Development of a Cryopanel for the MAFF Beamline

P. G. Thirolf, M. Groß, D. Habs, and H.-J. Maier

A considerable fraction of the radioactivity produced in the MAFF fission target will consist of short-lived gaseous activity, like Krypton or Xenon fission products or the halogens Bromium and Iodine. It is intended to prevent migration and release of these volatile fission products by localizing them on a He-cooled cryopanel until transformation into non-volatile species by β decay. The required operational temperature below 20 K results from the vapour pressures of the gases and vapours that have to be pumped. At this temperature the usual rest gas components (except hydrogen) as well as the fission isotopes of Kr, Xe, Br, I will be frozen at remaining vapour pressures in the UHV region ($\leq 10^{-11}$ mbar). Such cryopanels will be installed in the MAFF beamtube at either side of the fission source (SR6-a and SR6-b). The design specifications for the cryopanel to be installed in both sides of the MAFF beam tube close to the fission source have to meet various partly contradicting requirements.

Limited by the inner diameter of the beamtube (250 mm) as well as by the MAFF fission source required to be moved inside the cryopanel, a compact design had to be developed, allowing in addition for a surrounding liquid nitrogen shield in order to minimize heating from the outside. As an adequate solution a double-wall tube (gap width 4 mm) with 6 spiral-like separated sections for in- and outlet of the cold He gas was designed, which is shown in Fig. 1 together with the surrounding nitrogen shield following the same concept. The same concept of double-wall tubes is used at the ultracold neutron source project UCN at the FRM-II. The cryopanel length is 1 m, the inner diameter of the He double-tube amounts to 157 mm, the minimum value needed still to be able to move the fission source inside the cryopanel. The outer diameter of the surrounding liquid nitrogen shield will be 240 mm, leaving 5 mm gap to the wall of the beam tube. The cryopanels will additionally provide the necessary high-vacuum conditions close to the fission source. The pumping capacity of the cryopanels is depending on the pressure and the gas type, amounting to about 12.7 $ls^{-1}cm^{-2}$ for nitrogen and 5.9 $ls^{-1}cm^{-2}$ for Xenon. The overall pumping capacity of the cryopanels on each side of the beam line will amount to about $8 \cdot 10^4 ls^{-1}$ for nitrogen and $4 \cdot 10^4 ls^{-1}$ for Xenon.

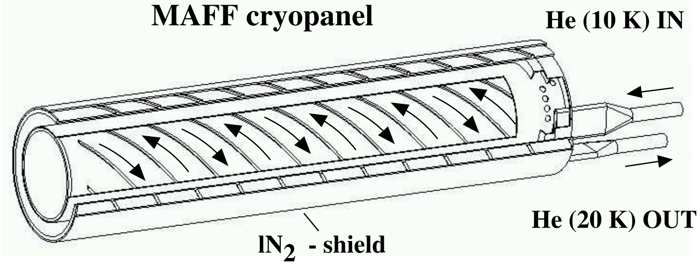

Fig. 1: Cryopanel for the MAFF beamline, designed for localizing short-lived gaseous radioactivity on the He-cooled panel surface. The He panel is surrounded by a liquid nitrogen shield.

Given the proximity to the source of the high neutron flux in the central region of the FRM-II, nuclear heating will considerably affect the cooling power required for an efficient operation of the cryosystem. Within a distance of about 1.6 m from the center of the neutron source nuclear heating (neutrons and γ) is estimated to about 170 mW/g of material exposed to the neutron flux. Thus keeping the cooling power and therefore the costs of the cryosystem in an affordable range limits the tolerable wall thickness of the cryopanel. However, safety regulations for pressure vessels within the framework of the German 'Druckbehälterverordnung' impose minimal standards on the wall thickness. Therefore integrity calculations were performed by the TÜV Rheinland in order to confirm that the foreseen wall thickness of 2 mm aluminum meets the stability requirements even in case of warming-up and subsequent expansion of the He inventory within the cryopanel unit, designed for an maximum overpressure of 5 bar. From these conditions a heating power of about 300 W was estimated (without nitrogen shield) that has to be cooled on either side of the MAFF fission source, requiring a He gas refrigerator for MAFF with a cooling capacity of about 1 kW. The He mass flow in the cryopanel will be 20 g/s at an input pressure of 1.8 bar.

Aluminum of the type 6061-T6 was chosen as material for the cryopanel because of its cryogenic specifications needed for the operation at an input temperature of 10 K, while the output temperature will be about 20 K. In addition material specifications and certificates for the use in a nuclear reactor environment already exist for Al 6061-T6, clearly facilitating the mandatory approval procedure. However, this material is not available on the European market and even quite some effort had to be invested to acquire seemless tubes of the right diameters from a US company.

In view of the cryopanel design shown in the Fig. 1 it is obvious that manufacturing the cryopanel requires special techniques and a prototyping phase to build up the technological knowledge, especially for the reliable connection between the inner and outer wall of the cryopanel tube by cryogenic shrinking. Furthermore it has to be guaranteed that all welding seems still allow for X-ray testing. It was decided to undergo this process from the start under the responsibility of a company that would also be able to manufacture the final system that has to be built under strict nuclear technology regulations and auspices by the approval agencies. Thus, based on our initial design, the company ACCEL (Bergisch Gladbach) will produce a prototype of the He cryopanel expected to be delivered in May 2002. It will be installed in the test beamline setup at the Garching accelerator laboratory and connected to the existing He refrigerator unit in order to allow for cooling tests in a geometrically realistic environment.