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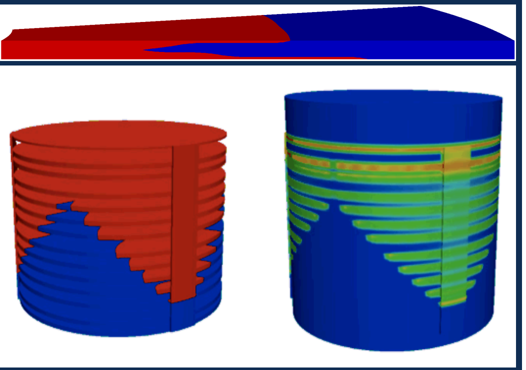

Modeling of Thermal Battery Initiation Using Level Sets

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Why Model Initiation?

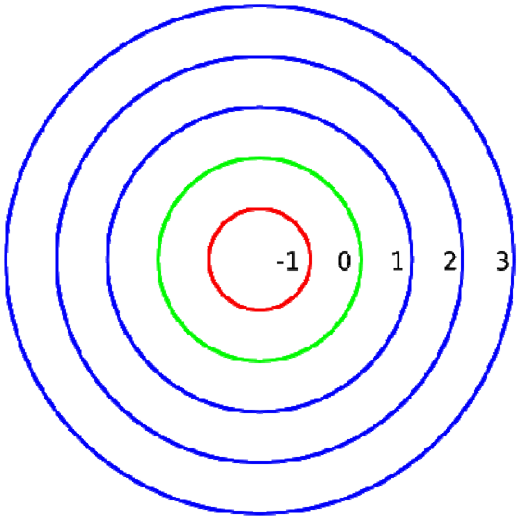
- Rise time sometimes a critical parameter
- Prediction of peak temperature can help avoid damage
  - material degradation
  - thermal runaway

Potential Routes

- Volumetric Heating
  - Neglects several key features
    - spatially-uniform
    - must choose a burn time
      - choice strongly affects peak temperature
- Reaction Modeling
  - Expensive

Level Sets

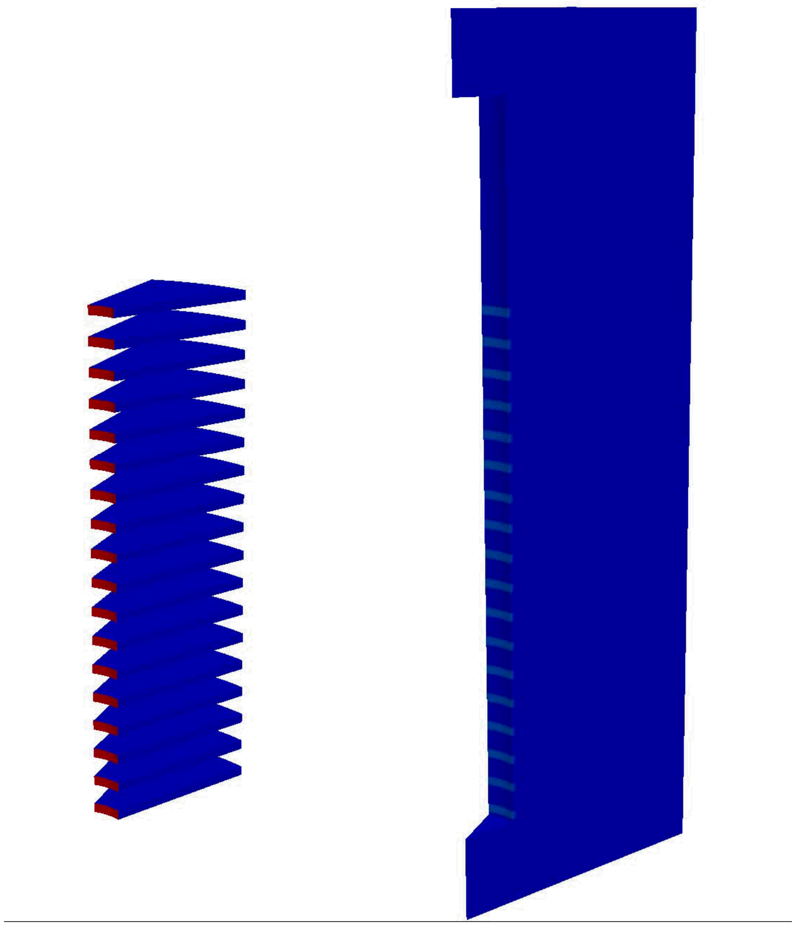
- Basically a signed distance from an interface.
  - Zero is interface location.
- Typically applied in dynamic interface problems.
  - multiphase flow
  - mold filling
  - foam decomposition



- Can apply special conditions at the interface.
  - In our case, we release heat as the interface passes.
- We move interface at a constant speed
  - Measured speeds available for most materials of interest.

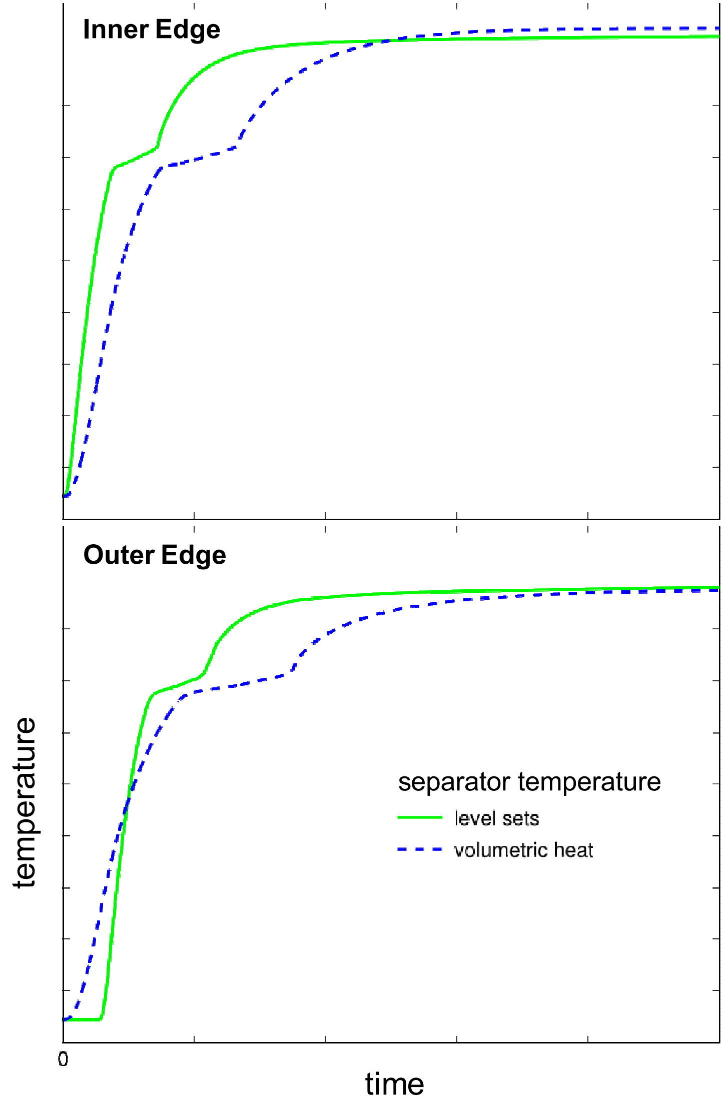
Results: Center-fired battery

- Axisymmetric geometry
  - Performed as a 10^{o} wedge
- Assumed simultaneous ignition of pellets
  - Burn front propagates as a cylinder with an expanding radius

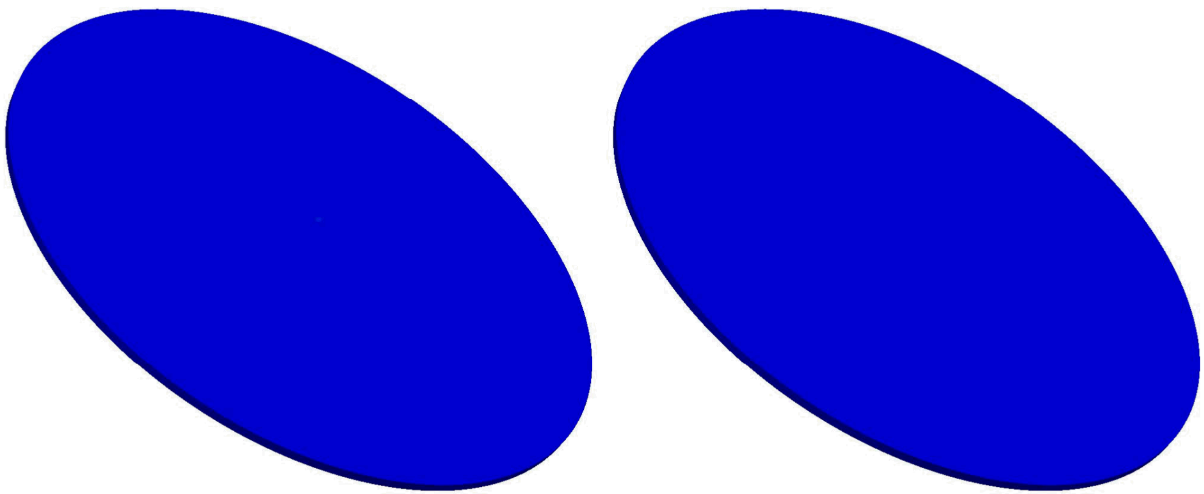


Comparison to Volumetric Heating

- Even for this simple case, significant differences appear
  - temperature rise steeper for LS
  - time lag visible in LS
- Long-time behavior comparable
  - LS most useful for initiation



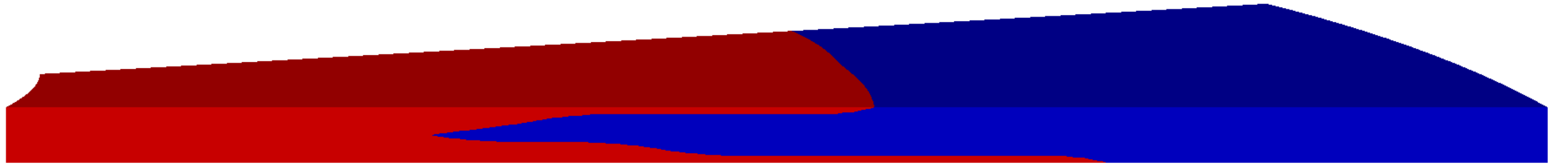
Comparison for a Single Pellet



- Volumetric heat captures behavior in an average sense
- Peak temperature missed
  - Can increase peak by reducing burn time
    - but then cooling starts too soon

Time-Accurate Simulations Provide Insight

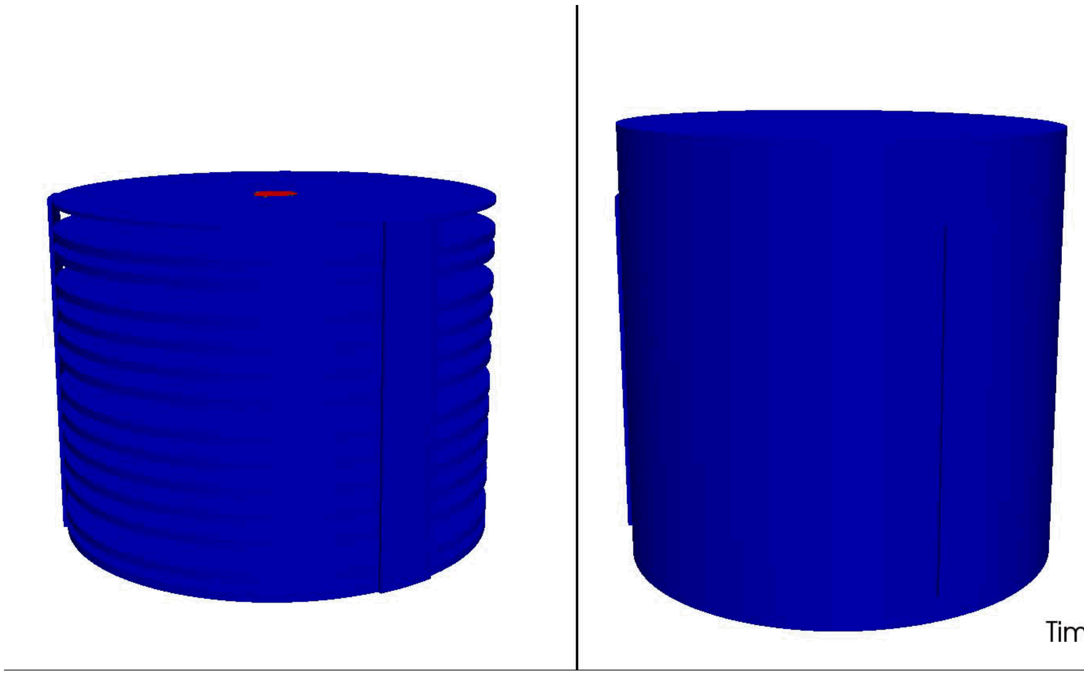
- Example: separator melting
  - Upper and lower surface temperatures differ due to number, size, and type of intervening materials
  - Extent of through-pellet melt related to electrical capacity



Red = melted
Blue = solid

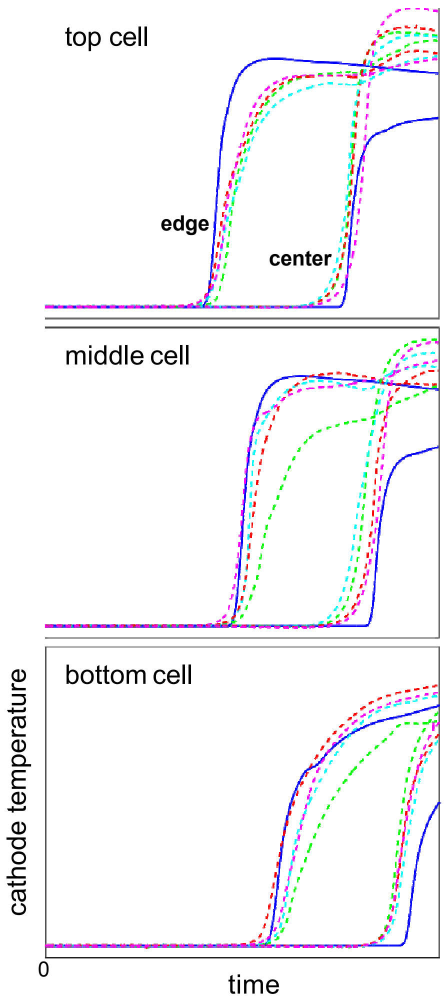
Results: Side-Fired Battery

- Much more complicated
  - Upper pellet ignites strips
  - Strips ignite lower pellets
- Many inherent time lags
  - Igniter to strips
  - Strips to pellets
  - Pellet edge to center
- In simulation at right, front speeds all equal
  - not generally true
  - not a requirement for LS



Comparison to Measurements

- Heat paper front speed more than twice that of pellets
- Time of temperature rise at edge and center of cathode and overall shape comparable to measurements
- Consistent underprediction of center temperature
  - likely material property related



Conclusions

- Thermal simulation with level set-based tracking of burn fronts provides a powerful means for investigating initiation in thermal batteries.
- Key differences were seen between results from this technique and the commonly-applied volumetric heating scheme.
- Good agreement with measurement was demonstrated for a side-fired battery with multiple burn front speeds.

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