7. INTEGRAL EXPERIMENTS

7.1 Thermal Reactors

Extensive integral experiments on minor actinides have been carried out and are planned especially in France. As for LWR,as a part of the SHERWOOD program, irradiation experiments were carried out by irradiating U02 pins doped with minor actinides at center of the material testing reactor MELUSINE. The capture reaction rates were measured for Am-241, Am-243, and Cm-244. During R&D on high conversion light water reactor, the ICARE program and the ERASME program were performed. In the ICARE program, two experimental U02 pins doped with minor actinides were irradiated at the center of 261 pin lattice of MOX fuel in the MELUCINE. The ERASME program was performed in the critical facility EOLE at Cadarache.

In the framework of the SPIN program, the ACINEAU experiment is planned to take place in the OSIRIS at Saclay at the end of 1994. The purpose is to assess the feasibility of transmutation of Np and Am in water reactors, to study the metallurgical behaviour of fuels and targets and the thermomechanical behaviour of the rods with a view of their subsequent optimization, and to compare the efficiency of actinide burning in a thermal flux with that in a fast flux.

7.2 Fast Reactors

Many integral experiments at fast reactors on minor actinides were carried out in several countries.

In the united state of America, irradiation experiment was performed at the experimental fast reactor EBR-II to measure the capture and fission rates of NP-237 together with major actinides. In the Fast Flux Test Facility (FFTF), transmutation of Tc-99 was measured using moderated assemblies at the periphery of the FFTF. Under the collaboration with the UKAEA, extensive irradiation experiments were carried out at the UK prototype fast reactor PFR. Irradiated minor actinides are NP-237,Pu-238,Pu-242, Pu-244,Am-241,Am-243 ,Cm-243,Cm-244 and higher Cm.

In France,PROFIL,TRAPU and SUPERFACT programs were performed in the French prototype fast reactor PHENIX. In the PROFIL program, separate isotope samples were irradiated,which included Np-237,Am-241,Am-243, Cm-244. In the TRAPU experiment, special fuel pins were irradiated and analyzed to identify the detailed isotope composition in the irradiated pins. The SUPERFACT program has allowed to conclude on the feasibility of transmutation of Np homogeneous fuels (in the range of 2% to 45%) and its extension to higher burnup (> 10 a%) is under way. In the fast critical assembly MASURUCA,physics experiments have been carried out, such as fission chamber measurement and reactivity measurement. The BALZAC experiment measured the reactivity/atom of minor Pu and Am-241 . Basing on the experiences of the SUPERFACT,a irradiation experiment of many pins with 2 % Np is planned to start in 1994 in the SUPERPHENIX.

In Japan,at the JAERI, a series of integral experiments were performed at the critical assembly FCA, to measure fission rate and sample reactivity of m.inor actinides, such as Np-237, Pu-238, Am-241 and Am-243. The measurements were made in the wide range

of neutron spectrum fields. Under the collaboration with the ORNL in the USA, the minor actinide samples irradiated at the PFR mentioned above were sent to the JAERI and are being analysed to verify the JENDL cross sections. At the PNC, reaction rate measurement of Np has been made at the pulse reactor YAYOI,and transmutation rate measurement and irradiation test of minor actinide containing pins are planned at the experimental fast reactor JOYO . The CRIEPI has proceeded nuclear data verification test at the KNK-II reactor under the collaboration with the TUI and KfK.

7.3 Accelerator-Driven Systems

S.Cierjacks overviewed the present status of integral validation experiments related to neutron and proton production ,and spallation and fission products [27].

(1) Experiments planned in the United State of America

An apparatus is built to generate the nuclides under conditions simulating a spallation neutron production,which is used at one of the beam lines of the Brookhaven National Laboratory's Alternate Gradient Synchrotrons. Target material used is lead or tungsten and proton fluence is determined by an aluminum foil. The lead or tungsten foils are irradiated to energies in the range of interest,about 1 GeV. and assayed for their gamma spectra, using germanium diode gamma detectors. The spectra are then analyzed for the quantities presence of the respective nuclides as a function of time after the end of irradiation.

The afterheat develops in target material due to formation of radionuclides during proton-bombardment spallation process. It is experimentally determined by directly evaluating the heat produced by the spallation-induced radioactivity using a novel type of calorimeter. The first experiments were made by use of the BNL Linac Isotope Producer with 0.2 GeV proton energy impinging on lead target.

An experimental study has been conducted at Texas A & M University to compare measured and calculated spallation product yields from a lead target. A special spallation product, decay gamma library was constructed and incorporated into the standard GENIE gamma-ray peak and nuclide identification software. A total of 11 different nuclides in nine mass chains were identified from the multichannel counting spectra. Additional experiments employing copper,gold and thorium targets are planned.

In order to resolve the difference between the code prediction and existing experimental data relating to the n/p parameter , a related experiment is made by creating a configuration that is simple enough from a material. and geometric standpoint.

The experiment uses the BNL's Alternate Gradient Syncrotron. Momentum-analyzed protons in the gigs-electron-volt range will pass through two "paddle" detectors,further defining their energy by time of flight and arranged to produce a coincidence for each proton of the correct energy passing through to a lead or tungsten target located within a neutron detector. This detector is a cylindrical (CH_2) moderator pierced by He-3 proportional counters arranged concentrically with the cylinder axis.

(2) Experiments planned in Japan

Spallation integral experiments are underway in order to obtain data on nuclide production, to estimate the yield of neutrons and spallation products, and to investigate the validity of the spallation simulation code NMTC/JAERI. The 500 MeV booster proton syncrotron facility at the National Laboratory of High Energy Physics (KEK) is used for the experiments. Target materials used so far are lead and tungsten. Experiment with a target of depleted uranium is also planned. The number of induced reactions in the activation samples were measured. The measured results agree fairly well with the prediction by NMTC/JAERI.

(3) Experiments planned in Switzerland

The experiment ATHENA is in progress at the Paul Scherrer Institute, which is aimed at solving some specific data and methods problems relating to the accelerator-based transmutation of actinides. In a first phase, thin samples of actinides are irradiated with 590 MeV protons from the PSI ring accelerator. The generated spallation and fission products are analyzed and are compared with theoretical predictions. The principal motivation is to confirm the high potential of the high-energy fission reactions for transmutation. In a second phase, it is proposed to study relating to multiplying target-blanket assemblies.