UNITED STATES NUCLEAR WASTE TECHNICAL REVIEW BOARD

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Meeting of the Panel on the Engineered Barrier System

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Shilo Inn

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Karen Konvalinka, C.S.R.

EASTERN IDAHO COURT REPORTERS
P. O. Box 50853
Idaho Falls, ID 83405

PROCEEDINGS

CHAIRMAN VERINK: I am Ellis Verink, a member of the U.S. Nuclear Waste Technical Review Board and chairman of the Board's Panel on the Engineered Barrier System.

On behalf of my colleagues on the Panel and myself, I would like to welcome you to this meeting and thank you for taking your time to attend and participate.

The Board was created in 1987 by an act of Congress. The Board consists of 11 scientists and engineers nominated by the National Academy of Sciences and appointed by the President. The Board's function is to evaluate the technical and scientific validity of the U.S. Department of Energy's activities under the Nuclear Waste Policy Act of 1982 as amended and to advise Congress and the Secretary of Energy of our findings and recommendations. In simplest terms, we are an independent peer review body. We are required to report to Congress and to the Secretary of Energy at least twice each year. Four such reports have been delivered, and we have just completed working on the fifth one. It should be printed and delivered by the end of this month.

Several members of the Board and of the Board's staff are present today, and I would like to introduce them to you briefly. The Board members include Dr. Clarence Allen, who is Professor Emeritus at the California Institute of Technology and is the Chair of the Board's Panel on Structural Geology and

Geoengineering.

Dr. Donald Langmuir is a professor at the Colorado School of Mines and is Co-Chair of the Board's Panel on Hydrogeology and Geochemistry.

Dr. Dennis Price is professor at Virginia Polytechnic Institute and State University and is Chair of the Board's Panel on Transportation and Systems.

I am a professor at the University of Florida.

The senior professional staff also are represented here. I'll introduce Dr. William Barnard. I guess he just stepped out. He is the Executive Director of the Board. He'll be sitting right here.

Dr. Carl Di Bella on my left, serves the Board's Panel on Engineered Barrier Systems.

Dr. Bob Luce serves the Board's Panel on Hydrology and Geochemistry.

Dr. Jack Parry serves the Board's Panel on Environment and Public Health.

Also attending are two other members of the staff, Ms. Karyn Severson, the Congressional Liaison person, will be here shortly.

The other is Ms. Linda Hiatt. She's in the back of the room, and she is the Meetings Coordinator for the Board.

You can recognize all of us by our blue name tags. If you're unfamiliar with the Board, please feel free to buttonhole anyone with a blue name tag during the breaks or after the meeting, whenever it's convenient. We'll be happy to discuss the Board's history, mission and activities.

The Nuclear Waste Policy Act of 1982 assigned the DOE the mission of developing permanent geologic repositories for the disposal of high level radioactive waste and spent nuclear fuel. Accordingly, much of the DOE's activities in the mid '80's were aimed at identifying and characterizing potential repository sites throughout the United States.

In 1987, Congress amended the Act to limit the DOE characterizing only the Yucca Mountain Site, the candidate site located roughly 100 miles northwest of Las Vegas. Now if the Yucca Mountain Site is found suitable, and if the repository is built there, then most of the waste disposed there will consist of containers of spent fuel from the nation's commercial nuclear power plants. However, there will be containers of high level waste from defense reprocessing activities at INEL, Hanford or Savannah River, which may be co-mingled with these containers of spent fuel.

And defense high level waste is the reason we're holding our meeting here this afternoon. We're interested in how much there is at the INEL, its range of compositions, and what is being planned to get it ready for repository disposal. Thus, the presentations scheduled today deal exclusively with INEL plans and the activities here for preparing high level waste for repository disposal. Our only concern, of course, is how the waste may affect repository design and projected performance.

We're very pleased that the meetings of the Board and its Panel are open to the public. This not only provides a valuable mechanism for the Board to receive public input to help the Board carry out its own function, but it gives the public a window on the Board's activities.

You will note that the meeting is being recorded. The meeting transcript will be available on a library-loan basis from our Arlington, Virginia office within a few weeks after the meeting.

This is the first formal Board activity at or near the INEL location. We're aware that this is a huge facility, and there are probably many activities unrelated to or only distally related to high level waste disposal and are, therefore, outside our area of purvue. I will solicit your participation periodically during the meeting, and if you have a question or comment, remember we are on tape and we want to be able to record your comments and questions accurately. So I would ask that you use the microphone - - where are the microphones? There's one right behind me. Come up here and use the microphone and identify yourself for the record.

I would like to request that remarks and questions be kept brief and be confined to today's subject matter.

Now is the time, I think, for us to get started. Once again, I want to welcome you and thank you for the effort you are making today to be here.

Our first speaker will be Ms. Linda Desell of DOE's Office of Civilian Radioactive Waste Management in Washington.

MS. DESELL: Thank you, Dr. Verink. My name is Linda Desell, and I am Chief of the Regulatory Integration Branch, Office of Systems and Compliance, Office of Civilian Radioactive Waste Management, and I want to briefly set the stage a little bit today so that the new folks in our audience will understand the context in which we'll be discussing some of the activities here at the INEL.

The Office of Civilian Radioactive Waste Management is responsible for implementing the Nuclear Waste Policy Act, as amended, and that requires placing defense waste in commercial repository unless the President finds that the defense waste is to be put in a repository - -

CHAIRMAN VERINK: There seems to be a feedback. Can we fix that?

(There was a brief break in the proceedings.)

MS. DESELL: As I was saying, defense waste would go into its own repository, unless the President found that a commercial repository and defense waste could be co-mingled together.

President Reagan did make that finding, and so our present plans are for defense and civilian radioactive waste to both be placed in the first repository.

Our office is also responsible for managing the development of the geologic repository, a monitored retrievable storage facility, and a transportation infrastructure that will support waste acceptance and disposal.

We also developed the requirements for waste acceptance from defense production facilities, and we will provide the transportation and disposal of high level waste from defense facilities, and this includes Savannah River Site, Hanford, and the Idaho National Engineering Laboratory.

Our current plans are to include disposal of approximately 7000 MTU equivalent of high level waste, approximately 10 percent of the repository volume in the first repository. This disposal will begin in 2010.

Our present reference waste volumes are shown here. However, based upon the presentations that were given at Hanford two days ago, we're going to go back and take a look at the waste volume here for the 1200 canisters at Hanford Site. That number may be going up.

The Office of Environmental Restoration & Waste Management, which oversees much of the activity that will be presented here today, is responsible for the environmental remediation and restoration of DOE's facilities. It manages the waste vitrification activities at Savannah River, Hanford and Idaho Falls, and it is responsible for producing a canistered high level waste form for disposal by OCRWM, and the requirements on the waste form are that it be consistent and done in accordance with a Quality Assurance Program.

OCRWM interfaces with the Office of Environmental Restoration Waste Management concerning the acceptance of the Quality Assurance Program and the review of selected technical documents to assure that the quality is consistent, and that it is developed and produced in accordance with the QA Program.

Thank you, Doctor, that completes my presentation.

CHAIRMAN VERINK: There will be a change in the spokesman for the next presentation. Instead of Kenneth Chacey, it will be Jeff Allison.

DR. ALLISON: Thank you, Doctor. My name is Jeff Allison, and as the headquarters representative of the Office of Environmental Restoration & Waste Management, I would like to welcome the Board and the members of the staff to the Idaho Falls facility.

This meeting is the third and final meeting in a series between DOE and the Nuclear Waste Technical Review Board on DOE's programs to solidify the defense high level waste.

The first meeting was held February 10th of this year at the Savannah River Site. The second meeting was held May 11th at the Hanford Site. As stated before, this is the final interaction in this series.

As was stated in DOE's Defense Waste Management Plan in

1983, the DOE will take a phased approach to the design, construction and operation of its high level waste developmentalization facilities. In this way, lessons learned from one facility can be factored into succeeding facilities. As the Board heard at the Savannah River Site, Defense Waste Processing Facility has been constructed and is undergoing start-up testing that will lead to radioactive operation in 1994.

On May 11th, earlier this week, the Board heard the plans for the design and construction of the Hanford Waste Vitrification Facility in Richland, Washington. Site preparation activities for that facility were recently begun, in fact, in April of this year to support a 1999 radioactive start-up date. Here in Idaho, the Board will hear of the developmental testing being performed to select a waste form and process for the immobilization of the Idaho high level waste.

The Office of Environmental Restoration & Waste Management appreciates the opportunity to brief the Board on the status of our program at this time. In addition, we want to work with RW to address any questions the Board may have regarding the DOE program for immobilization of defense waste.

At this time I would like to introduce our first speaker, who is Mike Bonkoski of DOE Idaho. I've asked all the speakers to provide a brief introductory statement regarding their background, qualifications and position within INEL complex so that Board members will have an idea of their qualifications and background.

MR. BONKOSKI: My name is Mike Bonkoski. I am a mechanical engineer, graduated from the University of Arizona, spent several years as a mechanical designer, joined the Department of Energy in 1978, worked primarily in the Solar Thermal Demonstration Program and the Solar Repowering Program, and then went to work on the High Energy Laser Facility, NOA Facility at Lawrence Livermore Laboratory before coming to the Idaho National Engineering Laboratory. Came here in '82 and worked primarily on construction projects at the Idaho Chemical Processing Plant. I worked briefly on the Special Isotope Separation Project, and now I'm the Director of Materials Processing Division for DOE Idaho Office that has - - my management oversight is of the Chemical Processing Plant and the Office of Civilian Radioactive Waste Programs at Idaho.

Today I'm going to talk about spent fuel and high level waste management operations at INEL. I'm going to give the background information that will be an overview and provide the background for the following speakers. The outline in my presentation will include discussion of the INEL mission. Our INEL mission centers chiefly around the Idaho Chemical Processing Plant, which I will refer to as CPP or the Chem Plant. It all means the same thing. I'll talk a little about the Three Mile Island Program, a little bit about the Office of Civilian Radioactive Waste and call that RW. Both the Three Mile Island

Program and the RW Programs are located at Test Area North that you'll be visiting tomorrow. I'll talk a little bit about spent fuel types and sources at INEL, a little bit about the transition planning.

You have caught us at an unfortunate time, in that the Secretary has announced they would no longer reprocess spent fuel at the Idaho Chemical Processing Plant. That reprocessing had been the crux or the hub of our spent fuel and high level waste management. We will still have the legacy of dealing with high level liquid waste resulting from previous reprocessing and now we'll have to deal with spent fuel without reprocessing.

The Idaho National Engineering Laboratory, which you will tour tomorrow, is located west of town. It's approximately 50 miles to our central facilities, and tomorrow you will be leaving and going to the Idaho Chemical Processing Plant, which is located right here. And then you'll be traveling to Test Area North, and then back to town. The site itself is almost 900 square miles, and it's at an elevation of almost 5,000 feet. And it's located over the biggest aquifer in the State.

Even though we're no longer reprocessing, I'm going to run through the reprocessing flow as it existed, so you understand the background for our current inventory of high level liquid waste.

The Idaho Chemical Processing Plant was built in 1949. It began reprocessing in 1953. It began calcining high level liquid waste in '63 and has undergone extensive upgrading and modification in the 1980's.

The previous ICPP mission was to reprocess government-owned spent nuclear fuels to recover the highly enriched uranium, Kr85 and manage the resulting radioactive hazardous waste from that process.

Essentially, the process flow consisted of receipt of the fuels, storage in underwater pools. We also have some dry fuel storage. The fuels were then removed and discharged into the dissolvers, where they were dissolved with acids. Resulting solutions were then run through an extraction system to extract the uranium. It resulted in liquid uranyl nitrate, and then that uranal nitrate was solidified into uranium oxide and shipped off for further use.

The resulting high level liquid waste was then stored in the tank farm, and the liquid wastes were calcined into solids and stored in storage bins. And this process will be discussed in a lot more detail by the following speakers.

This is a photograph of our FAST facility. This is where we bring in fuel to store in underwater pools. The pools are located in this portion of the building. The fuel is removed from the pools and dissolved in dissolver cells in this portion of the building.

This is a photograph of fuel being delivered to the FAST facility to the truck unloading bay. This is a cask that's been removed from the truck and is going into the fuel pools.

This is a photograph of the FAST water pools. This is primarily where we store the zirconium clad fuels, and this water in this pool is maintained at very high purity. In fact, we maintain this at drinking water standards.

The fluorinel dissolution process, which is a process we use for dissolving the zirconium clad fuels, is - - primarily consists with charging the dissolvers with fuel and hydrochloric acid, and the resulting solution is extremely corrosive, and the dissolver and the complexer are made of a special alloy, Hastaloy C4, and to avoid the corrosion that results in the rest of the plant, that fluoride ions are complexed in the complex vessel to avoid downstream corrosion in stainless steel pipes.

This is a photograph of the dissolver cell. It's all remote operations. This photograph is the control room for the dissolver. The resulting solution from the dissolver dissolution process is then forwarded to the extraction portion of the plant, which is the oldest part of the plant which was built in the '50's.

This is a photograph of the operating corridor in the solvent extraction area. The operating corridor runs down through the middle of heavily shielded cells on either side of the reactors where the extraction processes take place.

This is a photograph of the denitrator area. This is where the uranal nitrate is solidified into uranium oxide.

As part of our plans, the solvent extraction portion of the plant was to be upgraded. The Fuel Processing Restoration facility is currently under construction. It will be one of the casualties of not continuing to reprocess.

The waste solutions resulting from the reprocessing and, also, waste solutions from decontamination efforts over the years, we've decontaminated cells to do contact maintenance in the cells. Those solutions have also gone to the high level tanks.

The high level waste tanks consist of - - tank farm consists of eleven 300,000 gallon tanks, one of which is a spare. They have cooling coils. They are stainless steel tanks contained in concrete vaults, and I'll be talking a little bit more about that later on.

The liquid waste is transferred to the New Waste Calcining Facility which began operation in 1982, and there it's turned into a granular solid, and there will be much more discussion on that.

The high level liquid waste in the calciner, the resulting granular solid appears like sand or laundry detergent.

This is a depiction of the - - this is a model of the bin sets, and this is a couple of bin sets that are out there. The calcine material is stored in stainless steel bins inside concrete vaults. Its design life is 500 years.

Here's a slide that shows compared to volumes of high level liquid waste and calcine and then glass or ceramic.

This is a photograph of the New Waste Calciner with some of the bin sets in the background. The existing high level liquid waste tank farm has been cited by the EPA as not having secondary containment that meets RCRA requirements. Also, the ancillary bell, exterior bell boxes and piping does not have secondary containment that meets RCRA requirements. In addition, five of the 11 tanks, the vaults themselves do not meet current criteria. So in the works is a high level tank replacement project that would replace the first five tanks, and there's potential for a follow-up project that would replace the remaining six. These tanks are to be replaced in accordance with a consent order that was signed with the State of Idaho that allows for phased compliance with the gross amount compliance.

Essentially, the first five tanks would either be replaced or ceased to be used in 2009, the remaining tanks by 2015, and various phased compliance dates for the bell boxes and the ancillary piping.

The project objectives of the first phase are to replace the five seismically deficient tanks with vaults and upgrade the ancillary piping and bell boxes. It's also to design fuel removal equipment that will remove the remaining liquid at the bottom of the tanks and do that in accordance with the consent order.

I'll talk a little bit about Fort St. Vrain fuel, mainly because it's been in the news quite a bit lately. The Fort St. Vrain reactor came about because of the Atomic Energy Commission's power demonstration program that took place in the '50's and '60's. In 1965, the Atomic Energy Commission, Public Service Company of Colorado, and General Dynamics, signed an agreement to demonstrate high tech graphite reactor technology and subsequently the Fort St. Vrain reactor was built.

In 1980, the Department of Energy entered into a contract to take Fort St. Vrain's fuel and, in fact, we have taken three segments of Fort St. Vrain fuel, each segment consisting of 240 blocks of graphite fuel.

In 1989, the Fort St. Vrain reactor was shut down. We had planned to take the remaining Fort St. Vrain fuel. Both the State of Idaho and the Sho-Ban Indian Tribe have filed suits to prevent that from happening. And currently, there are still ongoing legal decisions.

The Fort St. Vrain fuel, the current fuel we have and the fuel we had planned are stored in the CPP 603 facility, which is located at the southwest part of the Chem Plant. It was built in 1975, and it was built to accommodate Fort St. Vrain fuel, Peach Bottom fuel and Rover fuel. Rover fuel has subsequently been reprocessed.

This is a photograph of a shipment from Fort St. Vrain fuel. The cask contains six blocks of fuel.

This is a photograph of the interior of the facility where we store the Fort St. Vrain fuel, and this is an artist's depiction that gives you a reference, as far as how much room the

Fort St. Vrain fuel would pick up.

I'd like to switch a little bit to the Three Mile Island Program. The Three Mile Island Program began shortly after the Three Mile Island accident. This gave an unfortunately unique opportunity to look at Three Mile Island fuel and some of the damage that occurred during the melt-down. They decided to ship the fuel to the INEL for an R & D Program to determine some of the causes and consequences and ultimate disposal was left to DOE's discretion.

The R & D efforts on Three Mile Island fuel have resulted in changes to operations of nuclear facilities, greatly enhanced safety and greatly better understanding of the melting sequence and attack on the vessel. And there still is a small amount of research ongoing.

The Three Mile Island fuel is currently stored at Test Area North, where you'll be going out there tomorrow. That fuel is stored in the Test Area North's pools. The pools are unlined. The facility is relatively old, and there is currently a planned project to move that fuel from those pools to dry storage, and it won't affect the length of time that the fuel is at the INEL. They will put it in better storage.

This is a funding profile for that project, and essentially the '92 activities consist mainly of doing environmental assessment, safety analysis and some initial conception design. It gives the near term activities, including the environmental assessment and so forth.

This is a spent fuel inventory at TAN, Test Area North. It consists of Three Mile Island reactor core debris, 342 canisters, approximately six million curies; some NRC fuel, 241 fuel rods, estimated 194,000 curies; some LOFT fuel assemblies, and these are the fuels that will be moved to dry storage.

We have an ongoing dry storage demonstration project at TAN as part of the Office of Civilian Radioactive Waste Management Program, where it's basically a demonstration reactor on site dry cask storage. This is some of the casks on the concrete pad, and the casks are monitored for leak proof, and just mainly for leak tightness. This is one of the facilities you'll see tomorrow.

Moving on to the spent fuel that we have in inventory today, we have spent fuel located at Argonne West, Idaho Chemical Processing Plant, the Test Reactor Area, Nuclear Reactor Facility and Test Area North. The predominance of the spent fuel is located at the Idaho Chemical Processing Plant.

The sources of fuel at the INEL include Naval Reactors, various test and research reactors, university reactors, EBR-II, Rover, Fort St. Vrain. Commercial light water is Three Mile Island rubble and Fermi fuel.

This gives a distribution of the current inventory by mass, and right now the highest configures are graphite fuel and zirconium fuel, zirconium from the Naval fuel and graphite from the Fort St. Vrain.

This depicts the distribution of fuel by source, and the commercial fuel and Naval fuels, Fort St. Vrain are the larger contributors.

I'd like to conclude by talking a little bit about transition planning. As I mentioned before, the basis for all our spent fuel and high level waste management planning has in the past been reprocessing. Now that we're no longer going to reprocess, we have to develop plans to put the reprocessing facility in a safe shut-down condition, and we have to transition those facilities to decon and decommissioning, and we're going to have to transition our planning from that of reprocessing to eventual disposal in ceramic form. We still have to do that for existing high level liquid waste. For the spent fuel, we have inventory that is not going to be reprocessed. We're in the very early stages of planning to disposition that fuel. And with that, I conclude.

CHAIRMAN VERINK: Are there any questions or comments, first from the Board or staff? Anyone in the audience have a question they would choose to place? Yes. Be sure to go to the microphone, give your name and connection.

MR. PLOGGER: My name is Scott Plogger, and I'm just here as a taxpayer.

My question is whether or not there's a legal requirement for the Three Mile Island waste to be removed from the 607 pools?

MR. BONKOSKI: Is there a legal requirement?

MR. PLOGGER: Or is it just measuring that improves safety, is there something analogous to the retrodriver for the concrete stainless bins out at CPP?

MR. BONKOSKI: There's no legal requirement. The existing pools are unlined. The amount of time that we have to store that fuel prior to repository or an MRS being available for that fuel is unknown, and it's a better interim storage than what it is right now.

MR. PLOGGER: That answers the question, thank you.

CHAIRMAN VERINK: There being no further questions, thank you very much.

MR. BONKOSKI: Okay, the next speaker is Brent Palmer, and he'll talk about the calcination process at the Idaho Chemical Processing Plant.

MR. PALMER: I received my education at BYU. I ended up with a Master's Degree in chemical and nuclear engineering. I've worked at the Chemical Processing Plant since 1969. During that time I've worked in most of the areas of production projects, technical engineering, a lot of others in the development of the calcination process.

The Chemical Processing Plant was originally designed in 1949, the first part of it. You must remember, back in those days that was in the early, very early stages of nuclear energy, and what we did there during that time was in its infancy. And a lot of decisions were made that we would make now - - this seems to be cutting out.

(A discussion was held off the record.)

MR. PALMER: In 1949 not a lot was known about nuclear energy, and the part of the plant that was built then is still there and we're still using it. And I'll go into some detail there.

The original reprocessing that was done was done on aluminum-type fuels, and later on the Navy fuel brought in zirconium clad, and after that we also processed stainless steel clad fuel and graphite clad fuel. So we have processed a great variety of fuels there, and the result is that the waste tank farm is quite a combination of different materials. The calcination process has proven adequate to handle this. It's very flexible. It's a good solid process, but it is an interim process. The speaker following me will talk about taking it the next step of the way. But my subject will be that interim process.

Here's an overview of the Waste Processing Facilities, and I'll point out to you what those are so on your tour tomorrow, you'll have a little bit . . .

This area here is the tank farm. The oldest part of the tank farm, originally two tanks were built. They're right here. This facility here is the off-gas treatment facility. Can I get in a position that's a little better for you, somehow?

The two old tanks are right here. This building here is the off-gas treatment facility, and most of that was built during that same time frame. It is - - it's there to clean up the off-gas from all of the processes. Those off gases are vented up the stack after the cleaning.

This process here is the original Waste Calcining Facility, and I'll go into more detail in a moment.

This facility is the New Waste Calcining Facility that took over after we ordered the old one out, and these are the Bin Sets that were associated with the old calciner and the Bin Sets associated with the new calciner.

There's a lot of structures above ground, but, of course, all the cells and the cells where the real processing is going on is below ground. The upper part is control room, ventilation equipment - - things that don't require shielding.

The calcine process is actually fairly simple. The word calcining is a fairly generic industrial term that's used when you perform a chemical process on a solid at elevated temperature. It's used like cement, for example. That's developed as a calcine process, and so the term was applied to our solidification of nuclear waste, but there's nothing special embedded in that particular term. All it is is evaporating the water from the waste, cleaning that water vapor and sending it up our stack, and so we've reduced the volume as a result by about a factor of eight to one. The solid material here is granular, and we store it in a manner that's safe for the long-term, until we vitrify it for the extreme long term.

So, simply, the material is stored in the tank. We transfer it into a feed tank facility. It goes through the calcination process in a calciner vessel, solids are transferred to Bin Sets that are shielded. The off-gases are cleaned up and vented up the stack.

When the ICPP was first built, started in 1949, long-term vision wasn't developed at all. There was no vision at that point of what they were going to do with the waste from the dissolution of the fuel elements. As I mentioned, these first fuel elements were aluminum clad, I think mostly from test reactors.

In the mid '60's, some of the scientists in the area decided to work on that problem, what to do with the liquid. This same type of work was going on at Hanford, and I assume at Savannah River, as well.

Now early on in the design of the Chemical Processing Plant, they made a very basic decision that was different than was made at Hanford and Savannah River. The decision was made to keep the liquid waste as an acidic solution and store it in stainless steel tanks. At the other sites the decision was made to neutralize that solution and store it in carbon steel tanks. Now I don't know the basis of that decision. I suspect it was economics. The carbon steel tanks are cheaper to make than stainless steel tanks.

For whatever the reason, the 11 tanks, or at least the first two tanks that the Chemical Processing Plant were made from stainless steel, and the solution was kept acidic and we continued in that vein ever since.

In the late '50's, the calcination process was started in development in the laboratory first, then in the pilot plant, and then the process looked good enough that the AEC decided to fund a demonstration process. And the vision for this old calcining facility was that it was just that, a pilot plant, not a large scale machine at all. It was designed for only about 60 gallons an hour, so rather small by most industrial standards. But it was built, along with it one Bin Set was built, a small Bin Set. It was started up hot in 1963, and for that first campaign it filled the first Bin Set totally and operated flawlessly, just absolutely flawlessly. Of course, it had been cold tested prior to that that worked out some bugs, but the process proved to be very good.

Because of the success there, other Bin Sets were constructed and built, and this facility operated very successfully from 1963 to 1981, and at that point we deemed that it was worn out, and not that it wouldn't still continue to function, but it was built with no remote maintenance capabilities, for example. It wasn't built to the standard that 20 years later were required of facilities, so, of course, by that time we had been thinking ahead and had the new calciner designed and built and ready to go into operation. But it did fill the first, what we call the first, second and third Bin Sets. It processed about four million gallons of waste, converted it to about 77,000 cubic feet of granular solids. It was the first facility in the United States to do anything like this, and continues with that record. It was, I

think, a really good record.

The New Waste Calcining Facility, of course, was designed to quite different standards than the old calcining facility, notably remote maintenance. Initially, worker radiation exposure didn't receive the attention it does today, and the set was designed and recognized we could do some things remotely up front and save worker radiation exposure to a large extent. And that was proven to be the case here. All of the valves that required change-out or work fairly routinely, pumps, any type of thing with motors on it, any type of things with moving parts that we felt, based on our experience with WCF, required remote work fairly routinely were made remote so we could do it with master slaves, par manipulators, cranes, or if we have to go in there, we also have the capability to decontaminate the facility, to save exposure, if that's a requirement.

It also increased the capacity. Where the old calciner operated at about 60 gallons an hour, this facility was designed for 3,000 gallons a day, quite an increase in through put.

The automated data collection in 1963 just about didn't exist at all, so the instruments of the old calciner were all pneumatic. Everything was hands on. You could turn - - the valves were mostly not remote at all. If it required a remote valve, a lot of them were just long reach rods through concrete wall. But with the new calciner, that's quite different. The controller is above ground, comfortably air conditioned, very nice working environment, where the old calciner was down in the bowels of the facility among the pipes and steam valves. Not what we enjoy by today's standards at all. It's kind of like riding around in my 1963 Ford Falcon. My daughter almost refuses to ride in it, because it doesn't have air conditioning. And I think our operators today would feel the same way if we forced them to operate in a facility like that. Our new facility is extremely nice.

Automated data collection, automated by computer. Alarms we can tran - - alarms we can see problems coming in advance. We can look back at history to see what happened years ago to compare with the day's happenings at the calciner, and it makes us much smarter operators, much safer operators. Makes us able to plan in advance for our shutdown more readily.

The facility is filled with leaded glass windows and master slaves so we can actually watch the process, see it and actually do work right on the vessel itself, the calciner vessel itself by looking through the windows and using the master slaves.

It's a wonderful change from the old facility.

As I mentioned, the actual calcination process is housed in one vessel. Ninety percent of the facility is actually devoted to cleaning up the off gases, making it suitable for release to the environment.

For the NW staff, we operated three campaigns so far. The first campaign went for a couple of years, one and a half million gallons. The second one, isn't 8,000 gallons, a little bit less. The third one, 475,000 gallons. We're actually still in the middle of the third campaign at the moment.

DR. BARNARD: Bill Barnard, Board Staff.

What happens during the two to three years between each of the campaigns?

MR. PALMER: Well, it's been an interesting story. After the first campaign - - the system ran extremely well during the first campaign, of course with that piece of equipment it should, and it did. However, after a couple of years of operation, there were some things that needed fixing. A lot of valves were sticking. The valves that controlled the flow of our solids had eroded, nozzles have eroded. We needed to change those out, the pumps that pumped the scrubbing solution. So we determined it was just time to shut down, so we did, took turns around where we corrected all of the things that had worn during that couple of years of operation, started back up again. The second campaign was pretty successful. We got almost everything calcined that we had planned on. Now the length of our campaign schedules were geared mostly to how much waste was available for calcining. This is tied to our fuel reprocessing. We'll process a certain batch of fuel and it produces 300,000 to 600,000 gallons of waste and then we calcine it as quickly as we can. That was the case with this. We calcined almost all we could, but unfortunately, we also long rated the bed. Normally with the fluidized bed, I don't know if you're all familiar with fluidized beds, but ours is a bed with bubbly sand-like material, and you like to be nice and free flowing. Well, we increased the feed rate at one point to a little higher than it should be and made some bigger chunks in there, so it was no longer as free flowing as it should be. So we shut down and dissolved that bed out.

When we were ready to start up, in fact we started with our cold feed just preparatory to our hot, and a line in the cell broke, so we had to stop and fix that line. After we had got the line repaired and just ready to start up again, some of the environmental issues hit. As I think you all recognize, the DOE in the last couple of years has changed their stance on RCRA and other environmental issues drastically. And at that point, we determined there was some things in our facility, Chem Plant as a whole, that needed to be repaired in order to make us compatible with the RCRA standards.

Double containment on some lines, for example. In 1949, double containment of some of the lines that are required now to be double contained then just wasn't there. So we stopped all processes throughout the Chemical Processing Plant and began a massive amount of work on double containing lines. Well, very little was done in calcine, because it was a new facility, but these corrections had to be made throughout the facility that calcining tied into. And that kept us down through that whole period.

I'm going to go through this process with a flow sheet in a little more detail in just a moment. The thing I wanted to show on this slide, I guess is a couple things. We do feed acidic waste, as I mentioned before. The particle size we try to control to in this fluidized bed is about .25 to .6 millimeters. If we keep it in that size range, we can fluidize around the heat transfer or mass transfer is maintained at the level we would like to use.

The bed temperature is maintained at a very very uniform 500 degrees Centigrade. We supply the process heat by literally spraying liquid kerosene into the bed through a spray nozzle, an atomized spray nozzle. We atomize with oxygen so we get an intimate mixture of kerosene and oxygen, and because the bed is maintained at 500 degrees Centigrade, the kerosene immediately combusts very completely and releases the heat. The waste is atomized with air through four nozzles, very similar to the fuel nozzles, and with the action of the fluidized bed, we get excellent heat and mass transfer and makes a very very uniform bed, a very uniform chemical process taking place throughout the bed.

The next line is on off gas treatment, and I think I'll just skip by that one and use the flow sheet to describe the process in a bit more detail. From the tank farm we feed into the feed tank. Now we do have to add a few additives, and these are important for the next step, the long-term step that Dr. Knecht will describe.

With aluminum nitrate waste, the additive we use is just a little bit of Boric Acid to make sure we get the crystalline structure we want in the final product. With the zirconium-type waste, which has been the bulk of our calcining in recent years, we have to add calcium nitrate. The zirconium clad fuel is dissolved in hydrochloric acid, and all of our facilities are built of stainless steel. Hydrochloric acid is very corrosive on stainless steel, so in order to keep this whole system intact, we have to complex the fluoride with aluminum nitrate in the upstream processes, and then we add calcium fluoride in this process in the feed tank. And the calcium forms calcium difluoride in the fluidized bed, so with that we tie up the fluoride as a solid. So with that addition, the calcium in the feed tank we assure noncorrosive, or at least suitably corrosive conditions in our system.

The picture of the calciner, I've described what happens there. Our calciner still is relatively small by industrial standards. It's five feet in diameter, near seven feet in diameter in the disengaging section.

The off-gas leaves the calciner - - we'll start here. Fluidizing air comes in, forces the bed to bubble. All the off-gas comes off through here, separates the fine particles from the off-gas stream in the cyclone. It comes down, is combined with a solid stream coming from the calciner bed itself, and that's sent off to solid storage by pneumatic transport. It's carried off by air.

The next step is cooling off the off-gas stream in the Quench Tank and cleaning of it by the Venturi scrubber and the rest of the vessels up there, just further cleaning the off-gas, and then reheat the off-gas to the point where it can go through the final filters.

Then we have four separate banks of final filters. We operate two banks at a time, so all the gas goes through three separate filter steps there.

That is transferred over to our atmospheric protection system, the older facility I showed you by the stack, where it goes through another filtering step, HEPA Filter step. It's monitored and then released up the stack.

I'm not sure how interested you are in the details of composition of the waste, but I've supplied this in case you were, and you may want to pencil this in on your slide. I didn't do this, and I probably should have. WM-187 is our zirconium fluoride-type waste as is WM-188. You can tell what they are if you just look at the components. That one is high in zirconium, and if you look at the fluoride, they're high in that. So it's pretty easy to tell, but those two are zirconium fluoride waste. WM-185 is what we call sodium waste. Sodium waste is the result of our decon activities.

The fourth column is WM-182. That's aluminum waste.

As I mentioned earlier, our processing here has been from a lot of different sources and, of course, in the fuels and the components in the cladding and other things, you do end up with a lot of different chemicals. And that's shown in that slide. It's quite a fairly complex chemical system. The important ones, as far as calcination is shown on the next slide. The first thing that happens, as I mentioned, is the evaporation of water, and that's the single biggest reaction. Of course, that's not really a chemical reaction. It's a physical reaction, and that's created as it goes up the stack.

The second is a decomposition of nitric acid. It was the nitric acid, hydrochloric acid solution, but the nitric acid is the greater component of the two. Nitric acid is converted, almost all of it is converted to either NO_2 or NO. It, like water vapor, is cleaned and discharged up the stack.

For aluminum clad fuel or for aluminum and zirconium clad fuel wastes, the aluminum nitrate converts, essentially, 100 percent to aluminum oxide. The nitrates associated with the aluminum convert to $N0_2$, similar to the above reaction from nitric acid. All of the metal nitrates, whether it's iron, chrome, nickel, whatever almost totally convert to the oxides. There are a few that might convert to the nitrates, but most of them go to the oxides form.

Zirconium fluoride is converted to zirconium oxide, and then all the hydrochloric acids, as I mentioned are converted to calcium difluoride, to assure it's noncorrosive.

The fission products make up just a small percentage of the total. Since we dissolve the entire fuel elements here, the bulk of the material we're dealing with is cladding material, and the fission products typically make up just a half a percent, probably, of our calcine by weight. They go mostly to their oxides, some to their nitrates.

I've shown in the next slides two types of calcine, the aluminum type, which is the one we started with. And it turns out it's the easiest one to calcine. Of course, it goes mostly just to aluminum oxide, with a little bit of sodium oxide and a little bit of mercuric oxide. The mercury is put into that stream as a catalyst to permit the aluminum to be dissolved in the nitric acid. So that's an additive we put in during processing.

I think here I'd probably better clarify one of our waste streams. I've termed it fluorinel here. That's a type of zirconium fluoride waste stream, and it's called fluorinel because it was produced by the fluorinel facility, the FAST facility that Mike Bonkoski mentioned a bit earlier, but this is zirconium fluoride stream.

The sodium stream mostly comes from the decontamination activities, as I mentioned, and it is different than our other solutions. And it deserves a little bit of attention, because it does affect our long-term handling of this waste.

DR. LANGMUIR: Langmuire, Board.

You mentioned some nitrate fission products still remaining. You don't show any nitrates in the analysis. Is there a significant amount of nitrate in the analysis?

MR. PALMER: No, the fission product material, as I said, makes up less than half a percent. And I've rounded everything up to a half a percent. So I just dropped anything off that was below half a percent. There are a few nitrates left, and I think this will tie in with what I was going to say, with our fluorinel sodium-type calcine. You get about seven percent by weight nitrate in the calcine.

Did you have a follow-up question related to that?

DR. LANGMUIR: Only curiosity. Is there a reasonable temperature one could cook this to to destroy all the nitrate salt entirely?

MR. PALMER: Yes. Now the reason we don't do that, we're limited to the 500 degrees Centigrade in the calcine by material construction. Now Dieter may be able to answer what happens to that in the vitrification. In fact, I'm sure he will.

DR. KNECHT: We will cover that.

MR. PALMER: But for us, we're limited by materials, and your question is a good lead into the point I want to make with this particular type of calcine. Our sodium waste has quite a bit of sodium in it. If you look back at that previous slide, and out of all the components that we have in these solutions, the sodium creates the biggest problem for us. Sodium just loves to form sodium nitrate in our calciner, and sodium nitrate, unfortunately, melts about - - I believe about 350 degrees Centigrade, which is significantly lower than our calcination temperature. So if we allow too much sodium in our calciner product, we start forming these agglomerates I mentioned earlier in our calciner bed. So in order to solidify our sodium-type waste, we've had to blend off fairly judiciously with our zirconium fluoride-type waste, and that's where this particular blend comes from that I've shown. Typically, we will blend four volumes of zirconium fluoride-type waste with one volume of sodium-type waste. And this gets the agglomerate species down to a loan of concentration we can calcine it and also store it in bins and assure it's retrievable.

Unfortunately, that has limited the amount of sodium we can put through the facility from time to time, so right now our inventory, the largest part of our inventory is sodium-type waste.\

Here is a picture I took of some of the calcine we've produced. It's not very technical. It gives you a pretty vivid idea of the size and texture of material. The upper one is straight zirconium fluoride-type calcine, and the lower one is the zirconium sodium blend-type calcine, and you can see they're essentially identical. The sodium blend-type calcine is just slightly rougher, but they're about the same size, approximately the same density. The sodium one is slightly more dense, but relative to a paper clip, and that's just a standard paper clip. It's like coarse sand material, easily pneumatically transported, which is the method we use for most of the transport of it, and it's pretty easy to handle.

From the calcine then it goes into storage in the bins that Mike mentioned. And the reason we - - some of the reasons we'd like to make it into calcine is because it is a safer waste form, and we get a significant volume reduction. Now depending on the type of waste, with the aluminum-type waste, we got about a ten to one volume reduction, with the zirconium-type waste about a seven to one volume reduction, and with the zirconium sodium blends, we're getting about a six to one, five and a half to six to one volume reduction, so there's a bit of a range there.

But a significant volume reduction. Also, the solid is not nearly as corrosive as the liquid form, so we can store it longer more safely. It's easy to monitor. It's easy to watch after, takes little attention.

The next slide is maybe of interest to you. It's the calcine inventory we currently have. The first four Bin Sets are full. The inventories are shown there in cubic feet, and the types of calcine that are in each of them.

Bin Set 5 is within somewhere between three or four days or a couple weeks of being clear full when we started back up again. And six and seven were empty, but ready to receive waste as soon as we complete our documentation.

DR. LANGMUIR: Langmuir here again, Board.

I presume these oxides, hydroxides are very microscopic. Do you store them under gas, dry them and store them in containers?

MR. PALMER: No.

DR. LANGMUIR: Because moisture is going to get in - -

MR. PALMER: There's no hydroxide forms. These are all oxides, but you're right in that they do readily absorb moisture. Now there's two things that happened. These are also quite hot. Radioactive decay keeps them very hot. The mechanism - - there isn't really a ready mechanism for moisture to get into them other than breathe, the tanks breathing in and out. All of them are hot enough that water isn't a problem at this point.

Now if they were sitting there for 500 years, you're right. We may have to do something in terms of purging vapor space. We currently do purge vapor space with dry air. It's about minus 40 degree Fahrenheit instrument air, so at this point there's no concern in that regard.

This gives you an idea of the differences between Bin Sets. Bin Set 1 was unique. It was in a square vault, consisting of four bins, very very conservatively designed in terms of heat generated capacity or heat removal capacity. It was built as a central bin surrounded by two concentric bins, so there was cooling available on all sides of these annuluses. It proved to be more conservatively designed than need be, so the following bins were simple right cylinders. Bin Set 2 there, for example, those cylinders are in the order of, I think, about 55 feet tall and 12 feet diameter, so they're quite large. The rest of them are similar. They're a little bit taller and bigger in diameter. The latest ones, I think, are about thirteen and a half feet in diameter. And in order to go to that bigger diameter and handle some of the waste we're planning for now, there is also a hole down the center of them to supply a little bit more cooling. But all in all, they're quite similar, have similar features.

There's a little better view of the first Bin Set. The material from the calciner is transported pneumatically in through this line, comes in through a Cyclone. The Cyclone separates solids and gas. The solids fall down into distribution systems into the bins. The gas is then sent back to the calcine, ties in with the other lines that were on the other drawing which you saw.

A little better picture of the newer style bins, very like - - exactly like the first one in terms of solids transport and distribution. The bin design itself is a little different.

With most of our systems in the radioactive industry, our equipment is quite small by comparison with industrial standards, but that isn't the case with the bins. These are quite large. You can see a fellow standing down here at the base of those bins. This is in Bin Set 3. This is the center bin, and there's the bin surrounding it, and the fellow standing there at the bottom. They're massive. They're quite large, but very well constructed. They're stainless steel. The vaults they're housed in are all concrete reinforced, concrete to meet seismic requirements. The base of the vault has a sump where we have continuous monitoring to detect any water ingress into the system. We have the ability to transport water out immediately if we discover some in there.

CHAIRMAN VERINK: Do you recall which alloy?

MR. PALMER: The first Bin Set was made of, I think, 347. The remaining ones, I think, were all three or four L, all 300 series.

DR. BARNARD: How much radiation does that fellow get standing next to those bins?

MR. PALMER: That fellow standing there wouldn't last long. The fields down in that area, I couldn't tell you for sure, but they're a few hundred R per hour at least and it could be as high as several hundred R six, seven hundred. I would guess, just guessing, three, four, five hundred R. So we wouldn't want to stay there very long.

That, of course, was taken before we put anything in there.

Any other details?

CHAIRMAN VERINK: The fluidized process of handling the granular material presumably gives you some erosion problems, or does it?

MR. PALMER: It does. With the first - - with the early calciner, that was one of the first things we discovered was erosion problems. Aluminum oxide, for example, recognizes as ceramic. Fortunately, particles turned into very nice spherical particles, so they weren't as erosive as they might have been. If you get this alpha alumina or alumina like you have in you grinding wheels, they wouldn't survive at all. Fortunately, it wasn't that abrasive, but it has been a considerable problem, and it shut us down in the old calciner a number of times. We'd have to go in and weld, reinforce some of the lines. During the time we were running the old calciner, in fact during the time I was involved, we initiated a program of erosion control testing, and we had been party to developing, I think, some fairly unique means of preventing erosion. And those are all incorporated in the new system, and our erosion problems have gone away. Things like blind T's, blind laterals, no inclines. You either go vertical or horizontal, incorporate wear pads with purge into any suspect area, so you know when it breaks through that layer before it gets down to the second layer. A number of innovative things, and we've been participating in pneumatic transport conferences ever since that time, around the world, in fact, to make sure we stay right on top of the technology and presented our work with those conferences, been very productive. But that problem has, essentially, been resolved for us.

DR. PARRY: Jack Parry, Staff.

Are the various types of calcine kept separate so that when you do reprocess them, further process them, you'll be able to handle them individually?

MR. PALMER: No, we've calcined - - when we calcine it, to calcine zirconium for quite awhile so they're in layers, but they haven't been kept separate. I'll have Dieter address how we handle that in the vitrification process, but they are not separate.

DR. PARRY: You have ways of easily extracting the calcine from the bins?

MR. PALMER: Yes, before we ever allow calcine to go into the bins, we do extensive testing in the Pilot Plant to actually produce the type of calcine that we would in the radioactive environments. We put it in some special testing apparatus where we load it to the pressure, seal it in the bins, store at elevated temperatures higher than we ever expect, leave it there for a length of time and then we literally retrieve it with retrievable apparatus that we would use in the bins themselves. At that point then we allow it to go into the bins. We have retrieved some from - - well, the one I was involved in is we put the nonradioactive calcine during cold testing. It hasn't been retrieved yet, and the way we're planning on retrieving it is by vacuuming it up literally, just putting a vacuum tube down there with a vibrating system on it and a remote system for being able to move it around. Retrieval lines are already installed in all the bins that way.

DR. PARRY: Have you seen any agglomeration of the calcine during storage?

MR. PALMER: No.

DR. LUCE: What might the composition of these undissolved solids be in your liquid wastes? They go from almost one to five percent in the composition.

MR. PALMER: They could be a number of things.

DR. LUCE: That's grams per liter, I'm sorry.

MR. PALMER: Most of it is probably sand from the desert, for example, it gets into the floor drains and goes down in the floor drains into our liquid waste system. So that's the biggest composition, other than the silica gel we use in our process or absorb. Any other thing that's insoluble and acidic in the environment, but mostly silica.

DR. LANGMUIR: Langmuir, Board.

What kind of temperatures do you contain in the calcine storage areas? You're looking at calcine containment with calcine material. What's the temperature range you find?

MR. PALMER: We control the temperature of the calcine bins, depending on the type of calcine that's in there. For example, in the first Bin Set it was strictly aluminum-type calcine, which is not susceptible to agglomeration at all. That material can go up to, gosh, I imagine 1500 Centigrade, maybe 2000 Centigrade before there's any problem at all. So we have allowed it to go up as high as, I believe, the limit was more like 750 degrees Centigrade. It did go as high as 600 Centigrade. With the zirconium fluoride, we can't allow it to go as high as that. Our limits, they are lower. We'd rather it didn't go any higher than, I believe, five or six hundred Centigrade. We've never had it go anywhere near that high. We keep it lower than that.

The sodium zirconium blend, however, is more critical. We don't want it go to that high, because the sodium nitrate that's in there does tend to agglomerate. So we maintain that at a significantly lower temperature, and we maintain the sodium concentration in the calcine so that it's compatible with those requirements.

DR. LANGMUIR: You have to ventilate these things for a long period of time. How do you ventilate it? How do you control the temperature?

MR. PALMER: By design of the bins and the radioactivity of the material that we feed to the calcine. If it's too hot, we don't feed it is what it amounts to.

But we don't - - we have forced ventilation available if we have to use it. We are designed, and the way we put the stuff in allows it to stabilize at required temperatures without forced ventilation.

We're having problems with the mike.

(A discussion was held off the record.)

MR. PALMER: Did we finish that answer?

CHAIRMAN VERINK: I think so, yes. Any other questions?

MR. COOK: Robert Cook.

Three questions. One, the storage tank capability, is that limited by ability to reprocess or to calcine that sodium waste?

MR. PALMER: I didn't hear your first word.

MR. COOK: We heard from the first speaker about the problem with the storage tanks and had to build new storage tanks into the future. Is that all associated with not being able to process sodium waste in the calciner?

MR. PALMER: It's associated with it. We currently have 11 tanks that Mike mentioned. One is maintained as a spare, and all ten of the others currently have waste in them.

MR. COOK: But the tank frame was way out in 2015, I think I saw, for getting new tanks in.

MR. PALMER: There's two things occurring. If we just calcine the waste that was in there and got rid of it, we're looking at, oh, probably five to seven years.

MR. COOK: Yes.

MR. PALMER: However, part of our charter is also to clean up the facilities that are already there and, of course, that does generate some of this type of waste that go to the tank farm and takes us out into the outer years quite a bit further with clean-up of facilities and handling of the waste. It's part of our new mission.

Just calcining what's there, five to seven years. Decon of the rest of the facility will go out many years beyond that, so you're right, the need for the new tank farm is tied to sodium wastes that's there and the waste that will be generated in the future as part of the handling the waste at the Site.

MR. COOK: So you've got a 15-year decon schedule for the - -

MR. PALMER: Our schedule for the long-term really hasn't been developed. But it would probably go beyond there, because one of the things that's going to happen is the vitrification facility that Dieter will talk to here in a moment that will be deconned, as well, so it goes out a long time.

MR. COOK: Another question, the new calciners versus the old calciner, about twice the capacity. Yet the old one ran for 20 years, you indicated, relatively flawlessly. What was the difference? I mean how did the old one run so good and the new one run with valve problems or whatever? What were the differences? Was the old one a fluidized bed?

MR. PALMER: The old one was very much like the new one.

All in all the new one has ran better than the old one. If I left that impression, it was just my inability to communicate. The new one does run significantly better. Most of the down time, as I mentioned, that you saw in the slide was tied into renovation of other facilities rather than the calciner. It kept us down because the calciner requires those support facilities in order to operate.

MR. COOK: One last question, on the off-gas system, it was mentioned in the first speech that you collected krypton 85, but you didn't mention that in the off-gas diagram. Is that collected from the calciner?

MR. PALMER: No, krypton 85 is released at the time fuel is dissolved and goes into the treatment facility then, and it never goes into the waste.

MR. COOK: What about the iodine 129?

MR. PALMER: Same situation, right. They stay as volatile species.

DR. DI BELLA: Carl Di Bella, Board staff. I'm unclear from Mike's presentation whether tank waste is a RCRA waste or not.

MR. PALMER: It is.

DR. DI BELLA: Can you say what the RCRA waste numbers are?

MR. PALMER: I can't tell you the numbers. Well, you have the component. The species that are a problem there, as far as RCRA, are things like cadmium, lead, mercury, those are the main ones. Fluoride, it's acidic, of course, so it's hazardous by a Ph lower than two. Those are the main species. Any other species, organics, you know, solvents like that, very very minuscule amount there, not a big problem. But we do have heavy metals that are a problem. But it is RCRA waste, and forces us into some renovation of the older facilities that didn't consider this back in 1949.

CHAIRMAN VERINK: I think with that, we will declare our break and start again at 2:50, ten minutes to 3:00.

(A recess was taken.)

DR. ALLISON: Our next speaker will be Dieter Knecht of Westinghouse Idaho. He'll be talking about the plans for disposal of Idaho high level waste.

DR. KNECHT: I've been working here since 1974. Prior to that I have a Ph.D in physical chemistry with post Doctorate work, and then when I started here, I started working on the krypton immobilization program, and there was an interest in tying up krypton from commercial nuclear power. And since about 1980, I've been involved with the high level waste, long-term high level waste program. I manage the high level waste program now for developing a new process for what we do with the calcine.

Okay, as of now, we have about 3500 cubic meters of calcine in our storage bin and about 7500 cubic meters of high level liquid waste, and most of that is sodium waste. There's some fluorinel and other dissolver waste which we will process off with part of the sodium waste, and then we'll have something like this remaining.

The land disposal restrictions apply to our waste, and as Brent mentioned, there is a mixed waste. And as of last Friday, we are prohibited from generating more waste, and I think right now there is a case by case extension to that prohibition that's been announced and is undergoing public review and will likely come in for a two-year extension to this prohibition.

What the program that we are developing will alleviate, it will provide the EPA the assurance that we are developing a process at a reasonable pace, so that we will be able to retrieve our waste to meet their standards.

In addition to that, the DOE Order directs that all new and readily retrievable waste be processed for eventual disposal.

In your handout - - I guess I won't go through this in any detail - - it just specifies the drivers for this program, which include both legal and other good practice-type drivers.

As you are aware, the three sites that have high level waste for the Department of Energy, and starting with the Defense Waste Management Plan and continuing in the five-year plans, we have a schedule for developing and implementing the process right now to vitrify the waste, and we have this plan for 1994 at Savannah River, '99 at Hanford and 2014 at the Chem Plant. Depending on funding, but I think we'll be on this kind of a schedule.

In your handout, I just have some of that early information from that Defense Waste Management Plan. It gives you a little more background on what the waste sources are. I'm sure you're pretty well versed in that already.

Because of the process that was described to you earlier, our waste is acidic, contains hydrochloric acid, which is complexed by aluminum in the tanks to prevent corrosion there and nitric acid. It contains all of the spent fuel cladding material, so we have quite a bit of zirconium in this, as well as some aluminum and the radionuclides.

The Chem Plant processes, almost exclusively, highly enriched fuels. So in the processing, there are soluble neutron poisons present, were present, boron and cadmium. And to prevent criticalities during that process of dissolution and subsequent handling of the waste until the uranium was separated out. So we have those materials present in the waste.

We have it calcined, as was described, and in comparison, the Savannah River, Hanford, West Valley Wastes are stored, neutralized and then stored as a liquid sludge mixture and some solids.

This explains in a little bit more detail where these different chemicals enter into the process and how it ends up in the waste. We add the soluble poisons in the dissolver. The dissolver itself contains hydrochloric and nitric acid. We add aluminum once the solution leaves the dissolver, so we prevent further destruction of the process equipment from the fluoride, and the aluminum complexes the fluoride to keep it from destroying everything else.

This is the type of material in our liquid waste, and then we take our liquid waste from the dissolution, as well as not shown here, but another tank of sodium bearing waste and we blend them together to calcine them. We add the calcium to react with the fluoride and form calcium fluoride so we protect all the piping and equipment in the calciner.

Typical composition from the waste is shown in this table. I have some more tables with some more detailed compositions. This would be a typical fluorinel sodium-type calcine, and it contains seven weight percent of alumina, 19 weight percent of zirconium, almost half of it is calcium fluoride, and the rest from the other materials. The fission products and actinides really are probably less than one percent of this material.

DR. LANGMUIR: Dieter, Donald Langmuir. Could you tell us a little bit about the U product, the extraction part of that system, what's happening there?

DR. KNECHT: Yes, the uranium gets converted to uranium oxide in the fluidized bed denitrator and got shipped off site to Oak Ridge in the past for further clean-up, and then it was used for the reactors at Savannah River. It's still highly enriched.

The waste does include plutonium. There is some plutonium in our waste, not very much plutonium 239, because there isn't much uranium 238 to produce it. But there's quite a bit of plutonium 238, and then other actinides are present in this, too.

This was coming in your handout as part of the next - - from the next speaker. I just thought I would throw it in here to give you, and you'll see it later on, just to show you that this is a composition of a simulated calcine we used to model the real calcine.

I have - - from the - - I think you're probably familiar with the integrated data base, and I have these tables which give you the - - this is a table of the liquid waste. I'll give you copies. Let me give you these copies here. I don't have quite enough.

And these are compositions of the zirconium fluoride waste, the sodium-bearing waste, and some of these I've shown more as ranges of composition of the elements, and then the fluorinel waste at the end.

The calcines which would go along with these are shown here, and the fluorinel sodium is very similar to the one that was in the other, within the other diagram.

There is quite a range. For example, the alumina calcine is 82 to 95 percent alumina. So it's - - when we eventually will make a glass ceramic out of it, that composition will be different, obviously, than the one we used to make the fluorinel sodium calcine into a Glass-Ceramic.

There's been an extensive amount of work done since, I think, probably the early '70's on developing waste forms for these different wastes. In fact, I think back in the '60's we had a picture of some of the early glass forms that were made actually from the radioactive alumina calcine and the zirconium calcine.

When we first started to develop the Defense Waste Management Plan to give our input to this Plan, we based that input on assuming that all of our waste would be converted to a glass by vitrification process. Unfortunately, because of the high zirconium alumina in the calcine, the waste loading ended up - -well, the waste loading is okay, but because of the fact that you only have one weight percent of fission products in the waste, we ended up generating quite a large volume of glass, in fact, probably more glass canisters than Savannah River and Hanford combined at that time.

So this led to an expanded program in the early 1980's to look at other ways of reducing our waste volume. And we evaluated quite a number of different technologies. The one that looks most promising to us is converting to Glass-Ceramic, and I'll go into it and show you why we think that will be an improved way of doing it.

You saw the picture before, and I have it in mine later on, but I'll just show you what the process looks like in this flow sheet and then go in to some more detail on what it gives you.

The process is a solid powder handling-type process, which is not an easy thing to do, but what we would see, we would take calcines from the tanks, the Bin Sets, and we would have to get a large batch together and mix it so we've got a uniform batch for that series of runs.

You hit on it very well earlier when you asked whether the calcines were segregated. They were not segregated and in some Bin Sets near the end of the processing of the old calciner have, in fact, layers of a number of different calcines in them. And these would have to be blended together in a batch to come up with the uniform composition, which would then have the right additives to make the Glass-Ceramic.

I guess the trade-off was that you couldn't build all the Bin Sets to keep the variety of different calcines, too, so we mixed them. But we do keep our liquids fairly well segregated.

The calcine does have to have nitrates removed, and that was another point raised. They are about, I think up to about

eight to ten weight percent of nitrate left in the calcine after calcination. If we left those nitrates in there, they would come off later on and create bubbles and would be a problem. So we do see a step where we would heat them probably to 600 degrees Centigrade, rather than 500, and drive off the decomposing nitrates and drive off the gases.

And then the calcine probably would require some grinding to get better mixing in the final product. Right now the largest parts of the calcine is about half a millimeter. We would try to get around 80 to 100 mesh or something around 80 mesh for further processing, would still be handling very well, as well as mixed for the later parts.

We would have to add some additive to make a Glass-Ceramic. It would have to be blended, and then it would have to fill a small can somewhere on the range of a little bit larger than two foot diameter, if we were going to a final canister of two foot size.

This can would have to be evacuated to pull out all the air and sealed, welded under vacuum. And then it would be transferred to a high isostatic press or really any kind of a high temperature densification high pressure unit. A hot uniaxial press is another option that could be used at this point. This press would heat the material to about 1000 degrees Centigrade, would compress it at about 10,000 to 20,000 pounds per square inch to form the final Glass-Ceramic product, which would then be loaded into the container to be shipped to the repository.

Are there any questions on this part here, on the unit operations?

CHAIRMAN VERINK: Has this been done, or is this projected?

DR. KNECHT: This is what we're developing, yes. We think it will be about the same type of plan as the DWPR in scope and cost.

DR. DI BELLA: Carl Di Bella, TRB staff. Tell me again what your time line is for your development.

DR. KNECHT: I will. I'll get into that further along. Right now, looking at our existing calcine, we project approximately 1950 canisters for the repository. In our old projections, which were in the integrated data base, we were up at about 7500 or so canisters generated - - produced by the year 2020. That would be the waste that would be immobilized from about 20 - -I think 2014 to 2020, and it wouldn't take care of all the calcine. Looking at our existing calcine 1950 canisters would take care of it, assuming the type of Glass-Ceramic product we're developing.

If we compared that with glass, that would be almost two and a half fold increase in volume. So it's quite a reduction to do that.

Now the canisters we're projecting here are not the size that Savannah River is, in fact, producing right now or will be producing. We have looked at using a large as possible sized canister for disposal. The spent fuel, 15-foot by two-foot two-inch diameter canisters, and as this evolves in the repository planning, we'll accommodate whatever we need to do. But right now we think this would be a much more efficient way of using the space up to use these smaller canisters. We can get it to the repository. It could be packaged in those canisters and placed that way.

The existing sodium waste would produce about another 1300 canisters, and future waste could produce 520 more, and we could have a total of 3770 at some point after a lot of decontamination and everything else. But the immediate first repository waste, I think, would be this waste here.

DR. DI BELLA: Carl Di Bella, TRB staff.

What sort of standards did you use for the material, as far as its repository performance to come up with the different compositions involved with the processes that you looked at?

DR. KNECHT: I have - - we'll get a lot more detail on some of the results that we found with the leach test and things like that. We are basically trying to meet the same kinds of standards of the glass waste.

DR. PRICE: Dennis Price, Board.

How are you talking to OPRA 1 with respect to the dimensions that you just gave for the canisters?

DR. KNECHT: We've had some very preliminary discussions with them just to say that this is what we would - - we're asking can we do this, and they thought it was a good idea to do it, but we haven't got into any great detail. I think they're re-evaluating everything right now, too, with the new contract. But I think I've heard that, but I don't have very close contact with them on that.

DR. PRICE: So there aren't discussions with casks or over packs or things like that?

DR. KNECHT: Not yet. We're looking at a 2014 hot starter, and I suppose we and the repository will go neck and neck with who starts first.

DR. BARNARD: Bill Barnard, Board staff.

The canisters for the Glass-Ceramic, are they the 15-foot diameter container?

DR. KNECHT: No, we're trying to look at the spent fuel containers that are 15 feet high by 26-inch diameter.

DR. BARNARD: Okay, so - -

DR. KNECHT: The Savannah River ones are ten-foot by two-foot diameter. And actually, the volume, depending on how efficiently we fill each one, the volume is a little bit under the factor of two.

DR. PRICE: If the volume is a little under a factor of two, how does this 3770 then compare with the 10,000 figure that you presented in terms of volume? Are you both talking about the same volume?

DR. KNECHT: Oh, I'm sorry, Jeff. I think you were going on the older size.

DR. ALLISON: Yeah, Jeff Allison.

I think the numbers that Linda presented are based on some earlier projections, I think of what was going to be processed in Idaho and in line with some of the comments that Mike Bonkoski made about the changes in the processing mission, I think from a vitrification standpoint, we're going to have to go back and revise our projections and look at those numbers again.

DR. KNECHT: Those earlier projections, I think were from an integrated data base, and in that to compare it with the other ones, we kept the canister size as the same as Savannah River. Those are around - - I think were around 7000 to 8000. But that was a moving target, because it was just the amount produced by 2020, and it wouldn't use up all of our calcine, and they just shut it off at 2020 for all the sites.

So right now, like our people have said, it's a new ballgame as far as the mission, and we have a lot less calcine in - - that's there now than we had projected for when we were starting up. We had projected a very large increase in our fuel processing, so that we would have easily quadrupled our existing volume of calcine by 2012 or 2014.

DR. PRICE: Given the number of canisters of similar dimensions to - - and I don't know if I can ask this right - - to Savannah River or Hanford, what is your current cost per canister for those total number of canisters that you are going to try to - - have you got a figure like that?

DR. KNECHT: For producing it?

DR. PRICE: Yeah, that might be comparable to - -

DR. KNECHT: I've seen that, and I don't like that concept, because it means the better that you do it, the higher your cost per canister. I don't know why - - I just don't like that kind of comparison, but we haven't looked at it, because we haven't really - - we're developing a process right now, and when we get a little further along, we'll start to have some conceptual designs on the facility, et cetera, in the operations. So right now what is concerning us here is the cost per canister per disposal. So that we're trying to maximize or minimize that by having this fit in as much waste in a canister as possible.

DR. PARRY: Jack Parry of the staff.

You had two other horizontal lines there, Glass/Pyrochemical and so forth. Could you explain those, please?

DR. KNECHT: Yes. We're right now trying to do some preliminary feasibility evaluations to see if there's some way that we can react the calcines to extract the fission products and actinides in a separate stream and divert a larger volume of low level waste. We're scheduled to - -

CHAIRMAN VERINK: Would you straighten that thing up in your necktie? You're not talking into the microphone.

DR. KNECHT: Let's just go with the podium. I think my battery is running down.

(A discussion was held off the record.)

DR. PRICE: Price, again, from the Board. Let me try to pursue just a little bit what I asked a minute ago. Even for ballpark ranges or estimates or rough guestimates, if you were putting this up with your process in a Savannah River or Hanford sized canister, and unfortunately I've seen a couple of different sizes put up, and I'm not sure which size is the right size. But you may have an idea about what that size is.

What would the cost be of this process as compared to other maybe cost figures we've heard? That's what I'm really after.

DR. KNECHT: Well, I think per unit volume of processing costs, we're looking at about the same type of range as Savannah River and Hanford will be charging to process theirs.

DR. PRICE: So you see similar costs - -

DR. KNECHT: I think so.

DR. PRICE: - - where they gave us a figure of per canister of $600,000 per canister - -

DR. KNECHT: Yeah, but again, I want to emphasize what should be compared is the amount of - - maybe the curies that you process. And that way put it on a common basis, rather than what comes out at the end. I think your input flow, you know, I mean you can have a process that comes out with one canister, and that plant would have to be gigantic in order to do all the steps to get it to that, because you've got all your input stream is really what's affecting the overall cost. It's not what comes out.

DR. PRICE: But how do they compare then?

DR. KNECHT: I would guess just at - - we're assuming that our process per unit volume of waste going in is going to be about the same as theirs. We don't see any reason why it should be greatly different.

Now I think people might argue with that, because there are a lot of differences in the process. But our existing facilities can help us - - have helped us a lot in estimating this, too. Our calcining costs run about somewhere in the 20 to 30 million dollar a year range. I think Savannah River's DWPF annual costs are probably around $50 million to $100 million range, and they're producing about 400 canisters a year. I don't think we'd be much different from those kinds of processing ranges. I think a typical DOE facility cost to operate them are all in that type of range, and this includes everything, not just the operators doing it, but everything associated with that process.

DR. PRICE: Yeah, that's what I was going to ask. In the comparisons you're making, are you considering from tank canister in either case?

DR. KNECHT: Excuse me, from what?

DR. PRICE: From the tank confinement storage tanks to the canister.

DR. KNECHT: Yes, uh-huh. That would be - - that includes - - we've already done the calcining. If we were doing it from liquid waste, it would include that cost from the first calcining and then moving into the . . .

This is a simple-minded type of picture to show you how the volumes differ. For the same volume of calcine shown in both processes, we need a lot more additive to make a glass compared to making a Glass-Ceramic. That's one of the major differences.

The other is that the density is a little bit higher in the Glass-Ceramic, about 3.1 grams per cc, versus 2.6 for a glass, and we end up with two canisters versus five.

You saw the next one before. Okay, just comparing the volumes - -

DR. DI BELLA: Dieter, Carl Di Bella, staff.

Just comparing volumes - - Dieter?

DR. KNECHT: Yes, you want the volumes?

DR. DI BELLA: Yes, I want to follow up. Suppose you were taking the calcine as it is and press it in the canister. What are you talking about relative volumes for that? Not hot, just under pressure?

DR. KNECHT: In the early tests that the contractor did for us when we first started looking at the Glass-Ceramic, they took a very prudent approach and said, "Well, let's just hip the calcine and not put anything in it," okay, and you form about the same density material if you hip it. But you don't tie up some of the radionuclides that need a glass face to tie them up, for example, the sodium, the boron is present, the cesium from the waste, strontium, some of those materials will come leaching out fairly quickly from just hipping the calcine. So we did have to add an additive to make a glass face which has the characteristics of all the other glass faces, and then it will make low leach rates using the standard leach test.

Now if you took the calcine loose, the volume is about twice the volume of the ceramic. Maybe I should point that out on this picture that you have in there which I skipped over. You notice the glass is - - in fact, it's one and a half times the volume of the calcine. So we increase the volume, if you just look at the calcine volume. The ceramic is about two and a half times less than the glass, or it's about a half of a calcine volume, if you just had the loosely - - just the normal packing calcine.

DR. DI BELLA: But the only way the leaching occurs is if there's a breach in the container, is that correct?

DR. KNECHT: Right, but the waste acceptance specifications specify that your product will meet certain conditions, and Savannah River has now the PCP test. Before it was the MCC-1 leach test, and we're right now still testing ours on the MCC-1, just as a comparative basis. And this just says that everything, the glass in their case is a good glass. Everything is tied up well. In our case, we would meet the same kind of stats.

DR. PRICE: Will the - - do you know, will the civilian radioactive waste spent fuel meet the test?

DR. KNECHT: I haven't measured it, but you need to talk to the people who have been testing it. I don't think that's been tested very much lately.

I think some years ago, I think this Panel met with people at Livermore and some of that was discussed then, but I know there's a person at Argonne who has done some of those tests, and I think Livermore might have done some in the past, but I can't really comment on how well. It meets quite a bit of that, but the source terms in there, too, we don't have in the Glass-Ceramic.

DR. LANGMUIR: Langmuir, Board. You talked about being able to get rid of uranium in the process of making calcine, and I thought you said it was possible, you were looking into ways perhaps with fission products in that same process so you could concentrate them and not have to deal with hot calcine materials and, perhaps, save additional volume.

DR. KNECHT: Oh, before you calcine?

DR. LANGMUIR: Somewhere in that process.

DR. KNECHT: It's too late now.

DR. LANGMUIR: Once you're beyond calcine, there's no way you can - -

DR. KNECHT: I was just putting up the pyrochemistry option as one possible way that might work. The other way, you could redissolve the calcine and then do an iclea separation of the actinides and then possibly the fission products, although you're dealing with an acidic stream which is not as well defined for, for example, an exchange of cesium and strontium.

DR. LANGMUIR: Are you working on those ideas?

DR. KNECHT: We're doing some minimal evaluation on it right now.

The pyrochemical treatment would involve heating the calcine in a salt mixture and we're just looking at what sorts of compositions might dissolve the calcine to get it all in a salt.

This is analogous to the integral fast reactor proposed for Argonne National Labs in which they would take the metal fuel, dissolve it in a salt, do the load separation pyrochemically, and then refabricate the new fuel and it would all be part contained of the integral fast reactor.

And this would take the - - first dissolve the calcine, transfer or use the same vessel for this step to electrochemically refine the material to separate the fission products and actinides and hopefully end up with a slag that's not highly radioactive. And that's a big - - I think that would be a big big problem, possible problem here, because we could create a very concentrated high level waste, as well as a less concentrated low high level waste and have a larger volume than what we started out with.

Then there's various options to what could be done. It could be tied up as an alloy. I think Argonne is evaluating a number of options for that, as well, including making glass out of that material.

It is based on existing technologies that's been in the complex for producing plutonium, but in those cases the material is not highly radioactive. You're dealing with a single component. You can do it in a glove box. In our case, it would have to be done remotely, and you have the whole fission product spectrum of the elements to deal with, as well as the actinides. So it's something worth checking, but I think we have to be very cautious about what we can assume would happened.

We're testing some of the heating to see what comes off. We will be testing to see if you can separate these materials from the radioactive and hazardous components, and then we would do the electrorefining. This was just started this year, and it's a fairly low level funded program to see if we can find any show stoppers in it to see if this is - - and then proceed further if it looks feasible at that stage.

The big issue, I think, is that we have to demonstrate the initial separation. And as I mentioned, this hasn't been done in a real highly radioactive environment with a large number of components. Other people are very interested in this, too. I think the Japanese have a program that Rockwell has done some of these tests for them. So it's not something that's just, you know, just we are looking at.

It could reduce a high level waste volume quite a bit, assuming that the slag is nonradioactive as a low level waste.

And in this estimate we talked of low level waste volume would end up being about the same volume as the original calcine, but that is really speculative until we see exactly what we have to add to it and understand the flow sheet.

This is a schedule that we see as our fastest schedule for getting this process developed and on line. And we show the initial work that we're in right now is testing for technology feasibility. This schedule assumes we have a large increase in funding in the next few years to really develop to do necessary tests to really establish the feasibility of all the equipment components, as well as the waste form.

You saw on the flow sheet there are a lot of unit operations that have to be tested, and we've already started doing some pilot plant mock-up tests of those operations to try to get a better handle of the type of valves you would need, the flow conditions for the type of process we would be looking at, some of the grinding tests. But we have a lot that has to be done in this next two years in order to meet the criteria to design the necessary pilot - - large pilot plant and full scale plant.

We see, envision that in about - - assuming, you know, that we're at this high paced program, that we would, by about 1998, be able to come up with some fairly good answers on the waste form and have had some radioactive waste form tests accomplished, as well as nonradioactive tests.

The next big decision point is the EIS, starting in the late 1990's, with the record of decision around 2003. And it would have coming into it all the development work we've done to show it's also feasible and have the design criteria.

This would then lead to a construction of the full scale plant. This is, I think, a typical type of construction and full testing schedule as we've seen with other facilities, both here and the DWPF. And we would start hot operations in 2014.

I'll skip the next one. It's the same material expressed in a different way.

What we have accomplished in our work so far is that we have prepared - - built some pilot plant mark-up units and tested for grinding, which would be particle sizing, blending. We're still - - need a lot more work on all of these, and solid flow valves. We have prepared some Glass-Ceramic forms and tested them, and the years since - - well, about by the late '70's, we had developed what we considered a very good glass for our waste. I'll show it - - you can pass these around. This would be the glass formation that we developed for our calcine. It's a lot more beautiful than the other ones. It's not opaque. It's got a nice green-blue color.

The Glass-Ceramic, you can look at it and see there's fine particles, recrystallized materials, and then the glass face.

And as I said, the leach test for the glass is very comparable to the proposed glasses for Savannah River and West Valley and, also, Hanford.

We have issued recent milestone reports on the process for vitrification and for the Glass-Ceramic process showing you the different unit operations and, also, saying what needs to be done to test it in the future. And we can get you copies of those.

I just want to compare the leach rates using the standard MCC-1 test and sort of the milestone or the point in the waste acceptance specifications that, of course, the defense, Savannah River waste, glass, is that these should be less than one in their preliminary specs. And I think we've managed to do that with some of our formulations for these elements, as well as for the glass.

We have a lot more work to do in the Glass-Ceramic to really show that we can make a consistent formulation. We can show the range of acceptable loading, range of acceptable waste compositions and other things, but I think we have a good start.

Dr. Raman will describe in more detail what we've seen in our waste tests so far.

DR. LANGMUIR: Langmuir, Board, one last question.

DR. KNECHT: Yes.

DR. LANGMUIR: The inference is that you know enough about the material that the calcium you have or the leach you have, the waste you've got so that you'll be able to adjust perhaps automatically the glass-making compound that you add once you get this thing onstream? Because you've got mixtures - -

DR. KNECHT: That would be the strategy, yes. It's similar to, I think, Savannah River's. We'll have a batch that they will process, and I don't remember the time frames, three months or something or six months. And they will have a formulation for that particular batch. And then they'll have a new batch and have a modified formulation.

What we would have to do is to have our development program be able to come up with a right range of compositions that we can pretty much say, "This batch will require this additive", and then do some tests on it and confirm it and keep doing it as we go along the same way.

Hanford is going to be even more variable, because of the different tanks. So I think we would all approach it about the same way.

DR. DI BELLA: Di Bella, TRB staff.

Just for comparison, what's the leach rate of the calcine?

DR. KNECHT: It's very high. It dissolves under these types of conditions. You could probably dissolve 30 percent in, you know, ten days or so. We have an external report on the leaching of calcine, which I could try to get for you.

DR. LANGMUIR: Wouldn't that calcine be basically a basic salt, Ph of around 14 if you put water in it?

DR. KNECHT: Right, it comes about - - I don't remember, somewhere in that range when you put it in water.

DR. LANGMUIR: You immobilize a lot of those trace elements in those alkaline solutions, too?

DR. KNECHT: Yes. It depends on how much excess water there is so you create an equilibrium situation.

I just want to mention one more thing. I think about 1978 we did a core drilling of Bin Set 3, which had been in - - the calcine had been in the Bin Set for about 12 years at that time, I think. And that was - - we drilled both through a zirconia calcine, predominantly a bin with zirconia, and we did one of alumina calcine. At that time we didn't have the zirconia sodium calcine or the fluorinel. But in each case, the calcine was tested for physical properties, and there was no evidence of calking or any problem.

We also were able to use some of those calcines to make some small radioactive glass forms similar to that one I passed around to you, that composition, and tested that for leach rates and other characteristics, and they tested the same as non-radioactive glass, both in the small scale and the pilot plan.

MS. HARRISON: Diana Harrison. I didn't really have a question, but I did want to address a comment that was made earlier. The PCT and the MCC-1 tests are tests specifically for vitrified waste forms, and they are to compare the glass to the environmental assessment glass.

It's really set up as a comparison. The WAPS containing those specifications is a waste acceptance preliminary specification for vitrified high level waste forms. If Idaho were to choose a ceramic waste form, if that's what they're going to end up with, it's - - the DOE will generate a new WAPS, a new specification for ceramics and would likely have a different test to determine the release or the durability of that waste form.

Regarding the spent fuel, that is undergoing some very rigorous dissolution and release studies that would be separate from the PCT, and I don't believe we've done any PCT tests on the spent fuel, because the mechanism formulas are very different, and I just wanted to clarify that.

DR. KNECHT: Thank you, Diana. I'd like to add something to that, too. This is, I think - - well, it's about 50 percent glass, 50 percent ceramic. According to the EPA standard or the EPA best demonstrated available technology to meet the RCRA-type waste, we think we'll also fit under their broad vitrification standard, according to their definition, and that this will also meet the same standards that the glass has met and, therefore, satisfy the land disposal restrictions.

If we have to, we can also do a - - I don't remember what they call it, treatability variance for our waste and create our other we have from that.

DR. PRICE: Relative to the LDR, Land Disposal Restriction, what are your constituents that make the waste?

DR. KNECHT: Cadmium, chromium are the major ones.

DR. PRICE: What about strontium?

DR. KNECHT: I don't think it's in there of high enough concentration. It's a fission product, so I don't think it's high enough it would have to be considered as a hazardous component.

DR. PRICE: Relative to the previous question I had on the iodine 129, do you incorporate that into the - -

DR. KNECHT: Well, it's not in the calcine, so we don't - -

DR. PRICE: Where is it? How do you dispose of it?

DR. KNECHT: I can let Brent discuss that.

DR. PALMER: The iodine is - - what was the other one you asked me about earlier, krypton 85. It's released during the dissolution process and doesn't end up in a calcine. So it's released during this - -

DR. PRICE: This was captured - - it was released.

MR. PALMER: Krypton 85 was captured.

DR. PRICE: What about the iodine 129?

MR. PALMER: No, it's not captured.

DR. PRICE: So it's gone, too?

MR. PALMER: That's correct.

DR. DI BELLA: I'm not up to date on the disposal regulations, but from what I recall, the only material for which vitrification is BDAT is arsenic. Is there some other stuff - -

DR. KNECHT: No, the EPA and the third period rule-making came out in June of 1990, said that for high level mixed waste, the BDAT standard is vitrification, and they issued that as an HL, and in that rule-making they also gave a two year case-by-case extension for all the DOE waste. And we're trying to get another two-year extension now. That's my understanding.

Mr. Raman.

MR. RAMAN: Good afternoon, Mr. Chairman, members of the Board. My name is S.V. Raman.

I will here present a short discussion on how we are trying to transform the high level waste calcine at ICPP into a durable body or an inorganic material.

My coscientists on this task are Krishna Vinjamuri and Bruce Staples. The project is supervised by Dr. Dieter Knecht.

Waste form is a solid body containing the waste, and in high level waste technology we recognize three such solids called glass, Glass-Ceramic and synthetic rock. Typically, we will call the waste form as glass when it is devoid of abundant crystalline matter, a Glass-Ceramic when it contains both amorphous and crystalline matter, and synthetic rock when the compositions of the amorphous and crystalline matter are analogous to natural rocks. At ICPP our efforts mainly concentrate on the development of Glass-Ceramic, with supporting experiments on glass as well as synthetic rock.

We will look at calcine characteristics, in the form of its chemistry and microstructure, the calcines that we are currently working with are simulated analogs of the actual hot calcine.

To transform the calcine into a solid inorganic material, chemical components are added, and this is what we call formulation.

The chemical mixture is then melted in a crucible and quenched to form glass, or is subjected to high temperature under pressure to form Glass-Ceramic.

We have been using X-ray powder diffraction, Polarized light microscopy, electron microscopy and electron microprobe to determine the interrelations among glass and crystals, and their chemical composition. The waste forms are tested for durability in deionized water at 90 degrees Centigrade, the test is called the MCC-1 test. The mechanical strength is also of interest here, we hope to address this issue in the near future. Currently, we carry out creep experiments, because creep is often an indicator of diffusion mechanism.

The composition of the calcine is quite diverse. B203 and A1203 may play dual role as glass formers and modifiers, there are several typical glass modifiers, like Ca0, Cd0, K20 and Na20. But in addition, there are large concentrations of refractory components like CaF2, Zr02 and Cr203 that have a very low solubility in a common borosilicate glass.

The calcine fragments are in the order of 200 microns, have a high porosity and have concentric nodular pattern.

The chemical species are also concentrically distributed. This distribution is particularly evident in the major elements of the calcine, namely A1, Na, Ca, Zr, B, Cr and

Cd, while the minor elements like S and Ce occur scattered, suggesting that there is no preferred chemical segregation.

In order to transform the calcine into glass or Glass-Ceramic, it is necessary to add silica. In addition, other components to tailor the formation of specific phases. Here are two formulations that are currently being investigated for forming Glass-Ceramic bodies. In formulation -I the calcine loading is maintained at 70 percent, silica at 25 percent and the components of B203, Ti and A1 metals are varied as shown in this diagram to form calcium titanium silicate called sphene, titanates and boron containing aluminosilicate glasses.

In formation -II the calcine loading is maintained at 80 percent, silica at ten percent, and the components of P205, metallic Si and A1 are varied as shown in the diagram to form phosphate bearing phases.

Sphene is a principal component in the Glass-Ceramic being developed by the Canadian Nuclear Fuel Waste Management Program as an alternative to nuclear waste from borosilicate glass. Here sphene and titanates are actinide bearing phases in nuclear waste forms.

In formulation -II apatite and phosphates are the actinide bearing phases.

The frit so formulated is mechanically mixed with calcine, cold pressed in a stainless steel container and vacuum sealed.

The waste form is developed in the hot isostatic press. The pressure is initially raised to about 15,000 PSI. This is followed by a rise in temperature and pressure to 1000 C and 20,000 PSI. At maximum P-T the waste form is maintained for two hours or so and then cooled. Since the waste forms contain glass, the microstructure is further stabilized by annealing in the neighborhood of glass transition region.

We are also carrying out a parallel basic study to determine the pressure-temperature stability of waste forms as a function of composition. Such a study would eventually be used for optimizing the process parameters. The diagram is largely based on concept of thermodynamics. We have at present two experimental data points, and additional experiments are currently in progress.

The waste forms vary in their microstructure as a function of composition. This cross-polarization light micrograph of one of the waste forms made using formulation -I. The microstructure look similar to a volcanic rock, where crystalline grains occur interlocked with intergranular glass. This particular waste form is abundant in zircon. Zircon in nature is a resistant mineral, and often contains Th in the Zr site of crystal structure.

Fine CaF2 grains of calcine grow into large sizes during hipping, and are here observed embedded in the glass matrix. At a high magnification like 1500X dendrites of sphene are noted in the glass. Sphene seems to be a host not only for actinides, as has been noted by Canadian Mines, but in our work it also seems to contain five percent Cd in the Ca site.

We have also attempted to crystallize feldspars in the waste forms. The feldspars could be a possible host for Sr, where Sr would occupy the Ca site. In fact, some of the feldspar rocks in nature are as old as 1.0 B.Y. The Adirondack Mountains are classic examples, whose age was determined because of the occurrence of radioactive Sr isotopes in them. Feldspar compositions in the optical microscope are determined by the conoscopic optical image shown here.

These are scanning electron micrographs that reveal the effect of additive composition on crystallization. The additive compositions are, like five percent B203 versus three percent B20, three percent Ti versus six percent Ti, and one percent A1 versus three percent A1. Although the additives are of different types, the absence and presence of zircon grains in glass islands is shared by all of them. The microstructures on either side are nearly similar. Possibly, the growth of these crystals is related to the viscosity of the liquid, and hence the glass structure.

The glass compositions of the two sets of micrographs, nearly have the same A1/Si ratio and are silica enriched, perhaps suggesting that tetrahedral substitution of A1 for Si. The compositions however, differ in the Ca content. The higher Ca content may promote crystallization, by unbridging the network which may lead to decrease in viscosity. Possibly, Ca variations in the glass result from the fractionation of Ca in titanate and aluminosilicate phases in the solid state prior to formation of the liquid. For example, increases in Ti and A1 contents would lead to increased extraction of Ca prior to melting.

The glass analysis also shows that in pure glass only about three to five percent CaF2 and Zr02 are dissolved. This low solubility places a similar limitation on the solubility of calcine in glass.

This waste form was made using formulation -2. Addition of phosphorous and water seems to promote a greater growth of CaF2, a more even distribution of grain boundary phases, and crystallization of apatite.

We are also pursuing our studies in the preparation of glass. Many glass formulations exist in the literature for accommodating high level nuclear waste. The general structure of glass is nearly similar, as a result despite variations in their chemistry, the mechanism of accommodation of nuclear waste is nearly the same. The exercise here was carried our to study what changes the ICPP calcine introduces to a typical glass. Batch composition B was chosen in the soda-silica-b2o3 system. The composition is far removed from Na20. The composition falls in the immiscible field. Possibly, the excess free energy leads to phase separation of the composition into pure silica and composition G. This is clearly evident in the microstructure of this glass.

The bright patch here is of pure silica. Possibly, one can also make use of this excess free energy to promote solubility of calcine. When 30 percent calcine is introduced, the glass appears very heterogenous, although there are no relics of unmelted calcine in this glass. Complex phase separation is introduced in the form of mottled structure and B203 containing bubbles in the soda aluminosilicate matrix.

We are commencing to probe into the structure of glass with calcine addition. The clear glass and the mottled structures were probed using laser Raman. This preliminary data indicates structural changes perhaps in the form bridging and nonbridging oxygens in the three dimensional versus the two dimensional network. We plan to pursue detailed studies to establish relations among glass structure, calcine loading and durability.

The table here shows the leach rates of waste forms for some of the important elements. Most of the leach rates are well below the lower limit of one gram/m2-day set by MCC test. But greater decreases in leach rates seem to occur with the formation of crystalline phases, and perhaps suggests that crystalline phases are more durable than glass. For example, when the crystalline phase NaA1Si308 is present in the waste form the leach rate of Na is the lowest. The leach rates are also likely to be affected by the glass structure. Glasses with lower viscosity and more open structure seem to increase the leach rate, thus this particular waste form shows a very large leach rate of 9.81 g/m20day for Na.

The components of calcine are partitioned into both glass and crystalline phases. The incompatible elements are preferentially accommodated in the glass, and the refractory components are contained in crystalline forms. Hence, it is possible to increase the calcine loading to 70 to 80 percent by forming a Glass-Ceramic body. In contrast to five percent loading in homogenous glass or 30 percent loading in heterogenous glass.

The natural phases like sphene, zircon, apatite, feldspars are hosts for actinides and lanthanides, and are also far more resistant than glass. It has been possible to synthesize these crystalline phases in the waste forms and enhance its durability.

No additional wastes are produced in the Glass-Ceramic process. This is because both glass soluble and insoluble components are accommodated by Glass-Ceramic. However, in pure glass melting additional waste in the form of glass-melter waste is produced.

In hot isostatic pressing, the volatile phase is contained in the waste form and dissolved in both crystalline phases. As a result, high temperature glasses as well as crystalline phases are formed at relatively lower temperatures. This may lead to energy savings.

Future development efforts will concentrate on engineering grain boundaries, formulations, processing parameters, by concentrating on issues of basic science, as well as development, because the present waste forms have several defects.

CHAIRMAN VERINK: Any questions, comments? We thank you very much. This completes our program for this afternoon. We thank the participants for their efforts and we'll be looking forward to seeing some of you tomorrow.

(The hearing was adjourned.)

REPORTER'S AFFIDAVIT

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I, KAREN KONVALINKA, do hereby certify that I am a Certified Shorthand Reporter and a Notary Public in and for the State of Idaho;

That I took down the proceedings aforesaid at the time and place therein named and thereafter reduced the same to typewriting under my direction and control.

I further certify that I have no interest in the event of the action.

WITNESS MY HAND AND SEAL this the ____ day of May, 1992.

(Signature)

Karen Konvalinka, C.S.R.,
Notary Public in and for
the State of Idaho,
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My commission expires: Perpetual