CONTRIBUTION OF THE "INSTITUTE FOR REFERENCE MATERIALS AND MEASUREMENTS" (Geel, Belgium) FOR THE STUDY OF LONG-LIVED NUCLEAR WASTE INCINERATION

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A new interest for the concept of actinides and long-lived fission products transmutation has recently been observed. In fact, this concept could help to solve the problems caused by the management of radioactive waste by reducing the quantity of long-lived isotopes which have to be stored in deep geological formations. Two ways are followed to carry out transmutation studies : actinide burner reactors and hybrid systems based on accelerators coupled with subcritical devices.

In the case of hybrid systems, the performances in term of long-lived radioactive waste transmutation efficiency are related to the neutronic properties of the subcritical medium, which are really very little dependant on the spallation reactions and the corresponding neutron source. In fact, a survey showed that the neutron spectrum in the subcritical medium is, after one mean free path of the neutron, the same as the spectrum in the same subcritical medium without external source. Therefore, the performances of the subcritical medium are connected with the same nuclear data as those used for standard fission reactor calculations.

For both types of solutions, more precise differential data are requested. In that way, a critical analysis has already been performed on ^{99}Tc at ECN-Petten for the JEF project. The conclusions show that a great improvement of the data is needed in the thermal and resonance energy ranges, in order to reach an accuracy of $\pm 5\% (1\sigma)$ for $E_{thermal} \leq E \leq$ 50keV.

Similarly, for actinides, there is a need for more accuracy on neutron data concerning ^{241}Am, ^{243}Am, ^{237}Np in the resonance region and on inelastic scattering. The determination of neutron data in the resonance region can only be made at the "GELINA Neutron Time of Flight Facility”, at Geel (Belgium). The Geel Electron LINear Accelerator (GELINA) is presently the most powerful pulsed neutron source for nuclear data measurements in Europe. It consists of an s-band electron linac, a post-acceleration compression system, a neutron producing target and a neutron flight path system. At full power, the electron energy is 100 MeV, the average current 100 μA. The 10 ns wide electron pulse delivered by the linac are compressed in the post-acceleration bunching system to pulses about 1 ns. The target most frequently in use is a mercury cooled rotary U target, yielding an average neutron output of 4. 10^{13} neutrons/s. The energy spectrum of these neutrons is similar to a fission spectrum. *Table 1* shows the characteristics of the accelerator.

Pulse length (ns)	Repeti- tion rate (Hz)	Peak current (A)	Mean current (µA)	Mean energy (MeV)	Mean power (kW)	n prod. rate in pulse (n/s)	Mean n rate (n Is)
Without compression							
5	800	12	48	110	5,3	6,4 10^{18}	2,5 10^{13}
10	800	12	96	100	9,6	5,6 10^{18}	4,4 10^{13}
100	800	1,5	120	87	10,4	6 10^{17}	4,8 10^{13}
1000	380	0,22	83	100	8,3	1 10^{17}	3,8 10^{13}
2000	250	0,22	110	100	11	1 10^{17}	5 10^{13}
With compression							
<1	800	-100	75	100	7,5	4,6 10^{19}	3,4 10^{13}
At lower energy							
2000	300	0,1	60	40	2.4	Photo activation	

Table 1 : characteristics of GELINA (J.M. Salomé - P. Rullhusen, IRMM-Geel)

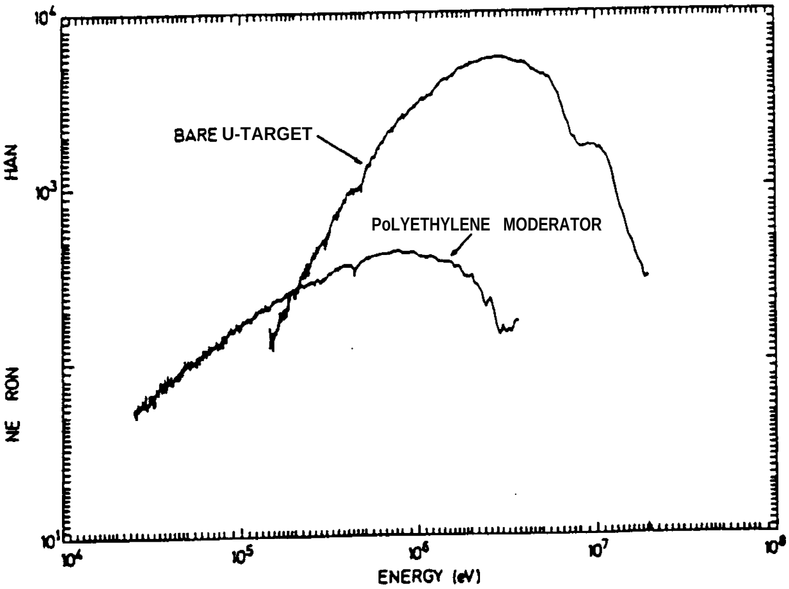

Figure 1 **:**
fast neutron fluxes at
L= 10m

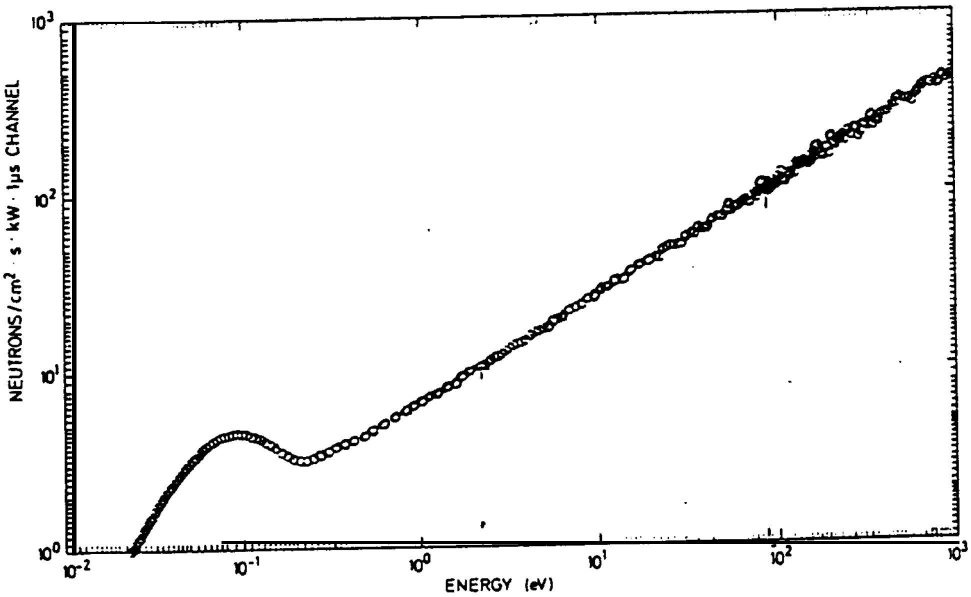

Figure 2 **:**
neutron flux from the polyethylene moderator at **L=10m**

Figure 1 and 2 show, at a distance of 10 m, the shape of the neutron flux emerging from the polyethylene moderator (used to get low energy neutrons). There are 10 neutron flight paths with lengths between 7 m and 390 m available for neutron data measurements. The energy of the neutron is measured with the time of flight method :

$$E\,[\mathrm{eV}] = \left(\frac{72.3 * \ell\,[\mathrm{m}]}{t\,[\mu s]}\right)^2$$

When the energy range of interest is low enough, the only opened channels are absorption (capture + fission) and elastic scattering. Moreover, if the nucleus is not fissile in the low energy range, the determination of resonance parameters can be done from one measurement of transmission and one of capture.

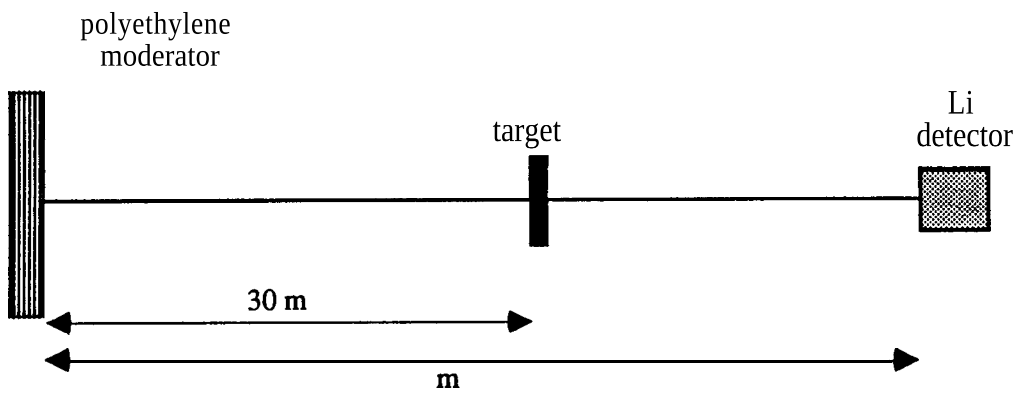

***Figure 3*:** transmission facility

Figure 3 shows the principle of the transmission facility. The neutron beam, coming from the moderator, interacts with the target to be studied. A reaction between an incoming neutron and a nuclide can be either a radiative capture or an elastic scattering. In both cases, the Li neutron detector will not detect it (the solid angle is too small for the detector to “see” the scattered neutrons). One measurement is done with the sample in the beam, an other one with the sample out. The ratio between the two sets of data given by the Li detector (after background correction, normalization...) gives the transmission coefficient, from which we can obtain the total cross section.

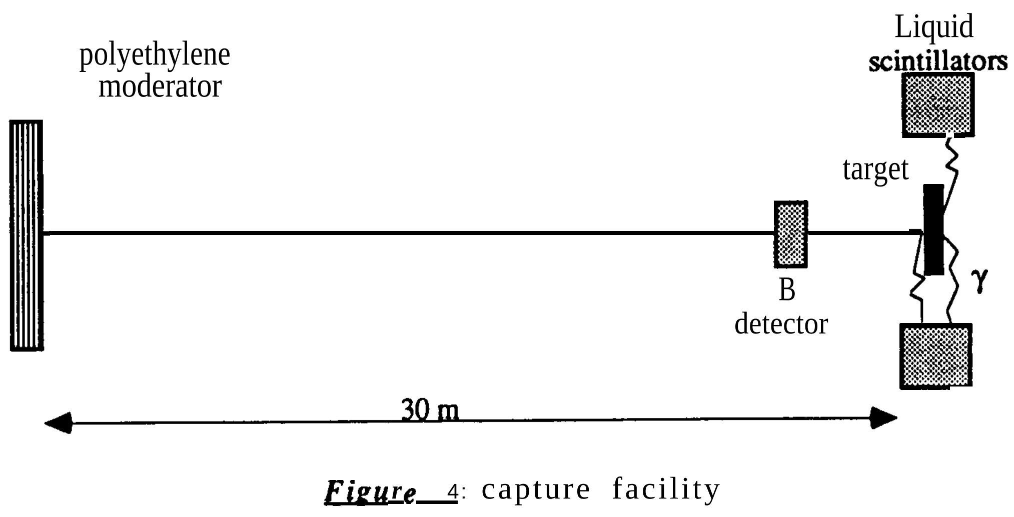

***Figure 4*:** capture facility

Figure 4 shows the principle of the capture facility. The neutron beam first interacts with the flux boron detector, then with the sample. If a radiative capture happens, one of the gamma emitted by the desexcitation of the compound nucleus can be detected by one of the C6D6 detectors, with the corresponding efficiency. The boron detector measures the neutron flux. The ratio between the information given by these two detectors, after several corrections (background, detectors efficiency, flight lenght, normalization...), produces the capture yield, from which we can deduce the radiative capture cross section.

The analysis of the total and capture cross sections by sophisticated processing codes produces the resonance parameters of the measured elements.

A first study of neptunium 237 will be performed by CEA at Geel in june 1994. The linac will be stopped from july 1994 to february 1995 for restoring. The next material to be studied will be technetium 99, in 1995.

Apart from the linac, there is also in the Geel center a Van de Graaf accelerator, which could be used to measure, if needed, other type of neutron interactions : (n,n'), (n,2n), neutron multiplicity.

This measurements are not only needed for the study of long-lived fission products incineration, they are also useful for fission reactors. In fact, a recent American study on nuclear data needs for the 90's mentions the interesting case of the fuel with which the power reactors are supplied : a margin of about 5% must be foreseen on the life of the fuel, due to the uncertainties on nuclear data concerning the fission products and the transuranium isotopes. A much larger margin is needed for advanced reactors, which use higher burn up. The improvement of the quality of nuclear data would allow to refine the estimates on the fuel performances at the end of the cycle. This would lead to important profits within very strict security rules.

But OECD points out that if we want to face up to the actual and future nuclear data needs, it would be necessary, from the general mind, to have at our disposal enough facilities and qualified specialists to perform the nuclear data measurements. For the moment, the means at our disposal are really insufficient, specially concerning the differential measurements. If a radically different policy is not rapidly set up, the expertise, essential for the nuclear data measurements, will not be transmitted and therefore will irremediably be lost.