*Transactions of the Korean Nuclear Society Spring Meeting*
*Jeju, Korea, May 23-24, 2019*

# PTLEAK – Program for Assessing the Channel Flow and Margin to Dryout of the CANDU Fuel Channel

Jong Yeob Jung [a*], Eun Hyun Ryu [a], Sunil Nijhawan [b]
[a]*Thermal Hydraulics Severe Accident Research Division, KAERI, Daedeok-daero 989-111, Daejeon, Korea*
[b]*Prolet Inc., Toronto, Canada*
[*]*Corresponding author: agahee@kaeri.re.kr*

## 1. Introduction

Degradation of fuel cooling and a departure from initial safety margins in the CANDU fuel channel may be caused either by a loss of overall flow along a fuel bundle due to an upstream loss of coolant or by a larger fraction of the flow bypassing the innards of the fuel bundle due to an enlargement of the pressure tube.

Since about 90's, we have analyzed an inlet feeder breaks that would cause flow stagnation (Stagnation Feeder Break Accident – one of the design basis accident for single channel event) in licensing safety assessments. A flow stagnation is defined as a range of break sizes (break discharges) at a specific locations that causes the flow downstream to decrease low enough to cause a fuel dryout (beyond CHF thermal hydraulic behavior).

In this study, we have developed a computer program PTLEAK which can assess the channel flow and margin to dryout of all 380 fuel channels at the same time. This code uses a library of raw feeder geometry data from the station based on the files used in the design calculations (NUCIRC) and also uses derived data on nominal channel powers under equilibrium core conditions. PTLEAK can be used in identifying the range of breaks that causes flow reduction on some or all of the fuel string down-stream of the break. For a specific break size it can be easily extended to compute fuel temperatures.

## 2. Purpose of PTLEAK

The purpose of computer code PTLEAK is to:

① Calculate channel flows and margins to dryout in the fuel channel after a break at any location within the flow path from inlet header to outlet header.

② Compute the effect on steady state channel thermal-hydraulics of pressure tube creep and feeder thinning with or without breaks at any chosen location in the channel flow path between the headers.

An axially variable diametrical creep profile of each fuel bundle location can be input to see the effect on channel flows and hence on margins to dryout. Since the effect of pressure tube creep on changes in overall and local flow redistributions is influenced by inlet and outlet feeder geometry and power profiles, the code allows a parametric assessment of effect of creep on a whole reactor basis. The effect of feeder thinning on channel flows is included by assuming a uniform thinning of all segments of the inlet feeders and another uniform thinning of all segments of outlet feeders.

When looking at effects of leaks and breaks in the flow path, a break can be postulated in any location at the feeders, end fittings or pressure tube and a range of break discharges at each location is automatically considered to determine the range that will cause flow degradation in parts of the fuel bundles that is significantly enough to cause fuel dryout. Onset of dryout is determined by comparing the heat and flow fluxes to dryout heat flux data and a number of correlations at local enthalpy and pressures.

## 3. Verification of PTLEAK

Analysis using the code PTLEAK can help identifying leak or break sizes at specific locations that can cause flow degradation in the fuel region such that the fuel integrity is challenged and perhaps channel integrity is also threatened. Fig. 1 shows the break locations and the effect of break on the fuel degradation in the fuel channel.

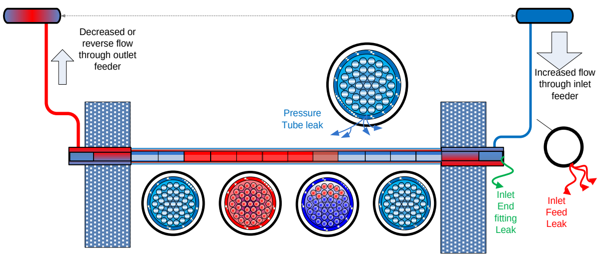


Fig. 1. Break locations and its effect on fuel degradation.

A number of code verification exercises are undertaken during its development. For one it compares computed flows to the corresponding 'design' channel flows at full power level. Fig. 2 shows the code prediction results of channel flows and compares them with the designed flow data. Comparison shows an average deviation is not much than 2.8%. Fig. 3 shows the majority of channel flows are calculated with difference between the predicted and design numbers no more than 1.0%. In this calculation, deformation of feeders or pressure tubes is not considered.

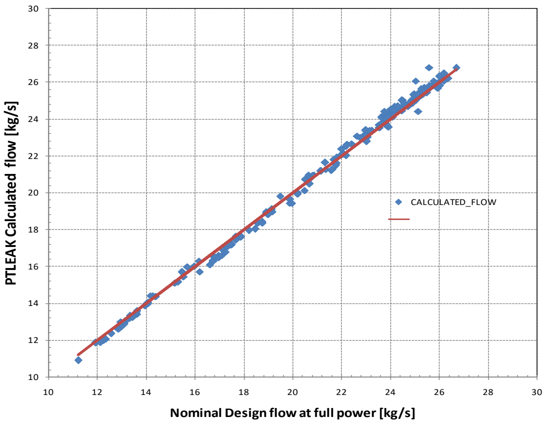


Fig. 2. Comparison of nominal channel flows from PTLEAK and design data at full power condition.

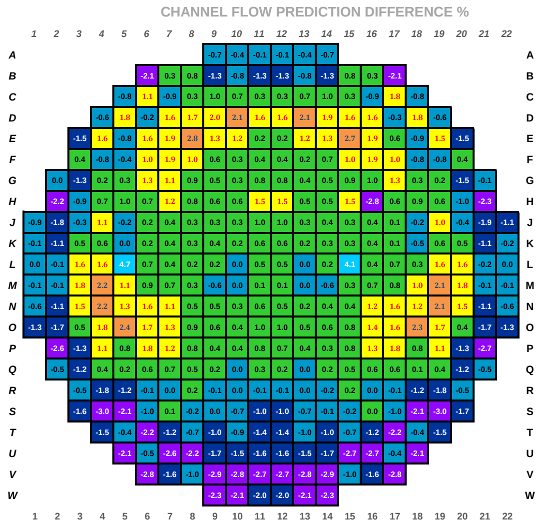


Fig. 3. Difference between predicted and design data.

Channel pressure drop data were extracted from Ref. 1 to verify the code for its prediction of channel flows and pressure drops before, within and after the fuel channel. Fig. 4 shows that the pressure distribution prediction as well as the inlet pressure are well predicted.

A novel approach to performing channel thermal hydraulic analysis is used. Instead of specifying a specific break size, a range of break discharges at the specified break location are postulated by varying the channel inlet flows over a wide range, recognizing that any break in a fuel channel any location would first increase the channel inlet flow. The reduced local pressure at the break location is then used to iterate the flows from that location to the outlet header. This gives an exact prediction of the break discharge which for specific local fluid properties provides an estimate of the break size. When the break is such that reverse flow from the outlet header to the break is predicted, a range of break sizes is estimated to incorporate mixing of the fluid returning from the outlet header.

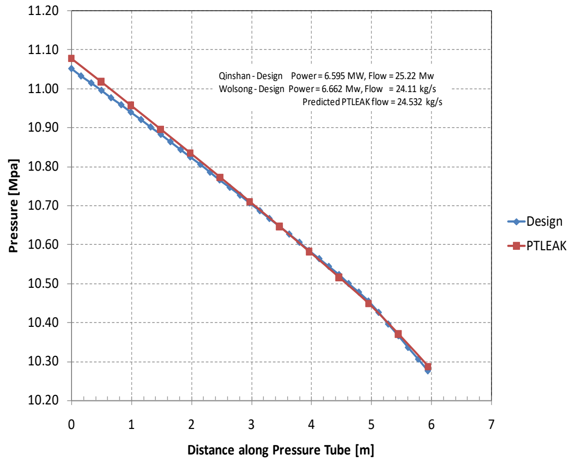


Fig. 4. Pressure drop along the pressure tube against design data for high power channel O6.

Header-to-header pressure drop is calculated to account for friction and/or geometry changes in the flow path that consists of a number of specific geometries and interfaces between them (feeders, end fittings, fuel). The pressure losses of each component are calculated by a reference pressure drop model in which the pressure drop is evaluated for a given flow and density and component specific loss coefficient and a flow dependent iterative friction factor.

When the fluid is in two-phase, a two-phase flow multiplier is applied to the single-phase pressure drop. The Martinelli-Nelson correlations for the two-phase flow multiplier are used. The void fraction for the two-phase pressure drop calculation is evaluated assuming that the two-phase flow is homogeneous (no slip).

## 4. Conclusions

The computer code PTLEAK which can calculate channel flows and margins to dryout in the fuel channel after a break at any location from inlet header to outlet header was developed. The code also can compute the effect on steady state channel thermal-hydraulics of pressure tube creep and feeder thinning with or without breaks at any chosen location between headers.

PTLEAK may be used in assessing the conservatism of former safety analysis for single channel event in any channel of 380 fuel channel.

## Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science and ICT). (NRF-2017M2A8A4017282).

## REFERENCES

[1] 98-33100-DM-000, Primary Heat Transport System Design Manual, Rev.0, July 1997