Implementation of Boundary Condition to THALES Code

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1. Introduction

The boundary condition of momentum equation of THALES code utilizes the exit pressure boundary to solve the elliptic partial difference momentum equations. This method is the same as the most of the subchannel analysis codes. Other codes such as VIPRE utilize the uniform pressure distribution as outlet boundary condition. In this case, uniform inlet flow rate is assumed.

2. Thermal Hydraulic Models in THALES

The COBRA type code is generally used for thermal hydraulic analysis in PWR (Pressurized Water Reactor) cores. The COBRA[1] type codes utilize the following pressure boundary condition.

$$dpi_{k-1} = dpi_k - \Delta z_k \left[(dp/dz)_i - (dp/dz)_j \right]_k$$
$$dpi_k = (p_i - p_j)_k$$

where i, j subscripts mean lateral adjacent channel index and k subscript means axial node index. Pressure distribution of reactor inlet is determined by outlet pressure distribution and inlet axial mass flow distribution. For OPR1000 and APR1400 plant, nominal outlet pressure distribution is determined by experiments and used in the core thermal hydraulic design. For off-nominal conditions, measured pressure distribution cannot be assumed to be equal to the nominal case. Therefore, generally uniform outlet pressure is assumed in off-nominal conditions. At the low flow case with high peaking power, it is difficult to assume the uniform pressure distribution due to high temperature gradient of hot assembly in the reactor core. Therefore, in this case, it is reasonable to assume zero axial gradient pressure boundary condition at core outlet to reflect high radial pressure differences.

In order to test the core flow field regarding the boundary conditions, analysis was performed for two core conditions. One condition is nominal plant operating condition. In this paper, generic THALES power distribution is used. The other is special case, low-power and high-peaking condition. For these condition, THALES[2] subchannel code calculation was performed applying 3 kinds of boundary conditions – nominal outlet pressure distribution used for core thermal hydraulic design, uniform outlet and zero gradient outlet called Neumann boundary condition.

2.1 Nominal Operation Case

Calculation results for nominal condition with respect to outlet boundary are shown Fig. 1. ~ Fig. 3. Operating condition of this case is shown in Table I.

Table I: Nominal Operating Condition

Pressure. (psia)	Inlet temp. (°F)	Core average mass flux (Mlbm/ft^2-hr)	Core average heat flux (MBtu/ft^2-hr)
2250.0	564.5	2.5502	0.188251

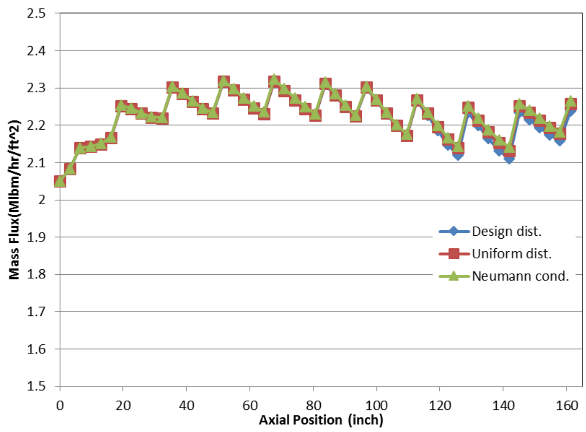

Fig. 1. Comparison of axial mass flux at nominal operation in hot channel (Design, Uniform and Neumann Condition)

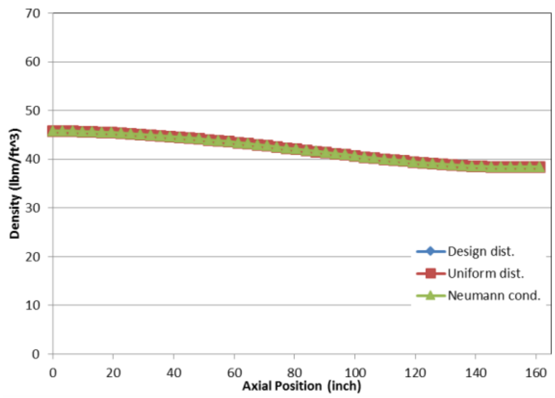

Fig. 2. Comparison of density at nominal operation in hot channel (Design, Uniform and Neumann Condition)

As shown in Fig. 1. ~ Fig. 3. results are almost equal between 3 boundary conditions. Nominal operation case has smooth power gradients inside core. Therefore, uniform or zero gradient boundary assumption is reasonable and makes a good agreement.

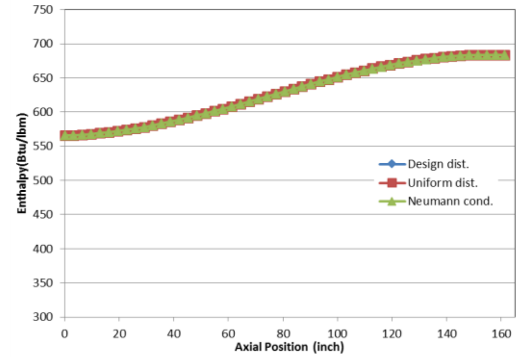

Fig. 3. Comparison of enthalpy at nominal operation in hot channel (Design, Uniform and Neumann Condition)

2.2 Low-power, High peaking case

The followings are results from low-power, high-peaking case. In this case, density is significantly decreased due to high power and low mass flow in hot channel. As a result, the lower density increases hot channel pressure, influences outlet pressure distribution. Calculation results with respect to outlet boundary conditions are shown in Fig. 4. ~ Fig. 6.

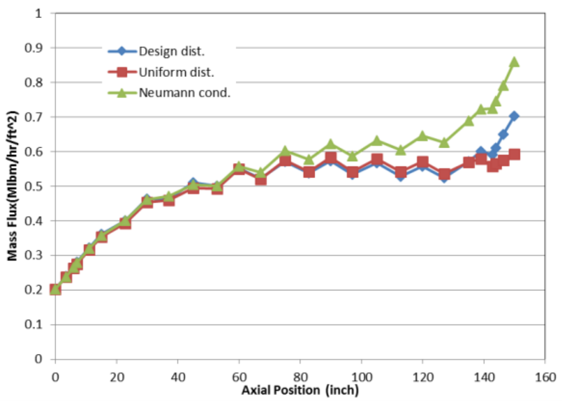

Fig. 4. Comparison of axial mass flux at low-power and high-peaking condition (Design, Uniform and Neumann Condition)

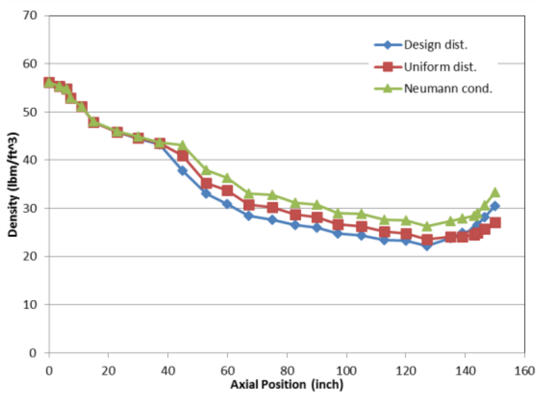

Fig. 5. Comparison of density at low-power and high-peaking condition (Design, Uniform and Neumann Condition)

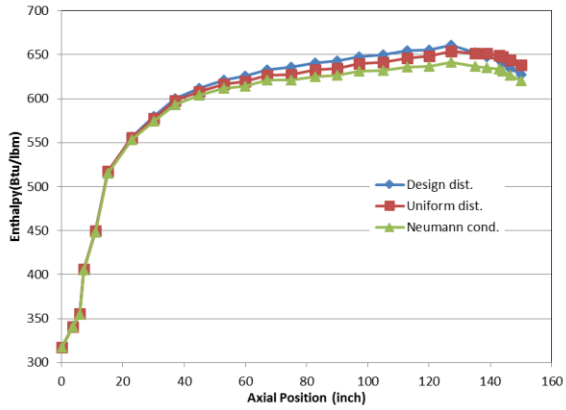

Fig. 6. Comparison of enthalpy at low-power and high-peaking condition (Design, Uniform and Neumann Condition)

3. Conclusions

For nominal operation case, there are no different results depending on the type of outlet pressure boundary condition. But low-power and high-peaking case, density difference for lateral direction becomes large due to high peaking power of core. Since density change causes pressure change, In this case, uniform outlet pressure distribution can’t be assumed anymore. Design outlet pressure distribution is measured at nominal core condition. Therefore, design outlet pressure distribution also can’t be used due to the difference in core power and flow rate. As a result, it is reasonable that neumann boundary condition is applied in low-power and high peaking core condition including various accident condition.

REFERENCES

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