ICANS XIV
14th Meeting of the International Collaboration on
Advanced Neutron Sources
June 14-19, 1998
Starved Rock Lodge, Utica, IL

ICANS-XIV : Working Group Report

Critical Heat Flux : Limitation to Solid Target ?

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Scope and aims :
Heat transfer limit is one of the key issues which limit the use of solid target in high power beam neutron source. It has been often spoken about and considered in setting up a concept of liquid metal target. It has however never been discussed about this limitation in scientific and technological manner based on experimental data. The aim of this session is to collect the results of the recent experimental efforts in the world which investigate a critical heat flux (CHF) of a thin plate with a very narrow gap of cooling channel, and to discuss and find a limitation of solid target from heat transfer view point.

Presentations :
Takeda (PSI) gave an introductory remark on the various boiling regime and its relevance to the heat transfer in terms of boiling curve. He explained the definitions of critical heat transfer (CHF), departure from nucleate boiling (DNB) and burn-out point. He emphasised that the pattern of boiling curve is strongly dependent on geometry, flow condition, system pressure etc. and one has to be careful in using the data from other sources.

Mishima (KUR) presented the experimental data on the CHF for the thin plate with a 2 mm gap for cooling water with respect to flow rate. The data on CHF was compared with existing correlation curves by Burgles and Dittus-Boelter. He estimated target temperature vs. beam power.

Hino (JAERI) introduced their experimental data of the rectangular channel for plate target configuration with a bypass to simulate multiple channel flow. He showed the CHF against mass velocity, gap distance, influence of inlet temperature and heated length. The Influence of flow excursion, which may arise by being affected from other channels in parallel, was also reported.

Pitcher (LANL) read a paper about the work done for the APT target, where the target geometry is rod bundle and the inlet flow is two-phase. They investigated CHF with respect to inlet flow mass flux and beam power. It showed that a flow instability is quite important which occurs prior to DNB. The onset of flow instability (OFI) depends strongly on the liquid quality (dissolved gas) and on a bypass flow once it happens.

Conclusion :
All of these studies made a comparison with the existing correlation curves and confirmed that those correlation curves can be used for evaluating a heat removal of the solid target. They raised the numbers for the maximum beam power to be limited as roughly 1 to 5 MW/m^2. But these values are strongly based on the system parameters, which are yet unjustified.

Following note would be a useful conclusion as a guideline for design concept :

ONB : Onset of Nucleate Boiling limits a beam power for a normal operation.
OFI : Onset of Flow Instability is a limit of normal operation for two-phase flow cooling.
CHF : Critical Heat Flux is a real limiting factor but under a certain accident scenario.

$$Q_{ONB} \leq Q_{CHF}/n \text{ where } n=1 \ldots 10$$

Important note is that the CHF (Q_{CHF}) is a limit value and cannot be adopted as a design value. The design value should be based on the Q_{ONB}, which is far smaller than these values.