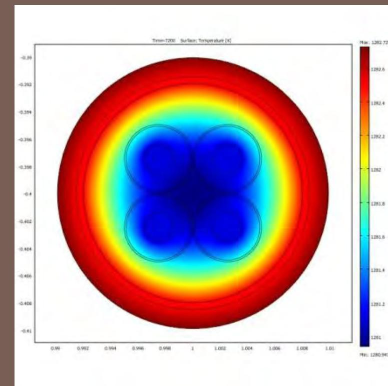
Engineering



MODELING THE THERMAL RESPONSE OF POWER CABLES IN A FIRE EXPOSURE

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Overview

- Introduction to Modeling
- Performance vs. Prescriptive Fire Design
- Developing the Model
  - The Easy Part – Boundary Conditions
  - The Tough Part – Determining Properties
  - The Tricky Part - Predicting Failures
- Results
- Conclusions

Introduction to Modeling

- Every field of engineering is becoming more dependent on modeling
- Advantages and Disadvantages
- Generally use finite element methods (FEM)
- Level of complexity can vary
- Can tailor model to specific conditions or change model “on the fly”

Performance vs. Prescriptive Fire Design

- Prescriptive based fire design is traditional method
  - Requires standardized testing
  - Every product must be tested
- Performance based design becoming more popular
  - Engineering work required
  - Modeling of several systems can be more cost effective than testing several systems
  - Validation testing may be required
  - After modeling is complete, a better understanding of the product is gained

Developing the Model

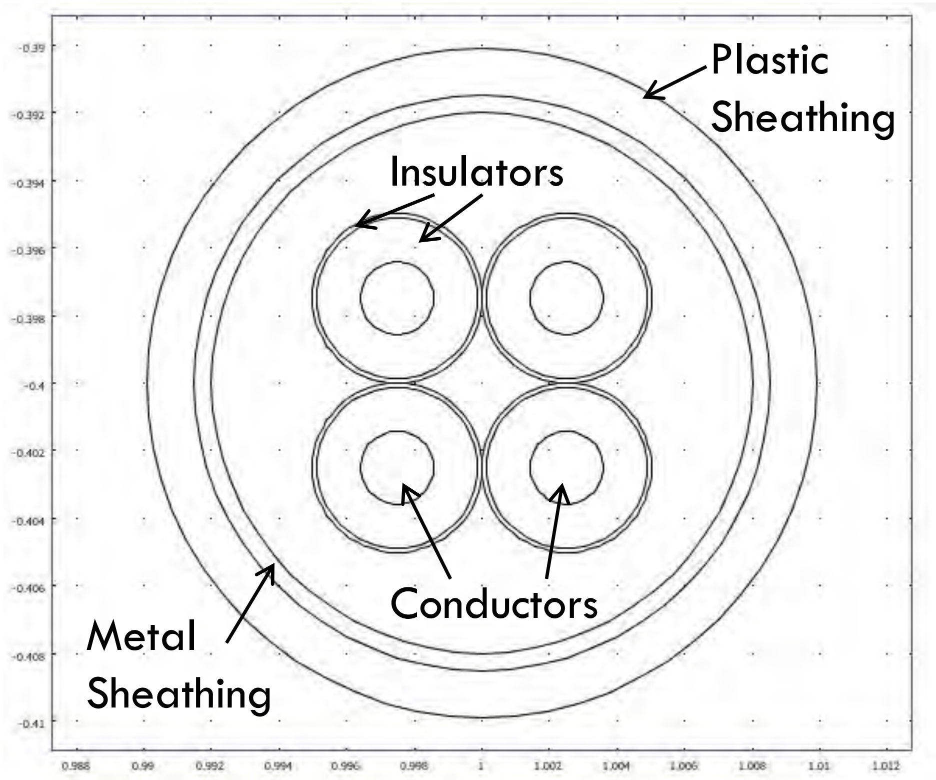
- Use Finite Element Methods
- Assume 2-dimensional heat transfer
- Use transient heat conduction equation:

$$\frac{\partial T}{\partial t} = \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \qquad \alpha = \frac{k}{\rho \cdot C_P}$$

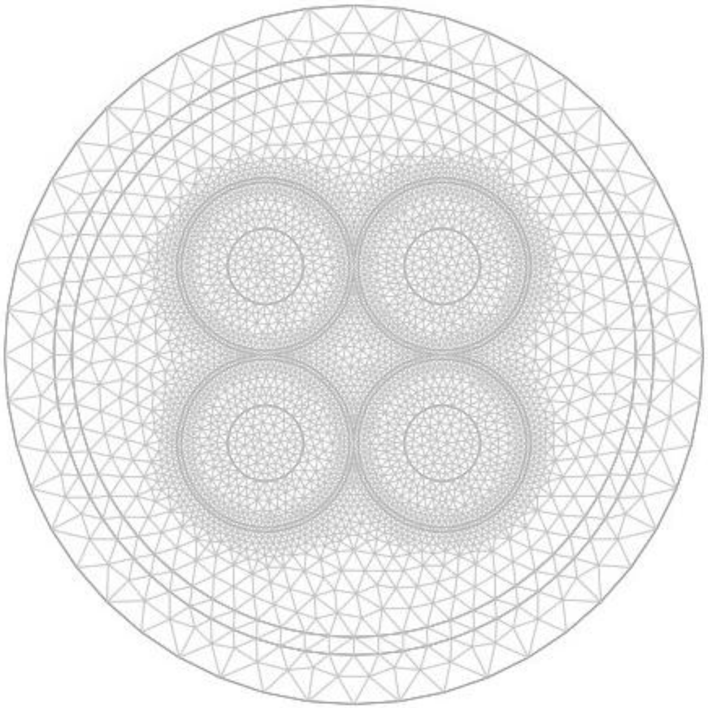
- In our case, we use a software package called Comsol Multiphysics but may also use Matlab or other software with FEM capabilities

Developing the Model

- Thermal Model – Geometry and Grid



Geometry

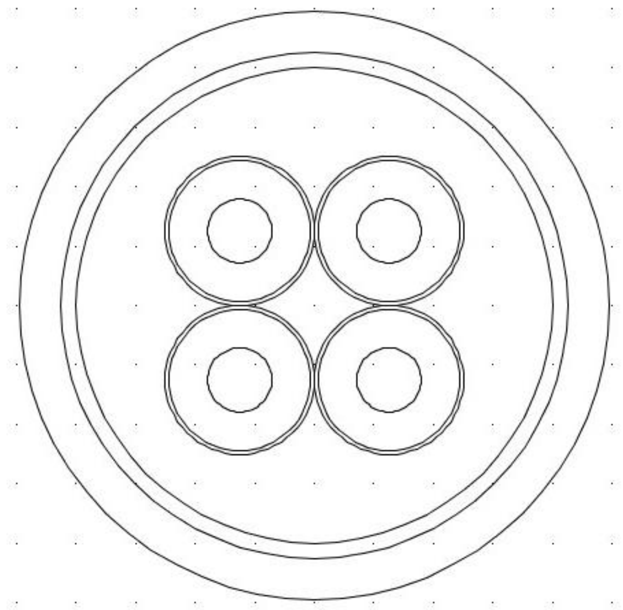


FEM Mesh

Developing the Model

- Boundary Conditions
  - Continuity at all interior boundaries
  - Convective and Radiative Heat Flux at Exterior Boundary
  - Assumptions:
    - ϵ = 0.5
    - h = 25 W/m²

$$\dot{q} = h\left(T_{surface} - T_{\infty}\right) + \varepsilon\sigma\left(T_{surface}^{4} - T_{\infty}^{4}\right)$$

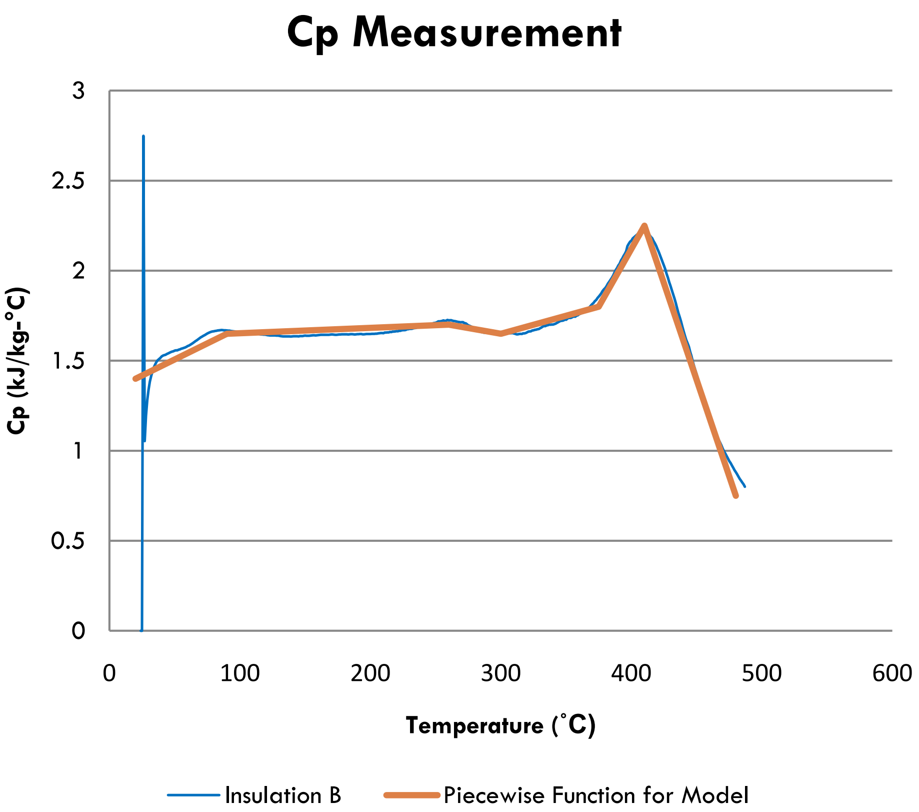


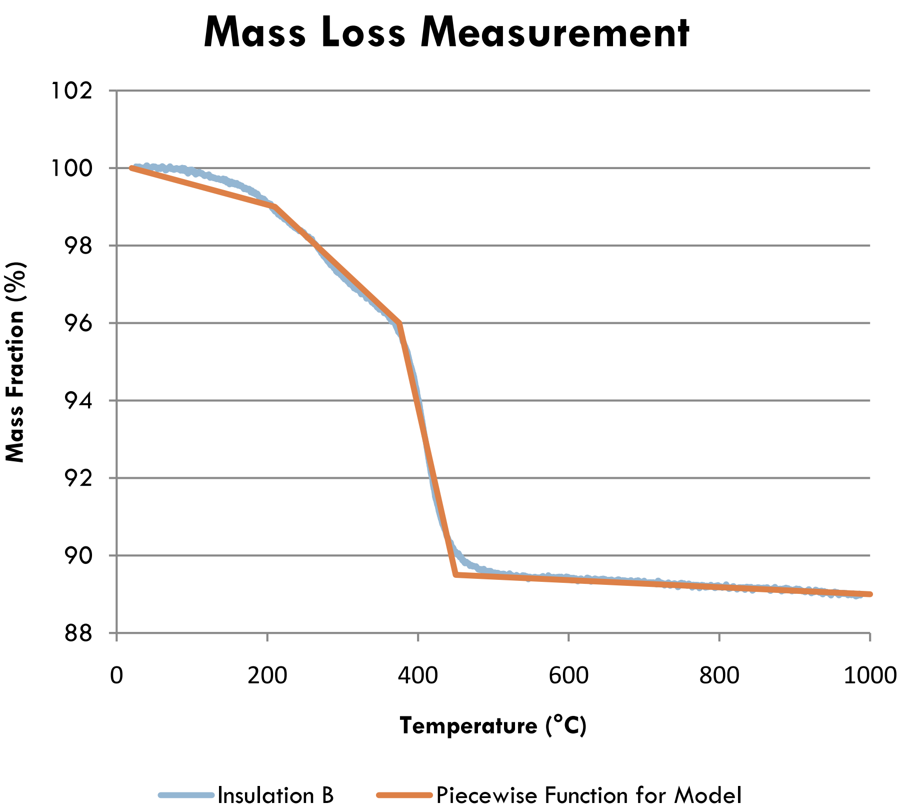
Developing the Model

- Determining Properties
  - Using Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) we can estimate the density (ρ) and specific heat capacity (C_P)
  - Using other techniques or using a DSC thermal conductivity (k) can be estimated

TA Instruments Thermal Analysis Equipment

Developing the Model



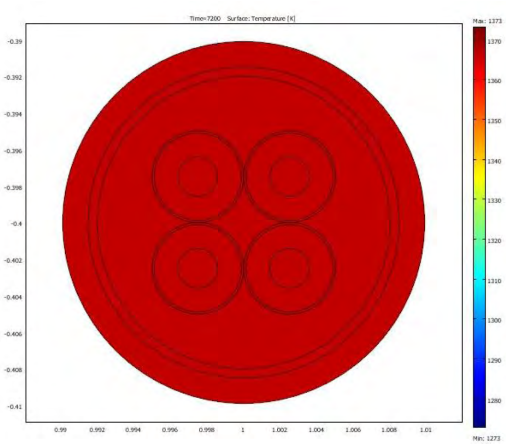


Developing the Model

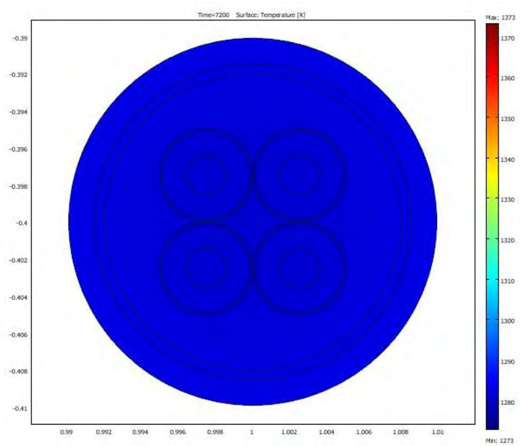
- Predicting Failures
  - Based on melting point of conductor
  - Based on decomposition of insulators
  - Based on…
    - Be creative
    - Know your modes of failure

Results

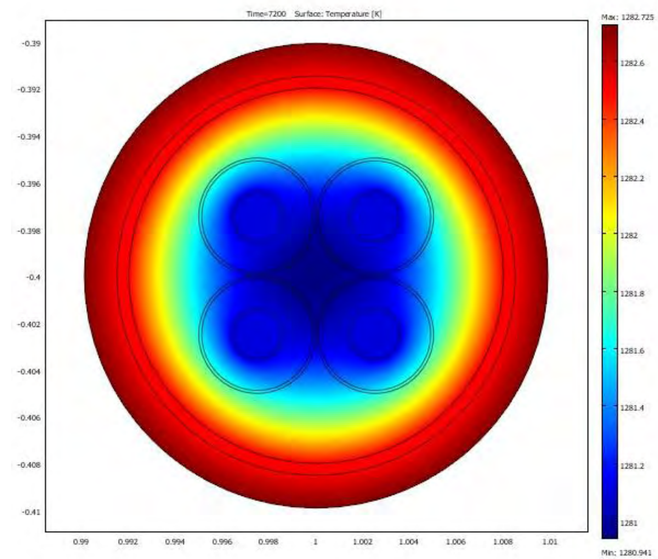
- Temperature Distribution after 2 Hrs.



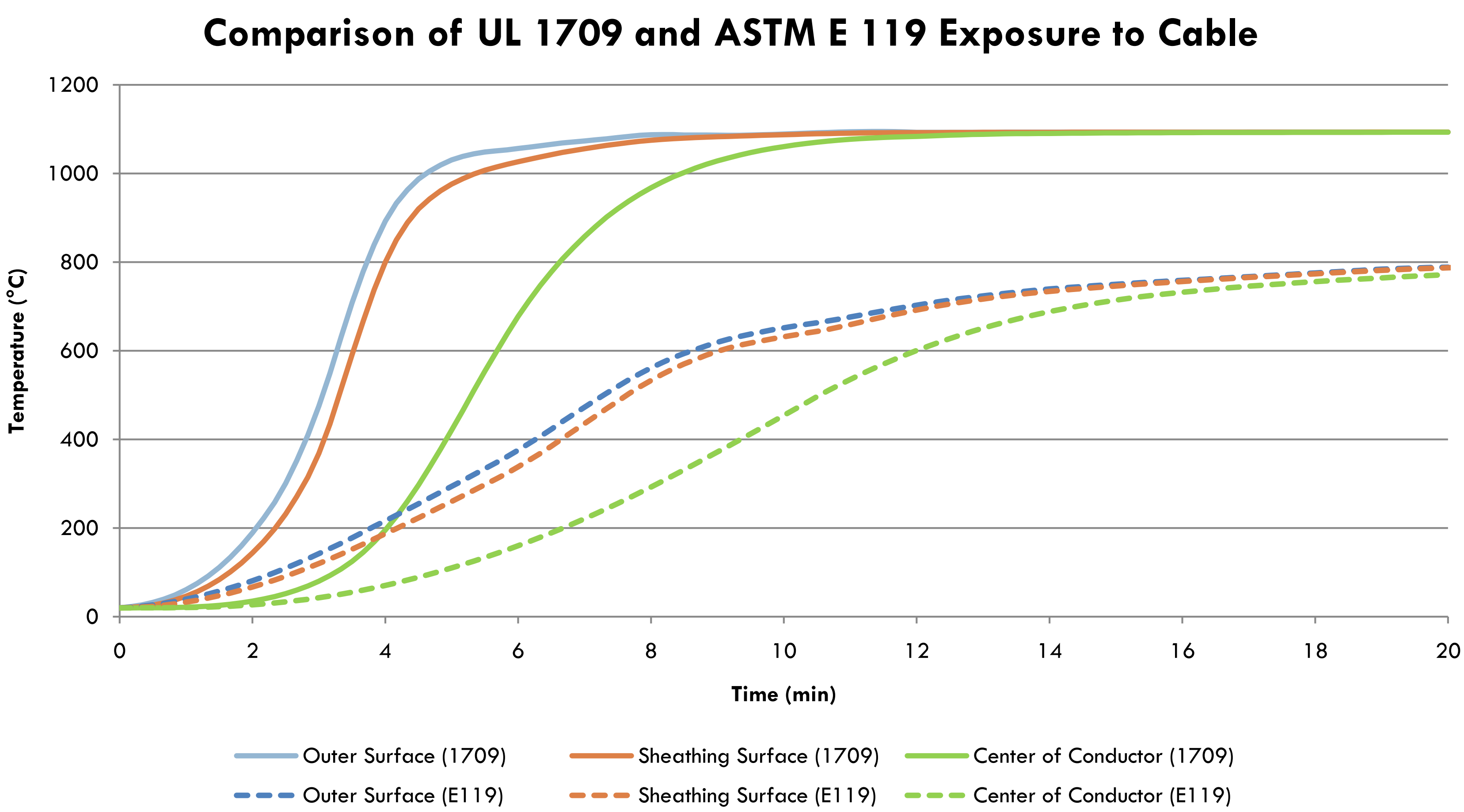
After UL 1709 Exposure



After ASTM E 119 Exposure



Results



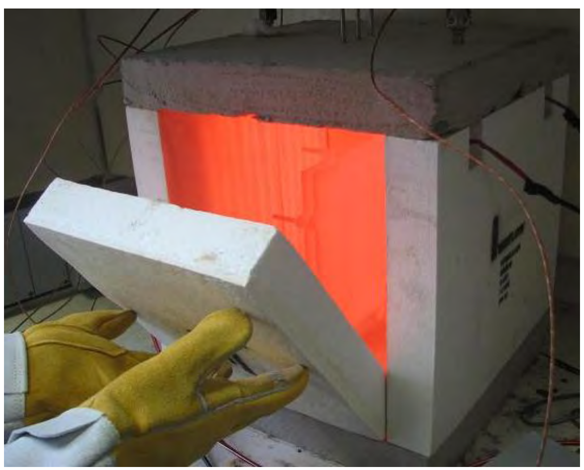
Comparison of UL 1709 and ASTM E 119 Exposure to Cable
Temperature (°C)
0
200
400
600
800
1000
1200
Time (min)
0
2
4
6
8
10
12
14
16
18
20
Outer Surface (1709)
Sheathing Surface (1709)
Center of Conductor (1709)
Outer Surface (E119)
Sheathing Surface (E119)
Center of Conductor (E119)

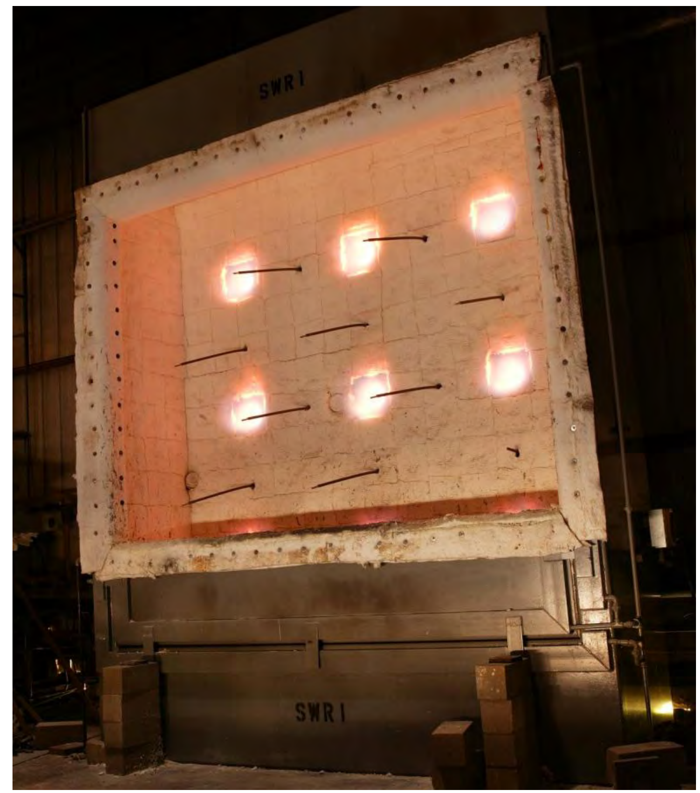
Conclusions

- Modeling Can Be More Cost Effective than Standardized Testing
- Model can be tuned for specific problems
- Easy to Alter Model
- Model is dependent on input (assumptions, properties, boundary conditions, etc.)

Questions?

www.fire.swri.org





Other Methods for Estimating Thermal Properties

- Parameter Estimation (Optimization)
  - Genetic Algorithm (GA)
  - Particle Swarm
- SwRI Currently Sponsoring an Internal Research Program Using GA to Predict Thermal Properties of Various Materials