MEGAPIE SPALLATION TARGET : Irradiation of the first prototypical spallation target for future ADS.

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ABSTRACT

A key experiment in the Accelerated Driven Systems roadmap, the MEGAwatt PIlot Experiment (MEGAPIE) (1 MW) was initiated in 1999 in order to design and build a liquid lead-bismuth spallation target, then to operate it into the Swiss spallation neutron facility SINQ at Paul Scherrer Institute (PSI) [1]. This target has been designed, manufactured then set-up, fitted with all the ancillary systems, on a Integral test stand in Paul Scherrer Institute for off-beam tests dedicated to thermo-hydraulic and operability tests, carried out during the last months of 2005 then moved to the final implementation in the SINQ facility, with the ancillary systems, for irradiation, carried out from 2006 August 14th to December 21st. The results obtained during the integral tests have shown that the target was well designed for a safe operation and allowed to validate the main procedures related to fill and drain, steady-state operation, and transients due to beam trips. The start-up procedure has been developed, and the operating and control parameters have been defined.

Very important results were obtained during irradiation particularly showing the very good operational behavior of the target, the heat exchanger and the Electro-magnetic pumps. Moreover a lot of results in the thermal hydraulic and neutronics fields, gas analysis have been gathered and will allow to validate the design studies and the models used for that. The successful behavior of the target and the results to come about irradiated materials will provide to ADS Community a unique relevant design and operational feedback, paving the way to the development of high power spallation targets for future ADS, option for the transmutation of nuclear wastes.

I. INTRODUCTION

Partitioning and Transmutation (P&T) techniques could contribute to reduce the radioactive inventory and its associated radiotoxicity. Sub-critical Accelerator Driven Systems (ADS) are potential candidates as dedicated transmutation systems, and thus their development is a relevant R&D topic in Europe. A key experiment in the ADS roadmap, the MEGAwatt PIlot Experiment (MEGAPIE) (1 MW) was initiated in 1999 in order to design and build a liquid lead-bismuth spallation target, then to operate it into the Swiss spallation neutron facility SINQ at Paul Scherrer Institute (PSI) [1]. The MEGAPIE project is supported by an international group of research institutions : PSI (Switzerland), CEA (France), FZK (Germany), CNRS (France), ENEA (Italia), SCK-CEN (Belgium), , DOE (USA), JAERI (Japan), KAERI (Korea) and European Commission. Many studies, carried out by the project partners addressed specific critical issues in the fields of neutronics, materials, thermal hydraulics, mass and heat transfer, structure mechanics and liquid metal technology, using analytical, numerical and experimental approaches. Moreover, it was necessary to perform safety and reliability assessments in order to demonstrate the integrity and operability of the target; and thus to develop the licensing process. To reach this goal, the design had mainly to consider the structural integrity of the target for normal operating conditions, transient situations and hypothetical accidents, and the capability to evacuate the deposited heat with the heat exchanger and the electromagnetic pump system.

The target has been designed by CNRS, CEA, IPUL and PSI; the main components of the target have been manufactured in France by ATEA Company and sub-contractors and in Latvia (EM pumps), then assembled in France. The ancillary systems have been designed and manufactured in Italy (Ansaldo, Criotec) and Switzerland (PSI).. The target has been shipped to PSI in May 2005.

After a description of the target and its main characteristics, result of the conceptual and detailed design studies, and a summary of the previous steps before irradiation, including integral tests, tests in support to safety, implementation of the target in the SINQ environment, commissioning tests, the irradiation phase will be described and main preliminary results presented and discussed. Finally the next steps related to decommissioning and post irradiation examination will be introduced.

II. MAIN CHARACTERISTICS OF THE MEGAPIE SYSTEM

1. Main constraints and options

The main constraint was first to design a completely different concept of target in the same geometry of the current spallation targets used at PSI. The second one was to develop and integrate two main prototypical systems: a specific heat removal system and an electro magnetic pump system for the hot heavy liquid metal in a very limited volume. The third one was to design a 9Cr martensitic steel (T91) beam window able to reach the assigned life duration. Lead bismuth eutectic (Pb44.5%-Bi55.5%) has been selected, due to its attractive neutronic and physical properties: heat transfer coefficient, low melting point (125°C); nevertheless bismuth induces to the production of activation products i.e. polonium,...The choice of T91 for the beam window were explained in [4].

2. Description of the target

A sketch of the target and its main properties are shown in Fig. 1 [4]. 650 kW thermal energy deposited in the LBE in the bottom part of the target is removed by forced upward circulation by the main inline electromagnetic pump through a 12-pin heat exchanger. The heat is evacuated from the THX via an intermediate diathermic oil and an intermediate water cooling loop to the PSI cooling system. The cooled LBE is then flowing down in the outer annulus (4 l/sec). The beam entrance window, welded to the Lower Liquid Metal Container, including the beam window, both manufactured with T91 ferritic/martensitic steel, is especially cooled by a cold LBE jet extracted at the Target heat exchanger THX outlet and pumped by a second EM pump (0.35 l/sec) through a small diameter pipe down to the beam window. A main flow guide tube, equipped with thermocouples, separates the hot LBE upflow from the cold down-flow in the outer annulus. Attached to the top of the tube is the Electromagnetic pump system, designed by IPUL (Institute of Physics in Latvia), consisting of the concentrically arranged by-pass pump and the in-line main pump on top of it. Both pumps are equipped with electromagnetic flow meters. The pump system is surrounded by the Target heat exchanger (THX), designed by CEA. A central rod is inserted inside the main flow guide tube carrying a 22 kW heater and neutron detectors, provided by CEA. The lower liquid metal container, the flange of the guide tube and the heat exchanger constitute the boundary for the LBE, called the hot part. The second boundary is formed by 3 components, which are separated by from the inner part by a gas space filled with either 0.5 bar He, described in [4]. The target contains tungsten to shield the head area from the intense radiation of the LBE and the noble gases and volatiles collected in the gas expansion tank.

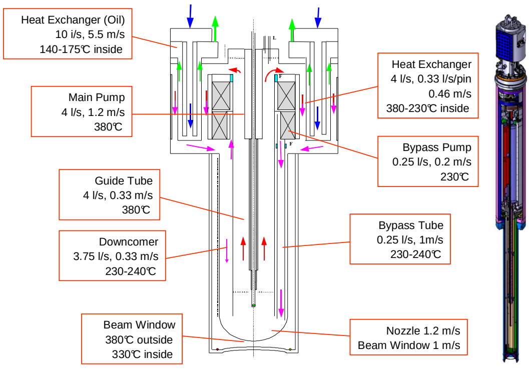

Fig.1 : Megapie target

The main characteristics of the target were recalled in [4](Table 1).

3. Description of ancillary systems

Whereas the target has been designed by CNRS-SUBATECH with the contribution of CEA and IPUL, the ancillary systems were designed by PSI, ENEA and Ansaldo. The main systems are :

- the Heat removal system already described above The Heat Removal System, HRS, with Diphyl THT oil a cooling medium and an intermediate water loop, already described.
- the Cover Gas System, CGS, to cope with the overpressure in the target and to assure the confinement of all radioactive gases produced by the spallation process (about 8 liters) and a regular and controlled venting. The gases are collected in the expansion tank and periodically evacuated via filters into a decay tank.
- the Insulation gas System, IGS.
- the LBE Fill and Drain System, F&D, with a double containment and an appropriate system for disconnecting the tubes after operation.
- the Beamline adaptations including advanced beam monitoring (see later).
- the Handling devices for the target decommissioning, storage, and dismantling.
- the Control system with the adaptation of the SINQ infrastructure.

All connections to the target have to pass by the target head. Components handling radioactive products under normal operation are placed in a second containment filled with He at a pressure below ambient. Activity is continuously monitored.

III SUMMARY OF THE PREVIOUS STEPS

The previous steps were the following ones [6]:

- the detailed design phase; The result was the definition of the target, as described in the previous chapter; several experiments and calculations were performed in order to support and validate the design [5].
- the target manufacturing [5], with respect to PSI Quality Assurance Standards,
- the integral tests [6], aimed to commission target and ancillary systems, to validate the target safe operability.
- the final target implementation in SINQ

1. Design support and validation [5]

The main relevant design issues were focalised :

- on the structural integrity of the target in order to keep all active material confined inside the target and this for normal operating conditions and hypothetical accidents,
- on performances of the heat exchanger to evacuate the deposited heat;
- on performances of the EM pump system,
- on the freezing properties of the LBE and the behaviour of the spallation products,
- on the integrity and coolability of the window.

These, and other, relevant issues streamlined the activities performed within the scientific design support by all the project partners. The main results were described in [4].

2. Target manufacturing

The target has been manufactured (Fig.2) by ATEA in Nantes (France).

Fig.2 : Target built by ATEA

The main feedback (view from ATEA) was the solutions found to solve difficulties for manufacturing due to variety of materials : 316L, T91, Tungsten,… complex geometry,...
The local cooperation between main designer (Subatech), Quality Assurance (PSI) and manufacturer was greatly appreciated. The Institute of Physics (IPUL) in Latvia designed, validated the pump concept by testing a prototype and manufactured the two pumps.

3. Integral tests in PSI

In order to demonstrate the target characteristics and safe operability prior to irradiation in 2006, the target manufactured was shipped to PSI and installed, fitted with all the ancillary systems, which have already been commissioned. , and has been tested out-of beam. The integral tests consisted of the following main tests :
- filling of the target with lead-bismuth eutectic,
- checking the operability of the main components of the target (heat exchanger, electromagnetic pumps,…)
- checking and calibration of the instrumentation (mainly flow-meters)
- carrying out the thermo-hydraulic tests with a heater to simulate heat deposition,
- perform transients for qualification of heat removal and control systems,….
The results of the target commissioning were positive: mechanical and electrical structures, heat removal, electromagnetic pumps operate properly, except some difficulties with a flow-meter.
Four thermal hydraulic tests were done and provided a good set of the data for the system characterization, using the RELAP5 code [6].

Close to the integral tests performed with the target, a full scale leak test (FSLT) was performed in Paul Scherrer Institut [7] with the goals to validate the design of the Lower Target Enclosure (LTE) under worst case leak conditions, and the leak detector system, implemented in the lower part of the LTE.

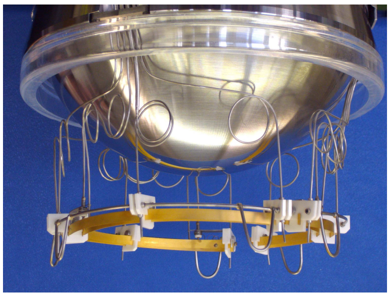

Fig.3: Leak Detector System

Complementary to the FSLT, within the framework of the general safety assessment, the potential consequences of 3 simultaneous failures of the target shells were investigated independently with MATTINA and SIMMER codes, able to model the hypothetical interaction between lead bismuth alloy and D_2O, inducing water vaporization and target pressurization (Target can withstand $P<30$ bar) [8]. The accidental sequence was evaluated, vapour explosion was excluded and the structure integrity was demonstrated, the maximum pressure being maintained largely below 30 bar.

An overall reliability study has been also performed by USDOE-LANL and CEA, which was documented by all the studies already performed within the framework of Design Support.
All these results have contributed to Safety and Reliability assessment and then to Target Licensing, by the Licensing Authorities and Regulatory Agencies (Swiss Federal Office of Public Health, Swiss Federal Nuclear Safety Inspectorate, Swiss Federal Office of Energy, Swiss Federal Nuclear Safety Commission).
Special attention had to be paid to the safe enclosure of the radioactive liquid metal and the gases and volatiles produced during normal irradiation and hypothetical accident conditions.

4. Final target implantation in SINQ

A the end of the integral tests the central rod of the target was cleaned then the neutron flux detector provided by CEA was inserted. The electrical cabling and other connections were installed in the target head. The LBE leak detector was then installed, prior to the final welding Lower target enclosure, with a qualified procedure. The LTE tightness was checked by X-ray and pressure and leak test. The target was then installed in SINQ, then connected to ancillary systems : Fill and Drain, Heat Removal System, Cover Gas System, Isolation Gas System,..

The beam has to be controlled, to avoid any damage on the window : for the Megapie target, due to the specific risks induced by the position of the window (bottom of the target) and the choice of a liquid lead-bismuth alloy ,four new Systems have been installed to watch for correct scattering in target and proper Beam Transport, in order to fullfill the following requirements : the beam has to be switched off within 100 ms if 10 % of the protons by-pass the target. One of the new system is the so-called VIMOS : Glowing of a mesh implemented in the beam duct is monitored via special optical measurement chain and software.

In order to fulfill the requirement of 1 mSv criterion for the public, in case of an incidental release, some measures for reduction of the source term were decided and carried out :
- better sealing of the buildings over and below the target, (TKE & STK), when installed in SINQ,
- inertization system provided by MESSER was provided to prevent inflammation by the thermal oil under the most extreme conditions : the “LowOx” system reduces the oxygen content to < 13%,(layout value : 11%) by nitrogen injection.
- Connecting the TKE with the Cooling Plant in order to reduce the possible activity concentration in air.
- upgrade of the ventilation system (earthquake resistant stand-alone exhaust equipment) and of the filter systems (both with activated carbon and particle filters).

Close to the target, a ventilation system was also up-dated to control locally the temperature.

IV TARGET IRRADIATION

1- Three main operational modes :

Main The target can be operated following three main operational modes :

1. Isolation case :

The target is “disconnected” from the Heat Removal System by closed isolation valves in oil loop; the two electromagnetic pumps are running (possibly at reduced power) and the target temperature is controlled by the central rod heater

2. Hot standby case :

The target is “connected” to the Heat Removal System; all pumps (lead-bismuth, oil and water) are running in nominal conditions and the target temperature is controlled by the three way valve in oil loop. Then the system is ready to accept beam operation.

3. Beam operation case :

The target is operated as in the hot standby case but with beam operation. If during the beam operation status, an anomaly in the signals is detected, the beam is switched off and the target will go into “hot standby case” or into “isolation case” if a critical problem is detected. If during the “hot standby”case, it is not possible to maintain the selected operational conditions, the target will go into “isolation case”

2- Target irradiation start-up procedure:

For the target start-up, three phases were suggested to go to full beam power by the Operating team of PSI :

→Phase 1: 20-50µA for 4h maximum,~8kW-20kW heating

This phase is mainly dedicated to check all "nuclear" instrumentation, and beam interruption system. During this phase, no significant heat is deposited into the target to get reliable thermohydraulic data.

This first beam was received on 2006 August 14th. At a relatively stable and constant beam current of 40 µA, which corresponds to about 25 kW of beam power, the target accumulated a total charge of 60 µAh.

→Phase 2: 200µA for 8h maximum, ~80kW heating

This phase was mainly dedicated to check the Heat Removal system control parameters, dosimetry,... however, the reaction of the Heat Removal System was anticipated to be modest as the oil three way valve will hardly move. Reaction of the target temperature control to beam-interrupts and trips can also be tested.

This phase of the start-up procedure was successfully accomplished on August 15 th, where the power was stepwise increased to 150 kW (250 µA proton current).

→Phase 3: :During this phase, it was foreseen to ramp up to full beam power in several steps: 200µA, 400µA, 600µA, 800µA, 1000µA, 1200µA

This phase was successfully accomplished on the 17th of August, when the power was stepwise increased to 700 kW (1200 µA proton current) (Fig.4)

At full beam power, LBE and oil pumping powers were further fine-tuned to get the required flowrates by once again using the thermal balance method

At each power level the beam was interrupted after some 10 minutes with a stable proton beam, to verify the predicted temperature transients in the target. Reviews were carried out after start-up phases, following quality insurance standards, in order to obtain final approval to go in steady state operation, from PSI and Swiss Federal Office of Public Health (BAG).

Steady state MEGAPIE operation for normal users was started on August 21st around 8:30 and continued until the normal annual winter shut-down starting on December 22nd, 2006.

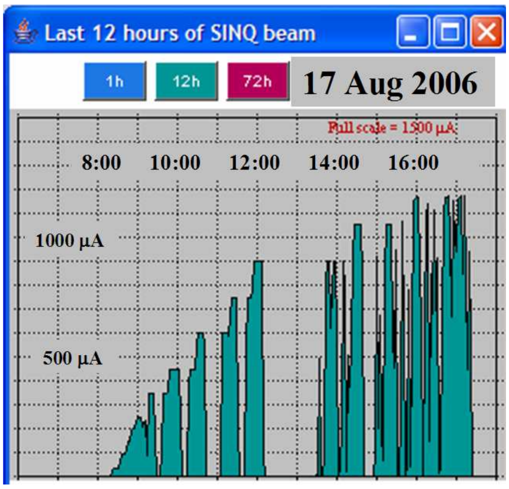

Fig. 4: Third phase of the start-up procedure

During the entire MEGAPIE irradiation experiment the target served as the source for the neutron scattering programme at PSI, respecting the required availability of neutrons: full power at >95% of the schedules operation time (continuous (51 MHz) 590 MeV proton beam hitting the target expected to reach routinely an average current around 1350 µA, corresponding to a beam power ~0.80 MW).

3- Overall Target operational feedback:

A first evaluation of this feedback has been done by the PSI operation team.

During the operation period, the system suffered:

~5500 beam Trip (<60s)

~ 570 beam interrupt (<8 hrs)

~ 6600 total beam transitions

The target behaviour was excellent both during stable operation and transients due to beam trips. The temperature distributions and transients were as expected, very close to predictions. The electromagnetic pumps (EMP) operated stable and reliably, without any indication of degradation so far. On the contrary, Electromagnetic Flow-meters (EMF) performances, and particularly accuracy, were low : difficulties were mainly induced by the proximity to EMP (leakage of magnetic flux) and by T transients due to immersion in LBE (> 10°C/s). There is a strong necessity to work on the optimization of flow-meters for targets or other integrated systems (EMP + EMF).

For the main MEGAPIE ancillary systems directly connected to the target, i.e. heat removal system (HRS), the cover gas system (CGS), and the insulation gas system (IGS), the operating feedback was positive in general. The heat removal capacity of the system was rather over sized. Oil degradation by radiolysis and pyrolysis was found to be less than anticipated. The main drawback of using oil is the need for fire protection which was achieved by inertization of the atmosphere in target head enclosure chamber TKE and in the beam transport vault. One lesson learned with the CGS (Control Gas System) was, that 'leak-tightness' for gases in the conventional definition is not the same as for radioactive gases: In spite of successful He leak tests according to specification a leak from the decay tank into the 2nd containment was detected by the very sensitive detector controlling the circulating gas. Although clearly detectable, the leak was sufficiently small such that the inventory could be released weekly by venting of the 2nd containment through the controlled exhaust system. A further lesson was to care for redundancy of vital sensors in such a complex system: one pressure transducer inside the enclosure controlling and recording the plenum gas pressure failed, most likely due to radiation damage, although qualified for radiation resistance up to a total Gamma-dose of 1 MGy. Switching to the remaining redundancy solved the problem at that time, but after that no redundancy remained. Thus, there is a high necessity to develop a reliable strategy to qualify the instrumentation (scientific-operational-safety related) and to define the level of redundancy required.

Another important feedback was the necessity to up-grade the gas sampling system, indispensable to control the inventory before venting.

In the IGS (Insulation Gas System), designed as closed volume, the pressure, expected to remain constant during target operation, only reacting to temperature variations, in fact increased by ~5 mbar/h. Thorough analysis gave evidence that oil from the HRS was leaking into the IGS volume, decomposed by radiolysis during beam operation. The gas produced further contained small amounts of radioactive gas from CGS, entering through a second (small) leak. The gas production urged a weekly venting of the IGS, thanks to installation of a 180 l decay vessel in the cooling plant and regular (weekly) venting into the exhaust system after a sufficient decay period and gas sampling.

The experience with the safety devices implemented to monitor the proton flux from SINQ was very positive : the VIMOS camera was replaced and worked satisfactorily; Stripe LBE Leak Detector gave satisfaction but the TC LBE Leak Detector was considered as the most sensitive Beam Diagnostic.

4- Experimental monitoring :

During irradiation phase of MEGAPIE, numerous operating parameters were monitored, including pressure, fluid flow-rates and temperatures.

A first analysis of the THX behavior shows, even if some issues remain on the measurement of flow rates and loss of accuracy of some physical data of LBE and oil, that this component is well described by the analytical model, used for the design. Nevertheless an effort is carried out for a better description of the oil path in THX cooling pin as a helical coil. A computational experiment with CFX10 has been conducted to find the HTC of a spiral cooling pin. The results were in good agreement with the widely used correlations, namely Dittus-Boelter and Petukhov et al. A new heat transfer correlation, which had a stronger dependence on both *Re* and *Pr* than the Dittus-Boelter's, was developed from the computation results [11]. Associated with a good assessment of the target thermal power, these improvements are necessary to improve the system analysis during irradiation using RELAP 5 system code, even if a good agreement between experimental data (obtained during Integral tests) and calculations both with standard and dedicated correlations was obtained. (Accuracy in the range of 5%).
Interpretation of the available thermocouples measurements in the lower part of the target close to the window is performed, using CFD codes in order to understand some large discrepancies, found between experiment and CFD.

The following main results are now well established: any variation of the main flow temperature play no roll on the beam window cooling and the by-pass flow, promoting a large scale secondary flow, which is capable to enhance heat transfer substantially, dominates the beam window cooling. the most sensitive Beam Diagnostic. A CFD Simulation of Warm Jet Thermograph Study on the MEGAPIE Target has validated this previous result. [11]

Experimental measurements of neutron fluxes at various positions of the facility, and of gas production allows now Monte Carlo calculations of the measured quantities to be performed, with the goal of codes validation MCNPX and FLUKA fitted with appropriate models (irradiation phase of

MEGAPIE. Thus, activities concentrate on two main goals:

1) experimental measurements of neutron fluxes at various positions of the facility, and of gas production; 2), performed during irradiation phase

2) Monte Carlo calculations of the measured quantities, with the goal of code validation (FLUKA, MCNPX fitted with appropriate spallation models.), being performed within the framework of MEGAPIE Initiative partnership.

Neutron flux measurements were performed in various places with different methods :

a- Measurements at beam lines or inside D2O tank:

- with activation foils(Measurement of the thermal neutron flux and of the epithermal flux (at a single resonance point at 4.9 eV by wrapping the foil with a Cd layer).
- with Bonner spheres (Measurements performed with poly spheres of different radius surrounding ^{3}He detectors, for sensitivity to different neutron energy range. (By Lausanne university)
- time-of-flight measurements performed at the SINQ ICON facility using a chopper
- neutron flux with activation Au foils inside D_2O tank (NAA/PNA stations)

A comparison between measurements (fluxes in n/cm2/s/mA) and calculations using MCNPX and FLUKA has shown that the gain in terms of neutron flux was around 80% in comparison with a solid metal target, greatly exceeding expectations. These experimental data are analysed in detail and more calculations are being performed by MEGAPIE partners.

b- Other neutron measurements :

- neutron flux inside the target using micro-fission chambers (Fig 6) [9].

Although spallation models are nowadays reliable and well qualified against a lot of experimental nuclear data, a precise neutronic characterisation is crucial for future ADS developments and to address the possibility to transmute minor actinides in such a system. These are the reasons why CEA has designed and built a neutron detector to measure “in situ” and to characterize the inner neutron flux of the target under irradiation. Height fission micro-chambers have been set-up inside the central control rod (Fig 5) for on-line monitoring (Neutron energy domain: from thermal to 10 MeV). ^{235}U chambers have been calibrated by gamma and mass spectrometry at ILL. Moreover, potentiality of such target in terms of incineration for ^{241}Am and ^{237}Np has been evaluated, thanks to two micro-chambers with these two minor actinides.

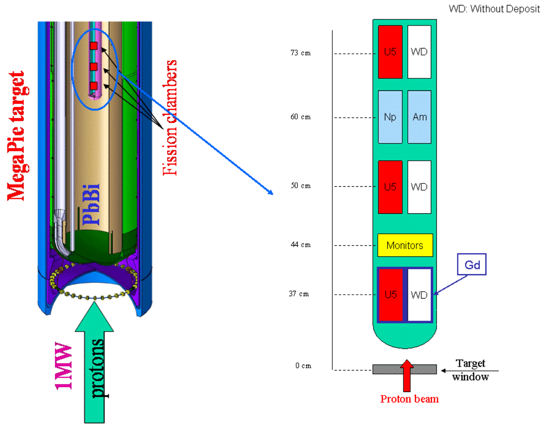

Fig 5: In situ neutron detector

The neutron detector has functioned reliably for all this time at a temperature around 400°C with frequent beam interruptions. During the whole irradiation phase the currents of the 8 fission chambers have been recorded every 2s.

Fig 6: Micro fission chamber

A great sensitivity of the neutron energy distribution to the presence of polluting materials in the Pb-B, i.e. boron (1 ppm in MEGAPIE) versus the neutron energy spectra is noticed inside the target, but has almost no effect on the neutron spectra.

Comparison of the measured fission rate with calculated values from simulations by the MCNPX transport code, using different physics model. Has shown that Bertini-Dressner seems to better fit with measurements. The experimental and also simulation work are still ongoing, focused on the study of the influence of the temperature of the LBE and of the different models used in MCNPX.

- delayed neutrons (DN) in the upper part of the target (Neutron detector based on ^{3}He counter) [10]

Besides the considerable amount of decay gamma activity in the irradiated liquid metal, a significant amount of the Delayed Neutron (DN) precursor activity can be accumulated in the target fluid. Due to the very short transit time (few seconds within one half-life of many DN precursors) from the window of the target into upper part where DNs may be important, it was very important to evaluate the DN flux as a function of position and determine if DNs may contribute significantly to the activation and dose , very useful for future Post Irradiation Examinations (It was calculated that with a prompt neutron flux in the TKE of about 10^5 n/cm^2/s, the DN flux should be one order of magnitude higher). A preliminary comparison between the DN decay curve measured and the result of a geometrical model involving three averaged liquid metal transit times and the DN precursor parameters (measured at PNPI Gatchina), has shown a rather good agreement.

During MEGAPIE irradiation, gas and volatile elements were produced, both stable and radioactive[2] [3]. Calculated values of stable gases indicated a production of about 1 l/month (mainly stable H and ^{4}He).Isotope production measurement was very important since spallation models used in Monte Carlo models are more sensitive to it than to neutron fluxes.
Moreover, the knowledge of the production rates of specific radioisotopes was necessary for the assessment of the disposal strategy of the target, and for the post irradiation examination (PIE). Five samples of the gas produced in the LBE during irradiation were taken, the first one about 1 day after start-up, then latter; then analyzed by mass and gamma spectroscopy, and the amount and composition of gases generated (^{4}He, stable and radioactive Ar, Kr, Xe, I) was determined.

V FURTHER MEGAPIE STEPS

After the irradiation, the target remained up to mid February in the operating position until the decay heat has decreased to about 300 W (to be checked). Controlled freezing of lead-bismuth eutectic (LBE) was necessary due to Expansion of solid LBE after re-crystallization: the expansion can be mitigated if the cooling rate is kept as low as 0.02 °C/min from solidification point to 60°C. A specific procedure for Freezing the LBE in Lower Target Enclosure was carried out.
Then, cooling circuits and gas volumes have been emptied, rinsed and dried, target was disconnected and sealed up with blind flanges, then it will be stored for several months. After about one year and a half, the target will be transferred to SWILAG hot laboratories, using a steel container (Fig 7) made of 2 concentric parts (inner contamination protection and Shielding).

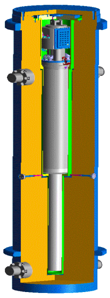

Fig N° 7: Container for target transportation

Then, the target will be cut with band saw (provided by Behringer), in 19 slices. About 8 (weight) % of the target will be transported to the Hotlab at PSI east as samples material for Post Irradiation examinations. The remaining target pieces (92%) will be conditioned in steel cylinder in a KC-T12 concrete container (TC2), for Storage and Disposal. This procedure has been approved by the National Cooperative for the Disposal of Radioactive Waste (NAGRA).

The objectives of the Post Irradiation Examinations (PIE) are to understand:
(a) microstructural, mechanical and chemical changes in the structural materials in the target induced by irradiation and LBE corrosion,
(b) the production, distribution and release of the spallation and corrosion products in the LBE.
The (PIE) will be carried out with a organized effort of the eight partners of the MEGAPIE initiative: CEA, CNRS, ENEA, FZK, JAEA, LANL-DOE, PSI and SCK.
For the structural material the following analysis will be performed :
- Non-destructive-test (NDT): Ultrasonic analysis of the thickness change at the beam window.
- microstructural, mechanical and surface analyses on the beam window, internal structures.
- Surface analyses on EMP tube,…
- Chemical analyses on spallation and corrosion products in the LBE and depositing at the Ag-absorber and cold-trap (Control Gas System).

VI CONCLUSIONS

The target has been designed, manufactured, and tested during integral tests, before irradiation carried out end of 2006.

These tests demonstrated the operability of the target and ancillary systems in steady state and transient situations and the Control System has been validated Stress analysis and supporting experiments like full scale leak test validated the design, the confinement strategy and the potential safe operation. All these experimental results demonstrated finally the ability of the target to be licensed and irradiated in SINQ. Implementation in SINQ was carried out and safety systems were up-dated or implemented to face events like oil fire, release of contamination, earthquakes, brutal vaporization of D2O. Start-up procedures and normal operating conditions were clearly defined and applied. Neutron and thermo hydraulic measurements were performed allowing now interpretation of the experiment and validation of the models used during design phase.

The next steps have been defined properly: decommissioning, Post Irradiation Examinations and waste management.
The already performed steps, conceptual and engineering design, manufacturing and assembly, safety and reliability assessment, thermo-hydraulic off-beam tests and irradiation have brought already to ADS Community a unique relevant design and operational feedback which will be a decisive contribution to the development of Accelerated Driven Systems, option for the transmutation of minor actinides.

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