Thermal-Fluid Modeling Using RELAP5 and COMSOL

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Hotspot Analysis

- Develop Analytic Model
- Develop RELAP5 and COMSOL Models
- Bulk Temperature and Clad/Coolant Temperature Profiles
- Turbulent Conductivity
- Value Added
- Qualifying Codes

HFIR Core Diagram

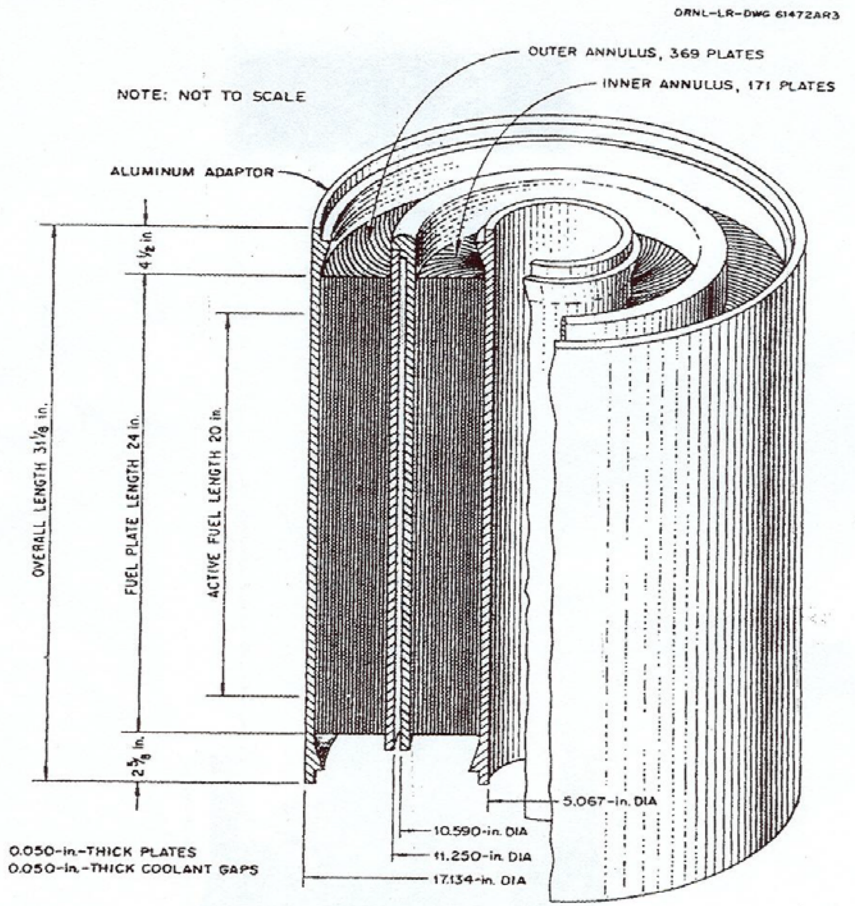
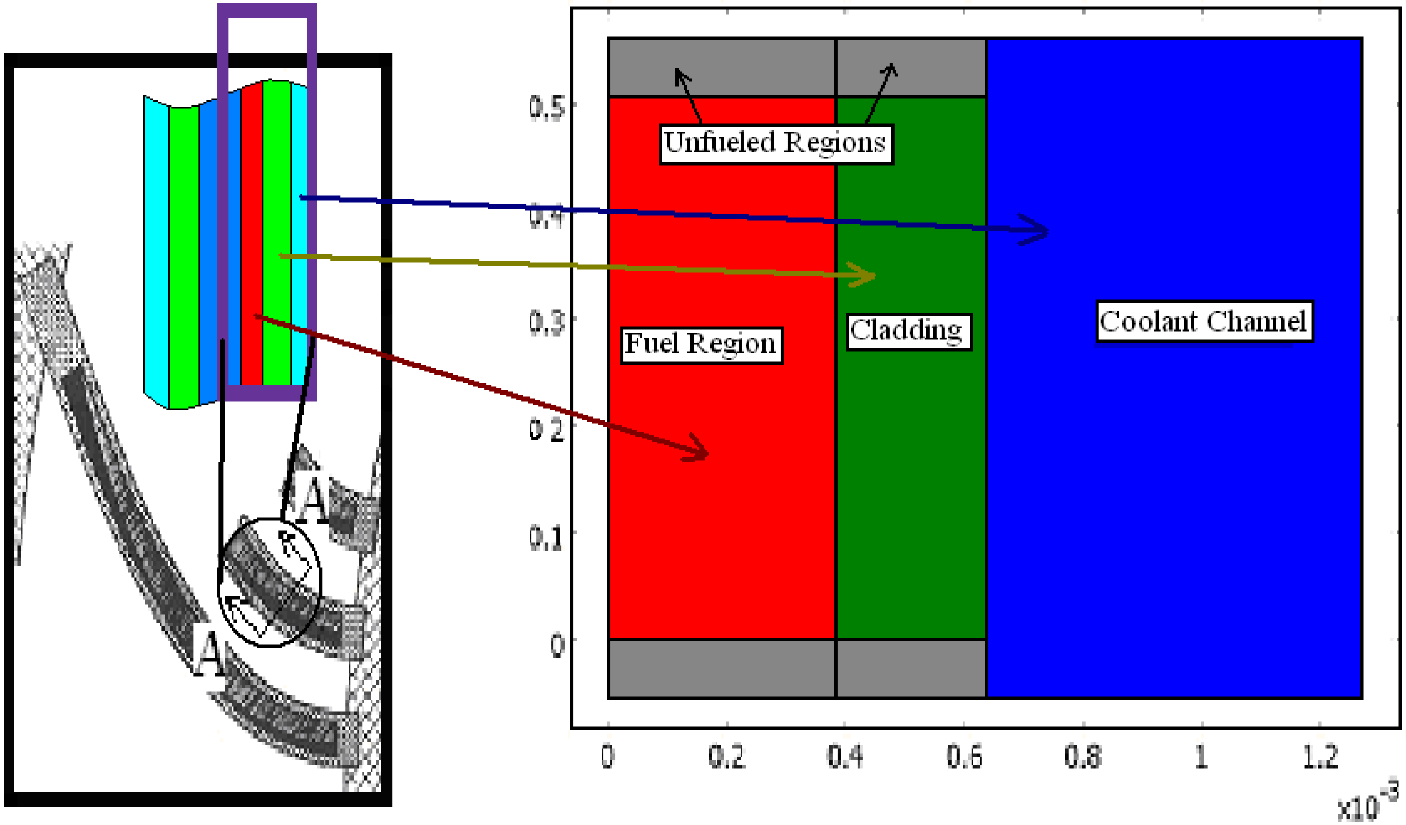


Fig. 3. HFIR Fuel Assembly.

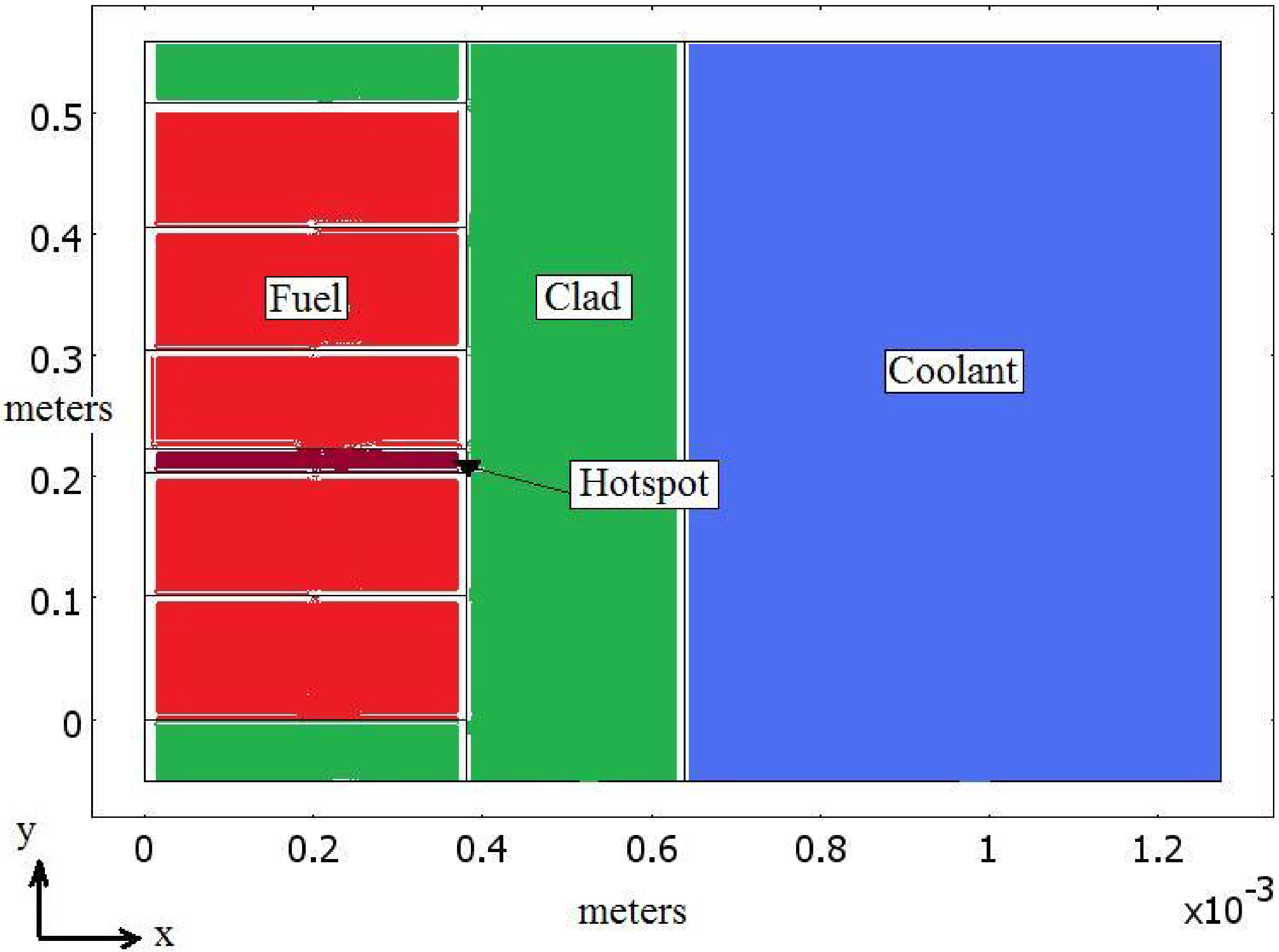
Model Diagram



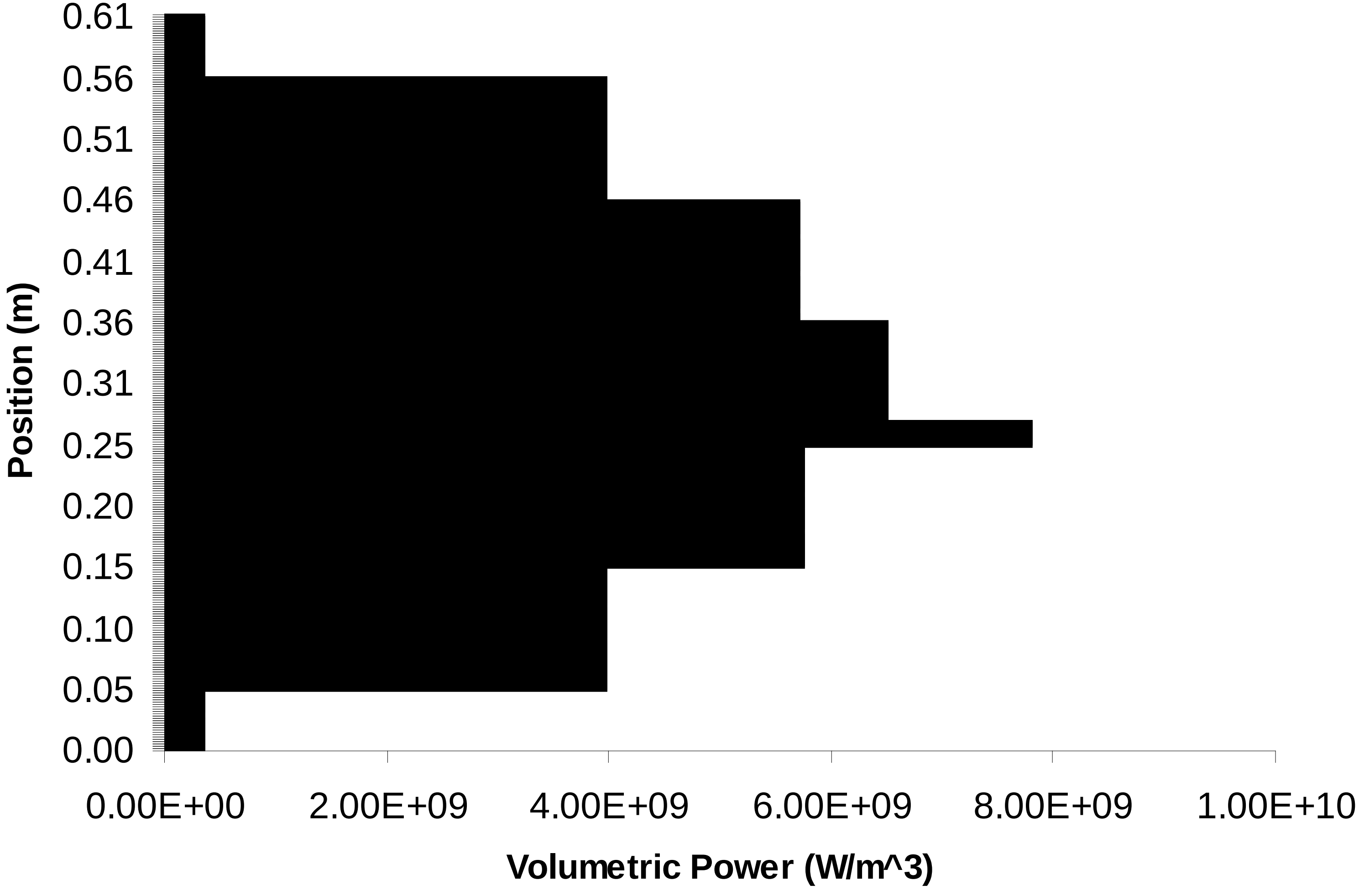
HFIR Cooling System Facts

- Flow Rate is -15.8 m/s (down flow)
- Pressure Drop is 100 psi
- Coolant Channel Gap = 0.00127 m
- Axial Length = 0.508 m
- Core Power = 85 MW

Hotspot Model



Power Profile



Analytic Development

- Simple Conservation of Energy

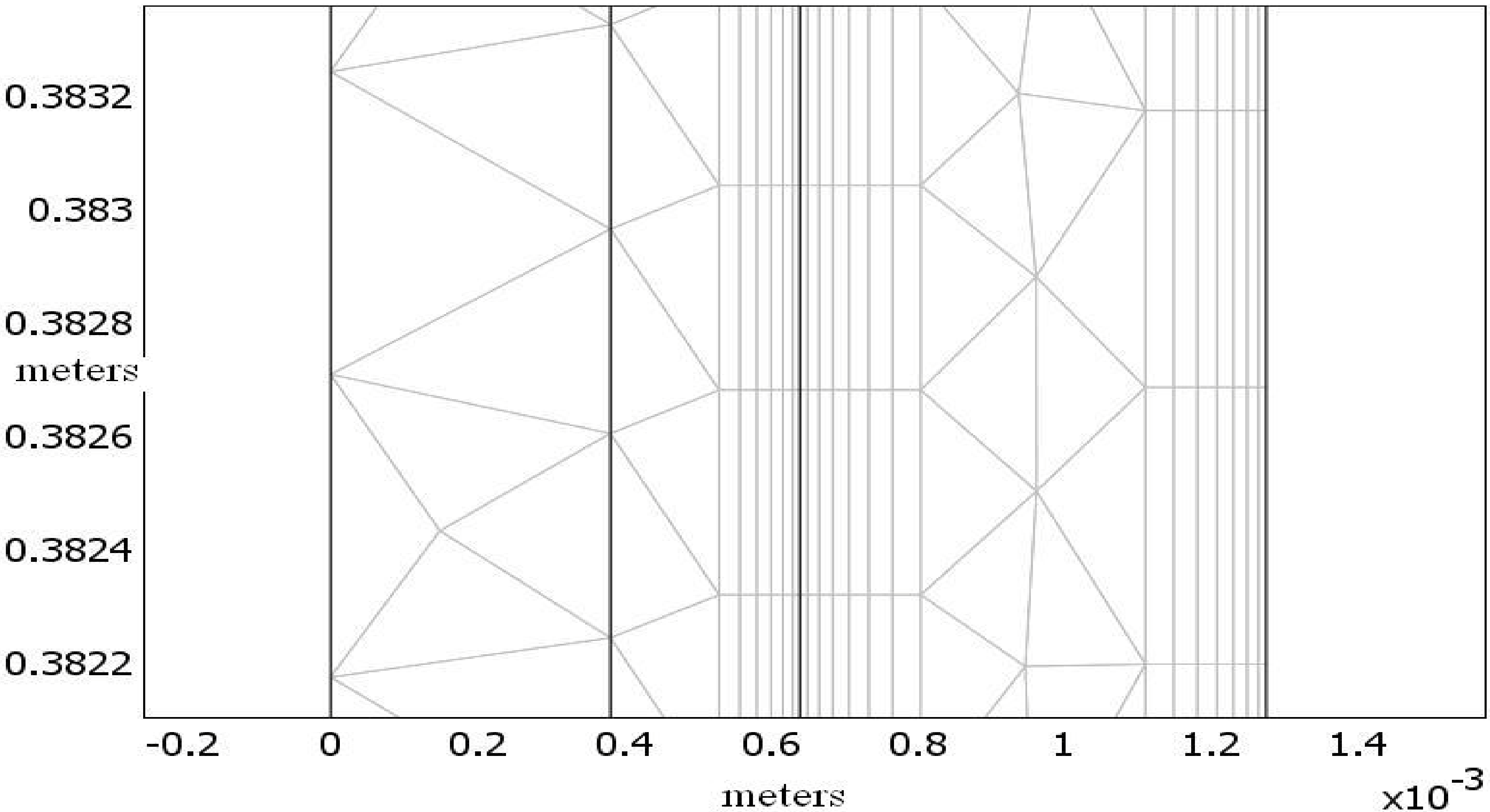
$$Q = \dot{m} c_p (T_{out} - T_{in})$$

- Functionalize material properties
- Heat Transfer Coefficient via Dittus Boelter

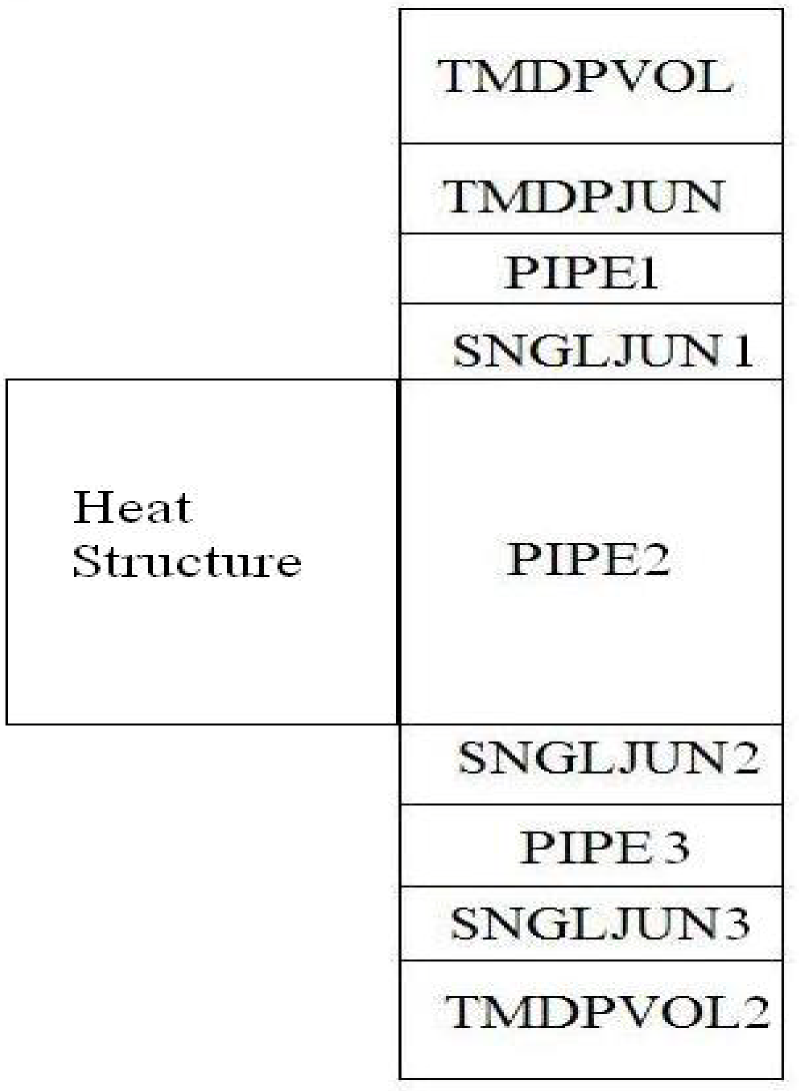
$$h = \frac{k(Nu)}{D_H}$$

$$Nu_{db} = 0.023\, \mathrm{Re}^{0.8}\, \mathrm{Pr}^{0.4}$$

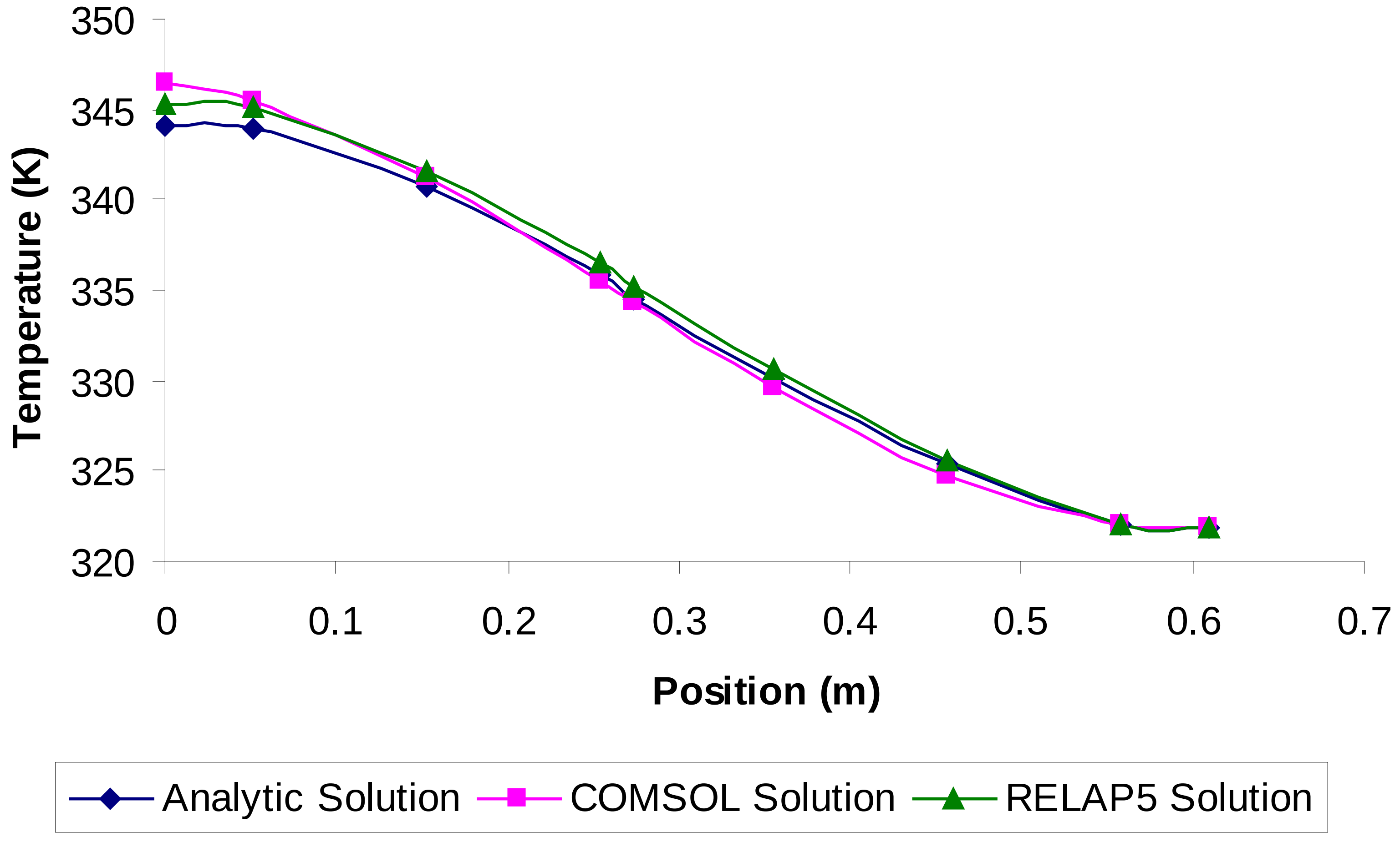
COMSOL Mesh Density



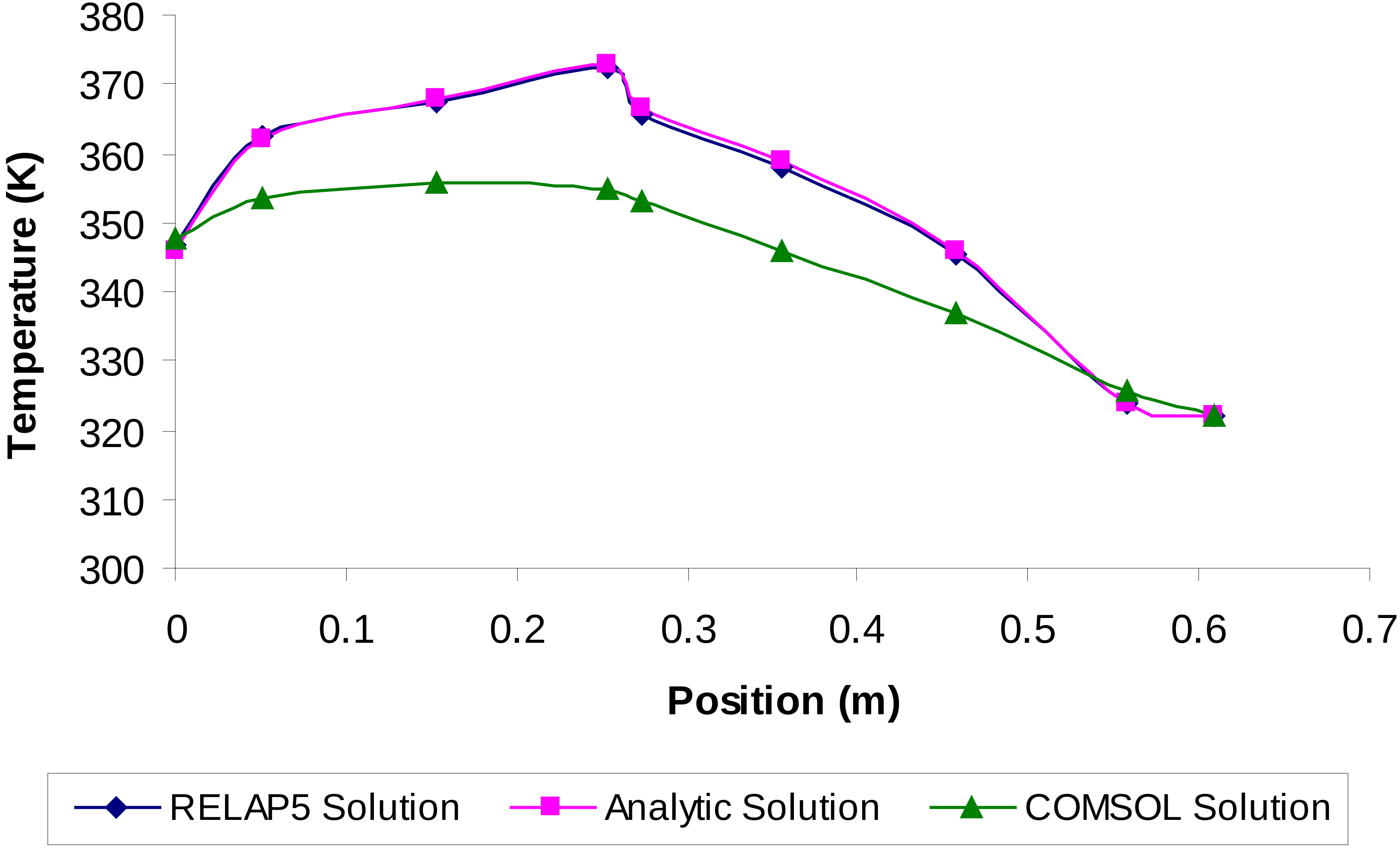
RELAP5 Simulation



R5 and Analytic Bulk Temperature, COMSOL Centerline Temperature



Clad/Coolant Temperature

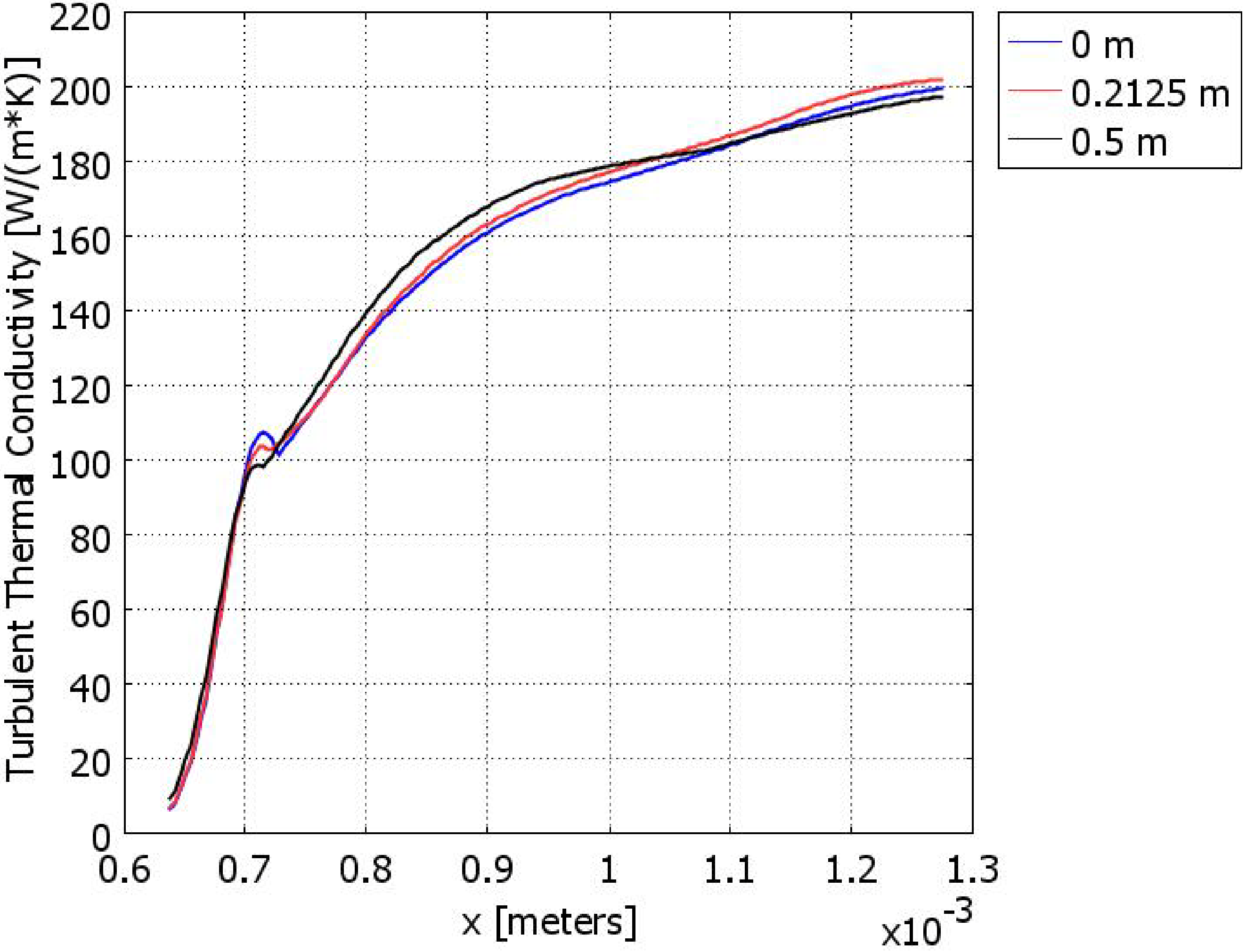


Turbulent Conductivity

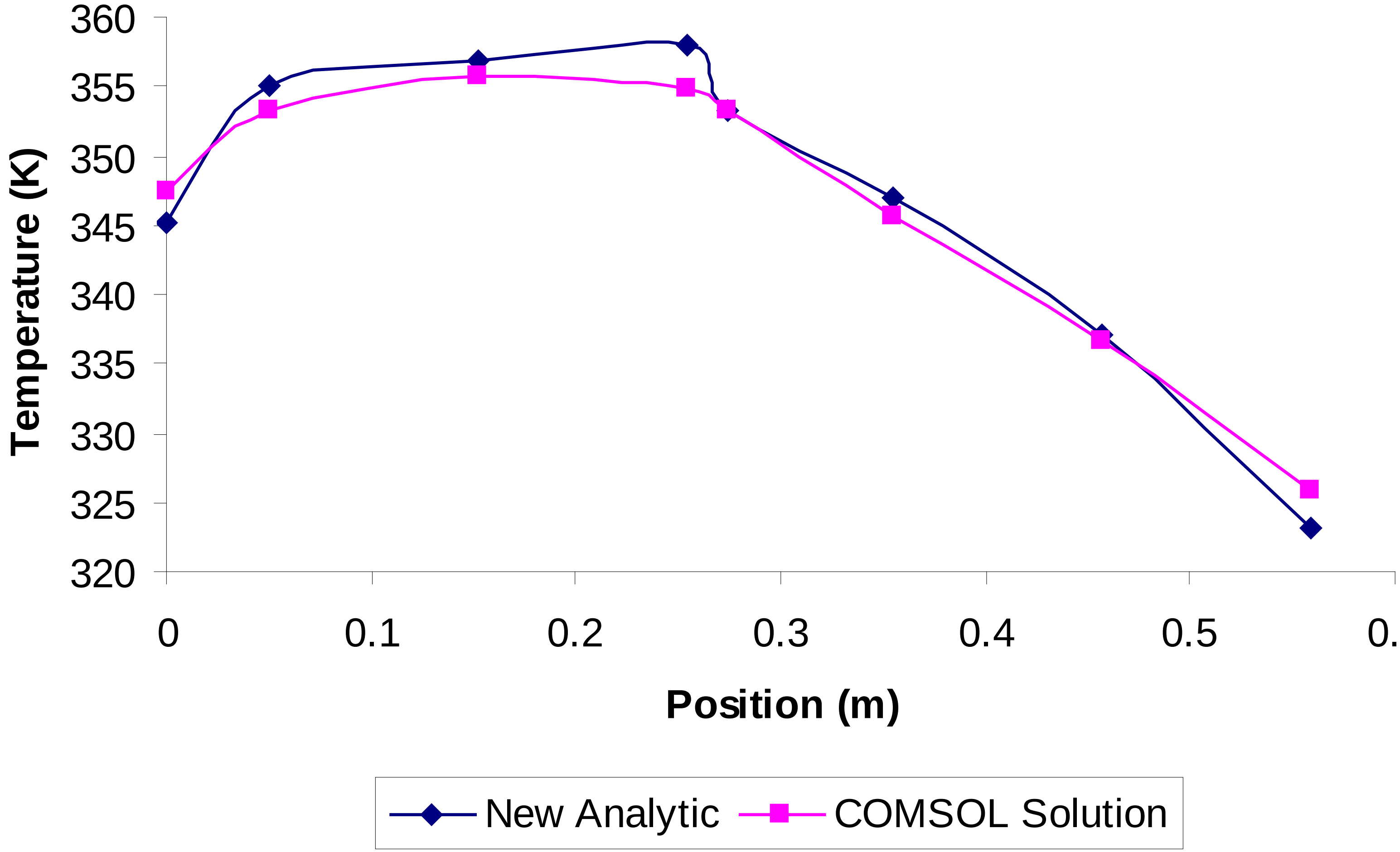
- Turbulence is suppressed in the near wall region such that diffusivity declines to molecular values.
- Turbulence enhances fluid effective conductivity, λ.

$$\lambda = \frac{c_p \upsilon}{\mathbf{Pr}_t}$$

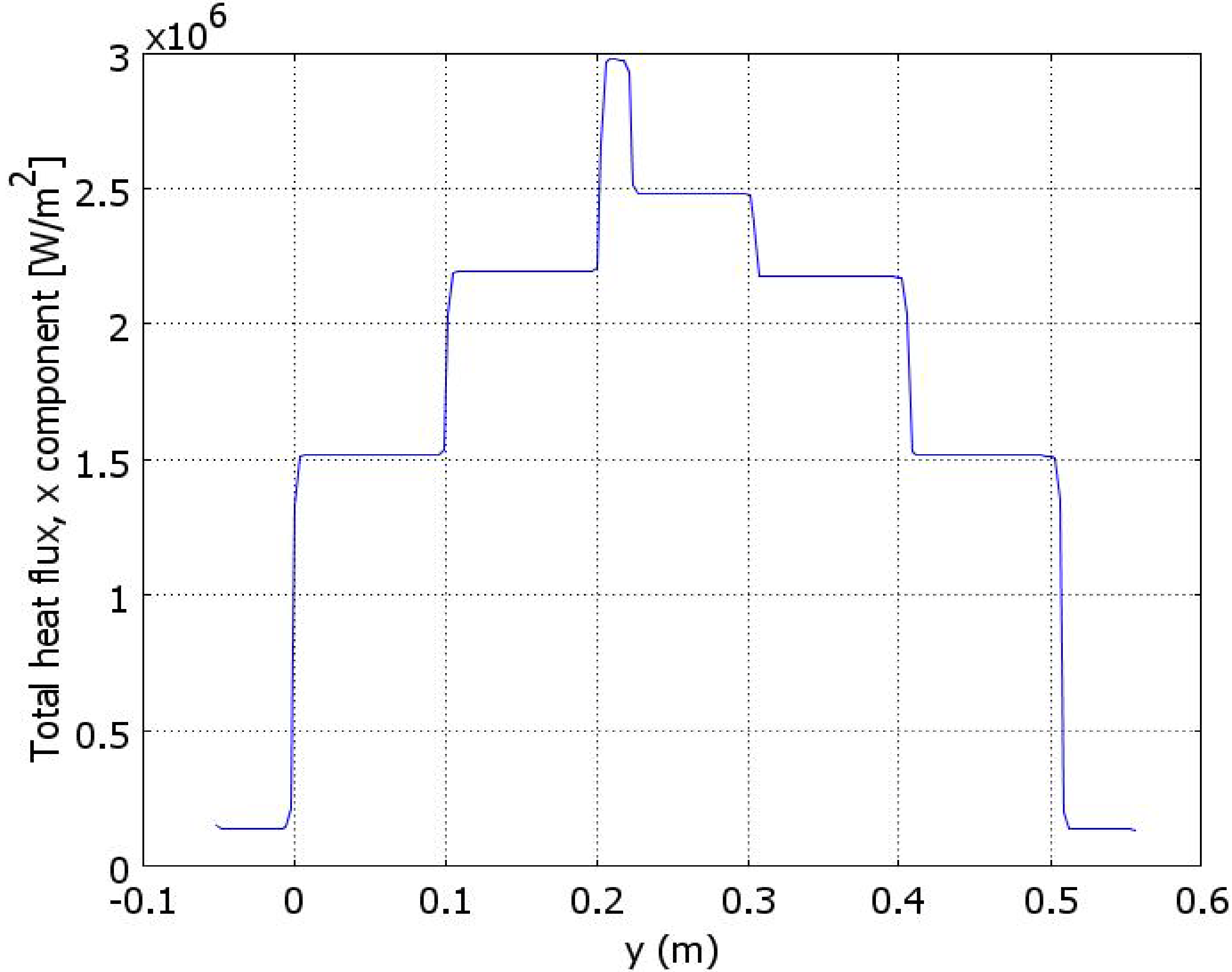
Turbulent Conductivity



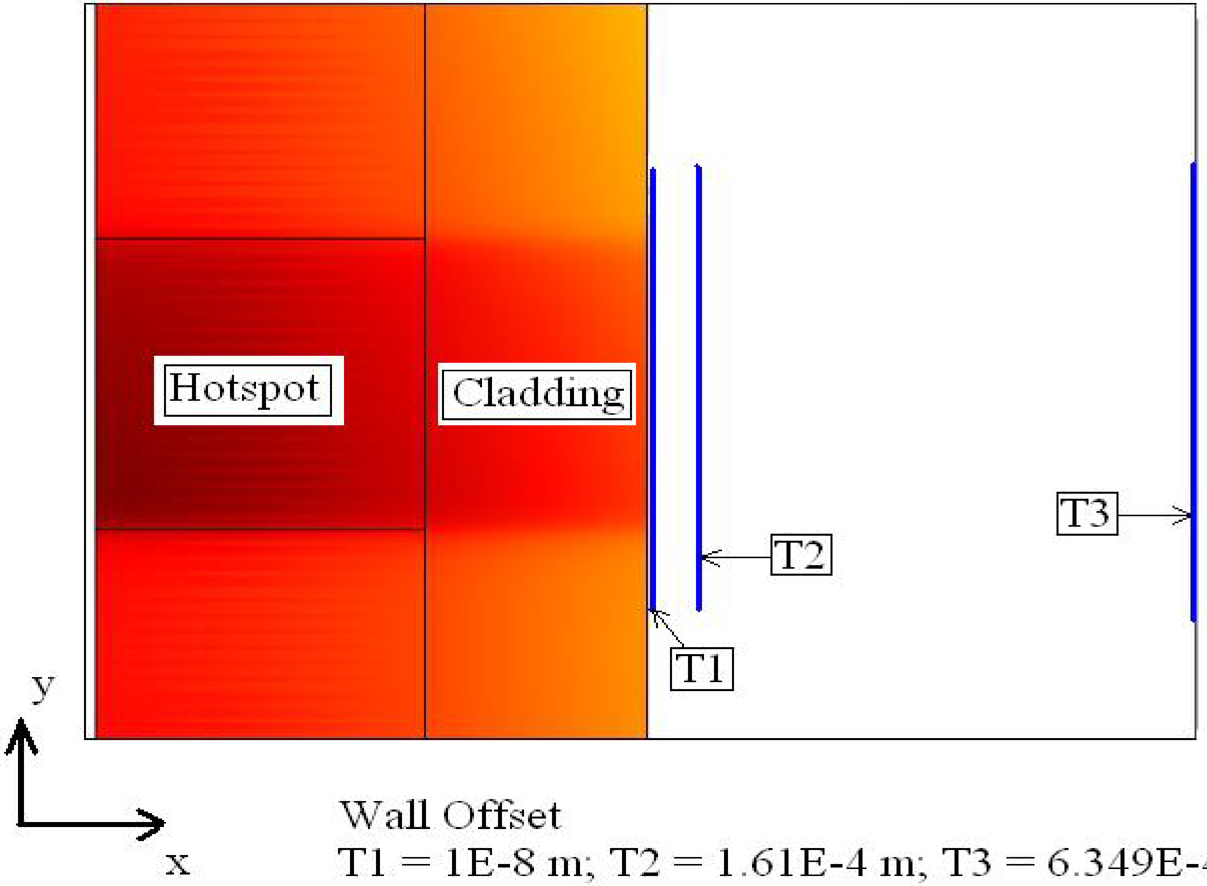
New Clad/Coolant Temperature



COMSOL Heat Flux at Clad/Coolant Interface

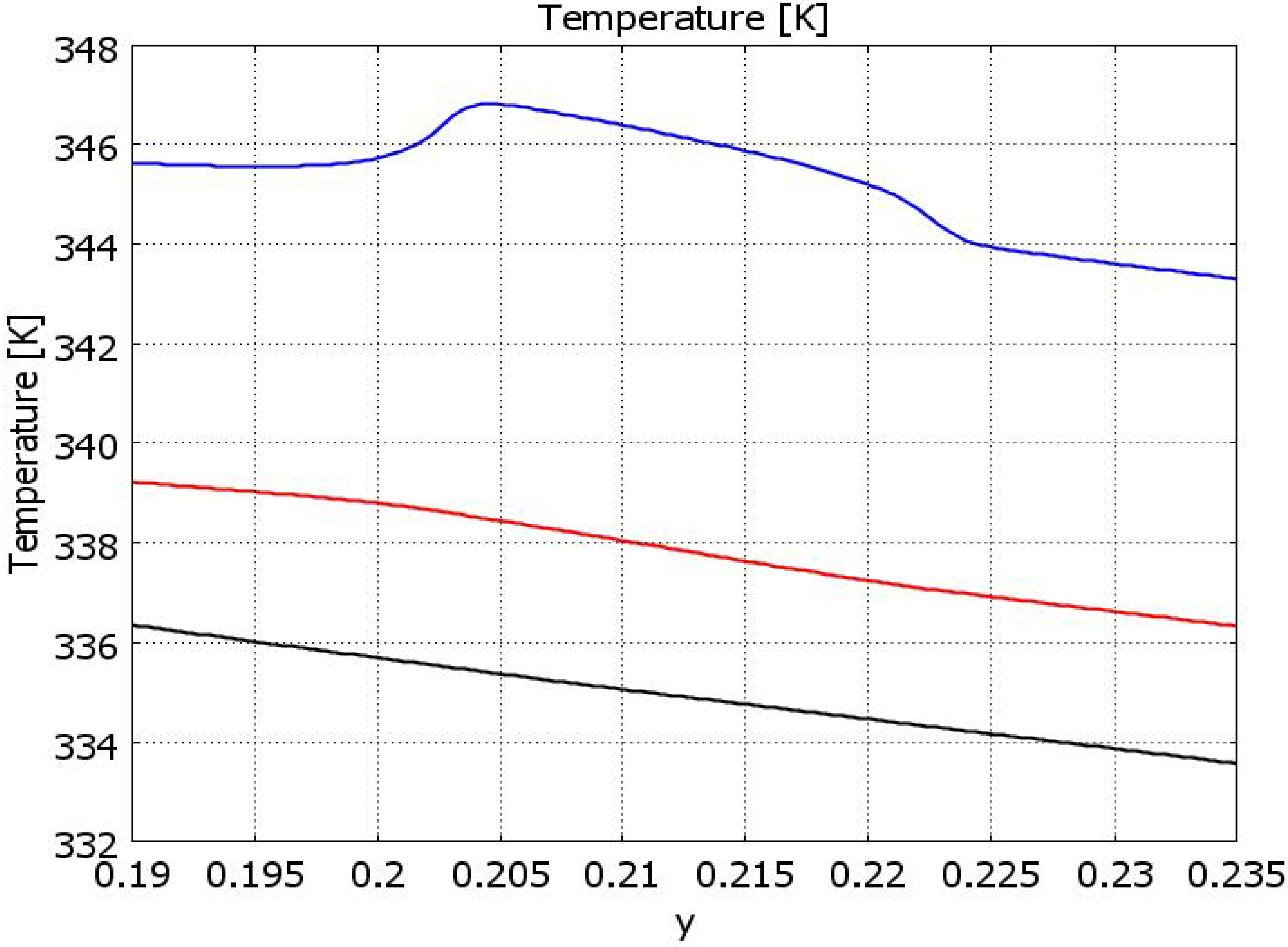


Fluid Temperature Profiles



Wall Offset
T1 = 1E-8 m; T2 = 1.61E-4 m; T3 = 6.349E-4 m

Fluid Hotspot Temperature Profile



Concluding Remarks

- RELAP5 and Analytic results agree.
- COMSOL predicts higher heat transfer coefficient.
- RELAP5 executes in $1/100^{th}$ the time and requires significantly less computational resources.
- COMSOL offers a lot of utility to the user and options to “tailor the physics” to a specific situation.