II. GENERAL SESSIONS - TARGET STATIONS

The following topics were used as guidelines for discussions during the general sessions on target stations:

Neutronics

- target/moderator design criteria
- target materials
- moderator materials
- reflected/decoupled and bare moderators
- cold moderators
- experimental-data/code-verification
- moderator heating
- backgrounds in neutron beams

Engineering

- engineering aspects of neutronic considerations
- target station diagnostics
- versatility inside target cavity interface between proton beam line and target station
- proton beam dumps
- shielding
- beam ports and shutters
- radiation monitoring

The sessions were unstructured. Summaries of most of the discussions held during the general sessions on target stations follow.

A. Target Development Work at the Rutherford Laboratory, A. Carne, RL

1. Uranium Growth Studies

The Rutherford Laboratory has a development contract with its neighbor establishment, AERE Harwell, to provide a metallurgical understanding of the behavior of Zircalory-2 clad uranium target plates during fabrication and operation under the SNS proton beam, and to determine possible methods of failure. There is further collaboration with Harwell in the design of a target for their 136-MeV electron linac. A test electron linac with an energy of about 15 MeV has been available to make studies of the effects of thermal cycling as a function of center temperature, uranium thickness (the cladding being 0.25 mm and constant), and plate fabrication by the hot rolling (HR) or hot pressing (HP) process. Preliminary results (due to M. S. Coates of AERE) are shown in Table I. The plates were air-plast cooled. Temperature change/pulse was ~ 30 °C. The centerline temperature was measured by thermocouples embedded in the uranium. The results indicate a possible threshold below which thermal cycling growth may be small as suggested by Gittus, "Metallurgy of Uranium". Also the test result, taken to determine the gross effects of beam switching on and off, indicate that the pulse-to-pulse thermal cycling is a more important effect than gross temperature changes.

2. Code Development

Development of target codes has continued, under F. Atchison. The RL version of the HETC package now contains the following major modifications:

- inclusion of high-energy fission as a competing process
- modified treatment of low-energy neutron induced fission
- use of ENDF/B cross-section data in O5R
- corrected Coulomb scattering code which allows segmentation of the target into plates.

For an input 800-MeV proton beam of 3×10^{13} p/pulse, 50 Hz, with a "square parabolic" distribution

$$\frac{I}{I_0} = \left[1 - \left(\frac{x}{x_0}\right)^2\right]\left[1 - \left(\frac{y}{y_0}\right)^2\right]$$

and $x_0 = y_0 = 3.816$ cm, incident on a solid uranium ($10 \times 10 \times 30$ cm^3) target, the following preliminary results have been obtained:

- total energy deposition 350 kW
- peak energy deposition 0.94 kW/cm^3
- peak-to-mean ratio in the target 8:1 when the entire target is included, 5:1 when only the volume under the beam is included.

Axial variation of the energy deposition indicates the peak at 2.5 cm, followed by an exponential decay with an effective mean-free path of 9.2 cm. The number of uranium nuclei destroyed per incident 800-MeV proton was found to be 4.9 fissions, 1.8 spallations, and 2.6 (n,γ) captures, totaling 9.3 nuclei-destroyed proton.. The saturation activity has been based on 3 short lived products/fission, 2 per (n,γ) and 1 per spallation giving a total of ~ 1.5×10^6 Ci. The corresponding decay heating is 26 kW; this latter figure has been included in the above total energy deposition.

3. Target-Plate Thickness

The above data has been used to define a preliminary set of target plate thicknesses. The optimum transverse dimensions of a clad-plate target are now being estimated, using as a figure-of-merit the 1 eV normal neutron flux from the 10 x 10 cm^2 open face of an H_2O moderator above a practical Inconel target box, with the target/moderator immersed in a 70-cm cube of D_2O reflector. The target plate thicknesses have been chosen to keep the centerline temperature in the uranium < 400 °C. The following preliminary set of plates has been obtained: 12 at 0.65 cm, 4 at 0.85 cm, 4 at 0.95 cm, 4 at 1.25 cm, 2 at 1.75 cm, and 5 at 2.45 cm; total 31 plates with an average uranium density of 84%.

The temperature has been held at 400 °C to keep clear of the regime of cavitation swelling, which appears to peak at 425-450 °C. Also at this temperature, and below, the effects of thermal cycling are expected to the reduced. Other radiation growth effects will be reduced by metallurgical processing.

4. Spallation Product Gases

Production of fission/spallation product gases has been estimated, with the following values at NTP:

H_2	He	Xe	Kr
1.6ℓ	0.35ℓ	1.46ℓ	0.29ℓ

with a total 3.7 ℓ/yr. If, as expected, hydrogen dissolves or diffuses through the material, this value reduces to 2.1 ℓ/yr. These gas quantities are not expected to cause problems.

5. Burn-up Rate

The term "burn-up" rate is given above as 9.3 ^{238}U nuclei destroyed per proton, of which 4.9 are due to fission. The corresponding rate for the peak plate is 2.1%/yr, with about 1.1%/yr due to fission. Comparing with conventional reactor fuel elements, a target lifetime in excess of four months can be expected.

TABLE I

GROWTH STUDIES FOR URANIUM PLATES

Nominal U thickness	Fabrication	℄ Temp (°C)	No. of Cycles	Total Growth	Growth /mm for 10^6 cycles
1 mm	HR	350	10^6	nil	nil
1 mm (same plate)	HR	500	10^6	5	5 ± 1
(repeat same)	HR	500	10^6	5	5
2 mm	HP	500	10^6	17	8.5
2 mm	HP	500-250	10^6 (0.25×10^6)	4	——

B. SNS Target Station and Shutters, A. Carne, RL

1. Target Station

The SNS target station has been designed to reduce the radiation at the outside surface of the bulk shield to less than 0.75 mrem/h. The shielding will, however, be weakened by the proposed 18 neutron-beam tubes serving the instruments in the experimental areas. The bulk shield will be a massive structure of mainly iron and concrete; nevertheless the proposed conceptual design has the flexibility to meet future experimental requirements which may call for changes in beam-tube layout within the bulk shield. Within the bulk shield each beam tube will be terminated by a shutter.

The bulk-shield dimensions have allowed for the angular distribution of fast neutrons emerging from the target. For a solid (10 x 10 x 30 cm^3) uranium target the following shielding thicknesses have been obtained:

to beam direction	0°	3.2-m Fe + 1.5-m concrete,	total 4.7 m
	90°	2.7-m Fe P 1.0-m concrete,	total 3.7 m