Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

BRIEFING BY REPRESENTATIVES OF DOE/ARGONNE

NATIONAL LABORATORY ON RESEARCH REACTORS

(Open to Public Attendance)

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BRIEFING BY REPRESENTATIVES OF

DOE/ARGONNE NATIONAL LABORATORY

ON RESEARCH REACTORS

(Open to Public Attendance)

Commissioners' Conference Room
Room 1130
1717 H Street, N.W.
Washington, D. C.

Wednesday, June 7, 1978

The Commission met, pursuant to notice at 9:40 a.m., Joseph Hendrie, Chairman, presiding.

PRESENT:

Chairman Hendrie
Commissioner Gilinsky

ALSO PRESENT:

R. Lewis (ANL)
R. Nack (DOE)
D. Hoyle (State)
W. Williamson (ACDA)
J. Hoyle
L. Gossick

PROCEEDINGS

CHAIRMAN HENDRIE: If we could come to order. Commissioner Kennedy, I'm afraid isn't going to make it and Commissioner Bradford will be in, in a bit. Why don't we go ahead.

The subject this morning is a briefing by representatives of DOE and Argonne National Laboratory on Research Reactors, and in particular on the development program aimed at reducing the needed level of enrichment of fuel for research reactors.

MR. LEWIS: I'm Dick Lewis from Argonne National Laboratory. Chairman Hendrie, Commissioner Gilinsky, I have taken the liberty of inviting two other gentlemen, Mr. Dixon Hoyle from Department of State and Mr. Richard Williamson from Arms Control Disarmament Agency.

They have been instrumental, particularly in policy portions of the development of this program, and I thought it might be useful for them to be here.

CHAIRMAN HENDRIE: We are very glad they could come.

MR. LEWIS: If you have in front of you the briefing documents that I prepared, and I can direct your attention to the table of contents, let me just quickly go over what we have here.

There is more detail than I will try to handle

verbally here, but basically I would like to start with review of the goals of the program, a few items on the research test reactor design considerations basically that feed in to the program ground rules, then a discussion of what determines the acceptability of reduced enrichment fuel in research reactors. From that, develop discussion on our current enrichment reduction strategy.

Then under Item 5, the program itself, I want to talk about the current organization and structure of the program. The reaction that we have had to it, both here in the United States and abroad, then the status of the program.

Item 6 and 7, I will just brush over very lightly and they review the current state of the art in research reactor fuel technology and the prospects for improvement of that technology. And then I want to spend just a couple of minutes talking about NRC actions that would help us in this program.

So to begin with the goals, this program is a part of the Non-Proliferation policy effort within the U.S. Government. In this particular case the principal goal of the program is to improve the proliferation resistance of fuels used in research and test reactors.

The particular concern is with highly enriched fuel during its fabrication, transport and storage prior to substantial burn up. It is felt that there is a potential for

diversion of the material, particularly in those activities.

Now generally this program is intended to provide a technical means for reducing the enrichment of the fuel substantially below 90 to 93 percent enrichment, both in U.S. and foreign reactors. The long-term goal is to reduce the enrichment below 20 percent or at least, to a minimum enrichment. Recognizing that there will probably always be a few very high power research reactors for which reduced enrichments will not be feasible.

Now, going to Item 2, starting on page 2, let me briefly touch on those aspects of research reactor design that can strain one's options in looking at reduced enrichments.

First of all the main objective of good research reactor design is maximum flux for a given cost. Because cost corolates very closely with power level in the reactor, you are generally talking about trying to maximumize flux to power ratio. That is done by minimizing core volume for a given power. That is sort of the key item for research reactors. You want to have small cores which lead you, of course, to maximizing volumetric power density.

Now,in that situation where you have high volumetric power densities the limiting factor in the design is the temperature of the coolant at the surface of the fuel element, at the fuel plate surface, and the factors that in turn determine that maximum temperature relative to say boiling, usually you are

talking about a factor relative to boiling. The factors that determine that temperature are the heat flux, that is the power per unit of surface area and how fast the coolant is flowing past the surface which determines boundary layer, thickness and therefore,dT (Delta T) across the boundary layer.

So generally, the higher power of reactor you are talking about or higher power density you need to increase the heat transfer surface area per unit volume of the reactor and flow faster. So that is why for higher power reactors you typically see thin plate, thin type designs with high flow rates.

Now, the key performance parameters in a research test reactor from the user's point of view are the fast flex in the core and the thermal flex in the reflectors and in the core flex traps. Generally thermal flex in the core or in the fuel is not a very important parameter, and as it turns out, the incore fast flux and the excore reflector flux trap thermalflexes are determined principally by the power density. So you come back to the power density again.

So much from the user's point of view, but from the physists point of view the problem, of course, also is to provide sufficient reactivity to overcome burn-up losses, operating losses in the temperature coefficient, xenon, samarium, the reactivity involved in the experiments in order to provide a certain amount of control.

Now, you have got a few ways to adjust reactivity and one, of course, is the core size, but here we want to minimize size, the moderator to U-235 ratio, U-235 loading in the core, the reflector type and size that you pick. Generally reactivity can be increased by increasing the core size, going to a more optimum order to U-235 ratio, increasing the U-235 loading or using better reflectors or moderators.

Now, burn-up losses are roughly in propotion to the fractional loss of U-235 per megawatt day. You are talking about maybe 1.25 grams per megawatt day of U-235 burn-out in the core. The reactivity loss is roughly proportional to the fraction, that is, of the total U-235 loading. So you can extend core life by increasing the total U-235 loading in the core. But this is limited by -- just putting in more U-235 is limited -- you don't want to get excessive reactivity from a safety point of view and also, you are limited by the fact that the fuel volume available is limited. And after providing for moderator and cladding, you can only do a certain amount by putting more U-235 in there, especially when you need a thin-type design.

Lastly, of course, one has to be sure and maintain in any variations, the negative power coefficients and temperature coefficients which for aluminum water plate type reactors, principally come from the under-moderated design. You are running on the low side of the water to a U-235 ratio

and you want to maintain that. For lower enrichment designs, of course, doppler becomes a factor, and for burn-up of poison situation such as in TRIGA, you can get some substantial negative temperature coefficient through the spectral-shifts accompanying temperature changes.

All right, those briefly are the main factors in the design.

Now, with regard to acceptability of reduced enrichment of fuel, I would like to say a few things here. starting on page 4. Research/test reactors all over the world, including the United States are under intense cost pressure and they have to keep cost down and are trying, at the same time, to maximize flux levels. This is every operator you talk to. I think, in that connection it has to be recognized at the outset that the use of lower enrichment fuels causes inherently poor flux-per-unit-power performance and higher cost relative to the use of higher enrichment fuels. This is particularly true for higher power reactors.

The reasons for that are that there is a somewhat lower reactivity per gram of U-235 at lower enrichments, patricularly if you get below about say 15 percent enrichment.

Secondly, and very important, is that simply putting in U-238 displaces core volume which you can't, therefore, use for other things such as clad or heat transfer surface.

Now, the reduced enrichment reactor design studies

that we are engaged in are aimed at minimizing the performance and cost penalties. In most cases, I think that acceptable reduced enrichment compromises can be found, but it has to be recognized that in all cases highly enriched fuel would still provide better performance. One example of the bind that you are in there is that we have under development higher uranium density fuel types for research reactors which we say will make it feasible to use lower enrichments in reactors. But it is true that one can turn that around and say, well, fine we can use the higher uranium density fuels, but at highly enriched uranium and get yet better performance. That is a sticky item.

Well, getting back to the acceptability of reduced enrichment fuels, if you simply lower the enrichment in current designs it really has a catastrophic effect. The reactivity, of course, immediately goes down and that drops core life of a given core way down or if you compensate by increasing the core size, your power density is down and therefore flux performance is down and you are faced with having to raise reactor power, a very costly item.

COMMISSIONER GILINSKY: Could you say something about the population of research reactors? In other words, there must be a relatively small number of higher power research reactors which are utilized to a great degree and asserts considerable pressure to perform and so on, and I would

guess a larger population of smaller reactors which are probably not used this intensively for which these considerations might be less relevant.

MR. LEWIS: In fact, I will get to that exact point, but to answer your question directly there are in the world on the order, I don't know, 90 or so research reactors. Of those, perhaps 20 are high power, high performance, and another 30 or so -- 40, are of intermediate power, 5 to 50 megawatts and the rest are lower power, a megawatt or two and below. It definitely is true that the low power ones can go to 20 percent now. It is really the intermediates that -- well, the high power it is very difficult. It is really the intermediates where a case-by-case situation has to be looked at.

All right, so I'm just saying here that simple reduction enrichment in current designs is basically a catastrophic situation for any research reactor and that needs to be avoided. So the criterion that we have adopted in the program that we consider practical from an acceptability standpoint for reduced enrichments is the following:

Use less than 20 percent enrichment fuel, or if that is not practical minimize the enrichment in a situation. Look at it case-by-case.

Secondly, as a basic criterion there should be no significant reactor performance reduction of flux per unit

power relative to high enriched fuel currently used in the existing reactor.

Now some reduction will probably be necessary, but no significant reduction compared to the existing highly-enriched reactor design. Now for new reactors it is less clear, but we have been taking as a working criteria that relative to high-enriched fuel designs typically used for that reactor at this time, at the same power that they should get approximately the same performance.

Thirdly, there should be minimum fuel cycle cost increases relative to current highly enriched fuel. There are going to be increases, but I hope not overwhelming.

Conversion to reduced enrichment fuel should raise a minimum of new safety and licensing issues, and this is particularly relevant to existing reactors.

Finally, for existing reactors there should be no requirement for reactor or facility modifications. In particular, no need to increase the power substantially because that really gets into a very costly operation.

So those are the criterion that we have used.

COMMISSIONER GILINSKY: What does that mean, no facility modification?

MR. LEWIS: Basically it means they should not have to raise their power levels substantially in order to reach the same or essentially the same flux performance, which means

from a technical point of view that the core size needs to remain the same since you have the power density.

CHAIRMAN HENDRIE: An interesting problem, in order to maintain the power density in these conditions, you actually have to slightly nominally hold the same, but actually slightly increase the U-235 density for unit volume of core, and what you are doing is taking out a little of the inert material in the fuel alloy and finding ways to replace it with uranium which your uranium has not got a lot of 238 in it.

MR. LEWIS: Exactly, you are stealing my punch line.

CHAIRMAN HENDRIE: Oh, sorry about that.

MR. LEWIS: That is exactly right, though, and that is an interesting problem and as it turns out, just to jump ahead a little bit the reason you can do something with that problem in the short run is because most reactors do not use the current state of the art with regard to uranium density, but for those who do use the current state of the art we have to go to higher uranium densities and that is what the development program is largely all about.

All right, so what is going on to Item 4, Enrichment Reduction Strategy: starting with those criterion then, what can be done? Well, if you go down the list of things you want to maintain, maintain reactor performance, flux per unit power, that requires that the reduced enrichment core must

have the same volume or -- and the same or perhaps somewhat more fissile mass than the highly enriched core. This implies to the first order that the U-235 density in the reduced enrichment core must be the same as or somewhat more than the U-235 density in the highly enriched core.

Secondly, maintaining fuel cycle cost requires that the burn-up capability for fuel element in the reduced enrichment case must be the same or greater than that in the highly enriched case and the cost of fabrication must be the same or less in the reduced enrichment case. That second one is probably not going to be met. The first one can be met though.

Now, the first of these requirements, that is burn-up capability again implies you need the same U-235 loading in the fuel element. Now the extent to which new safety and licensing issues are raised in any redesign are minimized by minimizing reactor design changes, particularly in the area of safety parameters, reactivity coefficient, safety margins and the physical barriers to fission product release. This implies avoiding changes, to among other things, core moderator to fuel ratio, heat transfer area per unit power and cladding materials.

Generally we would like to limit changes to just changing the fuel element and maybe increasing the flow rate.

Facility modifications can be avoided if the reactor

power doesn't have to be increased or if you don't have to have substantial thermal-hydraulic changes such as very much larger flow rates.

Now, these factors suggest an enrichment reductions strategy that is based on the working criterion that is necessary to maintain the U-235 loading per fuel element at least as large in the reduced enrichment design as in the current highly enriched design. It is true, as you point out, that reactivity or cost considerations may dictate somewhat higher U-235 loadings per fuel element in the lower enriched designs.

Now, U-235 loading can be maintained by increasing the uranium density in the fuel in proportion to the decrease in the enrichment, and/or by increasing the useable fuel meat volume per fuel element. This is the practical working criterion that we are using.

COMMISSIONER GILINSKY: What is fuel meat?

MR. LEWIS: If you think of a fuel plate, a typical research reactor has a cladding and then there is a region inside which is usually a mixture of some form of uranium and aluminum and that is called the fuel meat. It is thought of in the sandwich analogy, the clad is bread.

We have looked at a lot of these research reactor designs and at fuel capabilities and we feel that increased uranium density sufficient to permit enrichment reduction from 90 to 93 percent to 30 to 45 percent using this criterion can be

achieved in many existing MTR-plate-type fuel designs in the 5 to 50 megawatt range without changing the fuel meat volume, and that is substitution of state-of-the-art high uranium density U_3O_8 aluminum or UAL_x aluminum fuel meat technology for currently used relatively low uranium density, uranium aluminum alloy technology. Currently proven state-of-the-art fuel technology is not sufficient, however, to permit enrichment reduction below 20 percent for reactors, generally speaking, for reactors greater in power than 5 to 10 megawatts without substantial reduction in the U-235 density, therefore, we consider use of 20 percent for that range of power, say 5 to 50 megawatts probably -- well, it is not practical at the moment.

COMMISSIONER GILINSKY: Given the various constraints you have imposed on them.

MR. LEWIS: That's right.

Now, for reactors where there exists an excess design margin in power per unit of heat transfer area, that is typically for plate-type reactors of less than 5 to 10 megawatts, additional enrichment reduction to less than 20 percent I would say is possible by increasing the fuel thickness and maintaining moderator to fuel ratio or somewhat reducing that ratio and that means reducing the number of plates per fuel and increasing the flow somewhat. But I think that is quite practical for virtually all reactors in that -- almost

all reactors in that power range, say below 10 megawatts.

Now, very high uranium density uranium fuel meat technologies currently under development in the U.S. and in Europe, show promise of providing sufficient uranium density to permit enrichment reductions from 90/93 percent to below 20 percent while maintaining U-235 density regardless of the power level of the reactor, while maintaining reactor performance, I think, for virtually -- well, let's say 90-95 percent of the reactors in the world. That's what we are doing in a large part of the DOE programs, developing that new very high uranium density fuel.

A brief overview in Section 5 of the Program Organization, the budget and the schedule of the program. There are four major elements to the program. The first one is generic analytical studies of reduced-enrichment designs. Looking at them in four broad classes, aluminum plate water, the TRIGA, zirconium hydride designs, D_2O and UO_2 designs. Really, all aspects of designs are being looked at.

Then secondly, there are case studies being done for a very large number of new and existing reactors. For each one, looking at the enrichment reduction options for that specific reactor. The reactors fall very nicely into those classes, so these specifics are not an overwhelming job to do. We are doing these case studies also to support the Executive Branch reviews of export license applications and for

domestic reactors, reviewing their enrichment reduction options.

Thirdly, there is a portion of the program which provides technical support to intermediate enrichment reductions from 30 to 45 percent, and I should add there that that task has also taken the reduction to 20 percent enrichment where that can be done right away. And within that maybe near-term enrichment reduction effort which applies to all U.S. or foreign reactors supplied from the U.S., we are doing generic fuel engineering design studies, procurement specification sample preparations, safety analysis sample preparations, and also undertaking demonstration fuel fabrication programs where appropriate. And then there is the large low enrichment fuel development program which is aimed at developing uranium -- well, fuel meat technologies of sufficiently high density, uranium density to permit 20 percent enrichment use under our criteria in virtually all reactors except the highest power ones.

In that advance fuels program, we are looking at a wide variety of fuels and they are listed here, the U_3O_8 and the UAL_x fuels, they are currently the state of the art fuels. Silicide, uranium moly fuels, UO_2, TRIGA fuel developments also. We are seeking international participation and we are engaged not only in the metallurgical developments and associated burn-up tests, but also generic fuel design studies in looking

at fuel specs and safety analysis effects and undertaking demonstration programs.

Now, as currently structured this is invisioned to be a five-year, $10 million program initiated March 1st of this year. The budget break down, it is on page 11, should be taken, I think, with -- well, it is a tentative budget break down, for years beyond 1979 it is, of course ---

COMMISSIONER GILINSKY: This is DOE money?

MR. LEWIS: This is DOE money, but I included it so you can get a feeling for the general distribution of efforts between the design analysis, the intermediate enrichment application study efforts and the low enrichment work; and also the various organizations that are involved here.

COMMISSIONER GILINSKY: Do you have any where a list of these 90 reactors with an indication of which class they fall in to and what you think can be done with them?

MR. LEWIS: Yes, we do, both for the U.S. and for foreign reactors.

The list is relatively easy to come by. As to specific statements as to what class they fall in, we need to be somewhat hesitant on that. This is a matter of very great sensitivity to many reactors, and we have taken the tact that we do our own studies internally at Argonne, but before we publish a definitive statement on how far down enrichment they can go, we do studies jointly with the reactor involved. I

wouldn't mind sending you our internal working documents on that, but you have to realize that it is not easy to get all of the details of fuel design in a particular reactors, let's say BR-2 in Belgium. We found that when we were in Europe we did not have the current fuel design specifications on that reactor and as the result they were not a candidate for substantial enrichment reductions in the near term. It turns out ---

COMMISSIONER GILINSKY: Which is a lack of information?

MR. LEWIS: Well, we thought they were using the old uranium aluminum alloy technology. It turns out they had switched to uranium aluminide technology at the hightest currently available uranium density, and as the result they are at 93 percent enrichment, whereas the result in the short run there is no way to reduce their enrichment under our criteria. It will have to await the development of the higher density fuels. But it is that sort of thing that I really hesitate to give definitive answers on exactly how much enrichment reduction a given reactor is capable of without a study involving the reactor operation themselves. But broadly, any reactor below 5 megawatts can almost certainly go to reduced enrichments.

Now, the only exception is that there are a few cases and MIT is a good example, where even at 5 megawatts

they have gone for performance reasons, to high expense fuels, the state of the art ULA_x fuel at 93 percent enrichment. And they have very good performance at that power level.

Now for them, there is no technology switch you can make now that won't move them back in performance. But there are only very few of those.

COMMISSIONER GILINSKY: Well, it would be useful to have your internal working notes.

MR. LEWIS: I can give you those, the listing and they really are listed as our current thing is that they can go to such and such an enrichment.

COMMISSIONER GILINSKY: Haven't we sent out questionnaires asking for information.

MR. D. HOYLE: These have been done -- this information has normally been expected at the time the export license application is made.

We have, in some cases said that if they want to expedite the export licensing procedure when it occurs that they could give us that information in advance so that it could be reviewed by the Argonne people and we wouldn't have to start from scratch at the time the export license application was made. In fact, there are some people coming in from the European community, particular the NUKEM people in a couple of weeks, to go over all of the reactors for which they provide fuel to determine what information is lacking on those reactors

that we need for these analysis.

COMMISSIONER GILINSKY: Does the NRC staff get to take a look at this?

MR. D. HOYLE: Certainly the information is available. We have not actually to date gotten -- we have gotten sort of the details of the Argonne information, but I see no reason that -- we have gotten summaries, if you will.

COMMISSIONER GILINSKY: Is that normally sent forward with the applications or with your advice?

MR. D. HOYLE: Well, I think the problem that Dick hasn't yet hit on is that there are no fuel fabricators for most of these fuels. We have got a very practical problem. Even though the fuels exist, the fabricators don't exist, and this has been one of the things we have been trying in the last few weeks to help resolve.

The manufactures have been manufacturing the fuels in accordance largely -- of course, there is no U.S. fuel fabricators of plate-type fuels any longer since U.S. Nuclear has gone out of the business, except those which utilize DOE-owned equipment and do this on a cost-plus, fixed-fee basis and their capacity is rather limited. So most of the capacity for plate-type fuel exists in Western Europe, NUKEM and CERCA specifically, and of course, they have even been fabricating the GETR fuel and for the Sterling Forest carbide reactor in Germany.

COMMISSIONER GILINSKY: Well, were do we go from here then, suppose Argonne concludes that a certain class of reactors with no degradation in performance accept lower enrichment fuel, what happens then?

MR. D. HOYLE: Well, I think it is a carrot and stick proposition, again. We ultimately are going to have to force the issue. On the other hand, in our recent visit to Europe to NUKEM and CERCA we found that these companies had anticipated this development and were in the process of getting ready, at least in terms of looking at advanced developments and so on.

Now, again, one of the real problems is they are handling one enrichment currently, 93 percent, and it complicates their manufacturing life substantially to go to two or even to three enrichments. Some have indicated they don't want to handle more than the maximum of two under any circumstance. In this intermediate enrichment which Dick has briefly alluded to, we have told everyone that we are not going to have 17 intermediate enrichments. We are going to ultimately, after some screening, decide on one enrichment so there will only be basically three, 20, something between say 30 and 45, and a 93 percent.

They are moving toward this certainly, and General Atomic has announced a 20 percent fuel which would be a replacement for its current 70 and 93 percent fuels. In

some cases this is based on an extrapolation of really, a state of the art technology, but they seem to have a high degree of confidence in this, going from essentially 12 weight percent uranium to 45 weight percent uranium in their fuel.

So some of these fuels conceivably could be used in reactors currently using plate-type fuels, but again to some extent that the reactor operator has -- he may be reluctant to change for a number of reasons, including the necessity of getting new regulatory approvals and so forth of his national authorities. So it is going to take a little while and it is a number of sort of coordinated and parallel actions, I think, are going to be necessary to ---

COMMISSIONER GILINSKY: But this other aspect is also being addressed, in other words, how to implement it?

MR. D. HOYLE: Oh, yes. We have talked with these fabricators, there is consideration being given to a meeting of fabricators from around the world, perhaps at Argonne in the fall.

I believe the European community is going to ask us to talk to users in the European community. The users, in fact, seem somewhat more reluctant, for understandable reasons, I think, than the fuel fabricators. The fuel fabricators' only concern is can they still make a profit, and that's their major concern.

MR. LEWIS: Okay, that brings us well in to this second point under the program, U.S. and Foreign Reaction to the Program. Briefly it has been following -- page 5, Section 5.2.

The reaction of U.S. and foreign research reactor operators and fuel suppliers to the thrust of the U.S. program has been favorable, I think it is fair to say, but cautious.

ANL is currently initiating reduced enrichment studies for new reactors, jointly with the Japanese and the Australians. In fact, personnel exchanges on those programs start this month. They are both designing new reactors, the only two new ones in the world that I know of.

We are also undertaking at ANL a numerous case studies of reduced enrichment conversions of existing U.S. and foreign reactors. Many of these are or will be joint studies with the affected groups.

Now, the U.S. and European fuel suppliers, I think, are moving quickly, much more quickly than I had expected to be in a position to supply high uranium density, low enriched replacement fuels for existing and new reactors at 20 and 45 percent enrichment starting in one to two years, maybe even a little less than a year.

The fuel fabricators, the commercial ones, are, of course, General Atomic for zirconium hydride uranium fuels. They have moved out very quickly, partly due to DOE sponsorship

of work there, but they are now talking about a complete line of 20 percent enriched fuel for all of their reactors. They plan not to produce any more highly enriched fuel.

MR. D. HOYLE: Incidentally, if I could interrupt, Dick, one of the major motivations in this has been the ever-increasing cost of physical security in highly enriched uranium fuel, and they now believe that about 40 percent of their fabrication costs are related to accountability and physical security. Now, while this won't entirely be eliminated by going to 20 percent or less, a major portion will.

MR. LEWIS: Especially if any of their work is 93.

MR. D. HOYLE: Yes.

COMMISSIONER GILINSKY: It seems to me to make a lot more sense by having lower enrichment fuel than by having a lot of policemen around and that really is a very desirable development.

MR. D. HOYLE: Well, that's the idea, that's the overall point of all of this.

COMMISSIONER GILINSKY: So it is a terribly important thing to do.

MR. D. HOYLE: We have sold the lowering of HEU largely to foreign countries not on the aspect that we mistrust your intentions, but rather we all have problems with terrorism and irresponsible parties. So really this program

is basically a physical security sold program, if you will.

MR. LEWIS: Now, NUKEM in Germany and CERCA in France have moved, I think, very quickly in doing -- they both produce ULA_X aluminide fuel types, and they have done an amazing amount of work in the last few months looking at very high uranium loadings. They won't tell us everything they know for proprietary reasons, but they are preparing for this coming up.

Reactor operators are much less up-beat. They are concerned, of course, primarily about reliability of fuel supply and about the performance of the reactors and very leery about problems that might be raised in safety and licensing reviews associated with going to the lower enrichments. They, of course are worried about the ratcheting effect that when the safety and licensing reviews are reopened, even for this item that other things would be brought in that would basically put them out of business. They are cautious, to say the least.

Then skipping on to page 15, as an overview statement, though most reactor operators in the U.S. and abroad, can see the feasibility of the U.S. enrichment reduction strategy broadly. Many operators of existing reactors at 30 megawatts and above feel that near-term enrichment reduction is infeasible for them, that is, enrichment reductions must await development of higher uranium density fuels. We generally

agree with that, especially for those reactors currently using the highest state of the art uranium density fuel technologies. So I think there is pretty much a meeting of the minds if you stick to the no reduction in performance criteria, but perhaps some increase in fuel cost if you go that way.

Now, let me skip over this area of Program Status, you can read that if you are interested, but it is underway -- substantially underway.

All right, let me just very briefly say with regard to Item 6, starting on page 18, there is an overview here of State-of-the-Art of Research Reactor Fuels Technology, we are talking about basically three fuel types: Aluminum plate fuel loaded with either uranium aluminum alloy at say 18 or 20 weight percent uranium, U_3O_8 aluminum or ULA_x aluminum and the latter two the state of the art is 42 to 45 weight percent.

Secondly, there are the U-ZrH TRIGA type rodded fuels that curently are produced at 8 and a half and 10 weight percent uranium and at 20, 70 and 93 percent enrichment and this is the GAI line. Then there us UO_2 rodded fuel that is used for a couple of reactors in the U.S., the so-called pulsor reactors. Well, the $U0_2$ rodded fuel is basically power reactor fuel.

Now, jumping over to page 21 let me just say a few

about the prospects for development of higher uranium loading fuels. First of all, increasing the weight percent of uranium in any one of these fuels increases the uranium density, both because the fuel meat density increases and because a fraction of the density, that is, the uranium increases.

The figure on the next page shows the effect, that is, there is a compounding effect, as you go to higher weight fractions of the dispursed fuel phase the uranium loadings in grams per cubic centimeter go up more rapidly than the weight fraction. It also illustrates how very low the uranium loadings are in these fuel meats, not only on the order of 2 ---

COMMISSIONER GILINSKY: Why is that, in order to get an alloy with good properties?

MR. LEWIS: Well, basically you want -- it is either metallurgical limits in the case of zirconium hydrides situation or what they thought were metallurgical limits, but in the aluminum plate-type arrangements what you need is very thin, very uniform distributions of fuel in the fuel meat to avoid hot spots and get a lot of heat transfer surface. And you need a reasonable economical fabrication technique such as rolling. But that's why this comes out -- I mean this compared with, for example, maybe 9 grams per cc, maybe 9 or 10 -- it would be 9 grams per cc in UO_2. So you see, you are

fighting that problem right off the bat.

CHAIRMAN HENDRIE: But the answer principally is yes to your question. The properties of your fuel meat under radiation -- temperature and radiation conditions are what you are fighting. You are also fighting fabrication probably to a certain extent. You load the meat compact up, you get to progressively harder materials to roll out and maintain in a fuel flight, the uniformity of distribution and the thickness properties and so on, the dog-boning, the fish-tailing out at the ends of the plates is getting to really be a fierce problem.

MR. WILLIAMSON: I think it is also safe to say frankly, that you are also fighting a lot of inertia. You could fabricate good fuels this way reasonably and cheaply, there wasn't much point in trying to do anything else until a couple of things happened once the development of the very very high flux reactors, on the one hand, and second the non-proliferation concerns.

MR. D. HOYLE: Well, this is not a big business. It is run on pretty profit margins, so the margin for research and development has witnessed the fact that some 9 fabricators have come and gone in the U.S. since the beginning days, 9 or 10.

NUKEM, for example, said that under the impetus of the new U.S. policy, when they first started looking at this

about a year ago, they now have learned a technique which they did not describe, which permits higher uranium loadings in all types of fuels, even and including the alloy fuels with yields which are as least as good or better than they had been getting before. So I agree with Rick, it is just sort of an inertia which is largely borne of economic considerations.

MR. LEWIS: That's why I think it is fair to say that the inertia comes from economics and conservatism. After all, you have got to have very reliable fuel and when you get one that works, you don't change that unless there is a very good reason.

COMMISSIONER GILINSKY: Well, there's a good reason.

MR. LEWIS: Okay, now you have a new criterion.

But briefly, what are the prospects for increased uranium loadings, and I would break this into three areas. The aluminum plate-type fuels, the TRIGA type fuels and special fuels.

Now, you can start with the state-of-the-art aluminum plate-type fuels, U_3O_8 or aluminide dispersions in aluminum, and you can raise the weight percent. And it is felt by the experts in the U.S. and I find now in Europe also, that you can probably go successfully from the 42 weigh percent uranium up to perhaps 60 or maybe 65 weight percent, particularly the aluminide looks attractive, but both are being

looked at. There are the problems that you alluded to in that but I think that will be successful. And that in itself would permit 95 percent of the reactors in the world to go to 20 percent, if you could just do that.

Now, in the second area of TRIGA, uranium zirconium hydride fuels, of course TRIGA has less of a problem. They are inherently a lower reactor. It is a rodded reactor and inherently you have got less heat transfer surface per gram of fuel and that sort of design, even though you make the pins -- we are talking about very small pins for their high power reactor. So they can more easily go to 20 percent for their market, but they have undertaken partially at DOE expense, development of higher uranium loading of zirconium hydride fuel, they have under development 20 weight percent, 30 weight percent and 45 weight percent.

They are very optimistic as it typical of General Atomic, I think generally, about all of those fuels. I guess I am less sure, but I'm sure that the 20 percent is feasible, maybe the 30 percent and hopefully the 45. They say they are ready to give a fixed price bit on fuel delivered at 45 weight percent and I can just say, well, I've got my fingers crossed for them.

There is a lot of testing, of course, that has to be done yet on that, in my view.

Now, going on then to the special fuels UO_2 -- one

way that you can use UO_2 is in platelet form, thin plats clad in Zircalloy. I am told that at various points in the U.S. fuel development program for power reactors such as EBWR, this was part of our program and it may be part of the military program for all I know, but the French, as a matter of fact, seriously plan to use thin plate UO_2, they call it their caramel fuel design, so seriously that CEA is currently fabricating a full core of this type of fuel for a Asyris which is a 70 megawatt reactor. It is currently using MTR, uranium aluminum plate type fuel and it will go to this thin UO_2 plate fuel at somewhere in the 7 to 8 percent enrichment range.

MR. D. HOYLE: If I might interject there, I think the big question perhaps is not whether this fuel will work, but what it will cost. What they are doing is on strictly a bench scale and most people think this will be a very expensive fuel to fabricate on a commercial scale.

MR. LEWIS: There is also the question of fuel reliability, because in order to make it reasonable economical, they are going to have to back off on quality of the fuel. And if they do that there are real questions as the French can see it whether the fuel can stand the power densities that are in these cores. So it is a test which is one of the French answers to the reduced enrichment problem.

Now, beyond the U_3O_8 and ULA_x work in the area of

special fuels the U.S. is currently looking at uranium 10 percent molly, uranium silicide and UC for fuel meats, either as platelets -- directly as platelets or as distributions in aluminum. Those are quite a bit more speculative, but they do hold out the prospect of much higher thermal conductivity than UO_2 and very high uranium densities.

If they were successful, I think you could talk about reducing all of the research reactors down, if not to 20 percent, at least to say 45 percent enrichment. But that has got to await the success of those developments.

I noticed in our discussions with the French that the CEA people were also looking at the U-10 molly for this application.

Well, in conclusion, let me just go to page 24 and make a pitch for a few things that the NRC could do to help us in the program.

Firstly, as we have already discussed with Bill Ross in Reactor Safeguards Branch in NRC, it would be very useful to have the NRC promulgate safeguards regulations, specifically for test and research reactors in the first place, reflecting their particular situation. But beyond that, regulations that would give credit for enrichment reductions below 93 percent, but substantially above 20 percent. And I think specifically 45 percent, but the optimum would be a sliding scale of, let's say the trigger quantity of fuel as a function

of enrichment.

Secondly, you are going to be receiving license applications for use of ULA_x aluminum, and probably U_3O_8 aluminum fuels in licensed reactors replacing uranium aluminum alloy fuels within the U.S. And these license applications, especially the first few would be very helpful to expedite these. The University of Michigan, in fact, has one now in and pending for a UAL_x conversion that happens to be at 93 percent enrichment and a very low weight percent. That is a particular situation, and when United Nuclear went out of business there were no sources for their fuel, so DOE asked Atomics International to make them fuel. Atomics International makes only aluminide fuels. So what they did, they backed off from the state-of-the-art weight percent way down to, I don't know, 5 weight percent or something, uranium a very low mix, but at 93 percent enrichment and gave them fuel that has their same U-235 per plate. But that conversion, there is a safety analysis report or license in for license review now, an addendum.

MR. D. HOYLE: Dick, if I could just interject one other thing here.

Not only do I think it is important to get some of these fuels in and demonstrated, I think that is going to be the proof test for the reactor operators, but since so many regulatory bodies abroad do look to the NRC's rule-making and

decisions in their own practice, that this would have sort of a double-barrel positive effect going toward lower enrichments, I believe.

MR. WILLIAMSON: In some places in the world that may well be the pacing item. In some countries, we were told the reactor operators are doing almost anything to not change anything, because they don't want to void their licensing set up as long as they don't change anything, you know, their license continues. The minute they change anything, even in the direction of greater safety, they need an entirely new license.

COMMISSIONER GILINSKY: We have that proplem too.

MR. WILLIAMSON: We were rather surprised by the degree to which, when we talked to people at the IAEA advisory group meeting that we all attended, how much the reactor operators were more concerned by the licensing and safety implications than they were by fuel cycle costs or whether the fuel would work or anything else.

COMMISSIONER GILINSKY: Well, who is in charge of this here, do we have somebody who is overseeing this here?

MR. GOSSICK: No, I think NRR is generally aware of what is going on, but I'm not sure. You talked to, I believe, Ross in Reactor Licensing.

MR. LEWIS: We gave a briefing similar to this to J. Miller?

MR. GOSSICK: Yes.

COMMISSIONER GILINSKY: Isn't he in Security?

CHAIRMAN HENDRIE: That's on the security side, to see what differences you might make with regard to 93 versus 45 to 20 on the security, maybe. The questions of reviewing applications for changeover to increased uranium loading decreased enrichment of fuels would come ---

MR. GOSSICK: Out of the operating reactor branch, probably, Stello, wouldn't it?

CHAIRMAN HENDRIE: Yes.

COMMISSIONER GILINSKY: It would seem to me it would be good if there was just somebody who is a contact point for others.

MR. LEWIS: So far, Bill Ross has done this.

MR. GOSSICK: Bill Ross has done that?

MR. LEWIS: Yes, but that's more in the safeguards area. But he has taken the initiative on that.

MR. GOSSICK: I will talk to Ed Case and see.

COMMISSIONER GILINSKY: See if this isn't important enough that there just out to be one person that you can go to.

MR. WILLIAMSON: One of the recommendations coming out of the advisory group meeting was that the IAEA consider holding a further special group, whether it be an advisory group or a meeting of consultants it wasn't clear, to assist

countries that wanted to look into questions of regulation, safety and what have you with respect to research reactors and the use of the low enriched fuels. I assume that the agency will accept that recommendation. We will be scheduling a meeting of experts and I think it is very clear that the countries concerned will be looking to the U.S., and that means in this case the NRC, for some leadership in how you go about making safety analysis for these new fuels and how you draft regulations to conform to the new fuels, et cetera. I don't know how quickly the IAEA will be moving on this, but I anticipate we will be having a meeting probably within 6 months to year in this area. So I think some preparatory work will probably be needed.

COMMISSIONER GILINSKY: This is all terribly important, unfortunately there are artifical constraints that impede this job.

Who is handling this at DOE?

MR. LEWIS: The people involved are Sal Ceja (C-E-J-A) in International Affairs and Wade Ballard (B-A-L-L-A-R-D) in Nuclear Energy. Wade is ---

COMMISSIONER GILINSKY: The research people aren't involved in it?

MR. LEWIS: No, this is all within Thorne's -- well, International Affairs is separate, but within Thorne's area.

COMMISSIONER GILINSKY: I would have thought that --

wouldn't John Deutch be funding some of this work here in the sense that ---

MR. LEWIS: Let me defer that---

COMMISSIONER GILINSKY: I guess I meant that some of the research efforts in the labs would only fall under him.

MR. LEWIS: Oh, the uses of reactors, definitely do.

CHAIRMAN HENDRIE: Yes, but John's research empire in the lab stems towards the basic research. I guess it is the non-biomedical basic research, physics, chemistry ---

COMMISSIONER GILINSKY: Well, is there some informal group of something that pursues this?

MR. D. HOYLE: Do you mean within DOE or otherwise? There is a subgroup, the NSC ad hoc group on nonproliferation which follows HEU matters. In fact, I chair that group and it has interagency representation including the NRC, I might add. We are going to have a meeting on Friday to bring people up to speed of that group.

CHAIRMAN HENDRIE: Who is our representative?

MR. D. HOYLE: Jim Shea or one of his people has participating in that.

MR. WILLIAMSON: Much of that same group, in turn, overlaps the same group on nuclear export control. So a lot of the same representatives are involved. So this gets cranked

into that quite heavily.

CHAIRMAN HENDRIE: Let's see, you are in touch with that group, that's fine. You have a good reason then to have contact in Reactor Safeguards Branch or the security aspects are covered. I think it would be useful to sort of bring on board the safety side reviewers in NRR who have to deal with applications to go over from the highly enriched flow direction--

MR. GOSSICK: I will talk with Ed and see what he wants to set up.

CHAIRMAN HENDRIE: -- the plate forms and so on and get a lead contact there. I think if NRC could do, particularly, work on the like, could do an effective job in reviewing amendments, or at least the first few when they finally come in, the reactors that will be coming in attempting to do this that that might encourage others to set forward and talk to fuel suppliers.

Are all the research reactors contracting -- they are having to contract in Europe, I guess, for elements?

MR. LEWIS: No, well, the ones that are privately funded, I think generally are, but those that could get their funding through DOE are generally now still going through DOE and DOE is seting up Atomics International to provide their fuel supplies.

CHAIRMAN HENDRIE: Plate-type?

MR. LEWIS: Plate-type.

MR. D. HOYLE: On a cost-plus, fixed-fee basis.

Well, actually they would provide it, whereas before they have been giving a financial grant toward the procurement of such fuel when U.S. Nuclear and others were operating. Now, they would simply just be providing the fuel ---

COMMISSIONER GILINSKY: We are still supporting ---

MR. D. HOYLE: Oh, yes. About a dozen or something like that. Ten, I think, something 8 or 10 which the University of Missouri of one of them, University of Michigan and so forth. This fortunately gives us a little additional leverage in trying to encourage the reactor operators to reduce enrichments, and we are going to try to make maximum use of that as well.

CHAIRMAN HENDRIE: Let's see, there is an outfit in Massachusetts that makes the ---

MR. LEWIS: Yes, that's Texas Instruments.

That's also CPFF.

CHAIRMAN HENDRIE: -- makes the HIFR fuel.

MR. LEWIS: Well, also they are going to production for HFRB in Brookhaven and ORR. Then again, there is no commercial fabricators, they want to use higher uranium density fuels but highly enriched. So they are going to Texas Instrucment, but that's CPFF.

Of course, AI in California primarily makes ATR fuel for the Naval facilities,and they are sort of branching in to this research reactor thing as means to divert some of the

overhead costs.

MR. D. HOYLE: But they made it very clear to us, although they were totally uninterested in getting in to this in a commerical basis, that it was again, a very small potential profit and a very high equipment investment.

MR. WILLIAMSON: I might make one or two other quick observations.

In the first place, with respect to safeguards and security, to the extent that there were matters that were either within the Executive Branch purview or in the combined purview of the Executive Branch and the NRC, we have already moved in several cases, away from the use of contained U-235 as a standard that we would set towards effective kilograms as a means of encouraging use of lower enrichments. I think that's one possible solution to the problem for domestic application here, as well.

MR. D. HOYLE: We will, by the way, shortly be requesting the NSC to interpret the Presidential threshold approval levels as being effective rather than contain kilograms. So that will encourage the use of lower enrichments.

CHAIRMAN HENDRIE: Let's see, a kilogram of 20 percent --

MR. D. HOYLE: This only applies to above 20 percent.

CHAIRMAN HENDRIE: -- is zero effective kilograms?

MR. D. HOYLE: Right, right.

So even 70 percent, roughly, would be only a little

more than half, in terms, that means you could go twice as much U-235 as you could ---

MR. WILLIAMSON: Six times the 45 percent, et cetera.

Secondly, we have talked briefly to the IAEA and to the Austrians about the possibility of a demonstration, a foreign demonstration at the Dedesivorsdorf Reactor. That is not the only candid, but it is one for a fairly early demonstration that these higher weight percent fuels can be used effectively. We do think that it is important to have a fairly early demonstration.

MR. LEWIS: I think it is worth saying that from a safety and license point of view that the intermediate enrichment reductions either to 45 percent or in some cases at 20, mean the introduction of existing technology. It is used in ATR, it is used in HIFR, HFBR and so on, so it is not totally new, but it is now for the reactors involved. They have to be assured of the safety and for many countries it is a new technology for them.

MR. D. HOYLE: We also believe that there will ---

CHAIRMAN HENDRIE: I don't think there is that much safety involved.

MR. LEWIS: I don't either.

CHAIRMAN HENDRIE: If you can run a 40 weight percent UAL mix in aluminum with uranium fully enriched and drive it out to high burnout, you sure don't look for much problem by taking

the same metallurgical mix that on a 20 percent enrichment and running that out until the reactivity is run down and you have to turn the machine off and reload, because you just will have fewer fissions per cubic centimeter of that matrix material for radiation damage ---

MR. LEWIS: But I have argued a fact on that basis that you probably don't need any demonstrations, big large scale demonstrations, full scale burnouts, but reactor operators are more conservative. They want to ---

CHAIRMAN HENDRIE: Ah, they talked to our licensing people.

(Laughter)

MR. D. HOYLE: I might also add that we expect some proposals for cooperation from the foreign fabricators, perhaps from CEA as well, which is developing the caramel fuel. The limitations are largely as one would suspect in the proprietary information area, but there might be exchanges of sample and some irradiations and reactors of the respected countries. We are kind of open, in a way, for proposals and there seems to be an interest in this area.

MR. WILLIAMSON: There is one final thing which has not been publicly announced which I think I can say here, and that is we hope to have an announcement, perhaps this week, at the UN special session on disarmament of a program of expanded cooperation in the nuclear field, modest program.

It is largely in the nature of a gesture, but included in that would be some money by the IAEA for 20 percent fuel and for fabrication services, so that instead of relying exclusively on the stick of not making HEU available, we will also have some carrots to offer people as a positive encouragement to lower enrichments.

COMMISSIONER GILINSKY: And you said that you may organize a seminar at Argonne?

MR. LEWIS: Well, there are two meetings that are coming up that are planned, one is primarily for fuel fabricators and for major R&D organizations such as CEA and the like where we would look at, first of all, generic problems in reduced enrichment designs, physics and engineering, and secondly, try to get the manufacturers to give us as much information as they will on where they stand on being able to manufacture this stuff.

We had planned to maybe organize such a thing in September or October of this year, probably by invitation only, but invite particularly the French, the Germans and the Japanese. Those are the main categories.

Then a broader meeting is planned probably next year by IAEA of reactor operators on the broad subject of upgrading and renewal of existing reactors and new reactors, the problems there. That will include case studies in enrichment reduction. So there are those things coming up.

CHAIRMAN HENDRIE: Okay. Lee, if you would look in to the NRR licensing side so that all of the NRC group ought to have interest in and participation in this so it could be brought forward and understand this effort and the usefulness of moving ahead with things like the specific case now in hand, the University of Michigan, that would be very good.

I thank you very much for coming, Dick.

COMMISSIONER GILINSKY: Thank you, that was a very nice briefing.

CHAIRMAN HENDRIE: We appreciate it very much. It was very informative and very helpful.

(Whereupon, the Commission took a brief recess at 10:45 then proceeded on to other business.)