T2K Target

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Abstract. We have reported the current development status of the graphite target for J-PARC neutrino beam-line. The conceptual design, the lifetime estimation, the cooling method based of the latest design, and the prototype productions are discussed.

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J-PARC ν BEAM LINE

The Tokai-to-Kamioka experiment (T2K) [1] is a next generation neutrino experiment, where the neutrino beam from Japan Proton Accelerator Research Complex (J-PARC) [2] in Tokai village travels 295 km before reaching the far detector, Super-Kamiokande (SK). The main topics of the T2K experiment are the search for the $\nu_\mu \rightarrow \nu_e$ appearance and the precise determination of neutrino oscillation parameters by the $\nu_\mu \rightarrow \nu_x$ disappearance. In the T2K experiment, we expect a ν_μ beam of about 100 times more intense than that in K2K, the on going long base line experiment in Japan.

The neutrino beam in T2K utilizes the ν_μ from π meson decays, where pions are produced by injecting protons from the J-PARC main ring (MR) to a target by a fast extraction. At the beginning of the experiment, MR accelerates 3.3×10^{14} protons to 30 GeV every 2.1 s and its beam power reaches 0.75 MW. Graphite is an unique solid material which can stand against the thermal shock. The maximum instantaneous temperature rise is 200 K and the heat load for the target is about 20 kW. The target is cooled by Helium gas. Target is installed inside the magnetic horn to focus the secondary pions towards SK direction. Thus the available space for the target is limited and the electrical insulation between the target and horn should be considered. The target and Horns are installed in the Huge He vessel.

CONCEPTUAL DESIGN OF T2K TARGET

Figure 1 shows the conceptual design of the T2K target. The target consists of isotropic graphite, IG-430 made

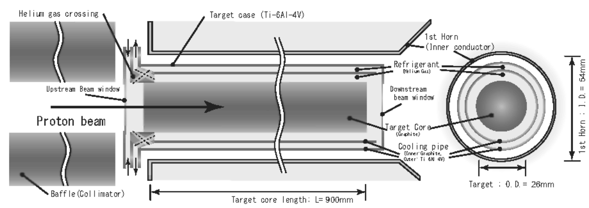

FIGURE 1. Conceptual design of T2K target

by Toyo Tanso Co. Ltd. It is installed inside the co-axial 2-layer pipe for the helium gas cooling where the inner pipe and outer pipe are made of graphite and Ti-6Al-4V, respectively. The target is detachable from 1st horn for the maintenance and exchange. The target temperature will be controlled between 400 $^\circ C$ (at the surface) and 700 $^\circ C$ (at the center) in which the the radiation damage of the graphite is minimum. Because of the its high temperature, the target lifetime is limited by the oxidative consumption by the air impurity in the helium gas. Thus the graphite parts are installed into the container made of Ti-6Al-4V and the purity of the refrigerant helium is kept high as mush as possible. The container has two beam-windows and they also should be cooled. The flow path of helium gas for target cooling is designed helium gas to cool the beam windows and target simultaneously.

We have estimated the lifetime of the target by estimating the safety factor which is defined as the tensile strength divided by the thermal shock stress. The safety factor of IG-430 is 3.5 before the oxidization. The speed of the oxidization of IG-430 at 800 $^\circ C$ measured in the helium atmosphere with 1,000 ppm oxygen is 4.0×10^{-5} mass%/hour/ppm [3]. The tensile strength of the oxidized graphite is measured as the function of the oxidative consumption. If the oxidative consumption

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become 4.5 %, the tensile strength become 60 % compared to the non-oxidized specimen [3]. We have estimated the safety factor of the target as the function of the beam-operation period from the speed of the oxidative consumption and the degradation of the tensile strength by assuming that the graphite temperature is 700 $^{\circ}C$ and that the oxygen concentration in the refrigerant is 100ppm. The estimated safety factor for the thermal shock is greater than 2 for 5 years operation.

TARGET STRUCTURE AND HELIUM GAS COOLING SIMULATION

We have almost finished the detailed design of the target structure and the flow of refrigerant helium. (Figure 2) The refrigerant helium gas is supplied from the intake pipe of the target container and stored in the buffer region at the outer circumference of the upstream region. Then, the helium gas flows along the upstream beam window of container. After cooling the upstream beam window, it is led to the gap between the outer pipe and the inner pipe through the six holes of the target graphite. It reaches the downstream end of the container and cools the downstream beam window. Then the helium gas change the flow direction towards the upstream. If flows through between the gap between the inner pipe and the target core and refrigerates the target core. Then the helium gas arrives at another buffer region at the outer circumference of the upstream part and return to the helium gas compressor at the machine room via the custom-made heat exchanger which is installed in support structure for the magnetic horn.

We have estimated the steady state temperature of the target and the pressure distribution for the helium gas by FEM simulation assuming the actual target design. We have checked that the target and Ti-alloy beam windows will be cooled efficiently. We have performed the Helium flow test by using the mock-up which has the same path for helium gas as the actual target, the custom-made heat exchanger and the actual He circulation system of which diagram is shown in Figure 3. We measured the helium gas flow rate and the pressure drop. The achieved flow rate is 606 Nm^3/h which corresponds to the helium gas speed of 204 m/s, while the requirement is 500 Nm^3/h. The pressure drop at the 1st heat exchanger is larger than the expectation, but it is within the Helium compressor capacity. We plan to do the 20 kW cooling test using the actual helium compressor system.

MANUFACTURING OF THE PROTOTYPE

We have made the prototype of the target components to confirm that they are manufactured with sufficient accuracy. The graphite parts, the target core and the inner cooling tube with 2mm thickness, are successfully obtained. We tested two methods of the graphite-graphite bonding. One bonding test-piece has a thread structure, and another one does not have a thread structure. Because the two methods are comparable, we are making two full-prototypes with actual structure in both type. We also made the thin Ti-alloy parts, Thin outer cooling pipe with the 0.3 mm thickness and the downstream beam window with 0.3 mm thickness, successfully. The joint between the outer-pipe and the downstream beam window by a micro-plasma welding is in good shape.

SUMMARY AND PLANS

The graphite target for T2K is cooled by helium gas and it is installed in Ti-alloy container to reduce oxidization. We can keep the safety factor against the thermal sock greater than two for five years, if we can keep the oxygen concentration less than 100 ppm. The design of the target structure is almost finished. Helium gas cooling scenario is confirmed by FEM simulation and the test with the mock-up and actual compressor system. We have checked that it is possible to produce graphite-parts and thin Ti-alloy parts and the bonding between graphite parts is in good shape by manufacturing prototypes. We are making the target prototype with actual structure and it will be delivered in Dec. 2007. T2K target will be installed in Autumn 2008 in the beam line.

REFERENCES

1. http://www-nu.kek.jp/jhfnu/index_e.htm
2. http://j-parc.jp
3. The oxidization speed of IG-430 and the tensile strength of the oxidized IG-430 are measured by Toyo sanso Co. Ltd. commissioned by KEK.

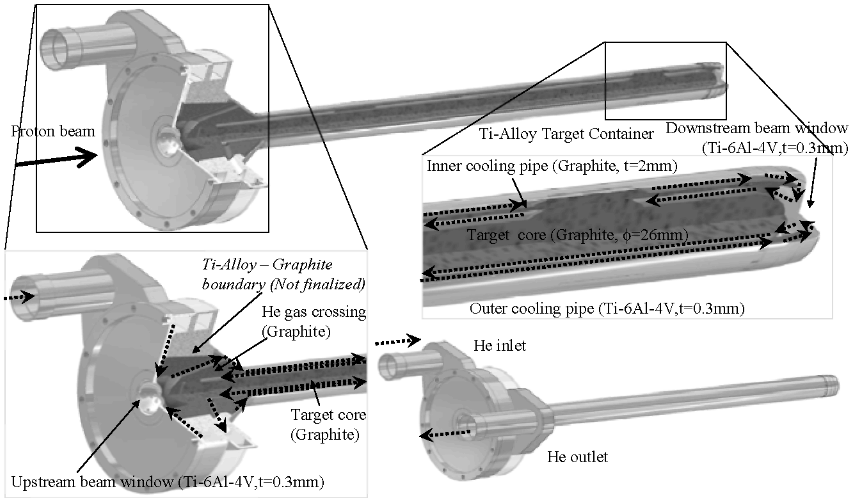

FIGURE 2. Detailed design of T2K target

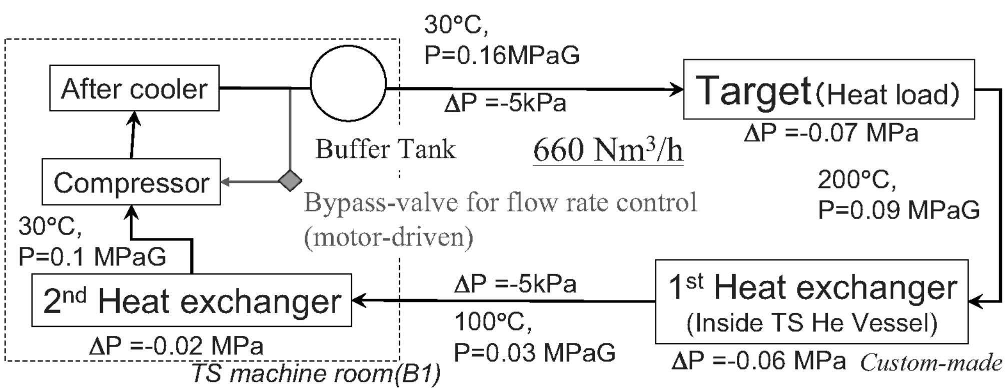

FIGURE 3. Diagram of the helium circulation system for the T2K target cooling