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INTERNATIONAL WORKING GROUP ON FAST REACTORS

THIRTEENTH ANNUAL MEETING

Vienna, Austria

9-11 April 1980

SUMMARY REPORT

Part III

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FOREWORD

The Thirteenth Annual Meeting of the IAEA International Working Group on Fast Reactors was held at the IAEA Headquarters, Vienna, Austria from 9 to 11 April 1980.

The Summary Report (Part I) contains the Minutes of the Meeting.

The Summary Report (Part II) contains the papers which review the national programme in the field of LMFBRs and other presentations at the Meeting.

The Summary Report (Part III) contains the discussions on the review of the national programmes.

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1. Discussion of Mr. Vautrey's Presentation

Dr. Rosen: I have a question on the leak in RAPSODIE. It is not clear to me where the leak has occurred. Is it in the primary vessel or in the primary piping?

Mr. Vautrey: As I said, unfortunately we don't know as yet. One difficulty is that it is a leak which almost doesn't exist. We have found traces of sodium vapour. There was no leakage as such, and all examinations have shown that in the double casing there was no sodium in amounts that could be visible or detected and this was in fact the difficulty we had in trying to find the leak. I said we thought we had found the place where the leak occurred - on the junction of the two primary pipes. At the present time RAPSODIE has been put into operation again but I would say with a certain caution that we can find more about it in order to clarify the situation regarding a very small leak. Since it's been operating we still find a few traces of sodium vapour and the exact position of the leak is not still known.

Dr. Inyutin: What reactor did you talk about when you mentioned that the generating cost was the same as that of an oil-fired plant? Was it Super-Phenix or was it Phenix?

Mr. Vautrey: Super-Phenix I (the cost is now expected to be close to the cost of the kwh produced by a desulphurised coal plant).

Dr. Smith: Could you say more on the refueling of Phenix? Have you taken fuel elements out during the course of the year and were there any increased friction loads when removing these fuel elements?

Mr. Vautrey: In Phenix we observed certain deformations of the assemblage and for this reason the operation of Phenix and the unloading of fuel subassemblies are done with a certain caution. We always take out the subassemblies without having any major difficulties due to the deformation. From this point of view we had no major problem in taking out the subassemblies but of course this deformation does exist.

Dr. Tomabechi: I'd like to ask one question. Perhaps you might have mentioned during the presentation but I missed. Could you please tell us the forecast for the time of the criticality of the Super-Phenix I and also the forecast for the time to put this power plant into the power operation? I understand the construction has been progressing in accordance with the schedule but nevertheless would you please tell us something more?

Mr. Vautrey: The first operation is expected by the end of 1983.

Dr. Smith: There is a part in the review of French national programme concerning Super-Phenix, page 14, the central paragraph, which Mr. Vautrey omitted to save time. Are any new factors of the construction of the power station adopted?

Mr. Vautrey: During 1979 no new arrangement for constructing the boiler of the plant was adopted. For example, the decision taken in 1979 as regards the sodium-air circuits for emergency cooling which I mentioned last year. On the other hand most of the studies carried out this year were devoted to justifying and verifying the sizing of the structures and components of the plant. This is a verification work on behaviour of materials with respect to the combination of loads and the different operation cases. This year was devoted to work on these problems. This work required important calculational test work related to the internal structures of the reactor block, the intermediate heat exchangers, the steam generators and the respective buildings.

Dr. Rosen: The leak is probably the most interesting thing when it has occurred. What happens to the nitrogen that is used for cooling or as an inert gas if there is a leak?

Mr. Vautrey: The nitrogen is basically there as a neutral gas in the double lining which is around the whole primary circuit and which therefore constitutes a safety lining, a safety barrier. The nitrogen is a neutral gas, opposing to the sodium. If there is a sodium leak the leak is contained of course in the double lining and during the work that I mentioned, in trying to find the sodium leak which we didn't find, we modified slightly and improved the barrier of this double lining, the containment of this double lining as well as the means of detecting and sampling the sodium. In the case of a leak this double lining could be voided of the sodium that has escaped into it.

Dr. Smith: Could I ask Mr. Vautrey to say some more about these test methods? And could you explain the method of using an electric arc struck between the piping and an electrode and observation of the sodium line?

Mr. Vautrey: Yes, we use an electrical arc in which we are looking for the yellow line which is the characteristic of sodium. We are looking for the sodium line.

Dr. Smith: How are metallographic replicas done in that small space?

Mr. Vautrey: With difficulty. The double lining of course, was opened to have access to that place but it was difficult.

Dr. Tomabechi: I have one further question to Mr. Vautrey. You have mentioned that there was a fast sheer fuel failure detected in May 1979. Would you please tell us what method did you detect this fuel failure with and what was the cause of this failure or what was the nature of this fuel failure?

Mr. Vautrey: The methods used were in fact the methods which already exist in the reactor. We have detection of fission gas in cover argon. That is the first detection method, the first one we use normally. Then the delayed neutron detection in sodium is done using samples near each intermediate exchanger. A location, finding the place of rupture or failure is done by sodium sampling above each assembly with a rotating system, a selection system. You can have sampling on an overall level for each assembly so that you can localize the place of failure. We can say that the whole detection system worked quite normally without any other intervention. As regards the nature of the failure I don't know if the assembly had already been examined. I don't think that we have any results at present time on that leak.

Dr. Smith: You have given us reassurance that one can detect and locate a failure in a core fuel element. What is the situation regarding blanket elements in Phenix and Super-Phenix? Do you have a location system for a fault in a radial blanket element?

Mr. Vautrey: No.

Dr. Smith: A blanket element failure could be detected on the bulk neutron detectors but it would be difficult to locate it.

Mr. Vautrey: From the technical point of view it is difficult to generalize the means of locating which I mentioned a few minutes ago, to all the assemblies and in particular the blanket assemblies.

Dr. Balz: Could I put one question to Mr. Vautrey? As regards Super-Phenix II you said that first possibilities of reducing cost were looked for and you said that you took into account technical, technological progress. Does this involve considerable change in Super-Phenix I and Super-Phenix II? Are you going to eliminate the dome of the reactor?

Mr. Vautrey: First of all I would say that as regards Super-Phenix II it is the preliminary study and a number of directions among which we are going to go have not yet been fixed. As regards the particular point you mentioned I think probably there will be no dome on Super-Phenix II. The reactor and all the primary components will be integrated to form a complete hall. There is no major change. I think I already pointed out last year and I can say it again. We are trying to have fuel assemblies in the core which are shorter in length. Studies are underway also to have cooling of the upper roof by gas. That is about all I can say. A general design resembles very much that of Super-Phenix I.

2. Discussion of Dr. Marth's Presentation

Dr. Smith: You mentioned that you will use the SIMMER code procedure to calculate the loading on the containment for the licensing authorities and that you would verify the SIMMER code. Now it is not really possible to verify the SIMMER code completely. What sort of verification will be needed by the licensing authorities?

Dr. Marth: It is not requested by the licensing authorities because it would be catastrophic. It's not an easy job to verify such a huge code but we want to have a certain reserve, a reserving puffer for the licensing people. If later on we need a concession by them we can tell them "Look, here we have too much reserve according to our latest very similar calculations, less is needed". For this reason we are going ahead to a similar code business in collaboration with our American colleagues.

Dr. Smith: I think the licensing authorities do require in Germany some calculation of the loading. What do they accept? Do they accept the calculations or do they try to check these? How difficult do they make it for you? Clearly, I'm interested in these problems.

Dr. Marth: There are some voices who ask licensing authorities to make their own cross check, to prepare a second verification on their own but the manpower, that is, some in power of these licensing people is not high enough. So, at the moment mostly it depends on our calculations and analysis checked by them thoroughly, but they do not put up a second redundant one.

Dr. Rosen: General question perhaps can be addressed to Mr. Vautrey after Dr. Marth and that's on the removal of the failed fuel from the KNK-2. It was gas signal and in the Phenix that was delayed neutron signal and it's the philosophy on pulling the pins as soon as you detect the failure. Mr. Vautrey indicated that the Phenix pin was removed off rapidly.

Dr. Marth: I didn't quite get your question.

Dr. Rosen: If you shut the reactor down and search for the failed fuel as soon as you detect the signal apparently after it reaches a certain level, you don't work with failed fuel. It's the philosophy on running with failed fuels that I'm interested in.

Dr. Marth: Well, you see, at that moment we had a fairly new reactor. We were not interested in running with failed fuels for a long time. We had a signal by the DND monitors and by the cover gas and it was quite sure to us that we had a failure and we immediately intended to localize element and take it out. It is a different situation then the situation let's say at BOR-60 or in the late years of DFR. We have to be prepared to make our inspection work at the piping system and we had so little activity in the coolant as possible.

Dr. Tomabechi: Are you satisfied, Dr. Rosen?

Dr. Rosen: Yes.

Mr. Vautrey: I could also make a few comments on that particular problem of failed pin. I think, in fact I've already said a bit about this at previous meetings but what I pointed out yesterday when I talked about Phenix is that it is the only case in Phenix when we had a burst clad which was accompanied by neutron emission. I pointed out in the past few years that we had some gas release. In other words, some pins were not completely leaked tight. These were probably wall defects and these were gas emissions which were extremely minute and which never interfered with the operation. So we didn't do anything in those cases and it did not cause us any problems and now these pins no longer exist simply because they were in assemblies which were unloaded. Now if we turn to RAPSODIE and I think I've already said this at some point in the past, when we run up against a pin which is releasing gas, what we do is to follow up the evolution of this phenomenon. In other words, we keep close track of this phenomenon and when the release has developed a little too far when the gas release has become a little too significant then we withdraw the pin and we do this because we want to have a clean reactor. We don't want to be troubled by any accumulation of different fission gases. If these gases were accumulated they would prevent any detection because they would actually cover up or mask any new developments or phenomena. So we withdraw the pin depending on the development of the gas release.

Dr. Smith: Could I comment on this business of removing failed fuel? I think this is an important consideration which will be developed as a result of experience in the various prototype reactors. We don't, I think, completely know whether the limiting factor on sub-assembly life will be the distortion in the sub-assembly itself. It may be possible in those circumstances to operate without failed pins because the pins would always outlive the sub-assembly or it may be that in the longer time it will be possible to increase burn-up, for which there is a big economic incentive, until you are beginning to get some end of life failures from pins. I think from the experience we have already of pin failures, for example, in RAPSODIE and Phenix and experimental pins in PFR, and a lot of pins in DFR which we deliberately failed, it is clear that the first type of failure is probably merely small cracks or wall defects which can safely be left in the reactor until the next convenient shutdown. I don't think anybody wants to run a reactor with pins which are failed to such an extent that particles of the fuel are being released and carried around the primary circuit. So the question that we have to determine experimentally or by experience in the reactors is whether we can detect the difference in signals between microcracks and grossly failed pins. If we can I think very probably the pins with only small cracks will be left in for economic reasons.

Now, if I could go on, the other question was the point mentioned about in-service inspection and under sodium viewing and the detection of small faults in the stainless steel structure of the reactor. This actually is one of the topics which will be covered in the Chester specialists' meeting, including the developments of such cracks or defects in structures under sodium for long periods. I wonder if Dr. Marth could give any indication of what sort of views are being taken in Germany about the occurrence of cracks under sodium in core support structures, in SNR-300 for example. The licensing authorities are asking that you should be able to detect microcracks as well as cracks several feet long. What view are they taking on the sensitivity required for under sodium viewing or under sodium inspection?

Dr. Marth: As I said, up to now the licensing authorities request that any weld in the tank and also in the piping of course but in the tank it's more complicated, that any welding in the tank should be monitored. They do not request us to find the cracks, say of microcrack or a large or small crack. They realize that with our present methods and in austenitic steel it is less easy than in ferritic steel to find small cracks due to the different scattering of the ultrasound in austenate. Of course there are different physical properties to be taken into account. If I recall proper I think a crack of 1 mm or shortly below is at the moment maximum which can be found with the present methods but they have to be modified, they have to be improved and what the authorities request is a very substantial I&T program which is at the moment going on. Let me say two more words on this business with failed fuel elements. Of course, in the future it's recommendable that one can go on until the next core switch is timed but one should also to my view try to repair so fuel elements. In most cases only one pin is failed and if you have to take out the whole fuel assemble and put aside with hundred pins, it's a waste of funds of course and I think we should make progress in repairing fuel elements. For instance we are trying to repair these elements also but with regards to the grid spacers it is not so easy then with helical wire spacers especially at the end of life. When you want to track out the pin it's breaking.

Dr. Inyutin: Mr. Marth, could you be kind enough to give me a reply to the following question. In connection with what you have mentioned the sodium uronex and the sodium plutonex, what sort of defects are they plugging up?

Dr. Marth: We drilled holes into fuel pins on purpose, exposed them to in-pile radiation and we realized that if the holes are not too large, some material of the pellet is coming out and in the hole where it comes into contact with outside sodium, there is some chemical compound forming, a compound consisting of sodium, uranium and plutonium oxide. And this compound is blocking the hole with the consequence that no gas release is happening anymore.

Dr. Inyutin: Mr. Marth, in your experiments did you notice the removal of these compounds by the coolant? Did the coolant remove these compounds? Did you notice that happening or not?

Dr. Marth: The statistics is too low for me to answer this question. In some cases it did, in some cases it did not. So as I've said if you're lucky the hole is removed or is not here anymore and if you're not lucky, it's still here.

3. Discussion of Dr. Paranjpe's presentation

Dr. Tomabechi: I understand partially the act of FBTR is similar to that of RHAPSODIE and you gave some information on pp. 3 and 4 on the reactor but I'd like to have some information about fuels, for instance the dimensions. And also I assume you will use the enriched uranium mixed with plutonium. What is the maximum rated power, linear heat date, those information, if possible.

Dr. Paranjpe: The fuel for FBTR is rather almost identical to the fuel of "Fortissimo", that is these are the small diameter pins. I think the diameter of the fuel pellet is 4 mm and along with the cladding it becomes 5 mm. I think 4.3 mm is the correct dimension of the pellet and the overall dimension including the cladding is 5 mm. The linear dimensions are the same as those of "Fortissimo" fuel, the linear power is also same as 400 watt per cm, but our safety group has not given us clearance to run the reactor at 400 watts per cm. in the first year. They have cleared us up to 300 watts per cm. but the circuit and the components have all been sized so that we will be able to run the reactor for linear powers up to 480 watts per cm. The small difference between "Fortissimo" and FBTR as regards the internals is that we have in addition to the core a combination of a nickel reflector and a thorium blanket. The idea of thorium blanket was to generate some Uranium 233 within the blanket and to take an advantage of the fact that an atom of Uranium 233 is, in terms of reactor worth more than the atoms of U_{235}. We could recycle the Uranium 233 generated in the blanket, in the reactor so that our purchase of enriched uranium would be limited to 2½ cores which are needed for completing the fuel cycle because something later within 1½ year we have to be allowed for reprocessing and refabrication. So our total inventory is 2½ cores and we hope to replace the U_{235} that will be burned with U_{233} recovered from the blanket. This way we want to combine our objective of reducing our long-term dependence on enriched uranium supplies from outside and also gain useful practical experience in irradiating thorium, reprocessing thorium and fabricating U_{233} with the problems associated with U_{232}.

Dr. Smith: Following on the last question then I'm a little confused. On page 4 you talked of breeding ratios which looked at first sight more like a breeding gain but if you have thorium maybe these are breeding ratios. What is the definition of these numbers that you have given? Are they breeding gains in terms of reactivity worth?

Dr. Paranjpe: I'm sorry there was inaccuracy in the presentation. It should have been called actually conversion ratio, so FBTR although we call it fast breeder reactor is not a breeder in the sense that we'll be generating more fissionable material. In fact because of the use of reflector, it is a conversional ratio which is only .5 but the plutonium that will be burnt will be able to find its own replacement and this conversion is essentially conversional thorium to U_{233} which will be about .5 and this will be sufficient to replace the U_{235} burnt. This small conversion ratio is because we are using a relatively thick reflector. I must admit that these informations are somewhat old in the sense that these parameters were optimized at one time, sometime in 1971 and we have not re-optimized the core by taking into account the present prices of enriched uranium. The core is very flexible so one could in the limit throw out the nickel reflector entirely and fill up its place with a blanket. We could get a breeding ratio greater than one. We have calculated that if we change the thing to a total blanket, that is if we eliminate the reflector altogether we could get a value close to 1.2.

Dr. Marth: Mr. Paranjpe, I'm referring to your last remarks on the thorium. I understand you have a lot of thorium down in India but is fast breeder reactor really the best machine to use your thorium? What is the philosophy behind that you are using thorium blankets and you have to have two cycles - thorium cycle, uranium cycle? Do you really think that you could use up your thorium reserves by introducing this fast breeder equipment?

Dr. Paranjpe: Yes, we are aware that fast breeder reactor is not the best place to use thorium but we still have used thorium in FBTR as I mentioned. One reason is that FBTR is a small reactor. It needs enriched uranium and we are trying to generate U_{233} in the blanket so that the enriched uranium that is consumed in the core could be replaced. This is one objective. Second objective is to make the maximum utilization of the investments made in the reactor. We have large amounts of thorium and we are interested in developing the fuel cycle aspects of thorium that is reprocessing thorium, pre-fabricating thorium. FBTR will help us in that direction by supplying irradiated thorium which we have to irradiate somewhere, and we're doing that in FBTR. For the second phase of the fast breeders we will concentrate essentially on uranium-plutonium cycle as mentioned on page 1 of my presentation.

Dr. Smith: So far as the use of thorium is concerned I think this was studied by INFCE and it was shown that at least in the expanding phases, it is better to use plutonium in order to cut down the total consumption of uranium. For the over-all system which I think is in fact the second phase referred to on page 1 of the Indian presentation it does not assume using thorium. On the longer run if you wish to use thorium you could do so in a fast reactor. Now I think you said that fast reactor is not the best place to use thorium. If you are talking about conversional ratio or breeding gain, in fact you can get a better breeding gain in the fast reactor with thorium than you can with any thermal system. The point rather is the breeding gain in a fast reactor is much better with plutonium than with thorium. Therefore you don't actually need to use thorium in most cases unless there are special circumstances such as we've just heard from Mr. Paranjpe where he actually wants the U_{233}. So it isn't really true to say that it's not the best place to use thorium. There are only special circumstances in which one needs to use thorium. That's the way that I put it.

Dr. Marth: You put it right but I mean you have the disadvantage if you use both materials. So you have to close both cycles which is quite an achievement.

Mr. Vautrey: I'd like to ask Dr. Paranjpe if he could already give us some indications as to the follow-up of the program after FBTR.

Dr. Paranjpe: I think it's little too early to talk about program after FBTR because we are not likely to get any significant financial grants for reactor projects much bigger than FBTR until FBTR is put into operation but there are indications that some money will be made availabel for continuation of the research and development towards larger fast breeder reactors. We are currently thinking it is only the first phase of thinking but the indications are that we will like to have reactors of about 500 MW electrical generation capacity to be put into operation sometime in middle '90s that is 1995 or so. So since it takes about 10 years in India to build the reactor, we should start construction sometime in '85 and therefore the next one or two years will be spent in the process of thinking which then will give rise to the phase of preliminary design beginning from 1982, that is approximately the time when FBTR work will be coming to an end and the engineers occupied with FBTR would become free.

Dr. Rosen: What is the composition of the fuel blanket? It looks from the information that it may be as much as 30% plutonium and no enrichment and you indicated thorium for the blankets but I didn't know whether you meant thorium oxide or not?

Dr. Paranjpe: The material is the same as for "Rhapsodie", that is 30% plutonium and 70% uranium. Uranium is enriched to 85% in U_{235}.

Dr. Tomabechi: Dr. Paranjpe, further question is whether thorium is metal or oxide?

Dr. Paranjpe: The thorium is used in the form of oxide.

Dr. Inyutin: Dr. Paranjpe, have you investigated the problem of the accumulation of U_{232} in the reprocessing process for the fuel including thorium and if yes, what consideration do you have about that matter?

Dr. Paranjpe: We have far made some calculations based on the cross-section sets. We have essentially the cross-section sets which are listed on page 5, second paragraph and it appears to us that if we use a nickel reflector, the nickel reflector will be quite effective in removing the high energy components of the neutrons which give rise to (n,2n) reactions and therefore the formation of U_{232}. So the U_{232} content of U_{233} is expected to be small. I don't remember the exact number today but qualitative speaking the number is such that if the fabrication is completed in about 6 weeks' time after the reprocessing we could carry out the fabrication in glow boxes with very limited local shielding.

Dr. Rosen: The steam conditions, the efficiency of the plant looks unusually low. It seems to be 30% and yet the sodium temperatures are high. Can you say something about that?

Dr. Paranjpe: This is mainly because of the fact that we are trying to have a steam turbine which can accept very high pressure, high temperature steam but the turbine is very small in size with the result that we are not in a position to take full advantage of the increase in efficiency which normally one obtains by regenerative feedwater heating. We have only 3 stages of feedwater heating in which we change the temperature from about 40°C at the outlet of the condenser of the water to 200°C before the water enters the steam generator. Whereas in conventional plants of larger sizes you will have something like 8 or 9 feedwater heaters and so each feedwater heater gives you almost one extra per cent efficiency because it brings the thermodynamic cycle more closer to the theoretical ideal of the reversible cycle. Secondly the first two stages of our turbine have only partial admission of steam because the steam turbine is too small to accept 70 tons of steam per hour. The steam rate is very low and therefore the efficiency of first few stages of our turbine is inherently low.

Dr. Tomabechi: In this connection I have one question. I think you have said you have this evaporator and superheater. Do you have reheater?

Dr. Paranjpe: No reheater. That is also one reason why the efficiency is little low.

Dr. Welch: My question is on the licensing procedure which you described for the fast reactor. Is this a special arrangement or is it the same arrangement that is used for the thermal reactors that are built in India?

Dr. Paranjpe: I think the arrangements are more or less same for thermal reactors and fast reactors. That is the licensing is essentially an in-house process of independent examinations but it is carried out in house that is within the department of atomic energy.

4. Discussion of Dr. Bruzzi's Presentation

Dr. Marth: Dr. Bruzzi, in the beginning you were talking of stepping up your coal program. My question is are you having any coal in your country or do you rely on world trade?

Dr. Bruzzi: As a matter of fact there is a little bit of coal of very bad quality in Sardinia. I think you know and the quantity is estimated at about some hundred million tons but this means not much coal and so I think at the moment we are using in Italy about 2.5 Million tons of coal coming from Poland, South Africa to produce electricity. The expanding program is based mainly on importation and not on the Italian coal. Anyway there are also programs to try to use the Italian coal by appropriate methods and also the processes of gasification and liquefaction are under consideration.

Dr. Smith: First of all, what is now the expected on power date for PEC and could I ask little bit more about the licensing procedures. Are there any political difficulties now or are there still substantial technical difficulties in the safety applications?

Dr. Bruzzi: This is really difficult question because I don't know whether it was clear from the first part of my presentation that political assessment, political situation in Italy is not so clear and so let's say that not only fast reactors but also other types of nuclear reactors are under a process of strong reconsideration by politicians. So, I think that I can officially answer to you that there is no precise date for PEC. The work is going ahead with the maximum speed which is compatible with the Italian system, but I think we can not indicate a date today.

Dr. Smith: Can you give an earliest date? If everything goes well there must now be an earliest date when you could possibly be on power.

Dr. Bruzzi: I don't know if it is significant to give an answer in this respect because you know it is not upon my willingness so I don't think it is worthwhile to give you an answer. I am sorry. Regarding the licensing - the official reason for the delay was because the structure of CNEN people involved in the PEC design work and commitment work was not in agreement with the rules of the regulating committee which is as a matter of fact located in CNEN itself. And so they asked I think one year and a half ago to set up a special group called commitment group which now includes not only CNEN people but also ENEL people. They have already experience in this sector because they have constructed power stations and it took long time to have this commitment group been operating because we had also changes in the leadership of CNEN. There was a change in the chairmanship and so also our programs were strongly revised by the new establishment of CNEN.

Dr. Paranjpe: I just would like to ask one question. What is the budget of PEC and how many engineers are working for the design and construction of PEC?

Dr. Bruzzi: What do you mean by budget?

Dr. Paranjpe: The capital cost of the station PEC.

Dr. Bruzzi: The total cost, that is the foreseen starting from now to the end of the construction. I can give you an official figure from this standpoint. I don't know the meaning of this figure but I'll give to you that one I have read on an official document. As I've told just before to Dr. Smith it is difficult to give a schedule for this reactor and so at the same time it is difficult to give cost figure. Anyway in the so-called guidelines for the five-year plan for CNEN, the amount of money necessary to build PEC is estimated for the work performed so far 130 billion of Lira (about $100 million) and about 650 billions Lira to complete the undertaking.

I can give you the figure for CNEN personnel. It is more difficult to give you a number as far as industry personnel is concerned because it is spread out all over so let's say that people working on fast reactors at CNEN are about 400 now but they include not only personnel for PEC but also people for research and development. As a matter of fact, the commitment group will be made up of about 120 people and there is a little bit more CNEN personnel working for PEC because CNEN in the design work is in charge of the core and fuel design directly and the rest of the plant has been assigned to NIRA which is the main contractor of the reactor.

5. Discussion of Dr. Inyutin's Presentation

Dr. Smith: In these last figures on doubling times, could Dr. Inyutin say what else has been assumed for curves of this sort? One needs to know reprocessing losses of plutonium and cycle times, in particular.

Dr. Inyutin: The solid lines are calculated for external fuel cycle of a half year. The dotted curves are calculated for outside fuel cycle equal to one year. The losses in the fuel cycle, we have adopted some standards which I think were considered by INFCE but I don't recall.

Dr. Smith: Could I ask about the fuel for BN-350? What limits the burn-up in practice? Is it the subassembly swelling or is it the life of the fuel pins? And in these curves, what is the number of failures in fuel pins? What mean density of fuel in the can was used? What swelling space was available in the can?

Dr. Inyutin: As for the first part of the question, for the fuel of BN-350 - when we planned BN-350 we assumed that the reactor would be operated with a burn-up of 5% of heavy nuclei. As I said the reactor worked for a long time in that regime. The fuel elements are replaced in most cases when they reach a 5% burn-up. We are not tempting fate here because what we can allow ourselves to do in working with defective fuel elements in BR-10 or BOR-60 is something which we can not allow ourselves to do in BN-350. Although we call it a pilot test industrial reactor, it is actually a real industrial reactor and it is giving an energy to an isolated industrial area and therefore the reliability of operation of BN-350 is something which is most important. The wish to have experiments on the failure of fuel elements of BN-350 is something which would lead to a sacrifice of reliability of energy supply. I hope I've replied satisfactorily to the first part of the question. As regards to the second part of the question, this concerns Fig. 5. Let me just find the appropriate place in the report.

Unfortunately I haven't here mentioned the information that Mr. Smith wishes to know. I think it would be right if we used as a basis for this calculation the data which relate to BN-350. The data in respect of that reactor can be found in the manual on fast reactors which was issued by our group.

Mr. Vautrey: I'd like to put a question which relates to BR-10. You said that it was shut down in September 1979 for reconstruction which was to be completed in 1982. Could you give me some details about the work that has to be done on that reactor?

Dr. Inyutin: The program for reconstruction of BR-10 includes exchanging the reactor vessel, exchanging the fuel elements that is replacing the core, a replacement of the protection and control system, a replacement of the instrumentation for control of reactor and improving the experimental equipment. The following data can be given:

- The neutron fluence with an energy greater than 0.1 MeV on the wall of the reactor vessel is 8.4×10^{22} neutron/cm^2.
- The fluence on the walls of channel in the center of the core is 8.1×10^{22} neutrons/cm^2.
- The fluence of the neutrons on the cladding in the central fuel elements is the same value, 8.1×10^{22}.

The fluence on the fuel cladding in the central region is less than the fluence on the walls of the reactor vessel because the reactor vessel has not ever been changed in the course of the operation. In other words the vessel has been in operation for a longer period of time. The maximum value for the plutonium burn-up is 14.1% heavy nuclei which is 1.4 times greater than the planned burn-up value. Now as for what else is going to be rebuilt, instead of having one of the neutron beams, we are going to set up several devices for material investigations to study radiation creep, in reactor long-term stability, plasticity and other mechanical properties of structural materials.

We are going to continue improving the system of monitoring the state of fuel elements. We're going to continue work on clarifying data on the distribution of fissile materials and corrosion products in the circuits. I've already said that by the end of September last year, the reactor shut down. In November the core was outloaded into storage chambers. All the assemblies were verified for leak tightness outside the reactor in a system which is used to reveal defects in fuel elements but I have already mentioned the result of that verification at the beginning of my presentation. At the present time a verification of the piping tightness has been carried out. We'll take now the sodium from the circuit and as I've already said we've unloaded the core. We've assembled a system for steam, gaseous and distillate washing out. The steam, gas washing out has already been carried out. I think that the distillate washing out is taking place this week. We are taking down the biological shielding which was set up at construction and other equipments. When we've finished washing out the circuit then we'll dry the circuit and then the reactor will be taken apart.

Dr. Paranjpe: I would just like to ask one question and that is regarding the capital cost of BN-600. What is the cost in comparison with the cost of a comparable light water reactor of types which have been built in Soviet Union?

Dr. Inyutin: The cost of a fast reactor compared to that of a light water reactor with the same power when you make cost comparisons in Soviet Union I assume, as in other countries can be only evaluated with some uncertainty of about 40-50%. You might say why do you have this great degree of vagueness? Well the vagueness is due to the vagueness induced into the evaluation.

Certain research works has been carried out with the cost of the capital expenditure of the prototype. Others prefer not to do that and put this sort of expenditure in a pure, clean form. That's why you get such a big scatter in the estimates. I don't think we've yet carried out a full capital investment balance sheet on BN-600 but if it might satisfy you I could mention the figure for the actual capital investment in BN-350. That is the specific capital investment in BN-350. We have estimated this to be equal to 350 rubles per kilowatt. That is the specific capital investment cost.

Mr. Vautrey: I want to put another question to Dr. Inyutin on the BOR-60 reactor. On that reactor I think you had some experiences and tests on the steam generators. Have you run a test for the sodium-water reaction in steam generator for the BOR-60 reactor?

Dr. Inyutin: I can't really recall any special sort of comments made on this question. In Dimitrovgrad this work on sodium-water reactions is being done for a long time now. I think there were two meetings on this topic. I do not really recall any sort of features that really need any kind of comments. Research has been done on the development of leaks beginning with microleaks.

Research has been done with initial leaks of water into sodium 10^{-3} grams/s. This process went up to the maximum leak at the final stage of more than 4 gram/s. There are some other data which were given in the report also.

Dr. Tomabechi: In connection with this steam generator I have one question. Today we have learned that the module type steam generator made by Czechoslovakia farm for BN-350 has been put into operation and since you have said BN-350 has been operating quite well at 650 MW (thermal), I assume there was no leak experience last year and my question is - are any original steam generators being still used at BN-350 or have you changed all the originally fabricated steam generators to the modified version of the steam generator?

Dr. Inyutin: I have mentioned that one of the steam generators has been working from the very beginning when it was set up and it has been working for more than 48,000 hours. All the other steam generators have either been dismantled or replaced.

Dr. Tomabechi: So, one unit of originally designed steam generator is still working?

Dr. Inyutin: Yes, you're quite right. And its performance has gone more than 48,000 hours.

Dr. Welch: I believe you said that in the reprocessing development work you have looked into reprocessing uranium and plutonium together so that they would remain in the right ratio for production of new fuel. Did you find that you needed more solvent extraction cycles to get the fission products removed as a consequence of this?

Dr. Inyutin: If you were to ask me what I least understand in the contents of this report, then I would have to confess that it's the chemical reprocessing of the spent fuel. I mentioned that mathematical modelling of this process has been carried out and corresponding results had been obtained. So if detailed data is required you could obtain this on the basis of a bilateral exchange but the details are certainly available. All we're doing is giving a general picture but the details are certainly available.

Dr. Rosen: There are two questions and I think the first question is a very simple one. Did I understand you correctly to say that you are replacing the reactor vessel in BR-10?

Dr. Inyutin: Yes, yes, that's right.

Dr. Rosen: The second question is what do you intend to do with failed fuel in BN-600? Do you intend to wait till the end of the operation of a core to replace the fuel or do you shut down? Or do you have any plan that you can tell us as far as running the reactor with failed fuel elements is concerned?

Dr. Inyutin: We would certainly love not to have any fuel failures. That's what we really want. We have been doing an intensive work for a long time on methods for operating if defective assemblies do occur. We have the philosophy that nothing terrible would happen if the reactor were to have from 0.1% to 1% of defective fuel elements.

Which figure is more acceptable - this depends on the operating conditions. In BR-10 for example the number of failed fuel elements was from 0.5 to 1%. In industrial type reactors such as BN-350 and BN-600 I think it would be desirable to lower this level but we are not totally excluding the possibility of operating with failed fuel elements. In other words we work to improve the reliability of the fuel elements. However there will always be some final probability even if it's very small but there's always a probability of a fuel failure. So what we're trying to do is to work out a way of operating with defective fuel elements although of course this doesn't give us any particular pleasure and, to repeat myself, we are working towards the reliability factor. That's the main factor - reliability of operation.

6. Discussion of Dr. Balz' Presentation

Dr. Paranjpe: I wish to ask Dr. Balz two questions. One is just a clarification. What is the European unit of account? Can you explain what this unit means? And my second question refers to the ultrasonic thermometer mentioned on page 8 of your presentation. Could you say something more about the basic concept for the ultrasonic thermometer?

Dr. Balz: The European unit of account (EUA) is a mixture of the different currencies of the Member States of the European Communities. One European unit of account is about 1.4 US $ (October 1979).

As concerns the basic concept of the ultrasonic thermometer development, I prefer to provide you some written information. We are foreseeing the application of the ultrasonic thermometer to post accident heat removal experiments for temperature measurements up to the UO_2 melting point.

Dr. Marth: This UNIPEDE report, is this a regular report which is being updated after certain time period again? I mean there was a

UNIPEDE report already five years ago and now you are announcing a new one.

Dr. Balz: The report under preparation is more than the up-dating of the former ones. It is above all an extension, in so far, as particular emphasis was given to an assessment of the influence of different fuel cycle parameters on the LMFBR penetration.

7. Discussion of Dr. Royen's Presentation

Dr. Smith: There is this question of two instances of possible overlaps between meetings sponsored by this group and activities of the OECD. It is important that we don't in fact have any serious overlap. We can take it that you let us know if there are any problems and that you will ensure there is no overlap.

Dr. Royen: This certainly will be. For instance a report mentioned on the first page, "It will start late in 1980". That means that the first draft will certainly not be available before figure after that. Your specialists' meeting may have taken place by that time or you will know better whether you intend to hold it or not but in any case I shall make sure that both groups are informed on this interaction.

8. Discussion of Dr. Smith's Presentation

Dr. Paranjpe: I'd like to ask one question to Dr. Smith. At the time the primary pumps were tripped for the natural circulation experiment, what was the condition of the secondary pumps and the boiler feed pumps?

Dr. Smith: At the time of the trip the secondary pumps were operating and so were the boiler feed pumps. I think what happens on the secondary circuit then is not important. In fact the heat is removed through the emergency decay circuit and not through the secondary circuits. I believe the secondary pumps were tripped but I don't actually have that information immediately in front of me. (In fact the secondary pumps were tripped).

Dr. Marth: Mr. Smith, on page 23 at the bottom you wrote about the possibility of removing pins in the second last paragraph and then you made remarks that you are going to introduce new concepts in fuel design such as grids supports and so on. My question is, did you have any problems in removing high point pins or what are the underlying facts?

Dr. Smith: Well, we have not yet put any of the PFR fuel through this reprocessing plant. We know that if pins swell as they have done in some experimental sub-assemblies, it becomes more difficult to pull them out through grids. Now we think that if these are designed correctly, then despite the swelling of the pins in the grids, the interactions will be such that it will be possible to pull these pins out either one by one or in large groups. It's a question of the time taken to dismantle the sub-assembly. The PFR methods in fact is to pull pins out one by one but this is a somewhat laborious procedure.

Dr. Marth: You are also talking of massive sharing of fuel assemblies with or without wrappers. I wonder because it takes a lot of strength to share large fuel bundles closely packed without taking them out of the wrapper.

Dr. Smith: I think what we're trying to indicate here is that this is one of the areas which is not finally determined. These are the various alternative ways that we are considering as possible methods of getting fuel from the sub-assembly into the dissolution plant. It's one of the difficult areas of fast reactor fuel.

Dr. Tomabechi: You told us that in the past, an experiment has been made to simulate the natural circulation tripping of the reactor at 50 MW (thermal). Is there any further following program to pursue this natural circulation experiment in the future?

Dr. Smith: Yes, there is a program to do this at increasingly large powers. This will be fitted into the program as appropriate and I think the intention is to do a trip from a higher power. I'm not sure what this higher power is. It's either 100 or a 150 MW (thermal).

This next round of tests will be done when there is a convenient time. We don't want to take up much reactor time for these experiments, but we do plan to carry them out and hopefully they will indicate in the end that one can safely trip from a full power with only natural convective cooling. Whether we would actually do deliberately the trip from full power or not, I don't know. It depends on the intermediate experiments.

Dr. Tomabechi: I understand the experimental data you obtained are very much encouraging to continue the experiment. And perhaps you will be in confidence in the near future that the natural circulation will be smoothly established even if the reactor will be shut down at full power. Do I understand it correctly?

Dr. Smith: Yes, we are confident here. There are two issues here. One is whether or not it is possible on PFR. Perhaps more important is whether it is possible to design a CFR in such a way that it would be possible. I believe at the moment that it will be possible to design CFR in that manner. But of course there is a little way to go and we are not at this stage claiming too much. I personally would not like to say positively that it will be possible in case I might be proved wrong. The indications are however very encouraging.

Dr. Rosen: My question is a funding question. I'm not sure you have the answer. I'm interested in knowing what kind of funds are being extended on the DCFR design program and if those funds are included in the 80 Million pounds that you indicated the authority was funding?

Dr. Smith: I think I'm correct in saying that those do not include the money which is directly being spent on the design office which is very small. The total money spent in the UK approaches a hundred million a year.

Dr. Inyutin: I have two questions. Dr. Smith, could you explain what you meant by the term electrical storms. That's on page 6. Second question - what's the reason for limiting the flow in the argon which cools the blanket area? You mentioned that in that paragraph.

Dr. Smith: The electrical storm is thunder and lightning - an electrical lightning strike on the power lines. Now the blockage of this argon circuit - I'm not too sure of that. Speaking from memory I think it's due to sodium oxide that somehow has blocked some circulating pipes.

Dr. Vautrey: Perhaps I could put a very small question. Page 22, Section 7.3 on CDFR. When you talked about burn-up level of 10%, did you mean the maximum burn-up or what did you mean by this?

Dr. Smith: 10% peak, maximum.

9. Discussion of Dr. Rosen's Presentation

Dr. Vautrey: A very small question - I didn't hear quite correctly. I would simply like to have confirmation as regards to the choices made for the CDS study. Could you tell me again for what burn-up the figure is? What burn-up is envisaged and also can you talk about the steam cycle?

Dr. Rosen: It's 80,000 MW days per ton burn-up. I'm not an expert on steam cycles but it's a steam cycle with a low recirculation rate. It's a circulation rate that initially was in the order of 1.5 but during the operation by lowering the recirculation pump speed is a little below 1.1.

Dr. Marth: Dr. Rosen, did I get you right? USDOE requests a certain amount let's say $300 Million and gets more by the Congress? Well, I'm asking because in our country it's the other way around. We always try to request more.

Dr. Rosen: It's usually the other way around in our country also, but the breeder reactor is a unique instance. There have also been other programs that have been somewhat similar. For instance, the gas reactor programme. The Administration has seem fit to cancel the HTGR program for the past two years and the Congress has restored it. The Clinch River breeder reactor was scheduled for phaseout this year but the Congress authorized $172 Million. Our legislative processes require that the Administration budget be reviewed by appropriate congressional committees.

Dr. Smith: On page 4 with your various objectives, you talk about obtaining fuel doubling times of less than 15 years or would this be for a very delayed program? Surely, there's no need for a small doubling time particularly if you start early.

Dr. Rosen: I would agree with you that depending on the nuclear growth low doubling times may not be necessary, certainly not as low as 15 years but when you have sufficient time, a programme to optimize costs is justified. I should mention that the CDS core design will be a heterogeneous core and I say that in the context of a carbide fuel's programme with a low doubling time. When you have sufficient time you can do some of the development work which some of the countries can not afford to undertake.

10. Discussion of Dr. Tomabechi's Presentation

Dr. Smith: Could I ask you whether there are any plans for reprocessing MONJU fuel and where this would be done?

Dr. Tomabechi: We haven't decided as yet formally. Only decision which has been made is we will not have the reprocessing plant at the site of MONJU. So either we will have the reprocessing plant somewhere else other than the site of MONJU or another possibility could be to cooperate with foreign country - to reprocess MONJU fuel. But according to the long-time programme of our Atomic Energy Commission there should be a reprocessing plant to be built in order to reprocess fuels from fast reactor in the future.

Dr. Smith: Have you given any thought to the design of transport flasks for moving spent fuel?

Dr. Tomabechi: We have designed flasks for transporting spent fuel from MONJU. We have conducted drop tests and also fire tests and other tests which are normally required. However, it's under the stage of developing and we haven't fabricated the flasks to be used practically for MONJU as yet. In other words we have fabricated models of the flasks and conducted tests.

Dr. Smith: Could I then just ask about this provisional design? How many sub-assemblies can you carry in a flask and roughly how heavy is the flask? And what coolant do you use?

Dr. Tomabechi: Effort has been made in the past several years in order to develop transport casks of spent fuels of both JOYO and MONJU. However, because of difference in time when such transport casks will be needed major effort in the past has been naturally devoted to the transport casks for JOYO.

Two types of casks have been developed for JOYO. One is a cask for transporting fuel pins of disassembled fuel subassemblies to a reprocessing plant and the other is for transporting subassemblies within the reactor site.

Detailed design of the former has been completed, but no commitment has been yet made to fabricate the cask. A licensing application for the later is being filed to the regulatory authority and it is planned to manufacture the cask during this fiscal year. The cask is capable to contain 8 JOYO subassemblies, cooled by water, and weighs about 30 tons.

Only a conceptual design work has been so far conducted for a transport cask for MONJU fuel. The preliminary study was made on a cask capable of transporting 6 MONJU subassemblies, cooled by Helium. The weight of the cask was estimated to be close to 100 tons. Such study will be continued further in the future.

Dr. Paranjpe: May I ask you one question about your helical coil steam generators? Have you examined the unit which has been taken out for effects like non-uniform temperature along the circumference of the tubes in those parts of the steam generator? That is, a two-phase mixture may be flowing and therefore you may get their separation.

Steam is within one part of the circumference and water is within another part of the circumference.

Dr. Tomabechi: Yes, we have conducted quite thorough inspection on the No. 1 steam generator after dismantling from the testing facility. And as far as I know we have observed no surprising phenomena after having operated during three of four thousand hours under the fast reactor condition.

Dr. Paranjpe: Did all the unit operate over the whole range? That means say from 20% of the rated output to 100% of the rated output with corresponding conditions of sodium temperature on the sodium side?

Dr. Tomabechi: Yes, we have a test facility which is called the 50 MW steam generator test facility. This facility can simulate most of the parameters of secondary circuit and water circuit of MONJU plant. The steam generator we mantled on this test facility is called the 50 MW steam generator No. 1. It had tube bundles with full size of that design for MONJU. However, number of the tubes was smaller because the total capacity is only 50 MW and the steam generator we are designing for MONJU is over 200 MW . We have operated this steam generator something from 15% to 100 % bearing the power of the steam generator.

Dr. Marth: I should like to congratulate you on your fast power rise with JOYO reactor. Really very quick. Let me ask you a question on this negative bowing coefficient. The reason seems not yet to be clear but is it of a major relevance for the safety or for the licensing area? How do the licensing people look at it?

Dr. Tomabechi: The total loss of reactivity observed is anyway much less than $1. Even if we have the sudden reactivity packed into the core it may cost only 10 or 15% in jump of the power.