40-8027/C-11

UNITED STATES ATOMIC ENERGY COMMISSION

IN THE MATTER OF:

[illegible]

Docket No. [illegible]

Place - Washington, D. C.

Date - Monday, 15 October 1973

Pages [illegible]

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UNITED STATES OF AMERICA

ATOMIC ENERGY COMMISSION

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In the matter of: :
: Docket No. SUB-1010
KERR-MC GEE CORPORATION :
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Courtroom No. 1
U. S. Tax Court
1111 Constitution Avenue, N. W.
Washington, D. C.

Monday, 15 October 1973

The hearing in the above-entitled matter was convened, pursuant to notice, at 10:00 a.m.

BEFORE:

JOHN FARMAKIDES, Chairman, Atomic Safety and Licensing Board

LESTER KORNBLITH, Member

DR. DALE BABCOCK, Member

APPEARANCES:

FRANCIS S. IRVINE, Esq., Kerr, David, Irvine, Burbage & Green, 600 Fidelity Plaza, Oklahoma City, Oklahoma; on behalf of Applicant.

ROY E. KINSEY, JR. and JAMES P. MURRAY, JR., Esqs., U. S. Atomic Energy Commission, Washington, D. C.; on behalf of Regulatory Staff.

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P R O C E E D I N G S

CHAIRMAN FARMAKIDES: Good morning, ladies and gentlemen. It is now 10:00 o'clock and the hearing will be in order.

This is the first day of the evidentiary session in the matter of the application of Kerr-McGee Corporation to amend its source material license so as to authorize sub-surface disposal of certain liquid radioactive wastes.

The amendment requested would permit the licensee to utilize deep well disposal of' raffinate wastes generated from the solvent extraction uranium purification process at its Sequoia facility.

The application was filed on May 15, 1972 and by letter dated September 29, 1972 the Deputy Director of the Regulatory Staff advised the licensee that its amended request had been denied.

The licensee then responded with additional information.

However, the Deputy Director again, by letter dated March 14, 1973, reaffirmed its denial.

On April 5, 1973 the licensee requested a hearing pursuant to 20 DFR 2.103. On July 10, 1973 the Atomic Energy Commission issued a notice of hearing published in the Federal Register at 28 FR 18921, directing that a hearing be held to consider this application of the Kerr-McGee

Corporation.

The notice of hearing directed the Board to consider and to decide certain issues in this proceeding which we have articulated earlier and they appear on page 3 of the transcript of the prehearing conference dated 14 August 1973.

On August 14, 1973 this Board held a prehearing conference in preparation for this evidentiary session.

At this time counsel for the Natural Resources Defense Fund appeared and argued on behalf of a "Petition To Require Publication of Proper Notice of Hearing" which had been filed with the Commission and the Board on August 7, 1973 by the Natural Resources Defense Fund.

Following such argument and in consultation with the parties the Board issued a prehearing conference order and notice of extension of time to intervene. This was published in the Federal Register on August 16, 1973, at 28 FR 22175.

Through this manner the Board gave notice and permitted an extension of time of thirty days within which petitions to intervene could be filed.

No petitions to intervene have been received and we assume that none have been filed.

Accordingly, by memorandum and order of this Board dated September 21, 1973, we called for the

evidentiary session to be held commencing today.

I believe that summarizes the actions taken to date.

I would further note in my preliminary remarks that in response to the Board's direction the parties have submitted a joint statement of proposed issues dated September 21, 1973.

The Board wishes to recognize the responsible action of the parties in agreeing to this joint statement of the issues.

Also, in response to a request that we made, the parties filed on September 21, 1973, a joint motion for scheduling which this Board has adopted with some minor changes.

We have also received all the testimony which the parties filed, so I think we are in the position of being able to proceed.

Last time we identified the other two members of the Board. On my right, Dr. Babcock and on my left Mr. Kornblith.

I would like to ask the parties now to make their appearances.

For the Applicant?

MR. IRVINE: Francis S. Irvine, Attorney, Kerr, Davis, Irvine, Burbage & Green, Oklahoma City, Oklahoma.

CHAIRMAN FARMAKIDES: For the Staff?

MR. KINSEY: Roy Kinsey, U.S. Atomic Energy Commission. And I would also like to identify my co-counsel Mr. James P. Murray, Chief, Rule-Making and Enforcement Council, U.S. Atomic Energy Commission.

CHAIRMAN FARMAKIDES: Thank you very much.

We are prepared to proceed.

I think the procedure that we had discussed was that the Applicant, as stated in the Joint motion for scheduling which we agreed to adopt, would put on its case first.

We will proceed with the Staff after the Applicant has completed and rests.

We would hope that the examination by both parties would make the record. If not, the Board is prepared to ask certain questions and we would hope that you would ask questions of the Applicant following the Applicant's direct case, but we would like to be certain that the witnesses of the Applicant hopefully will be made available to the Board if there are any further questions the Board should have after the Staff has made its case.

MR. IRVINE: Mr. Farmakides, if I might, we have one small problem here. Dr. Sternhagen, whose testimony has been submitted in here, is, as you can see, a medical doctor and has some cancer patients in New Mexico. We are going to

put his testimony on second in our presentation.

We would apprecaite it if any questions that need to be directed to Dr. Sternhagen by the Board could be done today, if possible, so that if at all possible he could go back tonight because he has difficulty having a replacement for himself in New Mexico.

CHAIRMAN FARMAKIDES: Yes. I think that would be something the Board would permit.

Any questions we might have, we will ask your panel, if you have one, and we really don't care who answers them, so long as the Applicant answers.

Let's proceed that way.

I also understand you all to agree to the fact that we would go ahead and accept the written testimony. You might summarize, if you will, but really it is the interrogation of the witnesses supporting that testimony that will be the main course of business today and tomorrow.

Is that correct, Mr. Irvine.

MR. IRVINE: Yes, sir.

Not knowing exactly how the Board intended to proceed, we had intended, I might say, to introduce the witnesses and introduce their written testimony and let them adopt it and then whatever questions we need or that the Board has or in the way of cross-examination can be asked.

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We have tried to present in our written testimony

as complete information as we possibly could.

CHAIRMAN FARMAKIDES: Mr. Kinsey, I assume this is satisfactory with you.

MR. KINSEY: That's correct, sir.

MR. IRVINE: May we ask one other question?

Will we be permitted redirect examination?

CHAIRMAN FARMAKIDES: Yes. We really want to develop all the facts, sir, and we want your case to be completely in the record as is the Staff's case.

It might be to your advantage -- and I think we did discuss this over the phone -- to go ahead and put on a panel of all of your witnesses. Perhaps this might be one easy way whereby we can just direct questions to the panel. Whoever on that panel can best answer that question proceeding to do so, sir.

MR. IRVINE: All right, sir.

CHAIRMAN FARMAKIDES: Is this all right with the Staff?

MR. KINSEY: The Staff had intended to use a three- or four-man panel.

CHAIRMAN FARMAKIDES: So you are going to do the same thing anyway?

MR. KINSEY: Yes, sir.

CHAIRMAN FARMAKIDES: Let's both sides do it. It will be more convenient, I would assume, unless there are

any specific questions that have to be directed to a particular person. Then we will indicate that Mr. So-and-So should answer the question. Otherwise the questions will be directed to the panel.

MR. IRVINE: Very good, sir.

For the purposes of convenience may we just have them introduce their written testimony one at a time and present the panel all at one time for any examination we need?

CHAIRMAN FARMAKIDES: Any way you want to do it.

MR. IRVINE: It doesn't make any difference to us.

CHAIRMAN FARMAKIDES: The easiest way from my point of view is for both sides to indicate they have no objection to the introduction of the testimony, with the credibility of the witnesses. You can stipulate that the testimony is what it purports to be and from that point on we can move ahead.

We do not have to worry about formalities. I do not believe there are any formalities in this case and that we can get down to the issues quickly.

If the two sides can agree to this, please let me know and you can both enter a joint stipulation.

MR. KINSEY: Yes, Mr. Chairman.

We would have one objection to the testimony of Mr. Shelly. Specifically the attachment.

CHAIRMAN FARMAKIDES: In other words, you have no

objection to the other testimony.

MR. KINSEY: That's correct, sir.

CHAIRMAN FARMAKIDES: And you would --

MR. KINSEY: The Staff would be more than willing to stipulate as to authenticity.

CHAIRMAN FARMAKIDES: And it may be received into evidence?

MR. KINSEY: That's correct.

Specifically I am referring to the attachment entitled the Applicant's Environmental Report.

CHAIRMAN FARMAKIDES: Do you have any objection, Mr. Irvine, to any testimony submitted by the Staff?

MR. IRVINE: No, sir.

CHAIRMAN FARMAKIDES: So you would have no problem seeing it received into evidence?

MR. IRVINE: No, sir.

CHAIRMAN FARMAKIDES: Both of you will have to be sure you identify all of your testimony properly so that you can refer to it later. You might want to identify each of the written testimony separately.

Let's go off the record for two or three minutes.

(Discussion off the record.)

CHAIRMAN FARMAKIDES: Let's go back on the record.

MR. IRVINE: Ifthe Board please, we would like to have the May 10, 1972 application attachments -- will they be

a part of the record automatically or do we need to introduce those at this time?

CHAIRMAN FARMAKIDES: The record is made by you.

MR. IRVINE: We would like to have the May 10, 1972 application and attachments made a part of the record, the information that was submitted on November 20, 1972 at the meeting that has been referred to here --

CHAIRMAN FARMAKIDES: How do you identify that, sir? How would you identify it? I don't know what information you are talking about.

MR. IRVINE: The geological documents and information, the information submitted by Mr. Gruy and associates.

CHAIRMAN FARMAKIDES: What is the title of that document?

Incidentally, all exhibits have to be in three copies. These are the rules. The reason being that we have to have copies to put in the public proceedings branch, copies for the Appeal Board and copies for ourselves. So if you don't have copies of these things, how can you file them as exhibits?

MR. IRVINE: They have already been entered. Copies have been furnished.

CHAIRMAN FARMAKIDES: Entered where? Not in this record.

MR. IRVINE: Copies have been furnished to the Board and I had thought that that was sufficient. We did not bring any extra copies with us.

CHAIRMAN FARMAKIDES: I think the rules are very clear. It is not copies of the Board that I am concerned with, it is the official copies for the public record. The public record is, of course, the public proceedings branch here. They are the ones who keep the public record, at 1717 H Street. They have to have a copy.

Also, we have to have a second copy which goes, then, up to the Appeal Board for its consideration if there is any appeal.

MR. IVINE: I am sure -- I feel certain that the copies have been filed with the public document room.

CHAIRMAN FARMAKIDES: Sir, I will take your word as counsel for the Applicant that this in fact has been done and I assume that you will do it if it has not been done.

MR. IRVINE: Yes, sir, we will.

CHAIRMAN FARMAKIDES: And you will check that, please?

MR. IRVINE: Yes, we will check that and find out.

May we then have permission to, at the conclusion of this hearing, leave the record open long enough for us to submit the extra copy that may be necessary for filing here?

CHAIRMAN FARMAKIDES: I assume that you are going

to comply with the rules of the Commission and those rules call for three copies. I assume, then, that if you have not yet submitted those three copies to the right people that you will do so.

MR. IRVINE: Yes, sir.

CHAIRMAN FARMAKIDES: What we might do is after this session is over perhaps we can get together informally and discuss a little bit further how this should be done. This is an extremely important aspect of this hearing.

Let's not use up any more time at this moment. You will be certain that this information is in the public record?

MR. IRVINE: I will, sir.

CHAIRMAN FARMAKIDES: What is it that you want to now identify for the record?

MR. IRVINE: The application and attachments dated May 10, 1972.

CHAIRMAN FARMAKIDES: Is there any problem with the Staff on that?

(No response.)

We will receive into the record as part of your direct case the application and the attachments to the application.

MR. IRVINE: And the geological and engineering information submitted at the meeting with the Atomic Energy

Commission on November 20, 1972.

CHAIRMAN FARMAKIDES: You have to be more specific, sir. If you want to make that your Exhibit Number 1 and then you take care of furnishing all that material as your Exhibit 1 --

MR. IRVINE: Yes.

CHAIRMAN FARMAKIDES: -- I am prepared to do that.

MR. IRVINE: Yes, sir. We will do that.

CHAIRMAN FARMAKIDES: Is there any objection to Exhibit Number 1?

MR. KINSEY: There is no objection, sir.

CHAIRMAN FARMAKIDES: Off the record.

(Discussion off the record.)

CHAIRMAN FARMAKIDES: Let's take a short recess.

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(Recess.)

CHAIRMAN FARMAKIDES: During this recess we had a little conversation with the parties and the attorneys thought that much of the evidence has already been identified. It is just a question of getting it into the record properly.

Mr. Irvine, will you proceed?

MR. IRVEINE: For Applicant's Exhibit Number 1, the original application and attachments thereto being Exhibits A through I.

CHAIRMAN FARMAKIDES: Applicant's Exhibit 1, with attachments A through I.

MR. IRVINE: Yes.

CHAIRMAN FARMAKIDES: And the attachments are the attachments to the applications?

MR. IRVINE: Yes, sir, and referenced in the application.

CHAIRMAN FARMAKIDES: Are there any objections to this being received into evidence?

MR. KINSEY: No objection.

CHAIRMAN FARMAKIDES: It will be so received.

(The documents referred to were marked Applicant's Exhibit Number 1A through 1I for identification, and were received into evidence.)

MR. IRVINE: Exhibit Number 2 consisting of several parts, Part A being a regional structure map, southeast Gore area, a regional or a structure map on the top of the arbuckle.

CHAIRMAN FARMAKIDES: That is actually 2A and 2B. 2C, diagrammatic cross-section showing relationship -- I am sorry, may we back off one time?

2C will be five overlays to accompany 2B.

CHAIRMAN FARMAKIDES: And these five overlays, are they identified separately?

MR. IRVINE: Yes, representing layers 1 through 5 of the five layers which the Gruy testimony has indicated.

CHAIRMAN FARMAKIDES: There is one overlay for each layer?

MR. IRVINE: Right.

CHAIRMAN FARMAKIDES: And each is identified with its corresponding layer?

MR. IRVINE: Yes, sir.

Exhibit 2D is a diagrammatic cross-section showing relationship of Morrow limestone to ground surface.

Exhibit 2E, diagrammatic cross-section showing relationship of Spiro sandstone to ground surface.

Exhibit 2F, copy of publication by H. J. Gruy & Associates, Inc. entitled Transient Pressure Analysis.

CHAIRMAN FARMAKIDES: What is the date on that, sir?

MR. IRVINE: I am sorry, sir, it does not bear a date. It was introduced on November 20, 1972, or itwas prepared on November 20, 1972.

DR. BABCOCK: I notice a number of documents that you and others have furnished don't bear any dates at all. Could I make a request that these get a date?

CHAIRMAN FARMAKIDES: I would be most appreciative.

The problem, of course, is keeping all this material separate and distinct so we can identify it easily and the date is the easiest way of identifying a document. If you put it on the document, please put it in the upper

right-hand corner. It is very helpful if all the dates are at one place so we can find the dates quickly.

MR. IRVINE: This brochure is not a special study. It is a brochure of services offered by the Gruy Associates. May we date it November 20, 1972?

CHAIRMAN FARMAKIDES: All right. Fine.

MR. IRVINE: Exhibit 2 G, another brochure prepared by Gruy & Associates dated November 20, 1972 entitled Reservoir Analysis By Numerical Simulation Models.

Exhibit 2H is an abstract prepared by John S. Rogers and others, Application of Numeric Simulation to a Multi-Zone Waste Storage Problem, with an attached letter from the Society of Petroleum Engineers dated September 22, 1972.

Exhibit 2I, a paper presented to the American Institute of Mining, Metallurgical and Petroleum Engineers on September 28, 1969, entitled Simultaneous Solution of Multi-Phase Reservoir Flow Equations.

CHAIRMAN FARMAKIDES: Is that all of Exhibit 2, sir?

MR. IRVINE: All of Exhibit 2, yes, sir.

CHAIRMAN FARMAKIDES: Any objection?

MR. KINSEY: No objection.

CHAIRMAN FARMAKIDES: It will be so marked and received into evidence as so identified.

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(The documents referred to were marked
Applicant's Exhibits 2A through 2I
for identification and were
received into evidence.)

MR. IRVINE: And pursuant to our conversation, we will furnish the requisite copies of these documents for filing.

Exhibit Number 3 consists of the written testimony and qualifications of the following: 3A, Dr. Phillip A. Chenoweth; 3B, H. J. Gruy; 3C, Dr. van Poollen; 3D, Dr. Charles J. Sternhagen. William C. Shelley.

CHAIRMAN FARMAKIDES: That is Applicant's Exhibit 3E?

MR. IRVINE: Yes, sir.

That is all of Exhibit 3.

I might state for the record that copies -- three copies have been furnished to Mr. Karas, the Chief of the Public Proceedings Staff, copies were supplied to the Atomic Safety and Licensing Appeal Board and copies were furnished to the Board and to the members of the Atomic Energy Commission.

CHAIRMAN FARMAKIDES: Are there any objections to marking Applicant's Exhibit 3A through E?

MR. KINSEY: There is no objection to the marking of any of these as exhibits.

CHAIRMAN FARMAKIDES: You do have an objection to --

MR. KINSEY: We would have an objection to a portion of Exhibit 3E, the testimony of Mr. Shelley.

CHAIRMAN FARMAKIDES: Then let's hold 3E out for the moment. We will discuss this later when we get to that point.

We will receive into evidence Applicant's Exhibits 3A through 3D.

(The documents referred to were marked Applicant's Exhibits 3A through 3D for identification and were received into evidence.)

CHAIRMAN FARMAKIDES: Are there any other exhibits that the Applicant is going to be offering?

MR. IRVINE: No, sir.

CHAIRMAN FARMAKIDES: Would the Staff like at this point to proffer all of its evidence?

MR. KINSEY: We can at this time.

CHAIRMAN FARMAKIDES: Why don't we do it and we will have it all at one place in the record. It will be convenient that way.

MR. KINSEY: Staff's Exhibit A would consist of the testimony and attached statement of qualifications of Mr. Donald A. Nussbauer.

Staff Exhibit B would consist of the testimony and attached statement of qualifications of Dr. Donald L. Warner.

Staff Exhibit C would consist of the testimony and attached statement of qualifications of Mr. John B. Robertson.

Staff Exhibit D would consist of the statement of qualifications of Mr. George D. DeBuchananne.

That composes the Staff's list of exhibits.

I also would refer to my letter to the Board of October 5, 1973 enclosing copies of the testimony and indicating that copies have been furnished to Mr. Karas in the public proceedings branch and the Atomic Safety and Licensing Appeal Board.

CHAIRMAN FARMAKIDES: Thank you, Mr. Kinsey.

Any objections to the proffer of the Staff?

MR. IRVINE: No, sir.

CHAIRMAN FARMAKIDES: They will be so identified and received in evidence as identified.

(The documents referred to were marked Staff Exhibits A through D for identification and were received into evidence.)

MR. IRVINE: If the Commission please, then we would --

CHAIRMAN FARMAKIDES: We are not the Commission. We are the Board.

MR. IRVINE: Excuse me. Do you object to the promotion?

Then, based upon our previous discussion, I would offer these exhibits and we will do so with the gentlemen who have prepared them.

I will call Dr. Chenoweth.

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Whereupon,

PHILIP CHENOWETH

was called as a witness on behalf of the Applicant and, having been first duly sworn, was examined and testified as follows:

DIRECT EXAMINATION

BY MR. IRVINE:

Q Would you state your name, please?

A Philip Chenoweth.

Q Where do you reside, sir?

A Tulsa, Oklahoma.

Q I hand you this document and ask if you can identify that?

A This is a list of my qualifications as a geologist.

Q Which has been submitted as a portion of Exhibit No. 3?

A Yes.

Q Do you adopt this as your testimony in connection with your qualifications?

A I do.

Q I hand you this document and the various attachments listed in here.

Do these need to be identified?

CHAIRMAN FARMAKIDES: What document are you handing to him?

MR. IRVINE: His prepared testimony with the maps and overlays that he has accompanying them.

CHAIRMAN FARMAKIDES: Are they attached to your testimony?

MR. IRVINE: They came all in this package.

CHAIRMAN FARMAKIDES: I know but are they physically attached to your testimony?

MR. IRVINE: They are not.

CHAIRMAN FARMAKIDES: I think you had better identify them individually so that we will know exactly what his testimony consists of.

BY MR. IRVINE:

Q I hand you this and ask if you can identify this document.

A This is my written testimony.

Q Do you adopt that as your testimony in this case?

A I do.

Q I hand you what has been marked Exhibit C-A to your testimony and ask if you can identify this for us.

A This is a geological highway map of the mid-continent region.

Q And I hand you what has been marked as Exhibit C-B to your testimony and ask if you can identify that.

A This is the structure map on top of the viola formation in the Webber's Falls area.

Q I hand you what has been marked Exhibit C-C to your testimony and ask if you can identify that for us.

A This is the structure map on the top of the Arbuckle group in the same Webber's Falls area.

Q I hand you what has been marked Exhibit C-D to your testimony and ask if you can identify that.

A This is a topographic map of the Webber's Falls area.

Q I hand you what has been marked Exhibit C-E to your testimony and ask if you can identify that.

A This is a structural cross section of the Webber's Falls area.

Q I hand you what has been marked Exhibit C-F and aks if you can identify that.

A C-F is a film overlay of the photogeologic interpretation in the same area.

Q Exhibit C-G to your testimony is physically attached to your testimony, isn't it?

A I believe it is.

Q And what is that, please?

A This is a tectonic map of the mid-continent region.

Q I hand you what has been marked Exhibit C-H to your testimony and ask if you can identify that.

A This is an interpretive sample log of the Kerr-McGee waste disposal.

Q Do you adopt all the exhibits and the testimony as your testimony in this case?

A I do.

MR. IRVINE: I have no further testimony from this witness.

CHAIRMAN FARMAKIDES: Could you kindly ask the witness to summarize his testimony? Since we obviously have some spectators here, it might be better at this point for the record to have a very short summary.

BY MR. IRVINE:

Q Dr. Chenoweth, would you please give us a short summary of the testimony you have presented here?

A I have made a geologic study of the area around the Kerr-McGee well which I identified as the Webber's Falls area, for a nearby town. This consists of a copy of United States Geological Survey topographic maps, subsurface structure maps which I prepared, a cross section which illustrates the subsurface structure and a narrative description of the geologic conditions in that area.

Q Could you summarize your findings in this matter, please?

A I have found that the well is located in a fault block, that is to say, a block bounded on four sides by structural displacements which we call faults. Two of those are obvious on the surface. The other two are located as a

result of deductive reasoning and certain surface features.

I also studied the rocks penetrated by the Kerr-McGee well and identified them on this interpretive sample log. They consist for the most part of interbedded sands, shales, silt, stones, limestone and dolomite.

The bottom of the well is in igneous rock, probably granite. I was also able to identify the Arbuckle group of formations which is the lowest of the sedimentary rocks in the well, which consists almost entirely of dolomite, generally impervious and nonporous but in a few intervals somewhat porous.

Generally speaking, the Arbuckle and all of the rocks in this well are impervious, or appear to be so in microscopic examination, with the exception of the few layers I mentioned.

CHAIRMAN FARMAKIDES: Thank you very much.

Does the Staff have cross?

MR. KINSEY: Yes, Mr. Chairman.

At this time I would like to request permission to use Mr. Donald Warner for purposes of technical interrogation of this witness. I think it would expedite the proceeding considerably.

CHAIRMAN FARMAKIDES: Mr. Irvine, do you have any objection?

MR. IRVINE: No, sir, we have no objection.

CHAIRMAN FARMAKIDES: I take it that Dr. Warner is expert in this area, at least more so than a lawyer?

MR. KINSEY: I believe you may say he is an expert. As you indicated, his statement of qualifications is already marked as an exhibit.

CHAIRMAN FARMAKIDES: We have used this proceeding in the past and it has implemented the proceedings so I do think it will be a contribution.

Dr. Warner?

DR. WARNER: The only question I would ask before I begin, you did mention earlier that you had the intent of presenting your -- the experts as a panel for interrogation. The only question I would ask is whether you intend to proceed with that or whether you prefer to have me cross-examine Dr. Chenoweth now.

CHAIRMAN FARMAKIDES: That was a suggestion that I made. It is Mr. Irvine's case. He can make it his own way. I have no problem with proceeding the way we are proceeding now.

Let's go ahead and proceed individually.

MR. IRVINE: Mr. Chairman, before he starts, we have no objection to the panel procedure, whichever would facilitate the matter or make it easiest for the Board to obtain the information that they need.

I introduced Dr. Chenoweth simply because of the

problem of identifying the various documents that had to be identified.

CHAIRMAN FARMAKIDES. We will proceed this way. This might also make it easier for the medical doctor to return today.

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CROSS-EXAMINATION

BY DR. WARNER:

Q Dr. Chenoweth, in Exhibits C-B and C-C of your testimony, the various faults in the vicinity of the Kerr-McGee well are represented in different ways; that is, some ome them are represented by solid lines where others are represented by dashed lines, the dashes being black in various cases.

Would you explain the difference between those shown by solid lines and those shown by dashed lines?

A Well, this is a common way of representing faults on the surface maps of this kind. Generally speaking, the solid lines represent a fault which is clearly located in that position. A dashed line is one where the position may vary within a few feet or miles. It is a matter of location.

Q Isn't it true that such faults on a legend of a map of this type -- that there is commonly a differentiation made in that the faults shown by solid lines are the ones which are visible on the surface as you previously described and have been shown to be there by wells which are closely

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enough spaced to in fact locate the fault without much question, whereas in the case of the dashed -- faults represented by dashed lines, as you, yourself, described they have been placed there on the basis of deductive reasoning and not necessarily on the basis of a specific bit of geologic evidence which would show that that is a unique location for the fault?

A The question is: Is it customary to show it on a legend?

Q Well, no. My question was: Isn't the difference that the faults shown by solid lines -- there is sufficient evidence to indicate that they in fact are there, whatever evidence that is, whereas the dashed lines indicate a fault located by inference or deduction?

A Yes.

Q In page 14 of your testimony you discussed the reasons for the possible existence of the so-called south fault. Among the reasons you cite the fact that the location coincides precisely with the barrier distance determined by Gruy and Associates.

If I correctly understand the Gruy report -- and it is possible that I don't because of the briefness of the report -- they did not actually locate this feature at all and only determined that it must be further than 29,000 feet away from the Kerr-McGee well. So in fact it doesn't

coincide precisely with any distance determined by Gruy but simply lies beyond this 29,500 foot point.

A Well, I have qualified that by saying almost precisely.

Q Well, in fact the fault could be some distance beyond the 29,500 foot point. This is only a minimum distance; is that not correct?

A It couldn't be very far because the other supporting evidence, the topographic evidence, for example, suggests that it is located at about that position.

Q Well, I am only referring to the Gruy report and your comment that it coincided precisely with their location, when their location isn't precise at all. In other words, they only set a minimum distance for this location and you then locate it on the basis of topographic features; would that be correct?

A That is right.

Q Aside from the topographic features that you mentioned, it could be located some distance beyond the 29,500 feet or might in fact not exist at all?

A It might. However, all the cases I can find are that this fault is indeed present. This is a matter of interpretation.

Q This is essentially what I am trying to establish, it is an interpretive feature rather than one that has been

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precisely located in any way. Aside from the topographic feature that you mentioned --

Well, okay.

MR. MURRAY: Excuse me, did you want to add anything, Dr. Chenoweth?

THE WITNESS: No.

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MR. MURRAY: Excuse me.

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BY DR. WARNER:

Q. With reference to the Webber's Falls fault on Page 15, this fault, at least as I understand it, is located in essentially the same way as the so-called south fault, except that in this case, the barrier distance determined by the Gruy study was rather precise.

However, if I again understand correctly, aside from the topographic features that you mentioned by which you determined the position location of this fault, it could occur anywhere between the Kerr-McGee well, and I believe the Bennett-Wilson well, which is to the north.

In other words, the only necessary structurally, or at least probably that there may be a fault somewhere between those two points and doesn't necessarily have to lie at this location which you show on your map.

A. Nevertheless, that is the most likely place for it to be.

Q. Based on the subsurface study, plus these topographic features which you find.

However, in fact, there might be several small faults which could accommodate structural interpretation as well as the one fault which you do show on your map.

In other words, the main reason, the main geologic reason for putting this fault there is the fact that it's difficult to accommodate the change in elevation without having

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some kind of a discontinuity in the fault.

A Yes.

Q On Pages 18 and 19, you state that extensive geologic analysis fails to reveal the presence of many faults other than the four shown in the structural map. This compares with this analysis on your overlay --

CHAIRMAN FARMAKIDES: Where is that stated?

DR. WARNER: At the very top of Page 19. This is with reference to the potential for other faults in this area.

BY DR. WARNER:

Q I would like to ask a question here with regard to this structural map. It seemed to me that in looking at that, you had added a new inferred fault that curves away from the Carlyle School fault here, one that hasn't occurred on the previous structural maps. It's south of the Kerr-McGee well.

MR. KORNBLITH: Excuse me, Mr. Warner, which of the maps are you referring to?

DR. WARNER: Well, either one. Exhibit CB would be fine.

CHAIRMAN FARMAKIDES: Let's be clear about that. That is Applicant's Exhibit 3 CB.

BY DR. WARNER:

Q You show a fault branching off to the West from the Carylyle School fault there, a dash showing that's inferred by you, and this hasn't occurred, I don't believe, on the other

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structural maps prior to yours.

A. That's correct.

Q. In other words, you did find another fault in that area, or inferred another fault in that area.

Taking the overlay to your map and placing it on the -- over the structure geologic map, it's apparent that from photogeologic analysis, a number of additional faults are shown between the Carlyle fault and the Marvel City fault, some of them indicated as probably -- as inferred, while others are qualified as being more definite in their location.

The point being that there are a number of smaller faults in this area.

MR. MURRAY: Will the record show, if we may, that the witness is nodding and agreeing with Dr. Warner.

CHAIRMAN FARMAKIDES: Did you agree?

THE WITNESS: There are a number of faults shown outside the area of interest.

BY DR. WARNER:

Q. First of all, I was pointing out this one additional fault that you had located there, Dr. Chenoweth. I was secondly referring to the fact that there are a number of additional faults shown on your overlay between those two faults that I mentioned.

Based on this type of evidence, would it not seem logical and in fact probable that in an area where two faults intersected such as the Carlyle School fault and the Webber's

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Falls fault that one might expect to find additional and perhaps smaller faults, sets of joints, as a result of this structural deformation.

A. It is possible, not necessarily so. Furthermore, sets of joints I doubt would be related. Joints are not the same as faults.

Q. Well, isn't it true that commonly in mapping -- doing geological mapping in an area where the rock exposures are very good and where you find relatively major faults such as the ones that are named here, that you also find numerous smaller features having the same direction as the major features, but being smaller in displacement or perhaps having no displacement, in which case, they would be joints, fractures, and small faults, accompanying the larger faults.

A. Yes, that is generally true.

Q. In Page 19 also, you state that the faults in the area are normal faults of the kind regarded as being responsible for trapping of oil and gas. Isn't it also true that these faults are well known as locations for seeps of oil and gas, for paths of mineralizing slushes in mining districts, and as areas in which high ground water well yields can be found, these facts all indicating that such features can be conduits as well as barriers in different circumstances?

A. It's certainly true that faults are avenues of mineralizing fluids in areas of metamorphic or igneous rocks. This does

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not qualify as that. It's also true that in shallow layers, shallow depths, ground waters find their way along faults.

But at dep ths of this kind, the kind we are talking about here, it's much more common to find that faults are traps.

DR. BABCOCK: What depths are you talking about?

THE WITNESS: This is on the order of 3,000 to 5,000 feet. The well is 3100.

CHAIRMAN FARMAKIDES: When you say traps, what do you mean?

THE WITNESS: A trap is an obstruction on the flow of fluids in the sursurface.

CHAIRMAN FARMAKIDES: They would act as pockets to contain --

THE WITNESS: In fact, the so-called trap to the oil is a very common feature. Here is a fault that provides a barrier to the movement of oil and gas. When it hits that, instead of rising to the surface, it's trapped in a pocket.

BY DR. WARNER:

Q. Dr. Chenoweth, are you familiar with the text, The Book Geology of Petroleum, by A. I. Levorson, published by the Freeman Corporation?

A. Yes, I am.

Q. I would like to quote to you from Levorson's text in which it says that "seepages of oil and gas are often associated

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with fallout crops. Thus, faults are commonly thought of as vertical channels permitting migration between reservoirs and to the surface. Many faults form the boundary plane of a pool of oil or gas. This may be due to the fact that the fault is tighly sealed and holds the petroleum from further migration or probably is more commonly due to higher fluid potentials within the channels and updip across the fault, which acts as an added barrier to the updip movement of petroleum."

Thus Levorson is stating that possibly, there are cases where faults in fact are impermeable, in themselves preventing the upward migration of petroleum, but perhaps are more commonly caused -- the oil accumulations are more commonly caused by a set of circumstances, including the downward potential of -- fluid potential, which prevents the petroleum migration.

In other words, it isn't the fault alone that is most commonly acting as the barrier to fluid movement, according to Levorson.

MR. IRVINE: Mr. Chairman, I think that we should raise an objection at this point. I think the interrogator is testifying at this time.

CHAIRMAN FARMAKIDES: I would think you should restate your question, sir. If you want him to -- when you restate your question if you want him to compare his opinion, or give you his opinion as to that statement, fine, but you are really testifying,

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and you are really interpreting that, so I am not quite sure what you are asking for.

DR. WARNER: I'm asking for his opinion of Levorson's statement. Dr. Chenoweth has expressed his opinion --

CHAIRMAN FARMAKIDES: identify that statement and ask for his opinion.

DR. WARNER: All right.

BY DR. WARNER:

Q With regard to the previous statement that I have just read, Dr. Chenoweth, would you care to comment on that in comparison with your earlier statement with regard to the capacity of fault for acting as petroleum traps.

MR. IRVINE: Mr. Chairman, may the statement be handed to the witness so that he might have a chance to look at it?

CHAIRMAN FARMAKIDES: Yes.

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(Document handed to witness.)

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CHAIRMAN FARMAKIDES: May I have that last statement read back?

(The reporter read the record, as requested.)

CHAIRMAN FARMAKIDES: In the future I would like to have copies of such statements given to the Board.

MR. MURRAY: The reason we haven't given you copies now is that we haven't marked the specific pages we are referring to. There are several pages in this textbook.

CHAIRMAN FARMAKIDES: We can identify it.

Dr. Chenoweth, can you give us your opinion, sir?

THE WITNESS: I could quote from this same text. "Many faults form the boundary plane of a pool of oil and gas, and this may be due to the fact that the fault is tightly sealed and holds the petroleum from further migration."

CHAIRMAN FARMAKIDES: What are you quoting from, sir?

THE WITNESS: This same textbook.

CHAIRMAN FARMAKIDES: What page?

THE WITNESS: Page 260.

DR. WARNER: I began my statement with that quotation.

CHAIRMAN FARMAKIDES: What is your opinion, sir?

THE WITNESS: I agree with it.

BY DR. WARNER:

Q I would like to have your comment with regard

to the latter part of the statement as well, Dr. Chenoweth.

A The latter part of the statement, which was just reread, is, "or it probably more commonly is due to higher fluid potentials within the fault channels."

Now we are over on page 261.

"An up-dip across the fault which acts as an added barrier to the up-dip movement of petroleum."

I agree with that.

Q I would like to ask you your opinion with regard to one more such statement, and this is from a publication Economic Mineral Deposits by Bateman, published by the Wiley Publishing Company in 1951.

Are you familiar with that text?

A No, I am not. I am familiar with Bateman.

Q I will read to you several short sentences from this, and then ask you for your opinion. This is with regard to faulting and the role it plays in the formation of other deposits or mineral deposits. It is at the bottom of page 333.

"Faulting plays a more important role than folding in connection with mineral deposits."

Then turning to page 334, "Faults serve as channelways for mineralizing solutions."

The statement I have previously read to you.

Then jumping to the end of that paragraph, "They

form and drain petroleum reservoirs."

I would again ask you for your opinion with regard to those statements.

A Those statements are true.

MR. KORNBLITH: Could I interrupt a moment? Could we get a definition of mineralizing solutions?

DR. WARNER: Is that appropriate for Dr. Chenoweth?

MR. KINSEY: Yes.

THE WITNESS: Ordinarily mineral deposits of the kind referred to here are metallic deposits such as gold, silver, and the like. These are thought of as originating by solutions which rise from molten rock at a place within the earth and find their way through various channels toward the surface where they are cooled and so identified.

CHAIRMAN FARMAKIDES: Does the Staff agree with that definition?

BY DR. WARNER:

Q Are not these solutions commonly simply water with the dissolved minerals in them?

A Yes.

Q In other words, water is flowing through these fault zones is what it says, with the minerals in solution, is that correct?

A That's correct.

However, this more frequently occurs in areas of igneous and metamorphic rocks than it does in rocks of the type we are dealing with here.

Q May I ask you, Dr. Chenoweth --

DR. BABCOCK: May I interrupt?

DR. WARNER: Yes. I am sorry.

DR. BABCOCK: We are talking about mineralizing solutions now. How much mineral content is in these solutions that you are speaking about? By mineral, I am speaking about calcium, magnesium, iron, the whole gamut.

In other words, how near pure is this water or how near saturated is this water?

THE WITNESS: In the case of a mineralizing solution, I can't answer that except to say that it is probably highly charged with mineral matter.

DR. BABCOCK: What I am getting at is, does it resemble in any way the type of water that Kerr-McGee intends to put down into the ground?

THE WITNESS: I seriously doubt that it does.

BY DR. WARNER:

Q Would you explain why you doubt that, Dr. Chenoweth?

In other words, I think that the solutions, for example, that form the mineral deposits -- I would cite as an example the solutions that may have formed of mineral

deposits in uranium deposits in the Colorado plateau area. How highly mineralized would you visualize those solutions as having been?

A   Well, now, if I am correct in my understanding, you are talking about an entirely different situation. The uranium deposits that I am familiar with -- I am not very familiar with any of them -- are places where fossil wood has been replaced in stream channels by migrating fluids.

Now there would probably be an extremely dilute solution. But the type of thing described by Bateman here, I rather imagine, is water rising from deep within the earth and it is probably not rain water which has seeped its way down, but is actually water originating that dissolves these minerals and redeposits them at a shallower level and I don't believe there has been any testing of this.

Q   Really what I am asking you, Dr. Chenoweth, is on what basis you believe that these mineralizing solutions are greatly different than the type of fluid that Kerr-McGee would be injecting, which is simply water with dissolved minerals?

A   It just seems likely that a fluid rising from a magma -- an area of molten rock -- would be more likely to be a strong solution.

Q   Would there be any material difference whether or not it had a larger content of dissolved solids or not? It is

again still water with dissolved solids, with dissolved minerals in it?

A No.

CHAIRMAN FARMAKIDES: I didn't understand that, sir.

THE WITNESS: I said no. Water with dissolved minerals in it is water with dissolved minerals.

BY DR. WARNER:

Q In page 3 of your testimony, you discuss the fact that faults may exist at the surface in some cases, and then die out at depth. Isn't it also common for faults to exist in brittle lower horizons and then to die out upward into shales in the form of folds and eventually not be apparent at all?

A Yes.

Q Again on page 19, you conclude that the Arbuckle group or formation -- it is not important, the distinction -- is shown to be homogenous, and that porous and permeable zones are constant in thickness and character for distances of at least several miles.

Yet turning back to page 15, you state that porosity and permeability are the result of dolomitization and are subject to the vagaries of the dolomitizing agents, indicating to me that such zones of porosity and permeability are -- have the potential for being rather erratic and perhaps

not widespread in individual cases. Would you agree with that?

In other words, essentially what I am saying is that I could agree with you that there are cases where zones are widespread. Could you also agree that there are cases, in fact commonly, where zones are not widespread, but because of the nature of them they are rather local?

A Yes, I would agree with that.

Q In page 17, you state that if there were leaks to the surface, that is, in the vicinity of the Kerr-McGee well, I presume, the surface waters would be highly polluted. Do you know what the fluid potential in the Arbuckle group is?

Do you know, in other words, what the reservoir pressure is in the Arbuckle group?

A Not precisely, no.

Q Then you don't know whether in fact there is potential for this to rise to the surface or not?

A As I recall, I was told that during the drilling of the well, the water did not rise to the surface.

Q If this is the case, then, there would be no natural tendency of this water to flow out there, so there would be no reason for the surface water to be polluted?

A That is exactly what I have said.

Q The point that I was trying to make is that this doesn't show that the fluid couldn't flow out. It simply

shows that there isn't potential there to drive it out. Perhaps it couldn't flow out, but at the same time we don't know.

A Well, it shows that it doesn't flow out at the present time.

Q It shows it doesn't flow out of the sand at the present time, all right.

Would you care to interpret and explain the origin of the several salt water springs that occur in the general vicinity of the Kerr-McGee well, not immediately close to it, but within several miles of the Kerr-McKgee well?

A I am afraid I can only answer that in general terms. There is a known salt spring six or eight miles away. I do know that the salt content of that water is less than the salt content of the water measured in the well. It is probably the result of an outcrop or a near-surface exposure of salt water bearing formation, probably in the Atoka.

Q Has there been any specific determination of the cause of this salt water spring?

A Not to my knowledge.

Q In the absence of such a determination, could it also be true that this salt water spring was leaking from some deeper formation, not necessarily the Arbuckle, because there is sufficient potential and pathways for this fluid to be forced in the surface in that particular case?

A It is possible that the salt water can be flowing from any one of the formations on this chart that I have prepared except the very shallowest.

CHAIRMAN FARMAKIDES: I am not clear. Excuse me for interrupting. You are saying that the salt water -- I assume you mean sodium chloride -- salt water from the salt spring?

THE WITNESS: Yes, sir.

CHAIRMAN FARMAKIDES: That that is a solution and is not as concentrated as the salt water from the well?

THE WITNESS: That's right.

CHAIRMAN FARMAKIDES: So there is a difference.

THE WITNESS: Considerable.

CHAIRMAN FARMAKIDES: Are you talking about the well sodium chloride solution is more dilute --

THE WITNESS: No, far more concentrated.

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BY DR. WARNER:

Q Could you tell me what the concentration of the water from that salt water spring is?

A I have that information. It is going to take a minute.

CHAIRMAN FARMAKIDES: If you give us that, give us the comparison, too. I think I would like to hear that comparison.

DR. BABCOCK: You mean comparison with the water in the well, down in the Arbuckle?

CHAIRMAN FARMAKIDES: Yes.

THE WITNESS: The spring we are referring to is described in this Oklahoma Geological Survey publication, Hydrographic Atlas No. 1.

CHAIRMAN FARMAKIDES: What date?

THE WITNESS: The date is 1969.

Ordinarily the salt content of waters of this kind is expressed by the concentration of the chlorides in the water. In this case the chloride scales off to be roughly 60,000 parts per million.

CHAIRMAN FARMAKIDES: Where?

THE WITNESS: In this spring that we are referring to located in section 19, township 12 north, range 20 east.

That is approximately ten miles southwest -- make that eight miles.

CHAIRMAN FARMAKIDES: How about the concentration?

THE WITNESS: The concentration in the well was 83,000 parts per million of sodium chloride.

DR. BABCOCK: The fact that this is more dilute than the material down in the well, does that prove that this water didn't come from the Arbuckle?

THE WITNESS: It does not prove that but it is highly suggestive of it.

DR. BABCOCK: Let's ask the question the other way around. Suppose it had been more concentrated than the water in the Arbuckle. Would that have proved that it came from the Arbuckle?

THE WITNESS: No, sir, I am afraid I can't tell you either way.

DR. BABCOCK: In other words, you can't -- okay.

CHAIRMAN FARMAKIDES: But it was suggestive, however, that it is less concentrated.

THE WITNESS: Yes.

MR. KORNBLITH: What did you say the comparative concentration in the Arbuckle water is?

THE WITNESS: The Arbuckle was 83,000 parts per million.

MR. KORNBLITH: Approximately a third more concentrated?

THE WITNESS: Yes.

BY DR. WARNER:

Q May I ask, Dr. Chenoweth, if you have any information on regional trends in salinity in the Arbuckle that would indicate what the variations in salinity are within the vicinity of this Kerr-McGee well?

A Well, I have -- yes, I have studied that. I don't have any proof with me at the moment but generally speaking the Arbuckle waters become more saline southwestward and fresher northeastward.

Q What kinds of variations in salinity do you find within the general area? Again, just the order of magnitude of variations?

A There is very little information, Dr. Warner, but I would say on the order of 5- or 10,000 parts per million.

Q Again I am not necessarily trying to establish specifically that this water is coming from the Arbuckle formation. I only wanted to establish the fact that it could be coming from some unit, as you said yourself, anywhere in the geological column there, and could possibly be leaking vertically upward to this spring?

A Yes.

DR. WARNER: That is all the questions I have.

CHAIRMAN FARMAKIDES: Thank you.

The board has some questions.

Did you have any redirect, Mr. Irvine?

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MR. IRVINE: Yes, I do.

REDIRECT EXAMINATION

BY MR. IRVINE:

Q Dr. Chenoweth, I hand you what has been admitted here as Applicant's Exhibit 2-E, cross section showing relationship with spirosandstone to ground surface, and ask if you have seen this document and if you can identify it?

A Yes, I have seen this.

Q What does that show in relation to the salt spring that you have previously testified to?

A This shows that the spring occurs at a point where the spirosandstone appears at the surface. Spiro is th: basal unit of the Atoka formation. Customarily -- not customarily -- in the general vicinity the spiro waters are salty.

Q I call your attention and ask if you can tell us what this portion, the down dip portion in here, indicates, if you know?

A I presume you mean this curved line at the top?

Q Yes.

A This is roughly the topography.

CHAIRMAN FARMAKIDES: Of What? Could you state for the record so we will be clear what you are looking at?

THE WITNESS: This is a cross section which shows not only the subsurface attitude of the rock surfaces but also the ground level.

CHAIRMAN FARMAKIDES: At the upper righthand corner of the map?

THE WITNESS: Clear across it.

BY MR. IRVINE:

Q It is the heavy dark blue lines across the top?

A Yes.

CHAIRMAN FARMAKIDES: All right.

THE WITNESS: The point where the spring comes is the foot of a rather steep escarpment.

BY MR. IRVINE:

Q In what kind of topography does this spring arise, if you know? In a stream, on open ground, or what?

A I don't know.

MR. IRVINE: That is all I have.

CHAIRMAN FARMAKIDES: The Board has some questions.

MR. KORNBLITH: Mr. Irvine, is that my copy that you borrowed earlier of the exhibit?

MR. IRVINE: Yes, sir, it is.

MR. KORNBLITH: Could I borrow it back?

Is Dr. Chenoweth the only witness you have on the question of salt springs?

MR. IRVINE: No, sir, he is the only one.

MR. KORNBLITH: I noted in the material submitted by the Staff there was a letter that Dr. Warner wrote in May of 1970 that referred to some information which one of the exhibits

that the Applicant had supplied the Staff prior to that time relating to natural salt water springs. It was exhibit M of Appendix B of the earlier application. We don't have that available to the Board and it is not in the record as having been introduced so far, but I ask if you are familiar with this. Is this material that you were involved in the preparation of?

THE WITNESS: I wasn't involved in the preparation of that material.

MR. IRVINE: If the Board please, the exhibit that you are talking about was the exhibit M to an application filed in 1970 which was withdrawn and all the documents were withdrawn. So w^at he is referring to is something that is not a part of this record.

MR. KORNBLITH: Do you have any one available, Mr. Irvine, who is familiar with the information on salt water springs that was contained in that document?

MR. IRVINE: No, sir. Mr. West, a geologist with Kerr-McGee did that particular study and he is not available at this time, at this moment.

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MR. KORNBLITH: All right, thank you.

Is this spring that you mentioned, the only salt water spring that you are aware of in the immediate vicinity?

THE WITNESS: There is one about 20 miles east of here, I believe.

MR. KORNBLITH: Is there any way -- I gather you stated earlier that there is no way of associating the source of the water that appears in this spring with any particular geologic formation, is that correct?

THE WITNESS: Except insofar as that cross section shows, the spiro sandstone occurs at the surface in the vicinity of the spring?

MR. KORNBLITH: Is this spiro layer one that underlies the site?

THE WITNESS: Yes.

MR. KORNBLITH: Of the present Kerr-McGee well?

THE WITNESS: Yes. Although it is not identified on my log, it occurs at a depth of approximately 400 feet below the site.

MR. KORNBLITH: Do you have in front of you Exhibit CE to your testimony?

This is the structural cross-section? Can you tell me where that falls with regard to the four layers you have shown?

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THE WITNESS: It is just above the wapanucka limestone. It is just above that.

MR. KORNBLITH: Was there evidence of this same type of water in the cores from this well?

THE WITNESS: I don't believe it was tested, but I can't answer that.

MR. KORNBLITH: While we are on this particular drawing, Dr. Warner was asking you earlier about the basis for locating the Webber's Falls fault. One basic reason for inferrring the fault there, I gather, is because of the difference in elevations of the various identifiable layers in the Sequoya well and this number 1 Wilson well, is that correct?

THE WITNESS: Yes, sir.

MR. KORNBLITH: But that in itself does not pin down where between those two points the fault lies?

THE WITNESS: No, sir.

MR. KORNBLITH: So from the evidence of those two wells, it could be anyplace inbetween, is that correct?

THE WITNESS: That is correct.

MR. KORNBLITH: You also identified the fact that the wapanucka limestone does not outcrop at the point where you would expect it to that you have identified on the drawing.

Would this indicate, then, that the Webber's Falls fault would have to be someplace between that anticipated

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point of outcropping and the Sequoyah well?

THE WITNESS: Yes, it does.

MR. KORNBLITH: So now we have worked it down to perhaps 2 miles.

What is the basis for selecting the particular location that you have selected within that two-miles zone?

THE WITNESS: That you can see by referring to the topographic map, which is Exhibit CD. I point out, Mr. Kornblith, that although faults are extremely common, it is rare to actually find the plane of a fault at the surface, except in quarries or mines or excavations of that nature.

Erosion rapidly removes any surface evidence, particularly these which have suffered their movement, probably more than 200 million years ago. There has been plenty of time to remove any surface exposure of the actual fault plane. But you will notice that Salt Branch Creek, and a bend in the Illinois River, a peculiar round mountain near the town of Gore, a pair of round maintains southeast of the Kerr-McGee site, all seem lined up.

Furthermore, they line up with the rather steep escarpment identified as Sausbee Mountain, north of the town of Gore.

MR. KORNBLITH: Does the fact that a mountain is round have a particular significance?

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THE WITNESS: It is a peculiar topographic feature for this area. None of these are conclusive points of evidence, but they are all circumstantial.

Whereas there is a fault located between the Kerr-McGee site and that nearest well or the point of projected out-crop on the wapanucka, this is the most likely place for that fault to occur.

MR. KORNBLITH: Thank you.

There was some discussion that you had with Dr. Warner earlier about this fault that you had shown on your Exhibit CB that has not previously been shown, one that branches out from the Carlyle School Fault.

I notice on Figure O-O, Exhibit CF, the overlay, that there is also an upward curve fault that lies 500 or so feet northeast from the fault that you marked, 500 or 1000 feet.

Is that the surface indication of the same fault? Can you associate those?

THE WITNESS: You are referring to one north or south of the well?

MR. KORNBLITH: Southwest of the well, and north of this branching fault, roughly parallell to the branching fault.

THE WITNESS: One I fail to find in the field and I identify that as probably a line of vegetation or a topographic feature rather than a -- my fault can be identified only for a

few feet from a point where it branches off the Carlyle School Fault. From there it passes westward beneath the alluvial valley of the flowing of the Arkansas River.

I have simply extended it because it seemed likely that it would be perhaps a mile or so in length. There is no surface evidence for it beyond that first segment of the dashed line.

MR. KORNBLITH: Just to make sure we are talking about the same fault in Exhibit CF, it is one that is in the same section as the beginning of this fault you were describing?

THE WITNESS: A very light dashed line which is an inferred fault. I could find no field evidence of it.

MR. KORNBLITH: Not the two that are perpendicular?

THE WITNESS: No.

MR. KORNBLITH: Can you define for me photogeologic interpretation?

THE WITNESS: This is a means of mapping surface structures by the use of stereoscopic air photos.

Stereoscopic photos reveal changes in topography and such features as lines of vegetation or changes in rock outcrops.

I might point out it is a very commonly used reconnaissance geologic tool.

MR. KORNBLITH: Did you prepare this overlay?

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THE WITNESS: Well, this is a copy of one prepared by the Geological Survey from which I have eliminated all but the fault and the inferred faults.

MR. KORNBLITH: What were the last few words you said?

THE WITNESS: I have eliminated from the Oklahoma survey's copy everything except the faults and the inferred faults.

MR. KORNBLITH: What additional type of material was on it?

THE WITNESS: What we call dip and strike symbols, symbols that show the attitude of the rock formations.

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MR. KORNBLITH: Referring once again to your Exhibit CB, on the wells there are certain symbols, numbers, and so on, below them. Could you explain this?

For instance, on the Kerr-McGee Sequoyah well there is a series of numbers on top which is 59, then 3122, and then B-477 and 383. Are these what?

THE WITNESS: It is at first number 179. It is the elevation, the variation at the wells to the depths of the well and the various standards for the Viola limestone, and that is a minus 477. That is the subsurface elevation. It is 477 feet below the level at that point. A standard for the Arbuckle, top of the Arbuckle, and it is a minus 583 feet, and that same structure goes for the others.

The little symbol, the circle, with the vertical and horizontal lines, indicates a dry oil or gas test.

Q What are the three little lines radiating out from the circle?

A That is the injection. And way over on the left side of the map there is a gas field where the wells look like little stars.

Incidentally, that has a fault trap.

CHAIRMAN FARMAKIDES: In other words, when you hit a paying well, you make a star out of it, but when it is dry, you ignore it.

MR. KORNBLITH: Take a look at the Cobb-Wilson well

which you referred to on one of your other exhibits. There the 775 is the surface elevation?

THE WITNESS: Yes.

MR. KORNBLITH: And 2134 is the total depth of the well below sea level, I guess?

THE WITNESS: No, below the surface.

MR. KORNBLITH: And that apparently does not go down to the Arbuckle layer, or what? I mean the Arbuckle is not identified.

THE WITNESS: No, it is not.

MR. KORNBLITH: Does that map show, in the vicinity of the Sequoyah well, all of the known wells and all of the information that was available about them?

THE WITNESS: Yes, sir, except for shallow water wells. They are not shown, for the core wells drilled by Kerr-McGee around the site.

MR. KORNBLITH: Everything that goes down into the layers of interest here?

THE WITNESS: Yes.

MR. KORNBLITH: I think that is all I have.

CHAIRMAN FARMAKIDES: Dr. Babcock?

DR. BABCOCK: Would your characterize your location of the faults as agreeing with the faults that have been predicted by the dry report or are there major differences?

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THE WITNESS: There are no major differences that I am aware of.

DR. BABCOCK: In other words, your study confirms the dry study or vice versa? I don't know which one came first.

THE WITNESS: Yes, sir.

DR. BABCOCK: I noticed in the dry study that the faults were not continuous. They would go down a few hundred feet and then jog over several hundred or a thousand feet and proceed downward again, and then jog back. Is that a common thing for faults to do?

THE WITNESS: I am not exactly sure what you are referring to. It is common for a fault plane to be irregular and instead of being like a perfectly smooth plane, it will be irregular, depending on the types of rocks that it intercepts.

DR. BABCOCK: I am now reading from Exhibit A, which is the H. J. Gruy and Associates report that went with the original applicaition. I am looking at Figure 5.

THE WITNESS: Is this the figure you are talking about?

DR. BABCOCK: That's correct.

THE WITNESS: This does not show faults, as far as I can tell.

DR. BABCOCK: It shows locations of boundaries.

THE WITNESS: These are fluid fronts. These curved lines are the front of the fluid.

DR. BABCOCK: But the boundary that is outlined there I interpreted as being the faults that were predicted by Mr. Gruy.

THE WITNESS: I am afraid I can't answer that, Dr. Babcock. I will have to let Mr. Guy answer that, sir. Mr. Gruy will testify.

DR. BABCOCK: These are not boundaries.

MR. GRUY: These aren't faults.

DR. BABCOCK: They are boundaries?

CHAIRMAN FARMAKIDES: We will talk about that later.

DR. BABCOCK: What I was getting at was I had interpreted Figures 5, 6, 7, 8, and 9 as being fluid boundaries that inhibited the flow of water from the well, which is the point in there, on outside. And in my layman's language, I was equating a boundary to a fault.

Now, then, the thing that was bothering me was that there is some rather major differences in the location of this fluid boundary as you go down at some of the faults. I am merely asking you if that is a common thing.

THE WITNESS: I can't answer it.

DR. BABCOCK: That is all I was getting at.

CHAIRMAN FARMAKIDES: We have one more question.

MR. KORNBLITH: Let me refer to page 19 of your

prepared testimony. You said about seven lines up from the bottom, "The Arbuckle group of formations is shown to be homogenous in local details and numerous careful workers have succeeded in correlating narrow zones over wide distances."

Could you explain to me what you mean by homogenous? Is this three-directional homogeneity,or are you talking about layers, or what do you mean here?

THE WITNESS: You might think of a sedimentary rock as consisting of layers like boards piled one on top of another. By homogenous I mean that a single board in that stack would be essentially be the same in all directions.

MR. KORNBLITH: But when this is a pile of interspersed pine, oak and so on, boards, one layer is not the same as the next?

THE WITNESS: That's right.

MR. KORNBLITH: The reason this bothered me a little bit is because your statement of homogeneity seemed to be inconsistent with the information in some of the other testimony showing the differences between the five layers in porosity and permeability, and of course the difference between the five layers and the intermediate layers.

So you are not inferring that in a vertical direction there is homogenity in the group?

THE WITNESS: No, except that the various units

of the Arbuckle group are similar in nature. They are all dolomite, they all contain varying amounts of sand, some shale, and the salicious material that we refer to as chert. But the crystal size, for example, or grain size varies from layer to layer. So does the sand content.

MR. KORNBLITH: Now, suppose you drilled another well, let us say a hundred yards away, just for the sake of a number, and you could identify the same layers in there. What sort of differences would you expect in permeability and porosity between the same layer? Could you give us any sort of quantitative guess?

THE WITNESS: A hundred yards away they would probably be identical.

MR. KONRBLITH: Could you give us two significant figures, or one, or three?

THE WITNESS: Two. This is not something you can quantify.

MR. KORNBLITH: One particular layer has a porosity of .089, we will say. Another sample, a hundred or two hundred yards away, you would expect to be within a few percent of that same value?

THE WITNESS: Yes.

MR. KORNBLITH: And some of these layers with 25 to 34 feet -- well, one was 34 feet thick. Along that whole 30 feet, would you expect to find the figures about the same?

I guess numbers were available. Were they the same or what sort of variations were there?

THE WITNESS: I cannot answer that, but I would expect there to be variations. It is not as though you drilled it through a cave, a cavern, for instance, where the porosity and permeability would be identical.

MR. KORNBLITH: So when you talk about it being homogenous within the layer, you really mean homogenous?

THE WITNESS: Yes.

MR. KORNBLITH: And homogenous means within a few percent?

Don't let me put words in your mouth, if this is not what you meant.

THE WITNESS: That's right. What I further meant here by saying correlating narrow zones over wide distances, to illustrate the lateral homogeneity in this, there is one unit -- well, there are several, but one in particular that can be identified from northeast Missouri to southern Oklahoma with very little difference. I am referring to the sandstone basin of the Ordovician series.

MR. KORNBLITH: Thank you. That is all I have.

CHAIRMAN FARMAKIDES: Thank you, Dr. Chenoweth.

Do you intend to stay here for the course of these hearings?

THE WITNESS: Yes.

MR. KINSEY: Dr. Warner had a series of questions he was wondering if he -- or one question he would like to ask which he omitted in his earlier questioning, which he would like to ask, if there is no objection.

CHAIRMAN FARMAKIDES: Is there any objection?

MR. IRVINE: No, sir.

CHAIRMAN FARMAKIDES: Ordinarily we wouldn't do this, but go ahead, Dr. Warner.

RECROSS-EXAMINATION

BY DR. WARNER:

Q I would like to relate it to the two questions you have just asked him, Dr. Kornblith. You asked if they were a hundred yards apart. I would pose the same question with regard to homogenity to Dr. Chenoweth if the wells were a half a mile apart. This is with regard to porosity and permeability continuity, not with regard to stratographic markers.

CHAIRMAN FARMAKIDES: Do you understand the question?

THE WITNESS: Yes, I understand the question. I am not sure I can answer it very briefly.

The nature of this permeability is such that it can diminish laterally and probably does. But it depends on the vagaries of the rock itself. That is, you might find this same permeable zone in one direction for a great distance, and

in another direction for only a short distance.

DR. BABCOCK: Would you put some numbers on "great" and "short"?

THE WITNESS: It is conceivable that a permeable zone like this could extend for five or six miles.

DR. BABCOCK: And that is a great distance?

THE WITNESS: Yes.

DR. BABCOCK: And a short distance?

THE WITNESS: Oh, a half mile.

BY DR. WARNER:

Q The second question was with regard to this locating of the fault. We were talking specifically about the Webbers Falls fault, the one nearest the Kerr-McKee well. If you were to wish to determine precisely where that fault existed or if in fact it did exist, what would you do? What procedure would you follow to determine as nearly as possible where that fault exists, if it does?

A In order to determine exactly whether it existed, one would have to excavate across the line of the fault and actually observe it.

Q Within a margin of error, let's say. I didn't mean to say that -- if you wanted to pin it down within a quarter of a mile, what would you have to do, or what could you do?

A There are various geophysical methods with which it might be located. That is, perhaps a seismic survey across

the line of fault. This is a technique for measuring the travel time of sound waves from the surface to a reflecting layer in the subsurface.

CHAIRMAN FARMAKIDES: To be a little more specific, with regard to Dr. Warner's questions, what did you do?

THE WITNESS: Nothing beyond what is stated in here.

BY DR. WARNER:

Q If you wanted to locate it more accurately, what would you or could you do? And he mentioned seismic, which is a further interpretative procedure. Then after you did the seismic survey to determine in fact if the fault existed, what would you then do?

CHAIRMAN FARMAKIDES: I am not sure -- this bothers me, sir.

So far as I understand this witness, he has said what he has done, which is an accurate, step-by-step approach.

Now, are you saying that it is not accurate and what he could have done would be accurate?

DR. WARNER: Well, the fault is at this point an inferred fault. The fact that a fault exists or does not exist is important to the question.

CHAIRMAN FARMAKIDES: Then could you restate your question?

DR. WARNER: Yes, I will be glad to.

BY DR. WARNER:

Q What procedure would you follow if you wished to locate or unequivocally determine that this fault does exist and where it exists and where it is in fact?

A As I stated earlier, the only way it could be unequivocally located is by trenching across the location.

Q Then I later qualified that to say within a quarter of a mile. Wouldn't drilling of additional shuttle holes to a marker bed accomplish the same thing?

A No, because there are other geological conditions which might account for the same situation.

Q Well, would you describe those?

A It could be a hole, for example.

Q Wouldn't the drilling of the wells and the seismic survey indicate rapid change in vertical location of these marker beds?

A Yes.

DR. WARNER: May I ask one more question?

CHAIRMAN FARMAKIDES: On the same problem?

DR. WARNER: No. It is a slightly different matter.

BY WARNER:

Q What would the first layer be above the Arbuckle, one that had sufficient porosity sufficient to obtain a small amount of water from it by pumping or put water into it by

injection in your analysis?

A The lowest permeable and porous zone would be the Simpson sands.

(Discussion off the record.)

CHAIRMAN FARMAKIDES: We will take a five-minute recess and reconvene.

(Recess.)

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CHAIRMAN FAMAKIDES: I would like, Mr. Irvine, if I can, to ask Dr. Chenoweth one last question. I need to have some further clarification. Dr. Chenoweth, would you please come back to the stand? It is just my own need to clarify something that I am a little confused on. Do I understand what you had said earlier, and looking at it from a general point of view, you have various layers of different types of materials, rocks and what-have-you.

THE WITNESS: Right.

CHAIRMAN FARMAKIDES: And ordinarily a fault would extend in a main through these layers. In other words, these layers, then, displace upward or downward, or perhaps some other way, but upwards or downwards in such a way that you have a plane. Well, now, Dr. Babcock had asked you something earlier and I wasn't clear. Did you suggest that these layers -- that, shall we say, you have layers A, B, C, D, E, F. Did you suggest that perhaps layer B and layer F would be displaced without C and E being displaced?

THE WITNESS: No. The question was what fault would go down a certain distance and then be continued a lateral distance from that.

CHAIRMAN FARMAKIDES: But now you are telling me that each of these layers will be displaced either upward or downward?

THE WITNESS: Of course it doesn't go on indefinitely.

CHAIRMAN FARMAKIDES: I understand that. Thank you, Doctor.

(Witness excused.)

CHAIRMAN FARMAKIDES: We can proceed.

MR. IRVINE: Dr. Sternhagen, please.

Whereupon,

CHARLES J. STERNHAGEN,

was called as a witness on behalf of the Applicant, and having been first duly sworn, was examined and testified as follows:

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DIRECT EXAMINATION

BY MR. IRVINE:

Q Would you state your name, please?

A Charles J. Sternhagen.

Q Dr. Sternhagen, I hand you a copy or a document which is identified as the prepared testimony of C. J. Sternhagen, M.D., to which is attached the qualifications of Charles J. Sternhagen, M.D., and ask if you can identify that document as such?

A Yes, sir, this is my prepared testimony and this is a brief resume of my qualifications.

Q Do you adopt that as your testimony in this cause?

A Yes, sir, I do.

CHAIRMAN FARMAKIDES: Could you briefly summarize your testimony, sir?

THE WITNESS: Yes, sir. This report deals primarily

with the radiation toxicity of the Raffinate disposal well and spring solutions at the Kerr-McGee Sequoya facility. Radium is accepted as the radiological toxic agent of primary interest.

There are four naturally occurring radioactive series. We are not discussing the very toxic radio nuclides of the actinium series which involves uranium 235. We are not talking about the decay of plutonium 241 in the neptonium series. We are only talking about the thorium and uranium series.

Now, the primary toxicity with uranium is to the kidney. However, the absorption in the gastrointestinal tract is in the range of about three percent to 300ths of a percent, so it is very obvious that Uranium 238 is tolerated in relatively great amounts by the oral route.

DR. BABCOCK: When you say uranium, are you qualifying it as to the chemical composition of the uranium or just uranium in any chemical composition?

THE WITNESS: Uranium in any chemical form is still uranium in terms of kidney toxicity.

DR. BABCOCK: I recognize that. I was wondering if you were talking about a specific uranium oxide or were you including uranium chloride, for example.

TH[illegible] WITNESS: I think we can include them all. Are ther[illegible] any other questions about uranium.

The next, thorium, generally seeks out the liver,

spleen, blood vessels and connective tissues. However, the absorption of thorium decay products in the gastrointestinal tract is very low, less than one thousandth of one percent absorbed at doses of 500 to 800 milligrams per kilogram, and 5 hundredths of a percent at 5 milligrams per kilogram.

Radium has a maximum permissible amount fixed in the body of one tenth of a microcurie. Radium is eliminated very rapidly the first week after ingestion. 70 percent the first 24 hours and 95 percent within five days.

Some of the figures on radium I think are important to put these solutions in perspective. The Great Salt Lake at Utah has 5 x 10^{-3} microcuries per milliliter. Curie Springs at Boulder, Colorado, has 2.6 x 10^{-4} microcuries per milliliter.

Normal ground water in the U.S. ranges from .58 to 3.9 x 10^{-8} microcuries per milliliter.

If a person could drink this solution straight a single ingestion of one liter would be relatively harmless because 90 to 95 percent would be eliminated within the first five days. Also, in order to develop a body burden it would require perhaps years of daily drinking for it to become harmful.

Since these solution concentrations in the wastes are so strong they cause a burning sensation and bad taste which would make it almost impossible to receive a dose of

radio nuclide of any significant level.

In calculating a worst possible accident or incident, we showed on the second figure that if you pumped the entire solution in to the Arbuckle -- in to the Illinois and Arkansas Rivers at various levels of a massive fault leak, the general dilution of those rivers would still be great enough that the concentrations would generally be below permissible limits.

It is my understanding that the way this area will be monitored and the high precision with which a leak from the reservoir can be detected, high precision and accuracy, I believe it is incredible that actual release through failure of the well or the reservoir would result in significant exposure to the population in this area.

CHAIRMAN FARMAKIDES: Thank you, sir.

Any cross?

MR. KINSEY: Yes.

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CROSS EXAMINATION

BY MR. KINSEY:

Q Dr. Sternhagen, I have just a few questions. Are you familiar with the linear concept of radiation effects?

A Yes, sir.

Q Could you describe what the concept is?

A In order to describe that it is necessary to describe non-linear concept also.

Q Please do.

A The linear effect means that the more radiation one has starting from zero, that this always is an effect and it is cumulative or increases in a straight line function. Non-linear effect merely means that there is a threshhold, an amount of radiation that one can have before there is a effect that can be measured or that can be harmful.

Q Do you subscribe to one or to the other of the two theories, and if so which one is it?

A We are compelled to the linear theory in fly genetics and that is because there they were able to measure down to very low radiation dosages and effect on genetics.

However, this is in all types of industrial genetics that I am aware of -- there are threshhold limits and this means that there are certain tolerable amounts that are allowed, that are logically not considered harmful or there are enough safety factors that those threshholds are allowed. So therefore in terms of somatic body effects, one is compelled to use threshhold limits, since that is how all the data is published.

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Q In terms of genetic effects, you would apply the linear concept?

A In terms of any genetics.

Q If I understand your testimony, essentially you intended to analyze possible radiological health and safety consequences in the event there were a release of the raffinate waste water from the disposal formation; is that a correct interpretation?

A I think so.

Q In your assessment, what considerations did you in fact give to possible long-term radiological effects from human exposure to waste water?

A Well, as I stated previously, the undiluted solution I think -- I think it has to be stated that it would be categorically impossible to drink it long term because it is too strong a solution. It causes too much burning of the linings of the mouth and digestive tract.

Q Would it be possible for the radiation level to reach maximum permissible concentrations in, let's say, a domestic water well before the salt concentration reached the detectable limit?

A I don't know.

CHAIRMAN FARMAKIDES: What was your answer, sir?

THE WITNESS: I don't know.

CHAIRMAN FARMAKIDES: Let it be clear for the

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record that we are talking about the waste disposal solution.

MR. KINSEY: Excuse me, sir, yes. I meant not the salt but the chemicals in the waste water.

THE WITNESS: Would you rephrase the question, please?

BY MR. KINSEY:

Q Would it be possible for the radium concentration to leak into a well along with the waste water and perhaps reach maximum permissible concentrations prior to the other chemicals in this waste water reaching such a level that they would be detectable by a potential recipient?

A I think that is possible.

DR. BABCOCK: You mean by "detectable" that the guy would spit it out, that he wouldn't like it, that the water would taste bad?

MR. KINSEY: Yes.

CHAIRMAN FARMAKIDES: Doctor, what was your answer?

THE WITNESS: I think the answer to that is that it is possible. I am not an expert in that area.

BY MR. KINSEY:

Q You selected release into the river as the worst case, in your opinion. Did you consider other alternative case situations as possibly being the worst case?

A Yes, we did. We racked our brains to consider which would be the worse and we thought this would be the

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worst.

Q May I ask what other cases you did consider?

A We considered a release on the property.

Q Did you consider what would be the possible radiological effects of a release -- you mean on the surface?

A Yes.

Q Did you consider what those radiological effects would be?

A The radiological effects would be very quickly stopped since if you had a release on the property you would simply have corrective action to stop the release. So, therefore, we felt that this would not be as bad since it could be more quickly corrected, perhaps.

Q Did you consider a release off-site at some unknown location on the surface?

A These are releases off-site.

Q Other than releasing to the river, on the land surface?

A Yes, I think we did consider that.

Q Would that include considerations of uptake and food sources, that is, radium uptake by plants and things of that nature?

A Yes, but again that, we felt, was not anywhere near what this worst possible act would be.

Q I am referring now to Figure 2 attached to your

testimony, concentrations resulting from injection of Raffinate or or Arbuckle formation into the Illinois and Arkansas River.

Am I correct in saying that these calculations are based or interpreted on the basis that the maximum permissible concentrations of radium in solution into unrestricted areas is 3 times 10^{-8} in accordance with Appendix B?

A Yes, sir.

Q When you performed these calculations, did you take into consideration the provisions of 10 CFR 20.106, Paragraph E, which in this volume is on page 153, which provides as follows:

"In addition to limiting concentrations in effluent streams, the Commission may limit quantities of radioactive materials released in air or water during a specified period of time if it appears that the daily intake of radioactive material from air, water or food by a suitable sample of an exposed population group averaged over a period not exceeding one year would otherwise exceed the daily intake resulting from continuous exposure to air or water containing one third the concentration of radioactive materials specified in Appendix B, Table 2 of this part."

If I interpret that section correctly, it means when we are dealing with release of effluents to water and to which there may be an exposed population,you would reduce

the MPC factor by two thirds. In effect, we would have a maximum permissible concentration of 1 times 10^{-8}.

Did you give any consideration to that interpretation?

A I think if you look at most of the figures, they are far below even though, far below.

Q I am leading up to a second question.

CHAIRMAN FARMAKIDES: Did you answer the earlier question, sir?

BY MR. KINSEY:

Q Did you consider 20.106, Paragraph E, in your interpretations of this data?

A I did not specifically do that.

Q The concentration of the radium 226 in relation to the maximum permissible limits as set forth in Appendix B you establish at approximately 100 times that value; am I correct?

A Would you repeat that, please?

Q In relating the radium concentration of the raffinate waste water to the maximum permissible concentrations set forth in Appendix B of Part 20, you indicate that the radium content of the raffinate is approximately 100 times MPC?

A I believe that is correct.

Q Would that not be correct?

A Yes.

Q With the radium concentrations in that waste water 700 times MPC, how would that affect your calculations in the overall sense?

A 700 instead of the --

Q Instead of 100. If the radium concentration in the waste water were 2.1 times 10^{-5} microcuries as opposed to the 340 times 10^{-8} microcuries, how would that affect your calculation?

A It would be a simple mathematical calculation. You would just simply multiply it out for each one of these solutions. So if it was -- you are saying if it was 7 times this concentrated?

Q Yes.

A You would multiply everything on this list by 7.

Q So in other words the minimum record 1970 for 1971 which is now 0.83, if my mathematics is any good, which it is not, it would come out to be approximately 3.15, would it not?

A Yes, sir. Please keep in mind that that is, you know, for a period of one day when the chance of that maximum worst accident occurring on one single day -- that happens to be the lowest day on record -- it would be an extremely small chance.

Q Is the minimum record 1971 just for one day or for an entire year, averaged over 365 days?

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A The average is the first number.

Q I see.

A Which is 0.0007. If you multiplied that by 7 you would still be way below what you quoted from the regulation.

Q But in any event, we could take all these values that you have here for the raffinate and simply multiply them by a factor of 7 to arrive at the appropriate values.

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A If I have understood you correctly, yes.

Q Thank you.

One point on your worst case analysis concerning the leakage into the river. Assuming a leakage or an escape of 19 gallons per minute, which I believe you indicate, wouldn't there be, near the point of discharge at least, a plume of effluent, waste water, extending downriver which would in fact be in concentrations greater than those ultimately indicated for the dilution?

A Definitely.

Q Would there be any potential radiological health and safety effects of this concentration of radium in this plume in the immediate area, either on wildlife, aquatic life or possible human contact?

A You have asked aquatic life, human -- you are including several things. I can't answer on several of those.

Q How about just human life?

A I don't think there would be any harm to humans.

CHAIRMAN FARMAKIDES: How about aquatic life, sir?

THE WITNESS: I think it is possible.

CHAIRMAN FARMAKIDES: How about vegetation growing in the river?

THE WITNESS: At that very point, yes, it is possible.

BY MR. KINSEY:

Q One further question. On page 4 of your testimony,

under the heading of radium, you indicate in the first sentence that the maximum permissible amount of radium fixed in the body is 0.1 microcurie. I ask if you are familiar with Report Number 2. It is a Staff report of the Federal Radiation Council dated September of 1961. It is entitled background material for the development of radiation protection standards.

Are you at all familiar with this document?

A I have seen it before, not recently.

Q I quote from page 12 of the document.

Excuse me, Mr. Chairman. I don't have extra copies of this.

CHAIRMAN FARMAKIDES: We are familiar with that. What paragraph are you pointing to?

MR. KINSEY: Paragraph 3.10.

BY MR. KINSEY:

Q It states, "In view of the above considerations the Council recommends as an alternative a radiation protection guide for bone, for individuals in the general population, a skeletal concentration of radium 226 corresponding to 0.003 micrograms in the adult skeleton. The radiation protection guide to be applied to the average suitable samples of an exposed population group is a skeletal concentration of radium 226 corresponding to 0.001 microgram in the adult skeleton."

Do you consider these recommendations of .003 and .001 microgram which were adopted pursuant to a memo to the President and approval thereof in 1961 -- can you reconcile these two figures with your maximum permissible amount of 0.1 microcurie on page 4 of your testimony?

A Yes. The latest publications -- these are quoted from the latest publications. One precedes the one you are talking about, which is ICRP Number 2. The latest publication has been within the last year or so and it has essentially the same figure as ICRP Publication Number 2, which is as stated here.

Q Is that figure for the general population?

A The general population figure as recommended in that document are to be reduced by a factor of 10.

Q Do you have the date of that?

A It is quoted on the references. Reference Number 6.

CHAIRMAN FARMAKIDES: What is the date of the document you were quoting from?

MR. KINSEY: September 1961.

DR. BABCOCK: In other words, that is three years later than the references the doctor is speaking about.

MR. KINSEY: Mr. Chairman, we have no further questions.

CHAIRMAN FARMAKIDES: Any redirect, Mr. Irvine?

MR. IRVINE: Perhaps I am somewhat out of order,

but perhaps since I am not quite fast enough on the difference in terminology, at this stage of the game we might object to the questions in connection with 20-103, Subsection E, on the grounds that they are talking there about a release in the air or water.

What we are talking about is an accident, the worst type of accident. Therefore, I think the question is probably irrelevant at this point.

CHAIRMAN FARMAKIDES: So you are moving that the questions be stricken?

MR. IRVINE: Yes, sir.

CHAIRMAN FARMAKIDES: Mr. Kinsey?

MR. KINSEY: We, sir, would argue that by accident or otherwise, a leakage from the formation into the river would constitute a release within the meaning of this or any other standard set in Part 20.

CHAIRMAN FARMAKIDES: We will allow the questions to stand.

The Board has a couple of questions.

Were you finished, Mr. Irvine?

MR. IRVINE: Yes, sir.

MR. KORNBLITH: Dr. Sternhagen, have you considered among other possible modes of release something along the lines where the raffinate comes up to the surface through a spring or lake of some sort and perhaps dries on

surface and then gets into the body through inhalation of dust or something of that sort?

THE WITNESS: Yes, we have considered that.

MR. KORNBLITH: Can you compare the results of that calculation to the results you have in the case where it is dissolved in the river?

THE WITNESS: Yes, sir. We felt in that instance most likely if the raffinate itself were coming forth on the surface it would cause sufficient damage that it would be easy to detect this.

MR. KORNBLITH: Damage to what?

THE WITNESS: To the foliage and ground cover.

MR. KORNBLITH: Would it be detectable through that mechanism before it had an opportunity to do any significant harm to people?

THE WITNESS: It should be.

MR. KORNBLITH: What is the relative toxicity inhaled in that manner compared to ingestion?

THE WITNESS: We feel that inhaled radionuclides in the open environment are virtually nontoxic because there is such a fantastic amount of dilution.

MR. KORNBLITH: You are relating it now to the dilution and not to the physiological effects; is that correct?

It is not because the respiratory system does not

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retain it and allow it to get into the other parts of the body?

THE WITNESS: It is because of the fact if it is exposed to the open air there has to be some mechanism for getting this material into the lung in sufficient quantities to do any harm.

This means that the particle size has to be between 3 and 5 microns, for instance, and there are a lot of other requirements.

MR. KORNBLITH: One other question. Are you familiar with this salt water spring that the preceding witness testified to and if so do you know the radium content of it?

THE WITNESS: No s'r, I don't believe I do.

MR. KORNBLITH: That is all.

end11

CHAIRMAN FARMAKIDES: I have a couple of questions for clarification.

Dr. Sternhagen, assuming that raffinate somehow or other leaked into some subsurface water and it was carried to wells being used in the area, for example, whether people wells or animal wells. You said earlier that a person could drink a liter of this without any harmful effects but it might -- that it would take years of drinking of this raffinate -- I assume once it was distilled -- or were you talking about the actual raffinate itself, undiluted?

THE WITNESS: The actual raffinate.

CHAIRMAN FARMAKIDES: It would take years of drinking that before there would be any harmful effects.

THE WITNESS: In terms of radium.

CHAIRMAN FARMAKIDES: How about the other radionuclides in there?

THE WITNESS: I don't think they would have any harmful effect either except after a long time.

CHAIRMAN FARMAKIDES: By a long time you mean years?

THE WITNESS: Perhaps years.

CHAIRMAN FARMAKIDES: How many years, 10 years, 5 years, 20 years?

THE WITNESS: Perhaps 5 years.

CHAIRMAN FARMAKIDES: So that after a period of

ty 2

time, 5 years, a person could be harmed by drinking the concentrated raffinate.

THE WITNESS: Well, may I say this: I feel that it is impossible to drink concentrated raffinate. So, therefore, even if one could drink it, you would probably not survive due to drinking other things in there. Radiation hazard from drinking it would be extremely negligible compared to the other hazards.

CHAIRMAN FARMAKIDES: I understood you to say that but later the Staff's question, I thought, was: Is it possible for there to be concentration up to a point where a person would not recognize its existence in that water? And I thought your answer was yes, there was such a possibility.

THE WITNESS: I think it is possible.

CHAIRMAN FARMAKIDES: At that point in time I am sure you get where the concentration is but the actual raffinate is something less than that but we are not sure how much less.

THE WITNESS: Right.

CHAIRMAN FARMAKIDES: Again I am trying to get a feel for myself as to what you meant by harm that could accrue to a human. What really triggered me off was the observation you made earlier that in a plume where you might have this Raffinate being discharged into the river at one spot, at that point you might have some deleterious effects to the

ty 3

aquatic life I think you said and also to the vegetation.

In answer to Mr. Kornblith's question you indicated that if this was coming up through the surface it would have an effect on the vegetation. That caused me to come back to what you said earlier and I am wondering if you could clarify that for me.

THE WITNESS: I think the solution is a salt branch solution and therefore if this were coming up to the surface it would make it very difficult for anything to grow right there. This would be easily visible either on inspection of the property or flying over it.

CHAIRMAN FARMAKIDES: But you don't think it could blow away or it could vaporize in such a way that it would put fumes into the air?

THE WITNESS: I don't think it could happen without it being detected by a monitoring system. If you took out all the monitoring systems then you are posing the question that all of this material is here and then essentially this is what the ponds are now.

CHAIRMAN FARMAKIDES: Thank you, sir.

The Board has no further questions.

Thank you very much.

(Witness excused.)

CHAIRMAN FARMAKIDES: Gentlemen, we can break now for lunch. It is 1:15. Let's reconvene at 2:30.

ty 4

End #12

Whereupon, at 1:15 p.m., the hearing was recessed, to reconvene at 2:30 p.m., this same day.)

AFTERNOON SESSION

(2:30 p.m.)

CHAIRMAN FARMAKIDES: Mr. Irvine, we are ready to proceed any time you are.

MR. IRVINE: Mr. Chairman, at this time we would like to avail ourselves of the opportunity to offer the rest of our witnesses as a panel and we would also request permission to submit to you the written qualifications of Mr. John S. Rodgers, who is an associate of Mr. H. J. Gruy and Associates, Inc. He will be one of the members of the panel.

CHAIRMAN FARMAKIDES: Are you going to submit those documents as exhibits?

MR. IRVINE: Yes, sir. Exhibit 3-E is the number.

CHAIRMAN FARMAKIDES: 3-E is Mr. Shelley.

MR. IRVINE: Then it would be 3-F.

CHAIRMAN FARMAKIDES: The qualifications of Mr. Rodgers?

MR. IRVINE: Yes, sir.

CHAIRMAN FARMAKIDES: Is there any objection to these being received?

MR. KINSEY: No.

CHAIRMAN FARMAKIDES: They will be received.

XXXXXXX

(The document referred to was marked Applicant's Exhibit No. 3-F for identification, and was received in evidence.)

XXXXXX Whereupon,

JOHN S. RODGERS, WILLIAM J. SHELLEY,

H. K. VAN POOLLEN AND H. J. GRUY

were called as witness on behalf of the Applicant and, having been first duly sworn, were examined and testified as follows:

DIRECT EXAMINATION

MR. IRVINE: Mr. Gruy, I hand you these documents and ask you if you can identify them.

MR. GRUY: Yes, this one is a copy of my qualifications statement and this is prepared testimony of H. J. Gruy and Associates, Inc. in the matter of Kerr-McGee Corporation, Amendment to Source Material.

MR. IRVINE: Do you adopt this testimony as your testimony in this cause?

MR. GRUY: I do.

MR. IRVINE: Dr. Van Poollen, I hand you this document and ask you what that document and the one attached represent to you?

MR. VAN POOLLEN: It is the prepared testimony of H. K. van Poolen and Associates, Inc., and it is a statement of qualifications called biographical information for myself.

DR. IRVINE: Do you adopt this as your testimony in this cause?

MR. VAN POOLLEN: Yes, sir.

MR. IRVINE: Mr. Shelley, I hand you this document and that which is attached to it and ask you if you can identify it for us, please.

MR. SHELLEY: It is entitled "Prepared Testimony of William J. Shelley, In the Matter of Kerr-McGee Corporation," and a biographical sketch of my qualifications.

MR. IRVINE: Do you accept this as your testimony in this cause?

MR. SHELLEY: Yes, I do.

MR. IRVINE: Mr. Rodgers, I hand you this copy and ask if you can identify this for me, please.

MR. RODGERS: Yes, sir, this is a statement of my qualifications.

MR. IRVINE: And you adopt that as your testimony in this cause?

MR. RODGERS: Yes, sir, I do.

MR. IRVINE: Would the Chairman still like to have a brief summary of the testimony of each of these individuals?

CHAIRMAN FARMAKIDES: Yes, sir.

MR. IRVINE: Mr. Gruy, would you give us a brief summary of your testimony, please?

CHAIRMAN FARMAKIDES: Mr. Kinsey, do you have something?

MR. KINSEY: Yes, Mr. Chairman. Is this testimony

now being offered into evidence at this time?

MR. IRVINE: Yes.

CHAIRMAN FARMAKIDES: I assume that Mr. Irvine, you are going to offer it into evidence, right?

MR. IRVINE: Yes.

CHAIRMAN FARMAKIDES: It has already been accepted, gentlemen, except for Mr. Shelley. Isn't that right?

MR. KINSEY: That is correct.

CHAIRMAN FARMAKIDES: The only one that has not been offered into evidence is Mr. Shelley. All the rest of it is in evidence. Why don't we at this point in time handle 3-E, Applicant's Exhibit 3-E, the testimony of Mr. Shelley.

I assume, Mr. Irvine, that you are offering 3-E into evidence at this point in time?

MR. IRVINE: Yes.

CHAIRMAN FARMAKIDES: Mr. Kinsey, proceed.

MR. KINSEY: Mr. Chairman, we would object to the offering into evidence of the Applicant's environmental report which is included as an attachment to Mr. Shelley's testimony after page 7, with the exception of the Figure 1 contained in that report which deals with the typical analysis of the Raffinate and disposal well. The pages are not numerated so I believe it is the next page -- it follows two pages after page 12 of the environmental report. That page

we would have no objection to.

CHAIRMAN FARMAKIDES: We are not focused with you, Mr. Kinsey. We have the Applicant's environmental report. It is identified as August 1973, Supplement No. 3.

Is that the one you had reference to?

MR. KINSEY: That is correct.

CHAIRMAN FARMAKIDES: You are saying that you would oppose this being admitted into evidence? For what reasons?

MR. KINSEY: On the basis that the hearing was noticed to consider the radiological health and safety considerations incident to the application, not the environmental considerations. That is, the notice of hearing that was issued by the Commission specifically provides that in the event that the Board finds in favor of Kerr-McGee on the radiological health and safety issues, it shall remand the matter back to the Director of Regulation of the Atomic Energy Commission for consideration of what environmental considerations need be considered under provisions, I believe, 40.32(e) of 10 CFR, plus it is the Staff's position here that consideration of the environmental effects would be somewhat premature.

In addition, the fact that the hearing was noticed for radiological health and safety considerations may have been a factor that might have led certain interested parties

ty 6

who might have wished to intervene on the environmental side to have deferred intervention until a later date.

CHAIRMAN FARMAKIDES: What harm then would there be in allowing this additional information to come in? I assume your proposed findings when you finally submit them will be limited to radiological health and safety, as would the Applicant's.

MR. KINSEY: I certainly see no prejudicial error in admitting this as part of the evidence.

CHAIRMAN FARMAKIDES: You are saying it is irrelevant?

MR. KINSEY: We believe it is irrelevant and premature to consider the environmental issues.

CHAIRMAN FARMAKIDES: Let's look at the joint statement of issues that you had agreed to.

Mr. Irvine, would that supplement to which the Staff objects have reference to any of those eight issues?

MR. IRVINE: In a broad general sense.

CHAIRMAN FARMAKIDES: To which ones, sir?

MR. IRVINE: I mean to the entire list of issues in a broad general sense. Let me point out to the Board that what we have here, although denominated and a part of the environmental report, this was put in because, as you can see, it is Supplement No. 3 to our original environmental report and it has to do only with a discussion of alternatives,

alternative solutions to the problem, and has nothing else to do with the environmental report. Since -- simply because at the juxtaposition of our filing this and filing the testimony of Mr. Shelley, we thought that this would be additional information that the Board might find useful since this question had been one which had been raised at an earlier time in the hearing.

CHAIRMAN FARMAKIDES: I see what you have just said is borne out by the first full page, which is a discussion of alternatives for the disposal of liquid Raffinate wastes.

MR. IRVINE: Yes, sir. I might say that Figure No. 1 that Mr. Kinsey has referred to is not a part of the enviornmental report but I believe on the first page of Mr. Shelley's testimony it is cited as a separate attachment to his testimony and it is not a part of the environmental report.

It starts with the second full paragraph on page 1 and carries over, as you can see -- a typical analysis of these liquids is shown on Figure 1 attached hereto.

CHAIRMAN FARMAKIDES: Is there anything else, sir?

MR. KINSEY: No, other than what I have said previously, to say again that we don't consider cost-benefit analysis relevant to the decision on the radiological health and safety aspects of the disposal.

ty 8

CHAIRMAN FARMAKIDES: Okay. The board ruled that we will accept the Supplemental 3, which is really a discussion of alternatives for the disposal of liquid Raffinate waste.

Are there any other objections to that testimony, Mr. Kinsey?

MR. KINSEY: No other objections.

CHAIRMAN FARMAKIDES: All right, it will be introduced into evidence as Applicant's Exhibit 3-E.

XXXXXXXX (The document referred to was marked Applicant's Exhibit No. 3-E for identification, and was received in evidence.)

End #13

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MR. IRVINE: Mr. Gruy, would you proceed with a summary of the testimony, please?

MR. GRUY: Well, starting with the table of contents here, we start out with an introduction of the T simulation of reservoir performance as it has grown in the oil and gas industry and also as applied to hydrological studies. Starting out with a single cell model where the cumulative net withdrawl of water is equal to the ridge water in place minus T amount of water remaining.

If you have two halves that are different, then you have to account for differences in production and the flow that takes place between them so you go to two cells. Then if you want to -- if you want a complex system model as they exist, you have to go to three dimensions to have blocks both horizontally and vertically. The mathematical considerations are given and the derivation of the mathematics and the construction of the model -- the validity of the model and the best method of obtaining a valid reservoir description as to determine the model with properties that will agree with the measured data.

In other words, one in which you can match your known history. In the study of the Kerr-McGee Number 1 waste storage well, careful analysis was made to match two separate performance considerations.

One, the calculated flow into and from the separate layers in agreement with that observed from the radioactive

dh2

tracer surveys and the calculated well bore pressure fall off curve, neither of which by themselves would have given a definitive thing, but having to match both of them, we feel that best.

Then we discussed the aspects of transient pressure testing, which is very commonly used in the oil fields for determining the shape of reservoirs, the properties of the reservoir rocks, and the size of the reservoirs. We have given a case history of examples here.

We have performed literally hundreds of these tests, a number of which, of course, we don't have any definite proof that our conclusions were right, but there have been a number of cases in which additional wells have been drilled and additional things done that proved that we were right.

In these hundreds of cases, I don't think there has been one where the obtaining of additional information, or the drilling of additional wells has proved that the solution was wrong.

Now, the case history that we have given here is one of a reservoir of gas that was bounded by a fault shown to the north and a gas-water contact to the south. The question was, what was the lateral extent of this reservoir in, I believe, the easterly direction, the westerly direction being closed off with water coming around to the fault.

From the test in a single well, we were able to confirm that the subsea or the horizontal distance to these

dh3

two partial boundaries, the fault to the north and gas-water contact to the south, and also determine the volume of gas that was in place within the reservoir. Then by calculating the distance it would have to extend to the east in order to contain this volume of gas, we got a limit to the east at which we did not think that it extended beyond because of possible variations in the water volume in the pores.

We drew two lines and said that the limit was somewhere between those two lines. Our client then declined to drill the proposed well at the location to the east, but they were able to make a deal with another operator that hadn't made such a study and the other operator drilled a dry hole at that location, which hole did not have the sand.

It did not extend to that distance. It was further confirmed by another operator, thinking of the high rewards of tapping into that gas reservoir and not having this study and not knowing where the extent of the sand ended, who drilled a well between the two dashed lines and also found no sand present or only a very small remnant, not enough to make a well.

This is the case history that we have given. Like I say, we could give many, many others of the same general nature. So this is something that we practice as a day to day part of our business and something in which we have great confidence.

DR. BABCOCK: I don't believe you stated, Mr. Gruy,

dh4

when the case history example that you are now quoting -- was this a case where you pumped water in to the well and measured the fall-off in pressure.

MR. GRUY: No, this was a case in which we produced gas out of the well, then shut it in and measured the buildup of pressure.

DR. BABCOCK: In other words, it's approximately the reverse.

MR. GRUY: Right.

Next, we have a discussion of the well testing and modeling of the Kerr-McGee Number 1 Sequoyah well which is detailed, showing the test data that we studied.

The included electrical well logs will, by the measurement of the natural electric potential generated in the hole by interaction of the fresh water and the drilling well and the salty water in the sand and the resistivities of the various layers, enable a practiced geologist to identify these lawyers and to tell something about the calculated porosity and something about the content, the salient of the water, and whether or not it's oil or gas-bearing, and approximately the saturations and this kind of thing.

Next, we have a caliper log, which is a log that is made by running a tool in the hole that measures the diameter of the whole at all points so that we know all the variations in the whole size.

dh5

In other words, you drill a whole with a bit out there circulating mud and the hole isn't exactly the size of the bit. Soft rock washes out a little more and makes a little bit larger hole than other types of rock. Then we had a density log which gives the density of the various rocks passed through.

Then we had a static pressure survey. We knew what the initial pressure within this Arbuckle formation was before we started our test. Then we made a water injection with a radioactive pressure survey and a temperature survey. What was done in this case is when injected with water into the formation at the same time, running a series of temperature surveys and a series of radioactive surveys, the radioactive surveys to locate the position of a radioactive slug dumped in the well hole.

Now, if a tool is run in a hole and a measurement of radioactive material is released in the well hole, and you pump it in at a known rate of gallons per minute, you run through that slug and you are accounting for all of it, and you know where the top and bottom of it is.

As you pump it down and keep running through it, you can tell if you lose any of that slug. For instance, if you had a hole in your casing, some of it would go out and you would have a diminution in your radioactive measures.

So, when this slug, due to the running back and forth of the instrument through it, got dispersed and diffused

dh6

in the hole so as to not be well recognizable, then we came up the hole a little bit from the latest measure and dumped a fresh slug. We started anew with clean water and tracked the next slug down.

If you will look, there are attachments showing those runs and how definite the position of the slug was.

We then ran a shut-in test after pumping and running pressure up. We shut the well in and ran a 145-hour fall-off test with a pressure instrument in the hole. Then we did additional water injection with radioactive tracer, followed by a profiling during shut-in.

In other words, when you shut it in, if it has been one homogenous layer, the water would have continued to move out and the pressure would have continued to fall off and the water would have continued to go in the hole with lesser rates as the pressure went off.

But what actually happened was that the water began to come out of the lower thickness shown and flow back up the hole and go out into the other zones. Now, this occurred because the lower zone, although the thickest and most permeable, was the smallest in area extent, or volume.

So, the pressure couldn't fall off in that, because it didn't have anywhere to go. We had pressured that up to a point lower than the pressure had bled off -- or higher than the pressure bled off in the upper zones as it continued to move out

dh7

away from the well in the upper zones, then the water came from the lower zone and went in to the upper zone.

The time and pressures at which this occurred gives us a very close calculation of the bottom -- of the volume of the bottom zone. The shape of this curve also gives the shape of the bottom zone and the distance to the bottom.

Now, the determination of the thickness and permeability in each one of these layers is done by the percent of the injection that was taken into those layers as determined from the radioactivity survey.

Now, we simplified the problem somewhat by dividing it into five layers. Actually, if you will refer to Exhibit Number C-3 attached to this testimony, you will see by the little dashed lines over here that zones 4 and 5 actually each consist of three lawyers.

However, there is a point of diminishing returns in the accuracy you get by continuing to break down into more and more layers. It appeared to us from the data we had that we could treat this group of three zones in 4 and 3 zones in 5 each as a single layer without pressurable loss of accuracy.

This whole thing is dependent upon material balance, the compressibility of the water and rock, the amount of pressure that goes up and the shape of the pressure fall-off curve, which is influenced by the shape of the rock.

You can readily see that if water starts going out

dh8

from a single point, in a circular manner at a certain volume and pressure that the pressure will fall off at some rate.

If, close to the well hole, as this volume of injected fluid -- if it hits a barrier, then the whole volume of injected fluid has got to go to the other half of the circle. So the rate and pressure difference, at which it goes will change at that point.

So we are able to see where these barriers occur by the times at which these pressure changes occur.

Now, that is very simple in one boundary of homogenous isotropic situation. When you get in to more complicated situations, you find that it must be checked where you can vary the boundaries and check the agreement of the theoretical curve as calculated with the boundaries that you put in to your model without actually measuring it.

Then you can move these boundaries selectively and see -- as you move it, you get a certain standard deviation on your track. Then you move it and you get a less -- a closer -- a less standard deviation. You move it again, and you get still less deviation. You move it again to get closer and instead of getting less, it moves away.

So you know you have a minimum point. You then begin to play with other aspects of the thing. We have played with this thing. We varied the permeability away from the well water. We varied the porosities. The varation of these things all make

dh9

a great deal of difference in the way you match your curve.

We have played this thing until we got what we thought was an acceptable match. We don't have an exactly perfect match, but we know the thing isn't exactly square down there, either.

But we didn't think it worthwhile, or that it really makes that much difference as to the exact shape of this thing or the exact difference in boundaries. We know that we are in a closed reservoir except for one side in two of the five layers, which was still taking water and water was still moving at a distance of some 29,000 feet.

We do know, however, that there is a very definite fault from the surface there at about 32,000 feet. So we think that there is no question, based on this and the high water salinity and the various things that we are in a closed block, and that we could detect from this, if these barriers that we see were permeable -- because we went back in and made these barriers permeable to various degrees to see if we could make an appreciable difference in the shape of the curve, and it does.

Now, as far as monitoring the situation, we feel that the best way to monitor it is to carefully observe the pressures of injection in this well, how the pressures build up as injection proceeds, and then shut it in periodically, run a sensitive instrument in the hole and measure the fall-off curve.

dh10

If we don't at various certain times see that we are getting pressure buildup, volume for volume, as the material balance should indicate -- when we hit the last boundary and those other two things -- or if there should be a rupture in one of these boundaries, we would immediately see a change in the shape of our pressure fall-off curves, and we could begin to search for the source of the leak.

This would occur, in my opinion, before you could get enough of a leak to do any damage. It has been suggested that additional wells might profitably be drilled to help monitor this situation.

In my opinion, although every little bit of information that you have has some additional value, this can best be monitored at this well. If a well is drilled to test the existence, for instance, of the Webber's Falls fault, it could prove a little closer where the Webber's Falls fault is.

But we are seeing a barrier at that distance, and we can't tell from this test what the direction is. It just happens that we can orient them so they fit the job. But if the well showed no fault, it wouldn't deny the fact that there is an end of permeable enforced continuity of the zone at about that point, which is really what we are looking for.

Now, we have interpreted these to be -- when we satisfy all five layers having a boundary at 1164 feet, we assume that that is the same boundary and it's probably a fault.

dh11

If we have got one of them, as we had in two cases, with a boundary that doesn't agree in distance with the boundary of any other layer, we assume that that is not a fault, that that is just a termination of the porosity and permeability in that zone.

So that a well could be drilled over there to test this thing and show no fault and still wouldn't prove that we didn't have the barrier.

Now, as far as drilling a well to test when we have a vertical leak into the shallow overlying zones, we know that all the overlying zones are very tight, very hard, tight, low permeability zones.

As I understand it, there are no aquifiers or no drinking water wells in the area except one very small volume well producing from some fractured shale at shallow depth. Due to the tight nature of these zones, any flow of them would have to be through a crack or a fracture.

Now, if the well you drill to monitor them didn't hit this same crack, you could have leakage without it showing in your monitoring well. So it seems like the chance of detecting the leakage with the monitoring well is not good enough to justify the expenditure for that well.

I think you would be pinning a false hope on it. But I sincerely believe that we can tell if that occurs from monitoring the pressure fall-off history of the injection well. I believe that about covers my prior testimony.

dh12

CHAIRMAN FARMAKIDES: Thank you.

MR. IRVINE: Mr. Chairman, may I ask one question? It's now a few minutes after 3:00. Dr. Sternhagen has a flight out of here at 5:00, and needs to leave. If there is no further need for him, might he be excused at this time?

CHAIRMAN FARMAKIDES: Thank you, Dr. Sternhagen. We have no further questions. You may be excused, sir.

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CHAIRMAN FARMAKIDES: Mr. Shelley or Mr. van Poollen, would you give us a short summary of what your statement is, sir?

MR. VAN POOLLEN: My role in this venture is somewhat different in that I was actually asked to review the work that had been done rather than doing original work.

There was a certain amount of credence to be lent to the tools that were used such as the modeling and transient well testing. So in my testimony I give a very brief review of the various techniques that have been used in the petroleum industry and in the groundwater industry which eventually led to the use of numerical reservoir models.

Also I make a statement that the transient well tests are commonly used. Those of you who have read it can see what kind of data is normally used for oil field analysis and for groundwater hydrology you merely eliminate all the hydrocarbons and you still have a similar set of data required.

Then I give a discussion of the theory, which I don't intend to go through here at all. I show both for the linear systems and for the radial flow systems. Then I make a statement on the state of the art which in essense says that all major oil companies use this type of numerical reservoir models.

I emphasize the fact that the United States

Geological Survey recently purchased a complete set of these models to make the groundwater studies. Then I show that I have used this kind of tool for various clients and I refer to one particular report which is -- and I ask for permission to have this presented in here -- and I show a page which is the result of a study we did for the Atomic Energy Commission entitled Projected Reservoir Performance, Rio Blanco Project, March 1973, available as an open file report.

I indicate the techniques used.

That report is similar to the ones used by Gruy.

Then I evaluated the Sequoyah well. I looked at the various bits of information that Mr. Gruy already outlined. I came to a conclusion that I could substantially agree with what Mr. Gruy has shown there.

I wish to apologize at this moment for the typographical error on page 11 in the bottom one-third of the middle paragraph. It says there "Assuming a pore space of 860,000 barrels." That should read 860,000,000 barrels.

So I assumed the number that was found in the model and I applied to this a total rock plus water compressibility of 6.8 times 10^{-6} psi to the minus 1 and I would calculate at 3.4 psi pressure increase after the injection of all this water during the test, which compared with the 5.5 psi that was actually found between the

pre-injection static survey and the extrapolated fall-off curve.

However, I am an engineer enough to realize this could also be a measurement error. Still, it is there.

Then, in reviewing Mr. Gruy's report in detail I concur with his method of attack; that is, to use the finite difference models, and to match the production.

I feel that the intelligence of both the pressure and the flow rates from one length to the other should give a quite high degree of reliability.

I independently evaluated the fall-off curve and definitely see the existing ceiling barrings.

I realize it is quite conceivable that not all boundaries were found and I indicate so.

I recommend that the finite character of the formation be determined more precisely during the early injection of waste fluids, which I discussed in my section on monitoring.

Under monitoring I make similar statements and I don't need to repeat them to Mr. Gruy. I did this all independently. I really don't feel concerned whether the finite character of the reservoir is due to faults or permeability pitch-outs as long as it is finite. I think we can prove this with well testing.

The statements on the other two wells, trying to

show that there is leakage to the seams and horizon, I don't consider that very practical for the same identical reasons that Mr. Gruy quoted, to have an additional observation within the arbuckle which to me does not seem to render more information thatn you can get with the one well.

This in essense concludes my summary.

CHAIRMAN FARMAKIDES: Mr. Shelley, would you summarize your statement, sir?

MR. SHELLEY: My statement essentially describes the approach of the nuclear division of Kerr-McGee to the problem of operating this well, specifically the monitoring portion of the operation, in the event that it were approved for disposal of raffinate fluids.

As a result of discussions with Mr. Gruy and Dr. van Poollen we have proposed a series of neutralized raffinate injections to provide additional reservoir information prior to the injection of raw raffinate which will have the effect of partially dissolving the dolomite formation, thereby changing the structure that Mr. Gruy sees in his model.

We feel it pertinent to confirm initially the model through the series of five sequences of injection, then operate the well with acid fluid for a sufficient period to change the reservoir rocks and ask Mr. Gruy then to

remodel the reservoir, thereby incorporating the progressive effect of dissolution of the reservoir rocks.

In addition, we would continue and enlarge upon a current surface and shallow subsurface monitoring which we are currently doing and have done since the start of production at the plant.

I have included Figure 1 which was used as a reference by Dr. Sternhagen and also the discussion of alternate methods of raffinate disposal prepared at the request of the Licensing Branch.

As a final evaluation, we have included a cost estimate to install the three wells suggested for monitoring. Mainly for information purposes.

It would certainly be used by Kerr-McGree management in undertaking the direction upon the completion of this hearing.

I believe hat covers it, Mr. Chairman.

CHAIRMAN FARMAKIDES: Thank you, sir.

The Staff?

MR. KINSEY: Mr. Chairman, with the Board's permission and with no objection from counsel for Kerr-McGee, we again would like to use Dr. Warner to cross-examine the witnesses.

In addition, Mr. Robertson, whose statements of qualifications are on the record, also has some questions

for Mr. Gruy and Dr. van Poollen.

I, as Staff counsel, have a few questions for Mr. Shelley.

MR. IRVINE: I have no objection, your Honor.

CHAIRMAN FARMAKIDES: The Board has no objection. You may proceed, sir.

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CROSS-EXAMINATION

DR. WARNER: Just to reiterate some of the points you have made, in the report a number of boundaries to fluid flow are shown and described. What type of geological feature could produce these boundaries?

MR. SHELLEY: Either faults or permeability barriers.

DR. WARNER: What more specifically would a permeability barrier be?

MR. SHELLEY: Permeability would be the loss of fluid transmissibility in the rock due to a loss of porosity or a filling of the pores with secondly deposition or shale or lack of dolomitization at that point.

DR. WARNER: Would this be a limit to the continuity of the porous material?

MR. SHELLEY: Yes.

DR. WARNER: Would you expect this to be a sharp demarcation?

MR. SHELLEY: I would in the case of a fault and in

the case of a permeability barrier it might or might not be.

DR. WARNER: Wouldn't you think that in the case of a permeability barrier it would more likely be a transitional zone that would gradually go from a porous zone to one which was not?

MR. SHELLEY: Yes.

DR. WARNER: Don't you think it is significant in this particular case to differentiate between the two types of boundaries where we can because of the nature of the project proposed?

MR. SHELLEY: Well, we considered it to be a fault. When all five of them terminated at the same distance, we assumed that they were probably the same barrier. So we have some faults and then we have some of the zones that are terminating before they get far enough to get to all the faults. So it is unquestionable here that we have some permeability barrier.

DR. WARNER: Well, specifically, though, the question I asked was don't you think it is important where possible to differentiate between the two?

MR. SHELLEY: If there were a long transition zone where there was a significant volume of reduced thickness and permeability, we could see it in the model and we have introduced these things as a method of checking this and we don't find that we can match it by doing this.

DR. WARNER: My point is that faults could more likely act as a leak whereas your permeability barrier -- your barrier caused by permeability loss doesn't provide the potential for vertical leakage, is the point I am trying to make.

MR. SHELLEY: This is possibly so. But we did not see any leakage in this test and we would have to build the pressure up to see what we see in oil fields and water injection projects in oil fields, a very substantial pressure buildup in the reservoir, without rupturing faults.

We can't say the fault wouldn't rupture at some elevated pressure, but I cannot from a model standpoint differentiate between a sharp barrier, an abrupt pinch-out, and a fault.

DR. WARNER: The reason I asked the question, in Dr. van Poollen's testimony he commented and I think it may have been just more from an engineering point of view than in the context of this particular case that the difference is academic and I was simply trying to point out that it is not academic, at least in my point of view, and I was simply asking if you believed that if the difference between the two is important simply because of the nature of the project we are discussing here.

MR. IRVINE: Mr. Chairman, may I suggest that we limit the questioning to cross-examination rather than

comments in this manner?

CHAIRMAN FARMAKIDES: That's right.

DR. WARNER: I think I asked a very straightforward question and I haven't gotten an answer to it.

CHAIRMAN FARMAKIDES: If you have a problem getting an answer, ask me, but don't testify on the record.

DR. WARNER: I am sorry. I am not experienced.

Well, I will reiterate the question again, then.

How does the panel feel, or is it important to differentiate between the two types of permeability boundaries, particularly because of the type of problem they are considering in this case?

MR. GRUY: I think it would be nice if you know the difference, but I don't think it is critical.

MR. VAN POOLLEN: I agree with that statement.

MR. GRUY: When you know it is a fault, you know where to look for a leak if you get one, where the fault comes to the surface.

DR. WARNER: If you don't distinguish between faults and other types of permeability barriers, then you do not know where to look; is that correct?

MR. GRUY: Well, you would know about the distance to look, but you would not have a particular trace on the ground to look at.

MR. VAN POOLLEN: So the thing to do is to look

and assume there are faults.

DR. WARNER: Then let's look at Figure 1 in your Gruy Report, the original report. Then would you consider it would be necessary to look for the possibility of leakage in the case of all these boundaries that are shown to bound the five layers that you have distinguished here in this case?

MR. GRUY: If I thought I had a leak I would certainly look at the trace of the surrounding fault, but I would also look over the entire surface of my area into which I thought my fluids were having an effect.

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DR. WARNER: Is it possible from a testing program alone to determine what the shape or the orientation, that is, the direction of these boundaries is?

MR. GRUY: It is not possible to tell the direction.

DR. WARNER: It is possible to tell the shape?

MR. GRUY: Yes.

DR. WARNER: Could you tell on a regular curved linear boundary -- from a linear boundary at a distance of 13,000 feet from the well?

MR. GRUY: It would depend upon the degree of testing and the degree of difference.

Now, we have been able to tell parallel boundaries and, of course, we couldn't tell if those lines were exactly

straight or wavered a little bit, and we can tell intercepting boundaries and we can tell the angle between that intersection and we can tell the angle between a line from the well to the intersection.

DR. WARNER: With a single well?

MR. GRUY: From these tests. But we cannot tell the direction. Some slight irregularities in those boundaries we couldn't tell.

Now, it would depend upon -- one of the things I wanted to do here was to check the exact geological conformation which was a little bit irregular and to see what effect it would have, a very minor effect upon the pressure. But this was done before we knew what the geological conformation would be and we didn't think it was worthwhile or important to try to make minor changes in whether these were 90 degree angles or 80 degree angles, It would effect the curve.

DR. WARNER: In your calculations of the distance of flow of the fluids -- there are two separate issues here and I would like to differentiate between them. I am not trying to interject a statement. I would simply like for the Board's -- for the purpose of --

CHAIRMAN FARMAKIDES: Why don't you confer with your counsel?

DR. WARNER: For the assistance of the Board I

would simply like to state that there are two separate htings to discuss in the reservoir engineering area, one being the pressure buildup which we have been discussing and the other thing being the distance of flow of the injected fluid. They are separate issues.

I would now be changing my questions to the distance and direction of flow to the fluid as opposed to the questions with regard to the pressure characteristics which I was asking just a moment ago.

With regard to the distance and direction of flow, were these calculations made on the basis that the porosity was uniform, the reservoir thickness uniform, and that the interface was a sharp boundary?

MR. SHELLEY: As for each layer, these assumptions were made with variations between the layers. I want to say that we also tested the effect of varying this. If it is uniform and you have radial flow out from the well, you have got one kind of pressure fall-off. It there is a sharp change and it is more permeable in one direction than the other, you tend to have linear flow and you have a different shape.

We have checked this and all the indications we have is that flow is substantially radial in all directions from the well.

DR. WARNER: Well, even though flow may be substantially radial, as you say -- and I am not necessarily

agreeing with you -- still in your calculations assume that the reservoirs in each case had a uniform thickness and that the boundary at the interface between the waste water and the formation water was a sharp one -- you assumed these things; is that correct?

MR. SHELLEY: Yes, in order to show in the other figures here the extent of the thing, that is assuming that the average boundary is sharp. There may be a little diffusion in that base.

DR. WARNER: You say there will be a little diffusion. Did you test the effects of introducing the concept of hydrodynamic dispersion into the distance that the waste water would travel?

MR. SHELLEY: No.

DR. WARNER: What would the effect of considering hydrodynamic dispersion be?

MR. SHELLEY: We think we are in a stagnant block where there is no hydrodynamic --

DR. WARNER: You are creating one by injecting waste water. Are you not creating a hydrodynamic gradient when you inject waste water?

MR. SHELLEY: Oh, yes.

DR. WARNER: Then is there not, may I ask, then -- there is the potential for hydrodynamic dispersion and the answer is -- and you did not consider it in your analysis; is

that correct?

MR. SHELLEY: We did not consider it, that's right. You mean the effect of dispersion due to the physical movement of the enlargement of the injected bubble?

DR. WARNER: Could any one of the panel use the bulletin board to indicate what in fact hydrodynamic dispersion is and what effect it would have on the calculations of the distance of travel of waste water?

CHAIRMAN FARMAKIDES: Do you need to do that or could we articulate it?

I would prefer it to be articulated. The record would be much more clear. Unless you can't articulate it. Then you can use the board. But I would prefer it be articulated.

DR. WARNER: I have asked if in some way you would explain what the effect of hydrodynamic dispersion is and what effect it would have on your calculations.

MR. RODGERS: In regard to the effect of the asymmetrical pressure distribution on the subsequent directional fluid movement.

I think what you are asking is really a --

CHAIRMAN FARMAKIDES: Would you speak up? I can't hear you.

MR. RODGERS: I think what Dr.Warner is asking in the problem is actually germane to asking him to do the

calculations for this specific problem.

I don't think you can speak in generalities in regard to this calculation because we are dealing with a very complex system. We are dealing with an asymmetric well location with respect to the boundaries and I think this is going to impose a very isometrical pressure distribution which correspondingly will affect the calculations.

CHAIRMAN FARMAKIDES: Could some of the panel give that answer?

MR. VAN POOLLEN: The concentrated ingredients -- you will not have sharp fronts, but dilution behind the fronts after it disperses, and ahead of the front. Consequently you will have a degree of further penetration.

CHAIRMAN FARMAKIDES: Would you repeat that back?

Could you define it again? You were going a little fast and I am not quite sure we were able to catch it.

MR. VAN POOLLEN: If we don't assume any hydrodynamic diffusion we will have a sharp front move through the reservoir. However, if concentration gradients are set up between the different salinities of the displacing and the displaced fluids, you will have an ion concentration growing away from a sharp front in both directions.

Consequently the displacing ion will be further into the formation than if you had just a sharp front.

CHAIRMAN FARMAKIDES: The displacing ion would do

what, sir?

MR. VAN POOLLEN: Would occur ahead of where you assumed a sharp front.

DR. WARNER: If I could rephrase what you are saying, Dr. Van Poollen, the waste water would be further than you would calculate it would be if you assumed a sharp front?

MR. VAN POOLLEN: By a degree, yes, sir.

DR. BABCOCK: Can I interrupt one second? You say it would be further and now you say it will be by a degree. Can you give me some kind of a rough estimate of what kind of distances we are talking about?

MR. VAN POOLLEN: I cannot give that because I didn't make that calculation.

DR. BABCOCK: The total distance of flow in here, in the Gruy Report, is about 800 feet. Would it be 9 feet or would it be 7800 feet?

MR. VAN POOLLEN: I will give it 10 percent.

DR. BABCOCK: Ninety feet?

MR. VAN POOLLEN: That is an engineering guess.

DR. BABCOCK: That is fine.

DR. WARNER: Are you familiar with studies of this type which have been done in place in the course of conducting underground water storage experiments in Israel, the determinations of the actual distances of water travel in

advance of the predicted fronts as a result of hydrodynamic dispersion?

MR. VAN POOLEN: I am familiar that work has been done, but I am not familiar with the numbers.

DR. WARNER: And it is generally true that in limestone and aquifers in which you have porosity developed by dolomization and solution features that hydrodynamics -- that dispersion tends to be greater than it is in, for example, sandstone aquifers?

In other words, limestone aquifers with solution porosity provide for the maximum amount of dispersion in comparison with other types of formations?

M . VAN POOLLEN: Now we are talking about dispersion?

DR. WARNER: Hydrodynamic dispersion.

MR. VAN POOLLEN: The other that we discussed was really more diffusion?

DR. WARNER: I am talking about the mechanical effect.

MR. VAN POOLLEN: You are now talking about permeaiblity variations and porosity variations?

DR. WARNER: Exactly.

MR. VAN POOLLEN: You certainly will have an additional effect of the front moving faster with a greater degree of permeability variation.

DR. WARNER: You estimated 10 percent and I understand now that in this case you meant chemical diffusion rather than the hydrodynamic or mechanical dispersion.

MR. VAN POOLLEN: No, sir, I meant by that the number if you moved through a homogeneous medium and you still will have also not just the diffusion, but you will also have the hydrodynamic dispersion .

We are now introducing the additional effect of permeability variation.

DR. WARNER: I would lump them all into the same effect, but in this case would you not say, then, that your estimate of 10 percent would be possibly -- could be very low if we introduce this variation in permeability and porosity which naturally occurs in this -- or commonly occurs in this type of rock vein?

MR. VAN POOLLEN: I did not study it and, therefore, I cannot say, really. I really cannot.

MR. GRUY: That might be the case if we had not broken it down into these layers, but I think that in breaking it into the layers we got into the layers are more homogeneous in themselves than the overall thing is, so that we have taken one element of permeability variation out of it.

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CHAIRMAN FARMAKIDES: For the Board, just to be sure, I am the poor lawyer here and I don't know exactly what you people are saying. I am trying to follow you but you are throwing out words like permeability variation, diffusion, dispersion, permeability. I have done my homework and I thought I followed you but would you come back and give me the relationship between these three terms?

MR. VAN POLLEN: Diffusion will take place in two stagnant fluids. The ions will go from one fluid to the other. The dispersion would happen when this interface is moving through the reservoir and you get a growth because some parts will stay behind and some parts will get ahead of the others through the microscopic spaces.

Then we have the permeability variation which you could view as having layers within the layer Mr. Gruy is describing which have high degrees of permeability variation, different permeabilities in each of the layers. And consequently the waste fluid will travel fastest in that streak which has the highest permeability.

CHAIRMAN FARMAKIDES: What is the significance of that?

MR. VAN POOLLEN: That it would get ahead of the sharp front which is assumed.

CHAIRMAN FARMAKIDES: So?

MR. GRUY: What he is getting at is that the circles

where I show the location of the injected fluid might actually be a little bit larger due to mixing at the front.

CHAIRMAN FARMAKIDES: Of the three points then. Would diffusion and dispersion be interrelated so that in fact you would have both diffusion and dispersion occurring at the same time.

MR. VAN POOLLEN: That is true.

CHAIRMAN FARMAKIDES: Does that meet with your definition, Dr. Warner.

DR. WARNER: Yes, sir, that is what I would define as hydrodynamic. It is commonly lumped into one constant. The statement that I would ask, then, is if -- I am not sure how to phrase this but in the absence of having the calculations, isn't it difficult to say that this will have a small effect? In fact, isn't it possible that it might have a very substantial effect? Are you not in a position to say whether it will be small or large?

MR. GRUY: I think it would be small in this case. Now, ordinarily we deal with this thing or I do -- with immiscible fluids, in other words, water displacing all of them, where you have an adverse mobility ratio. Here we are talking about miscible fluids, where you have miscibility. So that you would have good displacement so you wouldn't have viscous fingering because you have mobility ratio. You don't have an adverse mobility ratio like you do with water displaced in

heavy oil.

DR. WARNER: If in addition to these effects that we have been talking about now there were linear zones of high permeability that might be caused by solution phenomena, that might be caused by fracturing that occurred, at any time in the history of these rock units, might these types of features not provide for relatively directed linear flow to gain a much further distance than you would calculate in your assumption of a sharp front?

MR. GRUY: Yes, but we can tell the difference between radial flow and linear flow so we would know it if we have fractures. Day to day we analyze these build-up curves in the case of oil and gas wells to see whether we have fractures, the length of the fractures and the extent of the fractures. We can ascribe a certain percent of the permeability to the fracture system and a certain percent to the matrix. So there is a different flow regime that takes place there and it is noticeable in your pressure behavior.

DR. WARNER: I would like to direct these questions specifically to Dr. van Poollen since they are with regard to his testimony.

CHAIRMAN FARMAKIDES: Yes, sir.

DR. WARNER: Or page 11 of your report you discuss a calculated result of 3.4 psi as compared with a major value of 5.5 psi and I understand quite well how you made this

calculation and it is quite a logical thing to do. I appreciated your comment with regard to the engineering accuracy of the -- in this situation. Based on that I would like to ask you your opinion of the Gruy analysis of possible reservoir leakage which occurs on page 12 of their statement in which differences between leaky and non-leaky situation were in the order of magnitude of point 4 to point 6 psi and ask you what you feel the meaning of those kinds of numbers is in the context of your comment about the potential engineering accuracy of the measurements.

MR. VAN POOLLEN: I understand your questions and I have raised that question but I also understand that their statement is in addition based on the fact that in the larger region of time cancellation is available.

This quits at 150 hours but I have carried this out for a much longer time. I would like to, although you directed the question to me on that -- I would like to ask Mr. Rogers to explain more what additional pressure differences they did calculate.

MR. ROGERS: Dr. van Poollen, to the best of my knowledge the last point is shown on figure 14 of the previous Kerr-McGree submittal, exhibit A. The last point is shown in there --

MR. IRVINE: I am sorry but you are going to have to talk louder.

MR. RODGERS: The last point that is shown on this reference figure at 145 hours is to the best of my knowledge the last subsurface measured pressure point during the pressure point during the pressure fall-off tests conducted during July 1972 -- excuse me, 1971.

DR. WARNER: I guess the question I am really asking, John -- again I would like to refer it to Dr. van Poollen -- if you need to you may provide the information to him. My understanding is that in making this analysis of the potential for leakage the difference between a leaky and a non-leaky situation involves actually measurements that you made and these measurements were the differences between these two situations -- it would have only been less than a pound per square inch.

DR. VAN POOLLEN: However, the reason I don't object to that near as much is the fact that you can make a material balance calculation from your extrapolated pressure fall-off data and you should be able to get your numbers quite accurately. This is what is in my proposal of the monitoring scheme, that you inject for a certain period of time, obtain your fall-off data, that you then inject again for a certain period of time, again get your fall-off data. If you then see that your calculated power space is growing there must be a leak.

DR. WARNER: I think that you have answered my question. Really I was questioning the accuracy of the measurements and the statements they have made to date and I believe

you are saying that it would require additional testing, in fact, to verify this conclusion because the differences at this point are really too small to be dependable.

DR. VAN POOLLEN: Two things I would like to answer here. First of all, I concur with your statement that there should be more -- I mean, I presume that was a question.

DR. WARNER: Yes, it was a question at this time.

DR. VAN POOLLEN: At page 13 I state that it is recommended that the finite character of the information be determined more precisely during early injection of base fluids. See my section on that. So I definitely agree. Then I would like to point out that we should not mix up the words "sensitivity" and "position." But from an engineering point of view I agree that we should see some points of difference and I think that my suggestion in here during the monitoring would sufficiently satisfy that need.

DR. WARNER: I would like to ask just one more question.

CHAIRMAN FARMAKIDES: We are going to be exploring this very same area ourselves. This is an important area so what I am going to do is allow further cross and further redirect. Go ahead, please.

DR. WARNER: I have one more question and that is with regard to the monitoring, your feeling about monitoring in the Simpson formation. This morning I asked -- I will have

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to make this as a statement, I guess. I asked Dr. Chenoweth what the next porous and permeable formation was above the Arbuckle formation and his reply was the Simpson formation. Is that all right for me to recall that? He stated this and I was simply applying it as a basis for asking this question.

CHAIRMAN FARMAKIDES: All right.

MR. IRVINE: Now --

CHAIRMAN FARMAKIDES: Look, here is the problem. I very much want you to elucidate the record but I don't want you to do it at the expense of damaging this party. They have rights and so have you. You certainly have an opportunity of asking questions to clarify. If it is a question of -- if it is a problem here that you think is complicated and requires background or requires a foundation, then proceed. If you have a question as to how to do it, ask Mr. Kinsey.

DR. WARNER: All right. I believe I already have repeated the statement that was made this morning. Is that all right? The Simpson formation is the first porous and permeable layer above the Arbuckle formation?

MR. IRVINE: To which I think we should object on the basis that his testimony was that there was some 60 feet of the Simpson formation that was porous and permeability and not the entire formation.

CHAIRMAN FARMAKIDES: Whatever the record is, let the record speak for itself in terms of what he said. Now

proceed from that.

DR. WARNER: I would like to ask Dr. van Poollen if in addition to the monitoring of the well itself, the injection well itself, if there were certain vertical leakage, in fact if this is a continuous permeability zone, porous and permeable, even though it may have lower porosity and permeability, and if we put a monitoring well in to that, if there were vertical leakage, if it wouldn't be detectable at an early time by increased pressured in the Simpson zone? Wouldn't this also be an additional monitoring procedure to detect the possibility of vertical leakage?

MR. VAN POOLLEN: It would be inconclusive. It would only be conclusive if you had a pressure increase in that formation, which I very much doubt that it could ever occur under the situation of having a rather large section of impermeable formation and then the Simpson itself being fairly low permeability also.

On the other hand, if the permeability in the Simpson were high you would never see anything. So consequently, I don't expect that you would every find any measurement and therefore I consider this a waste of effort.

DR. WARNER: Let me ask you that question again with a little more detail. The closest fault or closest projected fault to the Kerr-McGee well is the one that is about 1100 feet to the northeast of the Kerr-McGee well. This possibly

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the nearest plane which might provide for vertical escape of the injected fluid or of the formation fluid in advance of the injected waste fluid.

The projected or proposed location of the Simpson monitor well was midway between the injection well and this fault, which is only a distance of 600 feet from the fault. Don't you think it is very likely that if there were any vertical fluid movement upward along that fault that it would be very possibly detectable in a Simpson -- in a well completed in the Simpson for the purpose of monitoring under those circumstances.

DR. VAN POOLLEN: I don't think you could measure.

MR. KINSEY: Mr. Chairman, Mr. Robertson has a few questions.

CHAIRMAN FARMAKIDES: Let's take a ten-minute recess.

(Recess.)

CHAIRMAN FARMAKIDES: All right, we will proceed.

Mr. Robertson, I think you were going to ask some questions.

MR. ROBERTSON: Yes.

I would like to expand a question on one point regarding detection of leakage into the overlying Simpson. Suppose 20 gallons a minute were leaking within 600 feet of a well. Would this be detectable?

DR. BABCOCK: Would you please say leaking from where to where?

MR. ROBERTSON: Leaking from the Arbuckle up into the Simpson within 600 feet of an observation level.

MR. GRUY: I think it would be detectable in the injection well but I am not sure it would be detectable in an observation well. If I may have a piece of chalk, I can demonstrate that on the blackboard.

We have got the Arbuckle here.

CHAIRMAN FARMAKIDES: Do you intend this to be in the record, sir? You will have to put it on a piece of paper too so someone else could be --

MR. GRUY: I will try to say it so that it will be unanswerable without the drawing.

If a well drilled through the Arbuckle is injected into the Arbuckle and a distance of 1,200 feet away or any distance away, there is a fault which leaks, with the

Arbuckle displaced upward and the Simpson somewhere above it, and the well were drilled to the Simpson, 600 feet from the fault, to monitor the leak, that you could have a very great leak along this fault which would just go on up and not be detectable in the Simpson.

In order to be detectable at this point, it has got to build up the pressure in this horizon and this is a very tight horizon and it would take not only pressure but time for that to be reflected over there, the rate at which that pressure is transmitted being a function of the permeability and the thickness as well as the pressure.

You could lead yourself into a false sense of security by seeing nothing here and still having a leak. So I see no point in spending the money to put the well there.

MR. ROBERTSON: My question was not that it was leaking past the Simpson but only into the Simpson.

MR. GRUY: Well, you said if it was leaking at the fault. I have no reason to think it would be plugged right there and that this would go around that way.

MR. ROBERTSON: You still didn't answer my question.

MR. GRUY: I don't think it would be detectable as quickly as you could detect it in the injection well, even assuming that you put a plug right there so that any leak had to be diverted.

MR. RODGERS: May I add something that might help?

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I believe you said 20 gallons per minute?

MR. ROBERTSON: Yes. This is just a hypothetical.

MR. RODGERS: That is equivalent, in the terms that we work in, in the oil and gas industry, to approximately 696 barrels per day. I believe we have testified that we can detect through the pressure behavior a leak of this magnitude of rate, or appreciably less than this.

So my guess is that you could detect it at that rate.

MR. GRUY: We could detect the leak in the injection well by monitoring the injection well, but whether or not you would see that in the Simpson would depend on how much pressure built up here opposite the Simpson and the permeability and thickness of the Simpson.

DR. BABCOCK: Just for the record, isn't about 20 gallons a minute the rate at which you plan to inject water into the well?

MR. SHELLEY: Yes, it is.

DR. BABCOCK: In other words, you are asking for a 100 percent leak.

MR. ROBERTSON: Yes. This is just a hypothetical case.

In the Gruy testimony, the one that was submitted for this hearing, on their Figure G-5 I have a question. It concerns the early portion of the pressure falloff curve

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in their well tests.

Were these points measured with the accuracy stated in the report of 0.55 psi?

MR. RODGERS: If I may, I will try to answer that. Actually, as you can see from the scale mode on this block, what we call the scale mode on the vertical scale is an increment of 2/10 of a psi and actually you can see from the trend and the variations in pressure profile -- you can see that the gauge is actually measuring a little better than what is publicized as the instrument sensitivity, which is at the figure of plus or minus 0.55 psi. But actually you can actually detect by visual observations on this graph a lesser degree of fluctuation.

MR. ROBERTSON: Can you be certain that these lesser degrees of fluctuation are real fluctuations or instrument error?

MR. GRUY: We can't be certain whether these are real or not or within the sensitivity of the instrument.

MR. ROBERTSON: If there were some change in the accuracy of those points on that figure, would not that affect the location of your straight line that you have drawn considerably?

MR. RODGERS: I am sorry to answer your question with a question. What do you mean by "accuracy"?

MR. ROBERTSON: Referring to this curve, if a few

of these points in this particular area where you have drawn your straight line were as much as 2/10 of a psi off, which is within the stated accuracy of your instrument, would not that greatly affect the location, the slope of that straight line?

MR. RODGERS: Not necessarily. The location of the straight line portion is actually based on the so-called calculation of the after-flow phenomenon that occurs in the well bore as a result of the surface shut-in. That is to say, at the surface when we shut the well in, the mass transfer at the surface instantaneously becomes zero. But because the well bore contains a compressible liquid then the bottom of the hole condition is such that these fluids continue to flow into the well bore space and compress the fluid.

So this is termed the so-called after-flow region and this analysis of this region is detectable in the pressure behavior and is actually one of the criteria that we use to detect the Point A or the beginning of the straight line portion. So if we didn't have variations of random statistical order, I would say no, that Point A would still be a valid determination.

MR. ROBERTSON: ~~Perhaps Point A would be --~~ could not Point C be at a different point if there were a 2/10 error in some of the points?

MR. RODGERS: No, because this well bore

stabilization event that occurs timewise prior to Point A, or the appearance of Point A, is the stabilization of the mass transfer in the well bore itself resulting from the fluid compressibility.

In the analyses of the data we examine this stabilization effect and actually determine that the stabilization timewise occurs at Point A or at a shut-in time of 0.1288 of an hour.

MR. ROBERTSON: Could you tell me how Point C was determined?

MR. GRUY: Point C is determined by the change in slope at that particular point in the line. Mr. Robertson: Then couldn't the slope be quite different if some of those points in that particular line were as much as 2/10 of a psi in error?

MR. GRUY: Well, I think the points speak for themselves in that the way they are lined up -- all we are after is the slope of that curve. Its exact position on the paper up and down is of no consequence here.

MR. ROBERTSON: Then the slope is important and that is what I am getting at. If there were errors in the location itself of those points the slope could change, could it not?

MR. GRUY: If we just had two points and one was off a half pound one way and the other a half pound the other way, it would change the slope. But we have good points

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here. They line up good and we have not found that we get errors in them.

MR. ROBERTSON: Then you say an accuracy of 0.55 really doesn't apply?

MR. GRUY: Not to this, I don't think.

MR. RODGERS: Let me qualify that. That is a published value called the precision of pressure measurement for the Sperry Sun gauge that was used. Actually this particular gauge is doing much better on sensivity or ability to detect the pressure change than the published figure of 0.55 psi.

As an idea of what this gauge is doing in regard to sensivity, the standard deviation of the least squares fit of this straight line portion is on the order of 0.01 psi plus or minus.

MR. GRUY: That is the sensitivity of this gauge at this time.

MR. ROBERTSON: Have you calibrated the gauge with standard laboratory calibration?

MR. RODGERS: Yes, the gauge itself is calibrated in the lab. It is calibrated at the measured well bore temperature.

MR. ROBERTSON: What kind of precision did you obtain in the calibration?

MR. RODGERS: The calibration is not done to deter-

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mine precisition. The calculation is done to calibrate the pressure elements of the instrument within the working pressure range and the working temperature range of the actual bore hole conditions.

MR. ROBERTSON: So you have no quantified measure of the precision of that instrument other than the stated 0.55.

MR. RODGERS: We know that we have a measurement, a statistical calculation that incorporates the sensitivity of the gauge and the pressure measurement in regard to the standard deviation of the least squares fit that straight line portion.

MR. ROBERTSON: Also in regard to the accuracy of those points, if there were some inaccuracy that would also determine where the break in the slope occurs that you used at Point C? If that break occurred at a significantly different place that would change the location of your first boundary; is that correct?

MR. GRUY: That is correct.

MR. ROBERTSON: The pressure falloff curve similar to this extended on out further was used to calibrate the location of other boundaries in the system; is that not true?

MR. RODGERS: In conjunction with the calculations done with the three dimensional model.

MR. GRUY: The position of these boundaries was

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not determined from inflection points on the curve alone. That was done to illustrate the effect but we took into account everything by putting it in a model with various boundaries in it and calculating the shape of the theoretical curve that would occur if the underground were exactly like our model.

Then we moved those boundaries in order to improve the fit of the measured data with the theoretical data. We did not rely on distances to inflections and maybe the inflection is here so it is so far and the next inflection may be here so it is so far.

We fit the whole shape of the whole curve in the model to the point that when we moved any of the boundaries we got a worse fit than we had. So the differences between the theoretical curve that we are calculating and the measured curve we have are due to some other shaped factors in the homogenous nature of the reservoirs than the ones that we are varying.

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MR. ROBERTSON: I have a question to clarify a point on the mathematics that you are using. Your equation is 4 and 4a in the same exhibit.

MR. GRUY: I would like to call on Dr. Van Poollen on that because he verified those equations and he can talk about the equations better than I can.

MR. ROBERTSON: It is page 7.

MR. KINSEY: It is page 7 of the testimony of Mr. Gruy.

MR. ROBERTSON: In developing and describing the mathematic equations used for a model such as this, I have a question on equation four, for instance, on the righthand term, the very last term following the equal sign. In that term, could you tell me, is the theta symbol porosity? Is that correct?

MR. VAN POOLLEN: That is correct.

MR. ROBERTSON: And that was used as a constant?

MR. GRUY: Yes. We did vary porosity in some runs to check the sensitivity to it. We found that in order to match we had to use porosities that we used which were those calculated from the location.

MR. ROBERTSON: And it was a constant?

MR. GRUY: Right.

MR. ROBERTSON: BW is the variation for water factor, is that correct? Was that constant?

MR. VAN POOLLEN: No, because then you would have an incompressible system. In essence here is what happens. Where you look at storage, with a storage coefficient, the petroleum people look at the product of thickness times porosity times compressability is incorporated in the formation volume factor.

MR. ROBERTSON: This is partly my lack of familiarity with petroleum terminology. It is mostly to clarify my own understanding because I am used to dealing with the terms you mentioned such as storage. They all deal with compressibility. But I wasn't clear how compressibility was varied or was allowed to vary. The point I make is this particular term doesn't have a pressure term in it.

MR. VAN POOLLEN: It does. It is hidden in the fact that you have the differentiation with respect to time of the quantity 1 over the formation volume factor. You can express that in terms of compressibility and pressure function with respect to time.

MR. ROBERTSON: I think that clarifies that point. These equations are different than the terms -- the terms are different than the ones Dr. van Poollen quoted in his testimony but I want to make sure that they were saying the same thing. I just wanted to clarify it.

Also in regard to compressibility, getting back to the Gruy testimony, you mentioned that your term for

compressibility of water but you do not mention the compressibility of the porous medium. Is that also incorporated?

MR. GRUY: That is also incorporated, compressibility of the whole system.

MR. ROBERTSON: What was the value used for total compressibility in the system?

MR. GRUY: I believe it was 8×10^{-6} of the volume provided, psi.

MR. ROBERTSON: In the Gruy testimony, exhibit G-6, which is page -- well, it doesn't have a page number but it is one of the figures at the end. I notice the triangular points used in these curves are for model-run number 16, is that correct?

MR. GRUY: Yes.

MR. ROBERTSON: I notice the point hear 120 hours -- these points display a pressure increase with time, triangular points, the last two triangular points. The last one is higher than the next-to-last one. How do you explain that?

MR. RODGERS: That could have been some oscillations in the numeric solution. However, in this particular example I would also note that it is significantly different from the measured data.

MR. ROBERTSON: Did you observe these oscillations in any other runs that do not show on these curves?

MR. RODGERS: Not to my knowledge.

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MR. ROBERTSON: Have any oscillating points been left off from these curves that you know of?

MR. RODGERS: As far as I know all calculated points that are calculated by the numeric model are shown.

MR. ROBERTSON: I might ask this question. A model of this type involves many complex variables, including permeability, thickness, porosity, elasticity of both water and rock matrix, boundary conditions, locations of boundaries, just to name a few, is that correct?

MR. GRUY: Yes.

MR. ROBERTSON: It is not possible with this many unknowns or poorly defined parameters in a system like this that you could develop a completely different model that would yield a response curve very similar to the one you have published here, is it?

MR. GRUY: I don't think so because we have got a lot of things to fit. We have got to fit the injectivity and the back flow as well as the falloff in pressure. A lot of these things that are known pretty well are held constant. The main things that we don't know, the thing we are looking for, is the position -- the shapre or whether or not this system is closed.

Certainly a small change in compressibility or a small change in porosity necessary to bring these in line is not going to invalidate the thing as far as the position of the boundaries.

MR. ROBERTSON: Do you know that the porosity is constant horizontally?

MR. GRUY: No.

MR. ROBERTSON: Do you know that the permeability is constant horizontally?

MR. GRUY: No. I know that it is not, but I know that it varies in such a manner as to be homogeneously inhomogenous because if it was very different from that, if there were large variations -- a small variation that is matched by another small variation that is matched by yet another. If there was a large variation where the permeability was twice what it was in another direction it would show in the shape of the curve and we have tested that.

MR. ROBERTSON: You have stated that you can detect linear flow versus radial flow and I don't question that, if it is strictly that. What about a system that is partly an iso-tropic, which means that permeability is direction oriented?

MR. GRUY: You would get a slope between what you get for linear and radial flow.

MR. ROBERTSON: How would you detect how much anisotropic --

MR. GRUY: This shows plainly in the early time period of the model before you hit boundaries.

MR. ROBERTSON: To what degree? Say there was a preferred direction of permeability, more so in one direction

than there was at right angles and still in a horizontal plane. What degree difference, say, if the permeability was ten times as much in one direction as it was at right angles -- could you detect that in your model?

MR. GRUY: I think we could because it wouldn't fit the radial flow falloff. It would fit the slope of one when you get on radial flow. There was no indication at all of any variation from radial flow.

MR. ROBERTSON: Could you detect a 2 to 1 difference?

MR. GRUY: Yes.

MR. ROBERTSON: That is very interesting.

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MR. GRUY: The model would show it.

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MR. ROBERTSON: In ground water hydrology, it's common in pressure transient testing or any other testing if at all possible to use observation wells for additional pressure measurement or head measurements. Is this common also in the petroleum industry?

MR. GRUY: It's sometimes done. It's not common.

MR. ROBERTSON: I think --

MR. GRUY: I can get a little additional information if you have an observation well to tell the time and the magnitude of the pressure change. We call it interference testing when we use more than one well.

MR. ROBERTSON: In the ground water industry it's common to find an observation well can yield a different interpretation of the reservoir than the injection well. Is this -- have you observed this in the petroleum industry?

MR. GRUY: No.

MR. ROBERTSON: In Figure 8 of your testimony --

CHAIRMAN FARMAKIDES: Are you talking to Dr. Gruy?

MR. ROBERTSON: Yes.

MR. KORNBLITH: Was there an answer to the previous question? I didn't hear it.

MR. ROBERTSON: He said no, he is not aware that such differences occur.

In Figure G-8, this figure describes the effect of varying the permeability -- the permeability of the boundary

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in your Gruy model, is that true?

MR. GRUY: Yes.

MR. ROBERTSON: It appears to me that the permeability of the boundary is fairly insensitive, the model is fairly insensitive, considering the accuracy of the numbers you are talking about; talking about these squares and triangles, there is a relatively small difference between the squares and the triangles. Would you say that is true?

MR. GRUY: Yes. Certainly it -- you couldn't differentiate between the squares and the Xs, between the calculated data with it and without.

DR. BABCOCK: Just a minute. He was asking about squares and triangles and you are talking about squares and Xs.

MR. GRUY: I am talking about squares and Xs and squares and triangles.

DR. BABCOCK: Let the record show he is talking about both.

MR. GRUY: The squares and Xs, you couldn't tell the difference between. That is a difference of .01 miliedarcy. The solutions giving the boundaries a permeability of .01 miliedarcy yields the difference between the Xs and the squares as far as the solution is concerned, which is not detectable.

However, if you make the boundaries have a permeability of .1 miliedarcy, then there is a detectable difference in the

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calculations.

MR. ROBERTSON: It appears to me the difference is not much more significant -- maybe you can clarify the difference -- the significance between the deviation in squares from the measured circles versus the deviation of a triangle. There does not appear to be a major significant difference.

MR. GRUY: We were comparing the model calculation with impermeable barriers and the model calculation with permeable barriers. With permeable barriers of .1 miliedarcy, there is a detectable difference in your model solutions. With 1 hundredth, there is not.

MR. ROBERTSON: Could you not vary it and make a variation in the model using that permeability, the permeability of .1 miliedarcy, for that barrier and still obtain -- manipulate the model to obtain a fit just as good.

MR. GRUY: We couldn't. Everything we did to this model at this point made to fit, would.

MR. ROBERTSON: And the squares you feel do not deviate significantly, is that correct, from the best fit model curve?

MR. GRUY: The squares don't deviate significantly from the Xs.

MR. ~~GRUY~~ Robertson: That, if I remember your figures, would allow a leakage of four or five barrels a day.

MR. GRUY: About 4.4 barrels a day.

MR. ROBERTSON: The triangles, on the other hand,

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would allow leakage of 40 barrels a day or so.

MR. GRUY: That's correct.

MR. ROBERTSON: So you feel it's feasible to have a leakage of four barrels a day without detection.

MR. GRUY: Right.

MR. ROBERTSON: But it's not feasible to have 40 barrels a day.

MR. GRUY: I think if we had 40 barrels a day, it would be detectable.

MR. ROBERTSON: How about 20?

MR. GRUY: Twenty would be questionable.

MR. ROBERTSON: Thank you.

I think I have one or two other questions.

MR. GRUY: But this precision will improve as time goes on. Once this has a closed system and you are just dealing with compressibility of the fluids and pressure buildup in a semi-steady state instead of expansion of the bubble itself, then you are going to be more sensitive.

MR. ROBERTSON: That concludes my questioning.

CHAIRMAN FARMAKIDES: Mr. Kinsey, you said you had a couple of questions.

MR. KINSEY: I used the term loosely, sir.

I would say I have about ten questions for Mr. Shelly, depending on responses, I may have more or less. If I could --

CHAIRMAN FARMAKIDES: Just proceed, sir.

MR. KINSEY: If I might also add, the Staff has a shuttle to catch at about 5:40 back to Bethesda.

CHAIRMAN FARMAKIDES: So what time do you --

MR. KINSEY: From H Street. So with Mr. Irvine's agreement, we would like to perhaps adjourn this at around 5:00.

CHAIRMAN FARMAKIDES: All right.

Let me say this, too: That means we will continue with the Panel tomorrow morning. Then we have the Staff's direct. We had better start early, then. We were thinking we might finish tomorrow.

MR. IRVINE: Yes.

CHAIRMAN FARMAKIDES: But the Board has quite a few questions on the points developed this afternoon and on the direct. So it may well be that we won't finish this Panel much before 10:00 or 11:00. I would think we ought to start early. How is 9:00 in the morning?

MR. IRVINE: That would be fine.

CHAIRMAN FARMAKIDES: All right, we will start at 9:00.

Let's go ahead and continue as far as we can today. You say 5:40?

MR. KINSEY: Yes, sir. We will probably have to hike it because cabs are almost impossible.

CHAIRMAN FARMAKIDES: I think your best bet is to go

ahead and walk up there. It won't take you more than 20 minutes to walk up so we can go until 5:15. I want to get in as much time today as I can.

MR. IRVINE: If they jog, we can go until 5:20.

MR. KINSEY: I have just been advised that we have a shuttle problem, too. The shuttle from Bethesda doesn't leave until 8:10, which might not get us here until a few minutes after 9:00.

CHAIRMAN FARMAKIDES: Well, we will wait for you.

MR. KINSEY: Okay.

Mr. Shelley, generally my line of questioning will dwell on this --

(Discussion off the record.)

MR. KINSEY: Getting back to Figure 1, Mr. Shelley, you used the word typical analysis. I would ask why you used the word typical in setting out these particular figures.

In other words, I am sort of getting at the technique you use for deriving these figures.

MR. SHELLEY: Our primary interest here is in the radionuclide. We have at various times measured the radionuclides. We find small variations in the quanity of radionuclides left in the raffinate. I label this typical in the case of radionuclides because it is typical of the kind of distribution of these materials we see.

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I resolved in the other chemical measurements we will get significantly varying concentrations as our source of field material varies.

As to the problem of handling raffinate, we do not believe the problem is significant. This is a typical example.

The next one might be, for instance, half of the sulfate and twice the chlorides. It might be higher or lower in sodium. But none of them significant in terms of a disposal problem.

MR. KINSEY: In arriving at these figures for the raffinate, did you take a sample of raffinate for this particular analysis?

MR. SHELLEY: Yes.

MR. KINSEY: Could you tell me was it a single sample or more than one?

MR. SHELLEY: I think this particular analysis was a composite of October of 1972. I don't have that reference with me. We take a portion out of each 5000-gallon batch, generate it and total it up and analyze it at the end of the month and label the composite.

MR. KINSEY: What frequency would the 5000-gallon batches be, if you recall?

MR. SHELLEY: In theory it would be about 4-1/3 hours. Actually due to varying feed rates or maintenance

problems or a number of things, it runs from four to eight hours to accumulate a batch.

MR. KINSEY: Where in the raffinate stream would you take a sample? Is it before leaving the solvent extraction plant? Is it from a pond?

MR. SHELLEY: The sample is taken out of a raffinate batch tank, of which we have two, and it is the last point of control that we have on the raffinate. From there it goes to neutralization and is dumped into the pond or into the well, whatever the term of the process may be.

The purpose for that sample is to examine the quantity of uranium and rerun the raffinate if it exceeds an economic level.

MR. KINSEY: Would the radionuclide figures vary depending upon the age of the yellowcake?

MR. SHELLEY: The answer to that is simply yes. We have seen variations from 280 to 400 microcuries per milliliter times 10 to the minus 8th. This varies by the age, it varies by the efficiency of the mill's extraction process. It may vary by the efficiency of our extraction process, although we very seldom see measurable radium in our product from the solvent extraction.

MR. KINSEY: Mr. Shelley, I have reference to the May 10, 1972 application, specifically the letter from, I believe, Mr. Parks to Mr. Muntzing in which on page IV-6,

under the heading "Disposal Well Radioactivity Releases," the pertinent language reads, "It is requested that specific approval be granted to release radioactivity by the deep well up to the following average concentrations: Radium 226, 2.1 times 10 to the minus 5th."

MR. SHELLEY: I am familiar with that.

MR. KINSEY: How would you reconcile this number which is higher than the 340 times 10 to the minus 8th?

MR. SHELLEY: As you suggested I think earlier in the afternoon, this amounts to 2100 times 10 to the minus 8th. This number was developed from -- this number was initially deve-oped for our initial submission of the license application for the use of the deep well. In other words, the 1970 submission. It was developed as the result of taking certain calculations of mill efficiency and arriving at the 2100 from the equilibrium content of the ore. The purpose in using this number is that we felt that this was a maximum number that this could ever be.

We felt at the same time that it would normally run somewhat lower. But I think it is a common practice in licensing to request the -- for a disposal of this nature to use the largest number that you are apt to face in the history of the plant.

I did not develop that number myself. It was devaloped by a predecessor. I have looked at his calculations

which are in our earlier license submittal and I have described what he has done, to the best of my recollection.

MR. KINSEY: Then is it fair to say that for purposes of the disposal well in the application which is under consideration in this proceeding that 340 times 10 to the minus 8th is the typical or the average concentration of the radium which will be in the raffinate stream?

MR. SHELLEY: I would prefer to use typical. We have not measured it enough to have an average.

MR. KINSEY: But presumably it will be somewhere within that neighborhood?

MR. SHELLEY: Yes, sir.

MR. KINSEY: I am saying 2100 versus 340.

MR. SHELLEY: Since the plant started, we have seen numbers around 340 rather than 2100.

MR. KINSEY: In discussing the section on monitoring, I have just one question: Do you recall Dr. Sternhagen's testimony this morning?

MR. SHELLEY: Yes, sir.

MR. KINSEY: I believe -- you can correct me if I am wrong -- that he indicated that from a toxological point of view, radium 226 was the more important radionuclide in the waste stream.

MR. SHELLEY: Yes, sir.

MR. KINSEY: I note the table showing the sample

frequencies and analyses between pages 2 and 3 of your testimony, and I note that the radium analysis is only to be conducted quarterly whereas all other analyses are to be conducted either weekly or monthly, and I am interested in why, if you might know.

MR. SHELLEY: We are dealing in the instance of a radium analysis -- we are dealing with a very low concentration of material as compared with either uranium, fluoride, nitrate calcium, sodium, et cetera. The method to analyze radium takes a minimum of 48 hours to get a reliable answer. Additional time is desired at low concentrations we see experienced in background in the Sequoya system. We normally let those -- we normally measure those five to seven days after they are taken and separated. Multiple samples in this case does not normally add to the quality of the measurement if you are dealing with background raidum.

If in the event we had any reason to suspect a leak and could pick it up in surface water, we would be dealing with a concentration presumably well above background and therefore we would go to a waekly or more frequent analysis as the case demanded.

MR. KINSEY: Mr. Shelley, do you recall in your 1970 application when you requested a specific limit on the amount of radium in which to inject into the deep well?

MR. SHELLEY: No, I do not recall. As I think Mr.

Irvine said earlier, that 1970 application was withdrawn.

MR. KINSEY: Would it make any difference if the requested limitation was substantially higher than what was subsequently requested in the 1972 application or the -- or in the testimony today?

MR. SHELLEY: I am afraid I don't understand your question.

MR. KINSEY: I will withdraw the question and move on.

When the raffinate is injected into the well, what do you estimate will happen to the solumble thorium and uranium and the other dissolved solids in the waste stream when the pH of the solution is neutralized upon coming in contact with the limestone dolomite formation?

MR. SHELLEY: By extrapolating from our current experience, when we neutralize in the tanks on the way to the pond, we find that we eliminate essentially uranium and thorium by precipitating them as oxides or hydroxides. We obviously form -- if you neutralize with ammonium, you form ammonium nitrate. We don't detect any measurable disappearance of other chemicals.

I am sure it could happen under varying situations of solubility. Therefore, in answer to your question, I would expect that the uranium and thorium would upon neutralization at the bottom of the well drop out as a solid

some place behind the neutralization front and would rest there essentially as a solid. The other materials, the ammonia -- if instead you had nitric acid being neutralized with ammonia, you would be neutralizing with calcium or magnesium. Therefore you would have calcium or magnesium nitrate in the solution at the bottom of the well and essentially leave the things unchanged.

MR. KINSEY: What effect do you expect these precipitated solvents would have the well bore interface? Would there be, for example, pressure build-up?

MR. SHELLEY: I can only refer to another paper that we heard at the underground waste disposal symposium in New Orleans last month, to which Dr. Warner refers later in his prepared testimony, wherein they neutralized hydrochloric acid solution containing ferrous chloride in a dolomite reservoir at New Johnsonville, Tennessee, and demonstrated to their satisfaction that the iron was precipitating in a front behind the neutralization front.

I would expect the iron in our material and the thorium and the uranium to follow essentially the same pattern as the iron did in that case. These are not instantaneous neutralizations. I think they would fall out, but I don't think we would see a plugging of the porosity.

MR. KINSEY: Do you envision the formation of carbon dioxide at the bottom of the well?

MR. SHELLEY: Certainly.

MR. KINSEY: On neutralization.

If I might ask, what do you anticipate will be the fate of the carbon dioxide?

MR. SHELLEY: It will either be expressed as a liquid or as carbonic acid, probably the latter, but we are well above the liquidation pressure of Co2.

MR. KINSEY: So that there would not occur any type of pressure build-up as a result of the formation of the carbon dioxide?

MR. SHELLEY: I can't say that with certainty. We are dealing with pressures in the range of 1200 psi at the bottom of the hole. The injection of liquid will have a pressure build-up. The dissolution of the solid will tend to reduce that pressure. The presence of 3Co2 will tend to increase it. I think you will see a different pressure down then than you would expect for any single mechanism.

CHAIRMAN FARMAKIDES: We will break now and reconvene at 9:00.

(Whereupon, at 5:07 p.m., the hearing was adjourned, to reconvene at 9:00 a.m., Tuesday, 16 October 1973.)