PANEL DISCUSSION – SUMMARY
Perspectives for the future development of P&T

Chairs: T. Mukaiyama (JAIF, Japan) and J. Laidler (ANL, USA)

Panelists:

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Each panellist made a presentation on perspectives for the future development of P&T. These presentation were followed by a general discussion involving all participants. Summaries of the presentations made by the panellists and highlights of the open discussion are given below.

Presentations of the panellists

Dr. T. Osugi (JNC, Japan)

First of all, I would like to emphasise the needs for international collaboration in the development of P&T systems. If we look at the long-term programme for P&T, using ADS, we mainly have to consider three fields of P&T. They are partitioning, fuel technology, and ADS technology. For partitioning, improvements in processes will be realised by 2010, and an engineering scale development will be pursued for a pilot plant construction in between 2020 and 2030. Concerning the fuel technology, fabrication tests of minor actinide (MA) nitride fuels and irradiation tests in reactors will be performed before constructing a pilot plant. At the same time, the ADS technology, including sub-critical system, spallation target and accelerator issues, will be developed and improved.

The development of ADS technology, we can be divided into three steps. The first step is being performed on a voluntary bases, using existing facilities, such as FCA, MUSE-4, MEGAPIE, and TRADE. The second step is to undertake experiments, using unique facilities, dedicated to ADS. They could include TEF-P, TEP-T, Myrrha or other future facilities that can also be used for fuel irradiation tests for ADS. These experiments are needed to realise the ADS, especially for the construction of a demonstration ADS. The final step will be the construction of a proto-type ADS plant. I do not yet know exactly what it would look like. For all that, I would like to propose a kind of "**Mailing Network System**" to exchange information of the facility specifications and to discuss ideas for the design of the next facilities. I think we really need a mailing network system as a first step to a close international collaboration for a prototype ADS plant. And time is now!! Thank you very much.

Dr. C-K. Park (KAERI, Korea)

Let me begin with reviewing the last ten years of P&T studies and what we have achieved during this period. As you may know, since I'm not directly technically involved in this area, this is what I believe you have been doing.

Please understand that this is my personal view. There are two roadmaps – one US and one EU. I think it is very important to know where you are going and what obstacles you would expect on the way. Another significant achievement, I think, is the OECD/NEA report "A Comparative Study on ADS and Fast Reactors in Advanced Nuclear Fuel Cycles". Through these efforts, there seems to be **some technical convergence on the reactor types, fuel and corresponding coolants**. You would like to have a dedicated burner with fast neutron spectrum, instead of utilising existing LWR's or liquid metal reactors for the transmutation. As a coolant, you may have lead-alloy or sodium. There are three fuel types – metal, nitride and oxide. You would like to have a pyro-process as a main recycling scheme with aqueous processes as a backup.

On the other hand, let me briefly mention the international collaboration programmes. The international programmes, I believe, have been component based rather than system based. And the co-operations were between institutions and between programmes, rather than between countries. They have occurred on a very regional basis.

Now, what are you going to do for the future? The environment has changed. So far, studies on P&T are based on a fuel cycle strategy where LWR is the major reactor type, but this will probably not be the case in the future. There are multinational multilateral nuclear system development initiatives for the next generation recators. As you know, there is the Generation IV initiative led by ten countries and the INPRO initiative led by the IAEA. I have to emphasise here that **these efforts are for new nuclear systems, including both reactor and the fuel cycle, rather than just the reactor development**. As you may know, the Generation IV programme is aiming at around 2030 for initial deployment. There are six Generation IV candidates with strong emphasis on sustainability, safety, economy and proliferation resistance and physical protection. I believe the R&D scope for these candidate systems will soon be available. Many technologies that we have been developing in this area are overlapping with these future reactor systems, especially the sodium or lead alloy fast reactors. The Generation IV and INPRO programmes are based on **government-level agreements**. With these environmental changes in mind, I would like to conclude my comments by the following two points. First, we have to look very carefully at the roles of P&T systems once again and decide when we are going to need them, and second, how we are going to achieve our goal in the framework of either Generation IV or INPRO. For both points, the two roadmaps that I already mentioned would be a big help. Thank you.

Dr. J. Laidler (ANL, USA)

I am going to emphasise the fuel cycle issues and I hope to stimulate some responses with some of the proposals that I will present.

In future developments, related to the fuel cycle, I propose that we address in some detail the **development of fabrication methods for minor actinide bearing fuels**. I think you will probably realise, if you look into it, that we just don't have a reasonable process at the moment for fabricating those fuels in a way that reduces the amount of waste generation or losses of material.

We need to operate at low sintering temperatures, perhaps by using cermet fuels produced by the infiltration methods that you've heard of. We can perhaps use external gelation processes to fabricate the fuel particles and I would also submit that we maybe should look at cermet fuels that are dispersions of oxide in metal. We should in addition consider the innovative fabrication techniques, such as vibratory compaction (VIPAC) processes and perhaps other more advanced techniques. I think the conventional present sintered pellet fuel fabrication method is not going to be economical, if we are dealing with minor actinides that are very high heat generators and create high radiation levels, especially after multiple recycling.

We need to look at the issue of whether it is necessary to separate americium from curium, for the purpose of storing curium for a period of decades to avoid the complications that it presents in fabrication.

In addition, I repeat the plea that I present virtually at every one of these meetings and that is: we absolutely need **a consensus set of international criteria** on what sort of parameters should to be imposed upon the separation processes, upon the fabrication processes, as far as purity of products, as far as recovery efficiencies, as far as losses of waste are concerned. We've tried to do this within various international bodies. The US programme now, the Advanced Fuel Cycle Programme, is beginning to develop its own set of criteria and we certainly would like to get some international participation. We also need to look at the feasibility of inserting minor actinide targets in a heterogeneous way in fast reactor systems. Is this a feasible approach?

I also submit that it's necessary to establish **a role for pyrochemical separations**. As one who has been involved in pyrochemical separations work almost from the beginning, I must say that it is misinterpreted as the answer to all of our dreams. It is not necessarily that. It may be very appropriate in certain applications and very inappropriate in other applications, and if we persist in trying to oversell this technology, then I think we'll find that we create more problems for ourselves than we create solutions. Pyrochemical separations are probably well advised for metal fuels and probably for nitride fuels. They may be useful for coated particle fuels and for inert matrix oxide fuels, if the matrix happens to be a material that's difficult to dissolve in nitric acid.

I think we should look at **processes such as UNEX**, single processes, which do a complex separation. This is one of them. There are other possibilities, but we need to look at efficient systems for separating actinides, lanthanides, cesium and strontium and other fission products.

Further, we should be open to the **development of hybrid systems, which are combinations of aqueous and non aqueous systems** to exploit the best features of each one of those methods and maybe a different combination for different fuel systems, but we have to facilitate among other things the removal and separation of the minor actinides from the lanthanides.

Finally, we need to be very sensitive to the **economics of the systems**. We cannot afford to have somebody make an unwise decision as far as the deployment of a process, which proves to be totally uneconomical, because this is a very small world and if one of us makes a stupid decision, it is going to impact everybody.

Dr. D. Hill (ORNL, USA)

I'm afraid this is going to sound like a conspiracy. In common with Dr. Park, I have to advise you that this is a personal view.

I spend a lot of time talking to members of the US government trying to convince them that they need to make investments in what I'll call fuel cycle R&D, as opposed to partitioning and transmutation. The question on my mind is "**Is there a viable alternative to long-term storage of spent fuel and/or minor actinides**?" But if you're a government official, that is part of a larger question. The larger question, which they're wrestling with today, is "what is the role of nuclear power and nuclear energy in the future energy supply". We, in the R&D community and in DOE as well, have evolved two initially separate but converging approaches. First, to understand the future role of nuclear energy, we asked what are the nuclear systems for the future? Criteria were set up and an international study was done (commonly known as Generation IV). The second question is: what can we do with spent fuel today? The role of partitioning and transmutation, to help Yucca Mountain utilisation, has become a key question in the current incarnation of advanced fuel cycle issues.

The comment to be emphasised here is, as best as I can remember, quoted directly to me by a senior member of the administration, who tried to explain why he should not be investing the government money in partitioning and transmutation. He said, “We don’t have a fuel cycle problem, we have a reactor problem. We are not building reactors in the US”. With the current reactors I can guarantee you that with Yucca Mountain, with some modest expansion, I can store the spent fuel. I don’t have a fuel cycle problem.

Now, in my first viewgraph I emphasise the word viability. I’m going to just replay a couple of things you’ve heard from Dr. Jim Laidler. We need, as a community, **solid performance criteria**. When I go in and talk to a government official, he would say, what are you going to do? How much will it cost? How much R&D? And even if you are successful, how will it be implemented? When will R&D give me an answer? The US government is sceptical about the value of fuel cycle R&D. It won’t stay convinced unless clear priorities are chosen, together with time scales. I don’t like to depress you but this is what it looks like trying to generate a programme for what is a crucial question. Remember the question is really, in one form or another, what is the long-term future of nuclear power? The key to answering that question, as I think everybody is aware, lies in technologies for fuels and separations. The US programme is formulated for the coming year in two main areas. One, which is asking the question what can you do with the 100 or so PWRs in the US. They are going to be around for a long time and they are almost all going to have life extension. Is there anything rational you can do with thermal neutrons? And the second part of the programme is cast in the Generation IV context. It’s making the link explicitly that Dr. Park alluded to. The other part of what we call the advanced fuel cycle initiative is being closely coupled now with the Generation IV programme.

Now, as Dr. Laidler said, we are a small community, we are small especially in the size of budget related to the magnitude of the problem. So, **we have to prioritise**. Now, the US will prioritise on its basis of what’s important to the US, other countries will prioritise differently. Another issue important in the US is **practicality** – how do you imagine transmutation being implemented in the deregulated energy market. You burn an actinide, it generates power. The government in the US is not in the business of selling power. So how do you implement? What are the financial and economic incentive structures you set in place to get this to operate?

The state of the art, as described this week, is that we have more questions than answers. Almost every type of concept is still under consideration somewhere, and I agree completely with Dr. Park – **international co-operation, not at the micro scale, but at the macro scale is essential**. This is the only way we are really going to make progress – before, frankly, governments lose enthusiasm. I’ve never met a government yet that’s willing to promote R&D with no particular outcome for an indefinite period.

Dr. P. Wydler (Switzerland)

agrees that, **in the future, the available R&D funds will have to be concentrated more effectively on the most promising concepts.** He would also like to draw the attention of the audience to the respective conclusions of the recently published NEA study “Accelerator-driven Systems (ADS) and Fast Reactors (FR) in Advanced Nuclear Fuel Cycles – A Comparative Study”. This study assessed the technological challenges of P&T in general and the ADS in particular, and it prioritised the needed R&D with respect to a representative set of fuel cycle strategies.

The table below summarises the R&D priorities for three transmutation strategies using fully closed fuel cycles. The strategies comprise the burning of the transuranic elements discharged from LWRs in IFR-type fast reactors (TRU burning in FR), the fast-spectrum accelerator-driven systems (TRU burning in ADS), and the Double Strata strategy initially proposed by Japan.

R&D area		**TRU burning in FR**	**TRU burning in ADS**	**Double strata**
Reactor	Accelerator		++	++
	Target		+++	+++
	Sub-critical core		+	+
Reprocessing	Urex for LWR-UOX	+	+	
	Purex for FR-MOX			+
	Pyro	+	++	+++
Fuel fabrication and testing	Oxide			+
	Nitride			+++
	Metal	++	+++	
Waste management	New waste forms	++	++	++
	Repository performance	++	++	+

Priority: + medium; ++ high; +++ very high

In the executive summary of the NEA report, the R&D needs are summarised as follows:

- *For the advanced systems in general:*
  Basic R&D in the fields of neutronics, liquid metals (mainly Pb/Pb-Bi), structural materials, fuels, and their reprocessing with emphasis on pyrochemistry.

- *For the ADS:*
  R&D on high power accelerators, spallation targets, neutronic behaviour of sub-critical systems, and safety analysis.
  - Demonstration at appropriate scale of fuels with high contents of minor actinides, involving fabrication, irradiation, and reprocessing of the fuels (requires fast-spectrum irradiation facilities).
  - Improvement of models for the simulation of materials behaviour under unusual load, irradiation and temperature conditions.
  - Comparative assessment of the advantages and disadvantages of alternative coolants for fast-spectrum systems.
  - Performance assessment of geological repositories using a P&T source term.

Dr. J. Knebel (FZK, Germany)

I think that it is a difficult and challenging job to combine national programmes, national ideas or industrial ideas into a big international issue that is, in the end, an operating transmutation machine. And when I look to Europe, we have the transmutation roadmap and within the European Community we have the ADOPT network. ADOPT combines different tasks looking at design, partitioning, fuel, nuclear data and fundamental support. In the task of fundamental support, we have to look into critical issues of materials and thermo-hydraulics and develop applicable solutions. Today, each of the already operating national laboratories looks at a certain small issue, but there should be a much better collaboration between laboratories and more exchange of scientists should be practised.

A good example of such a collaboration is the MEGAPIE Initiative, which aims at operating a heavy liquid metal spallation target at Paul Scherrer Institute (PSI), Switzerland. MEGAPIE has 1 MW of proton beam power, so that there is still a long way to go to prototypical conditions. In order to perform the scaling up, I would propose a centre of excellence to concentrate on single-effect and integral experiments that are larger in scale.

Therefore, for the successful future development of fundamental support work, my point is the following: we do need **a world-wide co-ordination and work plan of the analytical/ experimental/numerical activities in the fields of heavy liquid metal technologies, thermo-hydraulics and corrosion studies**. Right now, each association tries to do developments of their own, kind of hiding the latest know-how from others, and not combining the best solutions. However, in this politically difficult situation, we – scientists – have to join together and form a homogeneous community. This means: **Collaboration instead of competition!**

Dr. T. Mukaiyama (JAIF, Japan)

The first topic I would like mention is **nuclear data**, especially the nuclear data needs for designing a dedicated system for transmutation. The definition of a dedicated system is that a major fraction of the fuel comprises minor actinides, say around 50 or 60 percent of the fuel material is composed of minor actinides. In this case we need reliable neutron cross-section. But at the moment, as far as conceptual designing is concerned, these cross-section or data libraries are not adequate. We need, for example, much more reliable (n, 2n) cross-section, especially for hard neutron spectrum systems.

When we go further to the detailed designing of a dedicated system, we need a much more reliable data libraries and maybe similar levels of reliability of uranium and plutonium isotopes. Beyond that, we have very sparse measured data of minor actinides, fission yields and delayed neutron data, such as delayed neutron fractions and delayed neutron energy spectra. As far as I know, the majority of minor actinide cross-section activities are devoted to the field of evaluation and library development, based on a limited number of measured data or on theoretically predicted values, because measured data are non-existing. Handling of minor actinide samples for measurements is extremely difficult, but we need real measured data for a reliable system design. We need more work in the field of cross-section.

Now for the **partitioning and separation**, we have seen many processes presented at this meeting and in the past. Outside of these specialities, I wonder how far the chemists want to continue their scientific research. I believe we now need a scale-up for the engineering feasibility and with that we can also get some idea of what would be the radioactive waste from these partitioning and separation processes. The question is then how far chemists can continue their science; this means that at some time **we have to go from science to engineering**.

For the **development of fuel**, we need irradiation experiments. The problem we are facing now is that there is only a very limited number of reactors available for such experiments.

Now, the big issue for P&T is how to manage the **post transmutation waste**. P&T waste management is a key issue for discussing the merits of P&T. Merits and justification of P&T is not clear until P&T waste management methods are clearly understood. So far, most activities on P&T concentrate only on the front-end of P&T; front-end meaning partitioning and transmutation. Concerning the back-end of

P&T, i.e., treatment of post transmutation waste, only limited activities are going on. Even after P&T, final disposal is needed for most short-lived nuclides, and you should remember that around 85% of the fission products from minor actinides are stable. And the waste from P&T is quite different from the waste before P&T. The waste after P&T consists of a significant reduction of long-lived fission products and minor actinides. So present evaluations of the P&T effect comes from the geological community, based on its own scenario and using the current design of a final repository and the performance evaluation methods. However, the final disposal of P&T waste may need a different geological repository design than current designs, because this waste contains mostly short-lived nuclides; and for this waste, what kind of waste repositories are needed? Will solidification be needed? If so, is vitrification the only solution or not; and even in the case of vitirification, what is the concentration limit for most short-lived nuclides in a waste form? In addition, how should one dispose of solidified waste? For instance, placing them in a regular grid or dumping into a silo? However, these considerations may not be for the first repository, in order not to interfere with the existing final disposal policy. Once management of P&T waste is clearly understood, it can provide feedback to the design of P&T scenarios. In some cases, only partitioning will be needed. If Sr/Cs are separated for heat source removal, the concentration of the other materials in vitrified waste will be much higher. And also, the separation of Sr, Cs, Mo and stable fission product elements will reduce the waste volume up to 10 times. This was presented by Dr. Takaki of JNC in his presentation at this meeting.

So, in some scenarios, only partitioning will be sufficient. When further reduction of long-lived nuclide and Pu inventory is sought, transmutation is definitely needed. So in this case **when the management of P&T waste is really understood, then we can discuss how to optimise P&T.** Currently, the designers of P&T systems are proposing very high P&T efficiency, up to 99.9% or higher. Do we need such a high efficiency? Critical or sub-critical, power reactor or dedicated system? Thermal spectrum or fast spectrum? Once-through or multi-recycle?

The discussion should be based on the management of P&T waste. For this waste management form, **we need involvement of the geological community for developing transmutation waste management concepts**. This is inevitable. Around three years ago, the IAEA organised an international conference on the safety of waste management with around 300 participants, and 99.9% of the participants were from the waste management community. I was the only panellist from the P&T community, and in these circumstances, I felt as if being an alien amongst nuclear waste management community people. From the viewpoint of the geological community, P&T is still not a desirable approach. But in the further discussion on P&T, we have to invite the geological disposal community. **From the general viewpoint of nuclear waste management, the time may soon come when the geological disposal community will have to discuss how to avoid the necessity of a second or third repository.** In this context, the geological disposal community should seriously think about P&T.

Finally, I note that we have already lots of international collaborations. But **we need a kind of burden sharing collaboration** such as the MEGAPIE and MUSE initiatives; especially for information exchange or concept discussion. All such initiatives need big facilities. Currently, the nuclear community is facing inadequate resources for R&D. P&T is just a waste management issue and not a power generation issue. It is quite different from activities such as fast breeder reactor development, because the latter was a kind of competition and **waste management is a common issue among the nuclear countries**. So burden sharing and international collaborations are becoming much more important. One of these examples is the ITER-type co-operation in fusion development. This may be preferable also in the area of P&T.

Summary from the general discussion

Nuclear data issues

D. Hill (ORNL, USA)

The nuclear data issue is a case where co-operation at a lower level can be extremely valuable. Generation of data and subsequent evaluations will proceed world-wide; the data are being developed and we will all benefit from continuing **expansion of the co-operation**.

IPPE, Russian Federation

The problem of neutron data for an accelerator-driven system is very similar to that for new types of fast reactors, because both systems are similar. When we speak about neutron data for advanced sub-critical systems with minor actinides, new types of coolant and new types of other materials, we need to employ the design practices use for new fast reactors. **Integral experiments are a very essential part of this programme**. And our experience from the design of fast reactors showed that by using integral experiments it is possible **to reduce uncertainties in neutron data** to levels that are suitable for real engineering design. At IPPE, experiments are planed that will give us new information about minor actinides and various neutron data together with neutron data for lead bismuth and other materials. Any international co-operation in addition to specialists from France, Japan, and USA are welcome.

E. Gonzalez (CIEMAT, Spain)

We have seen that very valuable data from integral experiments are coming from Russian installations. We should not miss the opportunity to learn from these data for the new concepts like BREST or other reactors being developed, and also for the transmutation devices being developed.

We should try to find a way in which these data are combined with new data coming from differential measurements sponsored by the European Union and from other international co-operation frameworks. **All these data should be brought together and introduced into reactor physics simulation and prediction methods within an international framework** for example the NEA or the IAEA. Then we will make a breakthrough in nuclear data for minor actinides and transmutation systems.

Separations issues

J. Laidler (ANL, USA)

It is absolutely essential for us to **move to a scale** at which we can convincingly prove to decision making people that the processes that we have are indeed **economically and technically viable**. In the US programme we are proceeding with a very large scale demonstration of separation processes, both aqueous and non-aqueous to be completed by 2007, and these are demonstrations that are 1/20 of production scale, which is significant and is adequate to answer questions concerning the economical feasibility as well as the technical feasibility, and also give some information on waste generation and ability to meet specifications to criteria. It’s absolutely essential. The other point is that we absolutely need **co-ordination on an international scale**.

S. Tachimori (JAERI, Japan)

Reprocessing always involves high cost. An economical model should be developed. However, some more time would be needed before going to the engineering scale. **The aqueous process is a proven technology and pyrochemistry is a future technology. What to do in the future would depend on the situation in each country.**

J-P. Glatz (ITU, Germany)

Aqueous- and pyro-techniques should not be in competition with each other, because both of them have their position in the partitioning and transmutation strategy.

Regarding **the scaling up**, aqueous-techniques are more advanced and much more developed than pyro-techniques, so the step forward, in view of technical applications, is also more advanced. For pyro-techniques, we are at the stage now that we cannot really go to an industrial scale although in this conference we have seen that there are some parts of the process which are already developed on a larger scale.

There is no T without P. We should try to have a closer collaboration between those people who develop, for instance, the fuels or targets for the transmutation processes. It is very important that from the beginning, when we develop a new fuel, that immediately we think about the techniques we can apply for the partitioning, because only if those two aspects work closely together, then we can come to a good result.

J. Laidler (ANL, USA)

With regard to the concept of separating cesium and strontium for the purpose of reducing the heat load in the repository, is this a worthwhile step to incorporate in our processes or is it not cost-effective?

N. Takaki (JNC, Japan)

JNC has evaluated the effects of removing cesium and strontium from high-level liquid waste, and the results show that we can obtain **some benefit in form of a reduced waste volume and thus the size of the repository**. We are not sure **whether the benefit compensates the cost increase** by introducing new separation process.

J. Laidler (ANL, USA)

In the USA, we have done a similar study and found that **by removing the actinides** – all of the actinides including the uranium, technetium, iodine and Cs/Sr – **we increase the repository capacity by a factor of forty**. This means, in case of the Yucca Mountain repository capacity, that it then becomes the single repository for the entire nuclear era for even hundreds of years, if we operate for hundreds of years. **The issue is how we store this Cs/Sr.** Presently we are considering storing it on the surface for a period of 300 years until it has decayed. The issue is that it is a significant heat source that we have to deal with. We are looking at various options.

Fuel development issues

S. Pillon (CEA, France)

We need to focus all our activities on only one or two of the most promising candidates, because the fuel development activities demand a lot of time and people. The problem is also due to the reactors. We have a limited number of reactors for irradiation testing and not enough space in the reactor. For example, the PHENIX reactor is now fully booked for irradiation tests and we have to select and limit the number of fuels to test as much as possible.

H. Aït Abderrahim (SCK-CEN, Belgium)

The situation in the USA and in Europe is different. The USA has Yucca Mountain, but in Europe, we do not have anything similar. Moreover, European countries have very dense populations and they have different waste management policies. **P&T is absolutely needed in Europe.**

Merit of P&T, Waste after P&T, Collaboration with the waste management community, and International collaborations

T. Mukaiyama (JAIF, Japan)

We can discuss the further merit or the necessity of P&T only after waste form after P&T or a way of disposal becomes clear.

J-H. Ahn (UCB, USA)

Ten years ago, I think partitioning and transmutation was regarded as kind of a competitor to geological disposal. But now I think people don't think that way any more. It's part of more larger system of the nuclear power and I think that it should be that way. Still, I think that there is some kind of mis-communication or misunderstanding between the two communities. I have been thinking what was the reason or reasons for such mis-communication, and recently I came up with one idea and that is probably because the measures of geological repository performance we use in the geological community and you use in this community are quite different.

The radiological toxicity curve is decreasing with time and crossed by uranium toxicity. If you use that curve and show that to the geological repository community that means that you don't want to communicate with them because that does not include the geological repository performance at all, as that radiological hazard is the potential hazard of the spent fuel or the waste from the P&T before the disposal. If you would like to communicate with the geological community properly, you need to include that. On the other hand, we have also problems – one of the problems was that we did not have a proper model for the performance assessment of the geological repository. Let me show some examples. Usually we model the repository as a collection of many individual canisters, and we usually model a single canister first and then multiple that results by say *n* canisters. So we did not see the effect of mass reduction properly and in addition to that, in the repository performance assessment, we usually use the radio exposure dose rate as the performance measure. As you may know, the radiological exposure dose is based on the concentration of radionuclides in the ground water basically, whereas in this community most efforts have been devoted to decreasing the mass of the radionuclides in the waste. There is a big discrepancy or gap in the terms of the model development between the reduction of the mass and the effect of the radiological hazard in the downstream 20 km from the repository. There have been no good models so far, and I think that was one of the reasons why we couldn't communicate with each other very well. So I think the keen and urgent issue is to develop a good measure – actually we need multiple measures to view the repository performance and some of them should be based on the mass of the radionuclides, which should be disposed of in the repository, and some should be based on the concentration. For example, the heat generation is heavily dependent on the mass and concentration of the radionuclides in the waste form, but so far we have been looking at the radionuclide concentration in the ground water only. That's I think the major discrepancy. **We could develop good measures for the repository performance which could join or connect the effect or efforts of the partitioning and transmutation studies.**

If we were to continue with our nuclear energy for a long period of time, we need to expand the repository capacity and I heard many times in this conference that the repository capacity should be expanded, and more waste should be accepted by a repository. If we have more waste, the impact should be increased, but this will probably not be allowed by the public in the future. We need to go to more waste but less impact in the repository or from the repository. And for that, we have fortunately three kinds of technology. One is P&T. This is the most important part of the technology. In addition, we can do something by changing the repository design and the layout, and we can also redesign the pre-closure scheme like interim storage or separation of Cs/Sr and store that for a long time. By the combination of these technologies, we can improve the waste characteristics and improve the material and space utilisation in the repository. And I think this is the desired future – I call it the new regime and we need to move on from the nuclear legacy now to the new nuclear regime, which has much less impact on the repositories, with help of P&T technology and other repository technologies.

E. Gonzalez (CIEMAT, Spain)

I would like to add some comments on this topic. One thing, at least for me, that looks curious in this meeting is the **absence of the bodies responsible for waste management**. I'm not so aware of the situation in Japan and in the United States, but in the case of the European countries, this is quite a common. But I think **we should involve them in the discussions, which will force in a way the closer discussion of the communities related to the repository and the community that is looking on the waste production part of the nuclear cycle.** On the other hand, the very last final conclusion of the NEA report on fast reactors and ADS was that before you reflect on whether it is worth or not to do P&T, **we have to evaluate the impact on the final waste repository.**

V. Bhatnagar (EC)

On behalf of the European Commission, we have been thinking about these problems and the reality of the communication gap between the P&T community and the geological disposal community, and also the waste management agencies. In this respect a future programme that we are preparing now is looking towards the proposals in the cross-cutting regimes meaning that people of both communities should be involved. Some proposals that will study the impact of P&T on realistic geological disposal should be suggested. So I think that there is a need for more communication and possibly common meetings in which both communities are present and then they can understand and maybe then they will see the importance of P&T. So I think **we have to work together and we should not see these two communities as competing with each other but rather working together and I think that will help the situation.**

A. Stanculescu (IAEA)

As you know, we try to set up co-ordinated research projects around the technical scientific issues that are of interest to our member states. The important thing is that we include developed/developing countries. A co-ordinated research project has to be shared amongst all participants and they have to agree to commit themselves to resources, which then have to be shared in the member states in order to achieve these results, which have to be shared by everybody. On the first day, I mentioned that we are planning **a co-ordinated research project benchmark exercise on P&T ADS technology based on experiments**, not an analytical exercise but experiment related.

Now, I would also like to make a few comments, the first one is related to what Dr. Osugi said. He was proposing a network. Well, again in my presentation on Monday, I presented the **ADS research and development database,** which is something that could be one of the mechanisms for this network and I would also strongly encourage people to solicit input to this database. It is a working instrument on the Internet. It is open to everybody. You need a password, you need login information, but you just have to request it. Everybody can get it and provide data.

Now the last comment I wanted to make is related to what Dr. Mukaiyama said and his suggestion to include the geological community. I agree, but I don't necessarily see a problem. I mean what the geological community will tell us is how to translate risk into hazard. First of all, I'm not sure that the public opinion, that you have on your viewgraph on top, does care if it is hazard or risk. If we think that they don't care, we have to ask ourselves – do we want to spend the money to make the case that we reduce not only the hazard but also the risk. I want to stress that **we have to involve the geological community, but we have to involve the people who have the spent fuel.** They have to tell us who is responsible and who has to manage the spent fuel and I guess in many cases it's the government, but it's also the utilities.

T. Mukaiyama (JAIF, Japan)

If we can find another way of waste form production and another means for placement of waste in a repository site, then the current design of the repository will be much different after P&T. So I should say **the performance of P&T should be evaluated based on the advanced waste form concepts**, and not based on the evaluation of the current design of repositories. So we should develop some kind of a better waste form for most short-lived and long-lived nuclides.

Concluding remarks from the panel discussion chairmen

J. Laidler

I'm afraid the time is drawing late and we must come to a close. I want to thank you for your participation. It is very important to have a free and open expression of opinions and in a forum like this, there are not unacceptable opinions. It is important for everyone to express themselves and I thank you for doing that. So let's bring this session to a close; there are some further remarks from the chairman.

T. Mukaiyama

Thank you. You know Jeju is a place where the honeymooners come. This is a place where we think about the next generation, we have a very nice place for discussing the future. This is my final message. Thank you very much for participation.

Closing remarks

David Hill (ORNL, USA)

It falls on me to wrap up this information exchange meeting. This is the 7th meeting. I would like to add my personal thanks to Dr. Takehiko Mukaiyama, to Dr. Massimo Salvatores for the work that initiated this series of meetings and really rekindled interest in this subject again. They achieved something which is great, and it is up to us now, the community working in partitioning and transmutation and in the fuel cycle more general, to carry that forward.

I would also like to compliment the NEA as an organisation. It has sponsored seven of these meetings, it has supported the working party on partitioning and transmutation and other working parties which deal with related issues, and that has also been important. To the NEA, that abstract entity, I think we all owe a debt of thanks.

I support something Jim Laidler said – open debate and free debate is important. That's why we come to these meetings, more so in fact than just to listen to papers. I was very encouraged by the debate over the last couple of hours. There's a divergence of views based on, really, a divergence of national circumstances, but I think some themes came through. We always need to be questioning the assumptions behind what we do and making sure that we are answering the right questions. The community is small; the level of investment compared to the scale of the problem is small, which means that international co-operation at every level is mandatory.

Much has been done. That's obvious. You have seen the papers here this week. But there's still a lot to do. I noticed two, three or four times in different presentations and in poster sessions, that people emphasised the importance of what they are doing is providing the motivating force for drawing young people. We need viable motivated projects that will draw in the motivated students that will become the future of this programme. That was very pleasing for me personally and again I think it's a credit to all of you.

I thanked the NEA as an abstract entity and I need on behalf of you all to thank the organisers of this meeting, starting with the general co-chairs, who are Luis Echavarri, the Director General of NEA, and Chung-Won Cho, the Director General for Nuclear Energy of MOST, the organising chair, Chang-Kue Park, the Senior Vice President of KAERI, and I also thank the scientific chair of this meeting, Phillip Finck from Argonne, who put in all the work and unfortunately, at the last minute, was unable to attend, and the scientific advisory committee – I won't name all of you - you know who you are but everybody who contributes to reviewing and assessing papers, adds their little bit to the community.

I think that this meeting has been impeccably organised. What I want to add is the genius of the person who chose this spot, such a beautiful spot to have a meeting.

This was an information exchange held every two years. The next information exchange meeting, the 8th, has provisionally been decided to be held in Las Vegas, USA, approximately this time of year, two years ahead. The dates are not chosen. The University of Nevada, Las Vegas, is intimately involved in partitioning and transmutation studies. The Senate of Nevada has a keen interest in this subject. So I think that we can be sure of a welcome there and Dr. Laidler, my colleague from Argonne, will be acting as chair of that meeting. We'll get information out as soon as appropriate. Finally, I would just like to thank all my colleagues here on the panel, but mostly all of you for coming here, for participating in what has been an outstanding meeting. I hereby declare this meeting closed, and I will see you in Las Vegas.