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Confined single- and multiple-jet impingement heat transfer in helium-cooled beam window assemblies at a cyclotron facility

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Abstract content
   (Max 300 words)

Helium-cooled metallic beam windows of typically only a few tens of micro-meter in thickness are often employed to isolate the cyclotron vacuum from radionuclide production targets. This is also done at iThemba LABS, where these targets are bombarded outside the vacuum. The window foils have to be thin to limit energy degradation and radial spread of the proton beams and they have to be cooled to prevent melting under high-intensity bombardments. Standard finite differences or finite element numerical methods can be used to calculate steady-state temperature profiles for these windows under different bombardment conditions. These codes, however, need to be supplied with sufficiently accurate convection heat-transfer coefficients as input data for the calculations to be meaningful. These coefficients are, in general, dependent on the cooling medium, flow rate, temperature, pressure and flow geometry. Published values often differ by more than an order of magnitude.

General purpose theoretical solutions for convection heat transfer with good predictive power do not exist. In many applications, an alternative way to introduce parameters is by using dimensional analysis. In the case of forced convection, three dimensionless groups are almost always found in correlations, namely the Nusselt, Reynolds and Prandtl numbers. Typically, either a power law or some other empirical expression is employed. While the mathematical forms of these correlations do not readily have a simple physical interpretation, the individual dimensionless groups do. Experimental correlations for single- and multiple jet impingement heat transfer obtained with freon as cooling medium were recently successfully applied to water-cooled fluorine-18 targetry at the Edmonton PET Centre. These rather surprising results prompted us to apply them to helium-cooled beam windows, an area where dimensional analysis was not very successful in the past. Good agreement with experimental data was obtained. Heat-transfer coefficients obtained in this way have been used in calculating temperature profiles for all bombardment stations under maximum bombardment conditions.

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