dense granular flow target (DGT), which has the advantages of both the solid and liquid targets. DGT is designed with fluidized solid grains, which can effectively solve the problem of heat removal. As the target medium, the small diameter tungsten (grains) not only produce the neutron, but also transfer the heat deposed in the system by proton beam, and the removal capability is more than twice that of the usual liquid metals. Meanwhile, the dense granular flow can avoid instability of ordinary hydrodynamic fluid. Furthermore, theoretically fluidized solids target can bear more than a few dozen of MW beam power.

DGT uses tungsten grains as spallation material, leading to better neutron science characteristics while maintaining lower corrosive and product toxic. At the same time, because of the stability of granular flows, it has simpler design parameters. The program uses a redundant, fault-tolerant design: select mature industrial products, technology and relatively conservative operating parameters, maximize equipment life and reliable operation, and enhance security of accident conditions.

Preliminary calculations of this target show that the CIADS desired target with 2.5 MW beam power have an average temperature of less than 550 °C at the outlet, and 10 MW target system have an average temperature of less than 650 °C at the outlet. As soon as the DGT was put forth experts in this area made positive comments and showed great concerns: CERN neutron had beam experiments with a number of European laboratories; Belgium MYRRHA team had arranged staff and funding to carry out related designs. At present, the technical verification of DGT has already started.

**References**


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# 5 - 13 Thermohydraulics Experimental Research Progress of Spallation Target

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In order to verify the simulation results of the liquid metal target and the granular flow target, the spallation target laboratory have established several experimental benches and carried out some related experiments on these benches.

**1. Liquid Target Research**

A water loop has been established in 2012 for investigating the flow behaviors of water in windowless target and has been rebuilt in 2014 for experiments of window target. The experiments are conducted in an approximately 1:1 sized window target model shown in Fig. 1. The flow pattern inside the spallation area is visualized by means of the particle image velocimetry (PIV). The flow range of the present experiment is between 8.4 and 20 $m^3/h$, and several typical flow patterns are observed under the conditions of different inlets and outlets.

For researching behaviors of LBE (Lead-Bismuth Eutectic), LiMeTS (Liquid Metal Test Stand) was constructed by PSI (Paul Scherrer Institute) and has been handed over to IMP (Institute of Modern Physics) under a cooperation framework between PSI and IMP. LiMeTS has been transported at IMP in September 2014 and assembled in January 2015, which is shown in Fig. 2. LiMeTS was divided six independent parts in the transportation and combined together with the help of an integral platform. Then the electric lines and gas pipes are being connected in recent months. LiMeTS will play a vital role in the future research as a solid experimental basement.

Fig. 1 (color online) Window target model in the water loop.

Fig. 2 (color online) The photo of LiMeTS.

Fig. 3 (color online) The photo of STELA.

To be able to carry out the full-scale experiments with LBE, a large test facility STELA (Spallation Target Experimental Loop for ADS) has been constructed and installed in October 2014 as shown in Fig. 3. STELA mainly consists of the electromagnetic pump, air-cooled heat exchanger, impurities filter, electromagnetic flowmeter, expansion tank and sump tank. The maximum operation temperature of STELA is 600 °C and the maximum flow rate is up to 27 $m^3/h$. In the past few months, STELA was adjusted by testing all electric lines and instruments and flushed with high purity argon before and after heating. About 5 000 kg LBE was filled in the sump tank by using an appropriative melting tank. Based on STELA, the heat transfer characteristics of LBE/air and cooling of beam window will be studied.

**2. Granular Target Research**

The experiments are carried out in a spiral hoist which is established with specially shaped glass target. Stainless steel beads with the diameter 1.5 mm were used as granular flow materials. The vertical spiral hoist cannot elevate stainless steel beads from the hopper of spiral hoist to the top of the channel. In order to research the jamming transition problems in granular system, oblique spiral hoist with an inclination angle of 60° is used in our experiment. As shown in Fig. 4, with the increase of import flow, a dilute-dense transition of granular flow is observed. In particular, the system shows a balance interface between dilute flow and dense flow.

A test facility based on bucket elevator for granular target mechanical driven was built to investigate the transition phenomenon of the granular flow in spallation area (Fig. 5). It has a fixed speed driver mounted at the head of the elevator and powered by a 55 kW motor and gearbox, which drives the buckets at a speed of approximate 5.0 m/s. The range of the granular flow is from 20 to 200 $m^3/h$.

For studying the properties of granular flow and granular heat transfer, a big tank (Fig. 6) filled with inert gas was used to carry out granular flow experiments. A heap of steel beads and copper beads flowed through a pipe with cooling gas and without cooling gas. The outlet of the pipe had different shapes and angles. The experimental

Fig. 4 (color online) The oblique spiral hoist with an inclination angle of 60°.

Fig. 5 (color online) The mechanical driving test system for the granular target.

Fig. 6 (color online) The facility for static granular heat transfer experiments.

results showed that different outlets decided different granular flow morphologies. The heat transfer properties between static beads and flowing beads were also measured under different pressures of inert gas.