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High Current Radioisotope Production with Solid Target System

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1. Introduction

Remotely manipulated solid target systems have been developed at TRIUMF for the production of ^{201}Tl, ^{67}Ga, ^{111}In and ^{57}Co radioisotopes. An extension of these systems to accept a 400 μA 30 MeV proton beam has been designed. The design criteria included keeping the temperature of the water-cooled silver face of the target below 140° during irradiation. A combination of computer modeling and actual measurements employing thermocouples indicate the temperature to be significantly lower thereby permitting even higher beam currents. This paper will present these results and conclusions and also summarise the refinements and changes made to the hardware of the target stations and transfer system which feature high radiation hardness components to minimize maintenance and improve reliability.

2. Isotope Production at TRIUMF

Two isotope production cyclotrons (42 and 30 MeV) are operated at TRIUMF for Nordion Int. Inc. A total of four external beam solid target stations are in use (in addition to gas and PET targets). The solid target irradiation and transfer system was designed and built at TRIUMF a decade ago and a few minor improvements have been made over the years of operating these systems although the basic concept has remained the same [1,2].

A new target system [3] is being designed which, while still being based on the existing setup, incorporates several significant changes and improvements following past experience and the demand arising from the increase in beam capacity available (up from 6 to 12 kW per beamline). Construction of a prototype station was started last year with completion and installation scheduled for later this year.

3. Target

Figure 1 shows an unassembled 12 kW solid target with its shuttle in the background:

Fig. 1. The new 400μA/30 MeV (12kW) target.

The target is assembled from two major components: a pure silver substrate incorporating integral water cooling channels, and a copper plated aluminum body. These two parts are soldered together to form one assembly. The target material is electroplated onto the silver face and exposed to the particle beam at a 7° angle to spread the beam out over the 43×100 mm^2 active area. The cooling water flow patters was optimized

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by the shape of the cooling channels in the silver to keep the surface temperature below 140° at the center for a 12 kW beam. This criterion is essential where low melting point target materials are used. In practice, 400μA represents about 90% of the beam at the target station since about 10% of the beam is trimmed off on four collimators which form a rectangle shadowing the edges of the target face. After the removal of the electroplated target material these targets can be reused (about 10 times) after a short cooldown period.

4. Target Station

The station is shown in Figs. 2 and 3. Three modular subassemblies are mounted on an aluminum stand: landing terminal, vacuum/irradiation chamber and manipulator. By designing the target in such a way as to take maximum advantage of the geometrical limitations imposed by the existing hot cell receive terminals and the transfer lines to the irradiation areas it was possible to leave these components of the solid target system unchanged.

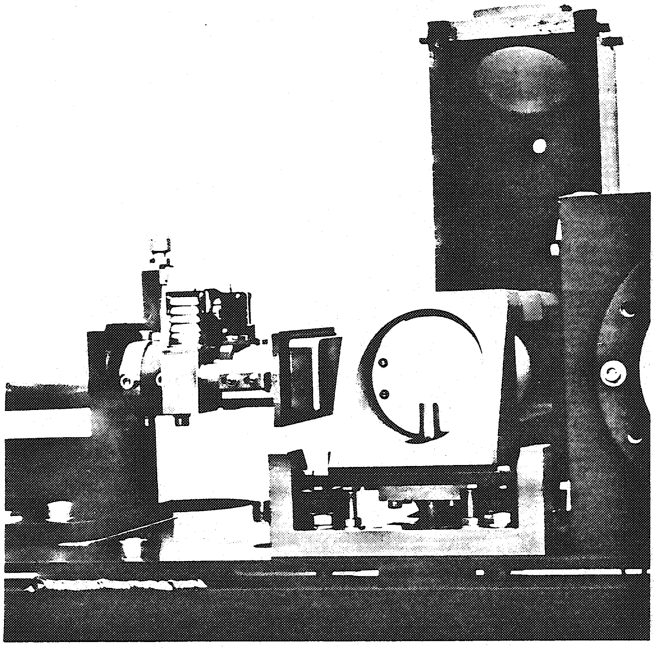

Fig. 2. The higher power (12kW) solid target station.

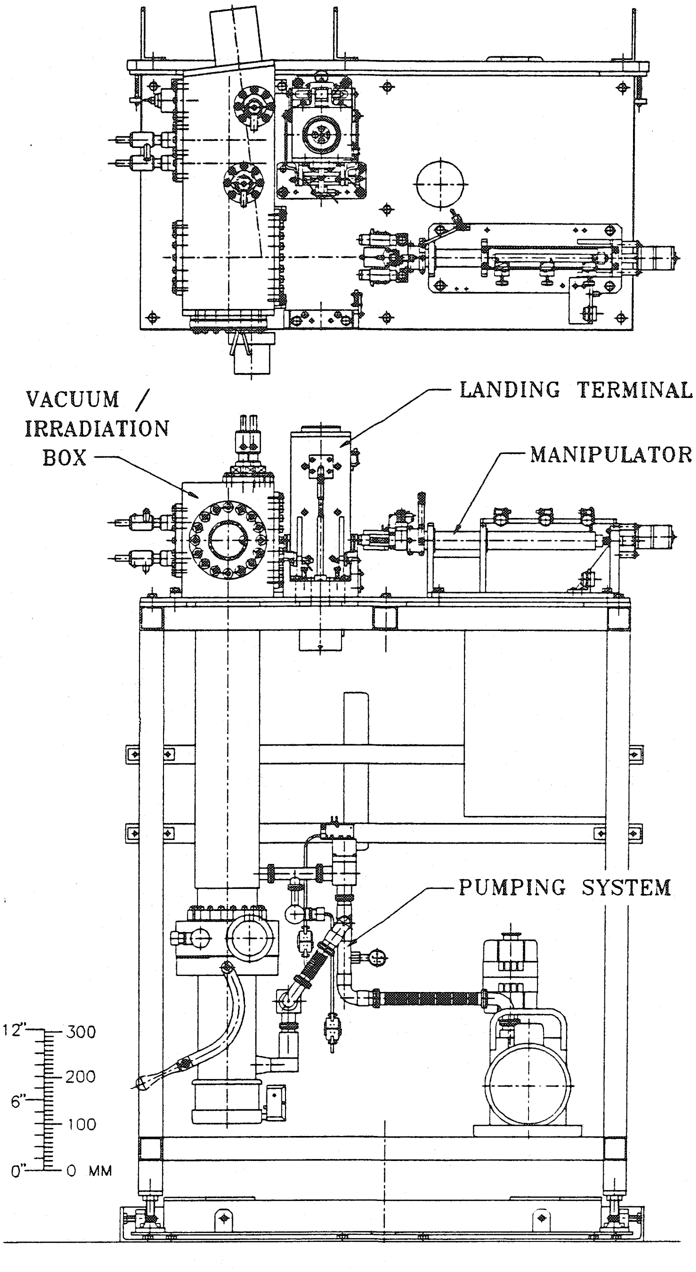

Fig. 3. Front elevation and top view of the 12 kW target station.

During operation the target (in its shuttle or "rabbit") is transferred via an air chute between the hot cell terminal and the target station. Its progress along the transfer line is monitored by a series of detectors actuated by a permanent magnet attached to the rabbit. The final detector, located close to the station, actuates a reverse air flow inside the landing terminal which acts to slow the rabbit to a "soft landing". During its descent the rabbit is oriented the required way (i.e. to face the extraction manipulator) by permanent magnets placed inside the terminal walls.

As the target is removed from the rabbit by the manipulator grabber cooling water connections are engaged. After the empty rabbit is returned to the receive terminal in the hot cell the target is moved into the irradiation position in the vacuum chamber and the chamber is then pumped down before beam is put on the target.

The complete operational cycle, as well as all interlocks, are controlled by an industrial programmable logic controller. Typically, complete target changes from the end of an irradiation on a target to the start of beam on the subsequent target take about 20 mins.

5. Radiation Hardness

Past experience with the existing 6kW target system has shown some downtime caused by radiation damage to certain components. Bearing this in mind the present high current design had the aim of minimizing this damage by prudent choice of materials and locations of components with respect to the beam and target. Pneumatic cylinders, for example, are fitted with graphite pistons and rod seals. The vacuum chamber employs metal seals in specially designed seats (Helicoflex) on all ports except the target flange. The elastomer O-ring on the target is used only for one irradiation. Electrical isolation is achieved by hard anodizing on aluminum or polyimide plastic ("Vespel" from Dupont) components.

Long-term testing under actual operating conditions for these materials (as well as others chosen for electrical wiring, water connections, etc.) proved their radiation hardness and suitability for this application.

6. Target surface temperature

An essential parameter in the target design was the surface temperature which should be kept below 140° [1]. Finite element analyses were made [4] of the heat flux and temperature distributions in the solid targets under different operational conditions. The existing target configuration and operational parameters were taken as a departure point and the various parameters were varied in order to establish limitations and ways of improving the thermal performance of the design.

To actually measure the temperature a special target was constructed. The silver face was coated with kapton except for certain spots which were masked off. The kapton was then cured and a thin layer of nickel was plated on top to produce a series of Ni/Ag thermal junctions with which the actual surface temperature (at the various locations) could be directly measured. The concept was tested on a running production target up to 7.5 kW and will be repeated up to 12 kW or more when the high current target system is in place. Extrapolation of the results (see Fig. 4) indicate a surface temperature actually lower than that expected by calculation. We anticipate a temperature rise of 70° above that of the inlet cooling water (~ 20°).

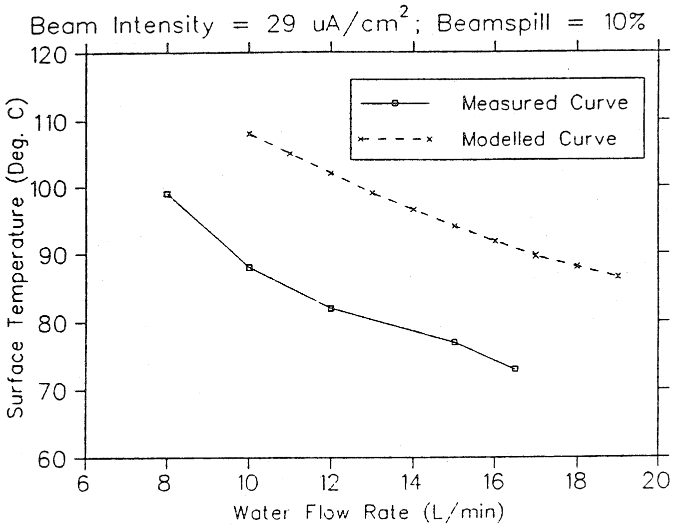

Fig. 4. Surface temperature predictions and measurements.

7. Conclusion

The existing solid target system at TRIUMF will be replaced with a high power system in the near future. This will permit full usage of the beam available from high current cyclotrons such as the EBCO TR30, installed at TRIUMF two years ago.

8. REFERENCES

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