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Title: THERMAL HYDRAULIC ANALYSIS OF LANL/IPPE/EDO-GP IMW LBE TARGET

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Thermal Hydraulic Analysis of LANL/IPPE/EDO-GP 1MW LBE Target

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The Accelerator-driven Transmutation of Waste (ATW) concept has been proposed by the United States and other countries to transmute plutonium, higher actinides, and other environmentally hazardous fission products. One of the key components in the ATW concept is a target which, via spallations, produces neutrons to transmute nuclear wastes. Since significant heat is generated during fissioning of the waste actinides, an efficient heat removal system is necessary. Liquid lead-bismuth eutectic (LBE) is an efficient coolant as well as a good spallation target for production of neutrons. The LBE coolant technology has been successfully used in Russian submarine's nuclear reactors.

The International Science and Technology Center (ISTC) has funded the Institute of Physics and Power Engineering (IPPE) and the Experiment and Design Organization-"Gidropress" (EDO-GP) of Russia to design and manufacture a pilot target (Target Circuit One - TC1) that incorporates Russian LBE technology into the ATW concept. The target is going to be tested in the 800 MeV, 1 MA proton beam at the Los Alamos National Laboratory (LANL) in two years. These target experiments will provide valuable information on the performance of LBE as both spallation target and coolant. They will also help to design target/blanket systems for future ATW facilities.

As a part of the preparation for the beam-on test, we have carried out a thermal hydraulic analysis for the TC1 target. The proton beam from an accelerator is injected into the target through a steel window. Liquid LBE flows in from an outer annulus channel, sweeps over a target window, and flows out from an inner channel. A diffuser plate is placed near the window to enhance flow around the window center, where the heat deposition from the proton beam is maximal. The heat deposition in the target uses the results from IPPE's neutronics calculations. Two scenarios are simulated, one for nominal beam power of 1 MW with at inlet temperature of 242°C and the other for 80% of the nominal one with an inlet temperatures of 235°C. The flow rate of liquid LBE is fixed at 14.2 m^3/h.

The thermal hydraulic analyses are carried out using two computational fluid dynamics software packages, FIDAP (licensed by Fluent Inc.) and CFX (licensed by AEA Technology). Both codes were carefully benchmarked and have been extensively used in many thermal hydraulic applications. FIDAP uses the finite-element method while CFX is based on the finite-volume method. Using two independent codes helps to reduce model-related uncertainties.

Up to today, we have carried out simulations with a 2D axi-symmetrical model. Studies with a 3D model are under way. The results from the 2D simulations show that the coolant flows through the target smoothly without any stagnation zone. This is important because recirculation may lead to undesired temperature buildup. Because of the diffuser plate, the majority of coolant is forced to sweep over the window center and pass through the center hole of the diffuser plate at a high speed (2.0 m/s). This swift flow of coolant plays a key role in cooling the center of the target window, where the energy deposition from the proton beam is the highest.

The calculated temperature ranges from 242 °C to 462 °C. The highest temperature occurs at the vacuum side of the target window center. This temperature range is within the proper working range for both the LBE coolant and the construction materials. The average temperature at the outlet is 360 °C. This temperature increase between the inlet and outlet is consistent with the total energy deposition in the target. There is a 30 ~ 40 °C temperature drop cross the window near the window center. The temperature variation in the target window is negligible 5 cm away from the centerline. The temperature in the diffuser plate varies from 250 °C to 280 °C, which is relatively small compared to that in the window.

The temperature distribution in the target with 80% nominal beam power is similar to that with nominal beam condition. The highest temperature still occurs at the vacuum side of the window but is reduced to 412 °C. The temperature drop in the window reduces correspondingly to about 25 °C.

In summary, we have carried out thermal hydraulic analyses for the LANL/IPPE/EDO-GP 1MW LBE target. It is shown that the current design is suitable for the beam-on tests. The diffuser plate successfully enhances the coolant flow around the window center but still manages to avoid generating circulation zone downstream. The temperature range is within the proper operation range for both the LBE coolant and the structural materials.

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