METHODOLOGY FOR FUEL CHANNEL INTEGRITY IN LARGE BREAK LOSS OF COOLANT ACCIDENT

M.H. BAYOUMI AND W.C. MUIR

Ontario Hydro, Reactor Safety and Operational Analysis Department
700 University Avenue, Toronto, Ontario, M5G-1X6

SUMMARY

During some postulated loss of coolant accidents, some fuel channels are cooled by degraded flow of superheated steam. As a result, the axial transport of heat from the fuel by convection is reduced and the radial heat transfer to the moderator by radiation and conduction becomes the dominant mechanism for heat removal. If the transient removal of the fuel decay heat plus the heat generated by the Zircaloy/steam reaction remains insufficient, rapid heating and resultant high temperature may cause fuel bundle and pressure tube chemical interaction and mechanical deformation and possible failure of the fuel channel.

Fuel channel integrity (FCI) during a large break loss of coolant accident (LBLOCA) is assured in order to demonstrate that the fuel remains in a known coolable geometry in all accident phases. In CANDU reactors, fuel channel integrity is demonstrated by analyses and supported by experimental results of various high fuel channel temperature transient experimental programs.

Factors affecting FCI during a LBLOCA are:

i. pressure tube ballooning under non-uniform circumferential temperature distributions[1,2,3];
ii. localized hotspots on the pressure tube due to fuel element/pressure tube or bearing pad/pressure tube contact[4];
iii. molten Zircaloy interaction with the pressure tube;
iv. thermal and chemical behaviour of the pressure tube and fuel sheath[5];
v. reverse flow impact of fuel bundles with channel component;
vi. fuel constrained axial thermal expansion;
vii. hydriding[6] and irradiation effects on pressure tube mechanical deformation; and
viii. moderator subcooling availability at the time of PT/CT contact due to PT ballooning.

The objective of this paper is to present a state-of-the-art overview of the methodology used to demonstrate fuel channel integrity in LBLOCA. The analytical tools used in the analysis and the experimental results used to support the analysis findings are discussed. The paper presents a comprehensive description of the current understanding and knowledge in support of fuel channel integrity in CANDU reactors.

REFERENCES

[1] BAYOUMI M.H., MUIR W.C., and KUNDURPI P.S., "Simulation of the Pressure Tube Circumferential Temperature Distribution Experiments (Boil-off Experiments)", Proceedings of the 4th International Conference on Simulation Methods in Nuclear Engineering, Montreal, Quebec, June 1993.

[2] BAYOUMI M.H., MUIR W.C., and KUNDURPI P.S., "Simulation of the Pressure Tube Circumferential Temperature Distribution Experiments (Variable Make-Up Water Series)", INC93: International Nuclear Congress and Exhibition, Toronto, Ontario, October 1993.

[3] BAYOUMI M.H., MUIR W.C., and KUNDURPI P.S., "Simulation and Investigation of the Pressure Tube Circumferential Temperature Distribution Experiments (Boil-off Series of Experiments)", presented at the 14th Annual Conference of the Canadian Nuclear Society, Montreal, Quebec, June 1994.

[4] BAYOUMI M.H., MUIR W.C., and MIDDELTON P.B., "Simulation and Analysis of Bearing Pad to Pressure Tube Contact Heat Transfer Under Large Break LOCA Conditions", presented at the 17th Annual Conference of the Canadian Nuclear Society, Fredericton, New Brunswick, June 1996.

[5] BAYOUMI M.H. et al, "Verification of CHAN-II (MOD 6) Against Experiments", presented at the 10th Annual Conference of Canadian Nuclear Society, Ottawa, Ontario, Canada, June 1989.

[6] MUIR W.C. and BAYOUMI M.H.,"Simulation and Analysis of the Thermal and Deformation Behaviour of "As-Received" and "Hydrided" Pressure Tubes Used in the Circumferential Temperature Distribution Experiments (End of Life/Pressure Tube Behaviour), presented at the 15th Annual Conference of the Canadian Nuclear Society, Saskatoon, Saskatchwan, June 1995.