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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE

June 6, 2006

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

171st MEETING

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TUESDAY

JUNE 6, 2006

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ROCKVILLE, MARYLAND

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The Advisory Committee met in Room T2B3 of the U.S. Nuclear Regulatory Commission, Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 1:00 p.m., Michael T. Ryan, Chairman, presiding.

PRESENT:

MICHAEL T. RYAN Chairman

ALLEN G. CROFF Vice Chairman

WILLIAM J. HINZE Member

RUTH F. WEINER Member

I N D E X

P R O C E E D I N G S

(1:03 p.m.)

CHAIRMAN RYAN: All right. Let's come to order please.

This is the first day of the 171st meeting of the Advisory Committee on Nuclear Waste. My name is Michael Ryan, Chairman of the ACNW.

The other members of the Committee present are Vice Chairman Allen Croff, Ruth Weiner, James Clarke is out sick for this meeting. He will be joining us next month as scheduled, and William Hinze is here.

We also have an Emeritus member of the Committee in the audience who is going to give a presentation, Dr. Ray Wymer. Welcome, Ray, thanks for being with us again.

During today's meeting the Committee will be briefed by Dr. Wymer on the theory and technology used in the past for reprocessing of spent nuclear fuel.

We will be updated by the NRC staff on the implications of a Department of Energy Nuclear Fuel Recycling Program through NRC's regulations concerning the licensing of spent nuclear fuel recycling facilities.

We will be briefed by the NRC staff on potential changes to the regulatory process that may be needed to accommodate spent fuel nuclear reprocessing.

And we will discuss the proposed white paper on the subject of reprocessing we hear about today.

John Flack is the Designated Federal Official for today's session.

This meeting is being conducted in accordance of the provisions of the Federal Advisory Committee Act.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's session. Should anyone wish to address the Committee, please make your wishes known to one of the Committee staff.

It is requested that speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so they can be readily heard.

It is also requested if you have cell phones or pages that you kindly turn them off.

Is Dr. Thadani coming? Or is he going to be joining us later? Okay, I'll just announce for everybody and we will make comment when Dr. Thadani joins us. He is coming up the hall, okay. Oh, thank you.

Ashok, we have come to the point in the agenda where we wanted to recognize formally for the record that this is your last Advisory Committee on Nuclear Waste meeting. We are thrilled that you are moving into a new phase of your life and career and retirement, semi-retirement, or travel and work as you see fit rather than as you are asked to come in.

We certainly want to recognize and appreciate your counsel and insights that you have offered to this Committee in the time you have been with us. It really has been helpful.

We have expanded into areas where we drew heavily on your expertise. And we really appreciate the effort that you put forward along with John Flack, I might add, to advise and educate the Committee on risk-informed approaches from the reactor side of the house. I think it has enriched our offering to the Commission and the advice we have given them.

And we certainly want to recognize for the record and tell you we very much appreciate all the hard work you have put in with us and for us and on our behalf.

So we wish you all the very best. And thank you very much for being with us.

Now we'll get to work on today's session. All right. Thank you. Thank you very much.

(Applause.)

CHAIRMAN RYAN: All right. And at this point, if you want to make any comments, please feel free.

MR. THADANI: The only comment is yes to everything you said. Semi-retirement, little bit of this, little bit of that.

CHAIRMAN RYAN: Well good for you. That's great. May you enjoy it and do well.

Let me turn over today's technical session to Allen Croff, Vice Chair, who is going to lead us in the afternoon sessions. Allen?

VICE CHAIRMAN CROFF: Thank you, Mike.

By way of introduction of both this afternoon's session and something that is going to go on into the future, today we are going to hear from first Dr. Ray Wymer on the historical technical aspects of reprocessing. And then we will hear from NMSS staff on regulations concerning the licensing of reprocessing and recycle facilities.

Again, mostly a status in what is and a

little bit about what might be. That will lead up to the end of the afternoon where we will talk some about a proposed white paper that we would like to have developed during the summer that will be more forward looking in a technical sense.

That is to try to understand what the Department of Energy is planning or pursuing in terms of recycle, the technology of it as fodder for our deliberations sometime near the end of the summer or the early fall in preparing some advice for the Commission.

We also hope to hear from the Department sometime during the summer but we are still trying to schedule that. That is the rough plan forward but today is sort of a historical tutorial background-kind of an afternoon.

With that, our first speaker is Dr. Ray Wymer. A brief bio, Ray was at Oak Ridge National Laboratory for nearly 40 years, ending up as Division Director in the Chemical Technology Division, which had a lot to do with developing reprocessing in this country. He is also a former member of this Committee.

With that, welcome back, Ray. The floor is yours.

DR. WYMER: Thanks, Allen. It is good to see familiar faces out there after I have been away three years.

CHAIRMAN RYAN: You can use the lapel mike if you would rather stand and work that way.

DR. WYMER: Okay. Can you hear me okay now?

PARTICIPANT: Just fine.

DR. WYMER: Okay.

PARTICIPANT: Is it all right with the reporter?

DR. WYMER: Okay? Thank you.

It was three years ago that I retired from this Committee. And I'm happy to say that all of you look the same that I remember seeing when I was here before. I've aged a little.

This talk today is one that I initiated many years ago at Oak Ridge National Laboratory and gave it for a lot of years in connection with trying to inform people who were largely from the Department of State, CIA, AEC at that time, later on DOE.

And the idea was to give these people an idea of what reprocessing is so when they went out into the field or tried to do their work back here in the states, that they at least had heard the language a little bit and understood some of the words.

They were certainly not experts and you are not going to be experts, if you aren't already, after you hear my talk today. That is, to give an elementary, a very elementary discussion of the nuclear fuel cycle reprocessing in particular.

Allen Croff picked up after I quit. He could give this talk just about as well as I could, I think. Maybe better. He improved on it and I picked up on his improvements and that is what you are going to see today -- my early work plus what he added to it over the years. Plus maybe one or two other things that I have added since.

I should say that I am anticipating that I am giving this talk to people who really are novices in the field, who are very bright, but who have not necessarily been exposed to this particular branch of knowledge.

If you don't fall in that category -- I know some of you don't -- if you are a lot better informed than that, why the door is back there. We will be taking names as you go out.

Anyway, we will start off here. I'm going to try to give you, as it says here, a historical overview. Very simply, why should you reprocess?

Well, there are several reasons. Possibly not all of them are listed here. One is there are valuable things left in the spent fuel despite the fact that we may be storing it in Yucca Mountain. There are valuable materials to be found in the nuclear reactor fuel.

Another reason to reprocess, it has been in the past, to obtain fissile material for military use. Of course the reprocessing plant at Idaho Falls is closed so we are not reprocessing out there recycled material.

One of the important ones and one that is important for the future is in connection with the Global Nuclear Energy Partnership and that is to reduce the amount of waste that is stored in the high-level waste repository proposed, as I recall the NRC is very careful in all of its writings to refer to the Yucca Mountain Repository as the proposed Yucca Mountain Repository.

And by reprocessing and recovering the waste materials from the spent fuel, you greatly reduce the volume required to be stored in Yucca Mountain because the PWR are 12 feet long and, you know, about eight or ten inches across square. And so you reduce the volume and also you can take out the good fissile material.

And if you go farther into the future, into the Global Nuclear Energy Partnership scheme if that gets off the ground and really flourishes, then also you will be taking out some of the heat producing elements which also are space limiters, as you know, in Yucca Mountain.

And finally, if you reprocess you don't have to store or dispose of the fissile material.

This is a very limited list of the kinds of fuels there are out there. But these are principle U.S.-type fuels, past, present, and future. Light Water Reactor fuel is reprocessed overseas but, as you all know, not in the United States anymore. And it really never was although it almost was.

And there are two kinds of fuels that are present in large amounts, the light water pressurized water reactor and light water boiling water reactor fuels. And, of course, the Fast Breeder Reactor, there is reprocessing going on overseas. We never really got to reprocessing here in this country except for the little bit of reprocessing on EBR-II fuel out at Idaho Falls.

And the HTGR fuel, there is no reprocessing anywhere. And that is a tough fuel. I worked about ten years on that at Oak Ridge National Laboratory. And that is a pretty tough row to hoe, to reprocess HTGR fuels.

But they are being considered actively now again after quite a hiatus as a potential new power-producing reactor fuel. They go to very high burn ups. They operate at very high temperatures.

The advantage of that, of course, is several fold. Not only do you get a lot greater thermal dynamic efficiency by operating at a higher temperature, you get closer to 40 percent efficiency instead of about 30 percent efficiency, which is about a 30 percent increase or more in utilization of the heat produced.

And at these high temperatures, with high temperature gas cooled reactors you are processing. A great many industrial reactors require high temperatures for various kinds of chemical processes and other kinds of industrial processes. And currently you need these kinds of temperatures if you are going to go into a hydrogen economy and produce hydrogen thermochemically, which is one of the major considerations these days.

You not only can produce hydrogen by -- I realize this is not all reprocessing but am giving you the benefit of my vast knowledge -- you can electrolyze water from the electricity produced from reactors but also you can run thermochemical processes, most of which run at about 750 degrees centigrade.

So HTGRs have several promises. And they also can be used as burners for actinides although not as efficiently as fast breeder reactors.

So while we have had a checkered and unproductive history in reprocessing, the West Valley Plant up in upstate New York operated, you see there, for about six years. A small plant, it was fraught with problems.

There were leaks in the plumbing. They would run people in and out so -- bring them in off the street so to speak and let them operate the plant until they got their dose, then they would fire them and bring in another bunch. But still they reprocessed a fair amount of fuel and produced some other fuels besides.

The Midwest reprocessing plant, the GE plant, never got off the ground. They built it and decided before they ever ran it that they hadn't better run it because it probably wouldn't run. And so what they use it for now is they have a large storage pool. And they store spent fuel there at present.

And that was going to be a rather novel plant. They were going to use -- the final clean up was fluoride volatility which is a very efficient way to separate uranium from almost everything else because except for tellurium and a few things like that that there aren't much of in spent fuel, not very many elements form volatile hexafluorides like uranium does. And so it proves to be a very good way to do a final clean up of uranium.

And of course the -- what they used to call the AGNS plant, the Allied General Nuclear Fuel Reprocessing Plant at Barnwell, with a standard PUREX plant, it came along at a very inopportune time. That was the time of the Carter administration when he said let's set an example to the rest of word and not reprocess. And nobody else will either.

And, of course, he was a little wrong in that regard. And so they stopped at that point. And I think this is probably about when the NRC stopped having an active interest in licensing reprocessing plants.

And that was long enough ago, as you see, 30 years ago, which means that everybody who knew about licensing that plant has retired or died or both. And pretty much so -- you people are pretty much starting from scratch here in the NRC with respect to licensing reprocessing plants. So this little primer we have here today is supposed to at least get you off the ground.

This is the compulsory nuclear fuel cycle diagram that shows that the whole thing starts in a reactor, you generate spent fuel. You get into shipping, which is a thorn in everybody's side, then you get into reprocessing which creates a couple of streams of waste -- a waste stream and a product stream. And it can be two product streams depending on how you handle it.

And then with the uranium, it is still more highly enriched in Uranium 235 than is natural uranium by a couple tenths of a percent. And so it is worthwhile to put it back through an enrichment.

However, it has, in the course of being irradiated, it has built up some uranium 236, which you can only recycle a couple of times and then you get into some pretty neat neutron poisons. And so you can only go around this loop a couple of times because of the uranium 236 buildup, and then you would start paying a penalty. But the first time through or two, you can re-enrich.

This also is sort of a troublesome cycle because some undesirable elements like technetium tend to recycle and so after a while, you begin to get a little bit of radiation in this part of the recycle which is not desirable.

Anyway, that is the whole cycle more or less. You can, of course, make -- well, I'll get to that later.

I've got about three slides that say they are the elements of the nuclear fuel cycle. Transportation is on there. It is not formally part of recycle but it is important. And if you don't transport it from the reactor, you can't reprocess it. Then, of course, there is onsite storage of the spent fuel, typically in storage pools. I'll say more about each of these things.

You have the so-called head end processes which involve treating the elements so that you can extract the fuel material. If you chopped it up or knocked the cladding off, the transfer of these pieces which you will see pictures of later to a dissolver and you dissolve them up to dissolve the fission products, dissolve the uranium, dissolve the plutonium, dissolve the higher actinides, what few there are.

And then you put it -- typically you take the dissolver solution and put it into an interim storage tank where you do the first real analysis. This is where you start running your for real material balance analyses.

You know pretty well what you have got from the exposure records on the fuel that the reactor sends you. But they are not nearly as precise and as complete and good as the analysis of the dissolver solution. So this is what you analyze and you track the fissile material with taking samples out of that tank.

Then you go on and you transfer the stuff out of the interim storage tank into the separation process equipment, which I will say quite a bit about, where you separate the uranium and plutonium. This is the way it was done, the way it is done in the present, and not necessarily the way it will be done entirely in the future.

You separate the uranium from plutonium from the fission products and other actinides, typically those plutonium and americium by solvent extraction. Then you have the uranium and plutonium together and you separate the plutonium from the uranium by adjusting conditions in the system. And I will say more about that. I'll say more about all of these.

When you convert the uranium and plutonium to the oxides if you are to prepare fuel from them. And that is being done overseas to some extent, and they you store the products onsite until you get ready to ship them off to the fabrication plant. And you store the waste fission products.

The high-level wastes are typically stored as a solution. It starts out as a nitric acid solution. We store that in a tank. And typical tank volumes, waste tank volumes, are a million gallons. They are good sized tanks. And a lot of solid waste are produced in the course of doing a reprocessing operation. And so those are stored also until you dispose of them.

Well, okay, let's go back up to the front end again and talk about transportation. And that's, as I said earlier, a troublesome operation in that people don't want spent fuel transported. They would just as soon it would magically go from the reactor to the reprocessing plant and not be on the roads or on the rivers or on the rails.

And the elements are large and the

shielding is heavy. And a 100 tons is not an unreasonable weight for a waste package loaded with fuel elements. And it is subject, of course, to federal, state, and local regulations. People have it pretty highly regulated. It is not part of reprocessing but it is very important.

This is one of many kinds of spent fuel shipping casks. You see the fins, the cooling fins to get rid of the heat. These spent fuel elements, even though some of them may be five, ten, 20, 30 years old -- they have been stored in the pool a long time some of them, they still are undergoing radioactive decay. And they store quite a bit of heat -- they generate quite a bit of heat.

And it is disposed of typically by air cooling. In some of the containers, it is forced air. Most of them it is convection.

There is another example, a little bit more detailed. If you can't read it, this one has impact fins which means you could drop it and something absorbs the shock. And this one has neutron shielding. Typically the neutrons are as much of a dose as gamma rays outside a spent fuel container. And sometimes more.

And this particular one says it has

uranium shielding material or the metallic uranium, which is a very good gamma ray absorber because it has a high atomic number and a lot of electrons for the gamma rays to rattle off on and lose energy as heat.

And there it is loaded on a rail car. I'm not sure I've mastered the modern age here yet. But these are -- this is a picture of a PWR fuel assembly. As you can see, you can't -- it doesn't tell you it is 12 feet tall but it is. And there are individual pins in there, fuel pins. They are zircaloy clad. And they are about a half inch diameter.

And they have uranium dioxide pellets which are a carefully crafted thing. The production of these pellets is a white glover operation as is the fabrication of the fuel element. I don't think a survival room in a hospital is any cleaner or worked out more carefully. Maybe not as much.

And you can see here is an end plate that the fuel pins stick into.

This is what assembly looks like. This is the spring that holds the pellets together. And also they provide a gas plenum space above and below the elements. So during radiation, fission product gas like xenon come off and they accumulate in these plenum areas.

And of course when you break open these things for reprocessing, you release that gas. That becomes part of your off gas problem.

Well I mentioned high temperature gas cooled reactors. This is a picture of what was a typical fuel element from the Peach Bottom reactor which operated out at Fort St. Vrain just outside of Denver for a number of years. This is all solid. That is about 14 inches across from the one flat place to the other.

These holes, maybe you can see, all through the top, little holes are rare sticks of graphite put in pencils of graphite about as big around as your finger. And in each of these pencils of graphite are millions if not billions of tiny spheres which are less than a millimeter typically in diameter. And that is where the fuel is.

So you take typically a metal tube and you pour all these little tiny sphere in there that have uranium 235 in them -- that's what these have -- 93 percent enriched, incidentally, and then you force pitch down into that tube and it surrounds all these little micro spheres.

And it is those pins then that are lowered into this large graphite piece -- block. These other holes are control rod hole or gas flow cooling holes. One or the other.

The micro spheres are, as I said, a millimeter in diameter. The actual piece of that tiny, tiny sphere that has fuel in it is about half that diameter. They are very small, maybe 400 microns. And then that is surrounded by pyrolytic carbon which is deposited much the same way you get soot in your chimney. You take gas like ethane or ethylene and you thermally decompose it and it coats everything. Of course it coats all the equipment as well but it coats the little spheres.

Then you move into another device. And you put in methyl silicone -- dimethyl or trimethyl silicone. And you heat that up and that decomposes into silicone dioxide which coats another layer around the spheres. And that is what really is a containment vessel. That little tiny silicone coating all these spheres is equivalent to that zircaloy cladding on that 14-foot long fuel element.

And then you put another layer of carbon on top of that. And that is the out shell. That is the protection for the inner stuff.

The inner carbon coating, the innermost layer of parliamentary deposit carbon is porous.The outermost layer is impervious. The innermost layer is porous to, again, to serve the same function that the plenum -- that the gas space above the fuel always did. It is a place for fission gases to accumulate without bursting that little sphere wide open and releasing the fission products. So that is a HTGR fuel element, none of which have been processed. But there is a lot of interest in HTGRs. And they probably will come along.

But, of course, we also have fast breeder reactors. This is -- it is more similar obviously to the water reactor fuels than is the HTGR. These are the fuel pins here. Typically they are stainless steel clad. You don't need to use zirconium. They use zirconium in light water reactor fuels because the neutrons are thermalized and they would be captured too much stainless steel.

John?

MR. LARKINS: Yes, in the forte varying fuel didn't you have both biso and triso?

DR. WYMER: It depends on whether or not you are going to have a blanket, John. The triso coated is the fuel particles. But if you are going to have a blanket like we were talking about having, it was a thorium breeder reactor. And they had a thorium blanket of those same kinds of graphite blocks.

And the thorium oxide or thorium oxycarbide is really what it was, they didn't make a pure carbide, that was coated with silicone and then with a graphite coating on the outside. But that was for the breeder blanket.

It's not likely, under most current plans although it may come along, that the next generation of HTGRS will probably --

MR. LARKINS: I just seem to remember -- I thought they had both types in --

DR. WYMER: Yes, they did. But one was the breeder blanket. And it was going to be a thorium fuel cycle reactor, which would be a really tough row to hoe. I spent about 10 years working on that particular concept.

And with thorium, a thorium breeder, you make uranium 233. Unfortunately, uranium 233 cannot be made without making uranium 232. Uranium 232 has a gamma that won't quit. And it is there in about 800 parts per million. And that's more than enough. It makes everything remote -- fabrication and everything else is remote at that point.

MEMBER WEINER: Is the HTGR fuel like the fuel for the pebble bed modular reactor?

DR. WYMER: Exactly the same except instead of putting in those little microspheres, they are exactly the same. So they are putting them in these great big block -- you surround them with a layer of graphite. In size, they are between a golf ball and a tennis ball. And you can throw them down and they bounce. They are tough.

The pebble bed reactor was an interesting concept because you have to keep moving the pebbles. And so you have a great big tank with a conical bottom and you put all these balls in there.

And, of course, they move at different speeds. They move down the side faster than they do down the middle. And so as they drop out the bottom of this cone, you count each one. And you decide then whether that one goes back into the top again or tat that becomes waste.

So the pebble bed reactor, that's the one that is currently being considered most accurately as a matter fact, you probably know, for a reason I don't understand. I guess because there is more experience with them. They had the -- the Germans bought the AVR and the HTGR both, both pebble bed reactors, one bigger than the other. And that is the direction that the current HTGR design is going rather than to these prisms.

But anyway, these are stainless steel clad, I was saying, because the neutrons in a fast reactor are fast, hence the name. And they are not well captured in steel. And, therefore, you don't have to worry about the neutron parasitic reactors gobbling up the neutrons that you would sooner have making fission reactions real rather than being lost other products.

CHAIRMAN RYAN: Ray, one other question. It is how things overlap. I mean I've heard that the HTGR fuel, because of its high burnup raises challenges in transportation, a topic you Touched upon earlier. And I guess what I'm thinking about as you are talking is how has this been treated as a system?

You know there is optimization from a reactor point of view, how you produce electricity, power, steam whatever it is, how do you optimize it from what you generate as wastes that need to be further processed in some way.

CHAIRMAN RYAN: I have never seen a study on that, Mike. There may be some going on today. I would hope so in connection with the plans that say South Africa has it for building an HTGR. But I never have seen a cradle to grave --if you could opt the aryan sites into that kind of optimization strategy or what you would look at if you were going to say, well, you know for this reactor or that reactor it is going to produce these wastes. And if you did it this way, you would produce uglier waste and if you did it that way you would produce less ugly waste.

I mean the uranium 2336 example is one that you don't want that around if you can avoid it.

CHAIRMAN RYAN: I would advise people to stay away from Detroit and the fuel cycle. There is a lot of uranium right here. You don't need to go to foreign for a long time.

DR. WYMER: And I'm like you. I don't know of any comprehensive or thorough studies that have been done. I'm looking for them. And I hear a lot of talk about, you know, interactions between transportation and fuel and, you know, toxicity of this and reprocessing of that.

And I'm really kind of interested if you have any insights as to pluses and minuses as you go through your talk. Those would be real helpful.

CHAIRMAN RYAN: Okay, I'll try to keep it in mind.

DR. WYMER: Okay, thanks. Yes?

MEMBER WEINER: The South Africans are

currently working on a transportation design for the pebble bed.

DR. WYMER: Are they? I wasn't aware of that.

MEMBER WEINER: Yes. We just had a tour of the pebble bed fabrication facility.

DR. WYMER: Oh, did you. I bet that was fun.

MEMBER WEINER: Yes.

DR. WYMER: I would like to do that.

Well, as all of you in this room know, the present storage is at the reactors, mostly in pools, some on concrete pads but that is where it is. And, of course, some of those sites have been storing fuel for a lot more than five years because there is no place else to put it. So they just started. An those reactors have been running some of them 40 years.

At the processing plant, typically you unload the fuel from the shipping containers and put it down into the pool of water. And this is s picture of a UK pool. I'm afraid it doesn't show you much. This is where the pool is. That is the water. And there are tracks for a crane to bring the casks.

You will see more of this in a video that I'm going to show later on so don't worry that you can't see much of this.

Anyway, you get some notion that it is a relatively equipment-packed area. It is not a simple -- nothing about reprocessing is really simple.

Obviously these things are extremely radioactive so all the operations are done by heavy shielding, typically using cranes and crane-operated manipulators and remote operations from outside the cell.

Fuel elements are chopped into small pieces. The PWR fuel, that 12-foot high thing as you will see later, is treated very poorly. I told you they built it like a white-glove operation and they treat it like a foundry. You know they just -- it almost breaks your heart to see what they do to that carefully fabricated fuel element. And the fission product gases are, of course, released and come off into the off-gas system.

Well, the way they cut it is with a -- just a big, massive, brute force operation. They take the fuel element, and you will see this, too, later, and they shove it in from the side. And they come across with a sheer that just crunches off about two inches of it. And there is a great squealing, creaking, grinding operation as they chop this thing up.

And this is iridium dioxide inside the fuel elements. Inside there is a zircaloy cladding. And it crumbles, of course, and falls out. And the pieces of zircaloy get all mangled and twisted. And some of the outside gets trapped inside. And it is a brute force operation.

And here is what it looks like -- some of the typicals of it. This is part of the oxide pellets. Those are the segments of cladding. You chop it up like this so you can get at it.

You only have an inch to go from each end with acid that dissolves the oxide. So you don't -- so you can get it dissolved in a finite time, reasonably sure you've got it all dissolved out of those pieces. So you cut it into pieces as long as you can get away with instead of dissolving everything outside the chunks.

That material you just saw is put into a dissolver. And I'll show you pictures of that later. And you can either chop right over the dissolver and drop it directly in or you can separate it and move the stuff separately into the dissolvers.

This is one version -- and there are as many versions of this as there are clever nuclear engineers and design engineers who want to come up with a new dissolver design. And there are lots of dissolver designs. There are some that are rotary, some that are continuous, up-screw types. And there is this type. You drop the fuel down into here. You put nitric acid in, dissolve the fuel, and, of course, you get the off-gas. This silver zircaloy trap is to collect the iodide. There are not many things that form insoluble iodide compounds. And so the silver iodide is relatively insoluble and it is a high surface material and you catch the iodide on the silver.

The rest of the off-gas goes into the off-gas treatment system. And, of course, you have to have a way to take off the spent fuel. So you have this basket which would take off the fragments of cladding. This basket allows you to do that.

You -- notice this has cooling coils as well as heating coils. When the reaction starts out and you start dissolving this uranium dioxide, it gets pretty hot. And it boils and froths and foams.

And they really want to control the rate of dissolution so you control the temperature by cooling and keeping it down to a reasonable operating temperature. Now as it gets dissolved, well then you have to heat it to get the last little bit dissolved.

This is another type of dissolver. This is where you drop the fuel pieces in. They are carried along in this spiral rotary thing. Balls come dropping out here. And the nitric acid solution which you put into it goes counter current to the direction that the fuel is going, which means you get a lot of good contact type with flush acid coming in. As you have more nearly completed the dissolution, it is harder and harder to dissolve the stuff out of the spent fuel -- out of those chopped up fragments.

You have fresh nitric acid solution hitting that. The nitric acid solution gets used up more and more and it is fairly well used up by the time it contacts the incoming fuel pieces. So they go counter current and you get a lot better efficiency on dissolving.

The problem with these dissolvers are in the seals. It is hard to maintain a seal when rotating equipment in a concentrated nitric acid solution. So these have that operating problem.

Well, as I mentioned earlier, the interim storage place after your dissolution is really the first chance you have to get an accurate analysis of the fissile element content of uranium and plutonium and anything else you want to look for. And that serves as a basis for your material balance and the subsequent reprocessing.

You have to adjust the acidity and the concentration in order to optimize the processing requirements. So you make a feed adjustment. And then depending on the type of equipment you use, you may or may not need to do a feed clarification. If you use -- and I will show you one later -- if you use what are called pulse columns, they are very tolerant of fine materials and solids that might come through.

If you use what called a centrifugal contractor, which has fast rotating parts that are spaced very close together, then you don't want any solids. You have to do a feed clarification in that operation.

What I've just showed you are the dissolvers. And one other thing that happens when you dissolve up these materials in nitric acid, you produce nitrogen oxides. You start with HNO3, which has pentavalent 5 valent nitrogen and you wind up with 4 valent and 2 valent nitrogen oxides. And they are recoverable. You can re-oxidize them in air and produce more nitric acid which is recycled through the plant so you use your nitric acid as completely as you can.

Ruthenium is not a volatile by itself but ruthenium tetroxide, RUO4, is a very volatile compound. However, if the fuel is long dissolved and it has been laying around 10, 20, 30 years, all of the -- not all but a significant amount of ruthenium has decayed. And the only ruthenium you have left is basically non-radioactive ruthenium or a very low level of radioactive ruthenium.

But in short cooled stuff, especially in fast reactor fuel reprocessing, that becomes a consideration. Iodine is always a consideration, of course, because it goes to the thyroid. And you don't want it out there amongst the babies.

And krypton is a problem unto itself because that is a noble gas. That means it doesn't react with anything to speak of. And there are special pieces of equipment that have been developed many years ago for moving krypton, none of which are in active use. But if we go to a lot of reprocessing and this becomes a big deal. And probably some recovery of the krypton will be required. At present, it is not.

And sometimes there is a Carbon 14 present. And if that is the case, then you have to do something about trapping whatever carbon dioxide comes off which in these kinds of fuels would be small. But in HTGR fuel reprocessing, it could be very large because of all the graphite you've got to get rid of. Typically you burn it.

MEMBER WEINER: Would you use cold traps for krypton and CO2?

DR. WYMER: That is kind of what you do, Ruth. It is basically one of those cold trapping operation. That is right. You just drop the temperature way down and you condense it. That's one of the ways you can do it.

With any of the other large solutions, you really carry out the separation, you adjust your concentration. Plutonium in this process exists in two valent states, the plus three and the plus four. And others. Plutonium is a weird element because you can have three valent states coexisting simultaneously and they can live with each in significant amounts. You know they are not just trace amounts but they are there in percentage amounts, all three valent states at the same time.

Only the Plutonium 4 really extracts good. So you have to do a valence adjustment. You have to adjust everything to the Plutonium Plus 4 so you get good removal of it. And that is what is done in this step.

This is kind of an important graph in that it tells you how the radioactivity decay. This is for high-level waste but that is the same as in fuel elements. How it decays with time.

And as sort of a reference point, the radioactivity of the original ore is indicated by this line. So if you get rid of that, you are getting to where people shouldn't be too upset by it. But you can see that the decay drops off very rapidly. This is years so if you hold it for 100 years, you are down here from about ten to the seventh down to ten to the fourth, a thousandfold reduction in the radioactivity.

So storing is a good idea -- particularly storing for at least five years before reprocessing would get you out here a ways. And if you can store it for longer than that like they are talking about Yucca Mountain, maybe 100 or 200 or 300 years, then you really do bring it down a lot before you close up the mountain which makes it really -- Yucca Mountain is a non-retrievable storage facility.

CHAIRMAN RYAN: Ray, let me, if I may, ask a question about that graph.

DR. WYMER: I'm not sure I could go back

to it.

CHAIRMAN RYAN: This group's total radioactivity fission products and actinides, and I sure understand it on that basis, but this is one of those points of overlap for me. When you think about performance assessment, you think about Carbon 14 and Neptunium, and Technetium 99. I wonder if we've got the same picture when you consider the mobile risk importance --

DR. WYMER: No, no, not at all. You're seeing many of those plus Yucca Mountain waste, and no, the toxicity, as you know, out here ten to the fifth years gets controlled by Neptunium and the Technetium. In the very short term, of course, it's controlled - you know all this, but you're asking for the benefit of other people. This is not - Cesium and Strontium are the controllers up there. As far as the hazard is concerned, the actinides, they abide. They're very long-lived, typically, and they become in the long run - Neptunium is one of them - they become a controlling radioactivity along with Technetium, and to a much lesser extent Iodine 129, but that's down. I don't know whether I'm answering your question or not.

CHAIRMAN RYAN: Well, you have. You sure

got to the summary from that perspective. The other kind of argument I've seen people talk about with this sort of a curve, not exactly the same, is while, if we reprocess the actinides go somewhere else, and all that. But at the end of the day, it's a zero sum gain.

DR. WYMER: That's right.

CHAIRMAN RYAN: If it's going out of a reprocessing plant to some other waste treatment line versus straight into Yucca Mountain, I think this is where my root question that I asked at the beginning comes from - how does it work as a system?

DR. WYMER: Well, the other thing that we haven't said much about is that part of the Global Nuclear Energy Partnership is you build a fast reactor some place about 30-40 years out into the future, and you take these - like all the UREX processes do, depending which UREX process you're talking about, they take one or more actinides out in a separate stream, as well as the Cesium and Strontium out of a separate stream. And those -- the actinides then are planned to be put in the fast reactor. And in a fact reactor, as you know, they'll have enough cross section that they will fission, and even the non-fissile actinides fission if you leave them in a fast reactor long enough, and that's in terms of fission products. And then you're dealing with the fission product waste instead of an actinide waste.

CHAIRMAN RYAN: But, again, I think you've hit the key point, is that it really relies on several modified or even new components of a total system to make sense out of all that.

DR. WYMER: It does. Well, if you're from Los Alamos you say I'll stick those actinides in a particle accelerator. If you're from any place else in the world, you say I'll put them in a fast reactor and burn them up. So that really -- it's a zero sum gain, as you said, unless you do that.

CHAIRMAN RYAN: Right.

DR. WYMER: If you convert them from actinides by burning them in a fast reactor --

CHAIRMAN RYAN: It's still a zero sum, though, because if you have a fast reactor and you're fissioning those --

DR. WYMER: But they're fission products instead of actinides.

CHAIRMAN RYAN: But there's a cost in terms of occupational exposure in terms of risk, risk assessment for that fast reactor, so you may end up with a different profile --

DR. WYMER: Refabricating the actinides.

CHAIRMAN RYAN: All of that, so all of that has to be taken into account.

DR. WYMER: Absolutely.

CHAIRMAN RYAN: And your point is if everything goes right, you've converted a long-lived radionuclide to a shorter lived one.

DR. WYMER: That's exactly right.

CHAIRMAN RYAN: Okay.

DR. WYMER: That's the reason for going from lactinides to actinides, that and the heat in Yucca Mountain. Really, that's right. There's no free lunch in any of this at all.

Okay. This is -- if you ever saw a simplified diagram of a complicated process, this is it. This is sodium hydroxide decladding. Well, that's only used if you have aluminum cladding on the fuel. If it's zircaloy or if it's graphite, or if it's stainless steel, this is replaced with shearing, that big mechanical shear that chops the stuff up. Anyway, one way or another, you cut it up so you can expose the uranium dioxide that's inside the spent fuel. You dissolve it with nitric acid, you've got the off-gas problem to deal with. You separate out the fission products, and someplace - and you send them over here into waste. You separate the plutonium and uranium, you remove the uranium from the plutonium, or plutonium from the uranium, whichever, and you put the waste into a tank concentrated by evaporation, and these days the plan is that you vitrify that nitric acid solution, make a bar of silicate glass out of it, recover the acid somewhere here. And if you're going to do MOX fuel fabrication which is being practiced a number of places in the world, you do that. So this is a very simplified block diagram of some of the operations, and it's not -- take it for what it's worth.

VICE CHAIRMAN CROFF: Ray, before you go on - with reference to that diagram, you might elaborate just a bit on the head-end for HTGR fuel, how it differs.

DR. WYMER: Okay. I don't have a picture of that, but if you have these graphite balls, for example, you crush them up, and you put them through a grinder, which is -- after you crush them, the gap of which is such that it will remove the graphite that's adhering to the little balls, but will not crush the balls. Now the balls are hard. You may take the outer layer of graphite, that non-porous outer layer, you may break some of those, but the silicate carbide containment vessel, which is only half a millimeter in diameter, that is not supposed to be fractured. So the idea is to remove as much carbon as you can, without losing any of the fuel stuff that's inside that little ball. And then that graphite becomes a waste, and there's quite a bit of it. And then you have another process whereby you grind up the liberated silicon carbide coated kernels which have the uranium dioxide or uranium carbide, or uranium oxide carbide, depending on what you make inside. You grind those up, and you dissolve that in nitric acid.

When you do that, you're not home-free, because it turns out when you dissolve uranium carbide or uranium oxicarbide particles, you make organic acids out of the graphite. Some of these are powerful, complex agents for uranium and plutonium, and so you have to have a process that is more than competitive with the complexing action of the mellitic gases, the various other organic gases that are forming complexing agents. It can be done, and it has been done, but it's not like falling off a log, it's not like dissolving UO2 in nitric acid. You've got a little work cut out for you, but you could do it. It's kind of messy. Is that what you wanted?

VICE CHAIRMAN CROFF: Yes.

DR. WYMER: Okay.

MR. FLACK: Ray, I'd just inject - the prism blocks have fuel insert, which makes it less of a waste, I guess, than the pebble bed, which includes the entire graphite in the ball. Right? Do the fuel elements inside because you can knock those out.

DR. WYMER: No, because -- nobody had come up yet, at the time we stopped working on it, with a final good way to move those sticks from the holes that they were pushed down into in that graphite block. There were various things proposed, like drilling. Of course, that breaks up the silicon carbide particles, and there's more graphite than was there in connection with that stick of graphite in which the little particles were contained, so there's probably a little bit more graphite actually from that process than the other.

Another way was to put kind of a brush, steel brush down in the hole. Another way, for those of you who are old enough and remember the Los Angeles problems, friends of mine called it the WATTS process, W-A-T-T-S, burning the whole block. Remember when there was a riot in Watts and they burned the whole block.

MR. LARKINS: That's what I thought they were talking about. This was the PGX graphite?

DR. WYMER: I'm not sure what that is.

MR. LARKINS: Yes. That's the block.

DR. WYMER: Oh, the *(2:00:53) fuel off.

MR. LARKINS: Yes, chop it and burn it.

DR. WYMER: Yes. They were going to grind -- one approach was to just break up the whole block and burn it, but if you ever tried to burn graphite, you know, it's hard. A solid piece of graphite, of theoretically dense graphite, you've got hold a blow-torch to it to make it burn. You've got to keep holding it there. It doesn't suddenly catch fire and burn, so it's not real simple.

MR. LARKINS: I wasn't old enough, but I --

DR. WYMER: No, you weren't. You don't know about burning the whole block. He was young. No. This is something I stole from back in the 70s. Some of you remember INSEC where this is the flow sheet that was turned out in one of the reports at that time. This was a 40 mega watt day per ton burn-up with only a three-year cooling time. The significance of the cooling time is that determines the amounts of some of the important fission products that are present, some of the shorter-lived fission products. Take the spent fuel in, put it in buffer storage. This is based on a thousand ton storage, which is a year's worth, 250-day operating year. Burn four tons a day, you go through a first extraction, and that separate the fission products from the uranium and plutonium. Then you do uranium and plutonium separation, you clean up each of those streams down there. Fission products and whatever else you didn't quite extract - nothing is perfect, nothing is clean. There's always a little bit uranium, little bit of plutonium lies up here. What you shoot for is less than a tenth of one percent of the plutonium, you like to be .05. And then the solvent that you use for solvent extraction, because of the high radiation, undergoes some radiolytic decomposition, the gamma rays and the beta decompose it to tributal phosphate, which is what you use, becomes dibutal phosphate, monobutal phosphates. Those are very strong complexing agents for uranium and plutonium, and if you cycle those back around again, they stay in the aqueous space, and I'll say more about this in a minute, but they stay in the nitric acid phase, instead of going into the phase that contains uranium and plutonium, and they will complex and hold it in the nitric acid phase which represents a loss to the process, so you have to do a solvent recycle, which produces a waste from your recycle operation. And then you have various other waste streams. Then you wind up, ideally, with your plutonium and uranium separated, products which you can later mix together in a different ratio to produce MOX fuel, if you want to. That's mixed uranium plutonium oxide fuel.

Okay. The process that's used to carry out this magic separation of uranium and plutonium from the fission products is a solvent extraction process, so-called. This is where I assume that you don't know anything. You take two liquid phases, one of them is tributal phosphate dissolved in something like kerosene, a nice pure kerosene, maybe 30 percent by volume is tributal phosphate, which is an industrial plasticizer. And the rest of it is kerosene, 60-70 percent is kerosene. And that's immiscible in water, and you shake that up with a nitric acid solution that you got by dissolving up the uranium and the spent fuel. And if you shake it up real good one way or another - I wouldn't advise a separatory funnel - and the uranium and plutonium are extracted, a little bit staying behind. And I'll show you more about that in a minute. And then in the aqueous phase remain the fission products.

Now what you do is this is not a really good clean separation. Some of the fission products stay with the uranium and plutonium, some of the uranium and plutonium stay with the fission products, so you take those two phases, you take the TBP phase that has the uranium and plutonium, and you shake it up with some more nitric acid, clean or nearly clean nitric acid, which back extracts the fission products out of the uranium and plutonium phase. And you shake the fission products phase that has some trace uranium and plutonium with it, with the tributal phosphate phase, and that extracts the other remaining traces of uranium and plutonium out of the fission product waste.

Now you do this in a fairly complicated way, which I'll explain to you as best I can in a minute. It isn't just that -- it's not exactly what I just said, but the effect is the same. Okay. Here's your kerosene and tributal phosphate, and there's your - as you can see, we're left uranium and plutonium back there along with the fission products, and the plutonium 4 and the uranium which is there is uranyl ion, uranium plus 6, goes up into the kerosene in the TBP phase, and that's just to give you a very simple picture.

Now don't get lost in this one. This shows you how much uranium and plutonium, and other things, are extracted as a function of nitric acid concentration. And as you can see, the higher the nitric acid concentration, the better these things are extracted. But you can also see that the distribution coefficient, which is the ratio of the concentration of uranium or plutonium in the aqueous and organic phases, that's what the distribution represents, the ratio of the concentrations. It starts out here at about 1 molar, about .1 for plutonium, which means you're not extracting it, 90 percent of it is staying in the aqueous phase, so you run the acidity on up here a little bit to about 4 or 5, and then you see you get above 1, so 1 means that half the plutonium is in the aqueous phase and half is in the organic phase, not too good. But if I now take that and extract it again, I'll get a half of a half left behind, and a half, of a half, of a half, so I do that seven times, I got over 99 percent of it extracted.

And you see the fission products now, ruthenium is an anomalous behavior, it goes down. Here's plutonium 3 - I said you had to get it up to plutonium 4 - you can't extract plutonium 3 worth a darn. It's way down there, only a thousandth. Zirconium extracts, and you scrub that out. That's one of the fission products that you take out by taking the organic phase and hitting it with 4 or 5 molar nitric acid, which keeps uranium and plutonium in the organic phase, but takes the zirconium out, so you can get the zirconium out good.

Then you see the rare earths which are a major component. That's lanthanum and cerium, and gadolinium, rare earths are not extracted hardly at all.

MEMBER WEINER: The plutonium 4 dissolved actually, or is it as the intrinsic colloid?

DR. WYMER: Yes. No, it dissolves. It forms plutonium 4 nitrates dot 2 TBPs or something. It's an actual adapt of compound. It forms a real species, just as the uranium does. They form an addition compound with tributal phosphate. Yes, you've got to worry about colloids, but not at 4 molar acid, but you get down to say .3 molar acid, then you start worrying about plutonium colloids.

Well, this is a pulse column. This is the workhorse of the whole separation process. You bring the tributal phosphate dissolved in kerosene here.

It's lighter than water and lighter than nitric acid solution, so it comes up the column. You bring in your fume from the dissolver at the top of this column, and it falls down. These things here are circular plates about like that, can't get any bigger than that because you get criticality problems, and there are a bunch of holes punched in them. And as the organic solvent goes up, it has to go through these holes. And is it does, of course, it goes through, bloop, bloop, bloop, makes droplets. And that gives you a high surface area, gives you a lot of area of contact so that you can extract the uranium and plutonium easily out of the down-coming aqueous feed.

Once again, the freshest best extracting power TBP is at the bottom where you need it, because that's where the plutonium and uranium are the most dilute, so you get the highest extraction power where you need it the most, because it's harder to extract dilute material than it is concentrated material. So these things run counter-current to each other, so you get these multiple stages. You can see here, we've got one, two, three, four, five, six, seven, twelve, thirteen, fourteen - in this particular picture fourteen - that's about the right number you have, anywhere from twelve to sixteen stages. Well, you know, seven stages you got over 99 percent, you got another four or five stages here, so you get a very complete extraction. You can get about 99.95 percent of plutonium in a well-run plant. They didn't originally when they started, but they do.

In order to help the system along, there's a little pump here that goes like that, and it pushes on the organic phase, it jerks it up through the pulse plates to give you the high surface area to give the efficiency of extraction. This shows you, if you could see over the table, one of these perforated plates. So that's the heart of the process.

Now there are other kinds of contactors, as I mentioned. I said that this is the one I told you was tolerant of fine particulate material. All it has to do is get through that hole, which is a pretty fair size. It's a millimeter or so, maybe a millimeter and a half, so you don't get a lot of dirt hanging up in it. There's that kind of device also on the Colorado Plateau for when they were mining and milling uranium, that and mixer settlers, because they would handle dirt - you can actually put in dirty solution of ore, dissolved ore through there, it would go through.

This is the centrifugal contactor, which I mentioned. It's a cream separator. It spins and slings the heavy phase to the outside, which is the water like phase of the tributal phosphate. It is pushed in by the water going out. The tolerance is close, so you can't tolerate any dirt. The advantage of this thing is it spins like mad, and it's a lot faster than a pulse column. A pulse column goes chunk, chunk, chunk, like that, as it pulls things through the pulse plate, but this thing spins and it does a very fast separation, fast extraction, fast phase separation of the two phases, and you could have a much smaller plant with this kind of a contactor than you can with a pulse column.

The drawbacks, of course, are it is a sophisticated, complicated mechanical device spinning at high speed, but they are used, and they're used successfully. There's not much else to say that can be said simply about it. They are used commercially on a large scale. One thing I ought to say, too.

One of the reasons for going to these, besides the throughput, is that they are relatively very small, and about a third of the cost of a reprocessing plant is in the concrete and the shielding. That's what you pay for. Because if can decrease the size of the cells that you have, the hot cells that you have, the shielded cells, you're a lot of money ahead. So it's two things, throughput and cost.

This is an actual bank of eight of them, there's four on this side, four on that side. They're commercially available in that size, or commercially available a lot bigger than that.

MR. LARKINS: Ray, in terms of the amount of material that you can process in those two, what types of rates, how much material can you process in a time?

DR. WYMER: You could probably - what you just saw there, probably close to a ton a day I would think, through eight contactors spinning at the rate they do. And they really put it through.

Okay. Well, this is just a list of the kinds of things you have to have in a reprocessing plant. You have glove boxes where you can deal with small amounts of radioactivity. You have hot cells where you do reprocessing and handling of materials, and other than reprocessing operations where you have a lot of radioactivity, say some kinds of waste. And the actual reprocessing plant, you have maybe two and a half, three feet of shielding around the reprocessing material were the very hot material comes in. Glove boxes are used for a variety of things. You can use them for working on equipment, anything you need to do hands-on that's not highly radioactive, they all have an off-gas system that they're hooked into.

Canyon is the name typically given to a very large scale reprocessing plant because they look like a canyon. You look down them, and there's these big walls, and you'll see a picture of it here in a little bit, so they call them canyons.

Now this is a line of hot cells. This particular line I think is probably ORNL. It looks like the TRU facility, to me, at ORNL. And these are hot cells, and these are the manipulator controls. People do things here that -- the motions here are reflected inside the hot cell by simple grasping manipulators. And it's a job that requires a good deal of depth perception on the part of the operators. And it takes a lot of training to do it well.

These are glove boxes, that typically people sit in front of these things for hours at a time with their hands in these gloves that push into there, and some of these gloves are very heavy, some of them are lead-lined. They have ground up powdered lead in them for gamma shielding. You can imagine working four or five hours in lead gloves, develop strong arms. There's part of the off-gas system.

MR. FLACK: Ray, is the robotics taking over in this area, or is it still --

DR. WYMER: And awful lot of robotics, particularly the French have really pushed the remote operations of robotics, yes, to keep the doses to their operators down, and it gives you a lot of precision, too. You'll see some of that in this tape that I'm going to show shortly.

This is the front of a hot cell. Again, the one at British Nuclear Fuels Limited, so you see the windows that they look through.

Now video - we've got two here, one of Magnox fuel being processed, another of oxide fuel being processed.

(A film was shown.)

DR. WYMER: Your handouts said it's a video of processing at Sellafield. There's a segment on there about processing at Sellafield, but I don't think it shows you enough more to warrant taking the time to show it to you. You saw the reprocessing plant, which is a more modern one that you've seen here in France.

CHAIRMAN RYAN: Actually, it would be interesting to compare the two.

DR. WYMER: Okay. Can you take it back to the beginning? It's the first segment on that tape.

PARTICIPANT: Have you started seeing it already?

DR. WYMER: I'm sorry?

PARTICIPANT: Have you already started looking at it?

DR. WYMER: No, no. All of this was France, so what you'll see now is Great Britain.

PARTICIPANT: The very beginning?

DR. WYMER: Yes, the very beginning.

PARTICIPANT: Why did they wait two years before --

DR. WYMER: Two years is still pretty hot at two years. Five is more typical.

CHAIRMAN RYAN: Ray, a couple of the drivers from two to five years is some of those ruthenium isotopes, are they not?

DR. WYMER: Yes, the half-life of some of those is long enough that there's still some there at two years.

CHAIRMAN RYAN: I think some of the other, if I recall, is iodine and some of the other things that are environmental release questions that tend to be gone at five plus years.

DR. WYMER: Although, the iodine 133, of course, 131 --

CHAIRMAN RYAN: 131 is long gone.

DR. WYMER: Eight days half-life.

CHAIRMAN RYAN: Yes, that's long gone.

DR. WYMER: Yes, the 139, of course, was ten to the seventh years, something like that. It's going to be around a while, but there's two sides to that radioactive decay coin. The fact that they have very long half-lives, they're going to be around a very long time. The fact that they have a very long half-live means they're not very radioactive, so it's a trade-off, kind of. Although, they're radioactive enough to be of concern.

CHAIRMAN RYAN: That depends. I mean, even some of those long-lived ones, like iodine 129, if you have enough stable iodine in your diet, you'll block it. If you don't have enough stable iodine in your diet, it's important, so it's interesting.

DR. WYMER: Sure, where the wigget is flooded out, absolutely. Sure.

CHAIRMAN RYAN: Carbon 14, the stable element intake in the diet determines what carbon 14 can get in.

DR. WYMER: Well, carbon 14 is sort of in the same boat as tritium. Tritium has a 12-year half-life, lot of tritium is released in the world various processes, but half-life 120 years.

PARTICIPANT: We're ready.

DR. WYMER: One-tenth of 1 percent. Okay. Let her roll. This is the Sellafield Plant now that's advertised on your hand-out, I hope.

(A film was shown.)

DR. WYMER: This film was about 25 years old. The Thorp Plant you saw was under construction will be closing down in either 2010 or 2011, after having served over 30 years. And they talked about using ferrasulfonate to reduce the plutonium from extractable plus 4 phase to the non-extractable, finely extractable plus 3 stage. Ferrasulfonate is no longer used because the presence of iron in it, which substantially increases the volume of the waste that has to be treated, so that the reducing agent now to reduce the plutonium to an unextractable form valence are all organic materials that are subject to decomposition, and they produce no solid waste, provides bulk waste to the vitrification plant. So that's been eliminated.

Virtually, all of the discharges into the -- it turns out, the Irish Sea on that early plant have been discontinued. They're down to extremely low level. Was not so good in the beginning for a number of years, and the Irish were not exactly happy campers about all that, and aren't today. And there probably is quite a bit of radioactivity in the sludge at the bottom of the Irish Sea. But at any rate, that's the way things stand. Let's see. There was something else I was going to say about that. Oh well, let's move on here.

Different solvents can be used other than tributal phosphate TBP. Things like carbon tetrachloride, in some rare cases, and you can use other acids, but these have never been used on a commercial scale. The French are doing a lot of work developing new reagents. One of the problems with tributal phosphate is that, as I said earlier, when it is subject to radiation it forms dibutal and monobutal phosphates which are not extracted, complexing agents, and they mess up the extraction. And also, the phosphate radical fuel 4 3 minus is irreducible residue. It's like iron, it doesn't go away, and so it becomes part of the waste, and adds to the waste volume, so getting rid of phosphates is another direction that people are going, but they have not gone there yet. Still tributal phosphate.

If you're not highly radioactive, you can use ion exchange, which is a lot like solvent extraction, except the phase that extracts the stuff you want in solid instead of liquid. And then can just simply remove the material then by another chemical reaction, remove the uranium and plutonium from the ion exchange resins. The problem with that is that ion exchange resins are organic materials, typically, and organic materials undergo radiation damage, and it's not uncommon in highly radioactive operations to start out with a column full of tiny beads about a millimeter in diameter of ion exchange resin, and when you're done you wind up with a column full of black tar, which you can't get out without -- and it's extremely radioactive, so you can only use this for fairly low levels of radiation.

A significant problem occurred at Savannah River a number of years back, where they were doing a plutonium clean-up on ion exchange resin. Turns out you can make a plutonium nitrate and ionic complex, about six nitrate ions instead of four, which would make it neutral. It becomes negative and ionic, and then you could separate that on anionic exchange column, but they lowered it onto the column that way and let the column go dry and, of course, the radiation made explosive gases. This thing blew up, so you've got to be careful with ion exchange, it has its limitations.

There are other ways to separate uranium and plutonium from fission products, which are not aqueous. This DUPIC process, in particular, merits some mention because that's being developed as a collaborative effort between Canada and South Korea. It's a very low decontamination process, and it involves - you must have two different kinds of reactors to make it work. You start out with fuel from a light water reactor, like a pressurized water reactor, and you knock it out of the cladding like before. And then instead of dissolving it, you just heat it up in air or ozone, oxygen. And when you do that, the uranium dioxide undergoes a phase change and it crumbles into a fine powder. And when it does that, it releases large high cross section fission product gases, like xenon, and they go off in the off-gas. So does, of course, the iodine, the ruthenium and everything else. It's volatile, and so you have this -- but you've gotten rid of some high cross section materials.

Now you couldn't just take this material then and reconstitute it into a light water reactor fuel because it still has too many fission products, and too many neutron absorbers, too many high cross section neutron absorbers. But once you put it into a heavy water reactor like CANDUs, they are much more efficient than light water reactors, and they will burn this kind of fuel, so the DUPIC process that's being developed involves light water reactor fuel, and then subsequently heavy water reactor fuel. These in tandem allow you to get the additional burn-up, and it's a very simple reprocessing operation. But, of course, it's all highly remote, the fabrication and everything else. I thought it's kind of interesting, and it's being worked.

MEMBER WEINER: Before you go away from that slide, if you can go back to it.

DR. WYMER: Can we go back to that slide?

MEMBER WEINER: I'm sorry. One more.

DR. WYMER: One more.

MEMBER WEINER: I'm surprised, is there a future for the EBR-II process?

DR. WYMER: No. The EBR-II was a very special process run out at Idaho Falls in their totally contained and inert atmosphere circular cell that they have out there, specifically for processing fuel from the EBR-II reactor. They ran the process. They shut the plant down. It worked, and basically, what they did, was they demonstrated on a commercial scale high temperature processing, pyrochemical processing, which was a major step forward. That is considered as the next - we talked about it a minute ago in connection with one of Mike's question. It's considered as a way of completing the Global Nuclear Energy Partnership cycle, for the processing, the mass breeder reactor fuel pyroprocessing, which is basically a fused salt process, fused fluorides, pretty corrosive, but not the less, it works. Okay?

MEMBER WEINER: Thanks. I wondered about what had happened.

DR. WYMER: Okay. Yes, it served its job and it's done. And it did work.

Ion exchange - I'm not going to belabor this - as I said, is a solid material, and put the liquid on it, the stuff you want, if you set the system up properly gets on the ion exchange resin. The other stuff runs out the bottom as waste. Then you pour some more liquids through it that liberates the uranium and plutonium from the ion exchange resin, and that's your product stream, so it's a two-step operation.

Now onto MOX fuel preparation. Ideally, you would use the uranium and plutonium both in light water reactor fuel, and instead of continuing to use enriched uranium all the time, you put plutonium in. It takes a little bit more plutonium, a percent or so more plutonium to get the same reactivity that you had from enriched uranium, but nonetheless, it certainly does work. And there are several countries doing this, and I'll say more about it here. Why don't I just go on to it.

These are the countries that are involved in it, Belgium, France, France has a couple of them, UK, Japan, and this gives you the status. You've got this in your hand-out. The capacities, they're either here or they're going to be here. And, of course, we're going to build one at Savannah River, a MOX fuel fabrication plant is currently being looked at by the NRG, because it'll be a commercial plant.

Fuel refabrication, I'm not going to dwell on. You basically take the oxides of either uranium or uranium and plutonium, press them into pellets. Typically, for light water reactor fuels they're about a half inch in diameter to about a half inch high, slightly dished on the top and bottom to allow for a little fission product gas, and they under fine irradiation they take them up to quite a high radiation these days, 40, 50, 55,000 mega watt days per ton, 38 used to be the standard. And they break up when you do that, so that makes it easier for them to come out of the cladding when you chop them up because they're already partially broken due to the radiation effects.

This is fuel pellet fabrication. I copied a Cogema flow sheet here. Fabricate the pellets from uranium and plutonium recycled scrap. They're bringing these in pure from the plant that makes the oxide from the solutions, the nitrate solutions, and then you recycle scrap, and you make the pellets, and you weigh them, and grind them up to get the right size, put in a binding agent which will burn-off on heating, press them in a hydraulic press, you center them, they shrink, you grind them to the right size, then you test them and you reject what didn't pass, and it goes back to scrap recycle. And the fabrication, you drop them into the zircaloy metal tubes, put the plugs on the ends, clean the outside, you pressurize them, do non-destructive testing on it to see that everything is uniform, then you package, you store them, and you ship them to where you want them to go. And these are highly sophisticated, very carefully carried out operations. And, of course, there's a lot, too, that you do, you sinter them either in an oven, or you can sinter them with induction heating.

VICE CHAIRMAN CROFF: Ray, I'd like to make one point on the refabrication that doesn't come through in a lot of the solids handling, which is a big part of a refab plant, handling and blending. But the word "scrap", there's a lot behind that because the scrap has to be redissolved in nitric acid from through solvent extraction process, reprecipitated, and then calcined again, so there are a lot of elements of reprocessing that Ray has talked about in a refab plant, and they are in the proposed plant down at --

DR. WYMER: Scrap can be several percent.

VICE CHAIRMAN CROFF: Yes, at Savannah River, that was all the discussion about red oil comes from the solvents. That's not evident, it's a rather cold flow sheet.

CHAIRMAN RYAN: Yes. Yes. One of the other things that I think about, too, when I hear some of these details is that at the moment, we deal with high level waste, low level waste, TRU, and a few other odds and ends. But when you talk about reprocessing being on the scheme, of course, the IAEA and the Europeans all have intermediate level waste.

DR. WYMER: They're trying to get away from that, though, as you probably know, that classification.

CHAIRMAN RYAN: But nonetheless, there is a component of fission products and waste that have a little bit of everything that's not economic, perhaps, to make recovery on. And I just wonder how -- it's an open question, but that's certainly something to think about as you optimize whatever system you look at, as you have to think about not only getting to some end waste, but also what are its ultimate disposal characteristics in whatever group of categories you end up with.

DR. WYMER: Yes. The idea that is being worked on is not totally here yet, is to work the process such that you clean up the low level waste low enough that it's true low level waste, and the rest of it all goes into high level waste. But it's hard, because a lot of things do fall into an intermediate category, as you have just implied, all of Europe has always had an intermediate level waste category, and we have always side-stepped it in our nomenclature, but not in our practice. And we only have low level waste and high level waste formally.

CHAIRMAN RYAN: If you take just the metals that we looked at in the grinding and crushing operation, which are always fun to see, we have irradiated hardware, stainless steel stuff that comes out of light water reactors, which is fairly straightforward. It's nickel 62, it's cobalt 60, and a dribble and a drab of whatever all else. I mean, some of them can be screaming hot like the stellite balls because there's so much cobalt in them, but that's a five-year half-life. It's a solvable problem. But then when you get to cladding hulls and stripped off magnesium, you get into -- first of all, chemical questions of magnesium are fun to think about, but then there's enough - like you said, there could be a few percent of what you really wanted to recover for reuse in fuel or other things, that raise the question - well, how is it low level waste if there's enough of that along the fuel component or plutonium, or whatever all else to deal with. Where's the cut-off point?

DR. WYMER: Yes. In the past, the cut-off point for the fissile materials have typically been an economic question. That day is going to come to an end, I think: You can afford to lose .05 percent, you can't afford to lose 2 percent of your plutonium, so that's been done on an economic, rather than on a technological basis.

CHAIRMAN RYAN: Even if you look at fresh fuel, enriched uranium fuel fabrication in the old days, it was hundreds of grams were acceptable in waste, and now they're recovering every last milligram that they can because it's so valuable.

DR. WYMER: That's right.

CHAIRMAN RYAN: The other aspect of it is risk-informing the decisions on what's in waste. It's not so much the economics of the chemical process, though those are clear drivers, but do you need to process more with the end point of what's in the waste in mind, versus the economics of just returning some material to useful purpose in fuel.

DR. WYMER: And those factors are becoming more and more important all the time.

CHAIRMAN RYAN: Yes.

VICE CHAIRMAN CROFF: I'd like to elaborate on Mike's line of discussion here. First, a reprocessing plant would produce a fair amount of what we would call remotely handled transuranic waste, what DOE would call that, which is greater than Class

C in the civilian world. And also, a rather substantial amount of remotely handled transuranic waste, very hot greater than Class C, the cladding holes being the prototypical example. Getting those down to less than transuranic levels based on historical examinations has been beyond heroic, and not deemed possible. The implication in the NRC world is what had been fairly modest amounts of greater than Class C, in a recycle scenario, it becomes a major waste stream that has to be dealt with somehow.

CHAIRMAN RYAN: Yes, the interesting thing of all of that is it's either source-based definitions or health physics-based definitions of contact and non-contact. And none of those definitions, none of them have anything to do with ultimate risk in a disposal setting, so you might find out that what seem to be pretty bright lines between one category and another, when you take it out of the operational setting and put it in a disposal setting, might not be so bright. So I think that's kind of what we're wrestling with here, is to think how do you go from operational and health physics and radiation protection-based views of how the world works, and economical and chemical process to say okay, I've got six bins of waste. What do they look like in a disposal setting, and what are the risks from that standpoint.

DR. WYMER: That's right.

CHAIRMAN RYAN: Thanks.

DR. WYMER: Just one detail, follow-up on that one on the cladding. A zircaloy cladding, even though it has had the fuel dissolved out of it with 4 or 4 molar nitric acid or higher, it's not really -- it's not ever completely decontaminated, because in the instance of fission, fission fragments and actinides recoil into the cladding deep enough that they do not dissolve out, and so they never become a totally clean waste. And typically these days, you take the whole bunch of those claddings and you just compress them into a great big cube of zircaloy cladding, almost theoretically dense. Okay. We've dealt on this.

MEMBER WEINER: Before you go away from that one.

DR. WYMER: One more, go back one more time.

MEMBER WEINER: Can we go one more time?

DR. WYMER: Can you go back there?

PARTICIPANT: Oh, you've got something on the screen.

DR. WYMER: You can back it up. Can I do that? Doesn't say back?

PARTICIPANT: It says previous.

DR. WYMER: Oh, previous. Okay. There we go. I can do that.

MEMBER WEINER: Thank you. As I recall, you made the statement at the beginning of your talk that waste volumes would be reduced if we went to reprocessing, but it looks to me that just from the volume point of view, just recognizing that the specific activity would be very different just from the volume point of view, looks to be increased. Are you thinking that you can separate out the fission products and store those in other ways?

DR. WYMER: I know what you're talking about. I was referring to the volume of waste in the repositories.

MEMBER WEINER: Okay.

DR. WYMER: As opposed to storage. There was a lot of liquid waste stored from these processes, that's right. If you're talking about the volume compared to the volume of the fuel, we make a lot more volume. But that then, of course, is vitrified, put in the containers, and then you don't have these 12 foot rods with a lot of space between the fuel elements.

MEMBER WEINER: So when it's vitrified, or immobilized in some way, you're not actually increasing the volume of waste. You've compressed it enough with getting rid of the fuel rods that the volume is actually less? I'm just curious about that.

DR. WYMER: I think I mentioned - I was talking about that in the context of the Global Nuclear Energy Partnership scheme, where you took out the actinides and the cesium, and the strontium, and in that case --

VICE CHAIRMAN CROFF: Ray, before you dig yourself in too deep here, believe it or not, the recent French experience is the total waste from the reprocessing plant is smaller than the volume of the spent fuel.

DR. WYMER: Yes.

VICE CHAIRMAN CROFF: Total, I mean true cladding. The whole enchilada.

DR. WYMER: Let me rehash what I --

MEMBER HINZE: By 50 percent, 100 percent?

MEMBER WEINER: Ten percent?

MEMBER HINZE: Twenty-five percent?

THE WITNESS: I don't think it can be 100 percent smaller. No, no.

CHAIRMAN RYAN: The volume has nothing to do with the risk.

VICE CHAIRMAN CROFF: The volume has nothing to do with the risk, but it's surprising what they have been able to do with volume. And by keeping chemicals that are volatile, like oxygen or whatever out of the system.

MEMBER HINZE: Well, the volume does have something to do with the risk if you involve human intrusion.

VICE CHAIRMAN CROFF: It has to do with storage space in this kind of stuff. But they've done amazing things on the volume issue.

DR. WYMER: Well, I'm going to be intruding on somebody else's time here, but I do want to answer the questions. The thought there was that by reducing -- by taking the actinides out and burning them, and by reducing the volume of that 12 foot element down into a 10 foot thing, put all together, taking into consideration the heat lobe which limits the spacing on the waste in the Yucca Mountain repository, you do reduce the footprint required.

MEMBER WEINER: Thank you.

DR. WYMER: From start to finish. This is the inside of million gallon tanks that never got anything in them, of course, because the plant never ran. These are all cooling coils inside, so these things are huge. Now, of course, what we have out at Hanford, we have at Savannah River, 177 of those tanks out at Hanford, and 50 some at Savannah River that need to be emptied and decommissioned in some way. They're pretty much empty now of liquid, but they have a lot of sludge and crystalized salts on the bottom. This is just an array of waste tanks at Savannah River.

This is - I think Allen must have put this together sometime. Where did you get that, Allen?

VICE CHAIRMAN CROFF: I stole it from you.

DR. WYMER: What?

VICE CHAIRMAN CROFF: Jerry Nickles.

DR. WYMER: Oh, Jerry. Oh, well. Yes. Jerry never was a slacker. Reprocessing capacity, a lot of these are trivial, but if you look at the output, you get an idea of what really is important here. We have UK, France, Russia, China, Japan coming on-stream with the Rokkasho-mura plant, which is in cold testing as we speak, I think. Have I missed one? India is doing some reprocessing, of course. Those are the big ones, and these others have toyed around with it. There's another slide, more of them here.

This is another continued list. And here are some carefully chosen references, if you want to know more than you think you want to know about reprocessing. Most of these are - if you really want to know, they're worth reading. In particular, I would commend to you - that I quit. (Laughing.) Any other questions? Okay. Let's go ahead and take questions. Ruth, any more?

MEMBER WEINER: Unfortunately, one. This is just a general question. Looking at all of the reprocessing reformulation of MOX fuel processes that you've just talked about, which would you choose if you had to choose one for future development, or are there specific processes that are most suited to specific fuels?

DR. WYMER: If you put aside the HTGRs, which are in a class all by themselves, I think for the next 20 or 30 years, it's all PUREX, hands down. After that, we may get into some of these UREX process, which are modified PUREX processes. The French may come on with some of their totally different extractants, other than TBP, in the future, mainly in connection with managing the waste, reduce the waste volume. But TBP has -- the reason it's been used and picked up and used for so many years, it's unusual for something to last that long - is because of all the desirable properties it has. It has the right viscosity, has the right flashpoint, has the right extractability for uranium and plutonium. It can be diluted with inexpensive kerosene. It just has a lot of advantages that are awfully hard to overcome. That's why eventually the French, who started out with things like BUTEX, and ourselves out at Hanford with hexone, we eventually -- everybody went to TBP for those reasons. It's cheap. So for the next 20-30 years, that's what you'll see, but there certainly is room for improvement.

The pyro processes do have some advantages. Few salt volatilities, such as they pushed for GNEP as a phase 2. That was all developed at Argonne National Lab, and it was demonstrated on the EBR-II fuel, and the plants are general smaller for give and throughput than the aqueous plants are. Of course, there are fluorides which is very corrosive, and they run it 400 degrees Centigrade, which is pretty hot, but not out of sight. They produce a waste that is somewhat difficult because it's a fused salt waste, and you have to fix it, but Argonne has developed some processes for fixing that fused salt fission product containing waste, so I think that has a future down the line a ways. And it's for applications like fast butal reactors where if you want to reprocess on a fast cycle, and you don't want to burn up your tributal phosphate with radiation damage, you do not burn up sodium fluoride, lithium fluoride with radiation. You do liberate a little fluorine gas over time, but it could be reconstituted easily, so I think that has a future.

MEMBER WEINER: Thank you.

CHAIRMAN RYAN: I think I asked the questions I was really keen on, Ray, as you talked. And the summary that I took away is that you'd agree with this idea of system optimization, and the points of optimization can be many, it can economics, it can be getting maximum kilowatt, mega watt days per ton on the fuel.

DR. WYMER: Very complex.

CHAIRMAN RYAN: It can be minimizing the waste you generate, it can be the ease of handling in the reprocessing plant, and costs all the way along the way, or can be ultimately one of the characteristics of the waste that allow for effective disposal. So somewhere amongst all of that, there's got to be --

DR. WYMER: There's an optimization.

CHAIRMAN RYAN: At least a range of options that one could look at, and I --

DR. WYMER: Some will be contradictory to others, and that's why you have to optimize.

CHAIRMAN RYAN: Absolutely. Absolutely. And I think you wrestle with what I few to be goofy definitions of contact and non-contact handled waste and things of that sort, when we ought to remember that uranium is uranium, is uranium. It doesn't matter where it came from, or where it's going, it's still uranium, and has, as I recall, a 4.51 times 10 to the 9th year half-life 238. Doesn't matter where it came from, so those kind of characteristics in balance, I think, at least what I think about when I think about rethinking reprocessing.

And the second part of that is risk-informing it along the way. And I would hate to say well, let's optimize on this waste disposal parameter, and finding out that we've increased an inordinate way to that savings risk to workers, or risk to something else in the system, or optimizing a reactor becomes 25 times more expensive for that little increment over here. So system is the magic word to me that we need to focus on. We can't have one kind of reactor - and we'll do that 30 years from now. I'm a little nervous about that.

DR. WYMER: My cynical view, Mike, is that each part of the fuel cycle will optimize themselves on economic basis, and then they will do whatever else is necessary being driven by regulators.

CHAIRMAN RYAN: And, I guess, what I'm suggesting is that the advice to regulators is don't let them do that, optimize the total system.

DR. WYMER: I'm a little scared of that, too.

CHAIRMAN RYAN: At least somewhere in the middle is the playground where the right answer can be formulated.

DR. WYMER: But people are loathe to do a total system analysis on anything. But, anyway, you're right.

CHAIRMAN RYAN: Well, I read a piece on the Global Initiative, and it looked to me just like the too cheap to meter stuff from the 50s.

DR. WYMER: Yes.

CHAIRMAN RYAN: And I was actually appalled at it, so history is -- we're doing the repeat history, I guess.

DR. WYMER: Oh, sure. You know that, Mike.

CHAIRMAN RYAN: Okay. Well, thanks. I appreciate the discussion because it really will help us shape how we take the technical information and turn it into a strategy.

DR. WYMER: Thanks for having me.

CHAIRMAN RYAN: Thanks for being here.

VICE CHAIRMAN CROFF: Not quite yet. First, a point to John Flack, but we hope to get the DOE people in later this summer to talk about the forward-looking program. We need to make sure to ask the question about whether they're doing system analyses.

CHAIRMAN RYAN: Right.

MR. FLACK: No, I think that is the key, because what are the drivers, and how -- because that's outside of our control.

VICE CHAIRMAN CROFF: I mean, ask it right now, and if there's a specific person that can talk to it for a half hour, let's get them here.

MEMBER HINZE: Well, a couple of very quick questions. One of your first slides, Ray, was reprocessing - why do it? If you were to put up a slide which would say reprocessing - why not do it, and you remove the political card, what would you have under that?

DR. WYMER: Why not do it?

MEMBER HINZE: Yes.

DR. WYMER: Well, I think -- I don't know whether this gets what you want. The only reason you reprocess is to conserve resources and to save money, so that's why you reprocess.

MEMBER HINZE: And so, the reason why you shouldn't do it then is?

DR. WYMER: The reason why you should not do it?

MEMBER HINZE: Yes.

DR. WYMER: Because of all these problems that Mike has been alluding to. I don't think you should not do it. It is my belief that Yucca Mountain will be a satisfactory repository for the waste. It's my belief that we can, in fact, reprocess safely, so I don't believe you should not do it.

MEMBER HINZE: I knew there was a good reason why we didn't see that slide.

DR. WYMER: Yes. When you get a speaker, you have to accept his presence.

MEMBER HINZE: The second question - you've given us a number of references here. I'm interested in a reference that would give me the best information, the most complete information on the waste from reprocessing in terms of volume, in terms of radiation, in terms of heat, et cetera. Is there some place where this is written so that a layman in this area could look at it and understand it?

DR. WYMER: Well, the best single reference on that list is the first one.

MEMBER HINZE: Is by Wymer?

DR. WYMER: No. I bagged mine about three -- I sprinkled them throughout, but I didn't put it first. The best one there is by Justin Long, and he covers almost everything. And that's an encyclopedic discussion of things. Now whether the waste is a key thrust of that, probably not, but it's in there. So if you want the best overview you can get, it's Justin Long's book.

MEMBER HINZE: So waste is not necessarily treated as an entity there, but has to be extracted --

DR. WYMER: That's what I found.

MEMBER HINZE: Okay. Thank you very much.

DR. WYMER: Piecemeal it out. Yes.

VICE CHAIRMAN CROFF: ACNW staff.

MR. FLACK: Just a question on your thoughts about the impact of reprocessing on the licensing of Yucca Mountain. Are these going to be someway coupled at some point, do you think? Will have a major effect on that licensing process?

DR. WYMER: That's one of the drivers, sort of the half-hidden agenda, DOE wanted to go to Global Nuclear Energy Partnership, it's to extend the lifetime of the Yucca Mountain repository by five-fold, by so dramatically reducing the volume of waste that goes into it.

MR. MAGRUDER: It can have a major effect, then --

DR. WYMER: No major effects.

MR. MAGRUDER: -- which is how do you quantify that in cost space? It just becomes not an economic --

DR. WYMER: Well, if you look at how much money it's taken so far, they'll save a lot of money. Build three or four more Yucca Mountains, some billions of dollars. So yes, it would be a major driver, to say nothing of the social and political problems associated with Yucca Mountain, and building another one.

MR. HAMDAN: Very quickly. I don't know, I didn't hear or see it, but I think this was fascinating. Maybe, I daresay, the best presentation I've heard at ACNW in the two years I've been here. Very brief question - if you were to start the reprocessing in the U.S., would you do it through boil out plants, or do it based on --

DR. WYMER: It's far enough along, the technology is far enough along, you would build a plant. You wouldn't build a powder plant for PUREX processing.

CHAIRMAN RYAN: And just a quick follow-up. I guess I took from the presentation, the videos even though they were dated somewhat, that the French seem to be in the world lead.

DR. WYMER: By a mile.

CHAIRMAN RYAN: By a mile. I just wanted to make sure that was clear.

DR. WYMER: Yes. I'm sorry, that should have come through loud and clear. They're shutting down the Thorp plant. They'll still be operating to do some reprocessing over there, but won't be the oxide fuel through the Thorp Plant.

CHAIRMAN RYAN: You didn't mention the newer Japanese activities, and they're kind of getting to where they're up and running.

DR. WYMER: Well, they have that little reprocessing plant, Tokai-mura, that is running for many years, the French built for them. They had a leaky dissolver that they almost sued the French over, but they took the Rokkasho-mura plant up on the upper end of Honshu, I think they're still cold testing, still running uranium through it.

VICE CHAIRMAN CROFF: No, they went hot about three or four weeks ago.

DR. WYMER: Have they gone hot now?

VICE CHAIRMAN CROFF: Just barely.

DR. WYMER: Then I'm behind. Oh, maybe I did read that. And only it's at a much lower capacity than the --

vICE CHAIRMAN CROFF: They're still feeling their way along. It's still shake down.

DR. WYMER: That's right. I remember seeing that now. Yes, that's a big plant, that's 800 to 1,000 tons a year, and it's a total French design.

CHAIRMAN RYAN: I mean, again, even though it's in Japan, it is French technology, and they have a pretty strong presence there, I guess.

DR. WYMER: Absolutely.

CHAIRMAN RYAN: Yes.

MR. THADANI: A quick one - today we have approved burn-up levels of 62,000 mega watt days metric ton.

DR. WYMER: It's that high now?

MR. THADANI: Yes. And some experiments

have been done to look at the condition of the fuel pellets, and the reactor reinsertion accident. But I don't think people have looked at it in the context of at the end how do you deal with the condition of the pellets, particularly if you go to reprocessing. And I'm hearing now some talk about perhaps going to 75,000 mega watt days per --

DR. WYMER: They're going to get into cladding problems.

MR. THADANI: And I'm wondering if that could pose significant challenges down the road.

DR. WYMER: I think it does. I think cladding becomes the driver at about that level. Yes.

MR. THADANI: And that's why I think Mike's point, that you have to take a total systems look, the issue is critical.

DR. WYMER: Yes, absolutely.

MR. THADANI: To look at up front, also.

CHAIRMAN RYAN: Well, you know - I mean, it's not only even the burn-up, it's simple things like design of the fuel. You know, if you're going to design it for optimal heat transfer versus designing it for some optimization between heat transfer, burn-up, and reprocessing schemes --

MR. LARKINS: It almost seems like we're

a little behind the power crew on that, because if you look and see what's happening, you've got maybe 15-25 proposed plants to be certified, either combined operating license and things like that over the next few years. And if those plants, those will all be current light water reactor-type fuel, so I'm not sure how do you go in and optimize early on on - actually fuel fabrication, I think is set.

MR. THADANI: All the economics are done up front.

CHAIRMAN RYAN: And for the current generation of reactors, I guess we're in for a dollar, so a dime extra is not a big deal. But by the same token, that's under the scheme that there isn't any reprocess, so the high burn-up, there's not a monitoring processing and things like that. But if the game changes in one regard, then maybe there are things at this early stage that can't be done, maybe not, or maybe they shouldn't be. But then I think you're going to go through the exercise, I think, about how to optimize.

MR. LARKINS: Yes, but I think we're going to be locked in even if we go to reprocessing, with almost current technology.

CHAIRMAN RYAN: That could very well be,

and again, there may be small changes that could improve, or there may not be. But I think it's worth the exercise to think about that.

DR. WYMER: Yes, definitely at least a crude first order, maybe zero order total systems look ought to be taken.

CHAIRMAN RYAN: And again, I mean, even if you leave the reactors out of it, and assume that's fixed is one option.

MR. LARKINS: How do you optimize reprocessing.

CHAIRMAN RYAN: Still optimize the reprocessing to look at waste products and end points.

MR. FLACK: It may also depend on whether you're going to build burners in the future, and you may want to reprocess in a way that allows you to prepare for that.

DR. WYMER: You know, there's such a thing as doing too much planning.

MR. FLACK: Have to be visionary, too.

CHAIRMAN RYAN: The number of degrees of freedom can get pretty awesome at some point.

DR. WYMER: Well, things change too much to plan too far. A 20-30 year horizon is okay, like my five years is worth some --

VICE CHAIRMAN CROFF: You want to use the microphone? We're being recorded.

DR. WYMER: Just as well you didn't hear that. Anything else?

VICE CHAIRMAN CROFF: I think we've reached the end of it, and we've run a bit over, so thank you very much. You hit the nail on the head in a great presentation. Stick around, we'll be getting back to you later. But let's go ahead and take a 15-minute break here, get back at 3:45.

DR. WYMER: That's the most flattering thing that was ever said to me.

VICE CHAIRMAN CROFF: We'll pick up with the NMSS part of this.

(Whereupon, the proceedings went off the record at 3:30 p.m. and went back on the record at 3:45 p.m.)

VICE CHAIRMAN CROFF: Let's go ahead and come back to order. We're going to move on and talk about sort of the regulatory side of this whole recycle thing.

And our next -- the lead for this little session is going to be Stu Magruder from the NMSS staff. And he's going to do a tag team with some of the other NMSS staff members. So I'll let you go ahead and introduce yourself more fully and them.

3) NRC'S SPENT NUCLEAR FUEL REPROCESSING REGULATION

MR. MAGRUDER: Okay. Actually, Joe Giitter, who is the Chief of the Special Projects Branch and the Fuel Cycle Division, will start off and kind of introduce things.

I'll do about the first half of the presentation roughly, and then Joe will do the last half. But obviously we'll be open to answer questions any time during the presentation.

MR. GIITTER: Thank you. As Stu said, I'm just going to provide a few opening remarks. And we'll start right in on the presentation and try and go through it because we realize we're a little bit behind schedule here.

We are fortunate in this morning we were able to go down and have our first meeting with the Department of Energy. I think we have more answers now than we did yesterday at this time.

There is still a lot of uncertainty with GNEP and we'll try to answer the questions that you have, but, really, it's something that's still at a very high level, fairly conceptual level. And a lot of the details haven't really been worked out yet.

So with that in mind, we will tell you

what we know, what we believe our role is going to be. And even that hasn't really been decided yet. The Commission has given us direction. We'll talk about that. But DOE, we haven't come to a complete agreement with DOE on that yet, although we're making very good progress and we had a very good meeting this morning.

With that, I'll let Stu go ahead and start the presentation.

MR. MAGRUDER: I don't trust myself with the pointer. Next slide.

As Joe mentioned, the presentation will focus on -- we'll start off with a discussion of GNEP, talk a little bit about what the NRC staff has been doing over the last few months, what we plan to do in the future, a little bit about what our regulatory authority is, and what we might do, you know, existing regulations.

We'll talk a little bit about the facilities that they're proposing, what our role would be in those, talk a little bit about some issues. You know, Dr. Ryan mentioned a bunch of very good points about taking a systematic look at this. There are a lot of trade-offs involved. And we'll raise some of those issues and then talk a little bit about the path forward.

Next slide, please. There is a lot of information in this slide. This is with DOE's advertising -- the Global Nuclear Energy Partnership, or GNEP, as we call it, is a very broad-reaching program, basically to restart; reprocessing; or, as they call it, recycling of spent nuclear fuel in the United States. And they're very up front about a lot of the purposes here.

I guess it's broader than just in the United States, to be fair. It really is a global initiative. It builds on the nuclear renaissance around the world, the desire to reduce, you know, emissions, the desire to make nuclear power available to more countries in the world, as you see, recycle used fuel, minimize waste, safely and securely allow nations, developing nations, to deploy.

And then the last bullet there, reduce the number of required U.S. geologic waste repositories to one for the remainder of this century. That's the goal. And we'll talk a little bit about how they plan to do that.

Like was talked about earlier today, it was difficult enough or it is difficult enough to license one repository. And the goal is not to have to license another one for a long time.

I mean, the President proposed this. The 2006 Appropriations Act directed DOE to develop a recycling plan. Dr. Croff and I were just talking about a plan and that it was just issued. It was supposed to be issued in March that Congress recommended that or directed them to do it, but it was just issued on May 31st, the official plan.

And we'll make sure that people have a copy of that. It's posted on the DOE Web site, but I don't know how to find it yet. I've got a copy from somebody from DOE. So we'll make sure that people get the link to it.

CHAIRMAN RYAN: Yes. Actually, if we could ask you to do that fairly soon, like before we leave this week, that would be helpful.

MR. MAGRUDER: Oh, definitely, yes.

CHAIRMAN RYAN: Okay. Thanks.

MR. MAGRUDER: We can do that.

MR. GIITTER: I've got a copy here. If I can get somebody on your staff to make copies?

MR. MAGRUDER: Right. And we'll get the link to everybody either later today or early tomorrow morning.

CHAIRMAN RYAN: That would be great.

MR. MAGRUDER: Next slide, please. This is a view of both the domestic side of it and the international side. And we'll talk mostly about the domestic side, obviously, because that's the main -- that will be the NRC's main role, although we do have a role in some of the international activities. We were talking this morning with DOE about export licenses for material and transferring technology to other countries and things like that.

MEMBER WEINER: Are you at the same time or is the program at the same time looking at expanding the use of nuclear-generated electricity and reducing the volume, the waste capacity needed to just one Yucca Mountain?

MR. MAGRUDER: Yes. That's the goal. Well, there are various scenarios, but --

MEMBER WEINER: Thank you.

MR. MAGRUDER: -- in any case, if you can burn the actinides in burner reactors, then all of the calculations have shown you just need one repository for the waste, the remaining high-level waste.

MR. GIITTER: That's assuming -- there are different scenarios, as Stu pointed out. And if we maintain the current call it market share, roughly 20 percent of electricity generated by nuclear power throughout the rest of the century, I think the estimate was an additional 8 Yucca Mountains or an additional 8 high-level waste repositories would be needed. And there is an expansion of that. If the market share goes beyond 20 percent, obviously there would be even more. So that was the basis for their estimate.

MEMBER WEINER: But the reduction to one with generation IV reactors also depended on maintaining the 20 percent market share. That was really my question.

MR. GIITTER: Okay.

MR. MAGRUDER: Right. And I guess there are various projections based on not reprocessing, recycling. And, as Joe mentioned, that would be multiple repositories required. Even under the scenario where the percentage of power produced from nuclear is increased above the current 20 percent, DOE still believes that only one repository would be required.

Okay. The next slide, this slide here, talks about the big picture of what would happen in the U.S. Essentially closing the fuel cycle, obviously all the processes up to going into a lightwater reactor would be the same.

Then there would be separation, some kind of probably aqueous process that would separate the material. We haven't or DOE has not decided exactly what that process would be, but they have decided that it will not be a Purex process.

There are a number of reasons for that. The main reason is proliferation concerns. They do not want to separate plutonium from other materials.

As was discussed earlier this afternoon, most of the aqueous processes are very similar to the Purex process. It's just where the different streams are. So a lot of the technology will be very similar, but it will not be a Purex process.

Can you go back, please? I'm sorry. Stay on this slide for a while. The idea is to separate some of the short-lived fission products, along with the uranium, possibly separate the uranium for recycling in a separate stream but take the strontium and cesium and store them, let them decay away and then eventually dispose of them as low-level waste.

Fission products would be theoretically the only waste stream that would end up in the high-level waste repository, the other fission products, the longer-lived fission products.

The transuranics from the reprocessing

facility would be fabricated into fuel. The type of fuel they haven't decided yet. But the fuel would be then burned in fast reactors, probably sodium-cooled fast reactors, but the prototype or I guess the design they're basing things on is the G.E. --

MR. GIITTER: Advanced liquid metal reactor.

MR. MAGRUDER: Yes, ALMR design. And then there would be a facility. Probably the same facility that manufactured the fuel for the fast reactors would reprocess that fuel or recycle that fuel. And they're talking about probably a pyroprocessing technology there.

And then, again, whatever fuel or whatever products, fission products, of the waste stream from that would go to the repository as well. So, as we talked about earlier, this significantly reduces the amount of waste, both heat and volume, that would end up in the repository.

The technology demonstration program is the first step of this, of the GNEP program here. As you can see, there are three main facilities that we're talking about or three main demonstration facilities.

ESD is engineering scale demonstration

facility. That will be a facility that will demonstrate whatever aqueous reprocessing technology they choose. And that would be the first one built.

They're talking about getting that operational. Here this slide says 2011. Now, this morning they told us somewhere between 2011 and 2015 depending on -- a little bit depends on the technology. Most of it I think depends on the funding level that they get.

But that would be just to demonstrate the technology. And they're talking fairly small scale. They're not sure exactly, but they're talking about tens or maybe low hundreds of tons per year for this facility.

The next facility time-wise that they would be talking about building would be a demonstration facility for the fast reactor or advanced burner test reactor, ABTR.

We talked briefly about that. That would be roughly the same size, what they're talking about, as the GEA ALMR design, several hundred megawatts probably.

And then, finally, you know, chronologically the advanced fuel cycle facility, which would be, again, a demonstration-scale facility, not a full commercial scale or full-scale facility. And that would be coming online in the late -- well, 2016 to 2020 roughly time frame.

MR. GIITTER: One of the things they told us this morning is that the advanced fuel cycle facility and the ABTR may be collocated, located at the same site.

MR. MAGRUDER: Right. Yes. I guess the vision for the longer term, after the technologies have been demonstrated, their goal is essentially to have modular designs and have essentially locations where you would have three, four, maybe five advanced burner reactors and one fuel reprocessing facility on the same site. So that you would ship in lightwater reactor fuel to the facility, but once you shipped that fuel in, it would just keep recycling the fuel from the advanced burner reactors through to the facility until eventually you have transmuted all of the actinides. And all you have left are fission products.

I mean, you would still have to transport the spent fuel from lightwater reactors, but you would not be transporting the other waste streams too far anyway we're talking about.

VICE CHAIRMAN CROFF: If we can, I would

like to let them get through the presentation as much as we can. I think it would make it difficult.

MR. MAGRUDER: Okay. A little bit more detail about the three facilities that we're talking about. Again, this is the engineered scale demonstration for the reprocessing technology. One of the goals, actually, one of the goals of the whole project, is to make all of these facilities eventually commercially viable. And a lot of that has to do, it seems that a lot of that has to do, with the fact that you're averting the cost of building more repositories.

Now, I mean, we didn't talk about their business plan or how they would get interested, but one of the goals of the demonstration facility is to gather cost data to determine the viability of these different facilities. And obviously one of the streams from this demonstration facility would be the separated transuranics for the advanced burner test reactor.

The next facility we've got here is the advanced fuel cycle facility, again, a multipurpose facility. This would be where the fuel would be fabricated. And they're also talking about -- I didn't mention it earlier but advanced simulation laboratory is a facility that they are also working on. Again, that would be a lot of code development there and trying to kind of go to the next step of code development.

MR. GIITTER: The DOE Office of Science is heavily involved in GNEP.

MR. MAGRUDER: Right.

MR. GIITTER: They're the ones leading the effort on the code development.

MR. MAGRUDER: Yes, yes. Most of the other stuff here is at the Nuclear Energy Office of DOE, although NNSA is also involved, especially in the international area.

I talked a little bit already about the advanced burner test reactor. Again, as we talked about earlier this afternoon, the goal is to -- you need fast neutrons to transmute the transuranics. And it seemed like the most economical way to do that is through a reactor.

This facility is the one that they have talked most about NRC involvement in. Their goal is to gather data and basically prepare a design certification package for this reactor so that it would be easy to license by the NRC.

And, as you can see, we put a little bit of information about, you know, some of the advanced reactors or the burner reactors or fast reactors that are operating around the world. The Phoenix in France and the BN-600 in Russia are similar scale.

I mentioned these already briefly, but the planning milestones, they're talking about operation of the simulation laboratory would be starting up relatively soon.

As I mentioned, we got a little bit updated on the dates this morning. Essentially they just kind of drew error margins around the dates that they had here and kind of gave themselves some more fudge room there.

The last bullet there, you know, they would like to get the advanced burner reactor itself operating by 2023 roughly. I see some notes there. They have published several public documents regarding GNEP. They published an advanced notice of intent, solicitation of interest for basically communities or facilities that would like to host some of these facilities, and got more than 30 expressions of interest. It varied from national labs to commercial facilities to communities that already have nuclear facilities located there. So there's a lot of interest, obviously, in doing something like this around the country.

Next slide. Here we go. We, actually Joe and some other folks, were approached by DOE last fall, I guess, for the first time about their proposal, right before they went public with it.

MR. GIITTER: Last summer, yes.

MR. MAGRUDER: Yes. Well, last summer even. And we started thinking about what the NRC role would be in this process here. In January, we started to write a Commission paper, which actually went up in March, kind of laying out what we knew about the program at the time and what some of our concerns might be, what we thought our role might be. That's SECY 06-0066.

The Commission considered that for a while, actually along with a paper that Commissioner McGaffigan wrote with his own personal views on reprocessing.

In the middle of May, they issued staff requirements memoranda to us, on both our paper and Commissioner McGaffigan's paper, basically saying that we should work with DOE to learn more about what they're proposing to develop a conceptual licensing process for these facilities.

Now, they also asked us to draft

legislation to clarify, I guess, the NRC role to give us authority over DOE facilities. Again, that's DOE. We talked about that a little bit today. I think we're in relatively agreement with DOE on this. For some small demonstration facility, technology demonstration facilities, on DOE sites, the NRC probably would not have to license the facilities.

We would be very interested in following, you know, obviously what they're doing so that we would be ready to license them if they built more facilities. But if they were to build larger-scale facilities or almost full-scale facilities, even if they were on DOE sites or owned by DOE, the Commission would like the NRC to license those facilities. So that's what this legislation would propose. I'm assuming that the commission asked for that based on discussions with Congress ahead of time, but I'm not sure.

Additional --

MR. GIITTER: I think, just to kind of add to what Stu said, the feeling is that we need to be involved in what DOE is doing, we need to understand it because if this does move to commercial scale at some point, we are going to be in a very difficult position to do a licensing review.

So it's better for us to understand the technology now. And if and when DOE moves towards commercial scale, we'll be in a much better position. And we'll be able to make determinations as to whether or not we need to do changes to our infrastructure and things like that.

MR. MAGRUDER: A little later on in the presentation, we'll talk about some of the specific license issues that we have gotten where we are with the current regulations and what we're proposing.

This is the second slide on what the Commission has directed us in the SRM. They asked us to work with DOE to see if we can come up with a cost-reimbursable agreement to fund NRC work for the next couple of years, mainly I think because they didn't -- well, a couple of reasons.

I think, one, they weren't quite sure what was going to happen. They didn't want to commit significant NRC resources to this project yet. And also I think they felt that it wouldn't be fair to build existing licensees for this work yet.

So we are starting to work with DOE on coming up with some kind of agreement. An alternative is to request additional funding from Congress.

Another thing they asked us to consider is incorporating elements of Part 52 in our conceptual licensing process, basically what we're planning to do for the new reactor licensees. And I think the reason they like that is it would be a one-step licensing process, where we would certify design, look at the facility or the site they're proposing, and then just have one hearing for the proposed facility.

They asked us to look at the full recycle option. In the paper, we weren't sure exactly what DOE was proposing. At one time they were considering recycling fuel back in commercial lightwater reactors. That was what we called the partial recycling option.

They decided not to do that. They decided to skip that and go directly to burning the fuel in fast reactors. So that's what this full recycle option is.

I guess maybe the most important thing is they told us to proceed at a pace commensurate with DOE's progress, not get out ahead of DOE, and kind of follow what they were doing.

A little bit of the legislative background here on what authority we actually do have with regard to DOE facilities. Obviously the Atomic Energy Act gives us authority for all commercial activities.

Energy Reorganization Act gave us limited authority for DOE facilities. As you can read here, section 202 is the applicable section. And that's specifically section 202(1) directed us authority for the Clinch River reactor and other reactors operated for the purposes of demonstrating suitability for commercial operation. So it's pretty clear that the advanced burner reactor or even the ABTR that DOE is considering building, we would have regulatory authority to license those facilities right now.

Sections 202(3) and (4) direct NRC for high-level waste receipt and storage but not for waste from DOE R&D activities. Part 5 directs NRC, gives us authority for DOE for the MO_x facility, which we're in the process of licensing right now at the Savannah River site.

DOE reprocessing facilities and TRU fuel fabrication facilities are not clearly subject to NRC regulation right now. And that's what the Commission I think wanted us to clarify. And OGC is actually currently working on that. And we expect to have draft legislation in the fall for Congress to consider in the next session early next year.

Existing regulations and processes and how we would apply. This is kind of the suite of regulations that could apply to these facilities. And I'll walk through each of these in a little bit more detail in the next few slides.

Part 50 is, as a lot of you probably remember, not just for utilization facilities or reactors but is also for production facilities. And here is the definition from Part 50 of production facilities.

Joe will talk about this in a little bit. This is what we licensed the reprocessing facilities back in the '60s and '70s under. And that's because it specifically says facilities for the separation of isotopes, of plutonium, processing of irradiated materials containing special nuclear material.

It's clear that Part 50 would apply now to reprocessing facilities. However, Part 50, as you are well-aware, is not tailored to reprocessing facilities. It really evolved to a regulation for lightwater reactors. And so it would be problematic, I think, to license a reprocessing facility under Part 50.

Next slide, please. Again, this is a little bit more on Part 50. As I said, it's evolved to really be specific to lightwater reactors. A lot of things even since we licensed most of the reactors here, a lot of regulations or a lot of parts to this have been added based on knowledge.

I think it's interesting or it's worth pointing out that Part 50 is a two-step licensing process. The licensee would have to or the applicant would have to get a construction permit, which entails public hearings. And then they would have to come in after the construction is completed and apply for an operating license, which is another chance for public hearings.

So we can go to the next slide here. A little bit more. Each step of the process, as I said earlier, would involve staff review, mandatory ACRS review, which is obviously public hearing before the Atomic Safety and Licensing Board, and then ultimately Commission review and decision. That's what the Part 50 licensing process is like.

Part 52. An ESP is an early site permit, which you may be familiar with, where staff would review sites based on kind of bounding, information about what facilities could go on the site. We would certify standard reactor designs. And then facilities could come in or a utility could come in for a combined license, a COL.

As I mentioned, it's a one-step process.

And basically what I mean by that is that once an early site permit has been granted and design certification has been granted, if an applicant married those up in a combined license application, there would be just one hearing at that time. And issues that had been decided in the design certification in the early site permit discussions unless things had changed, those issues would be considered settled and would not be considered for a hearing for the combined license.

Okay. Part 52 is really just a licensing process regulation, although there are a few additional requirements in there. But basically all of the technical requirements from Part 50 would apply. And a hearing may be requested, obviously. And the Commission would decide on the appropriate hearing procedures. So the reason we're discussing these is this is kind of a model that we would use for the licensing process for these new facilities.

Briefly, Part 70 is what we use to license facilities that handle special nuclear material. All of the existing fuel manufacturing facilities are licensed under Part 70.

The enrichment facilities, the gas centrifuge facilities -- well, I should say the gas centrifuge facilities are applying for licenses under Part 70. They haven't been granted them yet. LES is close to getting a license obviously. The MO_x facility we're reviewing under Part 70.

This is a one-step process. As noted here, we're doing the MO_x facility in two steps, mainly per DOE's request, to ensure some sort of schedule parity with the Russian MO_x facility. But it doesn't have to be. Part 70 is designed as a one-step process, where you apply. And once the NRC is done, then we actually issue a possession and use license. It's not called an operating license.

The key to Part 70 is that it's risk-informed. Subpart H was put in in 2000, which requires an integrated safety analysis. And it's based on likelihood and consequence of events.

We think this is a good model to follow for new facilities also. And we would probably apply some of this to the licensing of the new DOE facilities as well.

There was discussion earlier this afternoon about the waste products from these facilities. Certainly some of the products from the reprocessing facilities would fall under Part 30 or Part 72.

There are not very many Part 30 licensees, but a lot of the technical requirements from Part 30 would apply, we think, to some of the facilities here, same with Part 72.

There will be, you know, interim storage of different components. We are still working out -- obviously DOE is still figuring out their plans, but I'm sure that the NRC will be involved in at least reviewing a lot of the storage facilities, the waste-processing facilities, and such.

Certainly if the facilities are commercial, we would license facilities, but I think, even if they are DOE-owned and operated facilities, we would probably be involved in licensing them.

I guess we can go to the next one, talk a little bit about waste incidental reprocessing, of which all of you are much more familiar than I am. But basically I think a lot of the concepts anyway, the managing risk of waste would play a very prominent role in how we view the waste streams from here.

CHAIRMAN RYAN: Let me just pick up on one bullet, if I can, while it's up there.

MR. MAGRUDER: Yes, please.

CHAIRMAN RYAN: Highly radioactive doesn't mean it needs to be in a high-level waste repository.

Stellite balls are highly radioactive.

MR. MAGRUDER: Yes.

CHAIRMAN RYAN: Cobalt-60 sealed sources are highly radioactive.

MR. MAGRUDER: Exactly.

CHAIRMAN RYAN: So that's one of those other terms that I think we just -- in the same way we've got to be cautious about not using origin-based, we need to not use what I view to be a health physics base kind of definition, too.

MR. MAGRUDER: Exactly, exactly. Thank you.

And then just a note here that there are different criteria for different DOE facilities as far as what is not high-level waste. And, you know, we talked a little bit about the fact that we don't have any intermediate waste category in the United States.

You know, how we categorize this waste and what the waste forms will be will be a topic that we will be talking about a lot with DOE over the next 5-10 years, I'm sure. And it will be an area where we'll ask for your input, I'm sure, quite a bit on how to deal with this stuff, what's the best way for the country to deal with this stuff.

Let me turn it over to Joe now. We'll

talk a little bit more specifically about the facilities.

MR. GIITTER: Okay. As Stu mentioned, Stu talked about the various facilities, that NRC could be in a position of regulating those. And I guess the timing would depend on whether or not the draft legislation flies or whether these things go to commercial scale at some point in time.

Certainly a reprocessing facility if it's commercial is one that NRC would regulate. And, as Stu pointed out, Part 50 is really not probably the best option. In fact, it might be the path of greatest resistance if you want to license a reprocessing facility.

Fuel fabrication facility. Again, that's a facility that if it's commercial, NRC would probably regulate. DOE told us this morning that we would probably be collocated with the fast reactor facility, which makes sense.

DOE is of the view I don't think they want NRC to regulate the demonstration facilities. And so we'll see what happens, but, as a minimum, they do believe it's important, as I said, for NRC to work closely with them. So in the future, they will be licensable technologies.

Also, an interim storage facility, one that would store the short-lived fission products and some sort of a stable matrix, a lot of them DDK, and then eventually they would be disposed of as low-level waste; and then the vitrification facility, one that would vitrify the high-level long-lived waste stream, which is primarily fission products.

We may get some experience in this if it turns out that the Senate approves and we get the authorization from Congress to have safety oversight of the Hanford waste tanks.

You may know that the House Appropriations Committee did give NRC $10 million for that purpose, but, you know, we still have to see what happens with the Senate in the Conference Committee.

Reprocessing facilities. You saw from the videotapes of Sellafield and Mohawk, these are very, very large facilities. I know that some of you have been to Mohawk. I've been there myself. And they are very large, very expensive facilities.

I think West Valley is probably a good example of what not to do in terms of designing a reprocessing facility. Ideally, as we move forward, we will learn what we can, the lessons learned, from West Valley.

As Stu indicated, Part 50 really isn't intended for reprocessing facilities. And we would really need to -- if we are going to use Part 50, what we would probably have to do is to have the Commission give an order to the staff to tell the staff, give the staff explicit instructions on how to do the review. And that might be very difficult as well. But I think my feeling is that if we tried to use Part 50 to license a reprocessing facility, we wouldn't be successful.

That last bullet says the Commission could establish a licensing framework by identifying specific parts of the existing regulations and identifying new requirements. I think there would probably be a lot of exemption requests and it wouldn't be a very clean licensing process.

The alternative, there are really two alternatives. One is to develop an entirely new regulation. And that would ideally be a risk-informed performance-based regulation. But one of the things that I feel fairly strongly about is when you're licensing a new technology and you really don't understand that technology well, it's important to also have some deterministic criteria as well.

We even have that in Part 70. The general design criteria, of course, in 10 CFR 50 have been replicated to some degree in Part 70. And they're called principal design criteria, but they're very similar in some respects.

So, in addition to having a purely risk-informed performance-based regulation, there are some things where you have a safety net. And it's important to have some deterministic criteria, especially with new technologies that haven't been tested.

CHAIRMAN RYAN: Could you give us an example just so I understand what you mean better?

MR. GIITTER: Well, I can give you an example of MO_x. I can't go into details on this reprocessing facility, but one would be, you know, on the MO_x facility, it's very important to have emergency power.

Because of the concept of having zones, where as you move in towards the glove boxes, you have areas of lower pressure, you know, the confinement zones, you want to have emergency, a really reliable emergency, power system to ensure that you don't lose emergency power to the ventilation systems. That would be an example. And that's a deterministic requirement.

CHAIRMAN RYAN: That would be as opposed to relying on some other view of power with --

MR. GIITTER: That would be as opposed to, exactly, yes.

CHAIRMAN RYAN: Where there is a "low risk" of failure?

MR. GIITTER: Right, right.

CHAIRMAN RYAN: I'm with you. Okay. Thanks.

MR. GIITTER: So we are looking at possibly Part 70 there. We probably have to do some significant revisions to Part 70, but Part 70 does provide a good framework for regulation of that type of facility. It has a certain degree of flexibility.

We would also probably develop some new or we would certainly develop new regulatory guidance. We have done that. We did that for MO_x.

We came out with NUREG-1718, which was a standard review plan specifically for the MO_x fuel fabrication facility. We didn't do that for the LES and the USEC, the gas centrifuge licensing reviews, for a couple of reasons. We felt that the existing NUREG-1520, which is the standard review plan for fuel cycle facilities, was sufficient and also because those facilities were fairly low-risk facilities for fuel cycle facilities.

And, as I mentioned, there would be some changes to Part 70. One would be to address the fuel containing transuranics. There are some safety and technical differences between metallic and oxide fuel. We're not sure which way DOE is going to go yet, but that would be something that would possibly require a change to Part 70.

When you're dealing with recycled plutonium and transuranics, you're going to run into obviously some very challenging design considerations. And there's probably going to be a need for more shielding and more remote operation. And we may have to make some changes to Part 70 to address those types of design considerations. And there may be some new or different criticality safety considerations as well.

We do have some experience with the MO_x fabrication facility. One of the challenges we had was there wasn't a lot of benchmark data for plutonium, for weapons-grade plutonium. And we were able to get that. There is probably more benchmark data for recycled plutonium, and I know the French have a lot of that data.

As Stu indicated, there may be some

changes to Part 30 and Part 72. And also the WEIR non-high-level waste determinations. So, in essence, we would be looking at making changes to our infrastructure, our licensing regulatory infrastructure, to be able to review license applications or really be prepared to review these facilities that they do move towards commercial scale or if it's determined that NRC should do licensing reviews of these facilities.

CHAIRMAN RYAN: So far, though, you are talking about a scheme where you're driven by the facilities generating the materials, not by any forward-looking view to the question that we talked about with Dr. Weimer, are you generating a category of waste that hasn't been generated before in terms of --

MR. GIITTER: That's a very good question. I agree with your comment on the systematic approach. Right now all we know based on our conversations with DOE is what the facilities are going to be. We don't even know what the waste streams are going to be.

So I agree with your comment. And I think that forward-looking approach, taking a systematic view of the entire process is prudent. But at this point I really can't comment on what it would be because we just don't know.

CHAIRMAN RYAN: Fair enough. I appreciate that point, but I guess the caution that I see is don't slip into the trap of thinking just about the licensing of the facilities but make sure that you're really focused on what end products are being produced because if you look anywhere in the world, that's where the trouble starts.

MR. GIITTER: That's a good comment.

CHAIRMAN RYAN: Yes.

MR. MAGRUDER: I was encouraged a little bit this morning by the discussion that DOE had. I mean, it seems like they are at least considering the trade-offs that are involved in deciding what type of fuel to use, what --

CHAIRMAN RYAN: Well, again, if you look at the world system, that's where the wheels go off the tracks.

MR. MAGRUDER: Exactly, exactly. Whether they can get their arms around the whole thing and make rational decisions, I don't know, but they're at least trying to do that.

MR. GIITTER: The other thing we took a look at is whether Part 50 could be used to license a liquid metal reactor. Both Bob Pierson, our division director, and myself are probably two of the few people in NRC that actually have some experience in licensing liquid metal reactors. I worked for Westinghouse as a licensing engineer on Clinch River. And Bob was a manager in charge of NRC's preliminary licensing review of the ALMR back in the early '90s.

I can tell you from personal experience that it would be a very painful process to try to license an advanced liquid metal reactor under Part 50.

One of my jobs was to go through the standard review plan for lightwater reactors in the NUREG-800 and to show where the Clinch River deviated or met the standard review plan. And there were probably more instances where it didn't meet it than where it did.

And there are unique considerations with liquid metal reactors. One of the considerations is because the design and safety considerations are substantially different than lightwater reactors. The mindsets, some people are very uncomfortable.

For example, with Clinch River -- and I'm not sure about the ALMR, but the design requires redundant and diverse fast-acting shutdown systems because you have a positive void coefficient. And, you know, if you have voiding in the reactor, you can have a fairly significant reactivity excursion.

On the other hand, there are some safety advantages to using liquid metal reactors. You don't have to have systems in standby readiness, emergency core cooling systems in standby readiness. You have liquid metal, which doesn't boil until you reach about 1,623 degrees Fahrenheit at atmospheric pressure. And the operating hot leg temperature is around 2,000 degrees.

So you have a substantial built-in subcooling margin. And so you have more forgiveness for loss of heat sink accidents. Then, again, you have issues like the reactiveness of sodium in water and sodium in air.

But that is clearly going to be a challenge. And, again, I think we would need to look at possibly a new regulation or, going to the next page, something that the staff has been working on. And that is developing a technology-neutral framework for licensing advanced reactor designs.

CHAIRMAN RYAN: Could you talk a bit more about that? Before you leave that slide, could you talk a little bit more or are you going to go back to that in a minute?

MR. GIITTER: No. I can go back to it.

CHAIRMAN RYAN: The technology-neutral framework.

MR. GIITTER: Maybe Stu can comment on that because he worked on it.

MR. MAGRUDER: Yes. A while ago, yes. basically, the staff has been thinking about next generation reactors for several years, obviously. And the goal is to have kind of a set of high-level standards that any design would have to meet. They would have to -- there would be certain reliability requirements.

There would be certain health physics requirements and worker protection requirements. And they would have to meet the NRC quantitative health objectives, you know, for reactors and things like that.

And then we would try to develop kind of an over-arching set of principles that any design would have to meet. And the goal would be to try and apply these principles to this design, essentially.

So that eventually it would probably become a new Part 53 or whatever. I don't know what the next available regulation number is, but they were talking about developing a new regulation because of the diverse -- you know, the gas reactors or PBMR, you know, other types of liquid metal reactors besides the sodium reactors. So it's fairly high-level now, but we would try to apply those principles to this. Dr. Larkins has some comments.

MR. LARKINS: No. It's like you said. And I think it's just being discussed now. There are a couple of public workshops being planned in the next few months. The ACRS has reviewed the concept paper and commented on it. So I think it's probably still a little --

CHAIRMAN RYAN: A work in progress.

MR. LARKINS: Yes. It's a work in progress. It's still a little ways to go.

MR. GIITTER: There would be a number of security and safeguards issues, obviously, when you're talking about reprocessing spent fuel, possible changes to Part 73, Part 74, and Part 75.

And there may be changes to Part 51 to address the potential environmental impacts of spent fuel transportation to the facilities that are described here. I mean, Part 51 does address that already to some extent, but with the waste streams that may be generated and the number of facilities, it's probably going to be some additional reevaluation of the fuel cycle in Part 51. I know that the last time I checked, the tables in there hadn't been updated in some time.

Some potential issues that we have identified. Obviously in the fuel fabrication area, you're going to need increased shielding, health physics issues unique to reactor-grade plutonium.

I will say I've been to Malox, and it can be done. I'm convinced it can be done, and it can be done right. But, again, it's going to take -- you know, it's an issue. And, like anything, there is a certain amount of problem-solving that has to be done to get to that point.

There would likely be a large number of remote operations

radionuclide inventories. You're talking about in some cases very high radiation fields, large radionuclide inventories. Of course, spent fuel is always a challenge. Some of the spent fuel that would be processed would obviously be very old, even decades old, but with newer fuel, you know, you still have a significant heat load.

Another problem that has been discussed is americium-241. Americium-241 creates some interesting challenges because, as you can see from this curve here, you actually have a significant ingrowth of americium-241 with time.

The longer you let the spent fuel sit, the more ingrowth you have. And so ideally, especially if you're talking about reprocessing the spent fuel, it would be ideal to do it sooner, rather than later, to minimize the amount of 241 ingrowth.

I think the approach that people are talking about, though, as Stu indicated, you separate out the americium with the other transuranics, with the neptunium and curium and, of course, the plutonium. And you burn it in a fast reactor.

And 241, I believe, will fission at those neutron energies. You can significantly reduce the 241. But if you don't, then, you know, you've got a problem in terms of the --

CHAIRMAN RYAN: Could you just keep on that graph?

MR. GIITTER: Yes.

CHAIRMAN RYAN: I'm missing something. Americium ingrowth where? For recycles of fuel, the americium-241 goes with the plutonium, right?

MR. GIITTER: Right.

CHAIRMAN RYAN: It's going to grow in there, --

MR. GIITTER: Right, right.

CHAIRMAN RYAN: -- as opposed to grow in somewhere else, which I guess is in waste.

MR. GIITTER: Right.

CHAIRMAN RYAN: Okay. This is one of those interesting trade-offs. If you reprocess at five years, what issues do you raise in the reprocessing plant itself, dose to workers every day, --

MR. GIITTER: Right, that's right.

CHAIRMAN RYAN: -- as opposed to theoretical dose down the line somewhere. That's an interesting --

MR. GIITTER: This is one of the inputs that helps you optimize, making the best optimizations.

CHAIRMAN RYAN: But trading off real rem today versus hypothetical rem somewhere down the line is something to think about.

MR. MAGRUDER: Yes, it is. We brought that up with DOE this morning.

MR. GIITTER: These are some other issues that we thought about. Security obviously, the idea is that once you irradiate fuel, it's self-protecting, but if it's been sitting in a spent fuel pool for a couple of decades, it may not be as self-protecting as you might like. So there are obviously some proliferation issues there and, of course, transportation issues.

Social. What is really going to make this program move forward is whether or not it gets international acceptance because this is a program that involves a number of international partners.

India apparently has already agreed to sign on. The other countries may be a little more skeptical, may be taking a little bit of a wait and see attitude. But Russia appears to be eager to join. DOE is trying to line up as much international support as it can for this.

And, of course, things change with changing administrations. And I don't need to go into detail on that, but, I mean, as energy prices go up, as oil prices go up, people are more open to other technologies for producing energy and electricity.

Acceptance. Research. Well, our experience is mostly based on Purex, on the commercial level. And DOE is adamant that Purex is not going to work for this. They're looking at only a UREX+ or UREX plus something process, which, of course, includes the transuranics with the plutonium so that it is less of a proliferation concern. But that is going to require the cooperation of other countries as well.

And countries like France and Great Britain and even Japan that are operating currently using the Purex cycle may not be very excited about the idea of going to a UREX process.

One concern is, of course, the spot market price uranium. To some extent, it's going to drive the economics. And the last time I checked, the spot market price was about $43 a pound of U308. That's higher than spending in a long time, but in current dollars, it's actually considerably lower than it was in the '70s. In fact, in order for it to be at in real terms the same price as it was in the mid '70s, it would have to go to over $100 a pound.

CHAIRMAN RYAN: That's kind of a "So what?"

MR. GIITTER: Yes.

CHAIRMAN RYAN: I mean, that's like saying gasoline should be $9 a gallon based on the price in '63. You know, the point is there is an aggressive market for developing uranium resources. And the prices are going up.

MR. GIITTER: I guess my point is industry is primarily interested in the economics of this. And in --

CHAIRMAN RYAN: That's based on today's dollars. That's not based on what should have, could have been.

MR. GIITTER: Yes.

CHAIRMAN RYAN: I mean, I just don't follow that as being helpful. The fact is uranium is expensive, getting more expensive.

MR. GIITTER: It is expensive, but it is a relatively small percentage of --

CHAIRMAN RYAN: In the big picture, it's nothing.

MR. GIITTER: Well, yes. It's a small percentage of their O&M costs.

Radiological issues. This first bullet here, we were thinking before we talked to DOE this morning that they may have to use enriched uranium for the driver fuel for the advanced burner test reactor. They clarified that this morning and said no, they would just go to a higher plutonium concentration.

But, in any event, there may be some issues down the road with recycling that may have some ramifications for lightwater reactors. And we're not exactly sure what those are at this point in time.

Byproduct, low-level waste obviously needs to be minimized. And there were a number of waste streams that we're not -- as I said, we really don't know what all the waste streams are, but it's going to be a challenge, I think, relative to what we see our current waste streams, just to keep track of them and be able to figure out what the best solution is for minimizing the volume of waste, the best solution from an environmental perspective.

And there may be some wastes that are difficult. High-sodium or chloride waste may be difficult to vitrify. We saw that with the surplus plutonium disposition program for MO_x. It was originally planning to vitrify those wastes, and they decided that it was too difficult technically to do that. And they decided to MO_xify those wastes.

CHAIRMAN RYAN: One of the interesting things we haven't explicitly touched on today, either in Dr. Weimer's talk or your presentations, is mixed waste. This is probably as good a place as any to ask it. You don't really have a big mixed waste problem in radioactive waste management unless you reprocess.

So has anybody raised the mixed waste question? Have you heard any comment on that or --

MR. GIITTER: We haven't gotten into that kind of detail yet. You're right. I agree with what you said, but that is something that we are going to have to look at.

CHAIRMAN RYAN: Yes. Reactivity is one. Of course, when I see sodium, I think that's a reactive metal. So that's clearly going to be mixed waste as well as other things.

MR. GIITTER: The path forward. We did meet with DOE this morning to talk about -- it was just our initial kickoff meeting. They're planning to have another meeting in about one to two weeks to focus on the international issues.

As Stu indicated, OGC is currently working on drafting some legislation for NRC authority to regulate the demonstration facilities, and target for having that completed is the fall of this year.

We did talk a little bit about developing a conceptual licensing process. And when I say "conceptual," we're talking very high-level. One of the vote sheets on the SRM had asked us to do that by the end of 2007. So that's our intent, to try to do it at a conceptual level anyway, by the end of 2007.

As I indicated before, the conceptual licensing process would address not only the fuel cycle regulations but also regulations that would apply to the advanced burner test reactor. It would apply to possible changes to Part 51 for environmental reviews. It would apply to domestic and IAEA safeguards and import/export controls and, of course, waste management.

Our plan is to develop a task force that includes representatives from NMSS and NRR, Office of International Programs, the Office of Research, and the Office of General Counsel, and any other entities that may have an interest in this in trying to work this problem over the next year and a half and see where DOE goes with this and in the meantime work very closely with DOE to understand the technology.

We want to be able to ask the right questions and the tough questions so that when all is said and done, if they do decide to go to a commercial scale or Congress decides that we're going to regulate these facilities, that we will be in a position to do it.

CHAIRMAN RYAN: Okay.

MR. MAGRUDER: That concludes our presentation.

MR. GIITTER: Yes. That's it. Questions?

CHAIRMAN RYAN: Thank you. Bill?

MEMBER HINZE: A very quick question. The decision as to whether to develop a new regulation or supplement or modify existing regulations, have you thought about the criteria you are going to use to do that? What's the time frame of that decision and passing that up to the Commission?

MR. GIITTER: Well, as I said, our goal is to complete our -- I'll use the word design of a conceptual licensing process by the end of fiscal year 2007.

The criteria we're going to use, you know, it's going to be based on our experience, based on our licensing experience. In the materials arena, we have had some very good experience recently with MO_x and the gas centrifuge facilities. And, of course, NRR has had some experience with the Part 52 process.

MEMBER HINZE: But you won't have the experience of seeing these demonstration projects.

MR. GIITTER: That's correct. And that's why we're only talking about developing something at a conceptual level.

MEMBER HINZE: I understand. Thank you very much.

CHAIRMAN RYAN: One that kind of adds to Bill's question. I guess just hearing your presentation, again, I appreciate the fact that you are here in a very preliminary stage offering us your insight. So this is more of a dialogue than it is question and answer. I'm trying to learn from you as much as anything else.

It seems to me that with a demonstration facility, I understand that you don't want to regulate it because DOE certainly has its own structuring capabilities in that area, but, by the same token, it seems to me that not regulating it might be missing an opportunity.

Clearly you're going to be involved and active with it, but how could you meet in the middle? I mean, is there a way to help be involved in their process in some way in how they self-regulate it? They'll have to do something --

MR. GIITTER: Well, that's a --

CHAIRMAN RYAN: -- and learn from it and, by that process, improve your regulation for the full-blown facility and the commercialized version of it.

MR. GIITTER: I understand what your question is. My personal feeling is that we should regulate it, the demonstration facilities and, by going through that process, make further changes to our regulations so that when these facilities are at a commercial scale, that there will be less uncertainty.

But that's more of a political decision or a policy decision. You know, I can't comment on whether or not -- I don't know if that's going to be something that Congress would be in favor of.

I can tell you I know the DOE doesn't think we should, you know, license the demonstration facilities. And another interesting issue may be more than likely that these demonstration facilities are in existing DOE reservations. It doesn't mean we couldn't license them. The MO_x facility is probably a good example of a facility that's on a DOE reservation.

CHAIRMAN RYAN: I would just say that's something that maybe deserves some additional dialogue and thought because somewhere in the middle of not regulating it and regulating it, there is an opportunity to participate. We can learn an awful lot and I'm going to guess end up with an improved regulatory process at the end of the day.

MR. GIITTER: Right. And that's our plan as a minimum. And DOE agrees with us on that. If we don't regulate it, we will be working very closely with DOE. The question is, to what extent would we force them to go through an NRC-type licensing process.

CHAIRMAN RYAN: Point.

MR. GIITTER: And we tried that, for example, with a fast flux test facility with mixed results. Clinch River, as an example, did go through an NRC licensing process. And I think that was probably much more useful, both to the staff and to the applicant.

CHAIRMAN RYAN: The other question, I guess, -- and it's kind of off to the side, but I didn't hear anything that talked about how any agreement state entities would be involved if any of these are agreement states. I'm going to guess not. Have you thought about that dimension?

MR. GIITTER: We haven't.

MR. MAGRUDER: That has not come up at all. That's a very good point.

CHAIRMAN RYAN: Some of those parts are agreement state parts, too.

MR. GIITTER: Yes.

MR. MAGRUDER: Yes. That's a good point.

CHAIRMAN RYAN: And on DOE facilities, I know some agreement states, maybe not the agreement state program that is authorized by the NRC but the radiological health departments are involved in roles with DOE facilities in various states. So just tuck that away as something to think about maybe later on. That struck me as you were talking about some of the parts that are more familiar to me as they are adopted and agreement states, your fabrication, for example.

MR. MAGRUDER: Right.

CHAIRMAN RYAN: Thanks. Thank you.

MEMBER WEINER: I just have one. And it will certainly come up in regulation. It seems to me just from a very lay perspective that as far as nonproliferation is concerned, the genie is already out of the bottle. And I'm a little bit concerned that we're looking at regulation, sort of ex post facto regulation, that won't be doing anything.

By the way, I wanted to thank you for a very thorough discussion of something, where you really are just at the beginning. But I would like to hear your opinion about that since you're the regulator.

CHAIRMAN RYAN: I'm not sure, Ruth, what you mean by the genie is out of the bottle on proliferation. I'm going to need to understand your question a little bit better.

MEMBER WEINER: Well, you know, we keep

saying we're not going to produce plutonium because we're concerned about proliferation, but internationally there is a large number of countries. Plutonium has proliferated around and nuclear weapons have proliferated. We can't get away from that.

MR. MAGRUDER: But I think --

MEMBER WEINER: And we are also -- and another aspect of this is we are not in the leadership position for reprocessing. There are other countries that do it.

CHAIRMAN RYAN: Well, what's the question?

MEMBER WEINER: The question is since this regulation made a major point of saying that Purex is a no-no because we are concerned about proliferation, at least if I'm reading you correctly, --

MR. MAGRUDER: That's correct.

MEMBER WEINER: -- why is this a concern? And how effective do you think this concern is going to be? In other words, if we have a regulation that says in the United States, no Purex, a Purex-type process that gives you plutonium is a no-no, is that really going to do anything in the international arena? What do you think?

MR. MAGRUDER: Well, I agree with you the genie is already out of the bottle. And I think that the proliferation concern is only part of the motivation, actually, for not using Purex.

I mean, one of the things that DOE said this morning, which caught my attention, was that the United States wants to kind of retake the lead in nuclear technology and they wanted to get it back out in the forefront. I think what they see is everybody is doing Purex now. They're nothing new there, nothing exciting about Purex. Let's skip Purex and go to the next generation, which they see as UREX or some of the variants of UREX.

So I think, you know, proliferation is a nice thing to say. I mean, certainly we want to do all we can for nonproliferation, but I think the real reason is kind of trying to put the United States back into a leadership role and these technologies.

MEMBER WEINER: Do you think that is going to do it?

MR. MAGRUDER: I have no idea. You should ask Dr. Weimer, see what he --

(Laughter.)

MEMBER WEINER: I'm reminded that that is an unfair question, but I do thank you for that perspective.

VICE CHAIRMAN CROFF: I guess I maybe have a question or two here, which one to start with. I guess let me go back to the time when the NRC was trying to license a reprocessing plant and policy changed and it stopped, this being the Barnwell well.

At that time and subsequent to that time, the NRC did some rather considerable number of studies to cost-benefit studies to evaluate effluent releases; in other words, how much effluent control was desirable, how much of it was too much.

And I am sort of here bootstrapping off of what Mike mentioned earlier. A lot of what is going to be important in licensing these plants is what goes up the stack, what goes in the creek, and what wastes come out of it.

Back at the time there were these cost-benefit studies that arrived at some kind of an answer, there were a number of studies of how much, in particular, radionuclides could go up the stack, iodine, krypton, carbon-14, tritium, most of them based on the prevailing approach at the time, which relied very heavily on collective dose and adding out very small doses to an awful lot of people.

Since that time, there has been a lot of thinking about how you use collective dose. There was considerable technology development activity well subsequent to Barnwell to look at off-gas technologies.

Are all of these newer considerations reflected in regulation? Is there some considerable amount of work there that needs to be done to determine how much krypton or whatever can go up the stack.

And the final part of that is EPA has a standard or a requirement, I guess, in Part 190 concerning the release of krypton and iodine. Is there any consideration or have you heard anything on their part about reconsidering that standard?

MR. GIITTER: There is a lot of work that has to be done. And, as I said before, we're just getting into this. Unfortunately, I am not in a position to answer your questions, but it is something we're going to be looking at.

MR. MAGRUDER: I can't help on that one either. Sorry.

VICE CHAIRMAN CROFF: Okay. Second, I agree that the NRC should be involved to the maximum intent possible, I guess, or practical, to use a phrase, with DOE as they build these demonstration facilities.

Referring to this ESD, which is the first, I guess I call it a demonstration reprocessing plant, as I understand the description, it's now supposed to be operational, stated 2011, but maybe 2015 is what they have allowed.

In terms of federally funded large capital projects, that's close to the day after tomorrow. There's a very long, convoluted process of conceptual designs and budget approvals, which would lead me to conclude that DOE must be in some stage of the conceptual design at this point.

MR. GIITTER: Correct. And I'm probably sticking my neck out here a little bit, but I think that DOE may be looking in an existing facility. And when we met with them this morning, they did give us a list of facilities that they were looking at as potential facilities they could use as a starting point for the engineered scale demonstration.

VICE CHAIRMAN CROFF: Well, even if it's modifications, they're going to have to be rather substantial --

MR. GIITTER: Right.

VICE CHAIRMAN CROFF: -- to bring it up to licensable standards.

MR. GIITTER: Right. That's a lot. You would save a considerable amount of time relative to starting with a green site.

VICE CHAIRMAN CROFF: I don't know about that. It's the dollar numbers I think that drive the process, not the green --

CHAIRMAN RYAN: Of course, the trade-off is remodeling is always tougher than building something new.

VICE CHAIRMAN CROFF: Yes.

MR. MAGRUDER: They've told us that on the ESD, they got the CD-0, the approval for the concept, I guess, a couple of months ago, I guess. And their goal is to get the CD-1 sometime next summer, I think.

VICE CHAIRMAN CROFF: "CD" being critical decision?

MR. MAGRUDER: Right, right. They are planning to have a 30 percent conceptual design meeting sometime early fall on the ESD. So that gives you a rough idea of where they are. And they have invited us to that design meeting.

VICE CHAIRMAN CROFF: Okay. And have they said that this ESD, they're going to try to build it to be licensable as if it were to be licensed, even though it may not be?

MR. MAGRUDER: Yes.

VICE CHAIRMAN CROFF: That would seem to

prevent some --

MR. GIITTER: I'm not sure that I would go as far to say that they would say that it would be licensable under any particular regulation other than they would want to know if there's anything associated with the design that would be difficult for it to be licensed, which is a little different.

VICE CHAIRMAN CROFF: That would seem to present some interesting challenges in terms of telling them your expectations on, for example, effluent controls for six months. That's pretty formidable.

Okay. Let me pursue another line here. Coming, as we heard, in Dr. Weimer's talk, coming out of the plant, there are going to be any number of waste streams. You can imagine a high-level waste stream, be it vitrified or not, -- we'll see -- some amount of low-level waste, meaning class C or less, for which there is presumably a disposal destination, but a fairly substantial amount of what I would call transuranic waste, which is in DOE space greater than class C, everything from cladding holes to things contaminated from processing the plutonium and cleaning it up.

And right now the greater than class C

problem is not very large, but if this were to happen, it would become rather considerably larger.

Is there any dialogue with the, I guess it is, Department of Energy in this presumably forthcoming EIS on greater than class C? Is this on the radar screen?

MR. GIITTER: I believe it is, yes.

MR. MAGRUDER: That's my understanding.

MR. GIITTER: Right. They talked about that a little bit this morning.

VICE CHAIRMAN CROFF: Okay.

MR. GIITTER: As I said earlier, they're definitely trying to think holistically about what they are doing for the entire fuel cycle.

VICE CHAIRMAN CROFF: "They" would be talking about the NE people?

MR. GIITTER: Yes.

VICE CHAIRMAN CROFF: But have they made the connection back to the other parts of DOE that are doing the greater than class C thing?

MR. GIITTER: Yes, I think this is a major priority with the Secretary. And I'm trying to remember the organization in DOE, but they are working very closely with other offices in DOE. NE is driving the program, has a leadership role for the program, but all of the other, many of the other, offices in DOE are working on this.

I do have to say that I have worked with DOE on a number of other instances, and this is really the first time I have seen all of the offices working together. They seem to be anyway.

VICE CHAIRMAN CROFF: Okay. I think with that, ACNW staff? John Flack, you had a question earlier.

MR. FLACK: I have a lot of questions, but I think we'll get around to them over the next several months. I don't want to hold it up.

MR. LARKINS: Let me just ask a quick question. I noticed in the SRM, staff has directed to developing some type of legislation. Is that going to be the success path in terms of agency involvement or without the legislation, would you still see working with DOE in some cooperative fashion, develop some regulatory framework, at least some way of certifying or proving this facility?

MR. GIITTER: I think we would be in a stronger position personally, again, if we could regulate those facilities. But absent that, I think we can accomplish a lot without that. And DOE certainly seems to be willing to work with us. So I think there is a success path either way.

MR. LARKINS: I was thinking back because there have been a number of activities like this in the past, having been around through CRBR also doing HCDA calculations.

MR. GIITTER: Yes.

MR. LARKINS: I think there are several examples. I was wondering if compiling information on the areas where things have gone well and, you know, what do you consider a success and where there have been problems.

MR. MAGRUDER: That's a good point. As I mentioned earlier, one of the overriding goals of this program for them is to commercialize it. And they realize that unless the NRC agrees with what they're doing and would be receptive to an application from somebody, that it's a non-starter.

So they are very willing to work with us on making sure that if we don't regulate facilities right away, that they are very willing to work with us to make sure that whatever they are doing, we would not have a problem.

MR. LARKINS: But are you compiling information on where you think we've had success in the past and where there have been problems so you can sort of identify issues on --

MR. GIITTER: It's a knowledge management issue, John.

(Laughter.)

MR. LARKINS: Yes.

MR. GIITTER: I don't think we necessarily know. We're working on what we can.

MR. LARKINS: Yes.

MR. GIITTER: And, you know, unfortunately, there's not a lot of people around who have any experience when we did the licensing of Barnwell and Clinch River for that matter.

MR. LARKINS: Well, maybe we can help you pile in a knowledge management program to retrieve some of that information.

MR. GIITTER: Anything you could do to help would be appreciated.

MR. LARKINS: Okay.

CHAIRMAN RYAN: That's okay. I mean, that leads to another question, John. And that is resources and particularly people. If you'll look in this building, I guess I don't know the number, but it would be probably smaller than you would think of folks who are here and are involved in signing a license for a reactor or major fuel cycle facility.

It's a small fraction.

MR. GIITTER: Yes, it is.

CHAIRMAN RYAN: And here we are on the leading edge of an international cooperative program. We want to grasp the lead back, as my colleague suggested. Where are the people going to come from?

MR. GIITTER: We're going to --

CHAIRMAN RYAN: Thermal hydraulic people. I mean, go up and down the list.

MR. GIITTER: Assuming this program moves forward, our goal is to hire people. And they are going to be new people, but they are going to be talented people and people who can come up and speak quickly.

CHAIRMAN RYAN: That's a great goal, but the point is when you look out there, the academic programs, which, you know, I know a little bit about, they're not out there. You try and find how many nuclear engineering programs are around the country today versus '65. It's a big difference.

MR. GIITTER: Well, and I can tell you if you want to talk about this, one of the strategies we have taken in fuel cycle is, instead of just going out to job fairs and trying to recruit people, we're trying to develop conduits where we can get talent from select universities.

Just fuel cycle, for example, we have a need for criticality safety engineers.

CHAIRMAN RYAN: Right.

MR. GIITTER: There are only two programs in the United States that have criticality safety programs: University of New Mexico and University of Tennessee. So what we have done in both of those schools is we have sent a senior chemical safety engineers out to do a colloquium to give them an idea of the type of research, the type of work that we're doing in the NRC to kind of whet their appetite.

We are also directing research at those universities; and in areas, for example, there's not a long of benchmark data for uranium-235 above five-weight percent. That's one area where we're working both with the University of Tennessee, University of New Mexico to have them help us out.

And we're sending managers down to have special recruitment sessions at those universities. We're doing what we can. But it takes a while to develop those kind of relationships.

CHAIRMAN RYAN: Yes. And I'm asking not to try and find a hole but to see if there is a way where this Committee could help you identify what some of those things might be and point them out to the Commission because, you know, as we write letters, it's always helpful to say, "We heard about a manpower need in this area."

Another area is ALARA engineering and shielding design and some of those things. Even those basic things are in complex facilities. I mean, we're putting people to work that sometimes it's their first big design project, probably more often than not.

So, you know, I would offer you the opportunity that if you see those opportunities or gaps or issues, don't hesitate to integrate those into what we hear about because we can maybe offer comment on them.

MR. GIITTER: I appreciate it.

CHAIRMAN RYAN: I'm sensitive to your challenge because, zoom, there's this whole big new fuel cycle. And I think about the numbers of folks, like you've said and some of the others have said, that have retired or passed or both. And where are we going to get the smart folks to fill the jobs? It's hard enough to compete with private industry for those graduates that are coming out.

MR. GIITTER: That's right. Yes.

CHAIRMAN RYAN: And you end up hiring a

lot of consultants and contracting for a lot of research and support activities. That's great, but that doesn't put them on your team here to get the job done.

MR. GIITTER: We just made an offer, Stu did, to an individual who was doing research for, I believe it was, Argonne National Lab related to GNEP. So we are doing what we can to --

CHAIRMAN RYAN: Oh, yes. And clearly you will be, but, you know, I'm not too sure it doesn't need to be notched up a bit.

MR. MAGRUDER: He turned down an offer from Exelon to come and work for us. I hope that's a good thing. I don't know.

VICE CHAIRMAN CROFF: Great. Latif?

MR. HAMDAN: What do we know about the DOE time line? When are they going to whatever it is they are going to do?

MR. GIITTER: It's on the slides.

MR. MAGRUDER: Add four years to it. As much as we know is on the slides, but, as I mentioned, a lot of it depends on the funding.

VICE CHAIRMAN CROFF: I think that's an excellent segue. First, thanks very much for an informative presentation in very preliminary circumstances.

Part of the path forward here I think we'll probably be seeing you guys through the summer, we hope in the July meeting, to get DOE in maybe to talk a little bit more about their schedule, but, more importantly, to get down a little bit into the technical details of what's a pyroprocess and what's a UREX and sort of tell us what they know and what they're thinking and where they're going at a more technical level. So we'll look forward to seeing you then.

And, with that, I think I would like to move into the next portion of the agenda, where we want to talk about a white paper.

Ray, do you want to come up to the table? Ray has been brought on board as a consultant to lead the development of a white paper on this while recycle ball of wax, whatever the thing is.

MR. LARKINS: I don't know whether it was mentioned, but this SRM also calls for the involvement of the ACRS and the ACNW in this whole activity. So this is a good precursor for --

VICE CHAIRMAN CROFF: Yes. That is the reason we're doing all of this. And we propose that a white paper on this subject area be the vehicle for helping the Committee get smart in terms of things like what are the process details to the extent they're known, what are the effluents, and what do we know about these processes and where they're going to give us the best basis we can for making recommendations.

That's basically where we want to get to in the white paper and presumably sometime in the fall, the white paper plus the collective briefings will be the basis for a letter to the Commission giving them our collective wisdom.

Sir?

MR. LARKINS: Do we still need to be on the transcript?

CHAIRMAN RYAN: So now we'll conclude the transcript today. Do we need the transcript tomorrow at all?

MR. LARKINS: No.

CHAIRMAN RYAN: Okay. So that's it.

(Whereupon, the foregoing matter was concluded at 5:21 p.m.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Nuclear Waste 171ST Meeting

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Katherine Sykora
Official Reporter
Neal R. Gross & Co., Inc.

AN INTRODUCTION TO HISTORICAL U.S. NUCLEAR FUEL RECYCLE

PRESENTED TO NUCLEAR REGULATORY COMMISSION STAFF

BY

DR. RAYMOND. G. WYMER

JUNE 6-7, 2006

REPROCESSING: WHAT IS IT?

Chemical separation of irradiated nuclear material from fission products and other actinide elements to recover fissile (e.g., 235U, 239Pu, ^{233}U) and fertile (e.g., ^{238}U, ^{232}Th) radionuclides

Reprocessing: Why Do It?

- Why reprocess?
  - Recover valuable fissile nuclides for us in nuclear reactor fuel
  - Obtain fissile material for military use
  - Reduce High-Level-Waste storage and disposal space requirements
  - Eliminate storage and disposal of fissile material

POWER REACTOR FUELS

- LWR (OVERSEAS REPROCESSING)
  1. PWR
  2. BWR

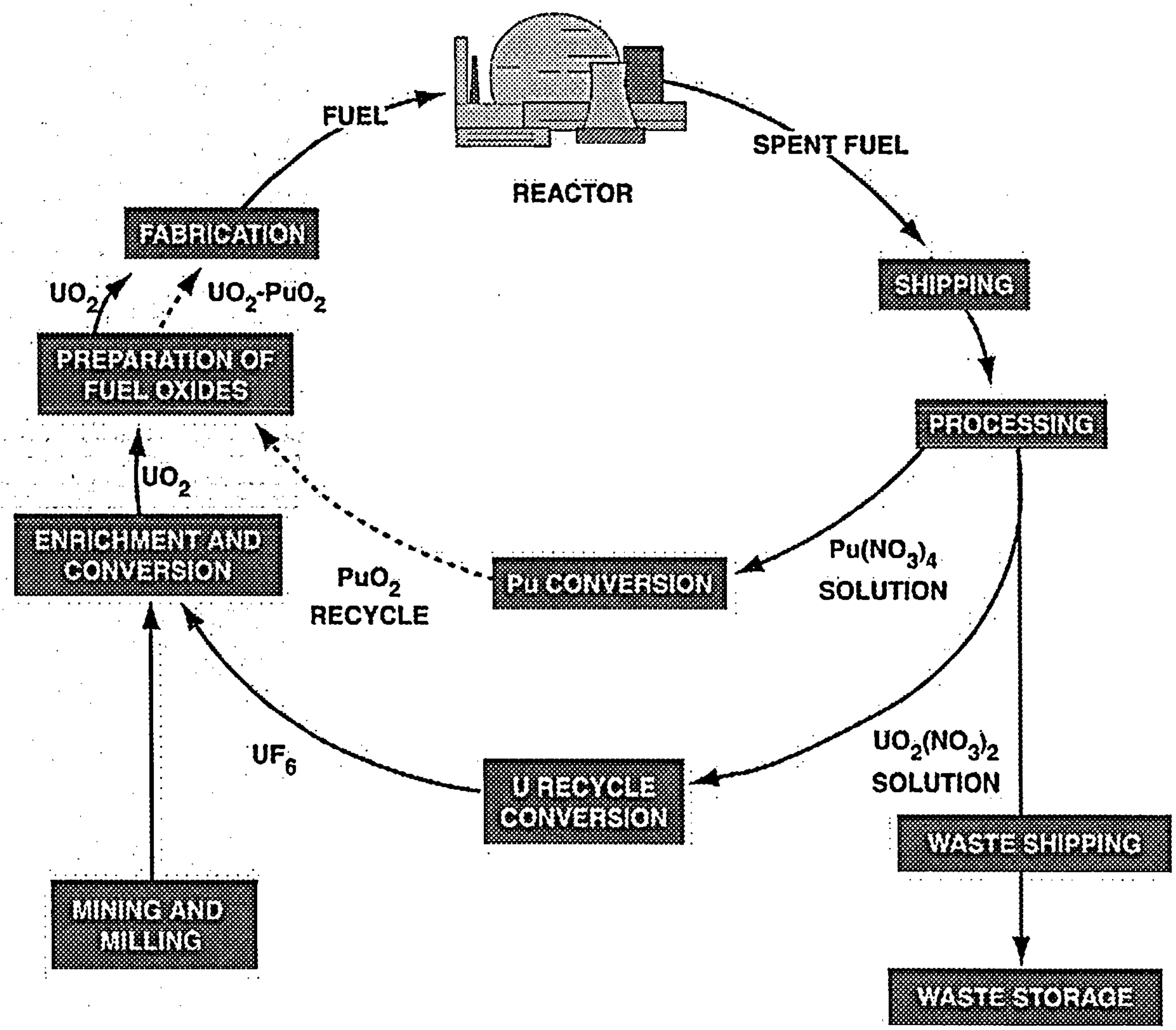
- FRB (LIMITED REPROCESSING)

- HTGR (NO REPROCESSING)

Reprocessing: U.S. Civilian History

- West Valley Plant (West Valley, New York)
  - Operated from 1966 to 1972 at a capacity of 1 MT fuel/day
  - Ceased operation in 1972
- Midwest Fuel Reprocessing Plant (Morris, Illinois)
  - A 1-MT fuel/day plant using PUREX solvent extraction followed by fluoride volatility cleanup of fission products Plant never operated, but spent fuel storage pool is still used
- Allied-Gulf Nuclear Fuel Reprocessing Plant (Barnwell, South Carolina)
  - standard PUREX process; capacity5 MT fuel/day
  - Licensing and construction stopped in 1976 due to change in U.S. policy that prohibited reprocessing

Nuclear Fuel Cycle for Light-Water Reactors



ELEMENTS OF THE NUCLEAR FUEL CYCLE

- TRANSPORTATION TO REPROCESSOR
- ON-SITE STORAGE OF SPENT FUEL
- CHOPPING/DECLADDING FUEL ELEMENTS TO EXPOSE THE FUEL MATERIAL
- TRANSFER OF FUEL TO DISSOLVER
- FUEL DISSOLUTION
- INTERIM STORAGE AND ANALYSIS OF DISSOLVER SOLUTION

ELEMENTS OF THE NUCLEAR FUEL CYCLE (CONT.)

- TRANSFER TO SEPARATION PROCESS EQUIPMENT
- SEPARATION OF U AND Pu FROM FISSION PRODUCTS AND ACTINIDES (Np, Am, Cm) BY SOLVENT EXTRACTION
- SEPARATION OF U FROM Pu BY ADJUSTING EXTRACTION CONDITIONS

ELEMENTS OF THE NUCLEAR FUEL CYCLE (CONT.)

- CONVERSION OF URANIUM AND PLUTONIUM TO OXIDES (SEPARATELY OR AS MOX)
- STORAGE OF PRODUCTS
- STORAGE OF WASTE FISSION PRODUCTS SOLUTIONS AND SOLIDS

ELEMENTS OF THE NUCLEAR FUEL CYCLE (CONT.)

- CLEANUP OF ORGANIC SOLVENT FOR RECYCLE
- TRANSFER OF PROCESSING WASTES TO LIQUID-WASTE STORAGE TANKS (FISSION PRODUCT SOLUTIONS) AS HIGH-LEVEL WASTE
- SOLID WASTES STORAGE AND DISPOSAL (DECLADDING HULLS, OTHER MISCELLANEOUS SOLID WASTES)

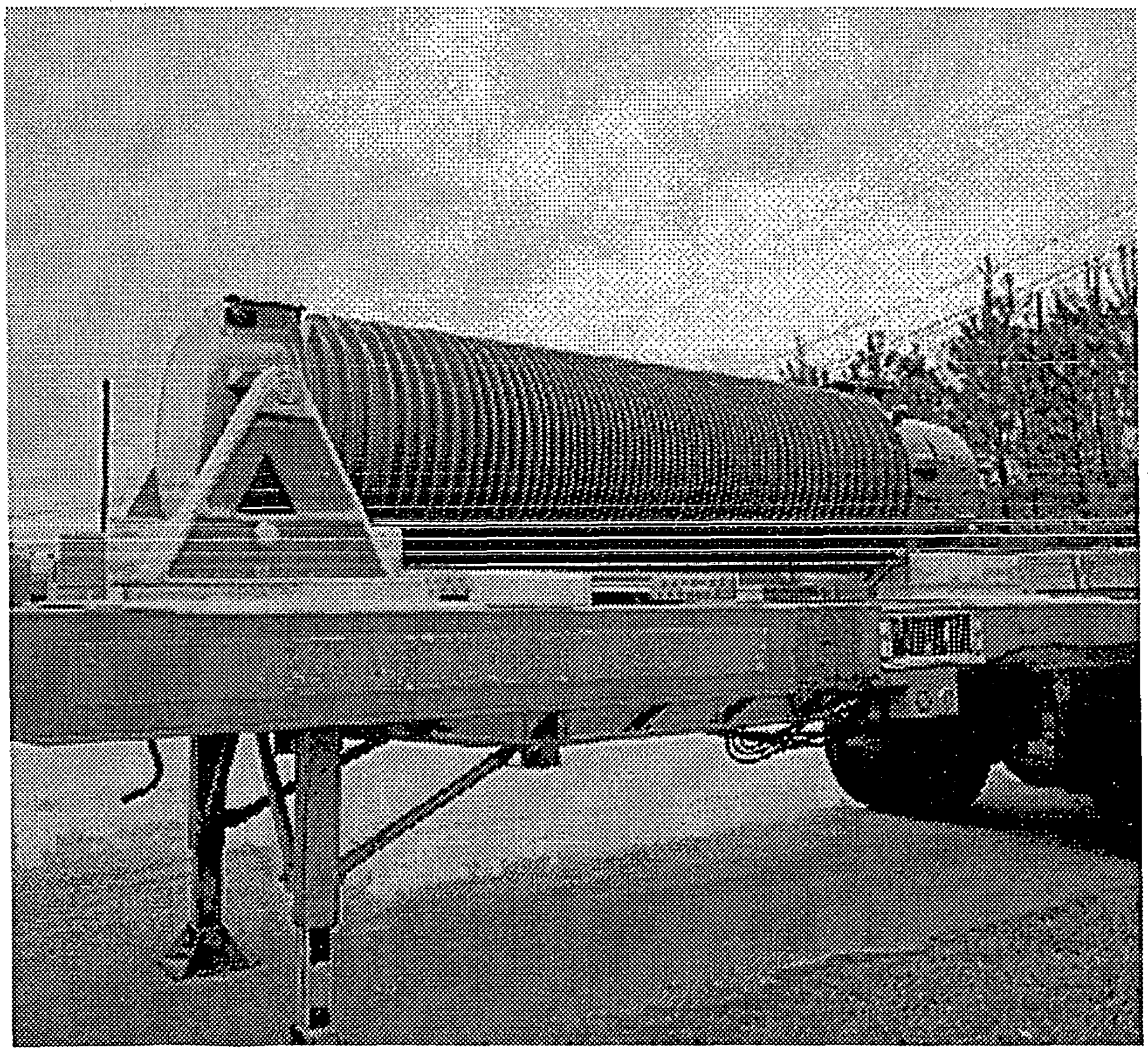
TRANSPORTATION TO REPROCESSOR

- FUEL IS TYPICALLY BWR OR PWR (ELEMENTS ARE UP TO 12 FEET LONG)
- TRANSPORTATION IS A VISIBLE AND OFTEN CONTENTIOUS OPERATION
- TRANSPORTATION CAN BE BY TRUCK, RAIL, OR (LESS FREQUENTLY) BARGE
- FEDERAL, STATE AND LOCAL AUTHORITIES ARE INFORMED

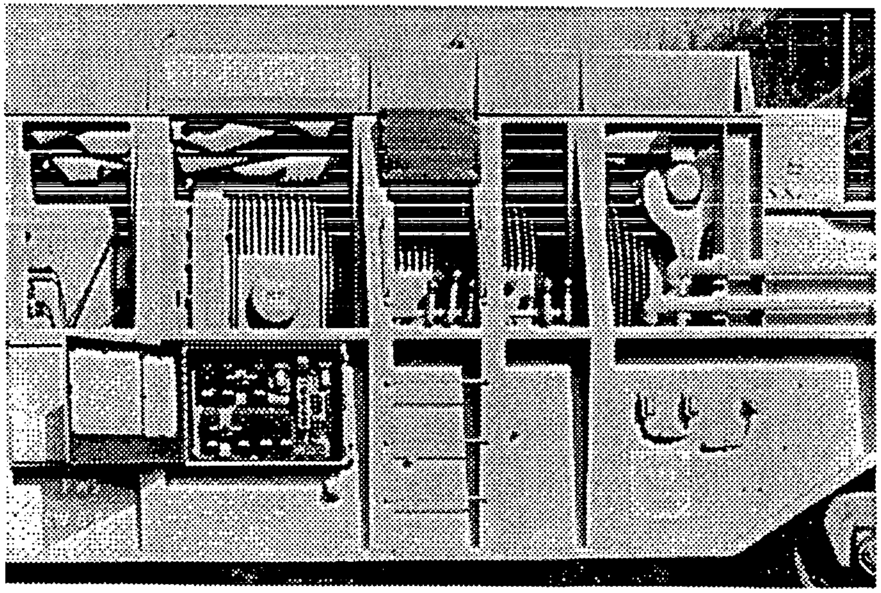
SPENT FUEL SHIPPING CASK

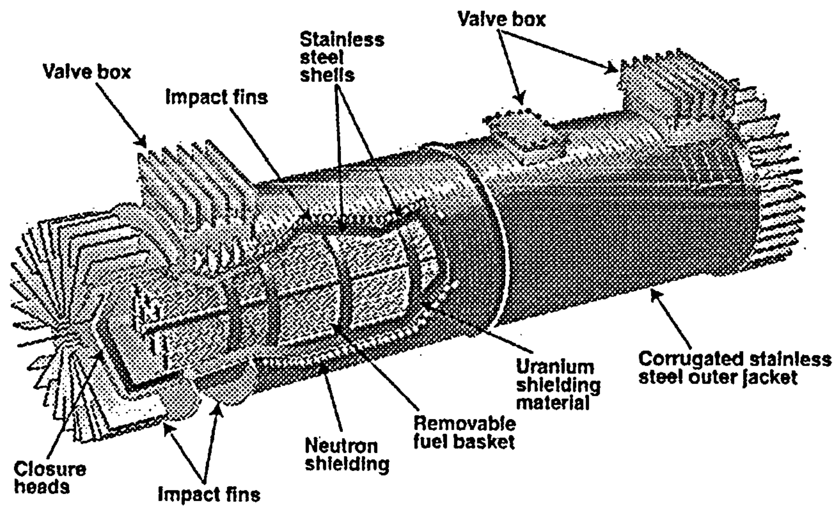
This exhibit shows a transportation package (commonly called a cask) for a single spent PWR or BWR fuel assembly on a trailer. A similar package might be used for solidified high-level waste. The package is much larger than the assembly because of the need for substantial amounts of metal (typically iron, lead, or uranium) to provide shielding from the penetrating radiation. When loaded, casks are typically very warm-to-hot on the outside surface because of the considerable decay heat emitted by the contents.

Spent Fuel Shipping Cask

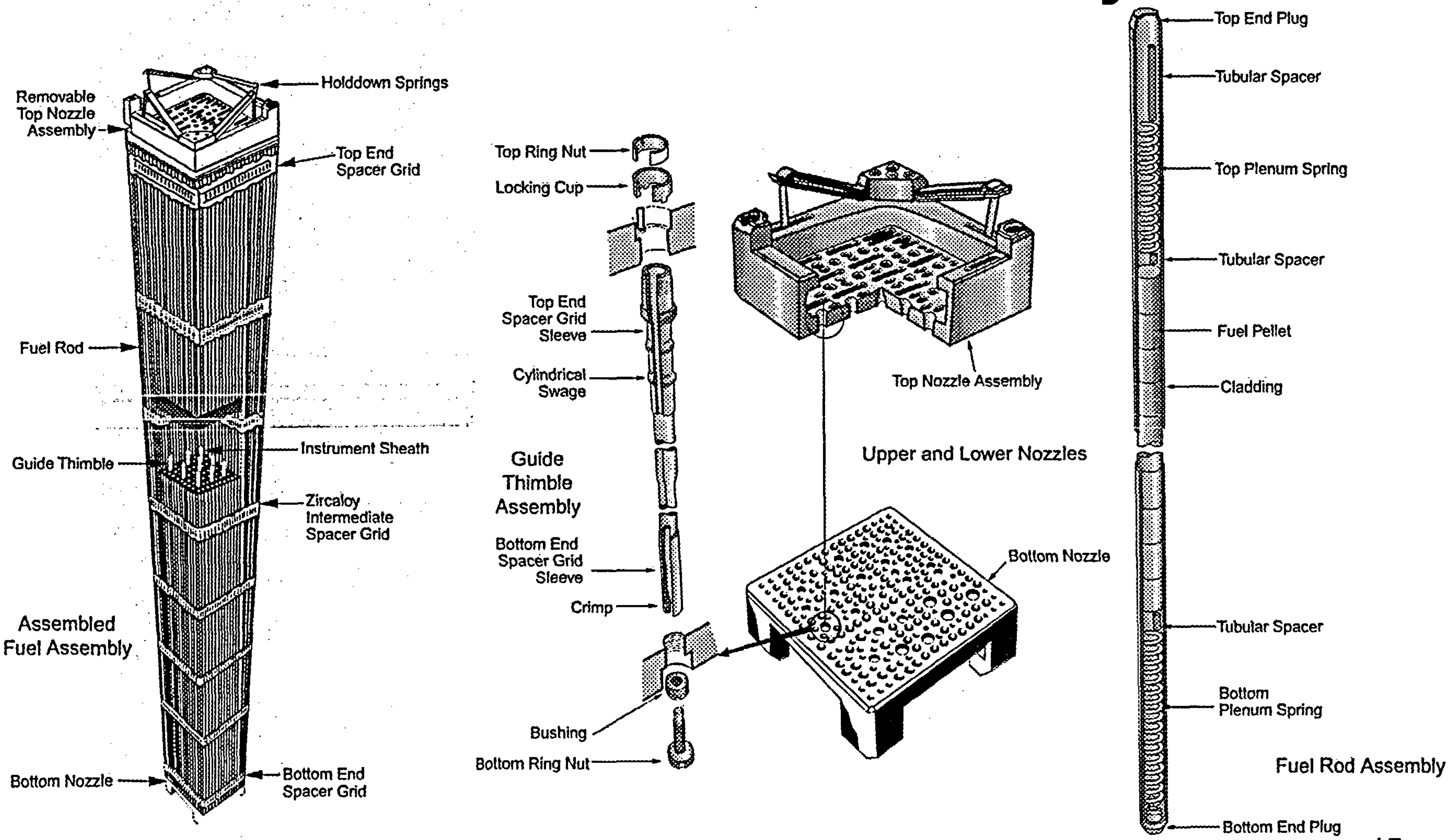


CUTAWAY OF SPENT FUEL SHIPPING CASK AND CASK ON RAILCAR

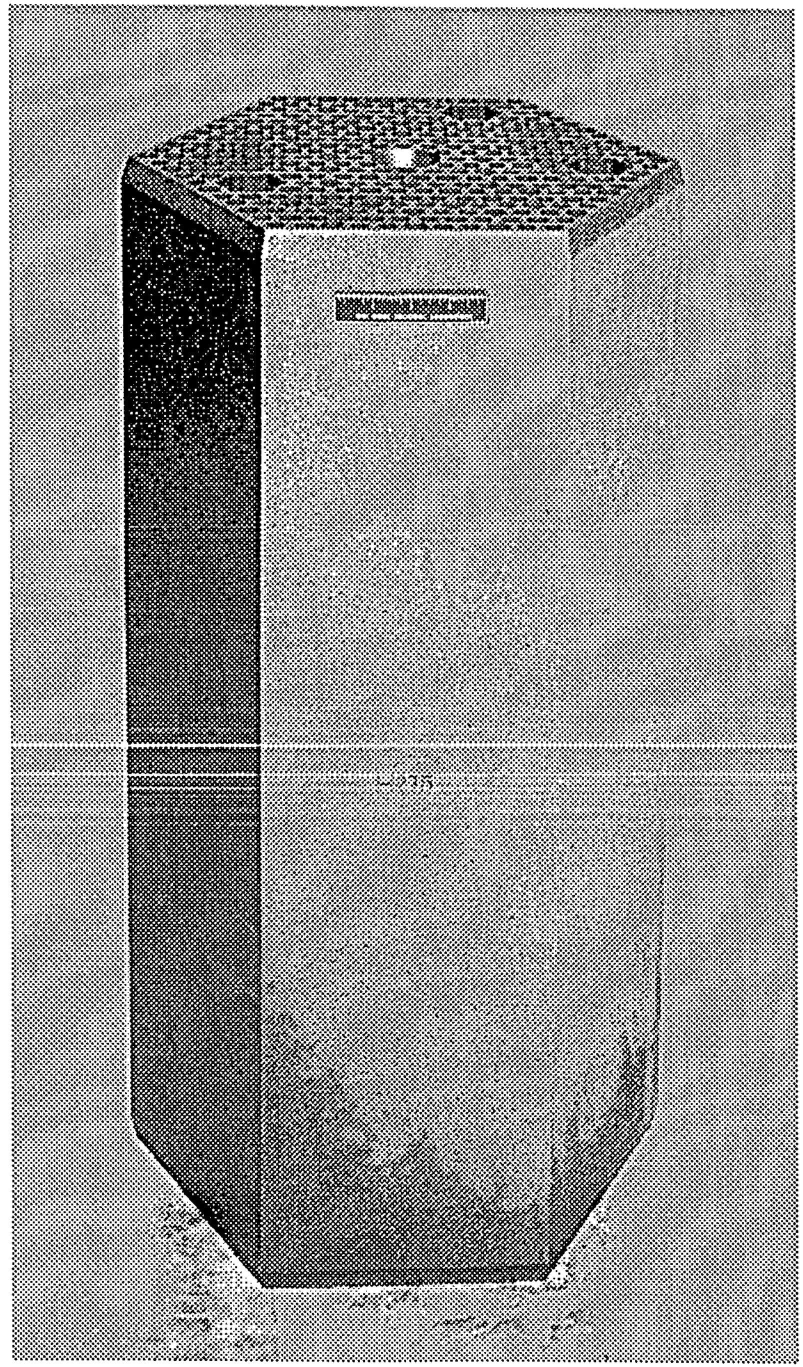




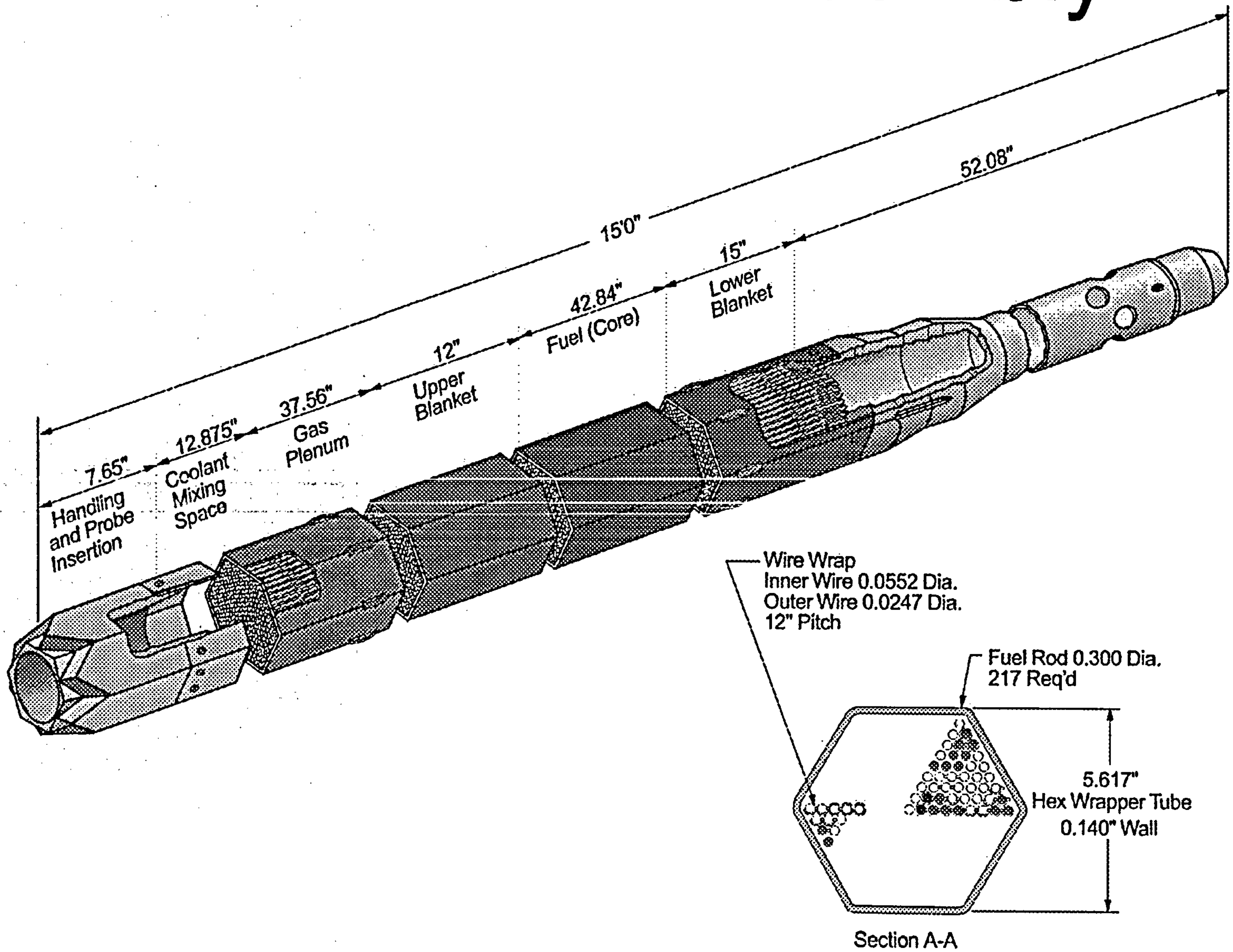
Major Components of PWR Fuel Assembly



HTGR Fuel Assembly



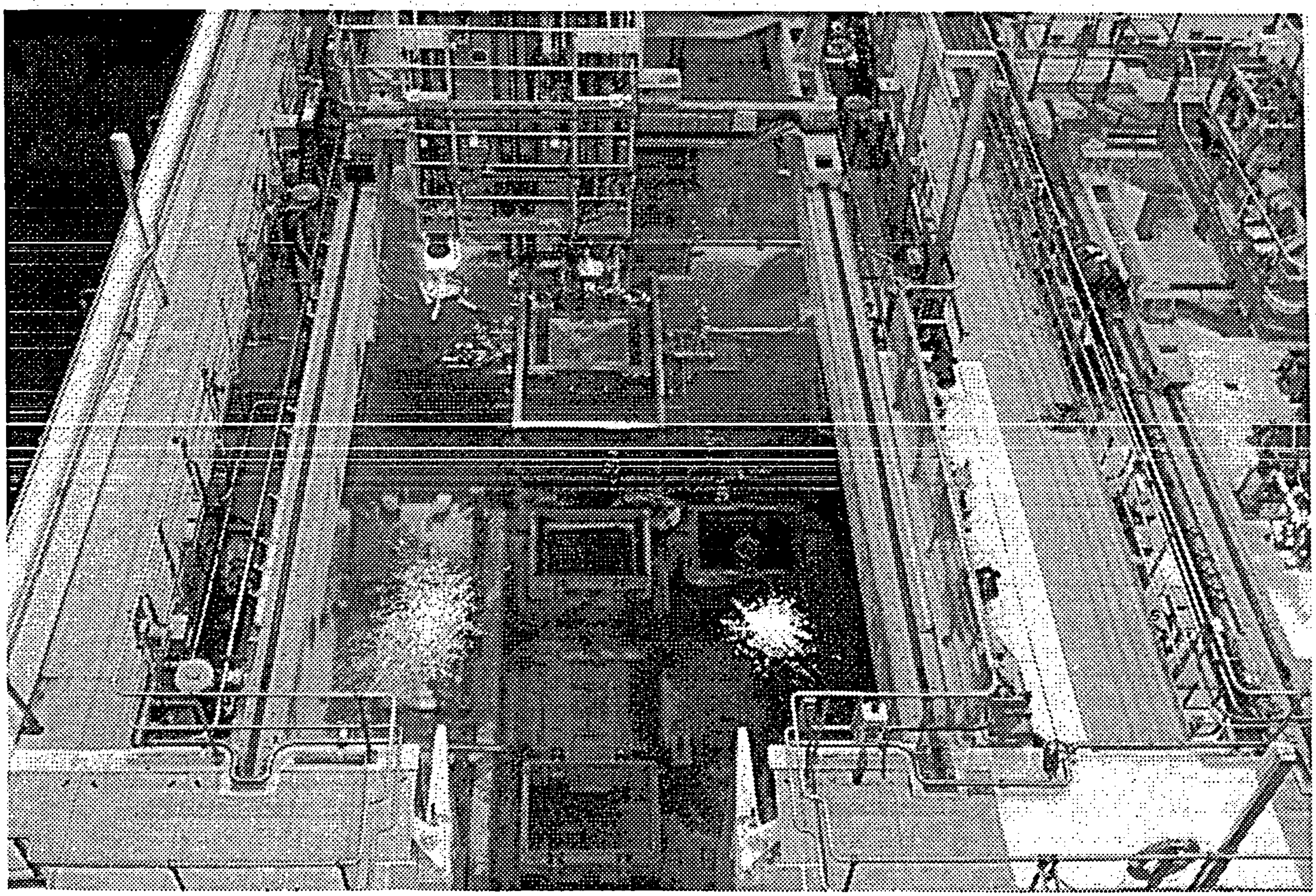
LMFBR Fuel Assembly



ON-SITE STORAGE OF SPENT FUEL

- AT PRESENT IN THE U.S. STORAGE IS MOSTLY AT REACTORS
- STORAGE AT THE REACTORS FOR MORE THAN 5 YEARS IS COMMON
- STORAGE AT REACTORS AND REPROCESSING PLANTS MAY BE IN WATER POOLS OR CASKS

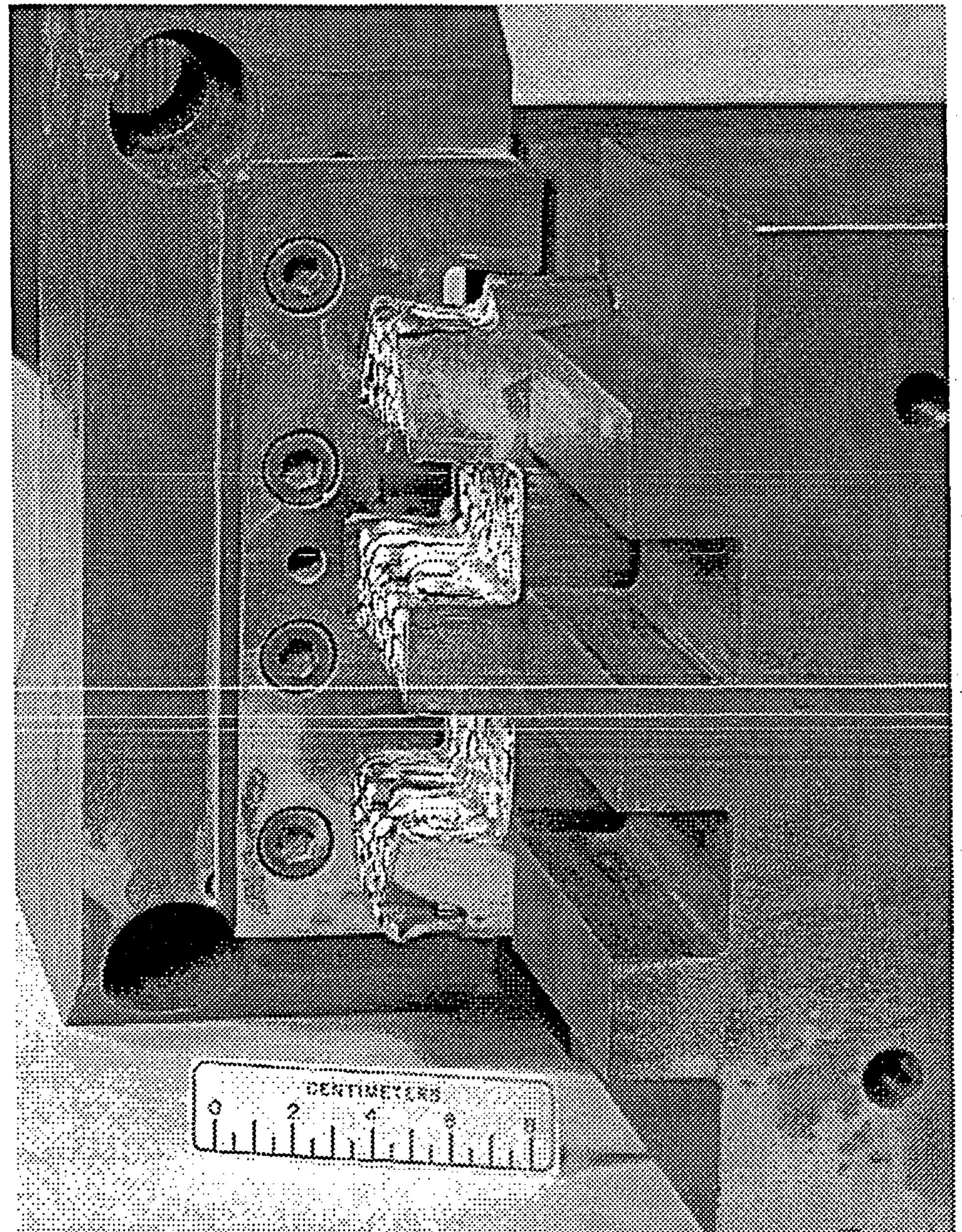
BNFL Fuel Pool



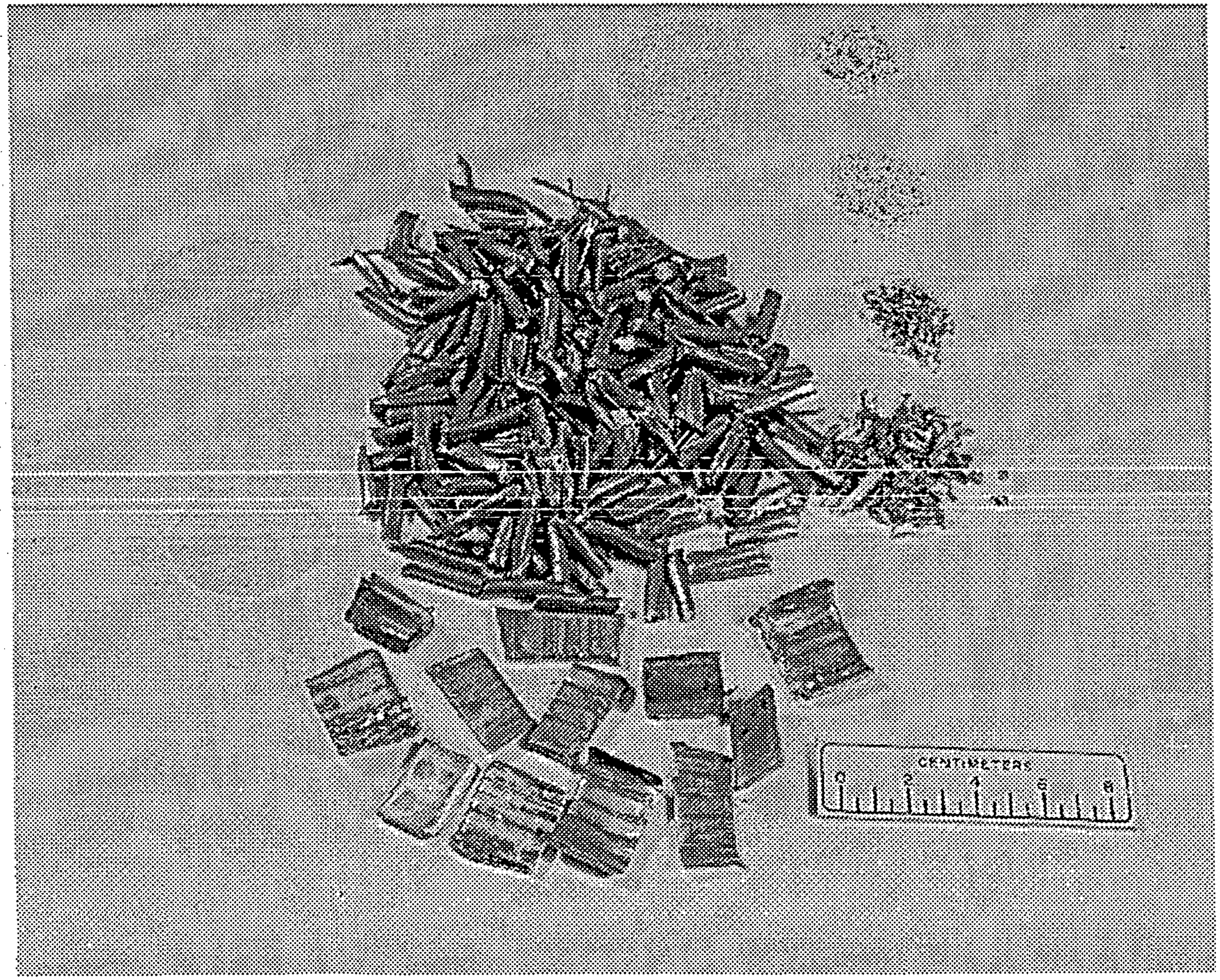
CHOPPING/DECLADDING FUEL ELEMENTS

- OPERATION REQUIRES HOT CELL CONTAINMENT
- FUEL ELEMENTS ARE CHOPPED INTO SMALL SEGMENTS (ONE- TO TWO-INCH PIECES) TO EXPOSE FUEL MATERIAL
- FISSION PRODUCT GASES ARE RELEASED AND MUST BE CONTAINED AND TREATED

Shear with Dummy Rods



Shear Products

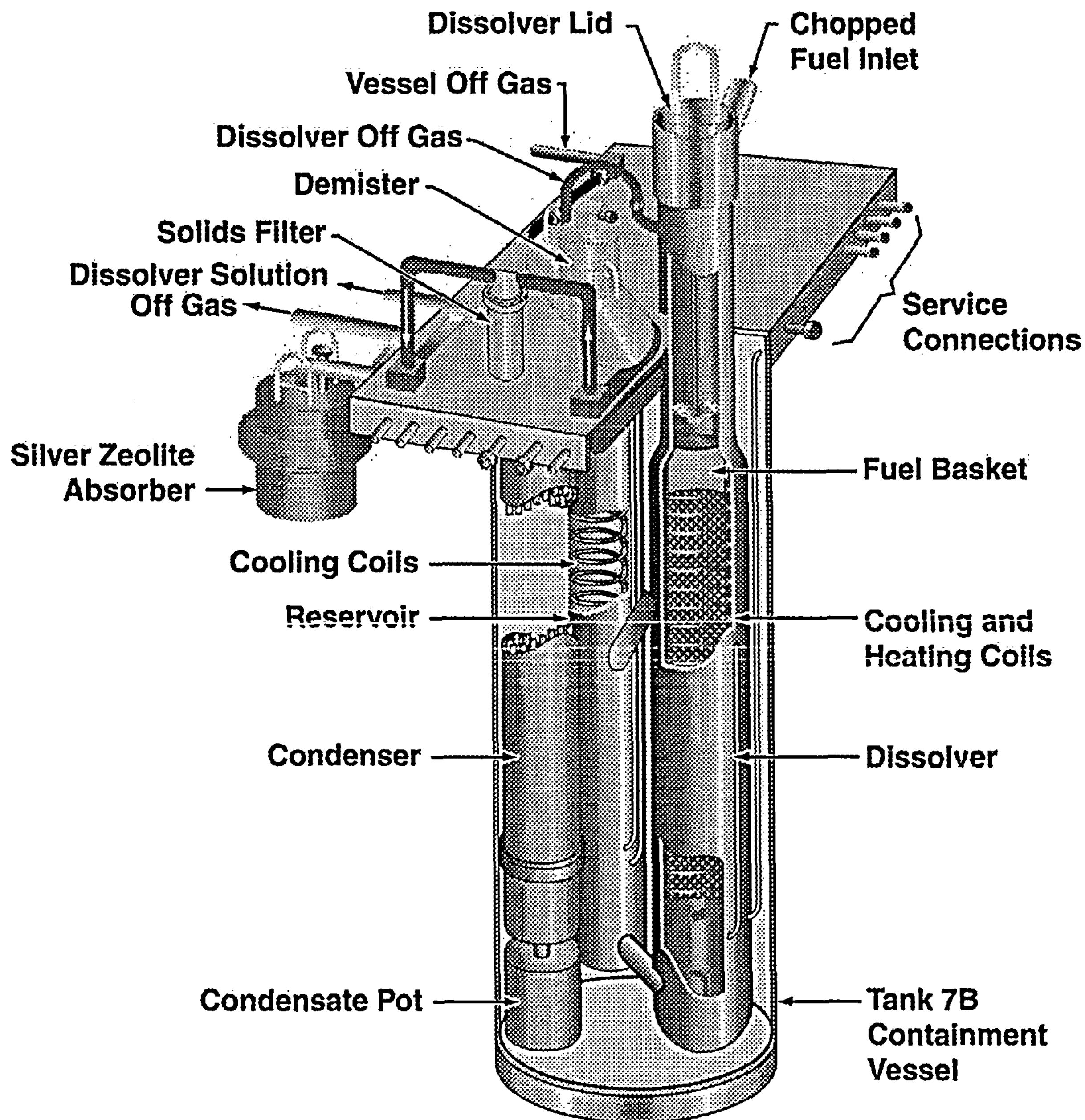


TRANSFER OF FUEL TO DISSOLVER

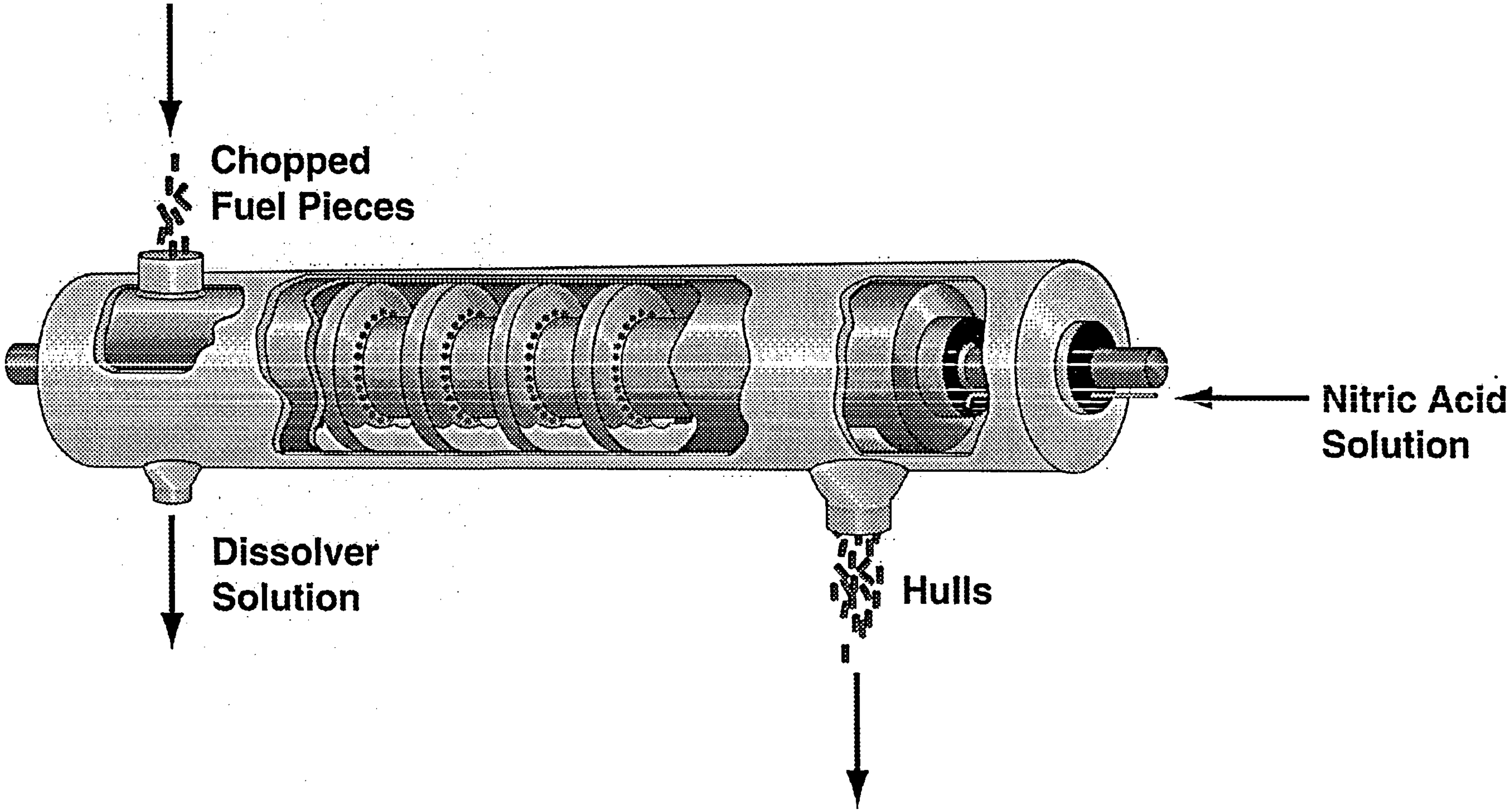
- CHOPPED UP FUEL PIECES AND FRAGMENTS ARE PUT IN THE DISSOLVER

- THIS OPERATION MAY BE CARRIED OUT CONCURRENTLY WITH THE CHOPPING STEP

Schematic of a Batch Dissolver



Schematic View of a Continuous Rotary Dissolver



INTERIM STORAGE AND ANALYSIS OF DISSOLVER SOLUTION

- AN ACCURATE FISSILE ELEMENT ANALYSIS AND ACCOUNTABILITY CHECK IS PERFORMED
- ADJUSTMENTS ARE MADE TO THE SOLUTION TO MEET SEPARATIONS FEED REQUIREMENTS
- FEED CLARIFICATION IS CARRIED OUT IN A CENTRFUGE

SPENT FUEL DISSOLUTION

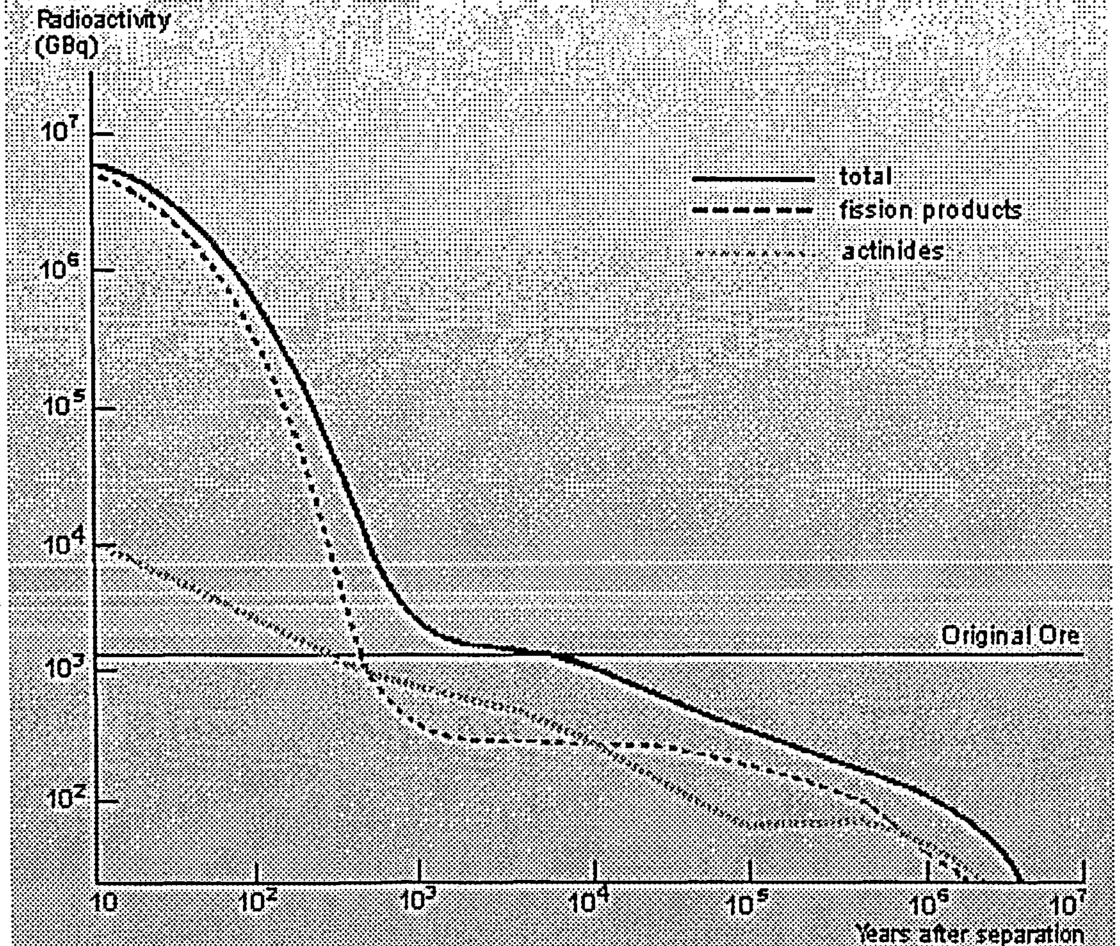
- CHOPPED FUEL GOES INTO NITRIC ACID IN THE DISSOLVER
- SEVERAL TYPES OF DISSOLVER ARE IN USE. THEY MAY BE BATCH OR CONTINUOUS
- RADIOACTIVE GASES EVOLVE FROM THE DISSOLVER – e.g., Ru, I, Kr, CO_2
- EVOLVED OXIDES OF NITROGEN ARE RECOVERED AND RECONSTITUTED TO NITRIC ACID

TRANSFER TO SEPARATIONS PROCESS EQUIPMENT

- ANALYZED SOLUTIONS ARE FED TO SEPARATIONS PROCESS EQUIPMENT
- NITRIC ACID CONCENTRATION IS ADJUSTED FOR URANIUM AND PLUTONIUM SEPARATION FROM FPs
- VALENCE OF Pu IS ADJUSTED TO REMOVE IT FROM URANIUM

Decay in radioactivity of high-level waste

from reprocessing one tonne of spent PWR fuel



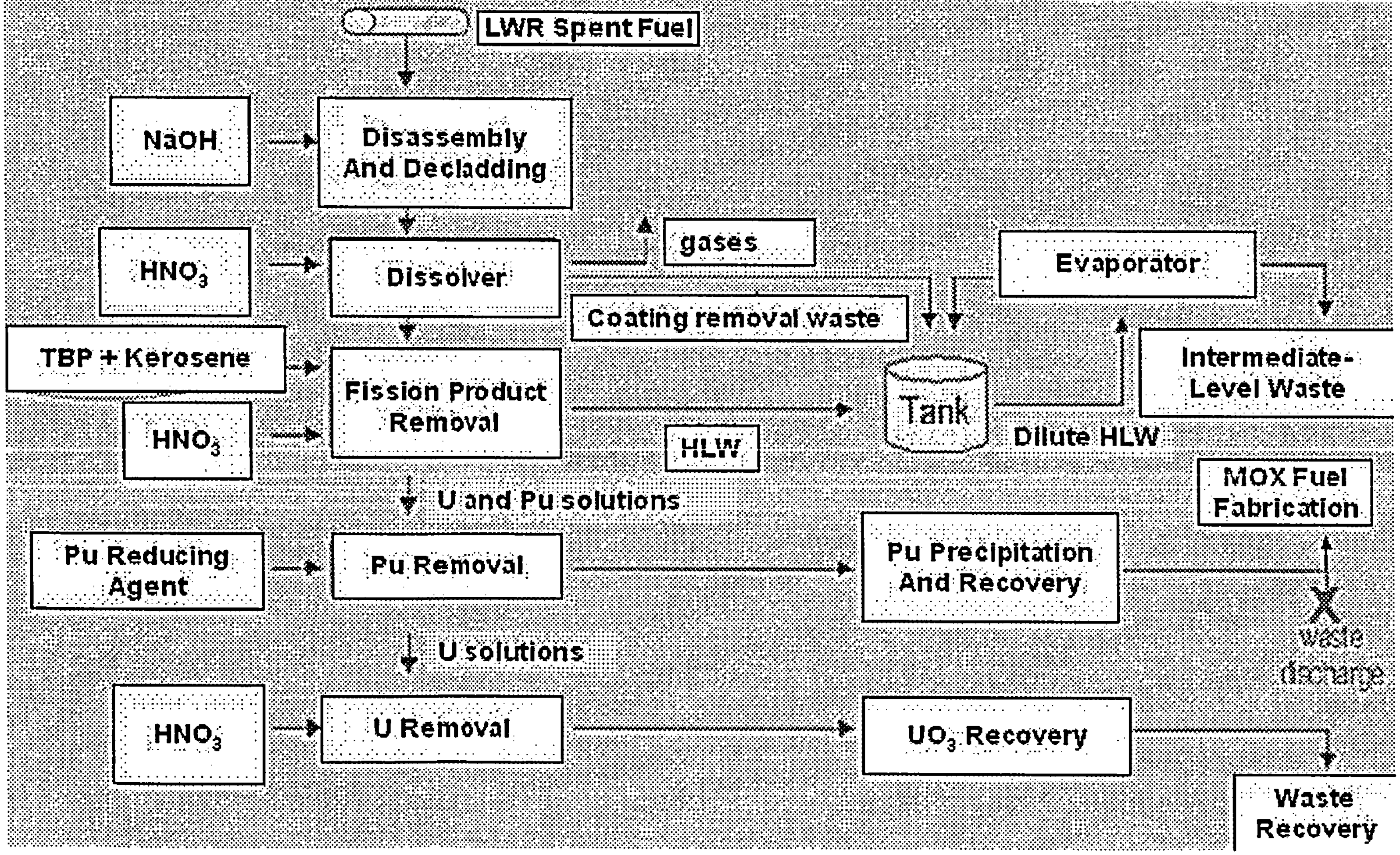
Gbq = 10^9 becquerel

The straight line shows the radioactivity of the corresponding amount of uranium ore.

NB both scales are logarithmic.

Source: OECD NEA 1996, *Radioactive Waste Management in Perspective*.

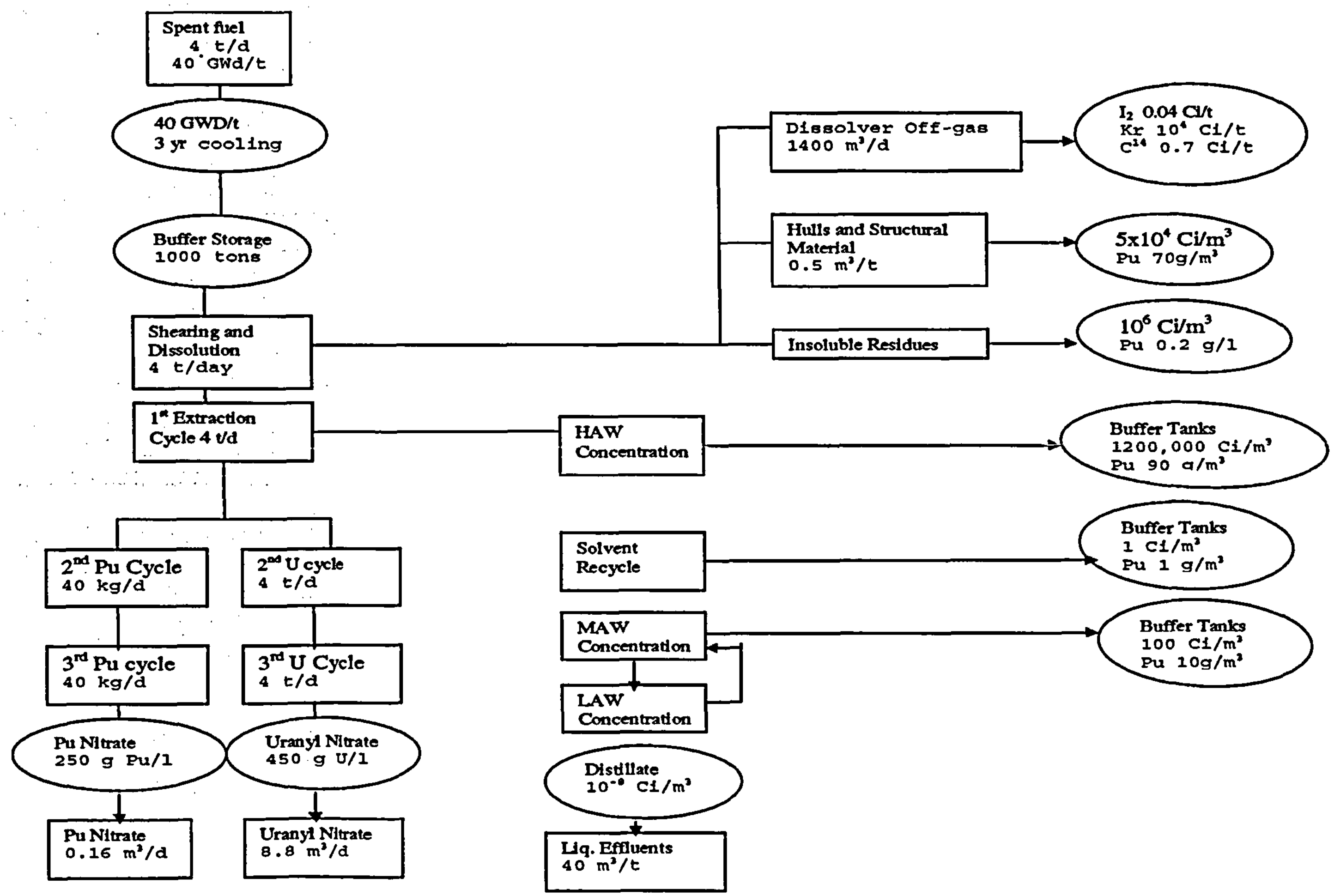
PUREX Reprocessing of Spent Fuel



REFERENCE FLOWSHEET

TAKEN FROM INFCE/PC/2/4

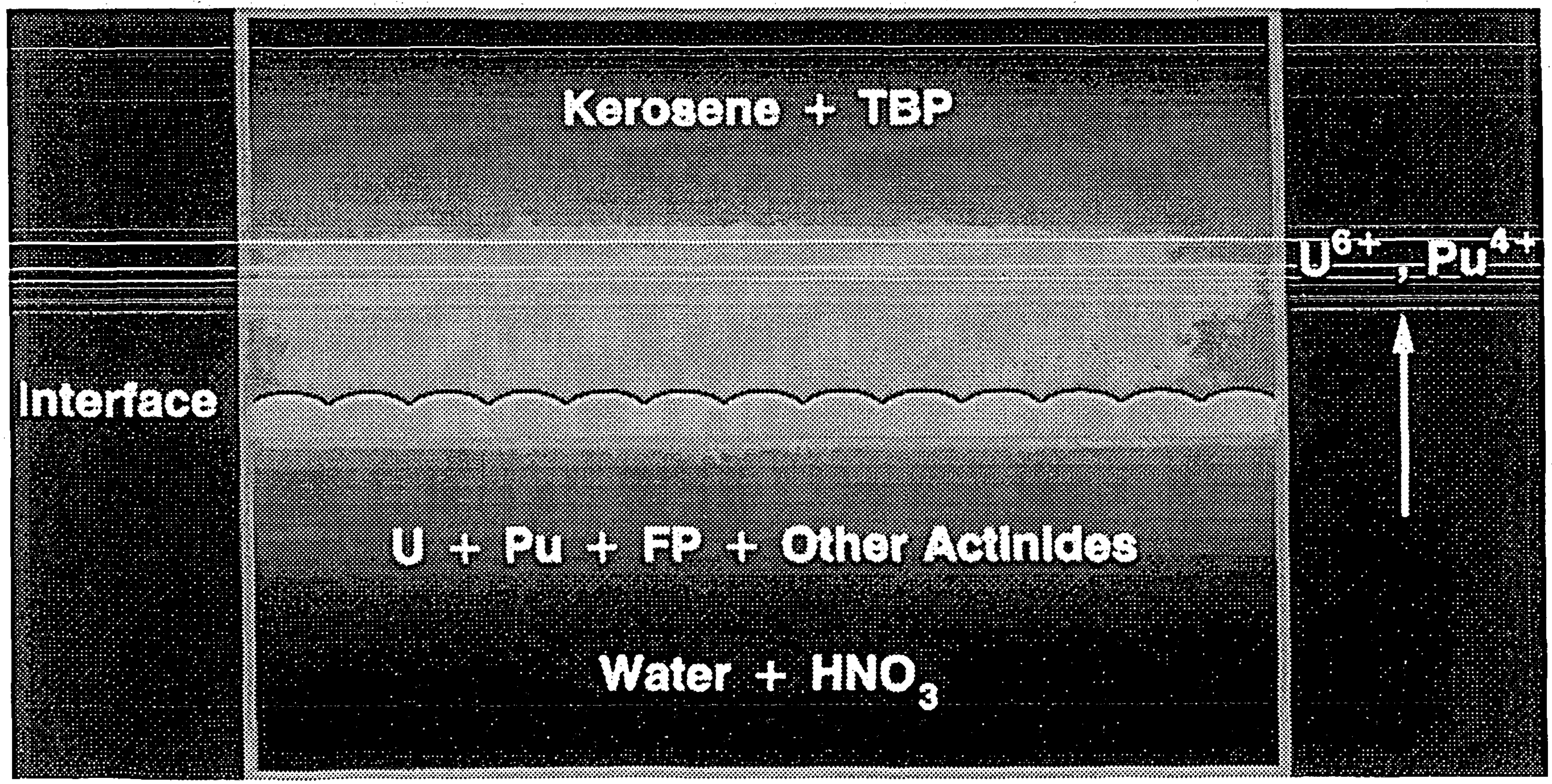
IAEA, January 1980



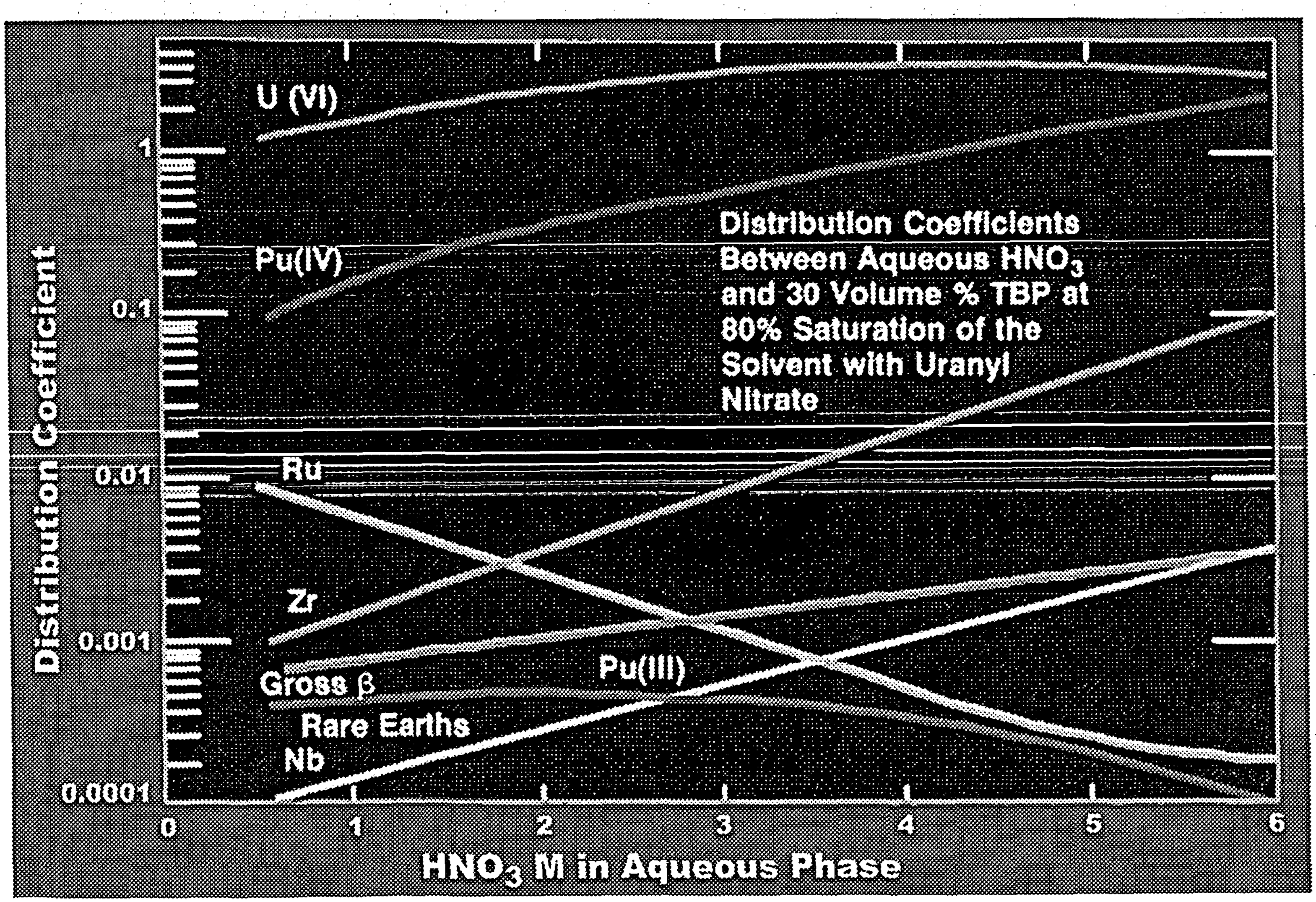
SOLVENT EXTRACTION

- AQUEOUS AND ORGANIC PHASES ARE CONTACTED BY ANY OF SEVERAL TYPES OF CONTACTORS
- AQUEOUS PHASE: NITRIC ACID (4-6 M) SOLUTION FROM FEED ADJUSTMENT
- ORGANIC PHASE: TRIBUTYL PHOSPHATE (TBP)/ HYDROCARBON DILUENT (30-40 % TBP BY VOLUME)

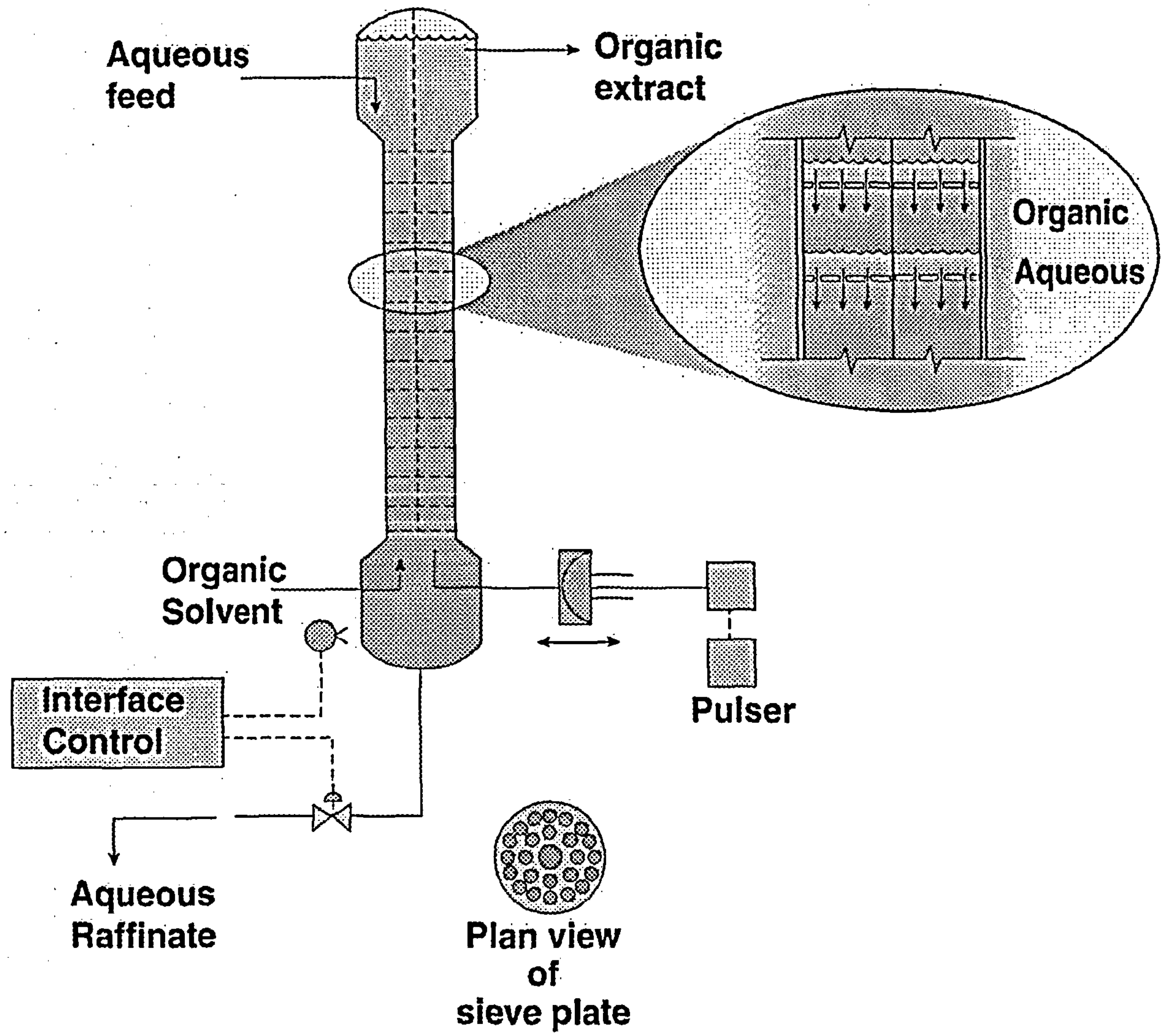
Basic PUREX Process (Solvent Extraction Contact Between Phases)



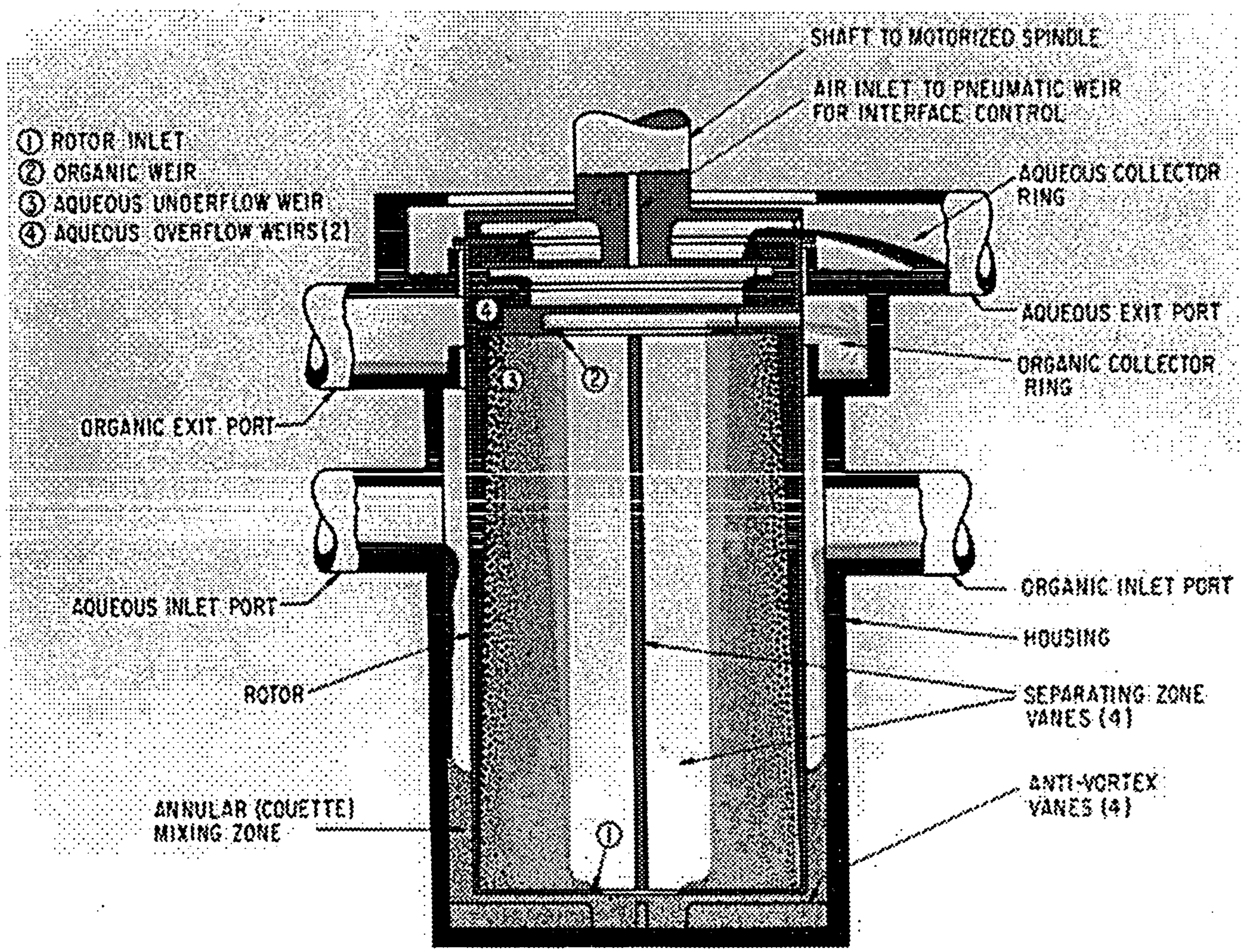
Distribution Coefficients



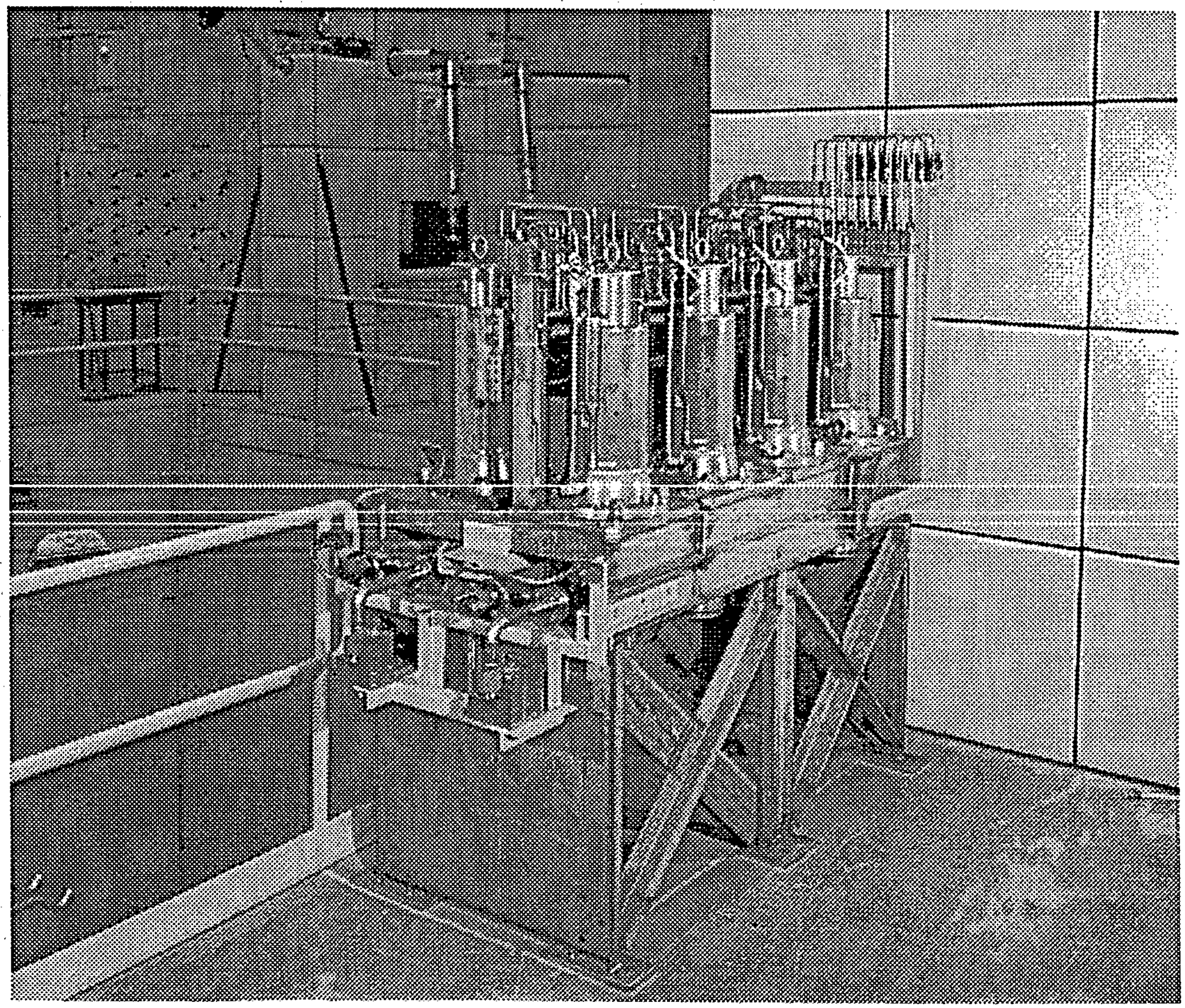
Schematic of Pulse Column



Centrifugal Contactor



Centrifugal Contactor Bank

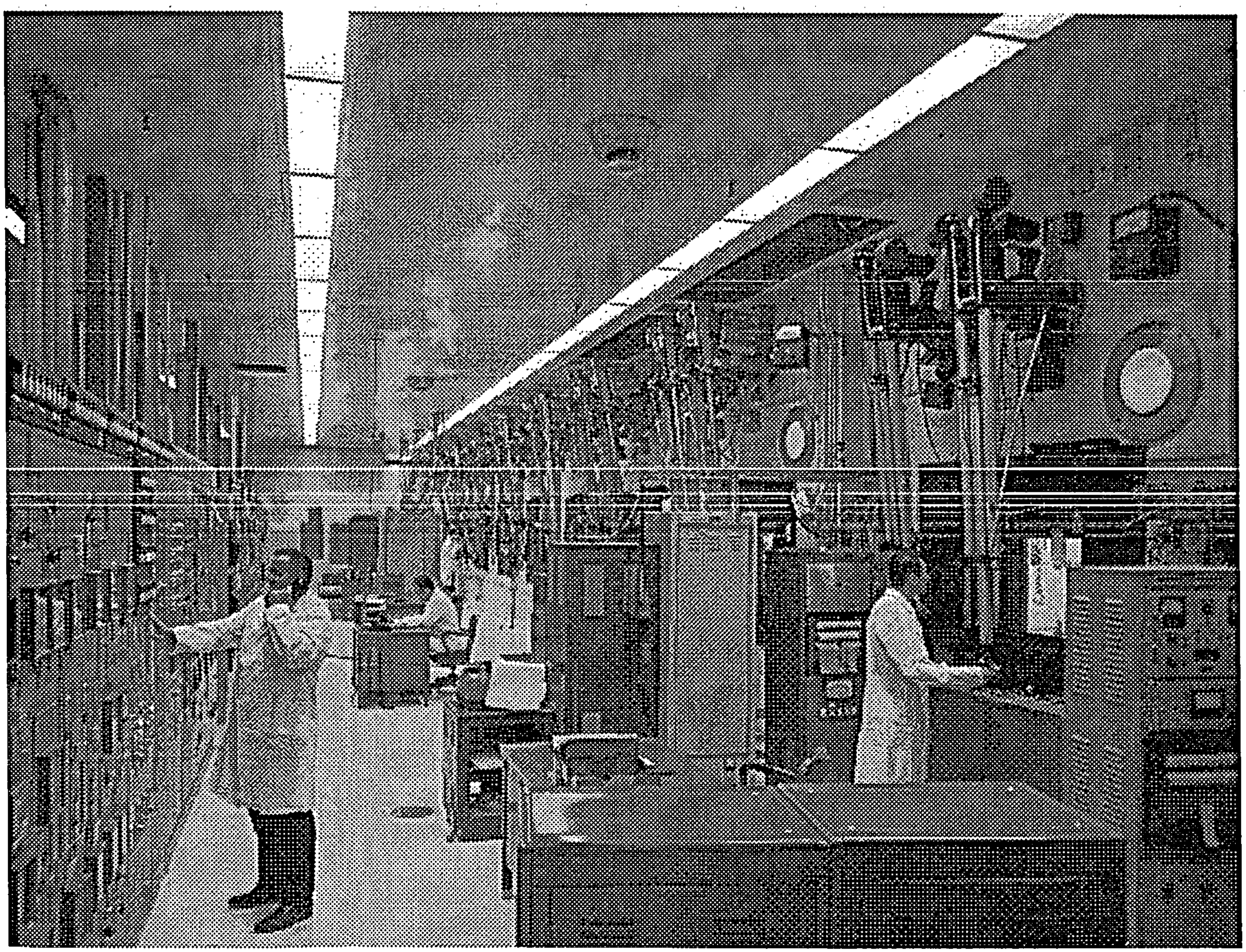


Reprocessing Facilities

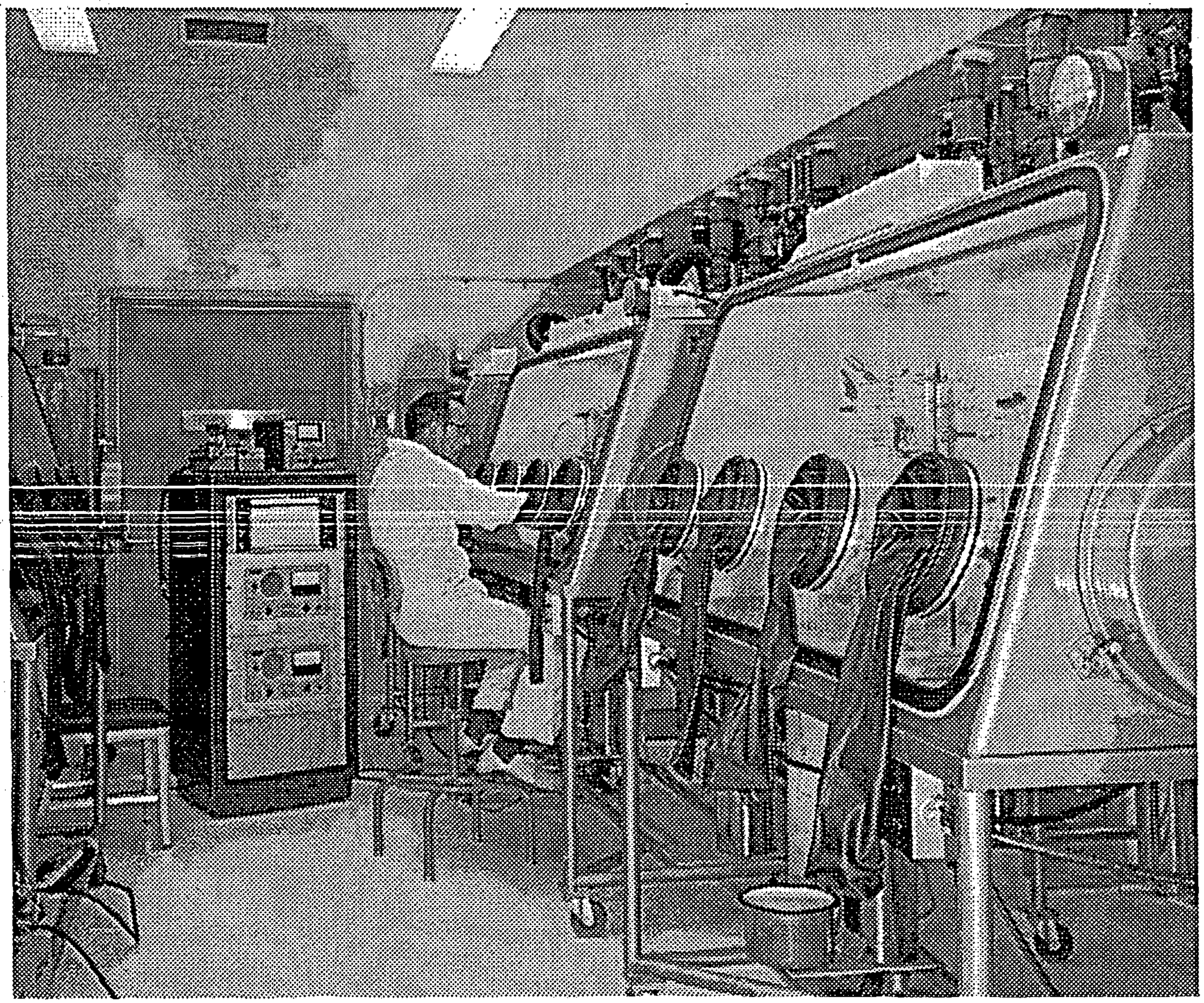
The nature of the reprocessing facility depends on the purpose and scale of operations

- Hot cells/glove boxes: R&D; small-scale or specialty production
  - Hot cell: An enclosure with thick radiation shielding, off-gas treatment, direct viewing, and (usually) remote manipulation of contents
  - Glove box: An enclosure with minimal radiation shielding, off-gas treatment, direct viewing, and hands-on manipulation of contents
- Canyons: Large-scale production activities
  - Canyon: A facility with hot cells, off-gas treatment, direct and/or remote viewing, and remote manipulation of equipment and processes during operation

Line of Hot Cells



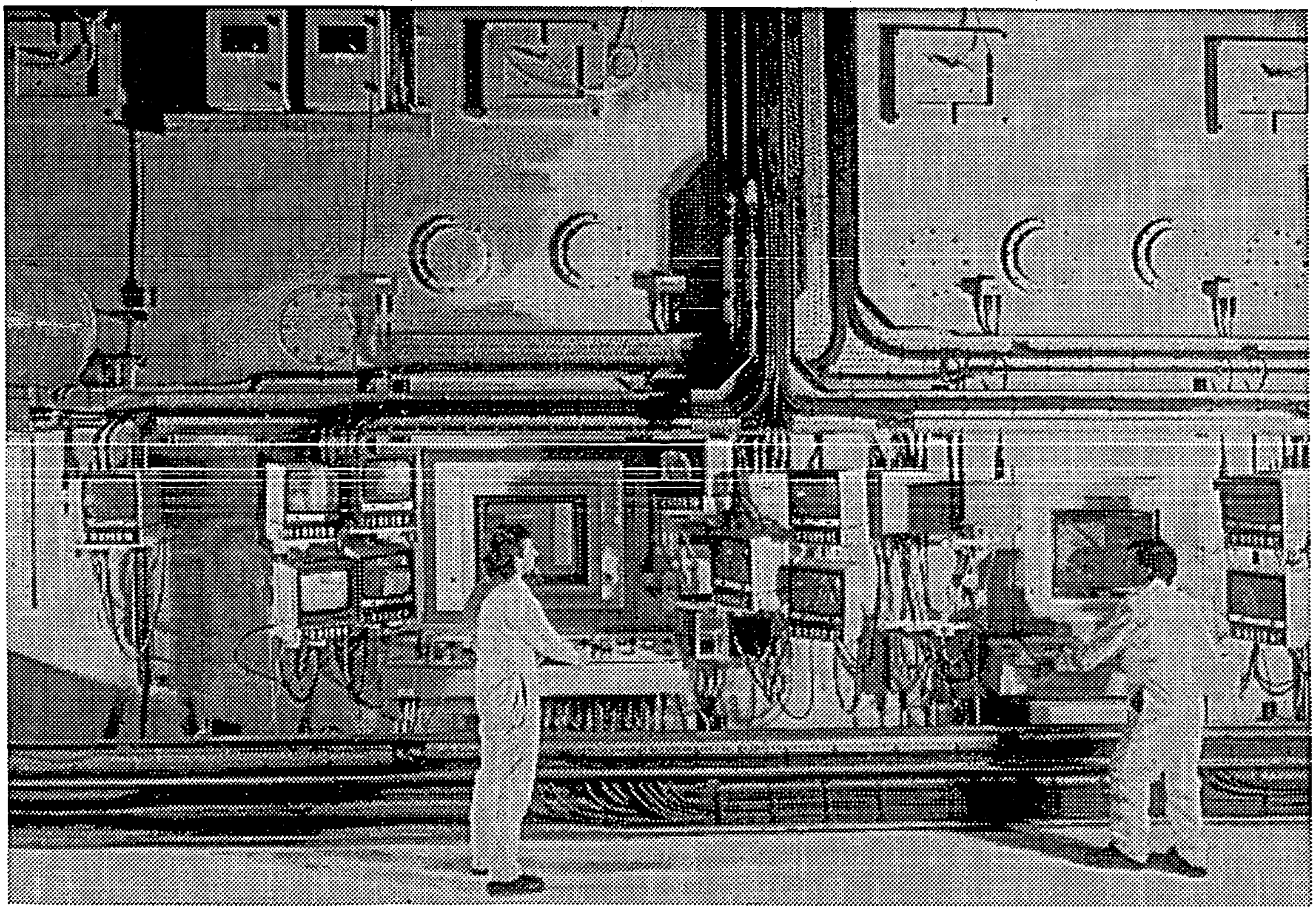
Glove Boxes



OPERATING AREA OF A CANYON FACILITY

The photo below shows the operating gallery of British Nuclear Fuels, Ltd.'s (BNFL's), large canyon-type reprocessing plant at Sellafield. Note the absence of manipulators and the presence of multiple video monitors and the control panels used to manage the process.

BNFL Plant Operating Area



SHOW A VIDEO OF SELLAFIELD REPROCESSING PLANT AND OPERATIONS

REPROCESSING TECHNOLOGY VARIATIONS

Numerous alternatives to the PUREX reprocessing technology are possible. The most straightforward involve the same conceptual flow sheet as PUREX but use organic extractants other than TBP (many of which are highly specialized) or other acid systems (e.g., hydrochloric acid, sulfuric acid).

Significant departures from the PUREX technology and concept can also be employed. One of the most straightforward is to use ion exchange instead of solvent extraction. The disadvantage of this approach is that the radiation damage effects in the first cycle are severe. This results in the need to change the ion exchange material frequently, which in turn yields significant operating complexity, costs, and solid wastes. However, in cases where time and results are more important than costs (or perhaps environmental consequences), ion exchange is a viable approach.

Radical departures from PUREX are also possible. "Fluoride volatility" processes have been extensively developed and demonstrated, although not deployed at any significant scale. These processes are based on the volatility of UF_6. They do not appear well suited to the recovery of plutonium because its fluorides are relatively unstable. Pyrochemical processes involving the use of molten salts, molten metals, and electrochemistry are also being studied in the United States and other countries. This type of technology has been used extensively in the production of plutonium for military use but has not had limited large-scale demonstration with the complex mixture of radioelements present in spent fuel.

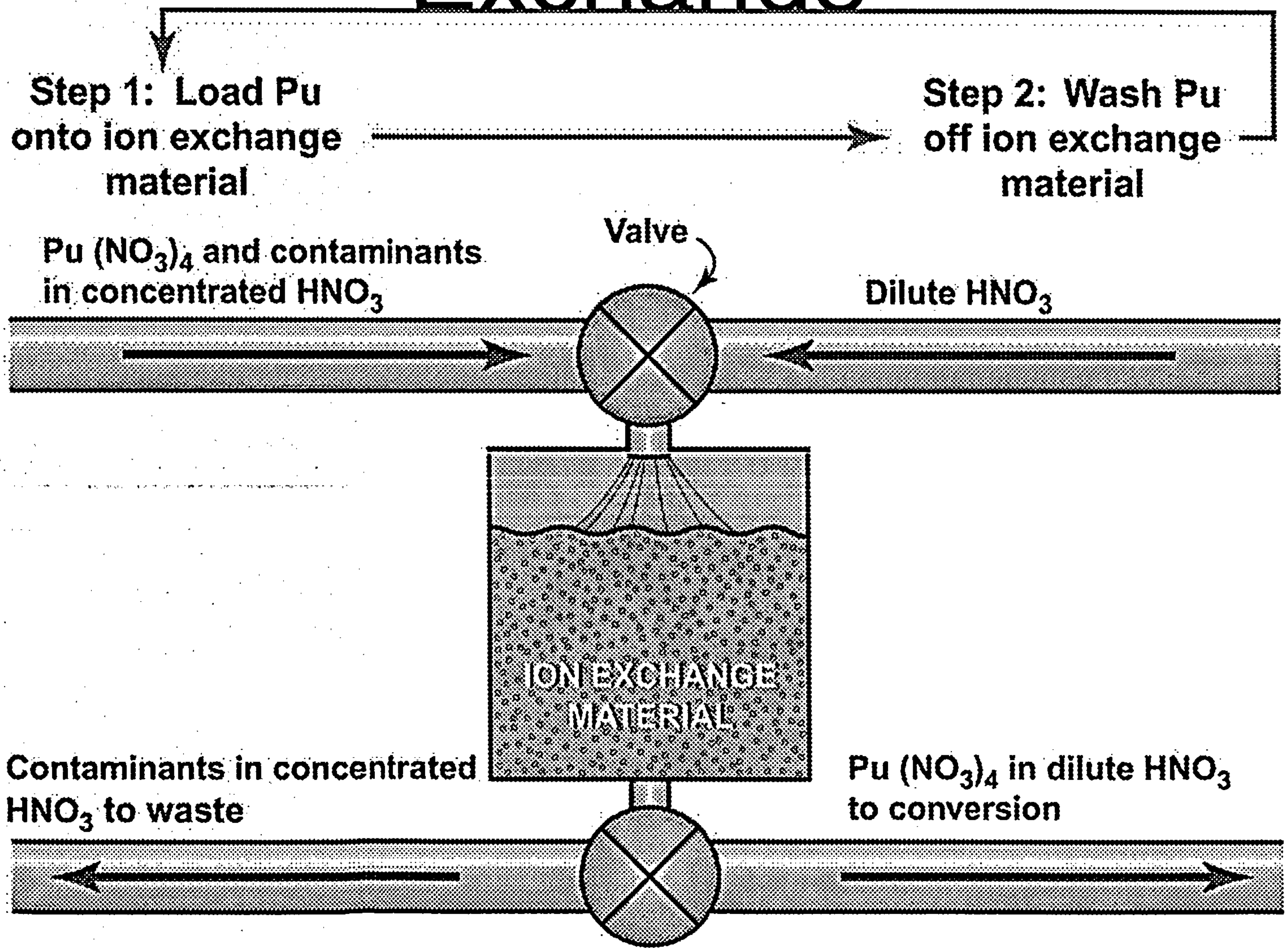
ReprocessingVariations

- Different solvent extraction reagents may be employed
  - Other organic extractants and diluents
  - Other acid systems (e.g., chloride, sulfate)

- Ion exchange can be substituted for solvent extraction
  - Major limitation: Operating complexity and damage to the typical organic ion exchange material result from high radiation levels

- Nonaqueous alternatives have been explored and have seen limited use
  - Fluoride volatility : Plant designed and partially built, but never operated
  - Pyrochemical : Basis for EBR-II; being studied in Russia, Japan, and the United States
  - DUPIC: Voloxidize spent LWR fuel and reconstitute it as fresh CANDU reactor fuel
  - Precipitation: Bismuth phosphate, peroxide

Cleanup of Plutonium by Ion Exchange



U OXIDE AND MOX FUEL PREPARATION

- URANIUM SOLUTION IS DENITRATED IN A FLUIDIZED BED TO FORM UO_2
- U AND Pu SOLUTIONS ARE MIXED, CONCENTRATED, AND CO-DENITRATED (BY MICROWAVE HEATING) TO PRODUCE A MIXED U/Pu OXIDE (MOX)

OXIDE (MOX) FUEL PREPARATION (CONT.)

- MIXED OXIDE IS CALCINED IN AIR IN AT 800 °C
- CALCINED PRODUCT IS HEATED IN A FURNACE IN H_2/N_2 AT 800 °C TO PRODUCE MOX FUEL MATERIAL
- (THIS TWO-STEP REDUCTION SAVES HYDROGEN)

MOX FUEL FABRICATION PLANTS

Taken from "Management of Separated Plutonium: The Technical Options" Nuclear Energy Agency, OECD 1997

COUNTRY	PLANT	t HM/y CURRENT	t HM/y ANTICIPATED	STATUS	REMARKS
Belgium	BN-Dessel	35	40	Since 1973	-
France	COGEMA	30	35	Since 1962	-
France	MELOX	Start-up	160	Since 1995	-
UK	BNFL-MDF	< 8	8	Since 1993	-
Belgium	BN-Dessel	-	40	Detailed Layout	Construction to be decided
UK	BNFL-SMP	-	120	Construction Started 1994	Operational in 1997
Japan	PNC=PFPF	10	10	Since 1988	For FBR Fuel
Japan	Unnamed	-	Approx. 100	Prelim; Concept. Design	Operation to start after 2000
France	MELOX Ext	-	50	Conceptutal Design Completed	Full Capacity after 2000

FUEL REFABRICATION

- LWR – U OXIDE, MOX PELLETS: ZIRCALOY CLADDING
- FBR – OXIDE, CARBIDE, OR NITRIDE PELLETS; METAL: SS CLAD
- HTGR- CARBIDE, OXYCARBIDE MICROSPHERES: GRAPHITE MATRIX
  1. GRAPHITE SPHERES
  2. GRAPHITE PRISMS

COGEMA MOX FABRICATION FLOWSHEET

PELLET FABRICATION

UO_2 PuO_2 SCRAP

WEIGHING AND LOT PREPARATION

BALL MILLING

FORCED SIEVING

ADDITIVE MIXING

PRESSING W/HYDRAULIC PRESS

SINTERING

DRY CENTERLESS GRINDING

TESTING AND SORTING OUT

ROD FABRICATION

PELLET COLUMN PREPARATION

ROD FILLING

UPPER END PLUG TIG

ROD DECONTAMINATION

PRESSURIZATION, VENT-HOLE TIG SEALING

FINAL N/D TESTING

PACKAGING

STORAGE

TRANSPORTATION TO ASSEMBLY

PRE-ASSEMBLY AND ASSEMBLING

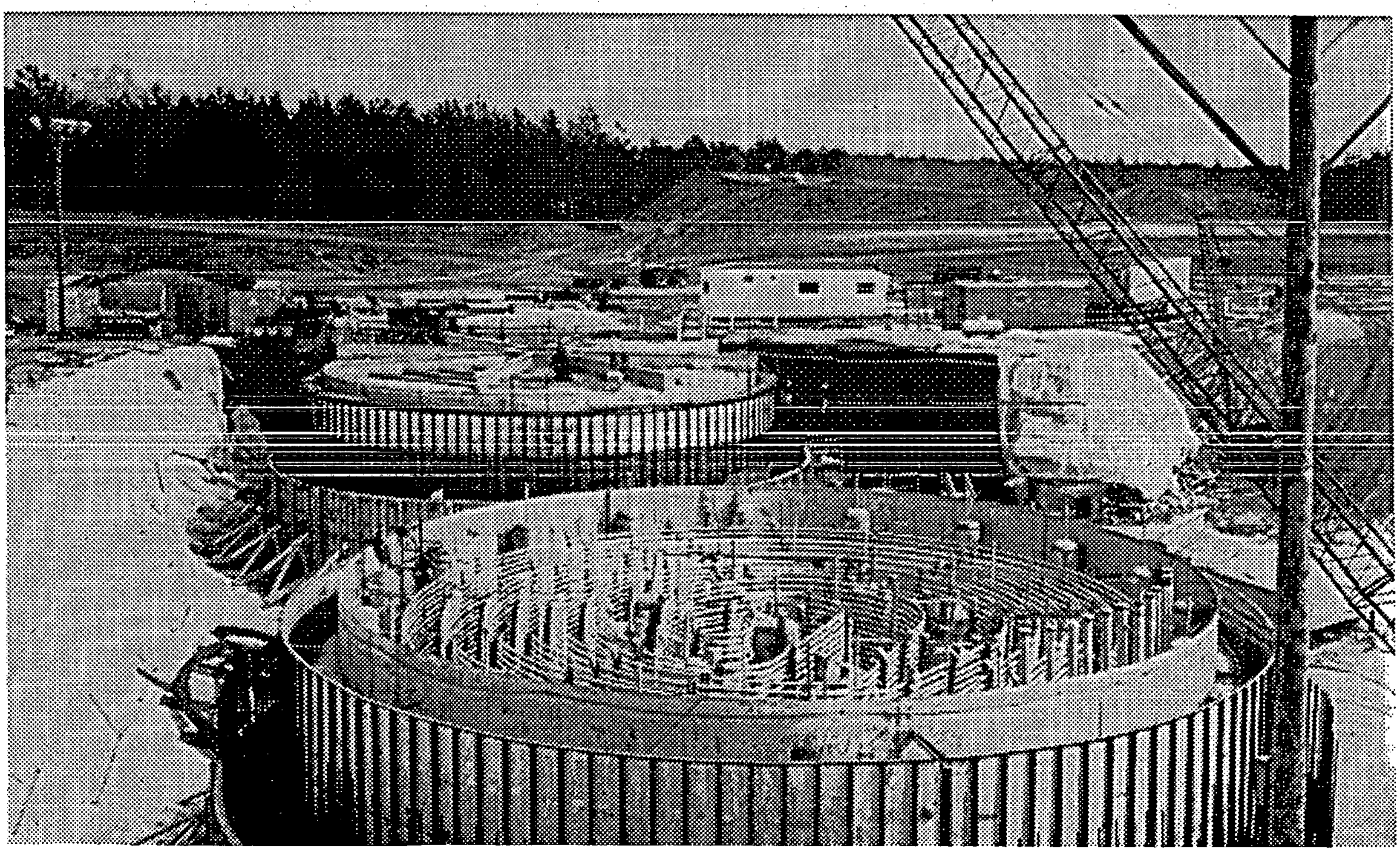
Management of Reprocessing Plant Wastes

- Liquid High-Level Waste (HLW) storage
  - Highly radioactive: generates heat

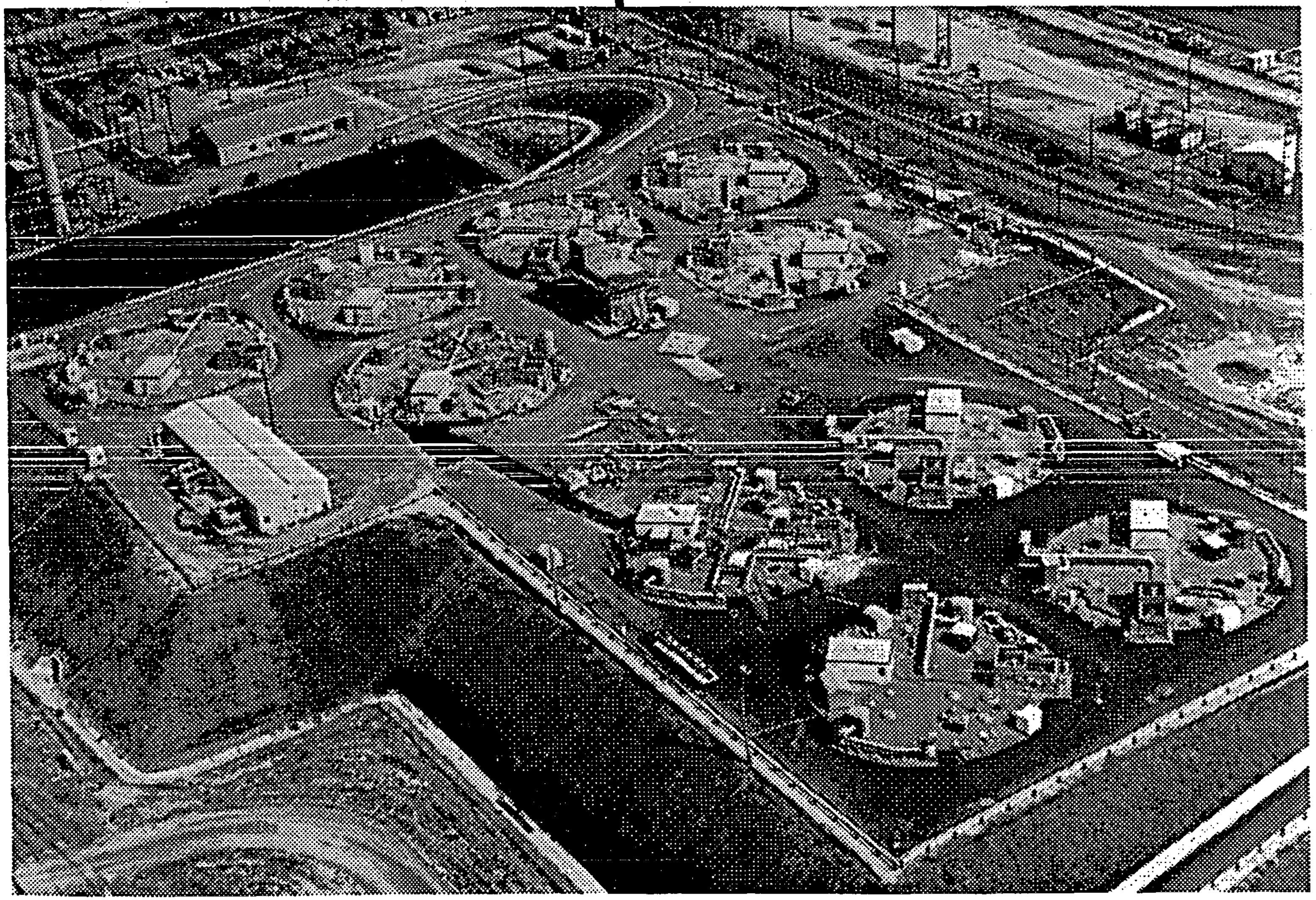
  Stored in large, cooled underground tanks until short-lived radionuclides (e.g., ^{137}Cs, ^{90}Sr) have decayed

  Waste treatment: Wastes converted to a solid for transport and disposal
  - HLW typically is converted to glass
  - Other liquid wastes are immobilized with cement; solids are drummed
- Waste disposal
  - HLW, cladding, TRU wastes: in a geologic repository
  - Other wastes: typically in surface trenches

AGNS HLW Tank Under Construction



Surface of SRP Tanks After Completion



Worldwide Reprocessing Capabilities

Country	*Site*	*Fuel*	*Start*	*Capacity, t U/year* Defense 0.5 kg Pu/t	Civil 30 kg Pu/t	Pilot plant	Hot cells
United States	Oak Ridge, ORNL	GCGR	1943			100	
United States	Hanford 221-T, BIPO4	LWGR	1944	1000			
United States	Hanford 221-B, BIPO4	LWGR	1945	1000			
Russia		Kyshtym	LWGR	1948	2500		
United Kingdom	Sellafield, B204-5	Magnox	1951	1200			
United States	Hanford REDOX	LWGR	1952	2400			
United States	Idaho, TBP-25	LWR	1953	100			
Sweden		HWR	1954				5
United States	Savannah River, 200F	HWR	1954	2700			
Canada	Chalk River	HWR	1955				5
Russia		Tomsk	LWGR	1955	3000		
United States	Hanford PUREX	LWGR	1956	2300			
Australia	Lucas Heights	LWRR	1957				5
Canada	Whiteshell	HWR	1957				5
France		Marcoule, UP1	Magnox	1958	400		
United Kingdom	Dounreay	LMR	1958		7		
Norway		LMRR	1959				5
Switzerland		LMRR	1959				5
Czech Republic		LWR	1960				5
Romania		LWRR	1960				5
Russia		Krasnoyarsk	LWGR	1960	2000		
India	Trombay, Pilot	HWR	1962			30	
Netherlands		HWRR	1962				5
India	Trombay, BARC	HWR	1964	100			
Egypt	LWRR	1965				5	
Israel	Dimona	HWR	1965	80			
Korea, DPRK	Nyonbyon	LWRR	1965				5
South Africa	Pelindaba	HWRR	1965				5
Belgium	Mol	LWR	1966		30		

Worldwide Reprocessing Capabilities (cont.)

Country	Site	Fuel	Start	Capacity, t U/year Defense 0.5 kg Pu/t	Civil 30 kg Pu/t	Pilot plant	Hot cells
France		La Hague, UP2	Magnox	1966	600		
United States	NFS West Valley	LWR	1966		300		
Iran	Teheran	LWRR	1967				5
China	Subei, Jiuguan	LWGR	1968	150			
Iraq	Tuwaitha	LWRR	1969				5
United Kingdom	Sellafield, B204	LWR	1969	300			
Germany	Julich	GCRR	1971				5
Germany	Karlsruhe, WAK	LWR	1971			35	
Korea, ROK	Daeduk	LWRR	1972				5
Taiwan		HWRR	1973			10	
France		La Hague, UP2	LWR	1976	800		
Japan	Tokai-mura	LWR	1977		200		
Pakistan	New Labs	HWR?	1977				5
China	Sichuan, Guangyuan	LWGR	1980	600			
India	Tarapur, PREFRE	HWR	1982		100		
Italy	Saluggia, EUREX	LWR	1983		10		
Italy	Trisaia, ITREC	LWR	1983		5		
Libya (LIA)	Tajoura	LWRR	1983				5
Brazil	Sao Paulo	LWRR	1986				5
Indonesia	Siwabessy	LWRR	1987				5
Korea, DPRK	Nyonbyon	Magnox	1989	250			
France		La Hague, UP3	LWR	1990		800	
Algeria	Ain Oussera	HWR	1993				5
India	Kalpakkam, KARP	HWR	1993	150			
Argentina	Ezeiza	HWR	1994				5
United Kingdom	Sellafield, THORP	LWR	1995		700		
Pakistan	Chasma	HWR?	1997	10			
China	Lanzhou	LWR	2000		300		
Japan	Rokkasho-mura	LWR	2003		800		

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NRC Regulations for Spent Nuclear Fuel Recycling

ACNW Presentation
June 6, 2006

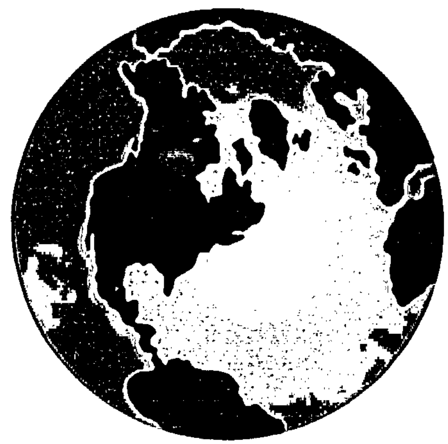
FCSS/MOFLS

Presentation Overview

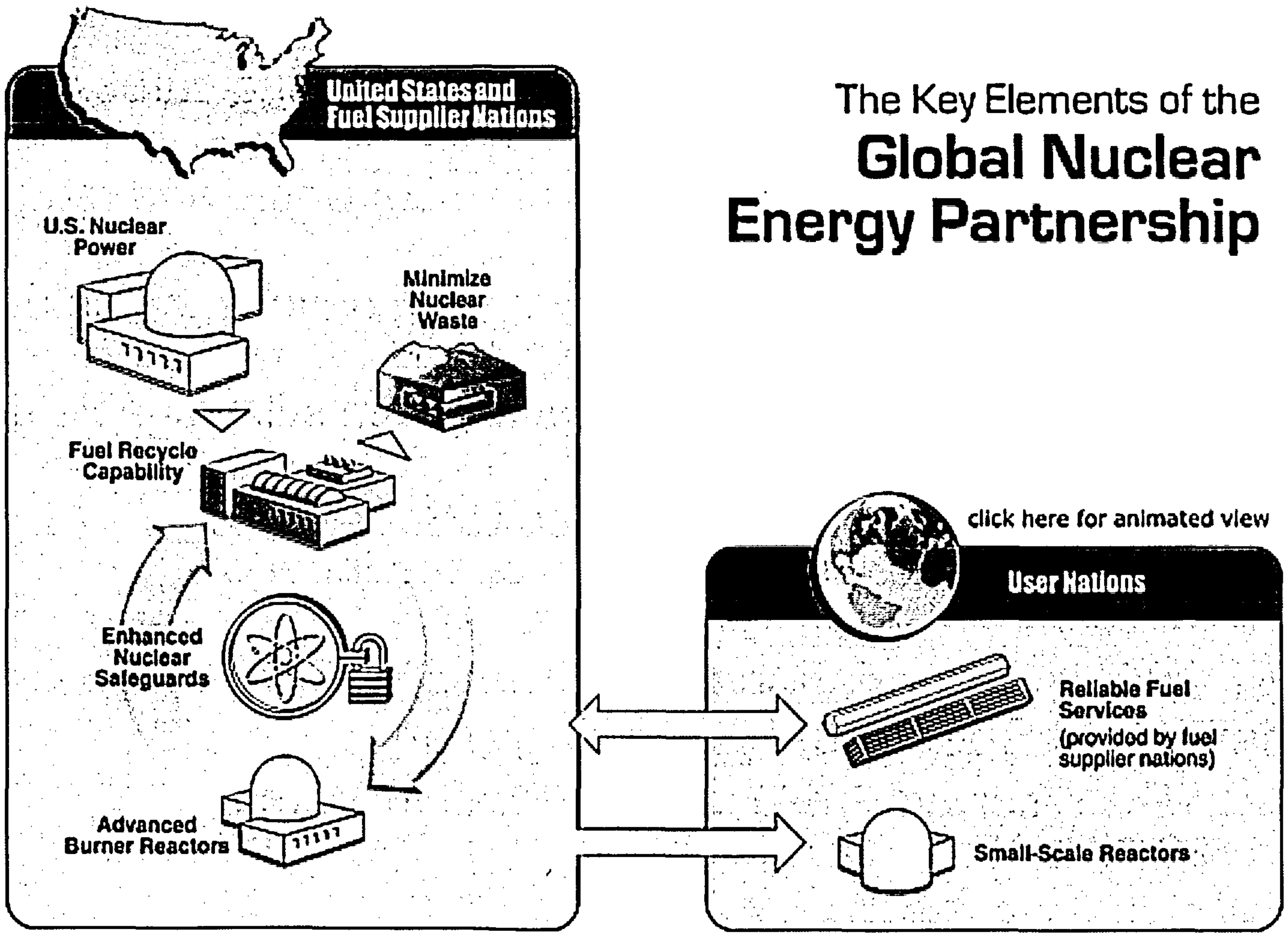
- Global Nuclear Energy Partnership (GNEP)
- Current NRC Staff Activities
- Regulatory Authority
- Existing NRC Regulations
- Facilities NRC Could Regulate
- Potential Issues
- Path Forward

Global Nuclear Energy Partnership (GNEP)

- GNEP Goals:
  - Provide abundant energy without generating carbon emissions or greenhouse gases
  - Recycle used nuclear fuel to minimize waste and reduce proliferation concerns
  - Safely and securely allow developing nations to deploy nuclear power to meet energy needs
  - Assure maximum energy recovery from still-valuable used nuclear fuel
  - Reduce the number of required U.S. geologic waste repositories to one for the remainder of this century
- FY 2006 Appropriations Act directs DOE to develop a Spent Fuel Recycling Plan
  - NRC received Pre-Decisional Draft in March 2006



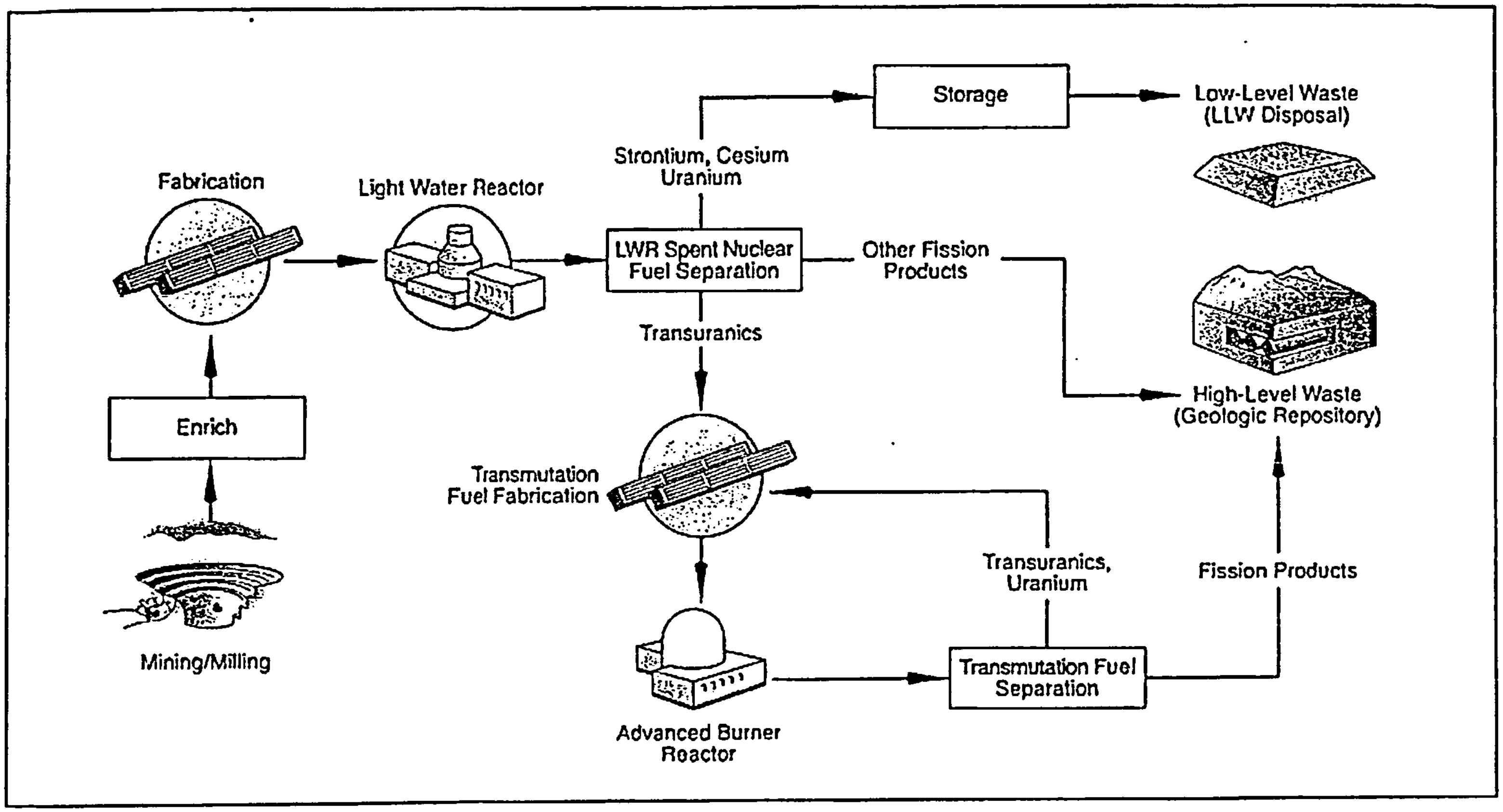
GNEP Elements



Fuel Services Program

GNEP Closed Fuel Cycle

March 2006



DOE prefers using fast reactors instead of LWRs – but currently no existing or planned commercial fast reactors in US/Europe

GNEP Technology Demonstration Program

March 2006

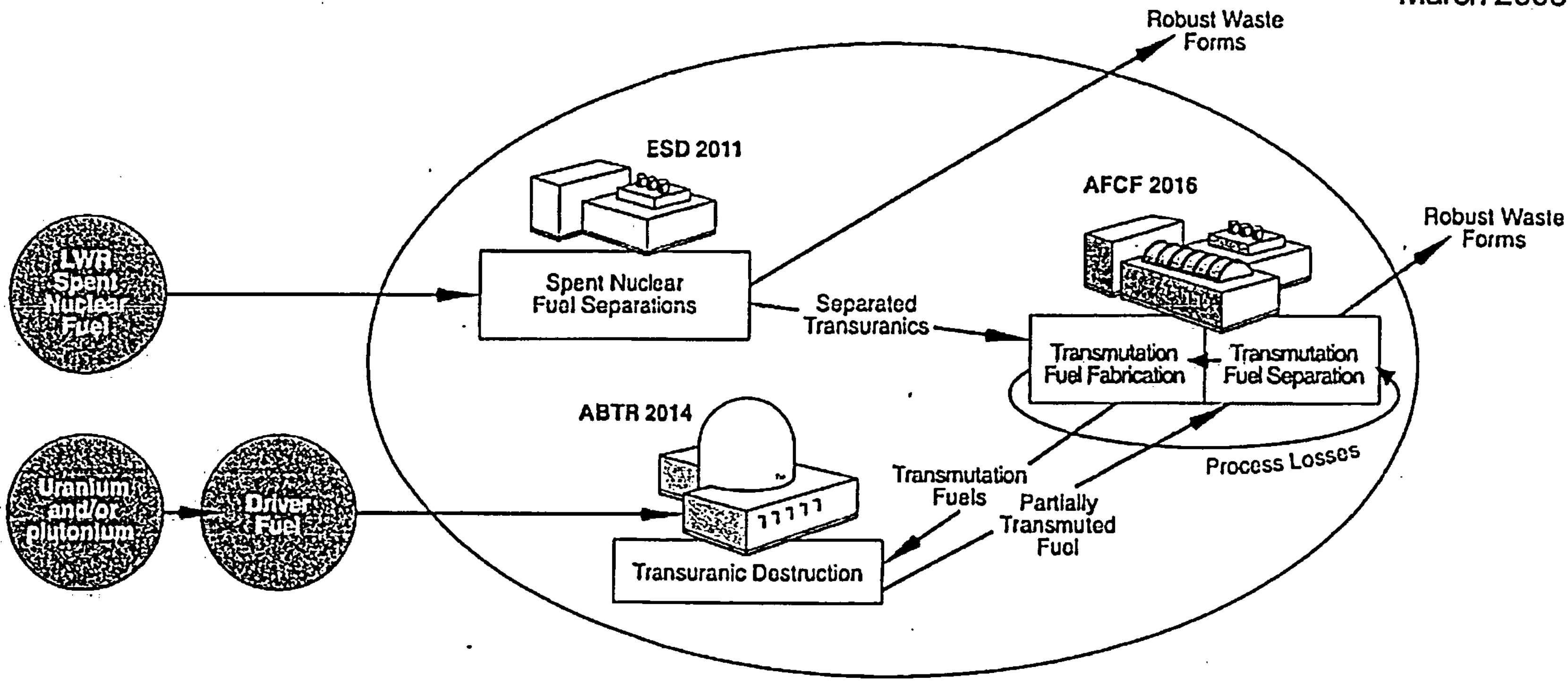
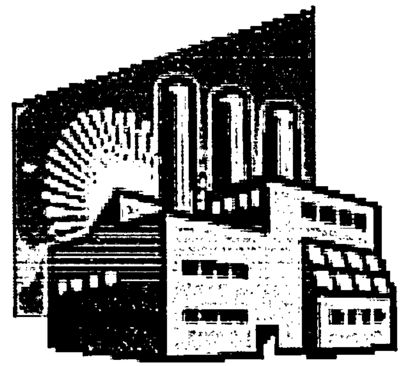


Figure 7 – GNEP Facilities and Materials Flow

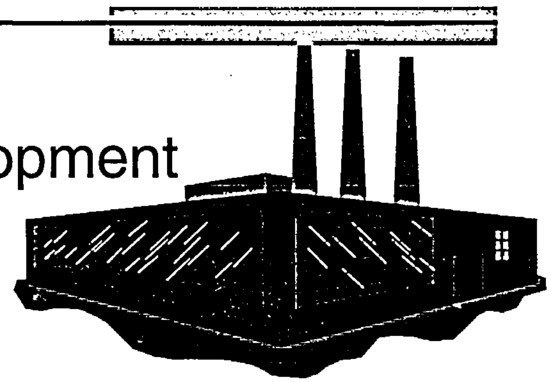
Three Demonstration Facilities Planned

Engineering Scale Demonstration (ESD)

- The ESD will:
  - Demonstrate a process that would separate the usable components in spent fuel from its waste components, without separating pure plutonium (e.g., UREX+)
  - Obtain cost and performance data that can guide future industrial plant design and operation
  - Provide separated transuranics (TRU) to support fuel requirements for Advanced Burner Test Reactor fuel testing



Advanced Fuel Cycle Facility (AFCF)

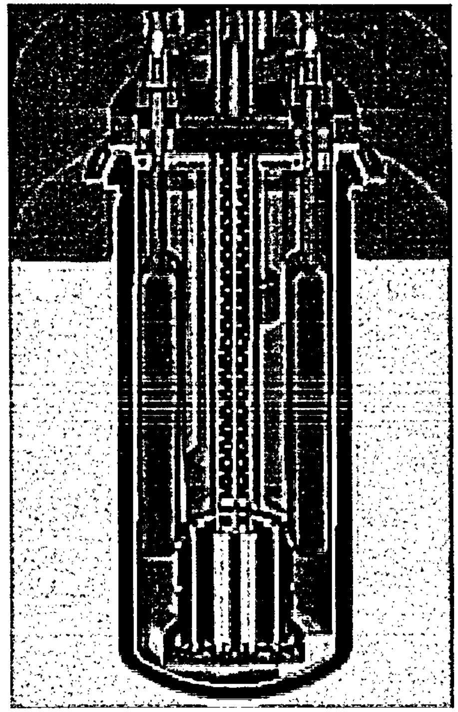


- The AFCF will:
  - Be a multi-purpose research and development laboratory for fuel cycle testing
  - Fabricate and support qualification of fuels to be used in the ABTR
  - Reprocess spent fuel after transmutation in the ABTR for second cycle fuel fabrication
- The Advanced Simulation Laboratory (ASL) will:
  - Support robust research and testing through computer simulation and visualization

Early NRC involvement in the demonstration facilities is needed!

Advanced Burner Test Reactor (ABTR)

- The ABTR will:
  - Take advantage of fast neutrons and repeated cycles to transmute transuranics into shorter-lived isotopes
  - Serve as a test reactor (~100MWe) for development and qualification of fuels and materials to support NRC design certification of a standard Advanced Burner Reactor (ABR) plant (~1000 MWe)
  - Encourage commercial deployment of more ABRs



The ABR would consist of several smaller modular units

Phoenix in France is 233 MWe

BN-600 in Russia is 560 MWe

GNEP Planning Milestones

- Operation of the ASL in 2008
- Design of the AFCF by 2010
  - First AFCF laboratory modules should begin operation in 2016
- Operation of the ESD by 2011
- Operation of the ABTR around 2014
- Operation of the ABR Standard Plant by about 2023

Awarded $3.3 million contract to Prepare EIS for Technology Demonstration Program!

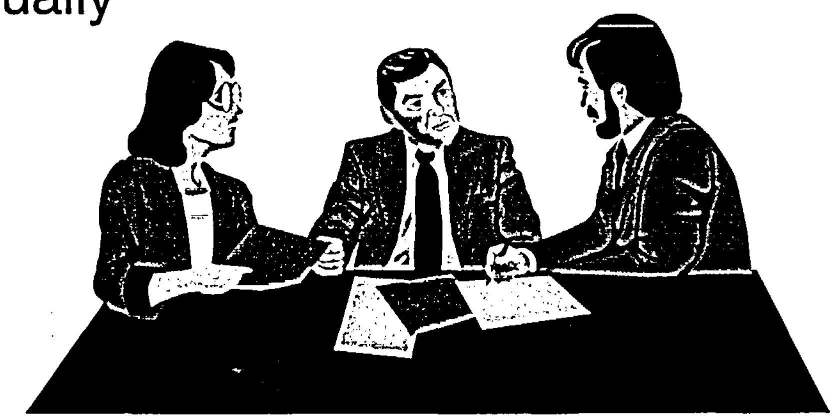
Received more than 30 expressions of interest in hosting the Technology Demonstration Program!

Current NRC Staff Activities

- SECY 06-0066 "Regulatory and Resource Implications of a DOE Spent Fuel Recycling Program" (ML060370037)
- Commission issued SRM May 16, 2006:
  - Develop conceptual licensing process for GNEP related facilities (inter-office task)
  - Prepare draft legislation that would give NRC licensing authority over demonstration scale DOE reprocessing, fuel fabrication, vitrification, and interim waste storage facilities

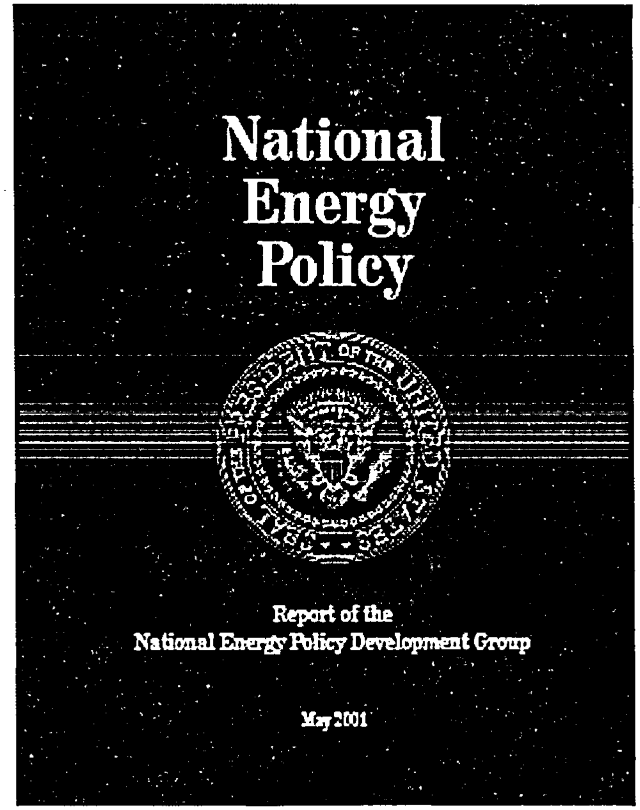
Current NRC Staff Activities

- Commission SRM (Cont'd)
  - Work with DOE to attain cost-reimbursable agreement or consider requesting non-fee based appropriation
  - Consider incorporating elements of Part 52 in conceptual process
  - Consider GNEP "full recycle" option (i.e., closed-fuel cycle)
  - Proceed at a pace commensurate with DOE's progress
    - Update Commission annually



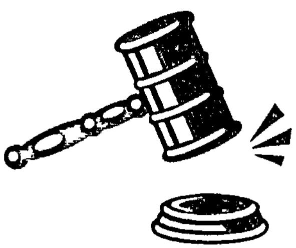
What Regulatory Authority does NRC Have?

- Atomic Energy Act of 1954 provides NRC authority for all (non-government) commercial activities
- Energy Reorganization Act of 1974
  - Established limited NRC authority with respect to DOE facilities
    - Sections 202(1) and (2) direct NRC regulatory authority for LMFBR and other reactors operated for the purposes of demonstrating suitability for commercial operation


National Energy Policy

Report of the National Energy Policy Development Group

May 2001

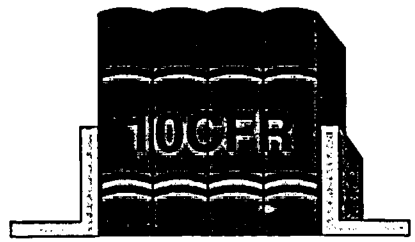


NRC Regulatory Authority

- Energy Reorganization Act of 1974 (cont'd)
  - Sections 202(3) and (4) direct NRC regulatory authority for high-level waste receipt and storage but <u>not</u> for waste from DOE R&D activity
  - Section 202(5) directs NRC regulatory authority for DOE MOX fuel fabrication use in a commercial reactor
- DOE reprocessing facilities and TRU fuel fabrication facilities are not clearly subject to NRC regulation

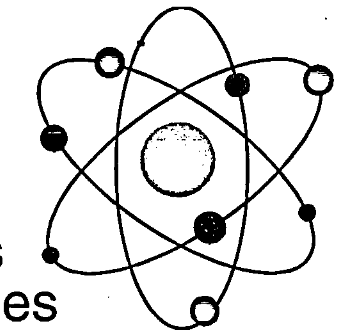
Existing NRC Regulations/Processes

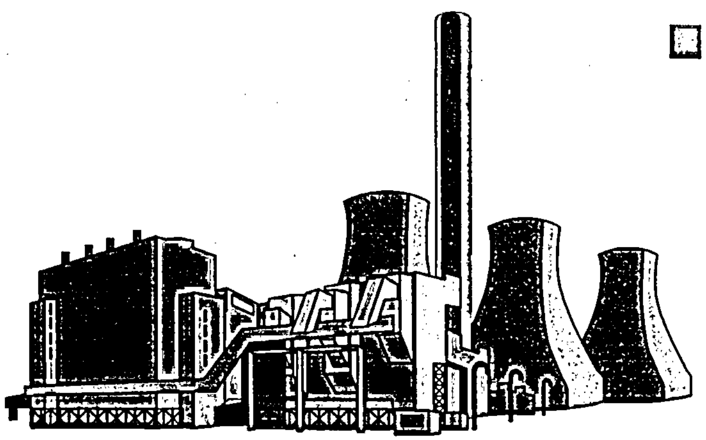
- Part 50: Domestic Licensing of Production and Utilization Facilities
- Part 52: ESPs, Standard Design Certifications, and Combined Operating Licenses for Nuclear Power Plants
- Part 70: Domestic Licensing of Facilities Handling Special Nuclear Material
- Part 72: Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-related Greater than Class C Waste
- Part 30: Rules for General Applicability to Domestic Licensing of Byproduct Material
- Waste Incidental to Reprocessing (WIR) Determinations



Part 50 – Production/Utilization Facilities

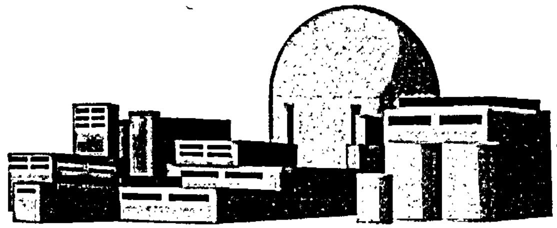
- Production facility:
  - Any nuclear reactor designed or used primarily for the formation of plutonium or uranium-233;
  - Any facility designed or used for the separation of the isotopes of plutonium, except laboratory scale facilities designed or used for experimental or analytical purposes only
  - Any facility designed or used for the processing of irradiated materials containing special nuclear material, [except laboratory scale facilities, facilities which handle small quantities of SNM, and facilities with licenses issued under parts 30 and 70]



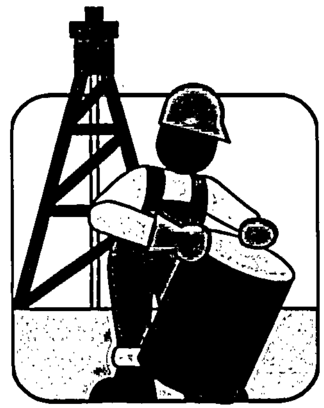


- Utilization facility:
  - Any nuclear reactor other than one designed or used primarily for the formation of plutonium or uranium-233

Part 50 – Production/Utilization Facilities



- Typically used to license LWRs
  - Some generic sections (independent of reactor technology)
  - Many requirements are specific to LWR design and technology
  - Examples – ECCS, ATWS, accident source terms, GDC (App A) and other appendices
- Two step process:
  - Construction Permit
  - Operating License

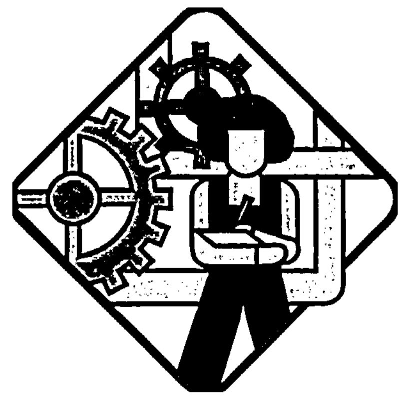


Part 50 – Production/Utilization Facilities

- Each step requires:
  - Application
  - Staff Review
  - Mandatory ACRS Review
  - Public Hearing Required – ASLB
    - At Construction Permit stage
    - Commission decision on whether needed at Operating License stage
  - Commission Review and Decision

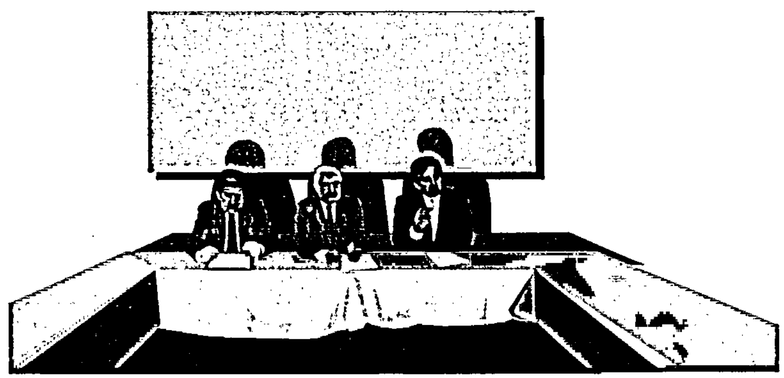
Part 52 – ESPs, Std Design Certifications, and COLs for Nuclear Power Plants

- Designed to facilitate design standardization and pre-approved siting
- One step licensing process:
  - Early site permit
    - Partial Construction Permit
    - ACRS report and public hearing required
  - Design certification
    - Part 50 requirements and certain reactor related additional items apply (e.g., requires design-specific PRA)
    - Separate from ESP or COL application
    - Certification established by rulemaking after ACRS review
    - Legislative hearing at Commission discretion



Part 52 – ESPs, Std Design Certifications, and COLs for Nuclear Power Plants

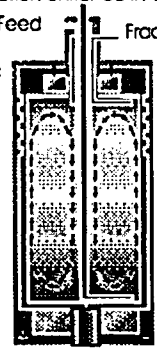
- One step licensing process (cont'd):
  - Combined Construction and Operating License
    - All of Part 50 requirements applicable
    - ACRS review
    - Commission publishes notice of intended operation
    - Hearing may be requested
    - Commission determines appropriate hearing procedures



Part 70: Special Nuclear Material

- Used to license facilities possessing SNM:
  - Pu, U^{233}, Enriched U^{233} or U^{235}
  - Gas Centrifuges (LES, USEC)
  - MOX Fuel Fabrication (for commercial use only)
  - Fuel Fabrication for LWRs (e.g., NFS, BWXT)
- One step process for licensing facilities
  - Enriched U facility (Part 193 of AEA)
  - MOX facility is two steps to ensure parity with Russian program
- Risk Informed
  - Subpart H requires Integrated Safety Analysis and performance requirements based on likelihood and consequences

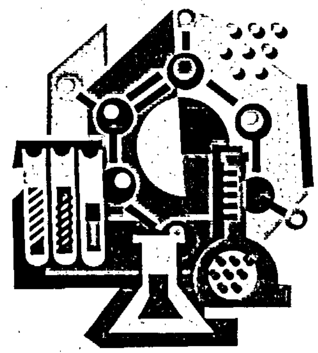
The Centrifuge



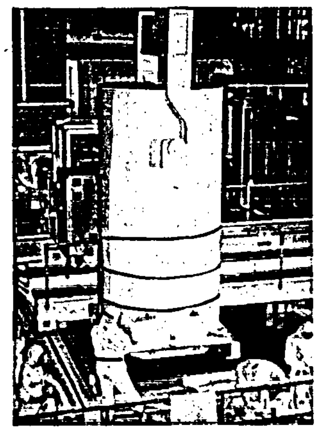
	Highly Unlikely	Unlikely	Not unlikely
High Consequence Publ Dose > 25 rem Worker Dose > 100 rem	Acceptable	Not Acceptable	Not Acceptable
Medium Consequence Publ Dose 5 - 25 rem Worker Dose 25 -100 rem Env releases > 5000 Tbl 2	Acceptable	Acceptable	Not Acceptable
Low Consequence Publ Dose < 5 rem Worker Dose < 25 rem	Acceptable	Acceptable	Acceptable

Part 30, 72: Byproduct Material and High-Level Waste (HLW)

- Part 30:
  - Applies to persons who manufacture, produce, transfer, receive, acquire, own, possess, or use byproduct material
  - Byproduct material means any radioactive material (except SNM) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing SNM



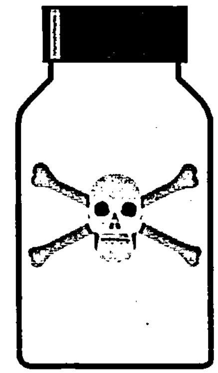
- Part 72:
  - Applies to the receipt transfer, packaging, and possession of power reactor spent fuel aged for at least one year, other radioactive materials associated with spent fuel storage, and greater than class C waste in a solid form...
  - HLW means the highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations...



- Fission product streams, in general, may meet criteria for regulation under these Parts
- Part 30 is subsidiary to Part 50 and 70

WIR/NDAA Determinations

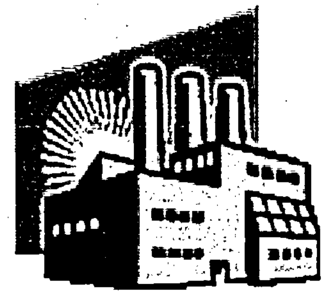
- Concept of WIR
  - Wastes can be managed based on their risk rather than the origin of the wastes
  - Some wastes from reprocessing are highly radioactive and need to be disposed of as HLW in a geologic repository, others do not
  - WIR does not pose the same risk to human health and the environment and does not need to be disposed of as HLW in order to manage risks



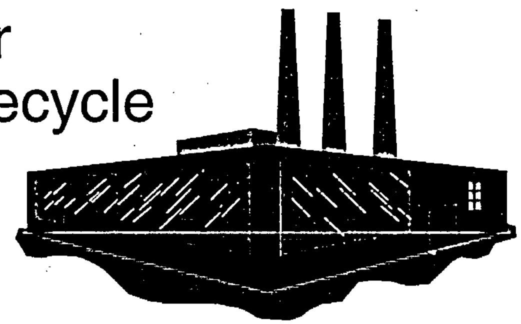
- Four sites have different criteria to determine non-HLW classification
  - West Valley – West Valley Demonstration Project Act and Commission's Final West Valley Policy Statement
  - SRS and Idaho – National Defense Authorization Act of 2005
  - Hanford – DOE Order 435.1

Facilities NRC Could Regulate

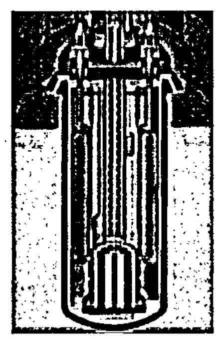
- Reprocessing Facility:
  - Will demonstrate spent LWR fuel separations technology (produces TRU stream and fission product streams) [ESD]



- Fuel Fabrication Facility:
  - Will demonstrate fabrication of fast reactor transmutation fuel using TRU from LWR recycle and/or TRU from fast reactor recycle, also advanced reprocessing [AFCF]

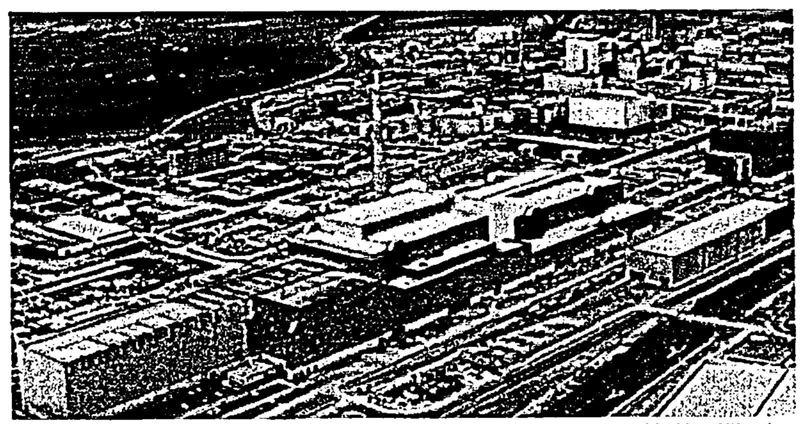


- Fast Reactor Facility:
  - Facility to demonstrate destruction of TRU (ABTR)
  - ABR -- DOE expects to develop a "standard" design



Facilities NRC Could Regulate

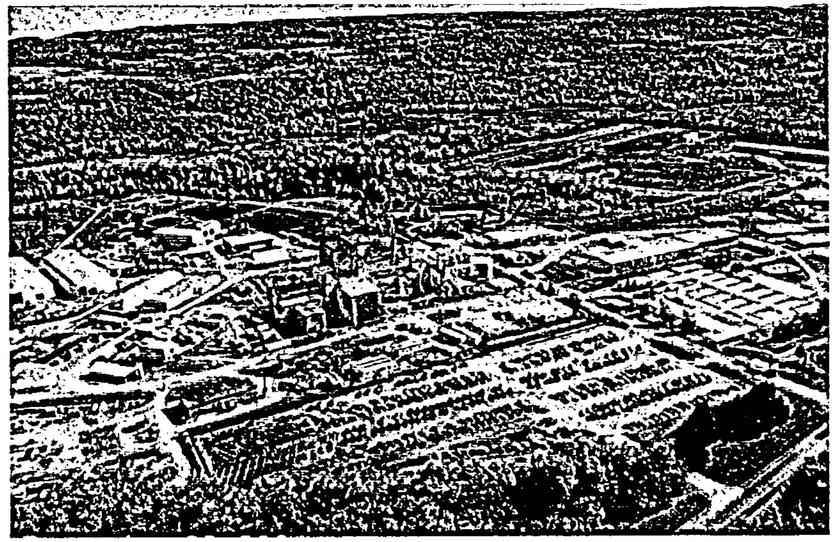
- Interim Storage Facility:
  - For interim storage of highly radioactive, short-lived FP stream from LWR fuel reprocessing (potential vitrification needed)
- Vitrification Facility
  - For vitrification of high level, long-lived waste stream for geologic repository
- Facilities could be co-located or combined (e.g., vitrification and interim storage conducted at reprocessing facility)



The Thermal Oxide Reprocessing Plant (THORP) in UK. This commercial facility treats spent fuel from UK and overseas reactors, separating the high-level waste from uranium & plutonium. The smaller black building on the right is the vitrification plant for this waste.

Reprocessing Facility

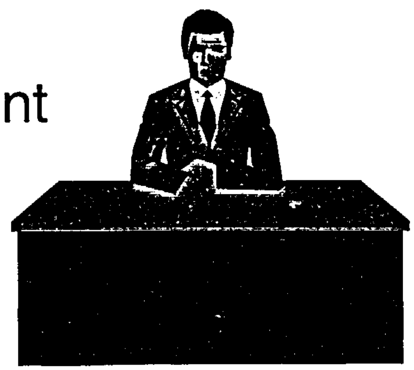
- First production facility licensed in the past 40 years (West Valley, NY – 1966)
- Part 50:
  - Most technical requirements are not applicable to reprocessing facilities
  - Regulations would need to be reviewed to determine what sections do/do not apply



West Valley

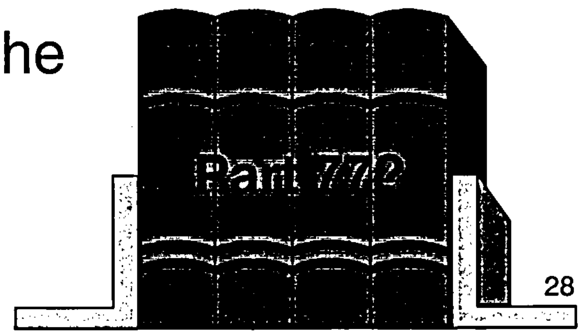
Reprocessing Facility

- Part 50 (cont'd):
  - Additional requirements would be established to address reprocessing facility-specific design and safety issues
    - Particularly issues associated with need for full-remote handling TRU and FP streams
  - Commission would establish the licensing framework by identifying specific parts of existing regulations and also establish new requirements in the order initiating the proceeding
    - Similar to process used for LES enrichment facility



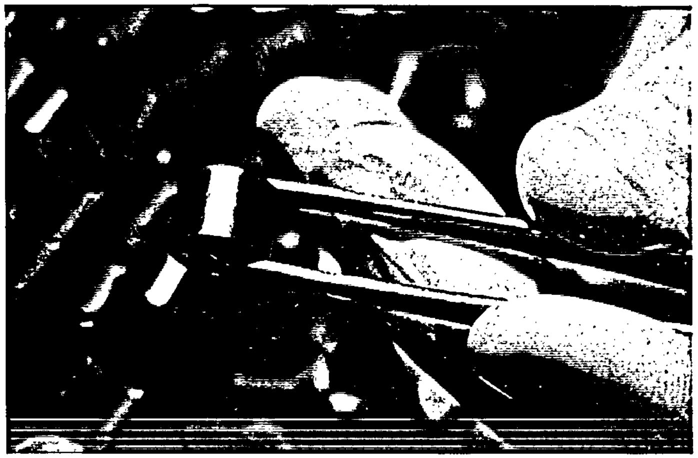
Reprocessing Facility

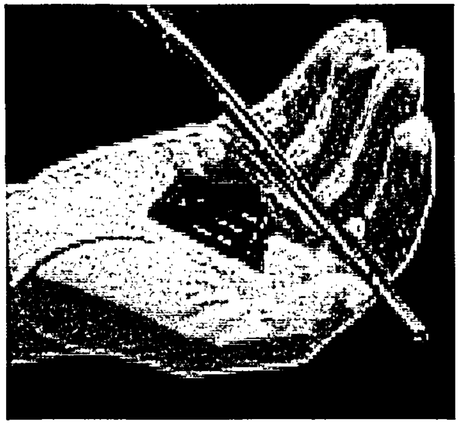
- Alternative - Develop a <u>new</u> risk-informed, performance-based regulation (or revise existing regulations) to address specific technical, safety, and policy issues which are specific to reprocessing facilities
  - Part 70 provides a good framework for new regulation or revisions
  - Commission has directed consideration of Part 52 (potential for design certification; COLs)
  - Also develop new regulatory guidance for review (similar to NUREG-1718, SRP for MFFF)
  - Potentially include requirements for vitrification and/or interim storage at the facility



Fuel Fabrication Facility

- Part 70:
  - Potentially revise regulatory requirements to address:
    - Fuel containing TRU
    - Safety and technical differences between metal and oxide fuel
    - Technical requirements associated with full remote operation
- Also develop new regulatory guidance for review (similar to NUREG-1520, SRP for Fuel Cycle Facilities)
  - New or different criticality safety considerations



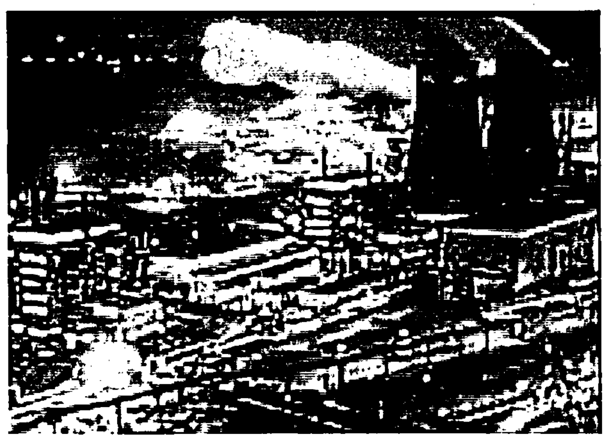


Interim Waste Storage and/or Vitrification Facility

- Part 30:
  - Potentially applicable to vitrification facility handling long-lived FPs (byproduct material)
- Part 72:
  - Potentially applicable to short-term storage (100 years) storage of Cs, Sr (HLW)
- WIR/Non-HLW determinations:
  - May apply to FP (Cs, Sr) stream after decay prior to LLW disposal
  - Modifications may be needed to existing acts/legislation to address GNEP wastes

Fast Reactor Facility

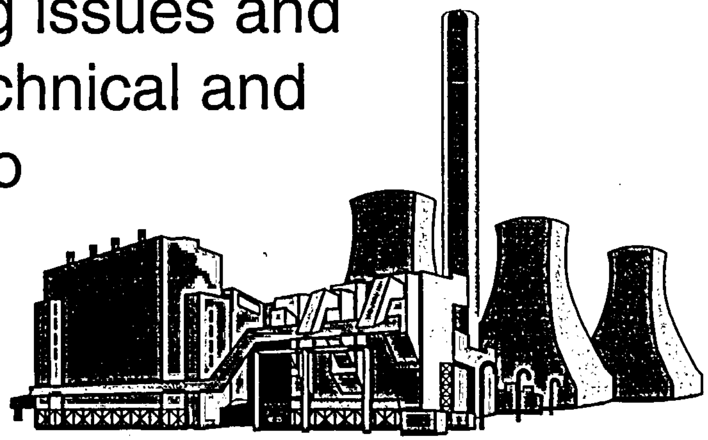
- Part 50:
  - Different control systems and safety considerations for sodium cooled fast reactor than LWRs
  - Would need to determine the applicability of the regulations to the fast reactor design and the need for exemptions and/or license conditions to address unique aspects of the design (e.g., Clinch River BR)
  - Procedurally possible to use Part 50 regardless of technology – may not be the most efficient or effective approach if more than one application is received (may incorporate Part 52 features)



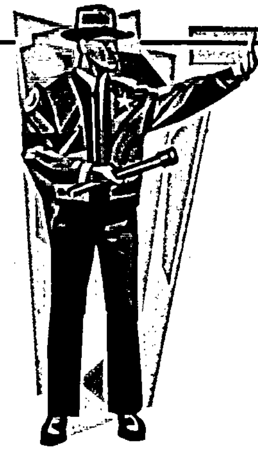
Sellafield

Fast Reactor Facility

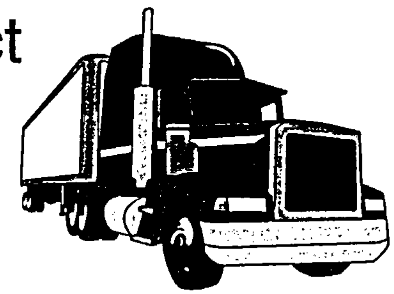
- Staff has begun working on a technology neutral framework for licensing advanced reactor designs
  - SECY-06-0007, "Staff Plan to Make a Risk-Informed and Performance-Based Revision to Part 50"
- Staff recommend pre-application interactions to identify key safety and licensing issues and developing a plan outlining the technical and regulatory infrastructure needed to license a fast reactor design



Other Changes to Regulations?

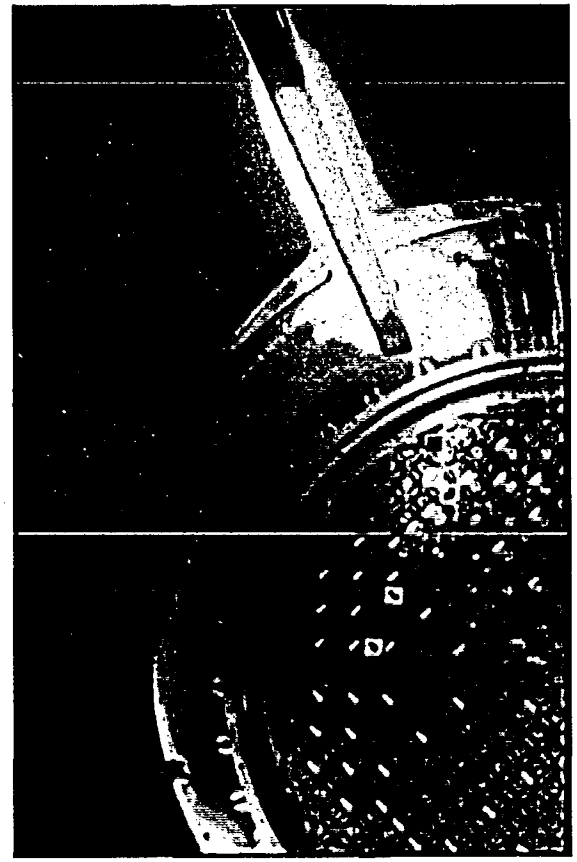


- Security and Safeguards
  - Changes may be needed to:
    - Part 73 (Physical Protection)
    - Part 74 (MC&A)
    - Part 75 (International Safeguards)
- Environmental Protection
  - Changes may be needed to Part 51 to address the potential environmental impacts of spent fuel transportation to the facilities and product shipment from the facilities



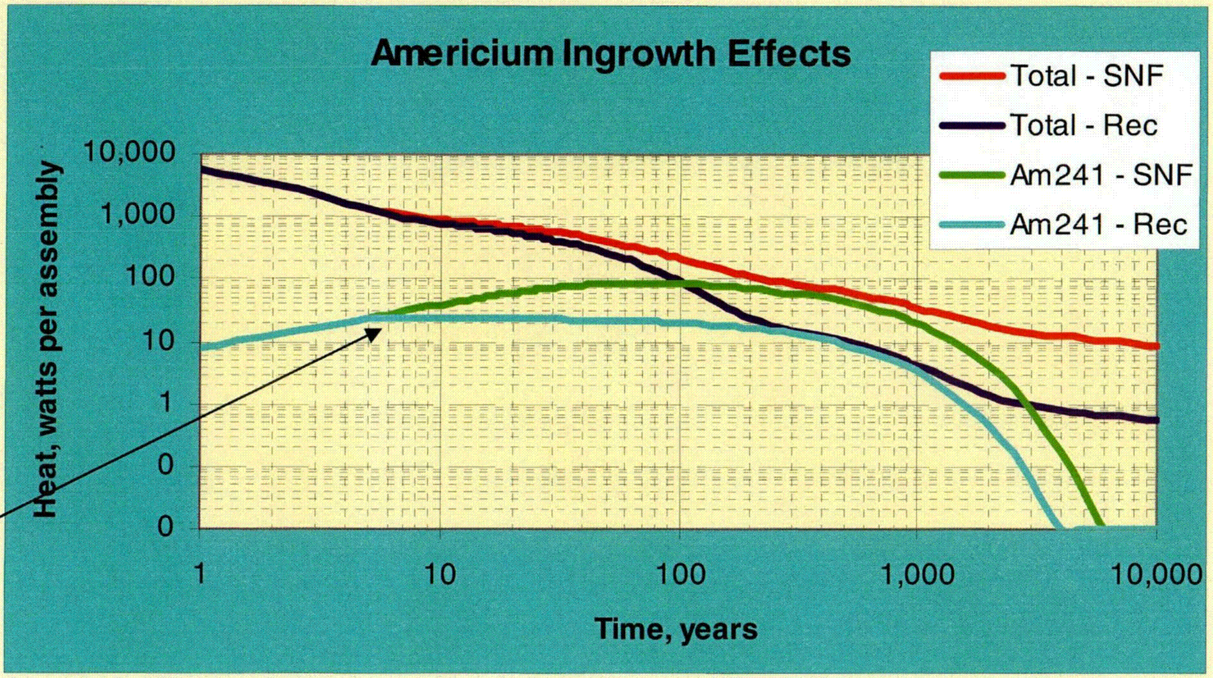
Potential Issues

- Fuel Fabrication
  - Increased shielding/health physics issues with reactor grade Pu
  - Full remote, heavily shielded operations because of intense direct radiation
  - Large radionuclide inventory with dynamic composition
  - Spent fuel is self-heating
    - Cooling must be accomplished
    - Temperature affects properties



Potential Issues

- Spent fuel should be recycled within 5 years to avoid significant Pu-241 decay to Americium-241
  - Am-241 presents health physics concerns during fuel fabrication (soft gamma emitter)
  - Am-241 buildup in LWRs would result in long term heat load in repository
  - If fast reactors are used, Am-241 is less of a problem – will likely fission



Am-241 generation from Pu-241 decay at 5 years

Rec = reprocessing after 5 years and recycle

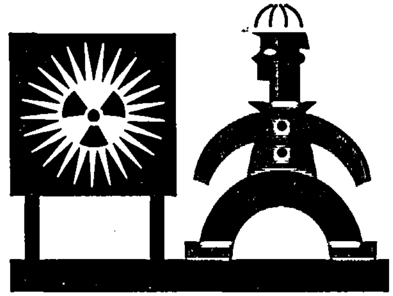
Potential Issues

- Security (proliferation)
  - Older fuel may not be self-protecting – may be more attractive for misuse
- Social
  - Major change in political philosophy - may change with varying administrations
- Acceptance
  - Only research has been done on new aqueous technologies whereas PUREX is commercial scale – international cooperation/financial assistance is desirable but uncertain

- Industry
  - Potential reduced need for additional uranium mines
  - Lifecycle for reactor fuel may need to be limited to 9-10 months (versus the current 18-24 months) to limit generation of Pu-241 which decays to Am-241

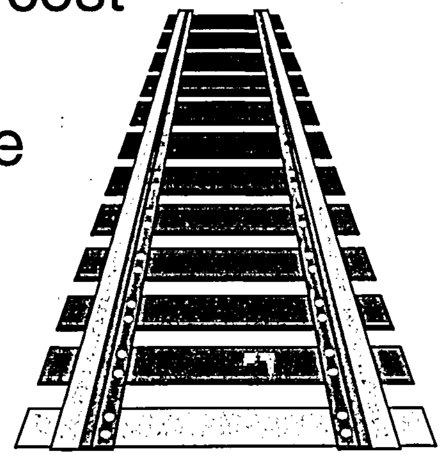
Potential Issues

- Radiological
  - Problems associated with enriching uranium to a higher reactivity for the driver fuel for an ABR – current facilities are licensed at 5%
  - More frequent core refueling would create greater exposures
- Environmental
  - Byproduct, LLW need to be minimized
- Waste
  - High sodium and/or chloride wastes may be difficult to vitrify
  - Uranium stream from reprocessing to waste? Or recycle?



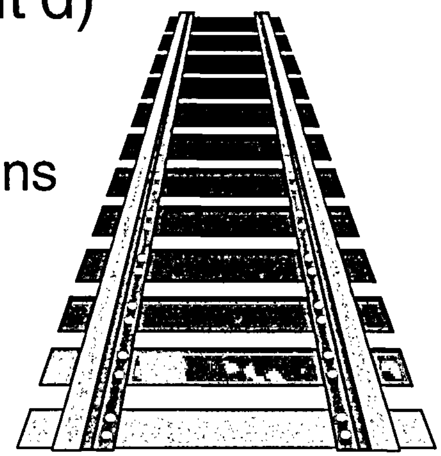
Path Forward

- Meet with DOE to discuss progress/timeline/cost-reimbursable agreement
- Draft legislation for NRC authority to regulate
- Develop conceptual licensing process
  - Form task group with NMSS, NRR, NSIR, RES, OGC
  - Licensing process:
    - Consider applicability of one-step licensing for enrichment facilities in Section 193 of Atomic Energy Act
    - Consider features of Part 52 process
    - Consider process EPA used to authorize operation of Waste Isolation Pilot Plant
    - Consider developing new regulation specific to reprocessing facilities



Path Forward

- Develop conceptual licensing process (cont'd)
  - Address the following:
    - Reactor and other fuel cycle safety regulations
    - Environmental reviews
    - Domestic and IAEA safeguards
    - Import and export controls
    - Waste management



Questions?

ACNW WHITE PAPER TENTATIVE OUTLINE

R. G. Wymer

June 6, 2006

I. INTRODUCTION
  - A. Legislative Status of U.S. Integrated Fuel Recycle Planning
  - B. Implications for Nuclear Regulatory Commission Involvement

II. Reprocessing Historical Overview
  - A. Wartime Reprocessing
    1. Bismuth Phosphate Process
    2. Redox (Hexone)
    3. Purex
  - B. Cold War Reprocessing
    1. Hanford
    2. Savannah River
    3. Idaho Falls

III. Early U.S. Commercial Reprocessing Attempts
  - A. Nuclear Fuel Services (West Valley Plant) - decommissioned
  - B. GE Morris Plant – never ran
  - C. Barnwell Plant – never ran

IV. INFCE Background Information
  - A. Context of the study
  - B. Principle Conclusions
  - C. Similarity to GNEP

V. International Power Reactor Reprocessing Status Summary
  - A. Introduction
  - B. Table of Countries
  - C. Brief Discussion of Key Players
    1. France
    2. UK
    3. Japan
    4. Russia
    5. China
    6. (India?)
    7. (South Korea DUPIC?)

VI. Implications for NRC of DOE Reprocessing Initiatives
  - A. NRC Licensing Responsibilities and Regulations
  - B. Implications of GESMO
  - C. Global Nuclear Energy Partnership (GNEP)
  - D. Introduction
  - E. Main GNEP Goals
    1. Proliferation Control
    2. Nuclear Fuel Fissile Material Re-use

3. Repository Benefits: reduced waste volume, reduced heat load, (Associated consequences of benefits: Cs and Sr Storage, destruction of actinides)
    a) Appendix A. Decay Heat in Spent Fuel

F. GNEP Timetable – Phased Approach
    1. Initial Operation Advanced Separation Facility: 2011
    2. Initial Operation Advanced Burner Test Reactor (ABTR) Using Conventional Fuels: 2014
    3. First Module Advanced Fuel Cycle Facility (AFCF): 2016; Operate Recycle Facility to Produce Actinide-Based Fuel for ABTR

G. Russian Equivalent Proposal – relation to GNEP

H. How GEN IV Fits In

I. Advanced Fuel Cycle Initiative (AFCI)

J. General Features

K. Types of Reactors in GEN IV
    1. Introduction
    2. PWR
    3. BWR
    4. FBR
    5. HTGR
    6. MSR

L. Types of Fuels
    1. LWR
    2. BWR
    3. FBR
        a) Oxide
        b) Metal
        c) Carbide/Nitride
    4. HTGR
        a) Pebble Bed
        b) Prismatic
    5. MSR

M. "Proliferation Resistant" Reprocessing
    1. Introduction
    2. Uranium-Plutonium Cycle
    3. Thorium-Uranium cycle
    4. Refabrication(?)

N. Reprocessing Flowsheets
    1. Urex + 1, 1a, 2, 3and 4
        a) Introduction
        b) Emphasis on Urex +1a
        c) Chemical and Material balance flowsheets
    2. Pyroprocessing
        a) Introduction
        b) Chemical and Material Balance Flowsheets
        c) Unusual Plant Design Features

3. Processing HTGR Fuels

VII. Recycle Facility Design and Operation

A. General Plant Construction, Design and Operating Features

1. Introduction
2. Siting
3. General Considerations
4. Licensing
    a) Environmental Impact Statement
    b) Operator Training
5. Fuel Receipt and Storage
6. Hot Cells
7. Reagent Tanks
8. Recycle Facilities
9. Product Tanks
10. Waste Storage
11. Central Control Room
12. Analysis Facility

B. Specific Plant Design Features – French input(?)

1. Material Balance Flowsheet (assume 800 te/yr?)
2. Equipment Flowsheet
3. Equipment Layout

C. Plant Operations

1. Introduction
2. Operator Training and Licensing
3. Spent Fuel Receiving
4. Spent Fuel Storage
5. Spent Fuel Inventory
6. Shearing and Dissolving
7. Separations
    a) Uranium
    b) Plutonium
8. Product Purifications
    a) Introduction
    b) Uranium
    c) Plutonium
9. Product Accountability
    a) Introduction
    b) Sampling Systems
    c) Record Keeping
10. Denitration of Products
    a) Introduction
    b) Concentrator
    c) Fluidized Bed Denitrator
11. Acid Recovery and Recycle
    a) Introduction
    b) Fractionator

c) Concentrator
12. Solvent Cleanup and Recycle
    a) Introduction
    b) Mixer-Settlers
    c) Concentrators
    d) Distillation Column
13. Gaseous Waste Treatment
    a) Introduction
    b) Spent Fuel shearing and dissolution off-gases
        (1) Condenser
        (2) NOX scrubber
        (3) I Desorption Column
        (4) Mist filter
        (5) HEPA Filters
        (6) Krypton
        (7) Tritium
        (8) C-14
    c) Vessel off-gas
        (1) Introduction
        (2) I Sorption Column
        (3) Mist filter
        (4) HEPA Filters
    d) Storage of Products
14. Low-activity liquid waste treatment
    a) Introduction
    b) Thermosyphon Concentrators
    c) Filtration Equipment
15. High-activity liquid waste treatment
    a) Introduction
    b) Concentrator
16. Solid waste treatment

D. Auxillary Systems
1. Reagent Storage
2. Storage of Waste
    a) Hull and End Piece Storage
    b) Spent Resin Storage
    c) LAW
    d) HLW
    e) Solid
3. Ventilation and Confinement
4. Material Transport Systems
    a) Cranes
    b) Liquids

E. Plant Safety
1. Radiological Safety
    a) Inherent in Plant Design

            (1) Introduction
            (2) Shielding
            (3) Ventilation
            (4) Alarm systems
            (5) Construction Features
                (a) Levels of containment
            (6) Natural Disaster Features
                (a) Tornadoes
                (b) Floods
                (c) Seismic Events
        b) Health Physics Measures
            (1) Protocols
            (2) Training
            (3) Instrumentation
        c) Radioactive Material Control
            (1) Containment
            (2) Transfers
            (3) Records (documentation)
        d) Scheduled Inspections
        e) Personnel protection
            (1) Written procedures
        f) QA Procedures
    2. Chemical Safety
        a) Introduction
        b) Ventilation
        c) Personnel protection
            (1) Written Procedures
        d) Material Control
            (1) Transfers and Use
                (a) Written procedures
            (2) Documentation
            (3) Record Reviews
        e) QA
            (1) Fire
            (2) Procedures
            (3) Documentation
            (4) Inspections
    3. Criticality Safety
        a) Dimensional
        b) Concentration
        c) Isotopic Composition
        d) Mass
        e) Location of Equipment
F. Plant security features
    1. Introduction
    2. External

        a) Fences
        b) Barriers
        c) Guards
    3. Internal
        a) Badges
        b) Code Entry
        c) Portal alarms
        d) Plant design

G. Advanced Plant and Process Features
    1. Introduction
    2. Proliferation resistance
        a) Improved processes
        b) Improved equipment
        c) Improved instrumentation
        d) Improved data collection and analysis
    3. Evolution of Waste Management concepts
        a) Decreased waste production
            (1) Improved processes
            (2) Recycling
        b) Volume reduction