# *Air Cooling Analysis of an ATR Fuel Element Using RELAP5 and ABAQUS*

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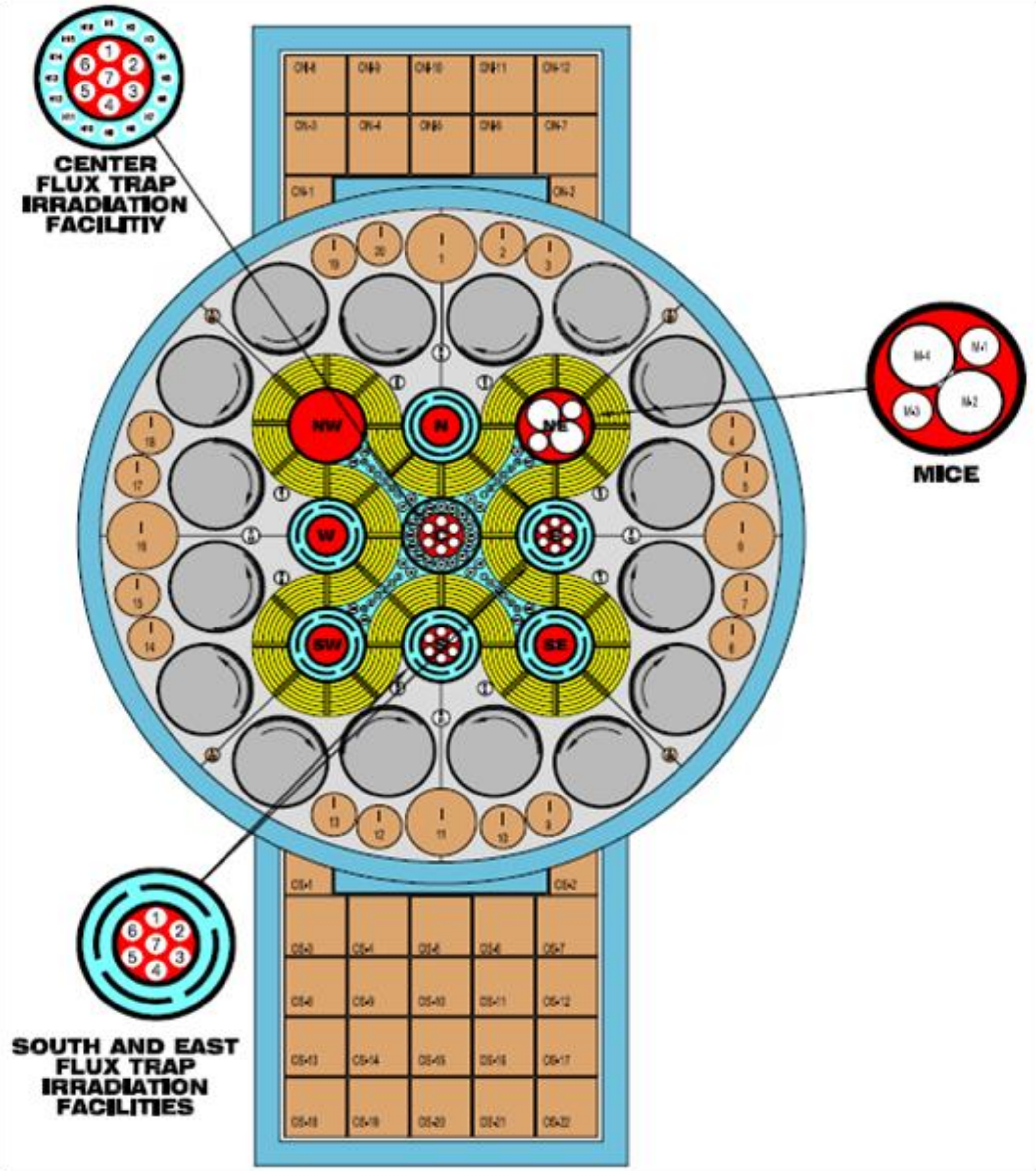
# *Outline*

- Motivation
- Model descriptions
  - RELAP5/MOD3
  - ABAQUS
- RELAP5-3D model used for comparison of results
- Results before and after RELAP5 code modifications
- Summary

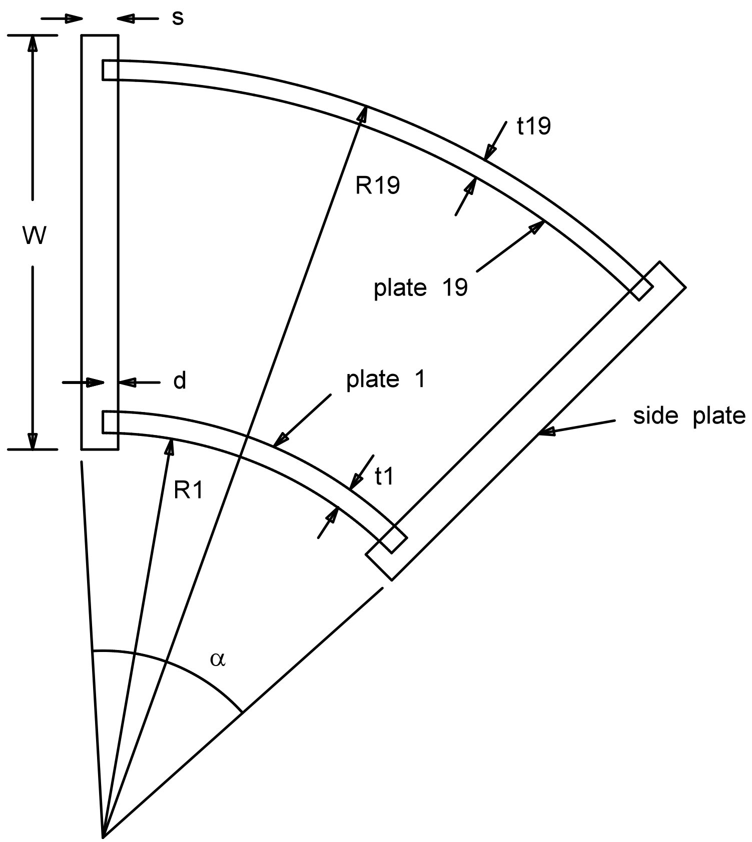
# *Motivation and Approach*

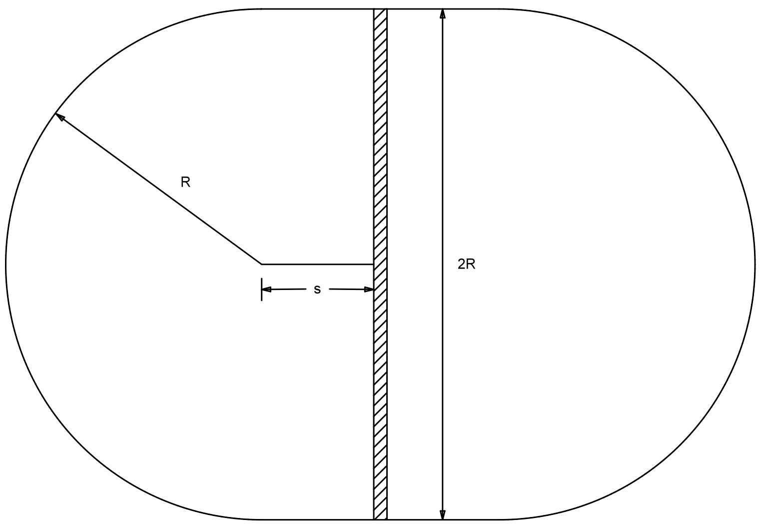
- ATR spent fuel is stored in canal while it cools
- Objective
  - Determine maximum power for fuel element in air that prevents melting in case of canal draining accident
- Modeling approach
  - Perform conservative analysis using validated codes
    - RELAP5/MOD3 Version 3.2.1.2: calculation of natural convection in air
    - ABAQUS: 3D heat conduction within fuel element

# ATR Core


CENTER FLUX TRAP IRRADIATION FACILITIY
MICE
SOUTH AND EAST FLUX TRAP IRRADIATION FACILITIES
NW
N
NE
W
E
C
SW
S
SE

# ATR Fuel Element/Storage Rack

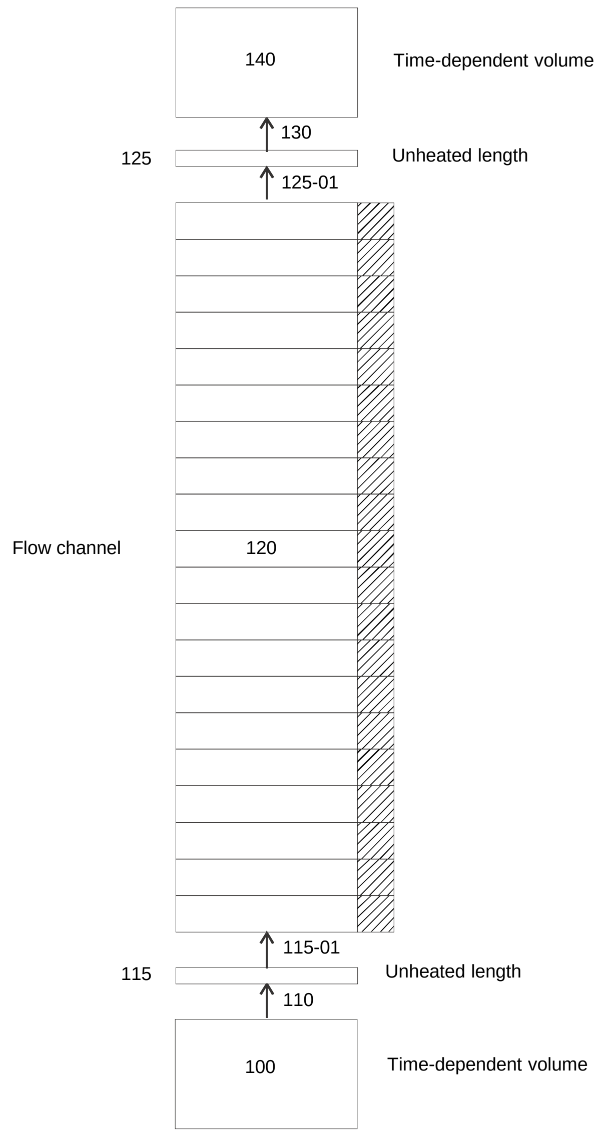


# RELAP5 Model Assumptions

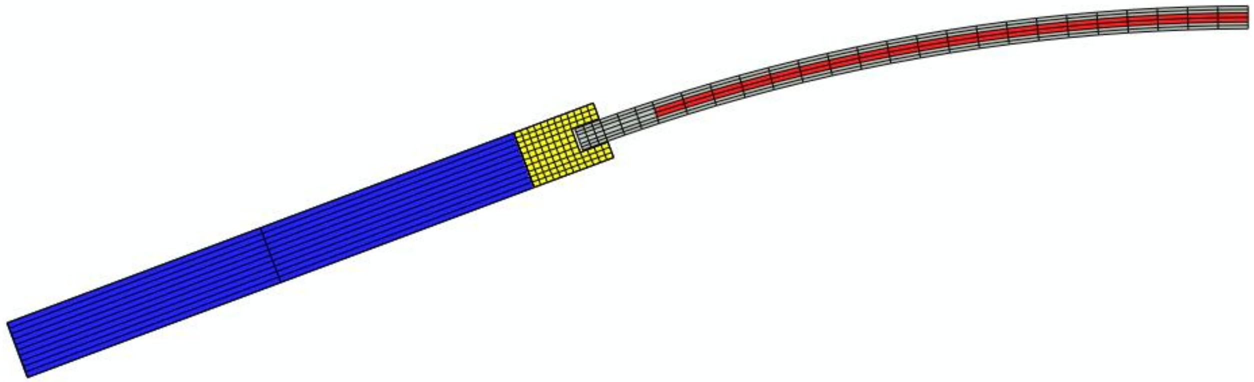
- All surfaces are adiabatic except outer surface of side plate
- Heat loss to channel via convection only (no radiation)
- Cosine axial power profile
- Air inlet temperature of 80 °F

# RELAP5 Model



# ABAQUS Model

- Half of an average fuel plate, section of side plate, and portion of coolant channel
- Gap between end of fuel plate and side plate = 0.007 in.
- Gap between sides of fuel plate and side plate = 0.002 in.



# ABAQUS Model Assumptions

- No direct thermal contact between fuel plate and side plate
- Heat transfer between fuel plate and side plate is thermal conduction through air only – no convection or radiation
- Heat transfer due to air flowing between fuel plates neglected (~30 W)
- Heat transfer from side plate to air uses laminar correlation:

$$\frac{hD}{k} = 4.36$$

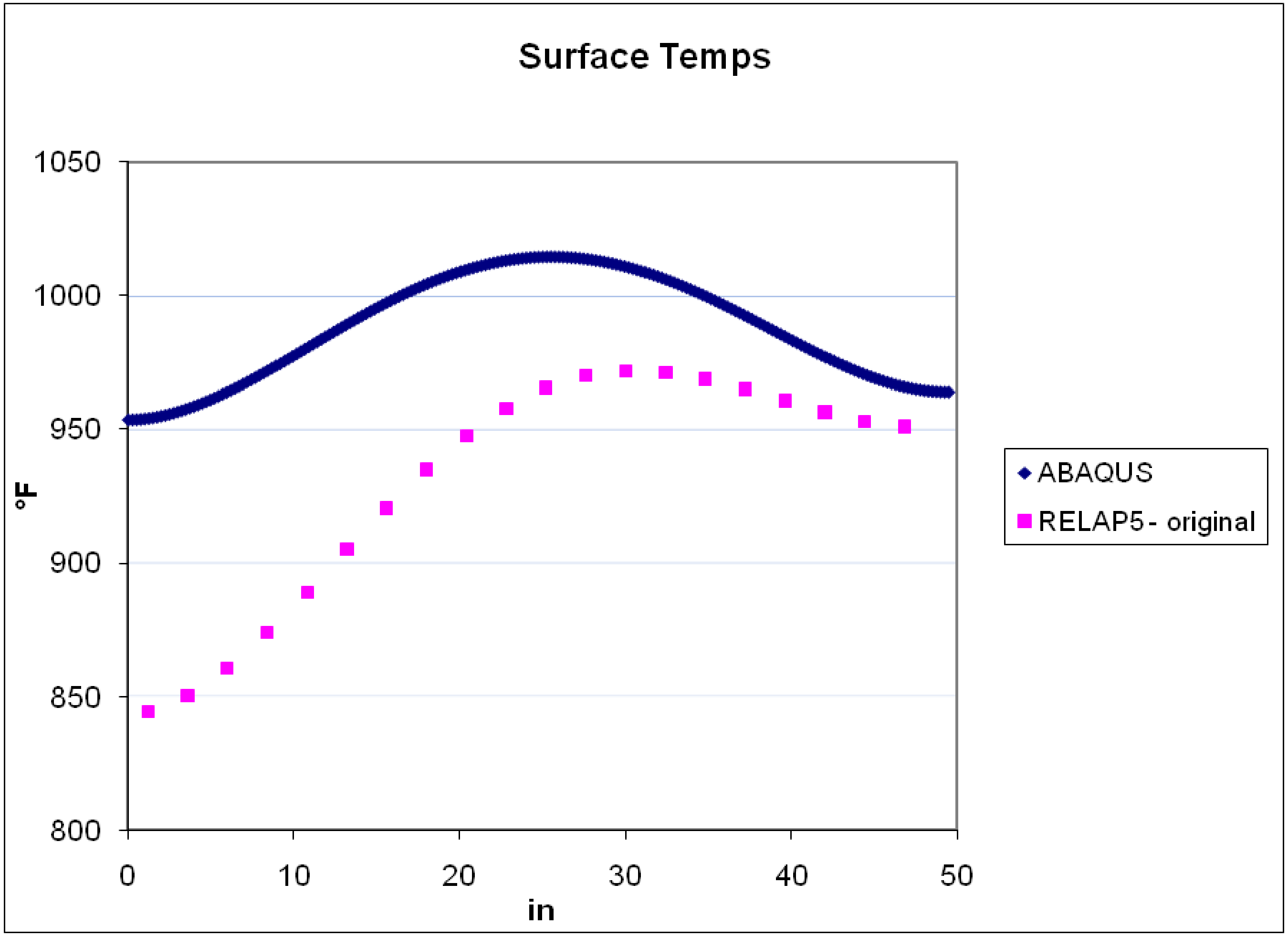
# *Solution Method*

- For a given power, RELAP5 calculates resulting air mass flow rate
- The laminar correlation and an assumed surface temperature are used to calculate heat transfer coefficients for input to ABAQUS
- Given the RELAP5-calculated flow rate, ABAQUS run iteratively until assumed and calculated surface temperatures converge
- The maximum power which results in peak temperature below solidus point for aluminum (1075 °F) is the predicted limit

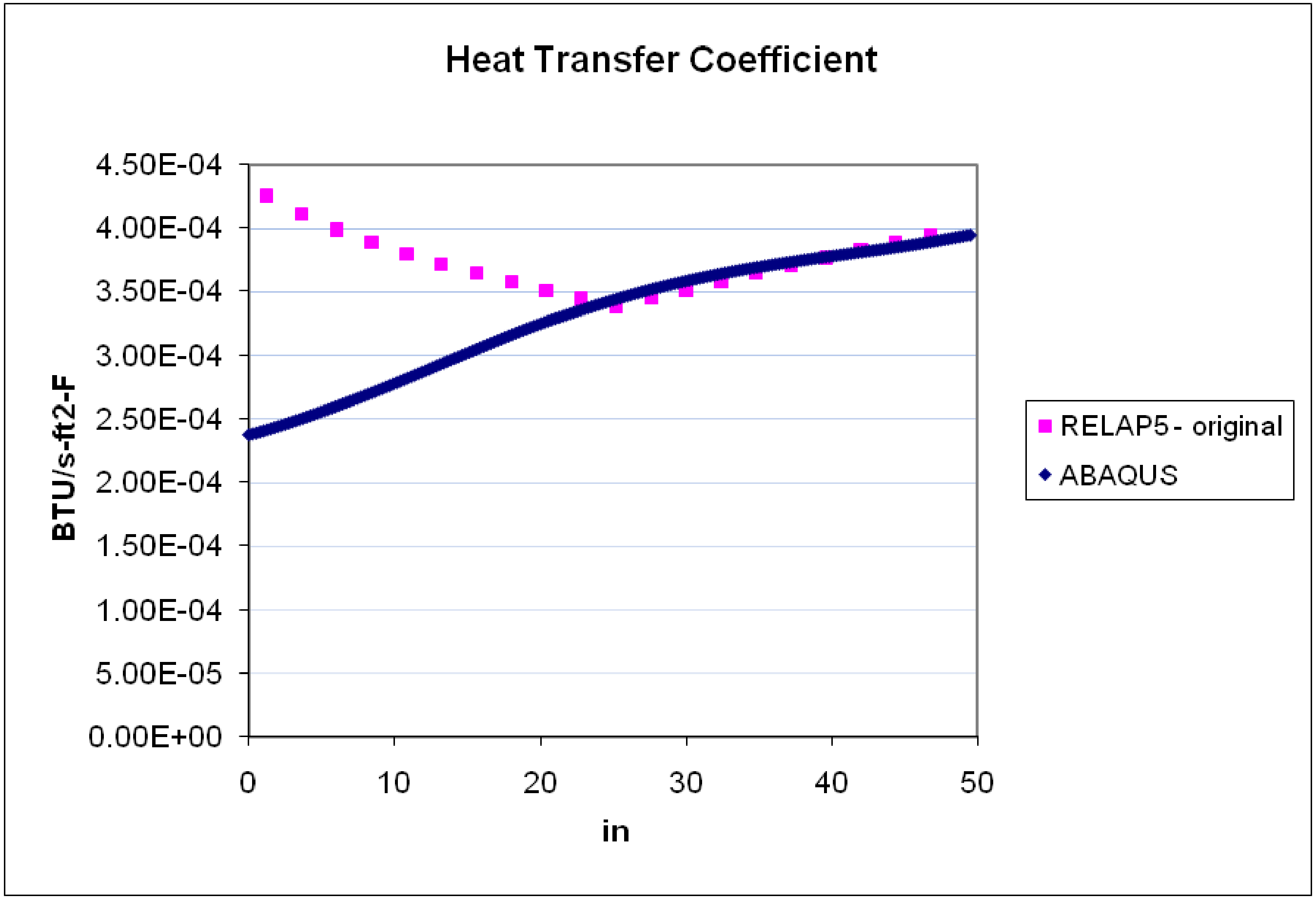
# *RELAP5-3D Axial Conduction Model*

- Direct comparison of ABAQUS and RELAP5/MOD3 results is difficult
  - ABAQUS is calculating axial conduction, whereas RELAP5/MOD3 is not
  - RELAP5/MOD3 model is assuming all heat deposited in side plate (no conduction through fuel)
- RELAP5-3D model using the 2-D conduction model (W6 = 3 on 1CCCG000 card) and gap conductance model was added
  - This model represents half of fuel plate, similar to ABAQUS model
  - Allows comparison of results to look for any major discrepancies

# Comparison with RELAP5-3D 2-D Model



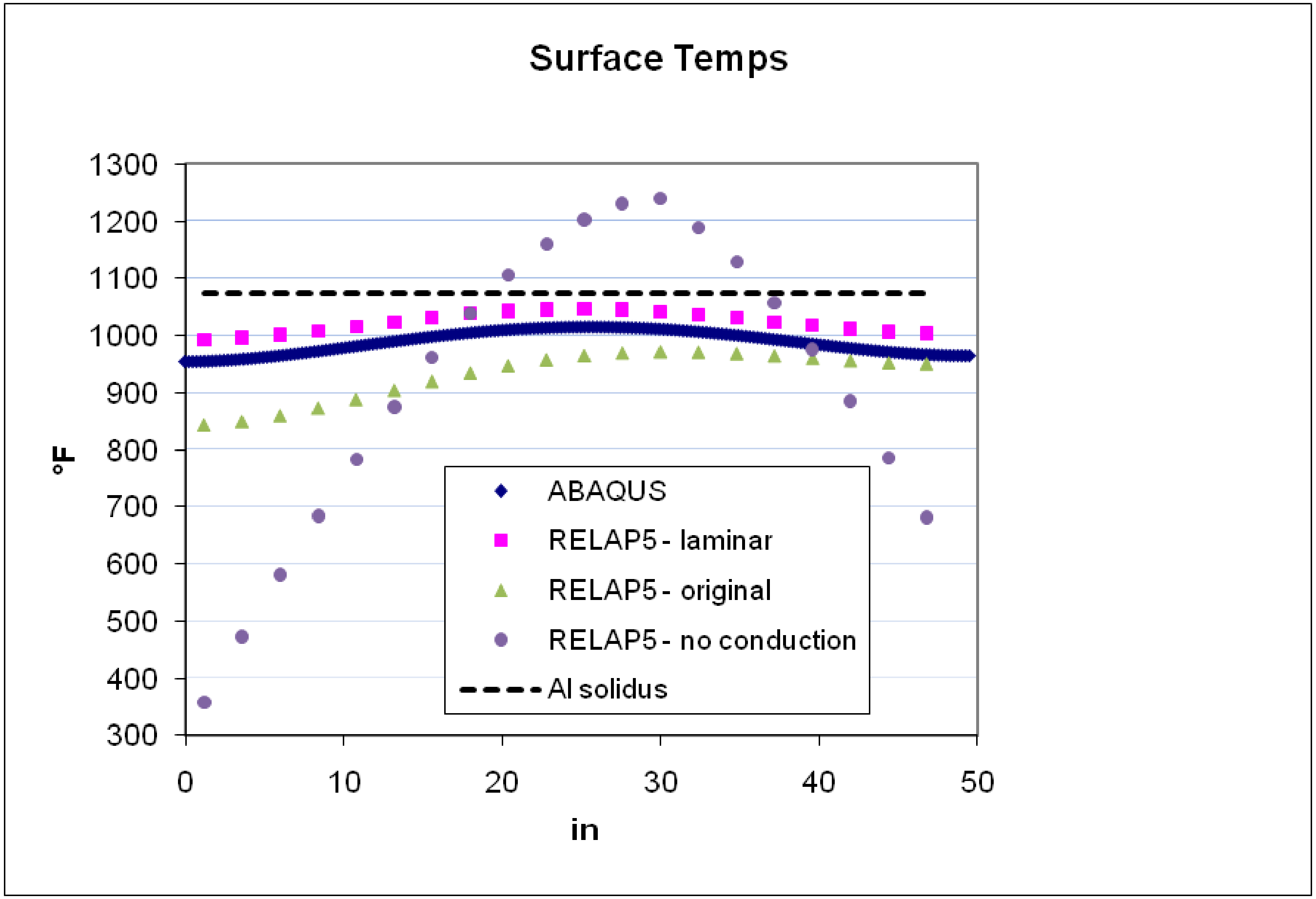
# Comparison with RELAP5-3D 2-D Model



# RELAP5 heat transfer correlations

- For convection to single-phase vapor, RELAP5 chooses the largest of three correlations
  - Forced turbulent (Dittus-Boelter)
  - Forced laminar (Sellars-Tribus-Klein)
  - Natural convection (Churchill-Chu)
- Sellars-Tribus-Klein is used for the ABAQUS model
- Therefore, RELAP5 subroutine DITTUS was modified to choose only laminar correlation

# RELAP5-3D Laminar Convection Results



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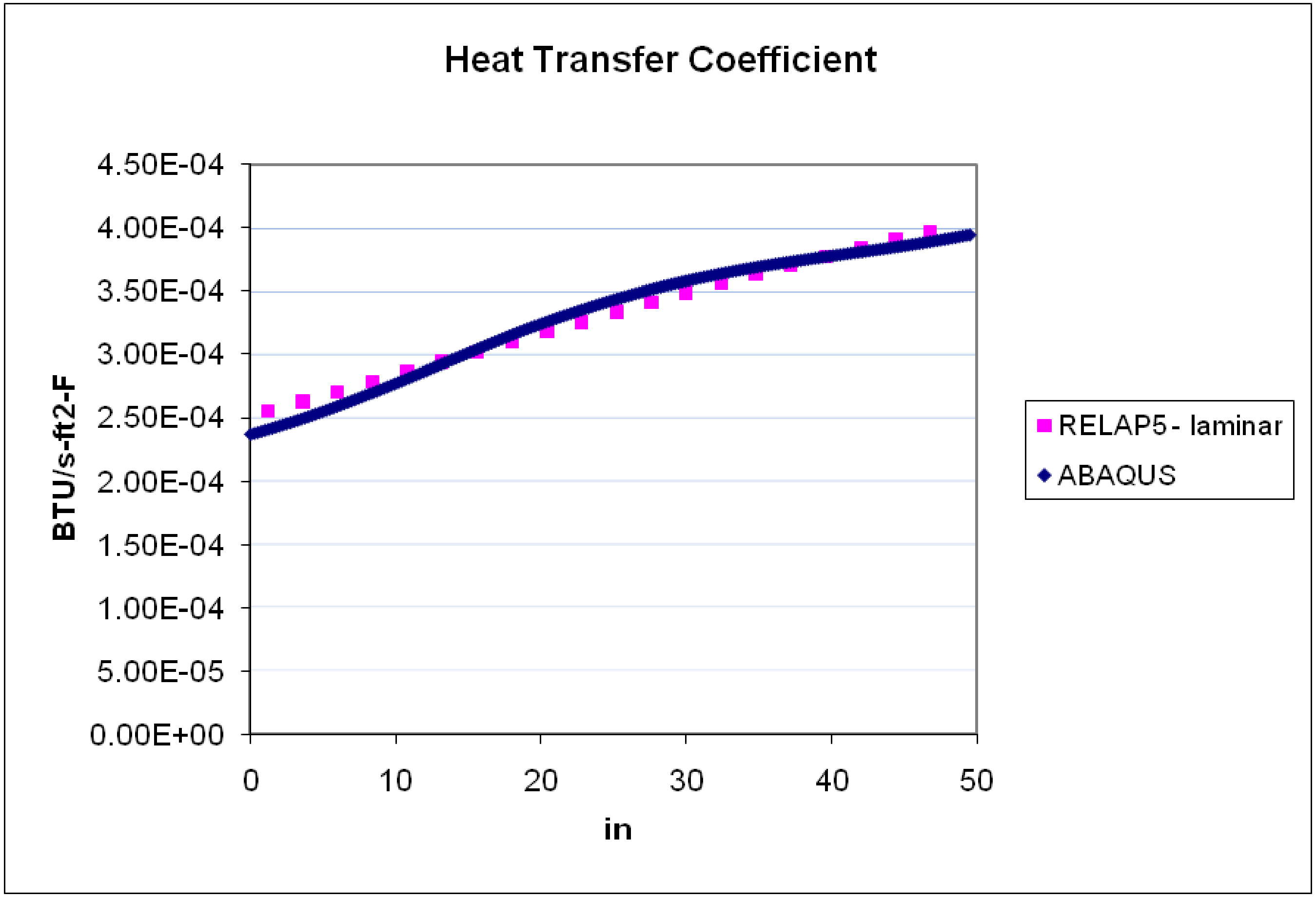

# *Summary*

- RELAP5/MOD3 and ABAQUS used to calculate conservative estimate of maximum fuel element power in air
- RELAP5-3D 2-D model used for confirmatory calculations
- Heat transfer coefficients calculated by RELAP5 are more realistic (but less conservative) than the laminar assumption
- Consideration of axial conduction is important