipated is not sufficient to justify the additional expenditures at this time to get that oil.

Q Had that been true here, then, the increased rates late in the life of the field could not have been brought about, is that correct?

A That is correct.

Q You have recovered, as I gather from this exhibit and your testimony, have or will in your opinion recover some two hundred thousand barrels of oil more than you would have recovered had you not increased your injection rate?

A Yes, that is correct.

Q Do you know what that will be in terms of recovery per acre foot from this lease at that time?

A You mean the additional recovery?

Q Well, all of the recovery. In other words, what percentage of the oil will you have recovered at that time under this lease?

A I don't have the figures in that fashion, what they will amount to, though, is about eighty-eight hundred barrels per acre.

Q Eighty-eight hundred barrels per acre?

A Yes.

Q Did you not testify a moment ago concerning the amount of recovery under a high injection rate on a very similar eighty-acres in this same pool?

A Yes, I did.

Q What was the recovery per acre from that lease?

A I think that recovery now is about eighty-five hundred barrels per acre.

Q In other words, it is in excess, then, of the recovery that will be obtained from this lease?

A No.

Q It will be?

A No, no, it isn't, but on the other lease the recovery has exceeded the recovery indicated by the, by all of the original core data. This lease is still going to fall somewhat short.

Q What do you think would have happened in this lease to the ultimate recovery, had you stepped up the injection rate, say back in 1952?

A I think that probably the ultimate recovery would have been somewhat greater than it is going to be under existing conditions.

Q What do you think would have been the result had you started out and maintained throughout the life of this flood such higher injection rate?

A I think the ultimate recovery would have been somewhat greater than it is going to be now.

Q Would it be a fair assumption from this exhibit that it shows that the longer you wait in the life of a flood to increase the injection rate, the more oil you waste?

A I think that that is essentially true, yes.

Q And that the way to waste the least is to start out with a high injection rate?

A Yes, that is my opinion.

Q You have heard the testimony of the applicant in this cause and have general information concerning the area covered by the application. Do you see any reason why the general conclusions you have given here would not apply to the area covered by that application?

A No, I do not.

Q I assume you feel the Commission should grant the application?

A Yes, I do.

Q Another point I would like to cover, you again, as Mr. Wright did, have talked in general terms, of general terms of water flood, or a rule of thumb. Do you have such a rule of thumb that you feel is a desired injection rate in a water flood project?

A Yes, in our opinion the desired rate and the rate we attempt to design for is about a barrel per day per acre foot with a settled rate.

Q It has been your experience in most water floods if that rate can be obtained, it will be the most efficient rate in the recovery of oil?

A Yes, I think it will, but I would also like to state that in many cases it is not possible to actually maintain an injection rate of a barrel a day per acre foot, because of the pressure limitations of the formations.

Q That is actually a limit imposed on you by the characteristics of the formation itself, is it not?

A Yes.

Q Now, when you talk about water floods, you talk about them collectively, it appears? Is that because all reservoirs are alike or because similar or like reservoirs are normally chosen for water flood projects?

A I think it is probably because similar reservoirs are chosen for water flood projects.

Q In other words, reservoirs with certain characteristics within a general range, then, have been found susceptible to successful water flooding, where other reservoirs with other types of characteristics have not?

A That is correct.

Q That is the reason you feel you can generalize concerning water flood operations as a group?

A Yes, that is correct.

MR. McGOWAN: You may cross examine.

MR. PORTER: Any questions of the witness?

MR. HINKLE: I don't know what the intention of the Commission is with reference to a recess. It depends on how long you are going to go. We can start our cross examination. I doubt if we can finish, if you are going to hold until 5:30. It might be better if you are going to recess to start in the morning.

MR. CAMPBELL: May the record show that I offered Exhibits 13, 14, 15, in evidence, please?

MR. McGOWAN: And also that I offered Sinclair's Exhibit 10?

MR. PORTER: Any objection to the admission of the exhibits? They will be admitted. Mr. Hinkle, would you proceed?

CROSS EXAMINATION

By MR. McGINNIS:

Q Mr. Earlougher, you have indicated that you are familiar with this particular project here, in which you agreed that this application should be granted. I believe you have also stated that you believe that the injection rates less than one barrel per acre foot per day tend to cause waste, while recognizing that in some cases you may not be able to do that for physical reasons, is that correct?

A Yes, I say that it is my opinion that it would be preferable to maintain a rate of one barrel per day per acre foot, if it were physically and economically possible to do so, in order to obtain the ultimate greatest recovery.

Q Are there any reasons why this Caprock area, this present application, why an injection rate of a barrel per acre foot per day cannot be maintained?

A I do not know. I have not studied it. I have not made a study of the applicant's Caprock pilot flood.

Q If it could be done in this field, then in your opinion that would tend to prevent waste and increase the ultimate recovery from the project?

A Yes, it would.

Q Even if there were some physical limitations upon this ability to inject up to a barrel per acre foot per day, wouldn't it be possible to frac the formation in such a manner that it could take the water?

A Yes, that is possible. That can be done in some formations.

Q Has that ever been done in connection with water flooding?

A It has on some projects with which we are working.

Q Based on the depth of this project and the permeabilities in it, do you see any reason why it couldn't take water at a barrel per acre foot per day?

A Well, I'm merely, at this time I'm not qualified to answer that because I have not made an engineering study of the data available on Caprock.

Q In your opinion would waste be prevented by fracing this formation so that it could take water at that rate, if it can't do so otherwise in this particular case that we are dealing with here?

A Well, I'll say it might be possible to do so.

Q And in any event it would prevent waste if you could do it, is that right?

A Yes, if you can do it without impairing it, some other factors pertaining to water flooding, principally if you can do it without causing channeling between the injection well and the producing well.

Q Now, what are the features which would exist in the reservoir which in its natural condition would prevent you from putting in a barrel per acre foot per day?

A Well, I think normally the principal limitation is one of permeability and of spacing, because of course the wider the spacing, the higher the injection rate per foot of exposed sand has to be, in order to maintain a barrel per day per acre foot injection rate.

Q What are your reasons why in your opinion that waste could be prevented out in this Caprock Queen Field by injecting a barrel per acre foot per day, rather than half a barrel per acre foot per day as proposed by Mr. Buckwalter?

A If an injection rate of one barrel per day per acre foot could be maintained, I think the third graph that I presented up here is illustrative of the reason why a greater ultimate oil recovery could be obtained, because the economic limit of that operation or any other operation is going to be governed, just as a matter of illustration now, is going to be governed by the oil rate as barrels per day per well, such as five barrels or seven barrels or ten barrels a day per well, and the oil rate is going to govern, be the principal governing factor as to economic limit.

Q Now, aside from the economic argument that you made and have exemplified by your third exhibit up here on the board, is there any basis from the point of view of physical waste, aside from the waste which you say would occur because of economic limits?

A Well, if the economic limit caused the abandonment of the project, then that results in physical waste.

Q In addition to that, though. I'm talking about any waste other than that waste that you have just outlined.

A From our observations and studies with many water flooding projects, so far as the physical principles alone are concerned, I think there may not be much difference in recovery with injection rates varying from half a barrel per day per acre foot, and one barrel per day per acre foot; however, as engineers, I think it's mandatory that economics be considered, and the effect of the economic limit upon the ultimate oil recovery.

Q Now when you answered that question, you said that you didn't think there would be much difference between a half a barrel and a barrel, economics aside. Now, would you please state where you think there would begin to be a difference, from a waste point of view?

A I think it occurs probably somewheres close below the half a barrel per day per acre foot. Now I base that statement upon our studies and observations of floods in which the injection rate has been as low as from three-tenths of a barrel per day per acre foot on down to the case which Mr. Wright testified to, in which the injection rate was only two-tenths per barrel per day per acre foot.

Q Where does the oil go that you don't get at a lower rate, what happens to it?

A The oil stays right in the sand.

Q Why doesn't it come out of the sand at the lower rate?

A That is something that the scientists have not yet answered. I think we know from our observations in the field that in these projects or in these sands where there has been a very slow water entry into the sand, that the water apparently can pass through the pores which are filled only with low pressure gas or with zero pressure gas if vacuum has been applied to the property.

Under these very low rates, it is apparent to me from field observations, that water can flow into the vacant pores without displacing oil ahead of it.

Q In other words, at low rates the water flows into the sand which contains oil, but doesn't displace the oil, is that it?

A It flows into the pores which contain only gas. I think that might be illustrated in a layman's language, to maybe simplify this problem to the Commission. I hope it will, but I think we will just assume we have a box of soda straws which are your conducting tubes; of course, if those straws, if each straw is filled with oil and you apply water pressure across the face of all those straws, oil has to move out of the straws. If, however, thirty percent of those straws, say, have no oil in them, and water pressure is subjected, or is placed against the end of the box under very low pressure, the water will all run through the empty straws. It wouldn't displace any oil. However, under a higher pressure and a higher rate, water will then start displacing oil from the straws in which the oil is contained.

Now, I'm not trying to say that represents reservoir conditions, it is solely for the purpose of illustration as to how it might happen.

Q Mr.Earlougher, in this group of straws that you have, you have some empty straws and some filled with oil, and you are putting water in equal pressure against the ends of all those straws. Is it your testimony that the water will move through the empty straws but will not move into and displace any of the oil from the straws that have oil in them, is that your testimony?

A Yes, under practically no pressure, just put the water against the end of it. You might get a little oil out, but because of the difference in the viscosity of the oil, you will find the bulk of your water flowing through the empty straws?

Q How much pressure in your opinion would it take,in the example that you have given,to get that oil to begin to flow through the straws?

A You know, I have never figured that out. As I say, the sole purpose of this was to try to help explain to the Commission how water might go, can go into pores which contain only gas, under extremely low pressure or even a vacuum.

Q I think your illustration was a good one to establish some of the principles involved, and I think it would be desirable to know at approximately what pressure you think the oil would begin to move.

A Well, I don't know, that would be an interesting experiment.

Q Now, you have, do you, sands that contain gas and no oil in them down here in this Graridge application in this Caprock Field? Do you have such sands in this particular field?

A Well, I presume that that, that having been an oil sand which is produced under primary depletion, that currently part of the pore space is filled with connate water, part of it with residual oil, the balance is gas space.

Q Now after you have obtained fill-up in a flood and have pushed these pores containing gas only, pushed the gas out of them and filled them with water, and you continue to exert water under pressure against the sand base down there, then at that time what happens, and why doesn't the oil move through the sands?

A Well, I wish I knew why it didn't, but I can just cite cases of individual wells which have been drilled and completed in the so-called water soaked areas, in which the cores clearly indicate that there is still a lot of mobile oil left in place, yet when the wells are put on production, all they produce is water.

Q Now, after fill-up has been obtained, the illustration of the straws that are empty and the straws full of oil no longer pertains, does it?

A No, that's right. However, I presume that the reason you don't move appreciable oil at that time is that you have established such a high percentage of water saturation that the permeability to water is greatly in excess of the permeability to oil.

Now again, I don't mean to imply that you wouldn't move any oil. You will move some oil, but hardly in commercial quantities; for example, one well I think of in that category, which was produced for six months, continued to produce about two to three barrels of oil per day and sixty to seventy barrels of water a day, and in this particular flood, two to three barrels of oil a day was not a commercial well.

Q Could the rate of injection have been stepped up in that particular case, in your opinion, and have resulted in increased oil production out of that well?

A That is a very interesting question. I think it might have been increased some, whether or not it would be economic to do it, I don't know. We would like to try that on some projects.

Q Well, now, the exhibit that you offered in evidence here, the Exhibit No. 10 that you offered in evidence, shows, does it not, that increased oil recovery from an individual well can be obtained by stepping up the water injection rate when oil production has begun to decline? That exhibit shows that, does it not?

A Yes, that was certainly true in this project.

Q In this particular field, it not only could happen, it did happen?

A That is right, but I believe I testified on direct examination that it was feasible in this field because it was a very rich lease with a very high potential water flood recovery, so that even the operator felt that he was justified in the expenditure of some $50,000.00 to try and get additional oil.

Q Now, sticking to the physical waste aspects of the thing, rather than the economics of it, in the case of your well that was making only three barrels a day, economics aside, is there any reason why it would not have acted just like this eighty-acre

Oklahoma lease acted by injection of increased amounts of water into the injection wells, wouldn't you have gotten a kick, or an increase in your oil production?

A I think that's entirely possible. I hope it's right, you are right.

Q Now, in the Graridge application in the Caprock Field application here which was presented by Mr. Buckwalter this morning, you will recall that it was his opinion that it would not or might not be possible to increase the oil recovery by increasing the injection rate from eighty barrels to four hundred barrels. Do you agree with his opinion in that connection?

A Well, in my opinion, my opinion is that physically it would be possible to obtain some increased production, an increased production rate, however, I don't believe that the ultimate recovery would be as high, and there's also the question as to whether or not it would be economically feasible to spend the additional money required at that time to increase the rate.

Q Now, I believe you testified in connection with the three exhibits that are against the back wall here, that the operating costs did not go up with increased injection. I believe that was one of the points that you emphasized when you were presenting your exhibits up there. Now if that is true, why would it be uneconomic to go forward and increase your injection rates from eighty barrels up to one hundred fifty, two hundred fifty, four hundred barrels, so as to maintain the fifty-seven barrel daily average production within proration on the lease to abandonment?

A Well, here presumably, if the flood were set up for an injection rate of only eighty barrels per day per well, then the water injection plant would be designed to supply, to handle an injection rate of eighty barrels per day per well; lower pressures would be, injection pressures would be required; also much lighter pumping equipment would be required. Then when the time came to step up the rates in order to attain additional rates, the old equipment or the original equipment designed for low pressures or low volumes, is going to have to be modified or changed, and replaced with heavier equipment which will furnish higher rates. Also it's generally the case pumping units will have to be changed out, pumping equipment will have to be changed out.

Q In the four hundred barrel injection rate case in the Graridge application, you are going to have to, from the very inception, put in equipment which is capable of handling that rate, are you not, in the very beginning in the four hundred barrel case?

A If you can use that rate, yes.

Q Could not that same equipment be used for an eighty barrel rate and later stepped up to a four hundred barrel rate without any purchase of new equipment or increased cost?

A Yes, if the big equipment were installed initially, it would be, but it's kind of poor business to go out and buy a lot of expensive equipment which can't be used and utilized for a number of years.

Q Your equipment costs would be the same in both cases?

A If designed for four hundred barrels a day per well.

Q One operating under proration and one operating with unlimited capacity, you would operate with the same equipment cost?

A I think any prudent operator who felt or knew that he was going to be restricted to eighty barrels per day per well injection certainly would purchase equipment capable of supplying that eighty barrels a day per well and not equipment which would supply four hundred barrels per day per well.

Q But if at the beginning of your project it was recognized that you had to operate within proration, it would then be prudent to put in equipment at the inception of the project which would be capable of injecting from eighty up to four hundred barrels, if you knew that you were going to have to operate under a regular unit allowable, rather than under an unlimited allowable, and your costs would be the same in both cases, wouldn't they?

A Yes.

Q So then the factor of additional cost for equipment completely drops out of the picture, does it not?

A Yes, except for the fact that you have expensive equipment which you have bought and paid for, and it's setting there and only running at twenty percent capacity.

Q In other words, you make a little less money on the project?

A That's right, and I can visualize projects where if that were the condition, it would make conditions so unfavorable that a prudent operator would make the decision not to proceed with the flood.

Q Of course, even in prorating fields, assuming that there was sufficient demand, you could make more money by producing more oil than the thirty-seven barrel unit allowable, couldn't you?

A Yes.

Q More money could be made by getting a faster payout?

A Right.

Q The same problem that exists in the prorated field as in the water flood, the same economic problem exists in both fields?

A Except you have one other factor in your water floods, your operating costs are appreciably higher than they are in your primary fields.

Q What are the factors, Mr. Earlougher, that make your costs higher in water flooding than in primary operations?

A They are the factors of water injection, maintaining the water supply, conditioning the water,pumping the water to the injection wells, generally, you have twice as many wells to keep track of; there is a good deal more data required, too, in order that you can properly analyze your results; also you will handle larger volumes of fluid on the producing side.

Q Now, in your opinion, Mr. Earlougher, could most any of the water floods that you have said could be operated at a profit and a reasonable payout, reasonable return on the investment, be operated profitably at thirty-seven barrels times the number of wells on the lease?

A No, I will say that all of them would not fit that picture. There are some of them that your statement would be true, but there are many others it would not be true.

Q Now we have heard testimony today that in Oklahoma the average for producing wells is somewhere around eight barrels, and that the top in the State of Oklahoma is somewhere around seventy-eight barrels. Now is it your opinion that those floods in Oklahoma are not operating at a reasonable payout or reasonable return on the investment?

A Some of them are, some aren't.

Q Mr. Sarlougher, referring you to your exhibit 10, I understood that it was your testimony that this exhibit shows that if the higher injection rate had been started back in 1952, that you would have recovered more oil than was recovered in fact or will be recovered in fact?

A Yes, I think that is correct.

Q Wherein does that exhibit show that fact, can you please explain that to us?

A That brings up a very interesting question which I'm glad to get into. It just happens that back in June of 1952, in fact, the decision was made in May by the operator that he wished to curtail his flood production from this lease because of excess profits tax, so thatthe, in effect, the peak production rate indicated on this curve for May of 1952, I don't think is the actual peak which would have been reached on this lease if the operator by his own choice had not decided that he just couldn't afford to produce so much oil that year. It happened it was a small corporation who had been relatively inactive back in the late forties; his base rate for the excess profits tax was extremely low, and this flood was coming up to too high a peak, so in the middle of that year he decided to cut back, even with the danger of some loss in ultimate recovery.

I thought that we had a condition here where we might do some regulating. The regulation was done by decreasing injection rates in the three inside wells and trying to pick some of it up on the outside line wells, to try to hold the oil on the eighty-acre lease. Well, you will note that the production declined to around four hundred ten barrels a day in December and was around four hundred thirty barrels a day or so in November; then it was about four hundred thirty barrels a day in December. In January the operator was ready to take his oil again, but much to the disappointment of several of us, it hit a peak of five hundred twenty barrels a day and immediately started a decline.

In comparing this lease with other leases in the area, we have, it's very reasonable to conclude that had this production rate not been cut back, it would have, if not continued to increase, it would have at least flattened for about seven to eight months and then declined. Under those conditions, the ultimate recovery would actually have been a few thousand barrels more than it's going to be under existing conditions.

Q How do you know that it will be?

A Well, that's my opinion, based upon a study of the detailed operating data, detailed well production data, and all of the information available on this lease.

Q This particular graph doesn't show that fact, does it, because you don't know what the conditions would have been if something else had happened out there on that lease? You can't portray that on this graph, can you?

A No, the performance of course can't reflect it, because you can't go back and do it over.

Q Is part of your opinion to the effect that oil was lost based on a comparison with another lease in this same field?

A Yes, sir.

Q Have you any information as to the original oil in place in the two leases, oil in place at various pertinent dates in the two leases?

A Yes, sir, we have.

Q Is there a relationship in your opinion between the oil that is there originally and what might be recovered on primary and on secondary?

A Actually the oil in place at the time water flooding started was very similar on both leases.

Q Did you have the same sand thickness on both leases?

A It was approximately the same. I don't have the figures here in front of me, but in each case we had, as I say, core data, complete core data from some twenty-two wells on each project. We had about as much reservoir information as it's possible to obtain.

Q How were your cores taken?

A Some of them were electro-drill cores, some were cable tool cores.

Q Were they taken with mud, water or air?

A Oh, they were taken with water. It so happens that up in this area and in northeastern Oklahoma, we have conditions that apparently are a good deal different than they are on the Gulf Coast, inasmuch as a lot of the reservoirs we have worked with were operated under vacuum for years, and we have found that cores cut with water will directly give you the oil saturation still in place, and water flood recovery estimates can be based directly on that data. Cores taken later in the life of a flood, of which we have had several, indicate and have shown a much lower saturation.

The difference in the oil saturation in the cores at the start of the flood, and anywhere from two to as long as six years later, we have found matches very closely the actual oil recovery obtained from the leases.

Q In your comparison of your rate of one barrel per acre foot per day which you say is a good rate, I believe you say, is that correct, a good rate?

A That's right.

Q And your comparison of floods that have been operated at that rate with floods that have been operated at a much lower rate, somewhere in the range of two-tenths or three-tenths of a barrel per acre foot per day, do you think that it is possible that the reason for the apparent recovery differences that you have observed is because the floods that were operated at the low rate were poorer floods which wouldn't take the water as easily to begin with; and that the floods that were operated at a barrel per acre foot per day were good floods that would take the water -- by good floods, I mean those that had more oil there to begin with?

A When you differentiate between your good floods and bad floods, first you define them as a good flood, one which would take the water, and a bad flood, one which wouldn't take the water, which would be a reflection of the permeability; and then, if I am not mistaken, you used another, the good flood had the good oil saturation and the poor one has a poor oil saturation. You have me a little confused there, because you are bringing in two different terms.

Q I'm sorry, I didn't intentionally do so. Let's put it this way. Your zones that have low permeability, I take it, you find it more difficult to have them take as much as one barrel per acre foot per day, is that right, where those that have high permeability, you can easily get in the barrel per acre foot per day?

A That is the general direction of the relationship between the two, yes.

Q Would you generally expect to get more oil out of those with the high permeability or the low permeability?

A What do you mean by "low permeability"?

Q Well, do you want me to give you a range?

A Yes, please.

Q Four millidarcies on the one hand, as against five hundred millidarcies on the other.

A If you have sufficient, providing the sand is at a great enough depth, the four millidarcies sands, in my opinion, will flood as well as five hundred millidarcy sands.

Q What would be the range of permeabilities that would be required before you would find difficulty at, say a depth of five thousand feet, of putting in a barrel per acre foot per day? How low would you have to go?

A Well, that brings up a very interesting question, that's probably something below one millidarcy.

Q If the depth were less, of course, you would be in a position to increase the permeability and still find difficulty in getting the water in?

A Yes.

Q In your opinion, would it be possible that there would be a correlation between the original oil in place in these floods that you flooded at less than a half barrel, than those that you flooded at a barrel?

A Let me just clear up one point. Now actually we have not flooded, we have not run any of the floods that we have engineered directly at no injection rates as low as two-tenths or three-tenths per barrel per acre foot.

Q You have never run one that low?

A That data has come from other floods that we studied later in the life, which were operated at those low rates; and in that connection, I recall one such flood which we reviewed that had been operated at an injection rate of about two-tenths barrels per day per acre, quite a little core data secured prior to water injection were available. The core data indicated a good oil saturation still in place, one very favorable for water flooding, and also a favorable permeability. In other words, it was a condition which would have supported and operated under injection rates of at least five-tenths of a barrel per day per acre foot, and possibly as much as three-quarters of a barrel per day per acre foot. However, the individuals who were operating this flood had chosen to use very low injection rates of about two-tenths a barrel per day per acre foot.

In turn, the water flood oil recovery from this operation was about fifty percent of that which has been obtained on other floods in the general area with similar sand conditions, but which were flooded at higher injection rates.

Q Did the other floods have the equivalent oil in place originally?

A Yes.

Q Was the low recovery from your two-tenths barrel flood due to early economic abandonment, or was it abandoned for economic reasons, or is there some other reason why the recovery wasn't there?

A We attribute it to the low rate of oil production and the relatively high economic limit. In other words, to answer your question, the economic limit is going to be, that is going to be one factor; however, in this case, if the production curve were extrapolated for as much as five or ten years beyond the economic limit, the ultimate recovery still would not be up to what reasonably could have been expected under higher rates.

Q What caused, in your opinion, what is there about that two-tenths barrel rate, aside from the economic limit aspects, which caused the oil to remain in the reservoir instead of being produced in that case?

A I don't know.

Q With respect to your Exhibit No. 14, I believe it's 14 -- excuse me, 15, the one that has the colors on it on the wall back there, was that prepared from a composite of a number of different floods, or in what manner was the information on that exhibit obtained?

A Well, I thought --

Q Perhaps I didn't understand.

A I thought that I explained that it was prepared from Exhibit 13, from the middle chart on the wall.

MR. COOLEY: 14 is your middle.

Q In other words, that was prepared from the same floods that you used on the first one of those three exhibits, is that right?

A Come again, please?

Q You used actual floods concerning which you have data in your files, is that right?

A Yes.

Q And how many floods did you use?

A We used seven floods in compiling the middle chart.

Q Were those floods equal in all respects except three, those seven floods?

A Would you explain what you mean by "equal"?

Q Sand thickness, permeability, oil saturation?

A No, they were not.

Q There were differences from one to the other?

A That is correct.

Q Was there a substantial range of differences between them?

A Yes, there were appreciable differences. In fact, those seven floods range from the most successful to, I think, one that only paid back the cost. We purposely picked a range of floods to, we studied a range of floods to see what we would get with this type of analysis, and it is, let's say it is indicated that throughout this range, the ultimate water requirements based on total pore space were similar.

Q Were you able to isolate the various differences in sand thickness, saturation, permeability, so that you could obtain solely the question of rate effect?

A No, well, actually the middle curve does not pertain to rate effect. For example, Exhibit 14 was used as a basis for constructing the rate time curves in Exhibit 15.

Q Each of those floods, on the assumptions that you have made there, have the same recovery efficiency, regardless of the produced rate?

A No, this does not deal with recovery efficiency. In this case the cumulative oil production as percent of possible ultimate, in this case the possible ultimate represents the actual ultimate which is being obtained in the field from each of these floods.

MR. McGINNIS: That's all.

MR. McGOWAN: I have two or three redirect questions, if I might.

REDIRECT EXAMINATION

By MR. McGOWAN:

Q Mr. Earlougher, when you were asked a question concerning the average well production in Oklahoma, the figures as I understood Mr. Stipes to give them, and I wondered if you understood them the same -- Mr. Stiles, I mean -- was that that was the average for all wells, whatever States they might be in, that was subject to water flood order in Oklahoma?

A Yes, that's the eight barrels per day.

Q You were asked if thirty-seven barrels per day for each producing and injection well on a unit would not be sufficient to take care of the production that would be needed from that unit. I believe you stated "no", to that question. Would that not depend to a great extent, possibly, upon the size of spacing in that unit?

A Yes, it would.

Q And it would depend, would it not, to a great extent upon the phase of that particular unit? It might not be enough during its peak, but might be enough during other periods of it?

A Yes.

Q We heard the phrase many times in your cross examination, "economics aside". How many operators would you estimate that you had evaluated a project for in your consulting business, how many different companies or clients have you evaluated projects for, just roughly?

A I don't know, several hundred.

Q Have you ever found one of them that asked you to evaluate one, economics aside?

A No, I haven't.

Q Would it be fair to say that a barrel of reserve is not a barrel of reserve unless it is economical to recover it?

A That is correct.

Q Would it not also be fair to say that oil left in the ground by reason of economics is waste just the same as if it were left in the ground for any other reason?

A Certainly.

Q Then a method that because of economics would leave oil in the ground that could be recovered economically by another method would be a wasteful method, would it not?

A Yes.

Q One other question, Mr. Sarlougher. We heard quite a bit on this business that you desire a barrel of water per day per acre foot injection rate. That is on the assumption, is it not, that you have a reservoir that is sufficiently susceptible to water flooding that it will take it?

A That is correct.

Q Now, if you have a reservoir that will take only a half a barrel or six-tenths of a barrel, then that obviously is the most efficient rate for that particular reservoir, is it not?

A That is a maximum rate, why, certainly it is the most efficient.

Q It simply means that you have a reservoir in that instance that is susceptible to water flood, as is one that will take a barrel?

A Yes.

MR. McGOWAN: That is all.

MR. PORTER: Any further questions of the witness? The witness may be excused.

(Witness excused.)

MR. PORTER: Is that all the witnesses you have, Mr. McGowan?

MR. McGOWAN: Yes.

MR. CAMPBELL: I understand Mr. Wright is going to be cross examined in the morning?

MR. PORTER: Yes.

MR. McGOWAN: Am I correct that your case in chief, except for rebuttal testimony, you are through with it?

MR. CAMPBELL: I'm not sure. I want to hear the rest of my case here. I'll make that decision when Mr. Wright is finished.

MR. McGOWAN: Being part of the applicant, we have rebuttal rights, too.

MR. PORTER: The hearing will recess until 9:00 o'clock in the morning.

(Whereupon, the hearing was recessed until 9:00 o'clock A.M. on Tuesday, October 29, 1957.)

BEFORE THE
OIL CONSERVATION COMMISSION
Santa Fe, New Mexico

IN THE MATTER OF:

CASE NO. 1324

TRANSCRIPT OF PROCEEDINGS

VOLUME 2

PAGES 204 - 428, INCLUSIVE

October 28, 29, & 30, 1957

DEARNLEY - MEIER & ASSOCIATES
INCORPORATED
GENERAL LAW REPORTERS
ALBUQUERQUE, NEW MEXICO
3-6691 5-9546

LAWYER'S NOTES

Page	Line	

I N D E X

MR. PORTER: The meeting will come to order, please. Mr. Hinkle, will you call your next witness.

MR. HINKLE: If the Commission, please, we would like to have Mr. Roy Bayes sworn.

(Witness sworn.)

ROY A. BAYES

having been first duly sworn, testified as follows:

DIRECT EXAMINATION

BY MR. HINKLE:

Q State your name, please.

A My name is Roy A. Bayes.

Q By whom are you employed, Mr. Bayes?

A Humble Oil and Refining Company.

Q Where are you located?

A Midland, Texas.

Q How long have you been with the Humble?

A Eleven years.

Q In what capacity?

A My present capacity is Assistant Division Petroleum Engineer in Humble's Western Division, which has headquarters at Midland, Texas.

Q Are you a graduate petroleum engineer?

A Yes, I graduated from Oklahoma University in 1943 with a

B. S. degree in Petroleum Engineering.

Q Have you practiced your profession since your graduation?

A After graduation, I went into the Army, sir, and joined Humble in 1946, and I have been with them ever since.

Q What has been the nature of your work with the Humble during the past 11 years?

A I spent about two years in Humble districts in routine training program, drilling and production operations; at a later date, I spent a year as District Engineer in charge of the engineering work in the district; for two years I was in Humble's southwestern, Southwest Texas Division office in Corpus Christi, and in the Reservoir Engineering Section. I spent two years in our Houston office coordinating unitization activity, in which Humble had interests. For three years then in Houston, and in Midland in reservoir engineering; the latter two of those three years, I was Division Reservoir Engineer at Midland, and for the past year, I have served as Assistant Division Petroleum Engineer, in charge of general field and reservoir engineering.

Q Have you had occasion recently to make a study of the probable effect of unrestricted water flood projects in New Mexico on the state allowable?

A Yes, sir.

Q Do you have any exhibits which you have prepared --

A Yes, sir, I do, sir.

Q -- giving the results of your study?

A Yes, sir.

Q Will you refer to Humble's Exhibit 17, and explain to the Commission what it is, and what it shows?

A We have endeavored to investigate the effect of various oil production rates upon the unit allowable of New Mexico. We felt if we could establish a realistic relationship between total allowable production and the State's unit allowable, we would then be in a position to single out any one field, or any group of fields, from the southeastern part of the State; and, furthermore, to single out any one rate in that field and determine what it's effect would be upon the unit allowable for the State.

The basis of our working has been the Commission's October 1957 allowable schedule, which at this time totals approximately 288,000 barrels of allowable production for October. Now, that includes some 9,000 barrels of condensate or distillate and we have deducted that amount, and are dealing only with oil, the precise number of 279,541 barrels, and for simplicity, I would like to just call that number from here on as 280,000 barrels.

We could take the October allowable schedule and determine what the unit allowable for the State would be for various unit allowable rates.

On the Commission's schedule is listed the capacity of wells to produce, their gas-oil ratio, so by assuming a unit allowable of less than the current 37, we could, by going through each of the approximate 9600 wells in the schedule, determine what the State allowable production would be, if for example, the unit were set at 36 or 35, or some other number.

This we have done, to establish the curves which are shown on Humble Exhibit 17, and I should like to explain just a minute as to how this was determined. There are four curves which are entitled "Penalized High Gas-Oil Ratio".

Incidentally, you notice vertically, this is the State unit allowable, and across, horizontally, the entire production for southeastern New Mexico in barrels per day. The curves shown are allowable for wells penalized for high gas-oil ratio. Those wells which are not capable of making the unit allowable, which we have entitled "Limited Capacity", and then allowables for wells which are capable of making the unit allowable, which are entitled, "Non-Marginal". I believe on the New Mexico schedule, the penalized for high ratio wells and the limited capacity wells are carried as marginal wells.

Now, on the points plotted opposite 37 unit allowable, we have determined by going through the 9600 wells on the schedule just how much of the State's 280,000 barrels allowable production goes to the penalized high ratio wells, to the limited capacity, and to the capable wells, and have added those three totals of oil together to determine the end point shown on the total curve, and this end point on the total curve opposite 37 is 280,000 barrels, the October allowable production.

We then assumed that the State allowable would be 34, and have produced through the allowable schedule for the 9600 wells, and determined what the allowable production for the State would be with a unit allowable of 34, to plot the point on the total curve; and we have done similarly for points of the unit allowable of 30 barrels, and the unit allowable of 27 barrels.

You might wonder why we found it necessary to delineate between a limited capacity and penalized high gas-oil ratio wells to arrive at this total curve. If the unit allowable is set at 37, and the well is capable of making 36 barrels, it falls in the marginal class; but if the unit allowable were 34 barrels, that 36-barrel well would then become a capable well, and would be subject to proration, so we have found it necessary to delineate between those two to establish this total curve.

We feel that that curve entitled "Total" on this exhibit is a realistic relationship between the unit allowable and the total allowable production for the southeastern part of the State. Now, with this total curve we are able then to single out any one field, or any group of fields, to assign any given oil production rates to those fields, and to determine what it's effect will be on the unit allowable.

We have done that on the next chart, and I should like to mention that for simplicity purposes, we have assumed that the State's market would remain at 280,000 barrels of allowable production, and then to see what the unit statewide allowable would have to be, holding to that 280,000 the same as for this month of October, if varying rates of production come into the picture.

In the interest of time, I shall not bother the Commission with the steps, the mechanics through which a field can be singled out and any individual oil production rate taken into account. It is a straightforward matter, and we can proceed directly to the next exhibit, which is Humble's Exhibit Number 18.

I should like to describe this exhibit. It is a plot, or it is entitled "Relationship Between the Statewide Unit Allowable and Producing Rate at the Caprock-Queen Field". The coordinates on the chart, unit allowable on the vertical scale; and horizontally, to describe this in easily understood terms, the horizontal factor is the Caprock-Queen allowable expressed in terms of barrels per day per producing well.

I should like to point out here that we have assumed on this chart first of all that the allowable production for the southeastern part of the State remains fixed at 280,000 barrels, and secondly, that the entire field is under effective water flood production: that it's under 5-spot production, and under a field-wide 5-spot program, one-half of the wells would be on injection service, one-half would be producing wells. So this horizontal factor, Caprock-Queen allowable barrels per day per producing well, means per producing well, as differentiated from an injection well. So, this is actually oil production from each well that produces oil when the field is under water flood production.

Now, from this relationship, we can choose any allowable rate that might be assigned to the Caprock-Queen's wells under water flood, and immediately tell what influence that would have upon the State unit allowable.

For example, if the average allowable for the field wells per well were 100 barrels per day, and it's necessary to hold to the 280,000 barrels market, we have but to reduce this hundred barrels per producing well allowable, and see that the unit allowable would have to be in the order of 33½ barrels per day to satisfy the 280,000 barrel total market.

Similarly, if the average producing well allowable is 150 barrels, the State unit allowable would then have to be about 30 barrels to satisfy this 280,000 total for the southeastern part of the State.

It might make it a little more explanatory, this curve, the first one on the Exhibit 17, the relationship of one barrel per day on the State's unit allowable is about 46 to 4700 barrels per day of extra production; in other words, for each 4700 barrels of production that's added onto the 9600 wells that are scheduled on the October schedule, to hold to the 280,000 barrels, the unit allowable will have to be dropped one barrel per day. We might look at it to be 46 - 4700 barrels per day added into the State is equivalent to one barrel per day on the unit allowable.

Q Mr. Bayes, this morning, I believe Mr. Cooley asked Mr. Wright on cross-examination for a comparison of primary and secondary investment in operating costs with reference to an incentive to water flood. Do you have any remarks you would like to make in connection, with respect to that matter?

A Yes. Let's take -- I forgot one thing I wanted to bring out here.

Q Go ahead.

A For each 4600 additional barrels of oil brought in to the State, then the effect is the one barrel on the unit allowable that I have mentioned. Now, it's not necessary for that 4600 barrels to come from the Caprock-Queen pool; that has a compounding effect; and if 4600 barrels comes on in the Caprock-Queen Pool, and 4600 barrels comes on in another pool, then it has the effect to hold to this 280,000 barrels to bring the State unit allowable down two barrels.

MR. HINKLE: Will you please read the question?

(Question read by reporter.)

A Yes, I believe I understood that statement made this morning regarding the relationship of investment and operating costs, as to primary and secondary recovery operations. As I understood Mr. Wright, he replied that investment and operating costs for the secondary operation were higher than the primary operation. It's been stated earlier in this hearing that Humble has no wells in the field. We have not drilled here, but we have wells at similar depths in the area, and we think a reasonable estimate of the cost to drill a well, to put a flow line on it, and a tank battery, to install the pumping unit, which certainly would be required, that drilling, complete, flow line, tank battery cost should be in the order of $40,000.00 per well.

Then I believe the applicant's, on their Exhibits Four and Five had developed almost complete economics for 1760 acre pilot area. Now, if that 1760 acre area was drilled on 40-acre density, that would be 44 wells, so the primary development costs for that unit should then be 44 times $40,000.00, or a million seven hundred and sixty thousand dollars. That's primary development investment only, and does not include pumping unit.

Then, from the Applicant's Exhibit Four also, it's given on that exhibit that to install, or to develop the secondary oil project, with the 400 barrel per day injection system, the development cost was $704,000.00; and eight years of operating expenses were a million and ten thousand dollars.

Now, the total of the secondary development costs and the eight years of secondary expenses, from the Applicant's Exhibit Four, totals a million seven hundred and fourteen thousand dollars.

Now, to drill that same area on a primary basis, just drill it and complete the wells, a million seven hundred and sixty thousand dollars, so it would cost more to drill a well for primary purposes than to install that secondary flood project and pay the operating expenses for eight years. That is equally true for the 80 barrels per day injection system that is listed on Exhibit Four.

I think the obvious point here is that you use the wells that exist when it comes time to start your water flood off, so the big investment is in the initial drilling, when the wells are first drilled.

MR. HINKLE: That's all.

MR. PORTER: Anyone have a question of the witness?

MR. CAMPBELL: I have some questions.

CROSS-EXAMINATION

BY MR. CAMPBELL:

Q Mr. Bayes, in your calculations with reference to the impact of water flood oil upon the State market, you have assumed throughout attaining 280,000 barrels per day demand, have you not, for allowable?

A Yes, sir.

Q Do you think that's a realistic approach?

A Mr. Campbell, I did not attempt to forecast or look into what the Bureau of Mines estimate might be, or the market demand. I simply chose this month of October, that's the number that we have before us, 37 barrels, and 280,000, and I think it serves to illustrate the purpose; to answer your question, sir, I do not know.

Q Well, do you not, or does your company not, anticipate that other things being equal, there will eventually be some increase in demand for domestic crude oil, or have you given up?

A Mr. Campbell, I think we could all say we hope there is some. I just tell you honestly, sir, I have no picture of the future.

Q If there is some, do you not think water flood oil is entitled to reasonable share of that market by it's development?

A Yes, sir. As has been stated, Humble is an active water flooder, and we recognize that as an operation, and I'm not -- don't mean to imply that we would like to deny water flood oil from a rightful place in the State market.

Q Well, then what is the basis for your exhibits then? Aren't you undertaking here to, in effect, exclude that water flood oil from New Mexico market in the future?

A Not at all, sir, but simply to show that if unrestricted production is granted, that it has to have the effect of working on the proratable oils.

Q Of course, that's quite obvious. May I ask you, sir, if you know, what is the total daily production of Humble in New Mexico in October?

A I'm not quite sure, Mr. Campbell. I could make a roundhouse guess. I'm not -- I think we are in the order of 10,000 barrels; I am not sure.

Q You studied the October allowable for this purpose, didn't you?

A Yes, sir, but 9600 is a lot of wells, and I don't remember the details.

Q Well, would you say 10,000 barrels?

A I think that's probably in the correct order, sir, I can look it up.

Q What percentage of the total daily allowable in New Mexico does that represent?

A Well, I believe that's about 3½%, if my 10,000 is right, sir.

Q How many known marginal units does Humble produce in New Mexico?

A I do not know, sir.

Q This would not have any effect upon your marginal unit, would it?

A It would not have any effect only at such time as the unit allowable was less than the present capacity of the well.

Q Well, do you know approximately how many top unit allowable wells Humble operates in New Mexico?

A No, I do not, sir.

Q Do you have any idea of the percentage of your production of 10,000 barrels per day, which is marginal and which is non-marginal?

A I do not, sir.

Q Isn't it a fact, Mr. Bayes, your principal concern about the impact of water flood oil in this situation is not upon the Humble primary production in New Mexico, but in the State of Texas?

A No, I would not say that at all, Mr. Campbell. Insofar as my work here is concerned, it has no relationship to Texas.

Q Doesn't Humble have a considerable amount of primary production in the Gulf Coast area of Texas?

A Yes.

Q Isn't the pipeline,which services that area out of West Texas and New Mexico a factor in the allowables in that area in Texas?

A Mr. Campbell, I don't really know the answer to your question. I have seen maps on which pipelines are drawn, and I have the recollection that it is the system from New Mexico and West Texas goes on to the Gulf Coast.

Q Then, as a matter of fact, isn't it the principal concern of Humble, that pipeline may be full of oil before it reaches your Gulf Coast production?

A That has nothing to do with what I am saying today, sir.

Q Mr. Bayes, in connection with your presentation, you at least left the impression that it's the feeling of Humble that if there's going to be any sizable impact upon the primary production in New Mexico, or in the non-marginal production, or the rate of development, that capacity allowables should not be granted to water flood projects, is that your general position?

A Capacity production should not be granted to water flood projects.

Q Because it will have an impact on the other wells in the State?

A We feel those wells should be prorated, and take their rightful place with other wells.

Q Mr. Bayes,do you concede there are a number of other factors present in the determination of the available market for New Mexico crude oil?

A Yes, sir.

Q What are some of those other factors?

A Well, Mr. Campbell, I just might as well tell you, I'm not an expert on proration. I don't know what establishes the State's allowable or it's market, and I don't really think I would be helpful in --

Q Well, you presented these exhibits to indicate the impact of this particular phase of production on the market?

A On this month of October, 1957, basis, yes, sir.

Q Well, let me see if I can suggest some possibilities to you. Do you know anything about a deep well factor in the State of New Mexico, based upon the cost of drilling deep wells?

A Yes, sir.

Q Do you know anything about additional allowable that is occasionally given to wells in New Mexico on a spacing basis, on a unit basis?

A Yes,sir.

Q Do you think those are factors affecting the production from other wells in the State of New Mexico, or the allowables assignable to them?

A They are factors, very definitely, sir. They are included in the first exhibit I gave.

Q If you will pardon the expression, don't you think imports have some impact on the market demand for New Mexico crude oil?

A I think so, yes, sir.

Q Let me ask you this question: If it be true that to restrict the production of water flood wells below their capacity would result in waste, don't you think that's the last place where you should try to adjust the New Mexico allowable with regard to market demand?

A No, sir, I wouldn't say that was the last place.

Q Even though assuming that it would result in waste, I realize you disagree on that point; but assume there is a question of that factor, don't you think that there should be, if it is an impact, and we are assuming, that there should be other methods of restricting production that will not result in waste?

A Let me make sure I understood you. You want me first to assume there is waste?

Q If the wells are not produced at capacity without it, yes, sir.

A Now, you of course know that we as a company do not take that position.

Q I realize that.

A Yes.

Q We have been making assumptions here for two days. I'm asking you to make --

A Now, would you ask me?

Q I want to know if that is the case, don't you feel, particularly as a reservoir engineer, that if that is the case, if there must be some adjustment of where we are going to reduce, what wells we are going to reduce to get down to the market demand, that should be the last place you should look to accomplish that result?

A I would answer you this way, sir. If there would be waste, then we should take steps to protect it, or minimize it.

Q Then your answer would be "yes"?

A Yes, under the assumption that you gave us.

MR. CAMPBELL: That's all.

MR. McGOWAN: I have one or two questions I would like to ask.

MR. PORTER: Go ahead.

BY MR. McGOWAN:

Q Now, in preparing this curve, you took into consideration the present production of the Caprock Pool, did you not?

A Yes, sir.

Q Do you have any reason to quarrel with the figure of slightly in excess of 12,000 barrels a day that was reflected upon the earlier exhibits, as the present daily production from the Caprock Pool?

A No, I would not quarrel with it; we used in excess of 13,000.

Q Let's use your figure then of 13,000; I like it better.

A Okay.

Q Now, you have also assumed in your effect of unrestricted water flood production on this, that the entire Caprock Pool would be developed at one time, have you not?

A That's correct. No, I didn't, I said it was all under water flood, sir.

Q Well, at the same time, simultaneously.

A Yes, sir.

Q Do you have any quarrel with the figure 19,000 as the peak of water flood production that would be reached in the Caprock Pool if it was all put under water flood, I believe, within three to five years was the figures you used?

A That is one of the applicant's exhibits, 7 or 8, I believe.

Q Then I'll ask you a question. Maybe you would rather answer it. What will be the total production daily from the Caprock Pool, unrestricted, if it is all rapidly developed as a water flood project?

A I don't know the answer to your question, sir.

Q The impact on the market though from such an action would only be the difference between that production and the present production, would it not?

A That's correct, sir, and I would like to go ahead to answer you a bit more. I know the 19,000 barrels that you refer to, which comes about as you set one set of assumptions, and developing at peak rate for the field.

Out of curiosity I checked that just to see what it would do, the 19,000, and there is a period of open curve of about three and a half years at which time the Caprock-Queen Pool ranges from about sixteen and a half thousand to 19,000. During which time the average production of the producing well ranges between 58 and 66 barrels per day, and that alone would have the effect, under the conditions outlined, for the charts, of about one barrel on the unit allowable. Now, that would not even be up to the 74.

Q And that is assuming, of course, the entire Caprock Pool would have been -- just walked out there and just developed it, it would come to it's peak all at once, just like that?

A No, I would like to say there are a number of things that influence what that peak would be. The 19,000 barrel peak is one set of assumptions which generated a curve.

Now, for example, that same curve is predicated on an injection rate of 400 barrels per well per day, which is -- there's no assurance that that would be the injection rate at all. If the injection rate is higher, we can expect that curve to go higher.

Then, also the rate of development you mentioned, that's most influential on that curve. There's no reason to wait until the field is in the stripper stage to put it under water flood, when you can make more money water flooding than primary. It's a good business venture to go into whether the well is capable of 25 or 30 barrels, and when a pilot responds as nicely as this one seems to be, there's no reason to think, I believe, that operators will not see a good business venture and move to take advantage of it.

One other situation which could change that 19,000 barrel peak, I think, preferably, would be for large areas of the field to be unitized, and certainly there are economic advantages to unitizing. Unitizing would have the effect, probably of delaying the time at which some leases would go under flood, because it takes time to unitize. But then that whole unit would go under flood reasonably simultaneously, with peak up, more simultaneously, and I suspect that 19,000 barrel curve would go considerably higher.

So I feel it very realistic to say that there can be other assumptions made, which will change or which change the peak oil production that has been shown.

Q Now, I believe you stated, however, under the assumptions that have been pretty well used in this hearing, the increase in the Caprock production by reason of water flood would reduce the State allowable by one barrel?

A I make that as a matter of fact statement, sir.

Q The problem before the Commission at the moment is unrestricted production for this 1700 acres, I believe. Have you calculated how much additional production would be produced from that 1760 acres by reason of unrestricted -- In other words, how much excess over the present production you get?

A No, I have not, sir.

Q It would be much less than that, wouldn't it?

A Oh, I'm sure it would be, sir.

Q If I told you we calculated it and arrived in the neighborhood of over 266 barrels a day, would you have reason to question it?

A No, if that is your number.

Q That would be a completely insignificant effect on the market demand?

A Yes, it would, I'm quite sure, sir, in this pilot area. I think what we have to look to is that if this application be granted, then certainly other areas will go under flood in the same field, and as a matter of fact, in New Mexico. I believe, in looking through Commission records and orders and engineering committee reports, that there are nine fields which have pilot floods in one stage or another which we might describe as active, and there are some 2600 wells in those nine fields. 2600, let me say, 40-acre units, and I think there would be no reason to -- I think we would expect that this application being granted in this field, that it would be asked in other fields, and as I mentioned awhile ago, the effect of unlimited production in the field compounds with the effect from other fields.

Q Of course, they might not all be so successful as this one, might they?

A That's true, sir.

Q By the same token, based upon,I think, everybody's testimony including Doctor Hocott, the project started now will probably not have reached it's peak production until the existing project was already past, would it?

A I didn't understand.

Q A project, even in the Caprock field, say started next month, would not reach it's production peak until the other project had past it, and was on the downgrade?

A It takes time to generate a peak; depends on injection.

Q That would spread out your peak of production?

A It's possible.

Q You talked about it being developed rapidly. Do you know of any unit anything like this size, even though where it was unitized, that's ever been developed just almost simultaneously, I believe was the word you used?

A Well, I guess one of the best examples I might -- or, let me see, an example in Texas, now, there's a move under foot to create a 9-section pilot in the Graybridge, which would be a part of a 75 to a hundred section unit, a very similar depleted condition. I see no reason why Caprock-Queen could not be unitized.

Q Are you familiar at all with the North Burbank unit in Oklahoma?

A Hardly, sir.

Q If I told you it included a total of 20,000 acres, would you accept that figure?

A Yes.

Q And if I told you by agreement they were developing it at the rate of a thousand acres a year because they felt that was the best management policy, would you accept that?

A Yes, sir.

Q Do you see any reason why we couldn't peak the Caprock field to follow that pattern as well as any other pattern?

A I think it could be a pattern, yes, sir.

MR. McGOWAN: That's all.

MR. PORTER: Anyone else have a question? The witness may be excused. Did you offer these?

MR. HINKLE: Yes, I would like to offer Humble's Exhibits 17 and 18 in evidence.

MR. PORTER: Without objection, they will be admitted.

MR. HINKLE: If the Commission please, we would like to have Mr. Frank W. Cole sworn.

(Witness sworn).

DIRECT EXAMINATION

BY MR. HINKLE:

Q State your name, please.

A Frank W. Cole.

Q Where do you live, Mr. Cole?

A Norman, Oklahoma.

Q By whom are you employed at the present time?

A University of Oklahoma.

Q In what capacity?

A Assistant Professor of Petroleum Engineering.

Q How long have you been Assistant Professor of Petroleum Engineering?

A I'm beginning my third year.

Q State to the Commission briefly, your educational background.

A I have a B. S. in Petroleum Engineering, from the University of Oklahoma in 1948; an M. S. in Petroleum Engineering from the University of Oklahoma in 1949. Immediately after graduation, I was employed by the Humble Oil and Refining Company as a Petroleum Engineer. During my graduate studies at the University, I was a Graduate Assistant and taught undergraduate labs. During my undergraduate days at the University, I worked during the summer for various oil companies. I was with Humble until 1955, with the exception of two years when I was recalled to active duty in the Navy as a petroleum specialist. In September of '55, I resigned from Humble, and returned to the University where I am presently occupied.

Q Do you have any present ties or connections with the Humble?

A None at all.

Q As a professor in the University, have you made any studies in connection with secondary recovery operations?

A Yes, I am part of the graduate research faculty, and we are continually engaged, and I am directing on the average of four to five research projects, continually, on various phases of reservoir engineering, some of which deal directly with secondary recovery, others which may deal only indirectly with secondary recovery.

Q Have you been a consultant from time to time --

A Yes,sir.

Q In connection with the secondary recovery operation?

A Since I have returned to the University, I have been engaged principally, of course, in academics. I have, however, done some consulting and am doing some at the present time, in secondary recovery work.

Q Have you served on any committees having anything to do with secondary recovery?

A No, sir, I have not.

Q Have you kept abreast of all the literature that's been published in connection with secondary recovery --

A Very definitely.

Q -- water flood projects?

A I have been interested in water flooding since I was in school, and have kept abreast of water flooding developments and concepts, and currently, I'm not this semester, but I will next semester, and the last previous semester, I taught a graduate course in secondary recovery.

Q Are you the author of any publications concerning water flood projects?

A I gave one paper last year on water flooding, one aspect of water flooding. I am just completing a textbook in conjunction with another Oklahoma University faculty member on Elementary

Petroleum Engineering. I am in the process of writing another textbook by myself on Reservoir Engineering, and very shortly, I have already completed the series, and very shortly a series in Reservoir Engineering will appear in one of the trade journals, so I have concentrated principally in Reservoir Engineering.

Q Have you, yourself, made any study of rate of production in connection with water flood projects?

A Yes, sir.

Q Mr. Cole, from your experience and study of secondary recovery operations, state whether or not, in your opinion, water flood projects can be controlled within wide limits of rates of production, and injection without loss of maximum ultimate recovery of oil from a pool or reservoir as a whole?

A In my opinion, water flood production can very definitely be curtailed within wide limits without loss of ultimate recovery.

MR. HINKLE: That's all.

MR. PORTER: Anyone have a question of the witness?

CROSS-EXAMINATION

BY MR. CAMPBELL:

Q Professor Cole, you stated that you presently didn't have any ties or connections with the Humble Oil Company, is that correct?

A That's correct.

Q Well, you are appearing before this Commission as a consultant for Humble, are you not?

A Humble asked me what my position was. Of course, since I worked for Humble, I know the Humble people, I see them occasionally when they come to school interviewing our prospective petroleum engineering prospects. We discussed this problem, it's a current problem of interest, and Humble knew my position, and when this came up, they called me last week and asked me if I would state my views, and I agreed to do so.

Q Well, I'm not criticising you, I just want to make your position clear. You are not testifying as a -- you are a professor at the University of Oklahoma, you are not representing the University of Oklahoma faculty, or engineering department in this hearing, are you?

A That's correct. The views I express are my own.

Q That's what I wanted to make clear.

A Fine.

Q Now, you stated a general conclusion about your belief that the rate of production could be curtailed without causing any loss of recoverable oil. How much actual field experience have you had in secondary recovery projects?

A My field experience in secondary recovery projects has been limited. However, we are dealing with basic concepts. In my opinion, there is fundamentally no difference between a secondary recovery project and a water drive project.

Q What you are doing here then is simply concurring with the testimony of Doctor Hocott, is that correct?

A I think, basically, Doctor Hocott's testimony is representative of the beliefs of most, if not all -- I would like to retract that "all", since there obviously are some qualified engineers here -- but the commonly accepted engineering belief at the present time, and it's the same principles which are being taught in all of our major universities at the present time.

Q You mean to say that the theories and conclusions of Doctor Hocott are concurred in by almost all of the engineers who operate secondary recovery projects in the field, is that what you are saying?

A Let me -- I can't say that. However, I can say this. Just last week I lectured before an A.I.M.E. study group in Oklahoma City, in which there were approximately 60 engineers of all different companies. The purpose of this lecture was to deliver basic reservoir engineering concepts, and we discussed these concepts point by point. One of the points I made, which wasn't important to me at the time, but which grows more important as I sit here these days, is that, fundamentally, there is no difference in the displacement processes involved in either water drive by secondary recovery, or water drive by primary recovery. It's interesting to me that I had not one remark made at the time I made that statement. It is a commonly accepted principle.

Q Well, were those research engineers?

A No, sir, with the exception of one company, who has a small research organization, I don't believe there were any research engineers. I would say that 90 percent of the people were not research engineers.

Q Where was the meeting?

A Oklahoma City.

Q When was it?

A This was last Thursday evening.

Q Now, do you base your general conclusions, as to this statement you made, upon these theories of capillary effects and imbibition,like Doctor Hocott apparently does, is that where you start in your thinking on that?

A I start my thinking -- I think Doctor Hocott presented it, unless you really want me to, I would rather not.

Q I would rather you wouldn't. I would rather you answer the question.

A Capillary pressure is one of the factors involved.

Q Do you think there's any disagreement among your research engineers or laboratory people,with regard to that, insofar as the elements involved, or the measurement of it, or the degree of it?

A To my knowledge, no.

Q No disagreement?

A That's correct. No basic disagreement on the principles involved.

MR. CAMPBELL: That's all.

MR. PORTER: Anyone else have a question?

BY MR. McGOWAN:

Q Mr. Cole, have you observed or controlled any water flood project developed on the theory you have advocated to see if that theory proved out in the field?

A Since I teach a secondary recovery course, which involves water flooding as one of the elements of secondary recovery, we take data on depleted fields and predict behavior of those fields by several commonly accepted techniques, and as a matter of interest, we have used Mr. Stiles' method, who is at this time sitting here, and talked to us before. In 1949, Mr. Stiles came up with a very nice arrangement for predicting water flood behavior. I tried the method at the time he delivered the paper, and found it to work very well on data from some Bureau of Mines reports.

I have tried it several times since then, and it's a standard policy to use the so-called Stiles Method as one of our tools in prediction processes.

His method is independent of rate, and as an illustration, you can take his method with a hundred barrels per day injection rate, and come up with a certain economic limit. You can take a different injection rate, and as long as you maintain your water and your oil producing rates at a sufficient rate, you will still arrive at the same ultimate recovery and the same economic limits.

Q But the answer to my question is, "No", is it not?

A No, the answer to your question is yes.

Q What water flood did you prove this theory on?

A Well, let's see, just to verify, I haven't really made this calculation in three or four months.

Q I'm not talking about calculations, Mr. Cole, I was talking about a water flood that has been evaluated, started, and produced, which performed just exactly as your theory said it would, and has proved that your theory will work on water flooding a field.

A Yes, I was going to take this data, this data that I worked with last night was the only data I had available, and as I say, I worked this thing several times in the past, but just to refresh my memory, I took Mr. Stiles' theory in the Benoit Sand flood in Illinois, wherein we had complete reservoir information. The water flood, as I recall, was essentially depleted. He had an injection rate of a hundred barrels per day in a 10-acre 5-spot with a 10-foot sand section which was equivalent to one barrel per acre foot per day, which is in our high injection rate, which we have been discussing.

I decided I would apply a case of realistics to this problem, so I used a hundred barrels per day, the same rate Mr. Stiles used, and until we had achieved reservoir fill-up. Then I dropped my injection rate back to, just to the very minimum case of approximately 25 to 30 barrels per day of oil production, maintained it at that rate until my relative permeability relationships were such that I could inject a little bit more water, increase my injection rate, until I finally I came back to the hundred barrels.

In the final analysis, the recovery was exactly the same at the exact economic limits. There was no difference in the two, as those of us who are familiar with those calculations know in advance.

Q You did this in the pool, or you did it on paper?

A I did this on paper; it's obvious.

Q Then you don't know that the pool would have performed that way, under those lower rates, do you, you are assuming?

A Yes, that's correct.

Q That's what I asked. That's all I have.

A All right.

MR. PORTER: Anyone else have a question? The witness may be excused.

MR. HINKLE: If the Commission, please, we would like to call Doctor George Fancher.

(Witness sworn.)

DIRECT EXAMINATION

BY MR. HINKLE:

Q State your name, please.

A George Fancher.

Q Where do you live, Mr. Fancher?

A Austin, Texas.

Q By whom are you employed?

A University of Texas, and the Texas Petroleum Research Committee.

Q And what is your capacity at the University?

A Professor of Petroleum Engineering; chairman of the, at the present time, and director of the Texas Petroleum Research Committee.

Q State to the Commission briefly, your educational background.

A Undergraduate work was done in California; I have taken graduate work at the University of Maryland, the University of Michigan, Colorado School of Mines. I have a Bachelor of Science degree, and a Master of Science degree, and a Doctor of Science degree.

Q Doctor of Science from the University of --

A From the Colorado School of Mines.

Q Colorado School of Mines. What year did you graduate from the Colorado School of Mines?

A 1930.

Q Have you had any experience in connection with secondary recovery operations?

A Well, just about 30 years.

Q When did they first start?

A In 1928 I was a graduate student at the University of Michigan.

Q And what area did that --

A In Pennsylvania. And then I went out to the Colorado School of Mines for three years, and in 1931 returned to the Penn-grade region as Assistant Professor of Petroleum Engineering, in charge of the Petroleum Research program there, for which the legislature of Pennsylvania had appropriated money. There, this program of research was begun to aid the Penngrade Crude Oil Association Producers, the principal factor of which were the Bradford Producers, the water flooding areas.

So my duties, I became deeply involved in the program of research there, in which came such things as the measurement of permeability, core analysis; we studied, made flood spot tests; we studied production data obtained, made numerous trips to Bradford and accumulated production data, and then endeavored to make studies of those.

Q Later on, did you have any experience in Texas, or any other states in connection with water flood projects?

A Yes, sir, I had the privilege of putting in the first legal water flood in the State of Kansas.

Q What year was that?

A That was in 1934, '34 and '35. I was employed by a small company, that's why I left Penn State, to aid in pioneering this water flooding out in that area.

At that time, to my knowledge, there was only one water flood in the midcontinent, and that was the Carter Oil Company's project, experimental project, down in the Netawaka area, but we put in, after some necessary bills were passed in the legislature to make this practice legal, they got Permit Number 2, and I put in the first water flood in the Sealy Pool in Greenwood County.

Q State of Texas?

A Kansas.

Q In Kansas?

A Later -- you asked about Texas?

Q Yes.

A Came to Texas in December '35, and in January, I believe, this would be subject to verification as to the month, the date, in January, appeared as a witness for the State on the first water flooding application in the State of Texas, by the Texas Company for the Fry Pool in Brown County, Texas. The hearing was held in Fort Worth. Following that hearing, which was widely attended by many operators from the Wichita Falls area, who had come down to protest, I, aided by counsel and advised periodic field trips, periodic examinations and results, the second, the third, and the fourth and a number of others.

Q Have you been a consultant from time to time in connection with water flood projects in the State of Texas and other places?

A Yes, sir.

Q What committees have you served on, or serving on at the present time, having anything to do with secondary recovery operations?

A Well, from the time of its organization in the eastern district of Pennsylvania, I was a member until the time when National Committees were abolished, that is, standing National Committees were abolished in 1950, I was a member of the Secondary Recovery Committee of the American Petroleum Institute.

During a good many years of that time, the latter years, when

I was in Texas, I was, in addition, Chairman of the Standing Sub-Committee on Secondary Recovery to that parent committee, in the southwestern district.

I have been a member of the Secondary Recovery Pressure Maintenance Committee, the Inter-State Oil Compact Commission since its organization.

Q Are you chairman of that committee at the present time?

A No, sir, I'm not chairman of the committee. I am called Meritorious Chairman.

Q During all this period of time, have you made any study of rate of production of water flood projects?

A Well, I have, although I have worked in oil, I mean, I have had practical experience in oil fields of California and some other places, the latter years principally in connection with consulting work; nevertheless, I have been teaching for many years, and been a member of the faculty at the University of Maryland, and at Michigan, and Colorado School of Mines, the Penn State College, and the University of Texas, and my job has been, in doing that, I have been very much interested in this method of increasing oil recovery, and I have studied that problem continuously.

That was particularly a problem, if you will permit a moment, in the depression when I went to Penn State, it was a critical problem, because the price of oil was dropping, the projects were under way, and the question arose, "Can these be curtailed?"

Naturally, there wasn't any unanimity of opinion as to whether they could, or what was the best way to do it when it must be done, but if you would sum it all up, I think Ralph Zucht, former president, one of the very pioneers in this work, made a fortune in it, former president of the Independent Oil Association of America, delegate from the Secretary of State to Great Britian during the war, as Petroleum Administrator, and occupier of many posts, and a well informed man, has said many times publicly and privately,that water flooding operations might be likened to the turning off and on of a spigot. He said that was one advantage of water flooding, that they could be turned on and off like a spigot --

Q Now, Doctor --

A -- opened in times of feast and shut in in times of famine.

Q -- in your experience in secondary recovery operations, state whether or not, in your opinion, water flood projects can be controlled within wide limits of rates of production, and injection, without loss of maximum ultimate recovery of oil from a pool or reservoir as a whole?

A They can.

MR. HINKLE: That's all.

MR. PORTER: Anyone have a question of the witness?

MR. CAMPBELL: Just a few.

MR. PORTER: Mr. Campbell.

CROSS-EXAMINATION

BY MR. CAMPBELL:

Q Doctor Fancher, you stated that you were now at the University of Texas?

A Well, I'm presuming what your question is. I'm appearing for the Humble Company.

Q All right. What is the Texas Petroleum Research Committee?

A The Texas Petroleum Research Committee is a state agency established by joint resolution of the Board of Directors at A. & M. College, the Board of Regents to the University of Texas, the Railroad Commission of Texas, and it's supported by appropriation from the State Legislature.

It's objective, it's charged with prosecuting research in the broad field of increasing ultimate oil recovery in the departments of petroleum engineering at the two educational institutions.

Q Is that committee still in process of conducting it's research and making it's investigations?

A Certainly. We employ graduate students and we have many, have some 15 or 20 projects under way at all times.

Q Are they working on a project in connection with water flooding?

A At the present time?

Q Yes.

A At A. & M. University there is a project under way there, under the supervision of Doctor Paul Crawford.

Q Are you participating in that study, as a member of the Committee?

A I'm not a member of the committee. I'm director of the research program. I'm employed by the committee.

Q Is the question of rate of production of water flood projects under consideration by the committee at this time?

A It's one factor we are studying; we are doing laboratory work; we are studying the mechanism of displacement of oil from sands and rocks.

Q You have already made up your mind on this question of rate of production, is that right?

A Yes, sir, insofar as our state of knowledge is now. I have been teaching it for many years.

MR. CAMPBELL: That's all.

A I have several, probably a thousand students that listen to this, in the industry.

MR. PORTER: Mr. Errebo.

MR. ERREBO: I have one or two questions, if the Commission, please.

A I might answer that, add just one thing, please, sir.

MR. CAMPBELL: Go ahead.

A I mean, any scientist is open to new evidence, and what I am saying is, we have made an earnest -- is that what I know today and all, as I have never seen convincing evidence to the contrary.

MR. CAMPBELL: When did you get here, Doctor?

A When did I get here?

MR. CAMPBELL: At this hearing?

A I got here yesterday afternoon.

MR. CAMPBELL: You weren't here the first day, were you?

A About 3:00, right after your afternoon recess. However, I have heard all the witnesses here many times. There wasn't anything new here, I hadn't heard.

MR. PORTER: On the same subject, I guess?

A Yes, sir, on various phases, depends on the angle.

MR. PORTER: Mr. Errebo, do you have a question?

MR. ERREBO: Yes.

BY MR. ERREBO:

Q Doctor Fancher, you quoted Mr. Zucht as stating that water floods can be turned on and off like a spigot?

A That's his familiar analogy.

Q Now, you have quoted that; I take it that you believe that, is that correct?

A Well, I think it's over-simplified, but I say it expresses, I said if there is any one opinion, I mean, there is diversity of opinion, if he could summarize talking to collective experience there, that is, certainly, when the president of the Penn-Grade Crude Oil Association, a man as well informed as Mr. Zucht, who had access to all the work and all the information, who was in the business, and made a fortune in it, would say that, it should be given some credence.

Q I'm asking for your opinion, Doctor Fancher? Do you believe a water flood can be turned off and on like a spigot?

A I say it is an over-simplified answer; I say it is indicative, however, of --

Q Now, Doctor Fancher --

A -- take it or leave it.

Q Do you believe that capillary pressure is important in the mechanism of water floods?

A Well, certainly, it's important in all oil production.

Q Do you believe that capillary pressure --

A That's the way oil -- I mean, that's the way oil accumulates, you know.

Q Now, when you turn that spigot off, does that turn off the effect of the capillary pressure that is actually within the sand?

A No, it's always there, that's why --

Q Always there, and always keeps accumulating, is that correct?

A That's right, and you have to overcome it, you have to take advantage of it. It's a slow force, weak force.

Q Just one other question, Doctor Fancher. You mentioned that you had designed, or at least had had a part in the institution of water flooding in the Fry Pool?

A No, I did not.

Q You did not?

A I said that I had the honor of being asked by the Railroad Commission of Texas, when I first joined the faculty of the University of Texas,to appear as a friendly witness for the State, at the first hearing, at the hearing of the first application for water flooding. You can't imagine in the depression, a time when there is pipeline proration, to come down to this heresy of putting water in an oil well; there was great consternation; I appeared as a witness, and explained what they are doing in Bradford.

MR. ERREBO: That's all.

MR. PORTER: Any further questions? Witness may be excused.

MR. HINKLE: My next witness is --

MR. PORTER: I think Doctor Fancher --

A Did you excuse me?

MR. PORTER: I excused you.

A I thought you did. They told me you didn't.

MR. PORTER: I was going to say, I think he gave me an idea. I'm going to try to look for some friendly witnesses.

MR. HINKLE: Our next witness is Doctor C. F. Weinaug. I would like to have him sworn.

(Witness sworn.)

DIRECT EXAMINATION

BY MR. HINKLE:

Q State your name, please.

A Charles F. Weinaug.

Q Where do you live?

A I live in Lawrence, Kansas.

Q Are you connected with the University of Kansas?

A I am. I am a professor there, and Chairman of the Department of Petroleum Engineering.

Q How long have you been in Kansas in that capacity?

A I have been there about nine years, a little over nine years: this is my tenth year..

Q Will you state to the Commission briefly your educational background?

A I went to a small school in my home town for two years; then transferred to the University of Michigan where I attained a Bachelor's degree in petroleum and chemical engineering in 1939; the following February I obtained a Master's degree in petroleum engineering, and in 1942 I obtained a Master's degree in chemical engineering from the University of Michigan.

After that, I was employed by the Research Department of Phillips Petroleum Company for approximately four and a half years in the fields of production, research, and petroleum and refining.

I then resigned that position to take a position as Associate Professor in Research Petroleum Engineering at the University of Texas, where I was employed for about two years.

At that time, I resigned to take my present position at the University of Kansas.

Q Have you been a member of any committees that studied secondary recovery methods of operation?

A I am a member of the Inter-State Oil Compact Commission, secretary, and studying the effect of rate of secondary recovery projects.

Q In your Department of Petroleum Engineering at the University of Kansas, have you carried on any research work in connection with water flood projects?

A We are continually engaged in studying the mechanisms of oil production, about the primary and secondary, and attempting to further our understanding of these mechanisms.

Q Have you kept abreast of all literature that has been published concerning secondary recovery methods in water flood projects?

A Yes, sir.

Q Have you acted as a consultant from time to time in connection with water flood projects?

A Not directly. I have visited people indidrectly that were affected by the effects of secondary recovery in various areas. I am also head of the Division of Petroleum Engineering at the State Geological Survey, and in that position I have made studies of secondary recovery in Kansas.

Q Have you made a personal study of rate of production in connection with water flood projects?

A In line with my duties, I have tried to study all the information that's available, and tried to segregate out the effect of rate,so that I could determine what the effect of rate was on ultimate recovery in secondary recovery projects.

Q Doctor Weinaug, from your experience and study of secondary recovery operations, state whether or not, in your opinion, water flood projects can be controlled within wide limits of rates of production and injection without loss of maximum ultimate recovery of oil from a pool or reservoir, as a whole?

A I believe they can.

MR. HINKLE: That's all.

MR. PORTER: Anyone have a question?

CROSS-EXAMINATION

BY MR. McGOWAN:

Q What do you mean, Doctor, by "wide limits of control"?

A Wide limits from extremely low rates that have been discussed; any rates that have been discussed here up to this high rate of a barrel per acre foot.

Q Doctor, have you ever put in and operated the completion and control of a water flood project?

A I had the misfortune of advising some people adversely in a flooding case. I advised them against flooding, however, their legal commitments prevented them from not going ahead. They had to go in and inject a pilot flood, and it was a failure, as advised.

Q Was their failure due to the injection rate?

A The failure of inability to inject about the project, because of the tight permeability in the area, it was a very shallow area, the oil saturation was low, the conditions were just not favorable for flooding at all. This was obvious from the core. If it hadn't been for the legal obligation, my clients would have abandoned the flood to start with.

MR. McGOWAN: I believe that's all.

MR. CAMPBELL: I have one question.

BY MR. CAMPBELL:

Q You stated, in answer to Mr. Hinkle's question concerning your general conclusion, that you had made efforts in the laboratory to study this matter, segregating out the rate of production, is that correct?

A Not only made efforts in the laboratory, but I have studied all field case histories in order to try to arrive at my conclusion that I now state.

Q Did you consider those purely from the physical waste, ultimate recovery point of view, or did you analyze them too from the point of economic limits?

A I have considered economic limits, yes, sir.

Q Do you generally advise people concerning the economic advisability of entering into these ventures in a consulting capacity?

A I don't generally advise people in this case, but I'm quite familiar with the economics involved in such a calculation.

Q I assume you are not appearing here as Chairman of the Department of Petroleum Engineering of the University of Kansas, but as a consultant for the Humble Oil and Refining Company?

A Humble asked me to appear here to put myself at the disposal of the Commission, to try to assist them in making this a sound decision in this case.

Q Now, wait a minute, are you employed by Humble Oil and Refining Company in this case as a consultant, or not?

A It would not make any difference in my decision, sir.

Q I am not saying that it would; I'm asking you for an answer to the question.

A Yes,sir.

MR. CAMPBELL: That's all.

MR. PORTER: Anyone else have a question?

MR. COOLEY: Yes, sir.

MR. PORTER: Mr. Cooley?

BY MR. COOLEY:

Q Doctor Weinaug, you said your observation of case histories of water flood projects, that you had observed through the years, has borne out your position. I would like to know if you can point to -- I wish you would please point to certain of the detailed characteristics as they compare with the high rate floods that we have seen presented here, which shows that these low rate floods have been successful, or as successful as they would have been had they been flooded at high rates.

Q The question of comparing floods that have been at two different rates, one has to consider the reservoir conditions quite thoroughly in order to make such a comparison.

In the area in Kansas, most of the floods have been conducted at what I consider high rates. Whenever a low rate is present, it isn't because it's operator didn't desire to have a high rate, it's because the reservoir conditions were such that he could not obtain a high rate; and when he couldn't obtain a high rate, reasons for this undoubtedly are the fact that the permeability is low, the oil saturation in this case would be low, the thickness, all the other variables that come in, would affect him adversely for recovery.

When you take these things into account, then the low rate did not affect the low recovery, that was there, there just wasn't the oil there to start with. When you take these things into account, you can account for the effect of the low recovery with the rates.

In addition to this, I have taken field histories, and applied the theories that we have had presented here today, and then made a comparison with these, the recoveries, and the rates of water-oil ratio with cumulative production, and I have matched these histories quite well without taking into account rate effects, so I assume from the studies, rate is then unimportant.

Q Doctor Weinaug, do you agree with Professor Cole that it is well settled among those who know, that water flood is not rate sensitive? I mean, he seemed to be appalled at the fact we were even hearing this hearing.

A I am about in that same position in listening to the testimony of yesterday. I am quite appalled at some of the ideas that

that were presented there.

Q Now, it seems to be the time for everybody to be appalled. I seem to be so at the fact that every operator, I think by your own testimony, every operator in the country practically is trying to flood at as high rate as he can. Does that get more oil quicker?

A I would advise any client that could get an unrestricted allowable to flood as fast as he can to put as many worth dollars in his pocket as he can, full well realizing that it had no effect on the ultimate recovery.

This fact of rate, and why these operators at a fast rate is not necessarily a question of ultimate recovery, it's a question of how many dollars you can return profit to your client.

Q Now, we all know these companies are all operating because they are secondary profit. Does the fact your present worth dollars aren't greater in a fast flood than they are in a slow flood -- there's more present worth dollars in a fast flood than a slow flood, because you get your money quicker?

A That's right.

Q Does that fact make it economical for this company that is flooding at a high rate, to recover more oil than it would if his present worth dollars are spread out? In plainer words, less over a longer period of time?

A I think I can state it this way: When you allow a company to flood at a higher rate than that allowed by the state allowable, you are really swapping present worth dollars out of primary productions people, into secondary production people's pockets.

Q I wasn't asking for a comparison or observation of what effect it might have on the primary recovery operators in the State. My question is: Is the fact that you will recover your greater amount of money quicker on a fast flood, does that economic fact permit that operator to recover more oil, before he reaches economic limit?

A No, sir, because at the time that he starts to take a decline at the end, he can always up his injection rate, and at this time keep from being shut off by the economic limit. The economic limit is not a function of the recovery of money previous to the day that abandonment occurs. It is a function of his out-of-pocket expenses on the day the abandonment occurs. If the out-of-pocket expenses the day abandonment occurs is greater than the income, the company is forced to abandon. This is what determines abandonment, not what the real return on capital investment previous to this time had been.

Q Now, as I conceive it, whether you would enter it upon the flood or not, assuming you had to borrow $250,000 to commence a flood, from the bank, they are going to charge you 6% interest.

A Yes, sir. If you have to pay that interest over a 10-year period of time, it might be ureconomical to embark upon the project at all. If you get enough money back to pay the $250,000 the first year, you would only have paid interest for one year. A, the applicant's exhibit, I believe, on the slow rate that is here, the slowest rate here shows a payout in two years.

Q This is a good flood; assume you have got one on the borderline of whether you should.

A I don't think you are going to find any operators where they have to borrow money, or otherwise, are going to flood in such a marginal case.

Q There must be some point at which, as you stretch out this payout, the present worth factor of 6% is figured into the applicant's exhibit, could be the determining factor of whether you enter upon the project at all, or not?

A Yes, sir.

Q And if the present worth factor were low enough, had the effect of deterring the operator from commencing the operation, then you would lose all of it?

A That's correct. I don't know of anyone that could make allowable that's in this area, that's it.

MR. COOLEY: That's all the questions I have.

BY MR. McGOWAN:

Q I have a question. Doctor, I didn't understand your answer as to whether or not there was a difference of opinion on this matter among the experts in the field. Did you say there was a difference of opinion, or was not?

A Well, I think it depends upon -- you see here that there is a difference of opinion here today.

Q You are a member of various committees studying such matters as this, are you not?

A Yes, sir.

Q Is there not a wide divergence of opinion in those committees, or at least in part of them?

A Yes, sir.

Q Well, then, it cannot be said that the experts in the field are in agreement on the theory that rate has no effect upon ultimate recovery, can it?

A I think what we are discussing is numbers of people in this particular case. Those who have made -- are qualified and have made studies of reservoir engineering as such, I believe the majority of them are in agreement.

Q We are not limiting it to the people in this case, we are talking about reservoir secondary recovery engineers, and research as a whole, and I believe then you could not fairly say that they are all in substantial agreement that rate has no effect, could you?

A Not all in substantial agreement, but I think you would find a considerable block of them.

Q Let's take a group, for instance, as the Inter-State Oil Compact Engineering Committee, isn't that group at least fairly evenly divided, or the majority on the side that rate does have an effect?

A I know the answer to your question, and I would like to answer it.

Q So do I.

A Because I think, but then again, this is in the state of balloting on the committee itself,and I don't think that it's right for me to answer it.

MR. McGOWAN: That's all.

MR. PORTER: Anyone else have a question? The witness may be excused.

MR. HINKLE: If the Commission, please, that's all the witnesses which we have.

MR. CAMPBELL: If the Commission, please, I would like to present two very brief rebuttal witnesses in this case. We would be happy to do it now, or in the morning, if the Commission prefers.

MR. PORTER: The Commission has decided to recess the hearing until 9:00 o'clock tomorrow morning.

MORNING SESSION
October 30, 1957, 9:00 a.m.

MR. PORTER: The meeting will come to order, please. The Commission recognizes Mr. Campbell.

MR. CAMPBELL: If the Commission, please, I would like to call Mr. Bridges as a witness in rebuttal. He has not been sworn yet.

(Witness sworn.)

P. N. BRIDGES

a witness, of lawful age, having been first duly sworn on oath, testified as follows:

DIRECT EXAMINATION

BY MR. CAMPBELL:

Q Will you state your name, please.

A P. N. Bridges.

Q Where do you live, Mr. Bridges?

A Abilene, Texas.

Q What is your profession?

A Consulting engineer, for Russell Engineering.

Q How long have you been in that organization?

A A little over three years.

Q Would you give the Commission a brief outline of your educational background, and your professional experience prior to that time?

A I am a graduate of M. I. T., got a Bachelor of Science in Chemical Engineering. Upon graduation, I went to work for Creole Petroleum Corporation for a year and a half, during which time, all of it was spent in this country, I spent some time in New Jersey in refinery operations; and then with the Carter Research Organization in Tulsa in laboratory research work. Upon leaving Carter, I joined Pan-American Petroleum Corporation, spent two and a half years in research work in their laboratory in Tulsa, and two and a half years in field operations, mostly in West Texas. At the time of leaving Pan American, I was district reservoir engineer for the Midland District. I joined Russell Engineering, and have been there a little over three years. Our firm specializes in secondary recovery work, and during that time most of my work has been involved in evaluation of properties, secondary recovery prospects, and some additional work on primary properties.

Q Is your company and you now engaged in consulting work in the operation of any water flood project in the State of New Mexico?

A Yes, sir, we are. We are engaged on a consulting basis for the Moab Building Corporation, U-Tex Exploration, and Charles S. Steen Operators in the High Lonesome Field. In addition, at the present time, I am chairman of the West Central Texas Water Flood Association. I was, while in Tulsa, secretary of the A. P. I.

Secondary Study Group. I am also at the present time president of the Society of Petroleum Engineers' Section in Abilene.

Q You have been here during the course of this case, have you not?

A Yes, sir, I have.

Q You have heard the testimony of the various witnesses?

A Yes, sir, I have.

Q Yesterday, I believe, Professor Cole stated that there was agreement among the people in the research field in connection with the theories that are being advanced here in connection with rate of injection, and so on. Doctor Hocott said there was substantial agreement, as I remember, and referred in his testimony to an article in Petroleum Technology Magazine, a paper, in October of 1957, written by a number of the research people for Pan-American Oil Corporation. Are you acquainted with that article?

A Yes, sir, I am.

Q Do you have that magazine here?

A Yes, sir, I do.

Q Will you refer to it, please? What page is it on?

A The article in question is on page 280, in the back section.

Q Now, would you, in connection with the testimony that there is substantial agreement among the research people on these subjects, will you refer to that article and indicate to the Commission whether or not you feel that there is such agreement as indicated by the article that has been referred to in this testimony.

A Yes, sir, before I start I want to make one point absolutely clear. Although I worked in Pan-American for a period of two and a half years, I am not at the present time employed by them, and I want the record to show that my remarks indicate my own opinion, and in no way reflect, in no way am I speaking for Pan-American's organization. The Exhibit No. 9, Humble Exhibit No. 9, had the statement at the bottom of it, which occurs on page 280, -- "The oil recovery performance of all three water floods was identical." I believe on the copy I have given the Commission, it is underlined. Now, going on reading the rest of that paragraph and the paragraph that follows it: "These results indicate that the magnitude of segregation of the fluids due to gravity is influenced by the average water injection rate rather than day to day or week to week variations.

"Model studies have indicated that when capillary effects are negligible, reduced injection and production rates can result in lower oil recovery to breakthrough. The magnitude of this rate sensitivity due to gravity effects is dependent upon the reservoir rock and fluid properties. The effect of gravity on oil recovery in uniform texture reservoirs may be estimated from the correlations presented in this paper. In some non-uniform reservoirs, gravity effects may have no practical effect on the oil recovery. However, segregation of the fluids due to gravity forces should be borne in mind when considering frontal-drive operations."

Following this article of Pan-American there is a page and a half of discussion by Mr. F. F. Perkins, Junior, with Humble Oil and Refining Company in Houston, Texas, which has in it this statement, which is over on the following page, 282: "The implication that the results of these experiments are generally applicable to field operations is misleading."

Then, following that discussion of the laboratory results by Humble, there is a reply by the authors of the paper. They state in this, "We believe a large portion of reservoir rocks exhibit only moderate wettability preference to either oil or water. The effects of capillary forces on the movement of injected water, as pointed out by Perkins, would be reversed in preferentially oil-wet rocks and are of importance only under strongly water-wet conditions. Actual detailed quantitative information on the lithology and the wettability preference of specific reservoirs is rarely, if ever, available. It is doubtful if, under these circumstances, generalization can be made on the effects of capillary forces on the gross movement of injected water in waterfloods."

Q Mr. Bridges, did that article, and the developments following it in the discussion in the critique there, indicate to you there is some substantial disagreement among the people in the research field as to the principles that have been discussed here in the last day or two?

A I certainly don't claim to be in a position to judge the adequacy of these various arguments. However, I would certainly conclude from this paper and not only this paper, but other papers in this same magazine, other articles in this same magazine, that there are substantial areas of disagreement as to the applicability of the laboratory data in the field.

MR. CAMPBELL: That's all.

MR. PORTER: Anyone have a question of the witness?

MR. McGINNIS: If I may, I would like to ask him a few questions.

MR. PORTER: Surely.

CROSS-EXAMINATION

BY MR. McGINNIS:

Q Mr. Bridges, when you were reading from page two hundred eighty, you did not read the last paragraph prior to the conclusions, did you, when you were reading out loud?

A No, sir, I did not want to read the whole article.

Q Would you please read the last sentence which appears prior to the conclusion?

A Would it be satisfactory to you if I read the whole paragraph, rather than just the last sentence?

Q Yes.

A "The results of model studies of secondary recovery operations indicate that the oil recovery to breakthrough of the injected fluid to the production wells is rate sensitive. When capillary effects can be neglected the lower the rate, the lower is the oil recovery, regardless if reduced rates are due to lower daily rates or intermittent operations. The magnitude of this rate sensitivity is also influenced by the permeability distribution within the reservoir. It appears that the more uniform the reservoir rock texture, the greater is the magnitude of rate sensitivity. Insofar as actual reservoirs are concerned, the possible influence of capillary effects must be considered, and each reservoir must be considered separately as to whether or not a variation in range of practical rates will have a significant effect on oil recovery."

MR. McGINNIS: That's all.

MR. PORTER: Any further questions of the witness? The witness may be excused.

MR. CAMPBELL: I would like to call Mr. Buckles, please.

(Witness sworn.)

GEORGE L. BUCKLES

a witness, of lawful age, having been first duly sworn on oath, testified as follows:

DIRECT EXAMINATION

BY MR. CAMPBELL:

Q Will you state your name, please.

A George L. Buckles.

Q Where do you live, Mr. Buckles?

A Monahans, Texas.

Q What is your business, or profession?

A I'm the owner of an oil consulting, oil production consulting business, specializing in water flood recovery.

Q Would you give the Commission a statement of your background in this field?

A I graduated from the University of Oklahoma in 1932. It was a bad year to get out of school, so I got a job as a roustabout in the Seminole, Oklahoma, Oil Fields, and stayed with oil operations from that time until the present, rather than going into exploration work. I have done almost all jobs conceivable in the oil fields. I specialized in water flooding in August 1945, and havebeen connected with water flooding work since that time.

I put in the first water flood for the Pure Oil Company in the State of Illinois in 1945. I don't mean the first water flood in Illinois, I mean the first water flood for the Pure Oil

Company.

I moved to the Permian Basin for the Forest Oil Corporation in 1948 to install their water flood operations in the South Ward Field. At that time the Forest Oil Corporation had produced over 70 million barrels of water flood oil. This water flood was installed in 1948, pilot flood was started in 1948, and '49. The flood is still in operation.

I formed the firm of Buckles and Hostetler as a consulting firm in October 1951. This firm was dissolved June the first this year, and I organized the company of George L. Buckles Company. We are now engaged as water flood consultants. We are now operating in an engineering and operating capacity, eleven water floods in the Permian Basin. My work has consisted and still consists of design of water plants, flood systems, evaluation, development, and operation, which includes supervision of drilling, setting production rates, injection rates, pressures, and so forth.

All the information I have is strictly from field experience. I might say that I have never been handicapped or burdened by too much technical information. I mean that in the sense that I did not have any preconceived ideas, but I'm naturally curious, and when things perform as I expect them to, and do it over and over many times, I accept the results as facts. I attempt to find an explanation, sometimes I can not do it, but I will agree that water flooding operations must obey sound physical principles.

Q Mr. Buckles, you have been here during the entire course of this hearing, have you not?

A Yes, sir.

Q You have heard the discussion concerning the rate of injection and rate of production in connection with water flood operations?

A Yes.

Q Based on your experience particularly in the Permian Basin area, the water floods that you have had contact with and worked with, would you please express your views with regard to that particular phase of the hearing?

A I might say that for the past 12 years I have come in contact with many water flood operators. I'm talking about people in the field that operate water floods. Admittedly, it is a controversial subject, but among the operators these controversies consist principally of well completion practices, water treating practices, and the like, but in every case I have encountered, all operators are unanimous in agreement that a successful water flood operation must be a continuous uninterrupted operation. All operators I know are now going to high rate, or high pressure floods, regardless of what they may say to the contrary.

Some of the companies I refer to are D. D. Fellman Oil and

Gas, Standard Oil of Texas, Humble Oil and Refining, Magnolia Petroleum, Gulf Oil Corporation, Sinclair, Ambassador, Tennessee Gas Transmission, Monterey, Sunray-Mid-Continent, and many others. All of the engineers for the applicant have testified that high rate produces more oil, and that a very low rate results in loss of ultimate recovery from a physical and economic standpoint.

Q Do you agree with that?

A I do. It is possible I may shed some light on the reason. In my experience in viewing many, many cores in Permian sands, including the Yates and the Queen in the field, I found that Permian sands in general are a series of sand lenses, separated by shale stringers, or tight sandy shale stringers, some of which extend from well to well across the field; others do not. In other words, in some cases there is communication vertically in the formation; in other cases there are not.

I have observed that the range of permeability in Permian Sands in the Permian Basin is high, that is ranging in the pay sand from minus one millidarcy to five hundred millidarcies plus. I have also observed that the porosity, regardless of permeability, is more uniform than the permeability, with an average of approximately 21% of total volume.

I have also observed that the oil saturation is high, regardless of permeability, so that there is almost as much oil in the low permeability or tight sand stringers as there is in the permeable streaks.

I have observed throughout the years that many wells having rather tight sands are very reluctant to take water without high pressures. I have some very recent information. On last Saturday, October 26th, we started a new water flood project in the Pecos Valley Field in Pecos County, Texas. This is in the upper Yates sand at an average depth of about 1460 feet from the surface. We put on twelve injection wells Saturday, Sunday, and Monday of this week. Six of these wells were known to be what we call "tight wells". That is, the range of permeability was from one-tenth to a maximum of ten millidarcies. The thickness in these six wells of what we call "pay sand" was approximately five feet, while the thickness of what we call "good wells" or the normal wells in the field was from ten to twelve feet, with a range of permeability also from less than one millidarcy to as high as 250 millidarcies.

However, all of the good wells had a portion of the sand with the range of permeabilities in the poor wells,the six wells I referred to. These six wells were not dry holes, due to the fact that we drilled them in with cable tools, had a good show of gas at the surface, and free oil came into the hole. We started injecting water into these six wells at 750 pounds surface pressure, these wells took at a rate of from zero to a maximum of eight barrels per day, which in my opinion would be at least an uneconomical rate. The other six wells took rates from 70 barrels per day to 244 barrels a day, at pressures from 220 to 500 pounds.

Our field men gradually increased these pressures on the tight wells, and as I recall, got up to a maximum of 78 barrels at a pressure of slightly less than 1,000 pound surface pressure.

Q What does that situation, what conclusion do you reach from that situation?

A It is obvious to me that if these tight sands will not take water at a commercial rate at 750 pounds pressure, the other wells, the good wells in the field having high permeable streaks would take good rates at the same pressure.

It is my conclusion that the sands in the good wells, having the same permeability range as the sands in the tight wells, would also not be taking water at 720 pounds. Therefore, we would only be flooding the permeable sands in the good wells, and would by-pass the oil in the tight portions of those wells, unless we increase the pressure on those wells to subject the tight sands to the same pressure we are subjecting the tight sands in the poor wells to make them take water.

Now, we had a pilot flood operation for the past year and a half in the North Scarborough Field in Northern Winkler County.

This field is adjacent to Lea County, New Mexico. The field extends into Lea County, New Mexico, and is called the Rhodes Field. The formation in this field is the lower Yates or possibly some sands below the Yates, there's slight confusion. At any rate, they are Permian Sands. The depth of these wells is from 3200 to 3300 feet.

We had six wells in the pilot flood, six injection wells. We gradually increased the pressure, surface pressure, on these six wells to 400 pounds per square inch. The wells at the present time at 400 pounds are taking an average of 155 barrels per day per well. We have approximately 25 feet of net pay sand, or less, in the field.

The flood responded very satisfactorily. We intended to expand the flood. We had a hearing at the Railroad Commission of Texas on September 24th, requesting maximum water flood allowables for this field. This request was granted. We are now expanding the flood and we started injection into three new injection wells this week. One of them would not take any water at all at 400 pounds. One well is taking from 10 to 15 barrels per day at 400 pounds pressure. The third well is responding the same as the pilot flood, that is, taking about 300 barrels per day at a vacuum on the surface.

Q Does that experience lead you to believe that it is necessary to maintain high pressure in order to obtain the greatest ultimate recovery of oil?

A Mr. Campbell, we intend to increase the pressure on these tight wells to find out how much it will take to make them take water. We purposely held the pressure on the pilot flood to 400 pounds to get information, knowing that we had a range above 400 pounds that we could use later, as soon as we found some information.

Now, only one of these three wells was cored, and all of the section was not cored. However, in the core, we found stringers of permeability in the core, ranging from two to eight millidarcies. This well had a good flow of gas and free oil came into the hole. We had to be careful in pulling the tools out of the hole, in cleaning the well out, to keep it from flowing, so in no instance could you call this a dry hole.

Q Now, there has been some testimony here that I believe the expression was used that you could turn these things off and on like a spigot. The suggestion was made by the Humble people that, "build these up to a rate not to exceed the allowable and then just maintain the rate, and you'll get the same amount of oil." What is your opinion with regard to that, based on your experience?

A Well, it's obvious to me that -- let's assume now that this field was pro-rated and we would have an injection rate sufficient to meet proration requirements. Then that injection rate would be low, necessarily the pressure would also be low; therefore, we would flood only these high permeable streaks and we would not be injecting water into the tight streaks, and when these streaks had flooded out, for example, these high permeable streaks, they would go to 100% water. At that time to maintain production, it would be necessary to increase pressure to the extent that it would flood these tight streaks. In our experience, we have found that when we flood out these permeable streaks at low rates, and then attempt to increase the pressure to flood out the tight streaks, we have an enormous increase in water production through the permeable streaks without a corresponding increase in production, oil production from the streaks, from the streaks that haven't been flooded out.

Now, to follow through a little bit on what we were talking about, I want to state that I have noted many other wells throughout several fields in the Permian Basin that would not take any water at all until we reached the relatively high pressure. Our conclusion is that the good wells have a considerable amount of pay with the same permeability as the tight wells, and that this permeability range will not take water until the pressure reaches the same as used in the tight wells.

Therefore, at low rates, or low pressures, we are flooding only part of the sand. If you have low rate in the sand, you have no movement of oil.

Q Now, on this other point I would like to ask you, during the course of the testimony I believe of Mr. Earlougher, the question came up about whether or not during the course of the operation of a flood you could not at that time by fracturing or some other method, increase the ability of the wells to take the water. What is your experience in that regard?

A We had occasion to consult with Mr. Barney Cockburn who lives in Artesia, had some production in the Corbin-Queen Sand Field in Lea County, which is in the same field called the North Maljamar Field in lower pay zones. He asked our opinion as to the possibilities of a flood of this production; also stated that they had fractured the wells, both the wells he intended to use as input wells and producing wells.

We cautioned him to the extent that we felt he might bypass water through these fractures in these injection wells, to his producing wells, and may have to plug these fractures in order to successfully flood this formation. These wells readily took water, and in our estimation, at a higher rate than they should than if they -- if they had not been fractured. He got an increase in oil all right, but in our estimation, a very quick premature production of water, and his oil production in his producing wells dropped to the same figure, or below, after water breakthrough that they were making prior to the water flood.

Therefore, we concluded that you are taking a big chance in attempting to fracture injection wells to increase injection rates.

Q Now, during the course of the testimony of the witnesses by Humble, there was considerable discussion of the possibility that by slowing down your rate of water input, that you might be able to take advantage of capillary effects in the reservoir. Of course, that would be some answer, if true, to previous statements here that you can't flood the tight sands without higher rates. What is your view on that question of capillary effects?

A Well, Mr. Campbell, I know very little about wettability of sands. However, from Mr. Hocott's testimony, I gather that a water-wet system has a continuous water contact throughout the formation. I would conclude from that, that almost any permeability, or in the ranges we are talking of when I mean "tight sands", ranges from less than one millidarcy to four or five, these wells would readily take water if they were water-wet in some proportion to their permeability.

In other words, they would take a measureable quantity of water that we find that Permian Sands in these tight wells will not take water. On the other hand, I assume also that if these sands were oil-wet that the oil would give a resistance to water invasion in these very tight sands, and that may be the reason why they will not take water. However, in my field experience, we set up a kind of a crude laboratory at the well. Now, when I was coring the Gordon Well Number 2 in 1948, now we were chip-coring the well. We first cored Number 1 with rotary, did not get the proper conclusions as to oil saturations, so we decided to chip-core the offset well which was 660 feet away, through the pay section.

Now, I might explain what a chip-core is. A chip-core is fragments of the formation that is drilled with the bit, a cable tool bit, or chipped off the bottom of the hole with a sand pump, and these chips are picked up, brought to the surface. Now, in chip-coring we furnish enough water in the well bore to adequately drill a very short section. In other words, we try to take one foot runs or less, and we get a sample of this one foot. These chip-cores vary in size from about the size of a dollar, assuming a quarter of an inch thickness, up to an inch in thickness and larger than a dollar.

As soon as these chips are cut from the formation, they are surrounded by water, then we bring them to the surface and clean them and can them, and send them to the laboratory. We are able to get porosity and permeability measurements, plus oil and water saturations from these chip-cores.

Now, accidentally in coring Gordon Well Number 2, we forgot the canning machine; we used a home canning machine to preserve these cores, and I got the idea if we would immerse these chips in water that we would preserve the oil saturations, pending the time to get the canning machine; so for several runs we cleaned the cores and put them in cans full of water. In no instance did any of the oil escape out of the cores to the surface of the water.

I knew nothing about imbibition at the time, but after reading about it since that time, and reading about experiments, I concluded that if there was such a thing as imbibition in these Permian Sands, the water would have gone into the core and displaced the oil, and it would have come to the surface, or a part of it.

These cores, after being sent to the laboratory, in this particular well averaged 44% of total pore space oil saturation, so there was enough oil in the cores to produce some oil, if the water had gone in. I don't say the water didn't go in, but I do say it didn't displace any oil. Since that time, we have made further crude experiments at the well in order to determine saturation in our own mind. We have a hot plate at the well, or some fire. We take these chip cores and immediately break a piece off and put it on the hot plate. If it dries up and no oil comes to the surface of the core, we conclude it is a gas sand, assuming it has permeability, and porosity. If oil boils out of the core in varying degrees, we try to estimate the oil saturation in our own mind. If oil comes out of the oil core put on the hot plate, we know it is saturated with oil. We then take the other portion of the chip and put it in water. We didn't just use any water, we take the water we are using to flood with.

In no case, in these experiments, have I ever noticed any oil coming out of the cores. We thought perhaps they were not saturated enough, so we decided to get three sets of samples from each foot, and can them at the well. Admittedly, these experiments were done later, however, these cores were actually canned after they were dried, wrapped up in wax paper and canned. We took one can to the core laboratories in Midland, and had them re-saturated with leased crude, so that we knew they were highly saturated. We knew the permeabilities because the other two cans were sent to the laboratory, or one of them, to get the permeability and oil saturation. We took these cores that were re-saturated and immersed them in water.

On the tight permeability sands, the sands that we are talking about, that imbibition show work in, in no instances did those give up any oil after the period of months; the only oil that ever came out of any of the cores were the very high permeability cores, I mean, range of 300 to 500 millidarcies.

Then, a very small quantity came out in one instance,a core, a whole group of cores that would cover the bottom of a fruit jar, only two drops came out, and we concluded that that was merely a gravity segregation. In no instance did any oil come out of the tight pore spaces.

We concluded from that then that the Permian Sands will not imbibe water and produce oil under that method.

Q Now, there has been testimony here in connection with the possibility in these five-spot water floods of migration of oil, and the abuse of correlative rights as a result of that migration. Exhibits were offered to indicate that, by the Humble witnesses. What is your experience in that regard?

A Well, our belief is that any arbitrary curtailment of rights in a water flood would aggravate the correlative rights condition.

Q Why is that?

A I feel there are two possibilities, if rates were curtailed or production was curtailed in a water flood.

One: If the rates or pressures were curtailed, in my opinion, we would flood only the permeable streaks of the pay, thereby losing oil.

The other alternative would be that if we maintained sufficient pressures in our injection wells to flood all of the sand, and the operator was not allowed to produce his oil, or maintain low pressures at his producing wells, that he would tend to migrate oil from his high pressure area to a low pressure area off of his property.

Q That would be due, in effect, to the back pressure situation because of his inability to pump off his oil from his well?

A It's been testified at this hearing that fluids migrate from a high pressure area to a low pressure area. If he maintained a high pressure on his sand, which would be necessary in my opinion, to produce the maximum quantity of oil, he would create a high pressure. If he was not allowed to produce his oil, he would have also a high pressure at his producing well. If the offset operator was not flooding, more oil would migrate off his property than would be the case if he was allowed to keep a low pressure area, as his wells, so he could produce the oil before it migrated off his property.

Q Have you had any experience in situations developing floods, where there had been previous attempts at flooding, and apparent failures?

A Well, yes.

Q State where those were.

A We might take the case in the Permian Basin. Forest Oil

Corporation had the temerity, or the optimism, to attempt a water flood in the South Ward Field, when the general opinion of operators in the South Ward Field and the North Ward, Estes Field, and the Kermit Field, the opinion was that you could not successfully flood Permian Sands.

The reason for this was that several floods had been attempted with very poor or at least unsatisfactory results. I had occasion in 1948 to be appointed to a committee on Secondary Recovery, API Committee in Midland. I attended the first meeting, and these fellows were all talking about gas re-pressuring. They finally asked what I intended to do, and I told them that we were going to attempt a water flood in the South Ward Field. One of the members called me aside and wanted to know - incidentally, he was an engineer of Humble - he wanted to know if the Forest Oil Corporation realized that there had been failures in the Yates Sands and that the concensus was that you could not flood the Yates Sand.

He also asked how much the Forest Oil Corporation were willing to spend. I told him, to the best of my information, about a quarter of a million dollars. He told me that the Humble Oil and Refining Company had instigated a flood on their Louise Richter lease in the south portion of the North Ward Estes Field in 1942, by injecting water into three old producing wells, and that this flood produced a very small quantity of oil. Eventually the water migrated to the adjacent producing wells, and the flood was abandoned in 1946. He concluded, and other people concluded, that this showed conclusive proof that it was very difficult, or impossible to flood Permian Sands. Therefore, he was rather amazed that the Forest Oil Corporation would have the nerve to invest $250,000 to put in a flood in the same formation, although it was a few miles south of this original flood.

He also pointed out that there were several flood attempts in the Kermit Field, I believe, stating to me that they were instigated in 1943. It is possible that they were instigated in 1944, but he said 1943, and that they were partially successful, that is, they produced some oil, and may have made a little money, but were not at all successful.

We went right ahead and installed the flood in the South Ward Field. We started injecting water into six injection wells the 16th of August, 1949, and started producing water flood oil the 13th of December, 1949. The impact of this flood had a great effect on water flooding in the Permian Basin, and I do have curves showing the primary production for the South Ward Field through the primary and secondary history, and also the Kermit Field, if you want to display the curves.

Q What was the result when you went back into these fields where floods had been attempted, was the result successful?

A Yes. Now, in this particular flood, Mr. Campbell, in the flood on the Richter lease where this old flood had been installed from 1942 to 1946, that flood after they went back was not as successful as floods in the same area on a comparative basis, from their primary production.

I don't know what conclusion to make of that; I don't know whether the flood was ruined, or anything else; however, I do know that it is not considered as satisfactory.

However, they are now conducting a successful flood on the Richter lease. In the case of the Kermit Field, in my estimation their attitude was a salvage proposition, so they did not use high pressures, or they even didn't use what we consider a pattern. However, after we showed that by high injection rates, and high pressure floods in the South Ward Field, activity greatly increased; both of these fields were reaching, that is in the old areas, were reaching economic limits and there were not as much as two-thirds of the wells in operation in 1949 as there was in 1937 and '38, under primary operation.

Q Now, Mr. Buckles, in connection with those two fields that you are referring to, do you attribute the increased production and the later success of the floods in those two fields, to a higher injection rate?

A That was certainly part of it. Of course, other factors entered into it, well completions, water treating, pattern, but it was my understanding that no pressures, no surface pressures, were used on these early floods, or that is, they were very light. In other words, we called them "dump floods"; they were allowed to take water by gravity, and their results were very poor, so poor to the extent that they concluded that you could not flood the Yates Sandin West Texas.

Q Now, Mr. Buckles, based on your experience in this Permian Basin area, do you concur with the other engineers who have testified on behalf of the applicant,that it is necessary to maintain a reasonably high injection rate, and to obtain a capacity allowable in order to properly operate a water flood in the Permian area?

A I certainly do. I would like to straighten one point up. When I refer to "high injection rates", I am not thinking of barrels per day per well, or per acre foot. I have just testified that in my opinion, it takes pressure to produce oil off the pay sands. My ideas of high rates in one well, would be different than high rates in another. My idea of high rates would be a maximum safe pressure at whatever the rate might be. That to me would be a high rate, because it's the maximum rate that you can put on that well without bypassing the oil zone, and increasing the permeability, but I do definitely believe that the only way to produce a maximum amount of oil is high pressure floods.

MR. CAMPBELL: I believe that's all.

MR. PORTER: Does anyone have a question of the witness?

MR. McGINNIS: No questions.

MR. PORTER: The witness may be excused.

(Witness excused.)

MR. PORTER: Do you have any more witnesses?

MR. CAMPBELL: No, sir.

MR. PORTER: Mr. Hinkle?

MR. HINKLE: We have no additional witnesses. Are you going to ask for statements?

MR. PORTER: Yes,sir.

MR. HINKLE: Do you want to make an opening and closing statement, Jack?

MR. CAMPBELL: I want to make a closing one. I don't care about the opening one.

MR. HINKLE: I understand there are a number of companies that will make statements, and I wonder if the Commission wants those statements before counsel for the active parties make their statements. It is immaterial to me.

MR. CAMPBELL: I would like to hear the statements before I make mine, and perhaps you would too.

MR. HINKLE: I mean of the different companies.

MR. CAMPBELL: That is what I mean.

MR. HINKLE: We would like to request that the other companies make their statements first.

MR. PORTER: Will counsel for the Humble and the applicant answer? You have heard the request from counsel for Humble and the applicant. Are there other parties that would like to make a statement?

MR.KERN: My name is Charles Kern with Sun Oil Company. We have a statement of position. Sun Oil Company is an operator in several fields in the State of New Mexico, and as such, has a vital interest both present and future, in the problems and policies of proration and production in this State.

It is Sun Oil Company's position that on the basis of the testimony offered, and the evidence received in this case, that the application of Graridge Corporation should be denied.

We do not feel the technical proof offered shows that capacity production of a water flood project such as the pilot project in the Caprock-Queen Pool is necessary in order to prevent waste. Based on our independent research and engineering studies, together with field experience with reservoirs of similar characteristics, we feel that no waste will occur if this water flood project is not granted capacity allowables.

There is no question but that the operator, knowing that prorationing is in effect and with advanced knowledge of the oil allowables available to him, can make the necessary compensation or adjustment in his operations to insure that he will achieve the greatest economic oil recovery.

We would not like to see any individual project granted a potentially larger share of the available market by means of unrestricted production and feel that approval of this application would set a precedent which could be detrimental to prorationing in New Mexico.

MR. PORTER: Thank you, Mr. Kerns. If any of you have prepared written statements, we would appreciate it if you would indicate that fact before you start your statement, and turn them in to the reporter, so she won't have to take it down.

Next. Mr. Kastler?

MR. KASTLER: I am Bill Kastler, Gulf Oil Corporation. Gulf concurs in the recommendations made by the applicant, Graridge, and we urge that the Commission grant the capacity water flood application.

MR. PORTER: Mr. Errebo.

MR. ERREBO: Burns Errebo with Sunray Mid-Continent Oil Company. Sunray owns a small amount of acreage in the Caprock Field; we have no water floods in the State of New Mexico.

Sunray's operations: We have 66 water floods, we have an interest in 66 water floods, and operate 43; in excess of 10% of our production comes from water floods, so that you can see that our interest lies heavily on the side of primary production.

We have seen in this hearing today a parade of witnesses. For the applicants we have heard testimony from some of the Nation's foremost water flood engineers; men of long experience who have come to grips with water flood problems, and faced the realities of operating a business at a profit. They have presented theoretical and actual field data to show that cutting back of water floods will cause loss of oil.

For the opponent you have seen and heard highly capable research engineers and some respective college professors. This testimony has been theoretical and based upon laboratory work. The most glaring defect in the opponent's case has been the absence of any field data, or case histories of Humble floods or for that matter, any floods, which are examples of successful floods at low rates.

We have seen a number of examples of successful floods at high rates in this hearing, on the basis of many years of field experience. We believe that the evidence in this case conclusively shows that there will be a loss of ultimate recovery, if water floods are restricted, and that for this Commission to deny this application would run a grave risk of causing waste.

MR. MILLER: If the Commission, please, R. F. Miller, General American Oil Company of Texas.

Our company operates some 20 water floods in Kansas, Oklahoma, Illinois, and Texas; and as the Commission knows, we are at present operating a pilot water flood project in the Grayburg Cooperative unit area in New Mexico. We wish to concur with Graridge Corporation and urge the Commission to grant the application, in order to encourage secondary recovery of oil.

Our case has been referred to several times in connection with the possible allowable program.

First I would like to point out that when this was first set up, which was several years ago, Humble was very much opposed to it, and appeared at the hearing against it. Now, they are using it as a good example. It would seem that some progress has been made.

I would also like to remind Humble that the present order as amended contains no single limitation on any well, because we could not afford to start the project at all until this was changed. We do not know whether the present formula will be sufficient for our project.

We think that the only safe approach is capacity allowable as requested by Graridge.

MR. WHITE: Charles White of Santa Fe, representing the Texas

Company.

The Texas Company believes that the Oil Conservation Commission should encourage bonafide secondary recovery and pressure maintenance projects, with the incentive of bonus type allowables.

In the case of pilot or proven secondary recovery projects involving the reservoirs in the latter stages of depletions, it is our belief that it should take the form of capacity allowables where possible. The incentive should consist of allowables of some nature where it has been proven to the Commission satisfactorily that the pressure maintenance project is being diligently and successfully operated at maximum efficiency.

In the case of the subject application, it is recommended that the Commission grant the capacity allowable in order that the project can be quickly and economically evaluated. It is the belief of the Texas Company that the granting of such capacity allowables will prevent waste, and not jeopardize correlative rights.

MR. SNYDER: Sam Snyder with Union Oil Company, California.

We operate some 32 wells in the Caprock-Queen Field,and have an interest in considerable other properties in the State of New Mexico.

We believe that the application of the Graridge Corporation should be granted, even though we are quite aware of the market situation at the present time.

We do not believe that there will be any appreciable affect upon the market.

MR. MOTTER: E. F. Motter with Cities Service Oil Company, Cities Service is an operator in the central portion of the Caprock Queen Pool and is at present in a planning stage for a pilot waterflood.

With two pilots now in operation and others being planned, we feel that should capacity production be granted, all operators now having and those seeking pilot waterfloods will ask for capacity production. With capacity production, pipelines servicing the pool will be loaded to a point where pipeline prorationing will probably be necessary, which may hinder further development of waterfloods in the Caprock Pool.

Cities Service is in favor of lease or unit allowables, i.e., each lease or unit be assigned top allowable for the number of 40 acre units in that lease or unit. This would mean the transfer of allowable from input wells on the lease to other well or wells producing from the basic lease or unit.

Since adequate water for waterflooding presents a major problem in this pool, by using lease allowables, immediate water demand will be much less than if the wells are allowed to produce to capacity.

MR. PETERS: Kenneth Peters for John M. Kelly. We are not operators in the Caprock-Queen Pool, but we are, however, interested in this case effect on the secondary recovery projects, and the State's market demand. We are vitally interested in the water flooding, and believe a bonus should be given to promote interest in such projects.

We do not feel that the entire State's crude oil market should be jeopardized by allowing capacity allowables in large fields such as the Caprock-Queen. In critical times, we feel that the water flood oil should not be exempt from severe pipeline prorationing.

Authorized allowables should be given with pipeline capacity, and market demand in mind.

We suggest that the Commission consider a project type allowable wherein each 40-acre unit receives a unit allowable, and the addition of these allowables would be the water flood project allowable. The operator can produce this allowable from the wells at his discretion. However, in future floods, small fields where pipeline facilities are adequate, and demand from primary fields will not be jeopardized, we would recommend a bonus allowable.

MR. KEITHLEY: Marshall Keithley of Forest Oil Corporation. I would like to make a statement of our position. Forest Oil Corporation operated over 100 pattern water floods in the State of Pennsylvania, Illinois, Kansas, Oklahoma, and Texas, with approximately 50 total number current in operation; has primary production in the State of New Mexico, no water flood operation.

Based on our water flooding experience over the past 32 years, we are convinced that high rates of injection with capacity production are necessary to obtain maximum ultimate recovery of oil. Although we have no water flood projects in the State of New Mexico, we believe that the Oil Conservation Commission of this State should not require an operator to restrict water flood production rates at individual wells, in order that the greatest ultimate oil recovery may be obtained. We, therefore, support Graridge's application in this case.

MR. SMITH: Kenneth Smith with Ambassador Oil Corporation.

Ambassador Oil Corporation has a position in this case, as being an operator of a pilot almost adjacent to the pilot water flood in question.

From our experience of operating over 25 water floods throughout Kansas, Oklahoma, and Texas, and based on studies of floods, other floods in these areas, we feel that the capacity allowable is an absolute necessity for a water flood operation in order to recover all the oil that would be recovered, due to the water flooding process.

We feel that the testimony shown here during this hearing, clearly indicates beyond any shadow of a doubt, that waste will incur if capacity allowables are not granted. We think that this question is so important that possibly the Commission, in order to prevent waste, ought to inquire of operators putting floods into the State of New Mexico, what rates they plan to use. We think this is of more importance even than limiting primary wells to 2,000 to one gas-oil ratio. We think definite waste will result in low flooding rates.

During the hearing, there were two schools of thought, there were two sides.

It is very evident that the one side was composed of field technicians and experts who did the actual application and had all the records available of water flood projects throughout the United States; the other school of thought composed of laboratory technicians and school teachers. It was very evident from the testimony here this morning that there is some disagreement between them, but there is practically no disagreement between the people that know what they are doing, and actually doing it.

We think that is the very strong point in this case. Another point that we have noticed is that the companies who have opposed us have large technical laboratories, and it appears that we have more voice in management than we might suspect, and might have control of management's position that they may take on various items. Even though they come up with certain results in the laboratory, they can't sell it to their own field people, and their own company, and here they come up here trying to sell it to the Oil Conservation Commission of New Mexico.

I think it is definitely proved that these laboratory processes have not developed to enough refinement that at this time that it can be applied to field operations. I don't think there is any question about that, that there is too much conflict in the two results. When laboratory data is presented to show why capacity allowables should not be granted, I think it has very little effect and should be given very little consideration.

Our position -- there is one other item that didn't come out here that I would like to call to the attention of the Commission. In the State of New Mexico, we have a little bit different position here. Most of the acreage is developed on 40-acre spacing. In some of the older water flood areas in Oklahoma and Texas, these wells were drilled on 10-acre spacing. They're operating at rates of 20 barrels per well per day on the producing wells, maybe 25, on a 10-acre basis. The withdrawals from the reservoir on this 80-acre five-spot, that is as much as ten times, its normal equivalent withdrawal would be 200 barrels in comparison to a 25 barrel on the 10-acre spacing. We think that should be considered in this hearing, that New Mexico does have a different acreage spacing problem, and the wells necessarily will require higher producing rates, and higher injection rates.

As a matter of interest to the Commission, we have done some research and find out that in the State of Texas, their water flood production only amounts to 3 to 4 percent of the total oil production. They have been granting capacity allowables and the water flood production has not taken any appreciable amount of the primary oil market.

As far as market demand is concerned, I think testimony has been shown that capacity allowables have a very negligible effect on the overall allowable picture. In this connection, it appears that the question actually results in whether or not water floods are going to be detrimentally curtailed in order to make room for foreign oil. In our opinion, the foreign oil has more than had its share of the United States market.

We concur with the application as requested, and respectfully request the Commission in the best interest of conservation to grant this request.

MR. WILSON: Merrill Wilson, Great Western Drilling Company.

We think that Graridge's position is well founded in this case, and it will have no adverse effect on the market, and urge that the Commission grant the applicant's application.

MR. ASHTON: Roger Ashton, of Frank Ashton and Fair, Incorporated. I am a rather strange animal here. I am an independent and a New Mexico Corporation. Yesterday, I felt a little as if I had gotten my schedule mixed, and stumbled into a seminar on advanced reservoir engineering. Up to that point, I had been pretty well able to glean some ideas of what is going on.

Our firm has been working on a water flood studyyat the Loco Hills Field for some time. Based on what I have heard here, I feel that secondary oil has equal merit with primary oil; that primary oil in some cases in these special deep allowables and so forth, can be controlled without loss where secondary oil being controlled can result in loss. The Loco Hills Field, based on our primary study, is going to be a very expensive project. We have been operating in the State of New Mexico since 1936. I would like to think that our organization and New Mexico are old friends in a business sense.

We like to feel that we are a progressive firm. We were the first firm to sand frack in the State of New Mexico, and we certainly like to keep our eye on development, and keep abreast of any development. I started out as a tool dresser in the oil field, and eventually worked up to where I am vice-president of our corporation.

Our operations are of necessity limited by practical economics. Because of our size, the potential flood prospects are very limited. We are not in the position of the large majors with holdings in many states. We cannot pick and choose. We have to do our flooding with what prospects we actually have available on hand.

Now, one thing that has been very evident to me here is that I note that New Mexico has been given the very dubious honor of being asked to take a special position in regards to water flood, one that her neighbors have not been asked to do. I don't quite understand why New Mexico should be singled out to take a special rate factor, when none of the neighbors have been asked to do so. I don't feel that secondary recovery in the State of New Mexico has a large impact factor on our oil market.

I have observed in the past that market share surrender for altruistic reasons usually results in that share of the market being supplanted from that source, that has the violent impact on our domestic market. I think I probably make myself clear in that regard.

I have observed on one hand we have theorists; on the other hand we have field practitioners. The combination of these two results in experience, and gentlemen, I'm the man that pays for that experience with hard cash.

Now, I come back to the old adage that "nothing succeeds like success". We recently drilled a well in the Loco Hills Oil Field, structurally it ran high, it was offset by production in three areas. The electric log, the gamma ray, neutron log, looked wonderful; the samples looked fine; the core analysis was excellent; everything pointed to a top allowable well. That well makes one barrel of oil, and 12 barrels of water. I wish some of these theorists could tell me why it is not an oil well, because theoretically it is an oil well.

I come back to another adage. We have all heard the statement that "the operation was a great success, but the patient died". Gentlemen, I find myself in the position of the patient.

MR. PORTER: Mr. Bridges?

MR. BRIDGES: P. N. Bridges, of Russell Engineering in Abilene, and Charles A. Steen, Operators.

We, after having heard all of the testimony that has been presented at this hearing, are certainly in accord with Graridge's application. We would like to go on the record as supporting it.

In addition, I would like to point out one thing that is obvious to us, which would be a very glaring weakness in the formula that has been proposed by Humble and some of the other companies, as far as pro-rating these floods. They have suggested that it would be possible to grant an allowable for each lease, on each unit, which could be used at the operator's discretion, so that he could take care of some of these high capacity wells.

Well, that works fine if you have a big block of acreage, and you can transfer your allowables from the 37-barrel unit allowable to wells out on the end of the flood performance, or before they have reached the peak, to wells on the peak. But such a rule as that would operate to the detriment of the man who is sitting there with one or two wells, 40 or 80-acre wells, of which there are a large number in all the field we are considering, and has no place to transfer allowables from to his high capacity wells, when they got to capacity. He is the only one that would be hurt by this proposed system of allowable transfers - the man with a large block of acres with a lot of wells to transfer them around to suit his own convenience, would hardly be affected by the unit allowable system of Humble's.

MR. McGINNIS: I assume that Sinclair is not an applicant and not in opposition to this. I think our position has been made fully clear to the Commission, and our reasons therefor.

I would like to just make this statement. I feel certain the Commission is aware that, all other matters aside, their concern here is how can water flood oil be recovered with the least waste. That is what you are concerned with. The testimony here at this hearing is not in dispute that there will be no preventable waste with a high rate of recovery. Both sides have admitted that there will be no waste at unlimited production as a result of high injection rates. There has been very competent testimony, based upon field experience and actual pool information examples, that restricted production will result in waste. The only logical explanation that seems to me to have been put forth to warrant the Commission running the risk of causing this waste by restricting production is the impact that unrestricted water flood production would have upon the market.

Well, market -- it won't reduce the over-all market, and that is what the State of New Mexico is concerned with - in the total amount of barrels produced. To the extent that the men who have operated these floods and observed them, and shown you that waste will occur by controlling the production, you would be causing physical waste, you would be depriving the State of New Mexico of gross production tax on the wasted oil, and of it's royalty on the oil where it is on State leases, which is of great interest.

It seems to me the decision is simple; that unrestricted production does not cause waste, that should obviously be your decision.

MR. PORTER: Anyone else?

MR. HINKLE: If the Commission, please, this is in my opinion one of the most important cases to come before the Commission for some time. This case sparks the beginning of a new era in the production and pro-ration history of New Mexico.

The decision of the Commission in this case will undoubtedly set a precedent in secondary recovery operations in New Mexico. New Mexico is one of the first oil producing states to pass a comprehensive conservation law, and it has served as a model for several of the other states. The decisions of the Commission in this case, refusing to make an exception to normal State allowable, or to give a preferential right in the sharing of the market to oil produced from floods, could likewise well serve as a model or forward step in conservation practices for the other oil producing states.

As I see the situation, it is the duty of this Commission to allocate or distribute the allowable productions among the fields and operators of the State upon a reasonable basis, and in such distribution, to recognize correlative rights.

Our statutes do not exempt oil produced by secondary recovery methods from normal pro-ration, nor do they specifically provide that the Commission may exempt oil produced other than by primary methods. The only way that this Commission may possibly make an exception to normal pro-ration is to show that to control the production from a water flood within the normal limits of unit allowables for the field pool, would constitute underground waste.

The burden is upon the applicant in this case to prove that an exception to normal unit pro-ration is necessary to prevent such waste. We believe that the applicant in this case has clearly failed to carry this burden. There is a conflict of evidence in the case on the question that a slow flood will reduce or tend to reduce, the total quantity of oil ultimately recoverable, but there is absolutely no evidence to show that to control production from floods within the limits of normal State allowables would in this instance, or in any other instance, constitute waste.

I think we were particularly fortunate in this case in having the testimony and opinions of such authorities as Professor Frank Cole of the University of Oklahoma; Doctor Weinaug of the University of Kansas; and Doctor George Fancher of the University of Texas, to the effect that water flood projects can be controlled within wide limits without loss of maximum ultimate recovery.

We believe that it is but a matter of time until this principle will be generally accepted in the industry. I believe that it is a foregone conclusion that takes but little wisdom to predict, that both our primary and secondary production in New Mexico will continue to increase, in the face of a rather static and probably decreasing market.

It would be far better for the Commission to decide upon the principle of controlled production in this case, at a time when water flooding is just beginning, rather than to try to cope with the problem after our normal pro-ration has been thrown completely out of kilter by unlimited production from water flood projects.

If the operators in the State know that controlled production is to be the rule, they can plan and control their operations and production accordingly, which will not present any economic loss.

The recommendation of the Humble is that lease or unit allowable be granted in this case, or in case of water flood projects, equal to the normal unit allowable, times the number of injection and producing wells involved. Under such a system, there will be an orderly plan and regulation of water floods that would tend to stabilize the exploration and develolment of oil in New Mexico. Otherwise, within a relatively short time, there can be nothing but chaos, coupled by an intolerable administration problem of proration by the Commission.

We believe that the evidence in this case clearly shows that production from water floods can be controlled within pro-ration limits without waste, and that the Commission should deny the application of Graridge.

MR. CAMPBELL: If the Commission, please, I would like to say at the outset of my closing argument, speaking both for the applicant and for myself, that I too am pleased that we had the testimony of these people who testified for Humble Company.

I have the greatest respect for people who operate in the research field, and I certainly don't intend to minimize the contributions that they have made, and I'm sure in the future will make to the petroleum industry, as well as other industrial activities.

I do feel, however, that it is almost elementary that a theory arrived at in the laboratory remains a theory until it has been put into actual operation. There has been no testimony here that even the company that adopts this theory has undertaken to put it into effect in the field. The people who testified on behalf of the applicant, as it has been stated, are people who have operated water flood projects in the field.

I cannot believe, as it has been implied by one of the witnesses for Humble, that these people are simply recommending something because it is something that his client likes to hear, so he can get his money back faster. I don't believe the Commission believes that. I have just as much confidence in the opinion of these people as I do in the opinions of those who testified for Humble.

The inescapable fact is that every witness here on behalf of the applicant has testified that unless we are permitted to produce these wells at capacity allowables, waste will result in one way or another. I think that is the ultimate question before the Commission, and it is the responsibility of the Commission, I think, to consider that factor above all others, including the impact upon market demand.

Now, just one word about the market demand part of this case. It seems to me quite obvious that those who oppose this application base their opposition essentially and primarily upon that basis.

In the first place, there seems to me to be some serious doubt whether the Commission could render a decision in this case, based solely upon that factor.

Correlative rights do not involve a right to share in the market, if they did there would be a lot more cases before this Commission at the present time. The correlative rights involve the right to produce your share of the oil and the distribution of the market is entirely a matter that is removed from the correlative rights aspect of our statutes, in my opinion.

If there is any question on this case, any question, assuming that there certainly is a question as to whether waste is going to result if capacity allowables are denied, it seems to me that the last place the Commission should undertake to control the market is in secondary recovery, or water flood projects.

I can't, in my own mind, distinguish why a person has a right to come before this Commission and get an allowable for drilling a 12,500 foot well that pays him a bonus, an incentive bonus to do it, on an economical basis, and come back and deny, or ask that the same privilege be denied in a secondary recovery project that is directly associated with the ultimate recovery of the greatest amount of oil. It just doesn't make sense to me.

I think there are other places where this market situation can be corrected, without running the risk of loss of New Mexico oil.

Now, New Mexico is late getting into the secondary recovery field. Testimony has been heard here that in Kansas and Oklahoma and Texas, there are large numbers of secondary recovery projects in operation, and that the production from those, at this stage at least, is not being limited. It seems unreasonable to me for New Mexico to once again find it is at the end of the pipeline and that these people come in and ask us to withdraw what I think is our rightful share of the secondary or water flood portion of the market for crude oil from New Mexico.

In the last analysis, that I think is the summary of the case that has been presented against this application. It is purely a question of who is going to get to sell their oil. I don't think that is a thing that this Commission should or is under the statutes to consider. The question you have to consider is whether there is going to be waste, and every witness of the applicant has testified that his field experience convinces him there will be.

I don't believe that the market demand question should override that basic consideration and obligation of this Commission. Therefore, I request, the applicant requests, that the Commission grant this application for capacity allowable.

MR. PORTER: Is there anything further in this case? If not, the Commission will take the case under advisement. The Hearing is adjourned.

STATE OF NEW MEXICO)
) ss
COUNTY OF BERNALILLO)

We, ADA DEARNLEY and MARIANNA MEIER, Notaries Public in and for the County of Bernalillo, State of New Mexico, do hereby certify that the foregoing and attached Transcript of Proceedings before the New Mexico Oil Conservation Commission, was reported by us in Stenotype and reduced to typewritten transcript; that same is a true and correct record to the best of our knowledge, skill and ability.

WITNESS our Hands and Seals, this, the __________ day of December 1957, in the City of Albuquerque, County of Bernalillo, State of New Mexico.

My Commission Expires
June 19, 1959. ______________________ Notary Public.

My Commission Expires
April 8, 1960. ______________________ Notary Public.