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PRESENT STATE OF THE ESS TANTALUM TARGET

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1. Introduction

The *Reference Design* of an ESS 5 MW target was presented in the figure 4.5 of the ESS outline report published in September 1995. This non-split target for horizontal injection has been composed of a stack of 55 target plates of tantalum hit by the proton beam with a circular footprint of 100 mm diameter. On both sides of the Ta-plates are stacks of Ni-plates integrated as reflector into the target container to result in a ratio of 3:1 between target width and height.

A decision made by the ESS Target Working Group in July 1995 gave way to the prefered development of a Mercury Target for the ESS which will come out in the *Final Conceptional Design*. The first designs of this ESS Mercury Target were presented by Dr. G.Bauer at the ICANS XIII. Nevertheless, the development of an ESS target of solid material is going on, serving as an *Option*. As the *Reference Design* has been fixed, the modifications made on it will lead to the ESS Tantalum Target.

2. Present geometry

A main goal in the design of an optional ESS Tantalum Target is to adapt the dimensions to those of the ESS Mercury Target. Doing so, the dimensions of the reflector and the configuration of moderators and their positions in the reflector are the same for both target concepts; this forms a good base for comparison. The reflector-moderator-assembly consists of a reflector with the dimensions 600 mm x 600 mm x 800 mm (x,y,z) and the reference moderator configuration (see ESS outline report). The reflector allows target dimensions with a cross section of 185 mm height (x) and 335 mm width (y) inserted. The length (z) of a target may be up to 700 mm.

The width of the container of the *Reference Design Target* is 600 mm (width of the Ta-stack: 120 mm, width of each Ni-stack: 140 mm, width of each water channel: 100 mm). As neutronic calculations done by Dr. D.Filges and Dr. R.D.Neef showed that the absence of the Ni-reflector inside of the target container hardly decreases the total neutron flux, the width of the target container has been decreased from 600 mm to 335 mm by taking the Ni-stacks out.

Furthermore, a second cooling system has been designed to allow the cooling of the decay heat of the target in case of failure of the main cooling system under 'beam off'-condition.

Keywords: ESS, target, tantalum, water cooling, helium cooling

Figure 1 shows the present geometry of the ESS Tantalum Target. In z-direction, the height of the target increases from 150 mm to 170 mm meanwhile the width increases from 240 mm to 330 mm. The beam window is part of the target container.

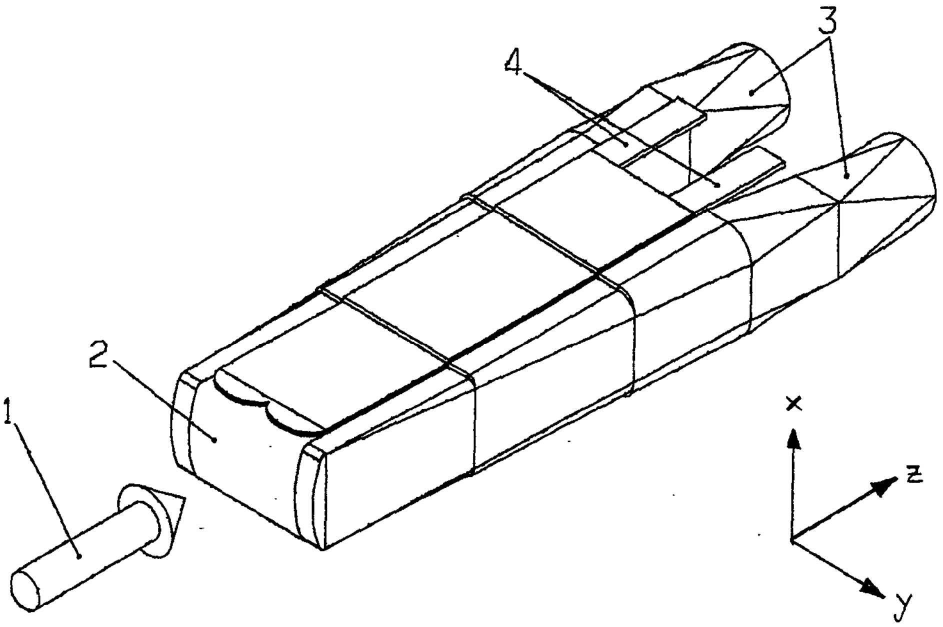

Figure 1 ESS Tantalum Target. 1: proton beam, 2: beam entrance window, 3: coolant in- and outlet of the main cooling, 4: coolant in- and outlet of the second cooling

The internal geometry of the ESS Tantalum Target (see figure 2) is mainly defined by the stack of 55 slightly 1D-bent rectangular target plates of tantalum with an increasing plate thickness from 2.6 mm to 30 mm. The front dimensions of the plates increase with z from 130 mm x 150 mm (x,y) to 150 mm x 170 mm. The cooling gaps have a minimum height of 0.7 mm where the plates contact each other. The average spacial part of cooling medium in the target is 8%.

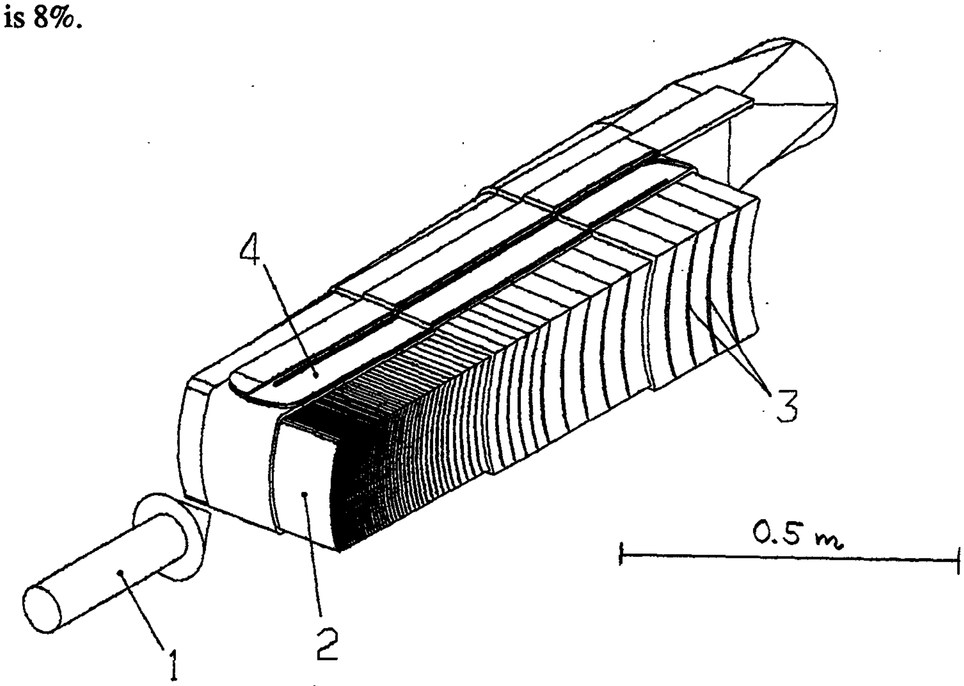

Figure 2 ESS Tantalum Target (cut away view). 1: proton beam, 2: stack of target plates, 3: gaps for main coolant flow, 4: channels for second coolant flow

3. Cooling of the target

The main cooling circuit has to have a performance of 3 MW which is 60% of the proton beam power. An estimation of the performance for the second cooling circuit is 250 kW in operation and 100 kW if the beam is 'off'. Investigations have been done so far only for the main cooling circuit. As cooling media water and helium have been studied.

3.1 Water cooling

On 5 MW beam power, the time averaged maximal volumetric heat deposition in the tantalum is 3100 W/cm^3. The plate thicknesses are chosen to give a heat flow of 375 W/cm^2 in the centre of each plate surface (see figure 3). Sufficient cooling of the target is guaranteed with a water mass flow of 80 kg/s leading to a heat transfer coefficient of about 3.5 W/cm^{2}K, a maximum plate surface temperatures of 180°C and a plate centre temperatures of 250°C. The relatively low surface temperature is chosen so that low pressure water can be used with no problems from boiling. The average water velocity of 7.5 m/s in the cooling gaps causes a pressure drop of nearly 0.1 MPa in the target. On average the water temperature increases about 20 K while passing through the gaps.

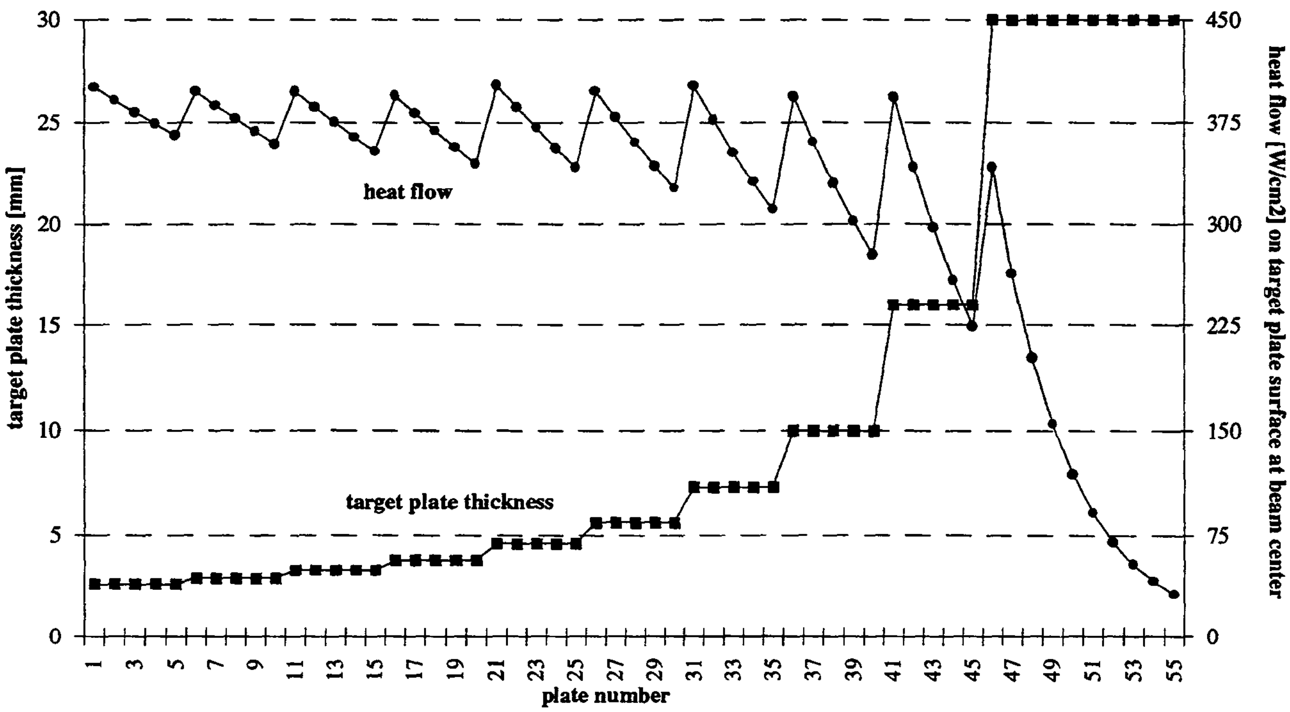

Figure 3 Target plate thicknesses and heat flow on the target plate surfaces at the beam center

3.2 Helium Cooling

As the water content in the target leads to the not wanted effect of premoderation in the target, helium cooling was investigated. The main question under the restrictions of an operation pressure below 10 bar and an helium velocity in the cooling gaps below the speed of sound is:

'What is the upper beam power limit for helium cooling?'

The thickness of the first target plates was decreased to 2 mm to give a heat flow of 300 W/cm^2 in the centre of each plate surface. While the average velocity of the helium is 360 m/s in the gaps the average heat transfer coefficients are 0.4 W/cm^{2}K under a He-pressure of 5 bar and 0.7 W/cm^{2}K under 10 bar. The figure 4 shows a viewgraph of the maximum helium and plate center surface temperature as a function of the proton beam power.

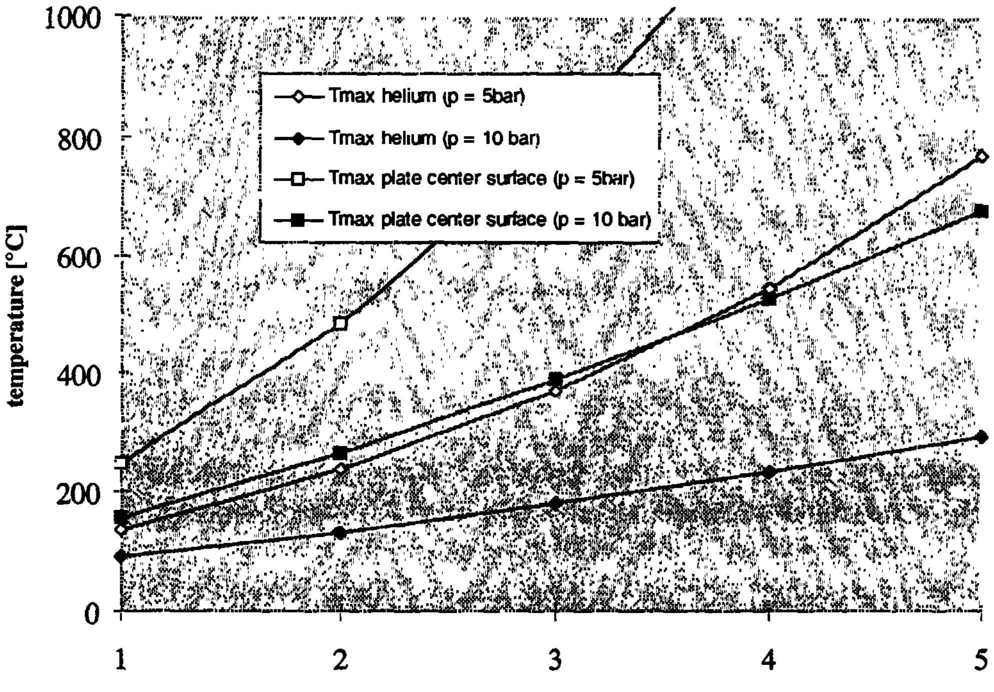

Figure 4 Maximum temperatures of the plate surface and the helium as function of the proton beam power

Conclusion: If the same plate temperatures would be accepted as in case of water cooling, the beam power should be ≤ 1 MW if the He-pressure is 5 bar and ≤ 2 MW if the He-pressure is 10 bar.

4. Mechanical stress in the target plates

So far, calculations have been made on the basis of an averaged, constant heat input and water cooling giving as results maximal stresses of about 50 MPa in the thinnest and 210 MPa in the thickest target plate. These values might be effectively reduced by slitting the plates. Pure unirridiated tantalum might stand 150 MPa at the operating temperatures; its characteristics could be strongly improved by choosing Ta-alloys.