SESSION 6: DISCUSSION SESSION

CHAIRMAN: M. SALVATORES (FRANCE)

Introduction by the Chairman

Without attempting a "summary of summaries", it is worthwhile to stress the fact that real progress has been achieved in three fields:

- chemistry of separation (see the summary of Dr. Baetslé);
- first cost figures have been announced for a P&T scenario in the frame of the EU strategic study;
- experimental irradiation of actinide-based fuels and targets has been launched in the frame of national or collaborative programmes.

The value of the information exchange meetings has been confirmed. However, in future meetings, one can look for a better focus on the main topics of P&T. Reports from other related working groups could be envisaged.

As far as system studies are concerned, the indications of this meeting can suggest an intercomparison between a P&T strategy based on "expanded" standard reactor/fuel cycle technology (as in the European Union study) and a P&T strategy based on the "double strata" proposed in the paper of Dr. Mukaiyama. Moreover, it would be worthwhile to consider the impact on system studies of the methods to account for secondary wastes from partitioning. It would also be relevant to address the impact the intercomparison (as done at TUI-Karlsruhe) of different extraction processes.

MAJOR PROGRAMMES AND INTERNATIONAL CO-OPERATION
Chairman: G.H. Stevens

Noted the report on new activities of the Nuclear Science Committee. Pleased that ways were found to have complementary work at the IAEA. The variety at of work under the European Community reported by M. Hugon was impressive.

This session displayed both major programmes and international activity. Japan is pursuing P&T as an integral part of their radioactive waste management research programme. The whole nuclear, and indeed, energy policy is being seen against a very different geopolitical background but the nuclear programme shows great consistency of aim. Within the P&T programme there is emphasis on basic technology, including beam technology, the being, apparently, of greater commitment to accelerator-driven fuel assemblies than is evident in most of Europe.

Referring to the paper by Salvatores and Viala, he noted the 15-year legally established basis for the French R&D programme. The paper pointed to the different foci for research presented by wastes buried in varying conditions. Attention was drawn to the need to consider all the daughter products of the radioisotopes that were finally disposed of, to take account of all secondary wastes, and to give due weight to off-normal or accident conditions. He agreed with the observation that it was too early to draw general conclusions. His main impression was that the main objective remains to remove plutonium from the biosphere but that it is worth continuing to look at the benefit of adding

other radioisotopes to the list to be removed. He noted the suggestion that accelerators have no advantages over reactors for transmuting actinides but may have with regard to fission products.

Dr. Kiselev presented the case for using "electro-nuclear facilities" to transmute actinides and other waste radioisotopes, and drew attention to the wide range of Russian research institutes that were engaged in studies on them. The existence of this body of knowledge could be useful in setting out future directions for international co-operation. A number of modes of operation of ENFs were outlined, including the use of fuels in liquid form for which technology would still need to be developed. MINATOM was said to consider fast reactors as the primary means for actinide burning with accelerators as a back-up technology. They were also capable of increasing the usable energy resource base in bringing plutonium and thorium into play.

Dr. Salvatores had indicated an impressive coherence of views about goals when presenting the joint paper by CEA and PNC. This closeness of view boded well for the future of collaboration.

The presentation by EFFTRA had shown that great progress had been made in setting up a collaboration with an impressive programme, making use of a variety of European reactors in appropriate ways. The spirit of compromise and co-operation was itself a lesson for all participants in P&T activities.

SYSTEMS STUDIES
Chairman: J. Lefèvre

Noted that system studies form, at the present state of P&T, the main focus of the meeting.

What is it possible to make, what limits are we capable to reach, what are the best routes to follow and at what financial and safety costs are we able to achieve P&T goals? These are the principal questions that need to be considered, even if they cannot be answered completely at this moment.

During this session, six presentations were made. Unfortunately, maybe because the term "system studies" was not sufficiently precised, only three of the presentations were really centered on the subject.

CEC study

Different strategies were considered:

- reference case: without reprocessing (R1).
- two scenarios with reprocessing (losses 0.3% U and 0.5% Pu) and reactor park burning UO_2 and MOX fuel (R2) and another reactor park including fast reactors (R3).

These scenarios without minor actinides (MA) separation and transmutation were compared with the following scenarios including MA partitioning and transmutation.

- RP1-1 compared to the R2 scenario, characterised essentially by transmutation in PWR for Np and Am with losses at recycling of O.3% U, O.5% Pu, 5% Np and Am and 100% Cm.
- RP1-2 compared to the R3 scenario, characterised essentially by transmutation in fast reactor with the same losses for MA.

At least the RP2 scenario take into account CAPRA type fast reactors and best reprocessing performances including Cm which was stored.

The results were important because all the hypotheses made were realistic and, therefore, even quantitatively were applicable.

The final estimation of extra cost was in the range of 20% to 55% for the PWR scenario and 10% to 50% for the fast reactor scenario.

The gain on radiotoxicity was in the range of 10 to 100 factor compared to reference scenario. The scenario RP2 (with CAPRA) gave the most interesting result.

These results of this system studies could be considered as the minimum that could be reached today. Further improvements could be expected in the future.

JAERI study

The main aspect of the concept was to consider a P&T cycle separated completely from the conventional commercial fuel cycle for power reactors; this concept was named "double stratum fuel cycle".

Partitioning allow to separate HLW elements in four groups: TRU, Tc+platinum group metals, Sr+Cs and other elements.

The transmutation was performed in dedicated transmutation system:

- Actinide Burner fast Reactor (ABR) with 2 types:
  - L-ABR = Pb-cooled ABR
  - P-ABR = He-cooled ABR

- two types of accelerator-based transmutation system:
  - solid system
  - molten salt system.

The fuel was nitride for the ABR systems and the fuel fabrication was described by the carbothermic reduction process. The reprocessing of nitride fuel was proposed by a pyrochemical process with the molten-salt electro-refining.

JAERI also defined a priority for nuclides to be considered with the separation objectives.

The economic part was considered to be premature since all processes were not at the industrial stage. In general, the estimations were always very optimistic.

If the preliminary economic estimates made were considered, it could be concluded that:

- MA partitioning facilities: 1% to 2.5% of costs of investment and operation of actual reprocessing.
- ABR: 2.5 to 5% of thermal power by commercial reactors.
- Accelerator: +50 to 100% of the total cost.

It would be interesting to follow this system study in the future.

PNC study

As the definition of a "systems study" was not made sufficiently clear, this presentation did not answer related questions.

There was no doubt that PNC was working on "systems studies". It would be interesting at a next meeting to have a presentation on this type of work.

CRIEPI study

As for PNC, the presentation was a description of a technical system and considered only the conceptual part of the system study. There was no economic estimation, perhaps also because the CRIEPI system was based on futuristic systems.

Presentation by V.V. Orlov

This presentation addressed essentially liquid lead-cooled fast reactors and their application to burn actinides and to transmute long-lived fission products.

The performances mentioned were interesting, but as for the preceding two presentations it was not really a system study.

Consumption of actinides in ALMR by M.L. Thompson

The same remark as for the preceding presentation could be made. Unfortunately, a presentation of the complementary paper, which was only distributed, "Economics of ALMR Deployment in the United States" by ORNL was not made. In fact, the content of that paper was more in the frame of a "systems study".

Conclusions

In conclusion, it was noted that, even if definition of the subject was not made sufficiently clear, it was very important to have had the first estimations on the whole P&T systems: technical concepts, investments and operational costs and radiotoxicity reducing performance. These types of systems studies would be essential for a proper appreciation of P&T efforts in different countries.

REACTORS, FUELS AND TARGETS
Chairman: T. Mukaiyama

In this session, 17 paper were presented: five paper on transmutation in fission reactors, six papers on accelearator transmutation, three papers on fuels, two papers on strategic studies of transmutation and one paper on related nuclear data.

1. Transmutation in fission reactors (five calculational papers)

The potential of fast reactors for transmutation of minor actinides (MA) was discussed and, in order to avoid the significant deterioration of neutronic safety parameters, a mazimum MA fraction of 5% in the fuel was recommended (Siemens of Germany and PNC of Japan). For a quantitative reduction of Tc-99 and I-129 in fast reactors, an irradiation time of 100-200 years will be needed (Siemens).

The long-term Am radiotoxicity can only be reduced when Am is irradiated at an extermely high thermal neutron flux. The most promising Tc-99 transmuter is the inner core of a fast reactor, regardless of moderation or non-moderation and the yearly transmutation mass is about 100 kg (4% of inventory) in a 3000 MW reactor (ECN Petten, Netherlands). KAERI (Korea) calculated the transmutation rate of MA, Tc-99 and I-129 in the central region of the multi-purpose research reactor "KMRR" for 206 days irradiation. The net transmutation is about 30% for MA, 13% for Tx-99 and 10% for I-129.

2. Accelerator based transmutation systems (one experimental and five calculational papers)

Several groups (ENEA of Italy, LANL of USA and a CERN group) recommended the liquid lead as the target and/or as the coolant material of accelerator driven transmutation or of energy production systems. Based on the experiments using a proton beam of energy between 0.6 to 2.75 GeV for the water-moderated sub-critical natural uranium target, the CERN group concluded that the optimal proton energy is above 1 GeV for the energy gain of about 30 and indicated that a 1 GeV cycloton can deliver a 10 mA proton beam using present day technology and that the limit will be around 20 mA. An overview of the Swedish research activities on accelerator driven transmutation systems was given (RIT and Uppsala University). The incentive of this work is to reduce the cost associated with geological repositories. The activities are concentrated at the universities with limited financial support from the industry and utility groups. An approach to dispose of Tc-99 and I-129 into outer solar space by using an accelerator was proposed by Dr. Takahashi of BNL (USA). PNC presented the paper on the electron accelerator transmutation of Sr-90 and Cs-137 by using the (g,n) reaction.

3. *Fuels and targets (one calculational and two experimental papers)*

Belgonucléaire studied the scenario of Pu and Am recycling in PWRs and concluded that one recycling step of Am in addition to Pu is the limit of recycling. The dose rate increase is significant when Am is added to the MOX fuel. CEA reported on the well-organised, wide range fuel and target studies under the SPIN program. These include fuel fabrication and irradiation for Np and Am homogenous recycling. Some of the irradiation experiments have been done and some will start in PHENIX, OSIRIS and SUPERPHENIX. Tc-99 irradiation experiment will also start in 1995. It is expected that some of the experimental data will be disclosed at the next NEA information Exchange meeting. JAERI has been developing the nitride fuel fabrication method and the pyro-chemical process of nitride fuel for the proposed JAERI Actinide Burner Reactor.

4. *Nuclear Data (one data evaluation paper)*

JAERI is compiling the evaluated nuclear data files in order to provide a reliable database for the OMEGA programme. On file contains neutron-induced reaction data of about 90 actinides for designing Actinide Burner Reactors in which MA is a major fuel component. The other file contains the high energy neutron and proton data for designing accelerator driven transmutation systems.

5. *Strategic studies on transmutation (two papers)*

ECN Petten is conducting the research programme "RAS" which is aimed at informing the public and advising the authorities on transmutation and conditioning of nuclear waste. The paper of ECN concluded that transmutation scenarios in which the waste are contaminated with U-234 are not preferable because they will, in the long run, lead to mobile Rn-222. Reduction of collective dose risk seem, at first sight, to be less relevant, because such risks are far below the natural dose risks, but there are incentives to reduce doses even below such marginally small values keeping in mind past resistance against ocean-dumping of low-level nuclear waste.

PSI of Switzerland developed a method for investigating the effectiveness of actinide transmutation systems. Systems having a wide range of characteristics were compared. One interesting result of the study is that, from the point of view of radiological risk reduction of waste in the long term, the U-Pu cycle and the Th-U cycle are similar.

6. *General remarks on the session*

On of the objectives of this session was to provide basic technical information for P&T system studies which were presented at session 3. Only two of the fuel related papers (CEA and JAERI) provided relevant information. Several national and international programmes on irradiation experiments of fuels containing MA have been launched. In order to facilitate further fruitful discussion on transmutation system studies, the experience and knowledge obtained from these irradiation experiments are indispensable.

CHEMISTRY
Chairman: L.H. Baetslé

The development of the DIAMEX process (CEA, France) has led to a successful treatment of highly active waste (HAW) without acidity reduction. The decontamination factor for the Am-Cm-RE fraction is $\geq 10^3$ which is sufficient to reduce the α activitiy of HLW.

Progress has also been made in the An/Ln separation by tests with TPTZ and Picolinamide. The oxydation of Am to Am(IV) with Ag(II) permits to envisage the selective separations of this element from a Am-Cm mixture.

The DIDPA process (JAERI, Japan) has been completed by a An/Ln separation and a Np co-separation. The previously reported processes have been confirmed and were ready for hot cell tests. The HAW solution has to be de-acidified to O.5-1M HNO_3 to be operational.

The PYROMETALLURGICAL separation process (CRIEPI, Japan) of MA by electro-reduction in a molten salt bath has been seriously improved by using liquid Bi instead of liquid Cd as reductor. The process is very complex and the experimental conditions (O_2 free atmosphere), as well as, the corrosive materials used remain a matter of concern.

A method using Crown ethers (ORNL, US) has been developed for the extraction of Tc from neutralized waste solutions.

The control of Np in the first extraction cycle of the PUREX process (JAERI, Japan) has been made possible by introducing a selective reduction step of Np(VI) to Np(V) with butyraldehyde. The process will be tested in the NUCEF hot cell.

The TRUEX process has been improved (PNC, Japan) by introducting salt free reagents. The process has been tested systematically in hot cells and constitutes one of the most effective MA extraction methods. The difficulty of stripping the loaded solvent remains a drawback.

The AEA (United Kingdom) has worked out medium level waste management and treatment methods based on electro-ion exchange, Ag(II) peroxidation of organic matter and dissolution of PuO_2.

A comparative test has been carried out at ITU Karlsruhe on the MA extraction ability of the TRPO, CMPO and DIPPA processes. This experimental "benchmark" exercise is a great step forward in assessing the extraction methods. The TRPO process is the most promising, because of its very high reversibility in the extraction and stripping steps. A critical analysis at AEA has shown that the existing MA extraction processes have a similar production of secondary effluents.

The AAEC emphasized the merits of SYNROC as a possible matrix for MA extracted from HAW solutions. The thermodynamic stability is a great advantage with respect to glass, but the fabrication conditions are not suitable for industrial upscaling with high activities.