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Repository Sealing Program

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BOARD MEMBERS PRESENT

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I N D E X

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P R O C E E D I N G S

(8:30 a.m.)

DR. DEERE: Good morning ladies and gentlemen. I am Don Deere and I am going to introduce Dr. Dennis Price who will be the moderator for our session this morning.

Dennis.

DR. PRICE: Thank you, Don.

You'll notice this morning that we start out with John Case and Ian Hynd. Before we begin with their presentation followed by the Fernandez and White presentations, I'd point out that after the break, we have a period of an hour for discussion. I would like to alert everybody to that hour of discussion, so you will be thinking of things that you would like to discuss and we invite of course the audience to participate in that period of discussion as well.

Without any further delay then, we have our first presentation on the Technology to Seal Shafts and Ramps with John Case and Ian Hynd.

MR. CASE: Good morning.

The title of my presentation is Technology to Seal Shafts and Ramps. This presentation was a collaborative effort between myself and Ian Hynd. However, Ian is unavailable; he is in South Africa on a consulting job. I am going to make the presentation this morning.

The outline of my presentation is, is that I am first of all going to discuss primary grouting of the modified permeability zone around a shaft seal. I am then going to discuss construction methods for liner removal which include fragmenting the liner and mucking the broken liner to the ground surface. I am then going to discuss placement of backfill; excavation of a keyway; placement of concrete; and then secondary grouting of the interface zone and modified permeability zones.

This presents a schematic of the final design for shaft seal as we see it. I should indicate that this work was done as part of the Exploratory Shaft Performance Analysis studies that we did for the Department of Energy to address issues with respect to whether the exploratory shafts would affect the long term performance of the repository. So it was done in that context. But, basically the final product that we would have would be, we would have a series of holes that would be drilled outward from the shaft to intercept the modified permeability zone. We would have removal of the liner at the place where the plug was placed, and also keying in the plug. This would be done for several purposes. One would be to remove perhaps a shallow zone of blast damage that might exist around the shaft. Also, it would promote the structural integrity in the sense that the plug would be resisting loads in bearing compression, as opposed to simple shear. Following construction of the plug, then we would drill additional holes for secondary grouting of the interface zone and perhaps the modified permeability zone.

After so many technical presentations, I think it might be appropriate to quote Shakespeare. He said in one of his plays: "All the world is a stage. All men and women are players. They make their entrances and exits and of men there are seven ages." And with that I introduce this picture. This shows the shaft stage from which we make entrances and exits to the areas where we are going to be sealing. What it is, is essentially it is fabricated out of structural steel; it has a series of different platforms; the steel would be constructed in such a way as to have a gap of perhaps nine inches at the boundary for safety reasons; and, there would be areas where things could be hoisted up and down the center of this shaft stage, or another term is a Galloway. Basically, this platform would be hoisted up and down the shafts in conducting the operations.

The first thing we would probably have to do would be to decide where we were going to place the seals. I think what we would do would be to conduct various geophysical surveys. These surveys might be shaft mapping. They might also be geophysical surveys such as cross-hole seismic resistivity or electrical resonance. And in the case of perhaps large fracture zones which we might be interested in isolating, or at least not proposing seals near large fracture zones, we may be using ground penetration radar surveys which have been used at the Waste Isolation Pilot Plant with considerable success in identifying large fracture zones.

After we had done that and we located the place for sealing, we would then proceed to obtain information about grouting. This might be done with a series of packer tests where we would test for the permeability of the rock. We would determine safe injection pressures. Some of the rules of thumb that have been developed is that the safe working pressures for grouting operations would be approximately .8 of the depth of cover. We might envision the need to pump grout at pressures of a pumping rate of one to fifteen gallons per minute with pressures to 700 psi.

I might also add that the permeability information would tell us things about what types of grout to use. If we had a higher conductivity materials, maybe we could go with normal particle sizes in terms of our grouts. If we have much smaller conductivities of the order of 10^{-5}, 10^{-6} centimeters per second, we may need to go to an ultra fine cement.

After we had determined information with respect to grouting, we would then proceed with grouting. We would probably use some sort of grouting of pattern as is shown here. We would go in and this is showing the shaft and developed elevation. We would start at one end, perhaps at this row here in the bottom row, grout there, come over here and do this at the same time (indicating), then here in the center, and then essentially just sort of fill in between here and here (indicating). Once we had done that, go into a central set of holes and do additional grouting. So we are grouting within the holes created by the top row and the bottom row.

This grouting would be done from the liner. Having the liner in place facilitates grouting and also provides protection during the operations. We might have a grout pipe that would be initially grouted into the shaft liner and then the hole would extend out into the modified permeability zone angled slightly downward. And then of course, we would attach our grouting hoses at this point.

Just to give you an idea of the types of equipment that we might use, this shows a small circular rail system that could be mounted on the shaft stage or Galloway. There are small carts here, such as here (indicating), and we could have then a Drilling Jumbo that would be pneumatically operated. We could use this to precisely locate places at which we would do our drilling.

Let me move on and talk about liner removal methods. We may want to remove the liner, not only at the location of the plug, but we may also need to remove it below as Joe had indicated before, there may be some reasons we would want to encourage drainage. We may have chemical compatibility problems with respect to leaving the liner in place that would pose problems. And so one of the things that we looked at in the study was to look at various methods for complete removal of the liner.

The methods that we looked at were several manual methods that would be hand-held pneumatic breakers, drilling and blasting, drill and use of hydraulic splitters, drill and use of nonexplosive drilling agent. Then, we looked at other methods that might be used in more of a higher production environment, an impact breaker and a roadheader boom.

The first four methods would be used from a single stage and could be used in conjunction with placement of backfill. The last two methods would be mounted on one stage and mucking and backfilling would occur from a second stage.

This shows the schematic of the production cycle that we would have. The Galloway is coming down to this area right here (indicating). What we have at the top deck is drilling that is taking place. Supervisors on this deck were loading it up with an agent or using hydraulic splitters on chains. As liners fragmented it drops down to the bottom.

After completion of that first cycle, then we would go in with our Cryderman, which would come down and pick up the chunks of the liner and place them into the bucket which then could be hoisted to the surface. We would then use the same equipment to bring backfill down to the bottom here and use the Cryderman to place the backfill. We might also use some manual compaction methods at that stage.

One of the things I point out about these operations is the need for safety. I don't think we have talked about safety, but safety is of extreme importance in operations that we are doing. In this particular operation, it will be important that the men know exactly what their jobs are and that they are at the right place at the right time.

This shows a picture of the shaft stage that is rigged in a different way. You would have a circular rail system down here possibly, and an Orange-Peel-Grab that could be operated and could be hoisted up and down. Then we could pick chunks of liner off at this point and place them into a bucket which could be hoisted to the surface.

Here is a picture of a Rotary Underdeck Mucking Unit. Basically, what we have is a Orange-Peel or Cactus

Grab that would be operated from a winch right here. This thing could rotate around and could also travel laterally like this and it could be used for precise placement of backfill. Here is a picture of a Cactus Grab. Basically it has pedals that are operated hydraulically. It can be used to pick something up and take it over to some other area and drop it. Anyway, this is the kind of equipment that could be used for the removal of the liner and placement of backfill in a shaft.

Here is another type of rigging on the base of the shaft stage. Basically, this picture here shows an Impact Breaker that is operated from this area (indicating). This thing could be swiveled around and the Impact Breaker could then impact and fragment the liner. Chunks of the liner would fall out. This stage would go to the surface and the mucking stage would then be used to remove the liner.

This shows a schematic of the emplacement of the concrete. What we would do is after we had removed the liner, we would probably go in here, construct a shaft keyway by drilling a series of lateral holes. Loading those up with some expansive agent we would fragment this part of the liner and then once we had developed a small platform, we would work our way down in removing the rock at that point. After we had done that then we would have a batch plant at the ground surface; we would pump concrete down.

The concrete would be tremmied into place. This is not correct here; this person would actually be using a rod to basically remove air voids from the concrete at this point. And then we would just work our way up, retreat the shaft stage out of that area.

After we had completed that, we would go in and have a series of seal grout pipes that we could remove. We could break those out at the very end, so we weren't introducing any steel into the system. And then from this point, we would have perhaps eight holes at the top midpoint and bottom of this shaft seal. We would essentially grout that interface zone to tighten that area up.

At this stage, I would like to address a little bit about what we would do if we had a ramp seals as opposed to a shaft seal. Most of this work was directed at looking at sealing in the exploratory shafts. Some of the things that we would do the same would be if the ramp was tunnel lined, lined with concrete, then we could use the similar grouting techniques that were portrayed here, grouting from that particular liner. If we had a shotcrete with welded wire mesh with shallow bolts, I think that we could probably remove those as part of the operation of keying the plug into the rock.

I would think that resin grouted bolts that extended far up into the rock at the points that we were wanting to locate to seals, might pose something of a problem in removing that artificial support.

I should also say, that one thing that would be different for a ramp seal would be we might want to angle the holes from the vertical so that the holes would intercept the dominate vertical fracture patterns that are in evidence in the welded fractured tuff.

After we had completed that operation, we would probably use similar manual methods for fragmenting the liner. Backfilling would be similar to what was presented yesterday in terms of backfilling. However, we would have problems with respect to emplacement of a concrete plug because of potential separation that may occur at the top. Now, some of the ideas that could be used for addressing that issue would be to construct temporary bulkheads, inject the concrete under a slight pressure, try to force it up towards the roof of the ramp seal. I think after we completed that, we still would have a problem with air voids that might form at the top of that plug. It would be very difficult, I think eliminate air voids perhaps at the top of the plug. However, after we completed that, we could go in there with our contact grouting and the contact grouting may be much more important in the case of the construction of the ramp seal, than in the case of the shaft seal, to try to tighten up that area that might exist at the top of the ramp seal.

With that, I conclude my presentation.

DR. PRICE: Any comments or questions?

DR. DEERE: Don Deere. I think you have made a very nice study of it certainly using techniques that will do the job and are available. I don't think there would be a great trouble, however, in emplacing either an incline ramp or a horizontal tunnel, the concrete plug and the seal, because this is sort of what is typically done in all of our hydraulic pressure tunnels. They do though have to come back in as you mentioned with angle holes to cross the contact. You have to wait a little while until the concrete cools down and shrinks, then come in. It is absolutely necessary that you do come in with that two or three rows of contact grouting right there at the contact to fill up what may have pulled away from the top. I don't see it as a great problem.

Right at the moment, they are removing very heavy concrete segments in the Channel Tunnel at the French Crossover Cavern. They have gone in again and they want to make it a production exercise. What they have gone to is the hydraulic ram, which you showed a picture of there with a long machine held super rock breaker or jack hammer and breaking these segments down as fast as they can and then lifting them out with a small shovel and putting them on the train.

Do you think there is any possibility that you can just leave that material and not have to haul it out? It probably won't be reinforced concrete, because it is in a circular shape and it may well just be a plan concrete.

MR. CASE: The issues that we looked at were that the NRC had raised some issues with respect to liner removal. If you can imagine a plume of water that is moving down the shaft somehow maybe at the contact zone it enters the shaft or perhaps there is some fracture zone that may enter the shaft and the water is moving down in the unsaturated zone. If it moves below the repository horizon into a sump, then that sump could fill up and it could simply drain below the repository and not pose a problem for water entering the repository.

Some of the concepts that I think Joe had showed earlier would incorporate a concept of drainage and there might be some advantage to removing the liner for that purpose. But other issues that have evolved with the project are, if we have a liner and we have the J-13 or nearly meteoric water contacting that material, could that alter the pH of the water, increase the pH, and cause some issues with respect to radionuclide migration. I think that was sort of the context in which it was looked at.

DR. DEERE: I guess I didn't state my question real well. I meant after you break the lining out, just break it small enough that you just compact it right in place and you mix it with the backfill.

MR. CASE: That is a possibility, yes.

DR. DEERE: Rather than hauling it up and then bring something else back down.

MR. CASE: Yes. It could be done that way. And in fact if it was done that way, then the Impact Breaker or the roadheader that would be mounted at the base of the shaft stage could be used at a much higher production rate. In other words you could really go in there and probably remove that liner at minimal cost, reducing the cost for that particular operation.

MR. FERNANDEZ: I think Tom Hinkebein had a question or a statement to make.

DR. HINKEBEIN: This is Tom Hinkebein. The comment with respect to leaving the liner in place is this. One of our sealing concepts has the bottom of the shaft as a drainage area. If you allow the concrete liner to drop to the bottom of the shaft, that could cause some problems with plugging in the bottom of the shaft. We have calculations of kinds of things that show that the concrete interaction with the tuff could cause the tuff to tighten up and make it less permeable.

If you were to create a zone near the bottom of the shaft, you know, you isolate it, we don't think that these interactions are going to be a very large range. But if you crate a zone of isolation and provide for some drainage structure near the bottom of the shaft there is certainly no reason why you couldn't leave a lot of that concrete there. It would take a lot of experimental confirmation at this point. But, the point is, is that if you can get that drainage structure secure so that you know that you have got to require drainage at the bottom of the shaft, then the concrete should pose no additional problems.

DR. CANTLON: But if it is more or less left in place incrementally as the filling goes on, you don't have it in any one place.

DR. HINKEBEIN: Right. So what you would have to do there is assure yourself that the backfill properties of a mixed concrete tuff would have appropriate hydraulic conductivity to allow your drainage.

DR. DEERE: I guess a concern would be that the calcite, calcium solutions coming out of the concrete with water moving through would do self-grouting.

DR. HINKEBEIN: That is exactly what happens, as a matter of fact. Your concrete solutions are high in calcium and when they hit the tuff you start to get calcite formations and a lot of other zeolitic minerals, feldspar type minerals tend to also precipitate. So, you do have a lot of alteration and that alteration is what you need to be careful about.

DR. DEERE: It does seem to me like it is geochemistry controlled.

MR. CASE: Yes.

MR. FERNANDEZ: I just had a comment here too.

The study we had done on the performance of the exploratory shafts, particularly the geochemistry study that we had performed, is an ideal case that where we can support the design activities, recognizing that we may have problems with the traditional concrete, or there may be more problems with the traditional concrete. Why not at the onset modify that concrete since in fact our concepts are to leave the majority of it in place, here we have a unique opportunity perhaps to get an enhanced concrete liner with minimal cost that will help us from a long term performance standpoint. Just an additional point of clarification, it is our designed concept to remove all of that material, all of the liner that is at the bottom of the shaft, which really is not that much concrete. So, it is more desirable I think, looking at other issues for example, settlement, to control the rock fill that you would put in there by eliminating the concrete. So, we avoid several issues. I think the overall cost of removing the concrete is minimal in comparison to the performance objectives that you are trying to achieve.

DR. PRICE: Any other questions?

What about the role of compaction of the backfill and settling of the backfill and so forth. Any concerns about that?

MR. CASE: We have done some calculations that have looked at those issues. I would say this, we think that given that we do laboratory testing to determine compactive properties of a backfill, and we go to some lengths to apply compaction principles to compacting those materials, we can achieve a good compactive effort. We can reduce the potential for settlement that would occur. We have done some calculations in terms of the amount of settlement.

We may have some settlement that would occur and I think, you know at the point of which the seal is supported, we would want to probably key that into the surrounding rock, so that we have load transfer that is occurring from the backfill above into a bearing compression in the rock. I think the fractured tuff has sufficient bearing capacity for us to do that. So if there was some potential for settlement to occur below the plug, we would still have a stable configuration.

Does that answer your question?

DR. PRICE: Yes.

MR. CASE: Okay.

DR. PRICE: Any other questions or comments from the table? Audience?

If not, we will go to the next player at the next stage, who shouldn't upstage or he'll have a "Case" on his hands.

MR. FERNANDEZ: Good morning. The subject of my presentation is some ongoing work that we are doing. We are actually getting very close to completing this work as the definition or the preliminary definition of the field test plans for the repository sealing program.

The reason why we did this work was two-fold. One, to provide focus for the sealing program and those additional areas that we need to perform. For example, supporting laboratory analysis and also numerical analysis that we feel are necessary in order to better understand the performance of sealing components.

The second reason for why we did this work was to support the current design activities. It was at the direction of Ted Petrie of the Department of Energy. He had requested us to provide information with respect to requirements for the overall facility; requirements that would be incorporated by all the principal investigators associated with the field testing programs and then coordinated by Los Alamos National Laboratories and provided to the designers as we get into the next design phase.

The purpose and the approach for the field testing work is described on this slide. The purpose is to reduce the uncertainties associates with the performance and emplacement of sealing components. You may recall my first presentation I had a great big rectangular box that said, the focus of the sealing program is to reduce the uncertainties associated with sealing. Those uncertainties fell into two categories; emplacement uncertainties, uncertainties that have been raised in John's presentation and Archie's presentation; also, the performance of the sealing components. That is the focus of the sealing program and the field testing program to reduce those uncertainties.

By reducing those uncertainties, we also resolve Issue 1.12, through the flow diagram that John White had presented yesterday. In one of the boxes, about half-way down on that particular issue resolution, process or logic diagram which is included in the SCP, and our approach to resolve the Issue 1.12 is field testing and laboratory testing.

The steps that were defined in the SCP, there were four steps. We had opted not to present a lot of detail on field testing, requirements or field test plans in the SCP, because, we felt it was slightly premature to do that.

We did however, define four steps in the SCP that we felt were logical steps to developing a field testing program in sealing. The first was to evaluate what information is needed; what site information is needed; and, what seal performance information is needed. In the SCP we had very detailed tables that had presented the hydrologic site properties that we needed; the miscellaneous properties such as the in situ stress state; the unconfined compressive stress of the Tiva Canyon, Topopah Spring, Paintbrush Tuff Member; places where seals would be located; thermal conductivity requirements in order for us to properly design cementitious seals; as well as seal performance issues.

The second step was to evaluate the adequacy of that information. We had also presented the performance allocation process. One part of the performance allocation process was to look at the information that we need and is that information available? What is the needed confidence in that information and do we have that confidence today? That is what the second step involved. The third step was to define what tests we currently would like to do in the sealing program; a preliminary definition of field test. The fourth step was to provide the detailed definition of the test.

Right now we've basically completed the first two steps and those are described in the SCP. We are at the process of defining these tests, a preliminary definition of the field test, and that is the work you will hear today.

As we develop further into the sealing program, we will provide detailed definition of the test prior to the implementation of those tests in the field.

The next slide shows the regulatory basis for testing. You may recall in John's presentation and several of my presentations, we referred back to the regulations, the 10 CFR60 regulations or the 40 CFR191 regulations. In 10 CFR60, the regulations really can be broken down to three areas; design testing, performance criteria and general criteria. The one that really directs this work I feel is 10 CFR60.142. And in Section 142, there are four sub-parts. The first is during the early or developmental stages of construction, a program of in situ testing of borehole and shaft seals, backfill. And it went on further to say that the thermal interaction effects of the backfill, the rock, the waste package and the ground-water effect should also be evaluated.

The second part said to test as early as is practicable. The third section specifically mentioned the backfill test, effectiveness of placement and compaction procedures should be evaluated. The final section said that test sections should be performed to evaluate the effectiveness of the borehole and shaft seals before full-scale emplacement of seals.

Now I just would like to go back to the first part here. During the early developmental stages of construction, I think the NRC by their comments back to us are inferring that this is in fact the initiation of construction of the underground facilities; the ramps for example, the exploratory studies facility. If you go back to the one slide that Jon White had presented yesterday, it is our intention to initiate field testing prior to license application and to continue field testing after that point in time in order to provide sufficient validation of the performance of sealing components.

In the testing program we basically have two categories of testing. The first is testing of the geologic features. You've heard by now through all of our discussions yesterday and today, primarily yesterday, that we are very much trying to tie our sealing performance to the site itself and to the design. There were three elements that I pointed out in my first presentation: site consideration, design consideration and the seal performance considerations.

It is very important then to understand what the nature is of the different geologic features that we are penetrating through. It is all tied to the total system performance assessment. For example, in the testing program, we have identified an understanding of the geologic and hydrologic properties of the Ghost Dance fault and other major geologic features. We've also identified other faults that may occur beneath alluvium. What sort of interrelationship is there between the surface to the subsurface? Perhaps shallow faults that would penetrate the upper portion of the ramp for example, but not necessarily go down into the underground facility.

Conversely, are there some other fractures or faults associated, penetrating through the Topopah Spring. Is there some sort of categorization scheme that we can use where we can categorize the fault or the geologic features into different units, and then apply that understanding to the overall performance assessment activities.

The second category is the evaluation of specific sealing concepts and sealing components. One part of our strategy is not just the sealing components, it is looking at the sealing concept; the concept of drainage. I think this concept has to be demonstrated and validated in the field, or at least better understood in the field, as well as the sealing components themselves.

Now, it is not necessarily the responsibility of the sealing program to do this type of testing where it works in conjunction with a specific test. We will evaluate the performance of the geologic and hydrologic performance of these unique features. But, for the most part, a lot of this testing has been described by the U.S. Geological Survey, the Bureau of Reclamation and other people in the project who will be performing that particular function of trying to understand and characterize these geologic features.

My discussion today, really will focus on the Category B testing; the evaluation of the concepts and the sealing components. I'll talk primarily about the field testing aspects, but I didn't want to ignore the fact that we will be using numerical analysis and laboratory testing in order to support the field testing activity. I think prior to fielding a very large expensive test, it is very important to understand what type of response we expect to get or think we might get out of these field tests to do a more thorough up front evaluation through the numerical analysis and laboratory testing.

I would like to briefly go through one slide apiece on the numerical analysis as well as the laboratory testing just to give you an idea of where we are with that right now. This by no means represents the comprehensive list of analysis that I believe will be necessary to do the field test, but they are the analyses that we have performed to this point in time, in order to give us a better understanding for some of the tests that we are proposing in the field testing program.

The first is a steady-state flow of water through plugs. We made some assumptions as to Darcy's Law, the parallel flow through the interface, modified permeability, and seal zones and we evaluated a number of conditions. I'll present some of the calculations just to give you a conceptual idea of what we have done there.

The second is in the area of hydration calculations to determine interface stress. John has presented some of that information yesterday. What I would like to do is again show a typical calculation that we have done to help us a little bit better to define the field test.

The third is the water flow through an inclined embankment. And I presented some of those results yesterday.

The laboratory testing to support the seal test are defined basically in two categories. Tom Hinkebein, yesterday, talked about the screening of the materials for the sealing program. Basically we are focusing in on two types or two categories of materials; earthen materials and cementitious materials.

There is some fundamental relationships that we need to understand in order to progress in our testing program. The relationship between density and water content for the earthen materials; particle gradation; hydraulic conductivity related to the density as well as to the particle gradation; selling capacity of clays as related to density just to give some examples.

For cementitious materials, they fall basically into two categories of characterization, performance and emplacement type of considerations. For example, workability would be considered an emplacement type of property that we would like to understand to make sure we can get this material underground over long distances if that seems appropriate, or over shorter distances. The set time and working time for the cementitious materials; the slump and viscosity, viscosity being also a performance issue of how well we can inject the grout into the different fractured rock media.

DR. CANTLON: Joe do you mean that, in the earthen materials, which of those categories of information would be useful to estimate slumping or settlement, because that is clearly going to be one of the key problems?

MR. FERNANDEZ: Well, you know, this doesn't necessarily represent a complete listing.

DR. CANTLON: I understand.

MR. CASE: Well, you know, typically your basic compaction type curves where we are looking at void ratio versus load for various material gradations and so forth would be the types of information and indeed I think on some of the crushed tuff experiments that have been done, we have data and information like that. So, actually it is something that should be included on that list.

DR. CANTLON: Compaction or settlement or something.

MR. FERNANDEZ: And as John pointed out, we have done some work in that already looking at crushed rock fill to find out what the consolidation properties would be. And as I also pointed out yesterday, it is an area that we need to continue a little bit more because we don't know what those relationships are for the material that we have in hand or will have in had.

DR. PRICE: Do you have a history or data on long term settlement over like 100 years?

MR. FERNANDEZ: We have done no laboratory testing. I don't mean to be facetious in that regard.

DR. PRICE: He is looking for long term funding.

MR. CASE: Most of the work I think we have is simple void ratio versus load type of information and then given that we have a column of backfill, we can calculate what kinds of compression would occur. We can also look at it from the standpoint of minimum void ratio and maximum void ratio and changes in void ratio that potentially could occur. In other words, you can go in the laboratory and determine minimum and maximum void ratios for most materials. So I think we have some information and calculations that we have looked at that we have generated. We have had some information on the amount of settlement that may occur. It's of the order of perhaps one to two percent of the height of the shaft. So, it could be fairly substantial.

DR. CANTLON: Couldn't you get some of these old mine dumps, many of which are now approaching 100 years old, and look at comparative densities on the tuff that is out there on the dumps to get some estimate?

MR. FERNANDEZ: Well, part of the available technologies work that we were doing was to try to get a better handle on case histories where we would be able to understand what some of the properties would be. It is hard to find that operation. That is not to say it doesn't exist, but in our resource pool, we have not found very many examples to get that performance information, to find out what the consolidation was for certain types of backfill.

There was a report that was put out, I think it was National Coal Board back in 1982, that talked about if you just dumped stuff down a shaft, you would expect to get a 70 percent settlement over the column of the shaft. That was considered in the original work that we had done. The one or two percent that John is talking about is the performance criteria that we had established in the original repository concepts. The work that was done at Waterways

Experiment Station to look at the consolidation behavior, we actually came up with our curves of consolidation versus time. So, in that since, we tried to compress the materials such that we would be able to reduce the void ratio or to reduce the porosity of the material.

DR. DEERE: I think there is another point, too. The friction that is exerted between the material and the walls is extremely important and how much of it hangs up on the side and doesn't get carried down. You can fill up to a certain depth or to a certain height, let's say, and keep on filling up. And if you put a pressure plate down at the bottom you don't even measure anything; no difference at all because it goes out by shear friction, which is shear generated. In filling a lot of our bins for instance, with soybeans or corn or oats, makes all the difference in the world, because, soybeans always give us greater pressures at the bottom. They also give us greater outward push and a lot of the failures that we have had in steel tanks have been where we have soybeans because of their low friction with respect to the other materials. I know we are not going to use soybeans.

MR. CASE: One of the things I would say here, we have some calculations we are currently working on, you know, this report on exploratory borehole strategies, and we have actually used the silo type formulas to take into account the friction that occurs on the sides to calculate potential loads that would occur on seals. We haven't presented any of that information here in these presentations. However, that information will be made available in the current report that we are writing. We are looking at that particular issue. We are also looking at issues that if there was water that built up within the backfill in terms of loading the plug, we could take into account the effective stress. In other words, not only the weight but we would do an effective stress analysis of what the stresses would be potentially in the plug and compare that with the potential strength of the material. In order to address your question here we do have those calculations and unfortunately we didn't bring them with us.

DR. DEERE: Another comment I would like to make, on your cementitious materials, I think your density heat of hydration, etc., are extremely important, not the density so much, but getting a cement that does not have a high heat of hydration, because that is what drives the cracking during cooling. In having built a lot of these plugs, I know we can get into trouble very easily. We have them crack, absolutely horizontal right down through the center of tunnel plug. It went in too hot and when it cooled down to ambient, there was a delta-T, a temperature change greater than about 15 degrees centigrade, which will crack it every time.

Ten is about the theoretical limit if you take the cracking strain and the coefficient of thermal expansion. But we have been able to get by at ten without any trouble and all the way up to 15. But when that delta-T becomes greater than that, it almost invariably will crack, and in one place.

You can get around that with your low heat of hydration cement which I know you are considering, possibly with fly ash or the silica which again will tend to lower the heat of hydration, but not the strength. You can still get the same strength it just builds up over a slower period of time. But, I think I am more worried about the really correct design of the cementitious materials than probably the earthen materials that go in between. They are just sort of a throw-away thing, don't you think? It is really the plugs that you are going to have at certain positions.

MR. CASE: Yes. I think that we would concentrate on the cementitious materials in terms of their structural strength. It is important to recognize that in the work that has been done, there is a relationship between structure and performance, hydrologic performance of sealing components. We are able to tighten up that interface zone and have a stable plug. It will also be one that will be low in terms of hydraulic conductivity.

DR. DEERE: Thank you.

MR. FERNANDEZ: Again the two categories that I mentioned before and the performance. Our approach in developing these field testing plans is to look at reducing the uncertainties in two areas; the performance uncertainties and the emplacement uncertainties.

Under the performance uncertainties we have a number of considerations that we have looked at. I mentioned earlier that in the SCP we had defined four tables that had listed the types of information we needed in order to assess the performance of the sealing components. They fell basically in these areas; hydrologic, structural, thermal, MPZ propagation and fines migration. As far as emplacement uncertainties: liner removal, grout placement, workability and casing removal.

After going through all of those tables, we basically had about 33 questions or uncertainties that we had defined. Having defined or summarized those uncertainties into those 33 questions, we came up with three different categories to resolve each one of these uncertainties, each one of these questions. The proposed action that would be required. The approach that should be used and the test that we feel would be necessary in order to reduce that uncertainty and the facility required.

We then took those three columns with that information from those 33 questions and then compiled that to say that these are the lists of tests that we feel would be necessary in order to reduce those uncertainties.

They fall into two categories; the seal component tests and the seal system tests. These in general, the seal component tests would be a simpler type test; the seal system tests would be the more complex type of tests that we had proposed.

What I have done is I have highlighted some of these and there should be a highlight for the backfill test as well, as far as what I feel would be the minimum test that should be proposed for the sealing program. I say this reflecting now back again to the regulations that I presented earlier, the Section 142 regulations.

These tests may not necessarily all be necessary after we get underground. I think the first issue is to find out what we are sealing. Then once we know what we are sealing we would be able to propose all these tests or some subset of these tests. The approach right now is to present all of the tests and then decide ultimately what we do need. But this is what we feel to be a comprehensive listing of tests in order to answer all the uncertainties.

Again the strategy that we are using here is kind of progressive component evaluation. We are taking the smaller tests, going to the intermediate tests and then going to the larger scale field test. First doing the simple tests to understand where some of the simple issues are and then going to more complex ones to try to incorporate these simple ideas. And that is what this really reflects also.

We have the small scale in situ tests going to a slightly more advanced tests, would be the intermediate borehole test, fracture grouting test for the Tiva Canyon and Topopah Spring Members. The purpose of the surface backfill test is to give us and allow us to better characterize the rock fill properties under more realistic conditions. The emphasis hopefully as you have seen by now is to try to incorporate the emplacement concerns or just the ability of emplacing these materials to find out how the emplacement activities would affect the quality of our materials.

The purpose of the surface backfill test is to run multiple tests in a large scale facility that would be on the order of 12 feet in diameter in which we would be able to place rockfill using the actual equipment that we would be using underground, but to have it be a relatively low cost activity. We would be able to vary our rock fill, to run flow tests, to run settlement tests, to look at the porewater pressure that might build up at the bottom of this backfilled culvert, if you will, at the surface, in order to understand what type of fines migration might we get in a rock fill material. Perhaps, also to place two different types of material and then look at what would happen if we inclined the structure just a little bit to simulate water flow in an underground facility? How well can we match our numerical analyses that were presented yesterday with this facility? Can we really validate this understanding or our numerical analyses through the use of this type of facility. It is meant to be a comparatively low-cost surface facility to answer many of the questions that we have currently defined in the SCP and also to respond to 10 CRF60.142.

The heated grout and block test, one of the issues or uncertainties that we were trying to address is what happens if you emplace a grout and you elevate the temperature? How does that grout respond to that temperature from a performance standpoint? Do you end up having a large fracture, or do you have a small fracture, or do you have any fracture at all? What are the limitations that we have in that regard? What is the appropriate grout that we should be using?

The heated grout and block test is kind of spinoff of the work that Sandia had done on the heated block test in the rock mechanics facility that Roger Zimmerman had done some time ago. It is just meant to capitalize on the knowledge that was gained in that facility.

The more detailed tests include the filter/single embankment tests. The objective of this particular test is really meant to better understand what the effects of this filter or single embankment or just the two materials butted up against one another would have on lateral migration of flow in a facility. Also, it is meant to take a look at the migration of water in the rock mass underneath this particular type of sealing component. So, it is certainly a more complex test.

The backfill tests and the bulkhead tests here are meant to be tests within the underground facility, looking at the interaction between the seal component and the rock surrounding that seal component. So it is meant to be an integrated test as opposed to a decoupled test as in the surface backfill test.

The large-scale shaft seal tests and the remote borehole sealing tests are actually meant to be full-scale tests to look at the response of these materials in actual geologic environment that we would intend to place these seal components in.

DR. PRICE: Excuse me. Where would be these tests be conducted, such as the surface backfill?

MR. FERNANDEZ: Oh, surface backfill tests?

DR. PRICE: Yes.

MR. FERNANDEZ: Somewhere at the surface close to the source of materials.

DR. PRICE: Are you talking about at the site?

MR. FERNANDEZ: It will be done at the site.

One of the reasons for having the tests is to have the availability of the materials as it is being excavated. We can stockpile it in an area and run the tests rather than having to haul it back down into the underground facility. Once we get that understanding at the surface, we would be able to incorporate that understanding into an underground test.

I mentioned some of the specific objectives for those tests, but there are also a number of common objectives for the tests. To demonstrate the placement of sealing components using current technologies. It is very obvious, but yet it has to be done.

To determine the effectiveness of the testing instrumentation, the range, the sensitivity and accuracy. These tests really have not been done before. There is no need to really conduct tests of this sophistication in a typical mining operation or a civil operation for the most part, although some measurements have been done certainly in civil operations to better understand some of the rock structure interactions. But, these sealing tests are typically not done, so we don't know how the instruments will respond to certain types of loadings that we would actually impose on these instruments.

To develop quality control procedures for emplacement. The field testing is not an end in itself. The field testing is to validate certain performances, but also to come up with quality control procedures that could be used by a fielding group to emplace these. What are some of the problems that we encountered in a field testing activity? We have to understand those problems and we have to come up with simple procedures in order to get high quality materials. Procedures that can be used in a very easy sense for somebody emplacing these materials; a very important coupling that we need to have between our testing and the emplacement of these materials.

And finally, to establish the reliability of the seal system under anticipated conditions and unanticipated conditions, a performance issue that will be associated with all of the field tests.

The potential testing areas are shown here. The figure on the left-hand side represents the proposed design, the option 30 that we are looking at down to the Topopah Spring Member. Here is the northern ramp and here is the souther ramp. We have the ramp interconnecting the two and we have the cross-ramp here. It doesn't have all the details that you've probably seen, but it is not really necessary to show those details.

This little loop on top and little loop on bottom represents the ramp going down to the Calico Hills member and here I have shown on the right side of this view graph, that ramp going down into the Calico Hills member and this is the primary drift at that level.

Now we have identified several areas in which to do testing. The approach is to do as much testing as we think is appropriate, outside of the repository boundary so as not to get into other issues associated with how will our test impact perhaps the conduct of other tests or how will our test impact the overall performance of the repository? It is a concern that was expressed in the SCP, presented in the SCP through calculations, etc. And our intention is to do as much again as we can outside of the repository boundary.

The assumptions that we used here is based on a 10 percent grade in the north ramp and a 1.6 percent grade in the south ramp. There are two large testing areas that we have proposed in the north ramp. One, to take a look at fractured rock mass in the Tiva Canyon which would be very similar to the fractured rock mass that would be encountered in the Topopah Spring member, the densely welded devitrified portion of the Tiva Canyon. The second would be performed in a non-welded zone going into the upper portion of the

Topopah Spring. Two major test facilities that potentially we are proposing.

The area indicated here, Area 5 and 6 really relate to two different types of tests that would be done at the main test level itself inside the perimeter drift. And the reason why we felt it was necessary to at least do one test looking at a filter single embankment concept or drainage concept is because I am not sure if that characterization or that similarity could be achieved anywhere else. However, we are proposing another area in this ramp here that if we go down there and we find out that the Topopah Spring member is the same here and here (indicating), then our logical place to do that validate testing would be to do it in this portion (indicating) of the ramp going down to the Calico Hills so we can avoid testing within the perimeter boundaries. So we have an optional area to do this testing to look at drainage in a water in a fractured rock mass.

In the Calico Hills member, we have really two different testing areas. This Area 3 which is to evaluate the effectiveness of the material itself and the emplacement aspects of just getting it down in the ground, what are the actual properties of the materials? It may be required to have two different testing areas. We really don't know until we are underground to find out what unusual problems, if there are any that we may need to seal as we penetrate from the Topopah Spring into the TSW2 portion of the Topopah Spring, to the TSW3 the vitrophere, down to the Calico Hills vitric-zeolitic. So, we need to first understand what is the material that we are penetrating and does it present from a performance assessment standpoint any unusual challenges that we need to address in the sealing program. That is why we have identified potential test areas here to do some sort of a bulkhead test if it is necessary.

We have proposed this test facility in Areas 1 and 2 that you saw in the previous diagram. Again, this is the ramp coming down at a 10 percent grade. It is actually beneficial to have a high ramp or that particular grade, because, it allows us to shorten up our facility and to reduce the cost. This ramp here represents a 20 percent grade going down to a lower structure, a lower drift area and this represents the upper drift area with a drift coming off of that of 10 percent. What we were trying to do was to get a minimum distance between the two drifting of approximately 50 feet. There were some routine mining considerations that we had as far as structural support when you get over 50 feet separation. So, we want to keep it basically at 50 feet, but also to provide access from this upper facility to the lower facility.

What we have here is a number of the tests that I just mentioned. The reason for having these tests done in one area is really to do a detailed characterization of the geology and hydrology in the area and try to minimize the disturbance in the area in so doing that characterization. Once we understand what that rock mass is like, we have a better idea of how to couple our seals, seal performance to that particular rock mass.

We have two shafts, large-scale shafts, 12 foot in diameter that are presented here. We have tried to have a second shaft or a second facility if you will, or second test, in all instances because this may be the first time that we will field these experiments. So, we need redundancy in our field tests. Ideally it would be nice to have a prototype facility to look at many of the issues to or to look at many of the objectives, the common objectives of field testing and look at the problems that we may experience with field instrumentation, the same approach that was used by Roger Zimmerman to do his prototype testing in G-Tunnel. That would be the ideal case, you know, to have a facility outside of the area to answer some of these common problems that we might expect or just questions that we have.

Nonetheless, if we stay at one facility, we need to have at least several different tests that would address potentially the same issue. These are the intermediate borehole tests that will provide access form the upper facility and the lower facility. We have one back here and one over here. We have a series of grouting experiments that would be done in these three corners of the facility. We also have some of the small scale tests that are done in the lower portion of this facility.

This is a rotation of that view. We had proposed a number of different size of tests, different diameter of tests, different length tests, in order to better understand what the effect would be of a cementitious seal as it hydrates in different sizes and different geometries. And that is what the intention of these boreholes would be at the bottom there.

I wanted to walk through just two of the tests very quickly. You have a more complete listing of our ideas as far as the tests, the objectives of the tests and then kind of a schematic of the test in your packet, but I don't think it is necessary to go through those in the interest of time.

Here is a small-scale in situ test. The objective is to characterize the thermal and the stress response of the hydration of cement to basically understand what is occurring at this interface? John had presented a number of calculations yesterday, varying some of these parameters in the analysis and basically trying to achieve the compressive stress at the interface here. Well the intention of this test is to basically understand what occurs with that interface stress as the cement hydrates. It is not meant to be a performance test in the true sense of the word. It is meant to get a basic understanding of what occurs with a cementitious seal. A cementitious seal that we would propose as a very usable material for someplace in the underground facility or in fact for the exploratory boreholes.

This just shows the different levels of instrumentation, thermocouple strain gauges, concrete stress meters and rock displacement gauges which is shown over in this location to get a sense of what the in situ stress state would be. These are done for different diameters and for different lengths again to look at the effects of geometry changes on these particular properties.

The tests that we are proposing is actually very similar to the work that has been done down in southeastern New Mexico in the WIPP facility. Here is John Stormant who used to be involved with this work here and one of his small-scale in situ tests. Here we have a concrete plug very similar to what we would have, it is just is in a different orientation; it is in a horizontal orientation rather than a vertical orientation. So, we could do the same thing if we felt it was necessary. Here is the instrumentation port coming out here with the instrumentation at different locations around the perimeter of the seal. So, what we are proposing here is not new. And it certainly has been done before.

A couple of the examples as far as the analysis that were done, again these are meant to be conceptual analysis for the purpose of our discussion here, to say that we have looked at the variation in the seal size, we have done this for boreholes as well as shafts, we really will focus in this column here. We have made certain assumptions on what the Young's Modulus would be, Poisson's Ratio, and other properties of the cementitious seal in order to come up with two different curves; one which addresses the interface stress which is what we are trying to characterize out in the field.

What this diagram shows is the relationship between the interface stress on the vertical axis and the time as the cementitious seal hydrates as a function of the different size of seals. What we are trying to do, well, what we will ultimately do in the field is to try to mimic this type of response to find out if our modeling efforts are really in fact correct.

The second figure represents a relationship between the temperature and again as a function of time for different seal plugs. We would suspect by these analysis, that in fact we are going to get a different response. And that is the reason for having multiple types of small-scale experiments in order to find out what that response truly is.

The second test, you know just progressing from that small-scale test and the understanding of doing that test is the intermediate borehole seal test. The purpose of this test is to characterize the hydrologic performance of the borehole seals. This would be done--our interest here is not now to understand if in fact we had a cementitious seal which would just conceptually say, we have some sort of a material here, that might be a cementitious seal or it could be a bentonitic seal that would be injected into the rock mass, but also to take a look at some other seal, whether that be a bentonitic seal or whether that be a cementitious seal and look at the actual response. When it comes down to the regulations, NRC will want to know what is the overall response to that material. I think this test will do that. We are not interested in understanding in this particular test, what some of the minute properties are or the stress state would be necessarily at this location. Hopefully by that time, we will have had an understanding. The purpose of this test is to look at the performance, the actual performance in the field of that particular test and the benefit of having the upper and lower drift is to perhaps monitor the whole system a little bit better as far as its overall performance.

DR. ALLEN: Joe, can I ask sort of a philosophic question here?

Our problem, it seems to me at the moment or the near future is to license the site. That is, to demonstrate that with current technology, we can adequately seal the facility. Yet, since most of the sealing is actually going to be done maybe a 100 years down the line, it is sort of ridiculous to think that the current technology is really going to be what is used in the eventual sealing process. Therefore, isn't our challenge at the moment to spend as little money as we can to license the site and adequately demonstrate that with current technology we could do it, recognizing that that indeed is not going to be the technology we are probably going to use 100 years from now.

MR. FERNANDEZ: I think you might have some debate on that point from the NRC. I guess it is looking at the regulations and giving the analysis that we presented yesterday. I think in the area of borehole sealing, I think there may be some seals that may be required to be in place well before the 100 year time frame that you are talking about, so these seals, I think would be actually necessary prior to license application.

Now, it can be argued by the NRC or other people as to whether or not these large-scale bulkhead tests will be necessary. I don't think we really understand what the response for example of the Calico Hills member would be right now. I don't think there has been enough numerical mechanical analyses done for the Calico Hills. That may require sealing much earlier than we think.

I guess right now, the intention of these field tests are to say these are the broad range of field testing that may be required, some of which would be done prior to license application and some which clearly would be done after license application.

DR. ALLEN: Well, okay, but our problem is still to spend the money most effectively.

MR. FERNANDEZ: I agree.

DR. ALLEN: And not over plan now for things that we are not going to use 100 years from now and in the meantime demonstrating to the NRC that indeed we could do it if necessary with current technology.

MR. FERNANDEZ: Certainly. I'll go back to the objective or the tasks that we were confronted with; we were given the tasks of actually coming up with a potential list of requirements for this underground facility that we would be able to help the designers with a little bit as they were planning the facility. That was one of the purposes for why we did this work. The other purpose was just to give us a better idea of the focus that we may need in the sealing program.

Don't get me wrong, I am not proposing, I'll reemphasize this; I am not proposing that these are all the tests that are required. I still think we need to get to the underground facility to find out what the characteristics of the rock are, to do the testing, to have the Geologic Survey or other groups to do the testing in order to find out what we have to seal. I think we need to do that. We stated that quite clearly in the SCP. We are not going to go ahead with these tests until we better understand what the geology is underground and the hydrology.

This is just a second set of tests to look at the performance aspects of sealing. Again, we are doing a parametric study here; we are varying the properties of the interface permeability, the change in pressure, plug length, as a function of the conductivity or the permeability of the seal itself. We did it both for boreholes and shafts. The intention for doing this type of calculation is to find out if we can actually field the experiment within a reasonable period of time and to actually measure any water flow if in fact we have an incredibly tight seal and we don't see any water flow after ten years, maybe the numerical analyses might be able to help us answer that question before we field the experiment.

This is just a diagram that looking at the different parameters that we evaluated, it would give us an insight as to the function of the permeability of the plug itself and also as a function of the assumptions of the interface zone or the MPZ and what types of flow rates we might expect in doing a particular test like this. Again, it is only meant to be conceptual at this point to give us a better understanding for the duration of the test, for example.

Finally, to carry the thought through is that the final test that would be performed would be remote borehole sealing test. And we would emplace a borehole out in the field in sequential lifts and evaluate the performance of that borehole. This is actually, we had proposed sequentially doing this test, or pouring different lifts in a plug. It was also recommended actually by work that was sponsored by the Nuclear Regulatory Commission that this was actually a preferred way of emplacing a seal underground. There has been some precedence for doing this work. The NRC did sponsor some work in sealing remote boreholes or boreholes that were actually shallow, but remote in the sense that they were from the surface down to a plug and they evaluated the performance of bentonite as well as cementitious plugs in granite.

There has also been some work associated with the Waste Isolation Pilot Plant, the Bell Canyon test that was done some years ago on a remote borehole seal. So we do have some precedence in this particular area as well.

This really concludes my presentation for the field testing work. There are a number of other field tests that for planning purposes we have defined in your packet there. I don't think it is necessary really to go through those, but if there are any questions right now, I will answer those questions.

DR. PRICE: Board questions?

DR. CANTLON: It would seem to me useful to take some the drillholes well away from the repository area and do some preliminary actual sealing operations and instrument them to find out things like slumping behavior and so on. Is any of that in the plan?

MR. FERNANDEZ: Yes, it is. In fact, we have proposed two boreholes well outside of the boundary, but part of Yucca Mountain Project. The reason for selecting well outside the boundary was based on some of the analysis that we had done. We really--actually we really went much further than 600 meters away as was defined here. Yes, that in my way of thinking would be the ideal thing to do.

DR. CANTLON: What sorts of tests now are proposed for that? Have you flushed that out yet?

MR. FERNANDEZ: Only as far as you have seen here and some other details. It is only a matter of some three to five page description.

DR. CANTLON: It is a part of what we have been looking at here?

MR. FERNANDEZ: It is a part of what you are looking at there. We are intending to complete this work in about a month.

DR. DEERE: I note that you have several pages here on the fracture grouting and the heated block grout test. I might just make a comment or ask a question about the fracture grouting test.

I think it would be very helpful to look at the new concepts of grout penetration based on the cohesion of the grout. Almost all the work in the literature is in terms of viscosity and this doesn't tell whether it is groutable or not, it is just how much time it takes to do it.

But, the cohesion property or the yield point property of the grout itself is very, very important in telling what your penetration will be at a given pressure, at a given aperture opening. I don't think this has been used very much. It is starting to be used on a few dam projects across the world, actually and it is one that you should really look at. The advantage is, it uses a stabilized grout. That means a grout that doesn't separate into a liquid phase and a precipitate, or not a precipitate it just simply settles out, but to use a stable grout that can maintain a single phase of a liquid. For very fine fractures, if you want to penetrate them, you should go to a low cohesion grout and it is not necessarily the super fine grout, because the super fine grout has so much activity it has a lot of cohesion.

You have to use something that will reduce the cohesion. In a number of these we are using fairly thick grouts, but putting in a super plasticizer that would reduce it. So this raises a question, can this technique be used in this environment here because we will have some type of an additive that would have to be placed. But, if it is, there is now theoretical studies available which allow this to be fairly well predicted. It is a different type of mechanical behavior grout that essentially has not be used in the past, but it is now available and has proven to be extremely interesting. It is probably more important than the size of the cement particle itself. It used to be thought that it was just the size of the cement particle, but it is certainly a combination.

I would like to get that into the record and I'll see that we get some information available.

MR. FERNANDEZ: Okay. I appreciate that. Thank you.

DR. PRICE: Any other comments or questions from the Board or Staff? Audience?

Motionless faces behind me. Thank you very much and I guess Jon White now will provide us with some concluding remarks.

DR. DEERE: While he is getting up there I will continue talking a little bit about the cohesion of the grout. An advantage of a grout that's cohesionless is that as it goes away from the borehole, you lose the pressure. So, you don't have to worry about jacking up the rock. You only have trouble with hydrofracting when you are grouting, when you have something that is so liquid that it doesn't lose its pressure as it goes away from the hole. And the worst thing you can use is water, of course. So, you can really move a lot of rock around if you raise the grouting pressure with a very thick grout or making a water pressure test. But, if you go into material that has cohesion, the very first centimeter that it leaves the borehole and starts going out, you have cohesion across the top interface, across the bottom interface so the pressure that gets transmitted out is decreased, so you end up with a specific diameter that you cannot push it farther without either increasing your pressure, which will then allow it to go another increment.

So what we have found is that we go with very high pressure grouts and don't have the problem of jacking. This is part that comes out of the theory and also out of the experience.

DR. WHITE: Thank you, Dr. Deere.

One of the previous speakers, John Case, brought us a quotation, and I thought of one that also might be somewhat appropriate. The book of Ecclesiastes quotes King Solomon as asking the question, "That which is a far off and exceedingly deep, who can find it out?" And as I flew up on Monday morning, I saw Yucca Mountain from the air and it certainly is far off. There is not much around there. And should a repository be built there it would be deep and we can all say that the Department of Energy intends to find it out. I was reflecting on these thoughts as Joe Fernandez was speaking. It certainly requires a solomonic degree of wisdom to do so.

We have seen the last two days an introductory history of the sealing program. We have discussed the technical requirements from the hydrologic and atmospheric points of view. We have been impressed with the strategies to seal the boreholes and the strategies to seal shafts and ramps. And Joe just finished telling us about the field test planning.

There are a few salient points that I would to mention here, but before that, I would like to address an issue that was raised from the audience concerning borehole reclamation. This was raised by Mr. Carl Johnson from the State of Nevada and he is very concerned about borehole reclamation.

I want to say that the Department of Energy has indicated many times in writing that it will follow as a matter of comity state and local laws and regulations that do not conflict with the Waste Policy Act. Also, the Waste Policy Act itself contains a requirement that should the Department leave the site and abandon it that the holes must be reclaimed.

I mention a personal thing here. I have been privileged to be the friend of many, many ranch families in the Wyoming and South Dakota areas and many of those families have had their property explored for minerals. They are very concerned about rutting; they are very concerned about piles of cuttings on the surface and so forth, and I understand those concerns.

When I was with the U.S. Geological Survey, I did a lot of drilling with regard to the federal minerals program and I interacted at great length with the environmental authorities in Montana and Wyoming. So, Mr. Johnson, I want you to understand that as the program element manager, that is an interest of considerable concern to me and I have a personal understanding of what the state's concerns really are.

As salient points, I thought that Joe Fernandez's comments about performance assessment, asking, well, how good must the system be? I thought that was very appropriate. And also appropriate is the integrated approach, which would incorporate performance and design calculations.

I was very interested in Tom Hinkebein's comments on hydration effects of cementitious seals. And I thought it was particularly important that the issue of a sealing plan for each hole was raised. It was very appropriate and it certainly indicates that we in the Department of Energy have a certain piece of work ahead of us to get those things prepared.

I was surprised at the number and variety of boreholes which are out there and the number and variety of methods of drilling and the conditions of the boreholes. I thought that was very important.

Finally, I was particularly impressed with the issue of characterizing the conditions of the boreholes and the idea of logging the boreholes from the point of view of sealing them and the point of view of placing the boreholes in various categories. It seems to me that there is probably application of that technology and that idea to the waste disposal efforts of other nations. There is a possible application to other geotechnical efforts.

We see here on example of a broad application of research that comes out of a project like this. Of course, that is a great benefit to the public.

Thank you for your attention. If there are other questions about programmatic aspects, I would be pleased to receive them.

DR. PRICE: Any final questions before break by the Board? From the Staff?

The audience will have your chance during discussion, if you quoted from Ecclesiastes, I'll return the quote. "The making of much books is a weariness of flesh"; so obviously it is time for our break.

DR. WHITE: Yes, sir, I heartily agree.

(Whereupon, a break was had off the record.)

DR. DEERE: Well, we are preparing to enter into discussion amongst the various presenters and those of you who are in the audience. I particularly think it would be of value if we would ask the NRC and if they could make some comments on the impressions that they have or any comments that they would care to make on any part of the presentation or any part of the problem. I believe we have three representatives from NRC. Would somebody like to make some comments?

MR. PHILIP: My name is Jake Philip, I am a geotechnical engineer from the Office of Research at NRC. I am program manger for sealing research program that we have, which was being conducted at the University of Arizona by Professor Jack Damon. Jack Damon is now head of the Mining Engineering Department at University of Nevada, Reno. A lot of the things that we heard about like things like interface strength, whether the plug could just actually dislodge from the hole and things like that, we have looked in our program. We have looked at cement hydration and how it affects--, because expansive stresses might cause some crack of the boreholes or the shafts and things like that. We have looked at the effect of dynamic loads on plugs. We have also had a field study where we looked at in situ performance of seals. We also have done permeameter tests where we looked at, these are lab tests permeameter tests, where we could simulate the in situ conditions of stress on the seal.

We have a lot of NUREG documents with us which gives us results of some of this work that we have done. I think that we could always make available those documents to you whenever you need it.

DR. DEERE: Thank you very much. Are there any questions of Mr. Philip?

Any other comments from NRC?

The USGS have a few people here. I wonder if anyone from USGS would like to make any comments of things that you agreed with or didn't agree with?

Would the State of Nevada like to comment now or come in as various topics come up? Carl.

MR. JOHNSON: Carl Johnson, State of Nevada. I have asked my questions and made my comments throughout the last day and a half. I don't have too much to add to that other than an observation and it is more of a topic that the Board might want to consider for the future. We have heard a lot of discussion over the last day and a half relative to sealing, but sealing with a outmoded now repository concept and that is two vertical shafts. We are now to the point of ramps and two levels of expiration. I think the Board might want to consider maybe six months or a year from now revisiting this topic and asking the Department to address these same topics relative to the new proposed exploratory facility.

DR. DEERE: Yes. Thank you very much, Carl. Are there any comments from DOE or about that?

MR. FERNANDEZ: I guess I would like to make a comment. A lot of the calculations that we have done to date really would support the new design as we currently foresee kind of a skeleton of that design developing right now.

It has always been our intention in the sealing program to try to make the calculations, performance calculations and design calculations broad enough in scope so that we can use them for modifications and design. In fact this isn't the first time the design has changed. You know there was a first design, then there was a conceptual design, which was actually maybe one in the same. It has been modified several times is my point. We have a sensitivity to that change and we have tried to maintain that flexibility in the analysis that we have done.

I do however concur that and I think I made this point in my presentation that we will have to go back and reevaluate the sealing concepts to make sure that there aren't some small perturbations. I did make the point that there were things to consider: site, design of the underground facility, and seal performance. And certainly in the area of repository design, you know, there may be locations of sealing components. That certainly will change. Perhaps a number of sealing components that may change. Maybe some aspects of the actual configuration that may change. So I just wanted to make that statement.

DR. DEERE: Thank you.

Max.

MR. BLANCHARD: Thank you, Don. I think that Carl makes a good point and that is try to keep the program current from both a design concept and a testing standpoint. From that standpoint a lot of what has been discussed by

Joe and his team today and yesterday, has very much a generic benefit from the overall test program and to the overall design concepts.

As a matter of practicality from an FY'92 funding standpoint, I have to suggest that probably not an awful lot more would be done in this area throughout this fiscal year, so a time period of six months may be a little too soon to see very much change.

One of the major things that will be coming in the seal program is some sort of a master study plan which will update what is in the current Chapter 8 for the sealing program and eventually under the Change Control Board into our SCP planning basis. That has not yet happened. And it has not happened to allow Joe and his team to develop their sealing concepts and tie them the way they have just been mentioning over the last couple of days. When the SCP was prepared, the group in general thought it was too premature to try and define those in very much detail. So, they have been doing that and I am not sure that they are yet even quite ready to prepare their first master study plan, but it is under the evolutionary stage. That is probably the next big thing this fiscal year, rather than major revisits in sealing concepts as they would apply to a newly evolved repository concept.

It would go along with the new version of the

ESF. To be sure we have to be sure to continue to look at the sealing aspects that would relate to the new ESF. But, as you know, we are not starting an intensive ESF design effort this year, it is only for the portals unless there is a significant shift in FY'92 budget.

Thank you, Don.

DR. DEERE: Thank you. Maybe this would be a time to expand a little bit more the information on what organizations are doing what work at the present time and what you anticipate will happen for '93, just to give us a little more of that picture. Ted, is that something, or John, Max?

MR. PETRIE: This is Ted Petrie. I intended to answer one other question first, Don, let me at least get over that and talk about fiscal '92 and then we can spend a little time on fiscal '93.

In fiscal '92, the emphasis is on surface based testing. And frankly in the seals area there are essentially in a sustaining mode. They have approximately four man years of effort in fiscal '92.

Now their major job from my viewpoint is to assure that the activities, as far as any boreholes are concerned or ESF is concerned are consistent with and do not preclude the sealing activities. That is their primary mission for this year. Now, of course, that is not a full-time task, but if it were, that is what they would do completely. So, they have other activities which are going on in fiscal '92 and I think I will let Joe expound a little bit upon that and then maybe we can talk about fiscal '93.

Joe.

MR. FERNANDEZ: The work that we currently are intending to do this year evolves around several different areas. One, is the completion of the development of the strategy for sealing exploratory boreholes. We viewed this over the last fiscal year to be fairly important, recognizing that were a number of other principal investigators in the project who would be interested in knowing were there some restrictions on their particular operations.

One area will be completion of a report looking at the strategy to seal exploratory boreholes. The second one will be completion of a report dealing with the field test planning activities, the ones that I presented in my last presentation. That will be completed this year as well.

We were also intending to, in the same spirit of addressing a strategy for sealing exploratory boreholes developing a strategy for backfilling and sealing the underground facilities, shafts and ramps, which would look at and have a similar type of approach that we use for the strategy for sealing boreholes, significance of backfilling, looking at the how, when and where questions in backfilling. So that is something else that we are attempting to initiate this year. Depending upon the complexity of that problem, sometimes we get into evaluating these problems and they are a little bit more complex to evaluate than is really apparent at the onset. Hopefully, we will try to complete that this year; that may go into next fiscal year.

Together with these major activities, there is the documentation of some other work and the presentation of the work that we have already talk about in different forums. We are intending to present some of the results on field testing and the hydration effects in the International High Level Radioactive Waste Management Conference in April or May of 1992. Also, the preparation of a journal article looking at the strategy to seal exploratory boreholes, and also the preparation of a degradation model report that will also be authored by Tom Hinkebein.

The documentation and going to these meetings consumes a fair amount of effort. This year I think, for us, it is going to be a high documentation year or discussion year and so in that sense we will incur a lot of costs from traveling and preparing our papers.

The final area that I have a personal interest in looking at, and I think it is also a very good programmatic interest looking at the effects of seismicity on sealing components. It is a very limited effort this year, but we are trying to make at least a little bit of headway in that area.

That kind of summarizes the work that we are intending to do this coming year.

DR. CANTLON: Could I follow up? Really, I thought that Ted commented that one of your major roles would be making sure that what you have learned here is fed into the design of the ongoing drilling program. I didn't hear you touch on that at all.

MR. FERNANDEZ: I don't mean to exclude that. It will.

DR. CANTLON: What actually is the process? How is doing what? I don't mean it in specifics, but what is the nature of that feedback process?

MR. PETRIE: Maybe I could. We have the design reviews (like this meeting) and when we have the design review the seals people look at it. We are asking them to review the Title I Design Summary Report. We will ask them to look at the designs of the boreholes which are appropriate. That's the ones which are going to be at the repository site. That is where they will be involved in it. They also are involved in preparation of the requirement documents. And there are going to be some modifications to those this year, which we will have to get them to help us with.

MR. FERNANDEZ: I think if we go back also to some work that Mike Hardy had presented, you know there may be very important issues that come out of this backfilling and sealing strategy of an underground facility. For example, the placement of the backfill. If we had to come up with a strategy to say place that early as opposed to late, I think the design people would be very much interested in that particular topic. So there may be fallouts that directly come out of the work that we are doing that would help the designers. It is just a matter of what is that interface, is the nature of the question. We have worked on that before and we have worked either directly with the Department of Energy or indirectly for example with Los Alamos National Laboratories in order to provide that design input.

DR. CANTLON: Within DOE, you have two other major operations that are engaged in filling. The Nevada Test Site clearing has done a lot of sealing operation, and the hydro-thermal people also have looked at especially thermal effects in sealing. What goes on internally within DOE to make that flow of information as adequate as it should be?

MR. PETRIE: I am not sure within the Department. The Sandia organization works on some of the work at the test site and feel reasonably confident that Joe was in touch with those folks. I don't have any specific connection with them

DR. CANTLON: Would it make good sense to look at some of these old seals that are setting over there now that are decades old and see what has happened? It would seem to me a very economical way to get a very good class of information for this climatic region, these geologies.

MR. FERNANDEZ: In fact, one of my presentations, the second presentation that I made, actually referred to an interface study report which we actually had cored into a number of the old concretes and the old grouts. We recognize this at the very beginning of the sealing program that this would be very economical to do this, and the fact it actually was because there were drilling crews out there and for very reasonable costs we were able to extract core and do some physical property testing on some of the very old core, 17 year old core and some of the younger core. So, we have done exactly what you are talking about as part of the interface study to get an initial handle on whether or not it was feasible and what types of problems they encountered out at the test site.

We still are working with people out at the test site. I still have personal connections with the Sandia office in Mercury to try to enhance our understanding through that process. One of the areas of available technology I had on my view graph, NTS at the bottom of the case histories visited, if you recall. And we actually have gone out there several times looking at some of these large cores following that initial study.

DR. DEERE: Wouldn't it also be valuable to get the information from Fennix and Sisson because I think they have been involved in the stemming and the design of a lot of these. I guess they were involved in the design of it perhaps. And REECO with the actual construction?

MR. FERNANDEZ: I have worked with a number of other people associated, not necessarily Sandia people, for example Bob Kennedy, Structural Mechanics, Inc. We have worked with him; Sandia has had him on contract to look at more of the seismic aspects of the repository design.

We have discussed things with him; we have discussed these particular issues, stemming designs, etc., at INTEL Corporation in California; people that have been historically involved out at the test site. It certainly is a wealth of information out at the test site. And also, I have talked to other people like Joe LaCombe at DNA to try to get the right contacts of people to talk to. He has helped us quite a bit, also.

MR. MCFARLAND: Every time there is an LOS constructor there is a backfilling, stemming operation. They are doing it right now. Every time an add-on is built or a test is conducted, there is a backfilling, i.e., a stemming operation. Joe LaCombe's people have been doing this for 20 years. I didn't see any reflection in your discussion on backfilling and stemming reflecting that experience and I believe it is pneumatic stowing.

MR. FERNANDEZ: No, it actually isn't.

MR. MCFARLAND: It isn't?

MR. FERNANDEZ: We asked the question of how much pneumatic stowing is actually down and is there any slinger type of technology for emplacing backfill. A lot of it is not in that area. The majority of what I was able to extract from the people at DNA and other people were large concrete pours.

MR. MCFARLAND: No. No.

MR. FERNANDEZ: I understand the stemming operations and there are variety of materials that they use. It hasn't frankly always been easy to get that information. There is some information that is classified. And in that nature itself, it is tough to get for a project like this.

MR. MCFARLAND: Have you gone to Joe LaCombe or Don Linger and specifically inquired?

MR. FERNANDEZ: Well I have sat down with Joe LaCombe three to four hours one afternoon and we chatted about what was available in all different areas.

MR. MCFARLAND: They do stem with crushed tuff. They back fill with material they excavate. I don't believe they very often use a plug; it is too expensive.

MR. FERNANDEZ: I think that is true for the vertical shots.

MR. MCFARLAND: I'm talking LOS, line of site tests.

MR. FERNANDEZ: In our discussions they didn't reflect the availability or our accessibility to that information, because our discussions were in a very general nature to look at anything that can support the sealing program.

MR. PETRIE: Times do change. Maybe it is the appropriate time to readdress that issue.

DR. CANTLON: It may be useful for the Board to suggest that that line of information flow is probably more constrictive than it needs to be.

MR. PETRIE: That may be noted.

DR. DEERE: I certainly agree that there is a wealth of information there and you obviously are getting what you can. There must be a lot also on the difficulty of keeping a hole, and getting the instrumentation packaged back out, and collapses, and leaving some of the things down the holes. We found out a great number of holes have things left down them, what do they call them, fish and junk? And I understand that the reason that they are down the holes is that they weren't easy to get out and that is why they are there.

So again, there may be a specific group that you could contact and get brought up to date on all of their problems with trying to seal the holes and getting out instrumentation packages that weren't designed so they could be picked up and brought out.

So again, I think the effort to contact them is probably paying off and would pay off more.

MR. FERNANDEZ: Just as a final point there, I did bring some view graphs from the Nevada Test Site, particular experiments that Sandia was involved in line of grouting operations and where they had emplaced instrumentation. I had a series of about five or six pictures here which actually had shown Sandia's and other people's, REECO's and F&S's operations as far as getting back into these areas to extract information, looking at the quality of--not necessarily looking at the quality of the interfaces. I don't think they always were interested in that, but rather to try to retrieve instrumentation that was used to measure some of the dynamics associated with the shot. So, I did have those; I just didn't present those.

DR. CANTLON: It would seem that the classification problem probably isn't the restriction with the geothermal side. What is the nature of the interplay with the geothermal experience in sealants?

MR. PETRIE: Joe, do you have anything to say on that?

MR. FERNANDEZ: There is no interface.

DR. CANTLON: Isn't there some USGS people here that know a little something about that? Could you give us a little bit of view about what is going on?

MR. WALLACE: Ray Wallace, U.S. Geological Survey.

From about January of '84 through October of '87 I was involved with a national and continental scientific drilling effort. I have seen and had experience with the horror stories, horrible experiences one can get into lost circulation problems in hot holes. In fact our bill for, lost circulation control was three quarters of a million dollars in the Sultan Sea scientific drilling effort. And I think it was about a half million dollars in a 2,500 foot hole drilled in Long Valley recently.

I would suggest you talk to Jim Dunn at Sandia and/or Peter Bisney. Also, as far as high temperature cements, there has been some work done at Brookhaven National Lab that might be of value to you. Other than that, I would certainly suggest the contacts there.

DR. PRICE: Go ahead, if it is on this topic.

DR. BLEJWAS: Tom Blejwas from Sandia. I also wanted to mention that we do have an interface with the people on the WIPP program who are also concerned about sealing and they have been looking more broadly recently to try to expand their technologies. For example, going in and visiting Strategic Petroleum Reserves and looking at some of their problems and trying to get information from that.

That is one of the ties that Joe already has and we will try to reinforce that more in the future.

DR. DEERE: Ted, you were going to go ahead and talk about perhaps fiscal year '93?

MR. PETRIE: There is not a lot I can say about '93 at this point, other than from our viewpoint the priorities are probably going to stay about the same. I have no reason to say they are going to change. We do expect at this point to get some greater funding that what we received in '92. When we find out what that is, we will be able to have a better idea of how we can tie the seals program in with our present program.

One thing I can say is that we expect the ESF design to be accelerated beyond what it is in '93. That will require then that we do some repository design efforts to go with it and of course some seals design effort sufficient for the repository design to go along with whatever the ESF needs.

Beyond that and what Max has already spoken of as a test plan in effect from the seals program, those would probably be the major references I would see in '93.

DR. DEERE: Thank you, Ted.

It would appear to me that one of the really close areas where you have started work and where you are going to have to continue working is when you start the actual excavation of the access ramp and you have a whole group of support items that you can use for support, whether it is precast concrete segments, whether it is shotcrete, whether it is rock bolts, what kind of rock bolt, rock bolt with chain link, rock bolts with shotcrete, or rock bolts with something else. And I think you are going to have to look and have a lot of interaction with Joe Fernandez's group as to which seems to be the most compatible. And I take it this will come up as you go ahead with ESF design.

MR. PETRIE: Absolutely. For the previous older design, the seals people had provided interface requirements on the ESF design. I am not sure what they were; I recall reading the drawings, but maybe Joe would remember. There were a specific set of interface requirements that were placed on the repository and then on the ESF as it related to the repository. And that same kind of effort has got to go on next year.

DR. DEERE: I would propose that we should have a meeting on this, but I think we are talking about a year off or something like that. I mean just dealing with this interface of seals and the ramps, because those are going to be the first part constructed for the first year or so.

MR. FERNANDEZ: A pragmatic concern that I have given the funding level, I would find that a meeting is all well and good, but unless there is additional funding to support these type of studies that you are potentially requesting here, you know, I don't see a meeting in a year as really feasible given the task that we currently have in front of us. We have "X" number of dollars and we have already extended ourselves a little bit in that regard. I just raise that as a concern that I personally have with people that I work with that we do have severe limitations in funding.

There's limitations for the entire project. We have to balance what is the most appropriate activities for the entire project and the Department of Energy has made the priorities for what we need to do consistent with other long term objectives.

MR. PETRIE: Of course, we do work up the schedules and the topics and the meetings with the Board. It is a mutual agreement. I am sure we won't do it unless we've got something to report.

DR. PRICE: Have you looked at the interface of the tunnel? It seems like in this thing, the smaller the opening, the easier the seal problem, generally. Smaller is better from a sealing standpoint, whereas it may not be better from other aspects, operational aspects, smaller is better. And have you looked at in-drift emplacement and waste package design as it interacts with the repository design question, smaller being better and backfill and so forth?

MR. FERNANDEZ: We have not had a strong interface with the waste package people to this time, although that is not to say we haven't had an interface. The preparation of the SCP provided a good opportunity for people across the project to interact with one another. It was in that activity preparing the SCP that we had that interaction.

What you are asking for sounds like what we may be doing in the backfill strategy paper, to try and incorporate the project concerns, waste package concerns with the backfilling strategy. Is there some constraint they would like to place on the sealing program, in particular the backfill or let's say some large seals.

We have in the past worked with the waste package people and it is reflected in our program. At one time we had a lot more cementitious based materials in the underground facility. Our strategy now is to minimize man-made materials as I mentioned in several of the presentations. So, we do have that interface that will continue hopefully this year with the development of the backfill strategy and a closer tie with the waste package people.

DR. PRICE: Did you have an assumption about vertical emplacement or horizontal emplacement in the walls or in-drift behind anything that was presented here today, or was it more general than that.

MR. FERNANDEZ: Let me see if I understand your question correctly. We actually evaluated it in the technical basis report both vertical and horizontal emplacement, both schemes. So, what we presented here is consistent with the current design basis of vertical emplacement.

DR. PRICE: But you didn't consider in-drift emplacement or the impact if instead of some type of canister design, you went to a universal cask design, you didn't get involved in those types of things? It certainly affects some of your operations.

MR. FERNANDEZ: As I understand these large cask designs are a newer philosophy or a new concept that has come out more recently. And because of that we haven't addressed that.

DR. PRICE: And do you agree smaller is better from a sealing standpoint?

MR. FERNANDEZ: Philosophically I probably do, but I think we would have to consider what the other problems might be. I may not be able to get the equipment that I thought I could get into some of these areas so maybe I would go strictly to pneumatic stowing as opposed to using mechanical compaction. I would have to think about that a little bit.

DR. DEERE: I would have to change the topic for a moment. In Costa Rica they are building a dam on top of tuff. In doing this, they have had to excavate a very large tunnel which they did all without blasting, just with a backhoe actually, and a dozer, about 30 feet in diameter; lined it and now the river is passing through that. They have diverted the river and are in then the process of cleaning up the bottom and coming up the abutment and getting ready to build the dam. The interesting thing, they have hit some lithophysae. I mean they are something. Things that are as much as 5 feet to 15 feet across and they are really decomposing pumice; gigantic pumice masses. These have been weathered down to practically nothing, so you have the large cavity.

What was interesting to me is that they detected some of these when they were drilling through the alluvial and found pockets; when they moved over the bedrock was ten feet higher. The reason was it was one of these large pumice boulders that had weathered.

They are mixing crushed tuff with a very small amount of cement, about ten percent of cement with water and just in a small little operation there and just dumping it in and backfilling this. It sets up to stronger than the tuff; it is not like a normal concrete, but it is a weak tufaceous concrete that has a enough rigidity and enough strength that it does a perfect job of replacing the material. They said," this has worked out so well that we are using it all over the area. We are using it for parking lots; we are using it here." It is not mixing it dry and then compacting it like you do cement, it is really making a very low tufaceous concrete with low cement content and spreading it.

There may be places were something like this could be worked into a backfill program or perhaps into a supporting strata for vehicle traffic in the ramps; these different possibilities.

That same project brings us back to where does the water move in unsaturated tuff? These slopes were cut at 1:1; 45 degree slope, 100 feet high. Pretty impressive. Pretty impressive exposure of seeing that much freshly excavated tuff. You could see the three joint sets in one of the major bands, perhaps 50 foot thick. Very interesting. No joints above it; no joints below it. So, it had something to do with the depositional history. Probably it could well be cooling cracks; we are not quite sure but think it may be.

Well, everything is dry; no water flowing. I am sure the tuff has a certain moisture content in it; maybe it is 40 percent or 50 percent, I don't really recall in terms of dry weight of the material. But, it has some water and a medium degree of saturation, I would imagine.

The week before I went down, which was only three or four weeks ago, they had three day's of rain. When I arrived and said," how is the project going?" Because it is a pretty small little dam and all this and that, and didn't have too much interest except it was on tuff. Everything is in tuff. And I had never worked where you had the abutments in tuff and the foundation in tuff and the tunnels in tuff. It is not a very strong tuff either; it is very weak, about half the strength of ours. After the third day of rain, they said suddenly we saw water. I said, where did you see it? Oh, in the joints, of course. And it is a point that we have been stressing for three years that we are convinced that when the water comes in, it doesn't have time to be sucked out. Of course, there is a potential, but there is also a permeability and how rapidly and how far the material can move before the water goes right on down through the joints. Right after the water started appearing at the surface of the cut and joints, they started to see some instability of the slope; everybody got out and, over a four hour period, they had a very, very large slide. It extended for 400 to 500 feet in one direction a 100 feet high. It really has ruined one of the abutments as they had designed it.

Well, this almost certainly was the buildup of some pressure in the joints. You actually had the porewater pressure causing uplift on the base and causing a hydraulic thrust on the incline surface and generating the failure of the slope.

So, a couple of things came out of that; seeing the lithophysae; seeing how they use the tuff in a very weak cement; and, then seeing how that in a dry abutment, you must remember when people say we are in unsaturated tuff, we don't have much experience in unsaturated rocks. Well, almost every abutment in the world is of unsaturated rocks and we saturate them just a few years later; so, we do have lots of experience of how material moves through grouting of unsaturated materials. But, it also shows that water moves into the joints but only when you have some prolonged heavy rains. This was a major storm in and actually must have filled up the joints to give it a little hydraulic thrust.

I think that is the comments I have there? Any more comments? I'm sure there are. Questions from the audience or comments from the audience on any of the topics that we have discussed?

Russ?

MR. MCFARLAND: In respect to Warner North, a question. I am sure he would not forgive me.

I would think that in understanding Warner's concern, one of the major questions he would have were he here, or one of the statements he would make is to stress the importance of an overall system performance assessment to reinforce your assumptions on the allocation to each of these plugs, the allocation of isolation to the plugs. You have consistently made a 1 percent assumption, that 1 percent of the releases would be allocated to the plugs. I wonder if that is really a tenth of a percent or ten percent. Do we have, have we a better understanding of really what is the need that you are representing by your plugs?

You may be striving for a very high impermeability when it is not necessary. You may be trying to reach to the state-of-the-art rather than the need. I have been converted by Warner. I would think that a system performance assessment would be essential before coming up with priorities on allocation of funds and really where are you going in the next few years in terms of where you put the money for your better understanding of the pieces of the system.

I hope Warner approves of that.

MR. PETRIE: I think Tom Blejwas would like to discuss it.

DR. BLEJWAS: I would just like to reiterate a point I tried to make yesterday. Either you don't agree or we miscommunicated, I'm not sure which.

If we are going to do a total system performance assessment; I presume you are talking about the total system being all of Yucca Mountain. The broad brush that we have to take at this point in time, the seals are in the noise. If you want them out of the noise you have to change things. In order to include them in the total system performance assessment, you are going to have to do something artificial. That is because as we have discussed in the past, when you deal with your models for performance assessment, you start out with mechanistic models. Eventually when you roll them up into total system, you have to make simplifications so that you can indeed do this probabilistic looking at everything. Those relatively simple models where the state-of-the-art is right now to roll everything up, would not be able to include the details of seals unless we had a separate scenario for seal failure or seal performance.

Right now we have not come up with a scenario whose combinations of probabilities would be adequate to include in the assessment so that you would be able to see it. We have to continue to look at those things, but without that I don't know of a good way to include it in the total system performance assessment.

DR. DEERE: Yesterday I commented about some problems in determination of the amount of damaged you have next to a blasted tunnel. This obviously affects your seal.

When we were in Sweden, we found that they were going through an experiment, in fact they had just finished it a couple of weeks prior in their hardrock laboratory. They are driving from the mainland out towards a small island at an incline of minus ten percent. It was very interesting. We went tearing down that in their truck all the way down to the face, and they manipulate very nicely in a ten percent grade. I also would point out that it was 5 meters in diameter and there was space all over for people to walk up and down and materials in and out and drilling, etc. They also had three alcoves driven off of the side.

Now, here was the question. One group who had been responsible for the design and responsible for getting the contract out and for monitoring the contract felt that the blasting that was being done, was not damaging the rock, too much; loosening it a little bit; opening the cracks a little bit; but this was an access over to the shaft. First they are going to spiral down in their drifts; going to spiral all the way down. So they said this is just an access underneath the water level to get over there. But another agency said, yes, but you shouldn't be damaging it to the extent that you can't do some tests, so you ought to do a better job of blasting.

After all, this is Sweden and this is where smooth wall blasting and all of the stuff came from, because they manufacture the dynamite. And they have practically no tunnel boring machines operating in Sweden, although they do at the moment have one going underneath the downtown area of Stockholm.

Well, they decided they would stop and they would make some studies on whether or not the blasting was good enough or they were damaging the rock more than they normally consider is a damaged zone. In Sweden, that is about 30 centimeters. They say we feel this with a well designed blasting round, you are not going to cause new fractures and reduce the modulus and increase the permeability more than about 30 centimeters.

What they decided to do was to make a little niche, more off to the side and drill ahead of the tunnel, a nice borehole and do all kinds of tests in that borehole; permeability; electrical resistance; borehole photography, sonoscope where they put a periscope down in and get a picture of the number and openings they could see of joints that were there naturally; maybe five or six different things. Then they drove the round ahead just as the contractor had been doing it before, and this was using for the five foot diameter, a total of about 65 blast holes. They loaded them the same way the contractor had been loading them and they shot it.

Then, they went back in. That hole which was over here, maybe they had a couple of parallel holes at 30 centimeters, 50 centimeters and a meter; and they went back in. They counted. They had twice the number of visible fractures after they had blasted. That doesn't mean they created a new one, but they certainly opened up an incipient one, and in some cases probably created some new ones. They had changes.

The most pronounced thing they had was electrical resistivity. Because, when they explained all of the five or six, we asked a question; well, what really worked the best? And the answer was the electrical resistivity worked the best. And the second was the actual counting of the number of fractures; we could see it.

Then we had him do another round, we did the measurements again and then we said, okay, we are going to design the round and it had about 85 or 89 boreholes. It had closer spacing on the peripheral holes; it had smaller loading in the peripheral holes, so they were really trying to get the true smooth wall blasting. They went ahead two or three rounds with that. What they found was there was a considerable decrease in the number of joints, a decrease in all of the things that had changed now were not changing at much.

They concluded that the contractor's blasting pattern was damaging the zone between one meter and one and a half meters. This was very interesting. But you could also go and look at the pattern that the contractor had been using, and you could see that this was not the best kind of blasting because blocks were out and you couldn't see the borehole cast of the normal. And yet, when they did it real careful, that looked very nice. When they went to the side into their alcoves or niches for their testing, they were very careful with their blasting. You could come and see these little alcoves that were maybe ten feet wide and 20 feet long and you could see every borehole that they had blasted to.

So, they had used the true Swedish smooth wall blasting and it just worked beautifully. But, they were not using it on the access tunnel. I guess the reason was they didn't feel, since it was an access tunnel, that it was quite as important to do that, because any testing they were going to do from that, the were going to do by driving an alcove, and that they would do very carefully. This was sort of a question between the two government authorities and they wanted to know what our comments were about this. I thought that was an interesting experience for you here.

When we went a couple of days later over to the Swiss Grimsel underground rock laboratory, we saw just a beautiful excavated, tunnel boring machine tunnel put in ten years ago with all kinds of experiments going on there now. I walked down that tunnel; it wasn't quite as big as the other, but I believe it was just about 12 feet in diameter. They were doing their permeability testing, etc. They had mapped the walls and the walls were beautiful to see. They were permeability testing. The damage they said as near as we can tell it is between zero and zero, with the rock boring; they just couldn't pick up any damage whatsoever. Of course, it was a strong rock, so you would not get any plastic yielding or anything such as that. But boy, could you see the weaknesses that were in the rock when they had the inclusions of some of the schists and shear zones, and they were doing an awful lot of testing there.

The interesting thing to me was that the first part of the tunnel, you could see the grooving, very much. There was a depth of about perhaps a half inch relief as they were boring forward. So you could get a three dimensional; any time fracture, you could actually see it running through that little groove, so you could get a strike and a dip very easily on it. But then they changed about halfway through the tunnel. They changed to more of a hard rock type. Instead of using a disk cutter that had inserts of tungsten carbide balls like Ingersall-Rand uses in their raised bores, they put on the regular disk cutters without those balls. There the amount of grooving was very,

very minimal; it was very, very smooth. You truly lost the three dimensional small effect, except where there was a fracture coming across and then there would be a little overbreak, then there you could see very nicely what the strike and dip was of that overbreak of the joint.

We then stood back and we would see a joint here and you could see it come up over here and back down over here (indicating), so you did have by putting yourself in line with it, for anything that had 12 foot extension, you could see it just coming up beautifully so there was no trouble whatsoever. Then you could examine the face like you were looking at a rock that had been cut for you by a rock saw and decide if there was or wasn't anything there. They said most of the time there wasn't. They did lots of permeability tests and it would take two, three, four months to get a cc of water in.

It was very intriguing and no doubt that the depth of damage is so much greater in the blasting. And the care with the blasting. I think this is one of the reasons that we have been thinking here of raised borings; maybe even drilled shafts if you came to that at one time, and certainly TBM drilled access drifts and exploratory drifts and things such as this. It really pays off.

Bill or anymore comments on what we saw, Russ?

MR. MCFARLAND: You might mention the need for borehole sealing and particularly the borehole at STRIPA that they intersected.

DR. DEERE: This was really something.

You've heard the Board from time to time talk about it's not the tiny, tiny little fractures that we think that are going to give us trouble and the large flows; it's the occasional one that has some continuity and goes through most of the formations, etc.

In their pre-study of the area with air photos and with a few drillholes, they found that they did have in the water area, and the reason the water was there, it was a small little strait, the reason the water was there was because there was a structural feature. And so they knew that this access was going to pass through the structural feature. So they had lots of piezometers in the island in a couple closer to the tunnel, and as they drilled into this feature, they were going to see how much water they got out of it and what happened to the other things to get a big picture. As I mentioned yesterday, when you have a saturated zone and you drain it, you can pick up a lot of information as to what is really carrying the water and where there are residual pressures.

They did something very nice. They drilled, I believe it was from the sea, a vertical hole and then they deflected it down to ten degrees slope. They carried that down as a pilot hole about ten feet or 20 feet or whatever above the drift. Just the week before we got there, they suddenly encountered it. This hole went all the way down and hit that deep feature about 500 feet farther down, and maybe 500 or 800 feet away. When they hit it, that water came out of that hole and just literally under 200 meters of pressure through a hole about that large. When we came down in our truck and I saw the face there and I saw this tunnel going off to the side, I said, what has happened here? They said, well we have abandoned that heading. We hit the old borehole and we got flooded; not from the sea coming down, we got flooded from the fault coming back up the borehole. And it was just coming out as much as you could expect from about a four or six inch hole.

They finally got a packer, not without difficulty, they got a packer in and it is leaking a little around the packer and through a few fractures. They are just bypassing it now and going off to the side and steeping. They had a small correction error apparently. The intent was not to hit the borehole. The borehole was to give them some idea of when they were going to hit the things.

We learned a lot on that trip. Somebody might want to say," well what are you doing looking at granite? Our site is not in granite." You do find all the types of problems and things that have worked and are working well.

Anything else Bill, that you had on that? We are writing a couple of these experiences up for our report of next May.

Comments, Clarence? You are Chairman of this committee.

DR. ALLEN: No.

DR. DEERE: No comment. That's good.

Any other comments from speakers, Board members? Tom?

DR. BLEJWAS: I just wanted to amplify on my answer to Russ's question, because I think I gave it too short an answer; it is really very complicated. It is a very difficult question for us to handle, because there are presumptions of using total system performance assessment to answer a lot of design questions. That is among the most difficult things to do with total system performance assessment. It is a very intriguing idea and it is a very good idea. I guess it is partly because of our own shortcomings that we tend to be defensive about this.

I did want to point out to you that I have answered the question partially, because, when I was talking yesterday about how we include potentially seals in total system performance assessment, I said we would include it in developing scenarios for what may happen, but also we have to modify the geometry and the conceptual models that we would use throughout the mountain as we do our sampling for performance.

It is because our models now have such large assumptions in them for things like what are the releases from the waste package? What is the lifetime of waste packages and how much Carbon 14 will get out? These can make differences of orders of magnitudes in terms of the releases to the accessible environment. Now if you tell me that you are going to change permeability by one percent perhaps, or change it for one percent of the mountain, unless you change it a real lot and create a very substantial pathway to the environment, I can't see that because these other uncertainties are so large, they swamp out the answer for that question that you are trying to ask.

MR. MCFARLAND: But isn't that knowledge again valuable in allocating resources and trying to establish priorities? If you don't know the need for the seals, why are we striving to such extremes to provide a seal that again reflects the extreme to the state-of-the-art, not the need? Shouldn't we first address those issues that drive our performance?

For example, a month ago, a month and a half ago we had the meeting on thermal. There were a great number of questions left that in my thinking should perhaps be addressed prior to putting monies into the design of a seal when we really don't know what performance requirements are going to put on that seal? The questions that Dr. Price raised on the configuration of the repository. There is a need for prioritization. We don't have the money we need, is the money we have being used in those areas that are going to give us this information as soon as possible?

DR. BLEJWAS: I think you have just raised a much bigger question, and I don't feel qualified to answer that question.

MR. MCFARLAND: You noticed I was looking at Max when I said that.

DR. BLEJWAS: I think I'll look at Max, too.

MR. BLANCHARD: The only answer I have, Russ, is that that is one of the reasons why we aren't involved in an extensive laboratory and field test program in seals right now.

MR. MCFARLAND: Thank you.

DR. BLEJWAS: Let me say one other thing in partial answer to your question. One of the things I think I learned from the ESF Alternatives Study, was that going through a process that's prescriptive to try to provide information for a decision, is a good idea, except that you have to remember that when you get the answers that come out from that process, they are dependent very highly on the assumptions that you make up front. And we have already seen that some of those assumptions have changed. Or we would use different assumptions if we were doing that study right now. Does that mean that every six months we go back and repeat a study like that? I hope not. That would mean that we would never make any progress.

I think what we have to do is make the best assumptions we can, go forward, and then continually question ourselves; that assumption has changed, do I have to do anything significant now that that assumption has changed? Or, can I proceed with getting a little bit more information and then again looking. We have to constantly be cycling through. And I think a lot of the plans that you will see, for example, test and evaluation plan that the DOE has indeed are designed to do that. They are designed as we get information, let's look at our assumptions, let's look at our knowledge. Do we need to do something different now? You can't go back and keep redoing those studies or you would never make any progress whatsoever.

MR. MCFARLAND: No, I don't mean to imply that.

DR. BLEJWAS: I didn't think you did, but that is only a partial answer.

DR. CASE: I would like to just make one comment here. I have had involvement also, in the Waste Isolation Pilot Plant project. One of the things that occurred on that project was, of course, at the time that we had put down instrumentations holes for geomechanics at the repository horizon, we started to obtain inflows of brine. There were a series of experiments that were being done, brine migration experiments that Sandia was involved with.

At a certain point, the amounts of brine were much larger and were in fact pressure driven. This led to several reports that we developed in identifying the brine problem. In other words that there is a potential for brine to come into the facility. More recent work I think has isolate the sources of that brine. But, nevertheless, the influx of brine in terms of salt consolidation is a very significant factor, and one that was not anticipated say ten years ago.

So, here is an instance where now that brine has some very beneficial affect actually, in terms of the centering of the crushed salt that would occur due to creep. The point I am just simply trying to make here is, as we obtain information about the site, as in this particular case, we may need to modify the design of those seals for such events as this, where the site characterization information that evolves and develops results in some fundamental changes in our thinking. I would just like to throw that out as a comment.

DR. CANTLON: I would get back to this problem of an overall system's assessment and the difficulty that the U.S.

program has because of the prescriptive nature of the regulations to which we are forced to design a system long before we know enough to design the system. The Europeans aren't under the handicap the U.S. is. We tend to have a prescriptive, regulatory driven system which requires a very large amount of information on the fit to those regulations at a time when the understanding and opportunities for a repository design are emerging. Our counterparts overseas don't have that impediment. We are driven to get minute detailed information far before we know whether that minute driven information has any relevance at all to the fundamental design.

If we went to a very high thermal load system, much of this system would go down the tubes. There would have been no reason to approach sealing with that set of starting points. So, we do have a very serious difficulty in the U.S. approach to this challenge.

MR. BLANCHARD: John you might be right, but I don't see those regulations changing which would cause us to do something different. At least not right now. And in the mean time, the posture the Department has taken to approach site suitability, is to rely on the properties of the site, not the seals. In otherwords, our approach in performance assessment and assessing the suitability of the site from magnitude and recurrence intervals have adverse impacts to containment in waste isolation caused by natural processes is to assume the seals don't work. And if we can't demonstrate by a significant margin, that that will be adequate, then seals won't be part of the demonstration of we have to have them because it is necessary to meet the release requirements. I think the site will not be, perhaps I don't have the authority to make this statement, but in my opinion, the site will not be found to be suitable within the Department. So a license application would never be prepared and sent to the NRC on that basis. I view the seals program as a confidence builder. Something you have to have; you do the very best you can with the equipment, the technology, that is available at the time. Everybody wants to expect to rely on it. They know that they will be able to rely on seal concepts for thousands of years because you can look around the world and see evidence that they last that long and longer, but that with respect to containment and isolation of the radionuclides and releases out of the waste package and groundwater travel time and things like that to a five kilometer boundary. That is not what we are relying on in determining the suitability of the site.

For instance, in the early site suitability evaluation that is going on right now, significant performance of any sort is not being relied on seals as a part of the engineered barrier.

DR. DEERE: I wish to thank all of you for your comments. The topic is certainly a broad topic. It was informative for us to see how many different areas are being investigated or have been investigated the last few years, and several of the real ones that are ongoing investigations that are planned for this year and next year.

I thought several times during the presentations that it was a shame that our groundwater specialist on the Board, Dr. Domenico wasn't here. And other times I thought it was a shame that Dr. Langmuir on the geochemistry panel wasn't here. This afternoon when we go see the tunnel boring machines we are very sad that Dr. Verink who is a metallurgy specialist is not going to be present, because what we are going to see this afternoon is a real break through in metallurgy.

The Robbins Company started, about 1985 with a major new development of machines which have now been produced and three of them are operating in Norway and going through at a very great rate. I hope they are going to make this presentation to us this afternoon of what went into this new development because it is just like the one-horse shay. When they got something better to make it really work, they didn't have quite enough backup on something else, so then the bearing had to be redesigned for that. When they got that going, then they found out the head wasn't quite rigid enough because you are now thrusting with another 25 or 50 percent of thrust and that went out. When you got the good metallurgy and your bit and you wanted to penetrate, then the local bearings of each disk went out, so it was a question of going all the way through. So, now their big machines have a very strong head, a very rigid head. Even the metallurgy of their cutters had to resist these very high pressures, maintain their hardness and sharpness without being brittle.

In trying to do it, they have found out. And now I think they are at a point where they are certainly leading in the world with what they can do with their cutters. We hope this afternoon we will find out that these major new impacts that we have in the tunnel TBM performance has been developed the hard way. It has been a step at a time. Dick Robbins himself is a mechanical engineer and this is the kind of thing he revels in. Unfortunately he is in Europe and will not be able to meet with us this afternoon, but we think some of their engineers will probably cover those topics.

We felt it was very appropriate that we would have a chance to meet in Seattle and go out there and take a look at that.

How many in the audience will be going this afternoon with us? Do we have quite a number? Very good. Very good. I am glad to see that.

DR. BARNARD: We have a bus that is going to take us out to the factory. According to the present schedule that bus will begin loading at 12:15 and leave at 12:30, so that should give us plenty of time to eat.

DR. DEERE: Thank you all.

(Whereupon, the proceedings were adjourned.)