SAFETY ANALYSIS OF THE ARC-100 SODIUM-COOLED FAST REACTOR

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OVERVIEW

- **ARC-100:**
  - 100 MWe fast reactor
  - Long-lived core with low burnup reactivity swing
  - Sodium coolant
  - Metallic fuel
  - Pool type

- **SAS4A/SASSYS-1 model represents:**
  - Core
  - Primary heat transport system
  - Secondary heat transport system
  - RVACS
  - DRACS

- **Safety Design Philosophy:**
  - Relies on passive safety
  - Leveraging safety characteristics of key design features

- **Unprotected transients analyzed:**
  - Station blackout
  - Loss of heat sink
  - Transient overpower
  - BOL, MOL, and EOL
SAS4A/SASSYS-1 CORE MODEL

Zones  Axial Nodes
NZONE

REFLECTOR

PLENUM
MZ
KZPIN

FUEL

1

NREFB

REFLECTOR

1

Axial Elevations

ZCOOL(MZ)

ZFM(MZ)

ZFM(1)

ZFI(1), Z = 0

ZFI(MZ+1)

Inner core (30)

Middle core (33)

Outer core (36)

Control rod (9)

Empty (1)

Reflector (42)

Shield (48)
SAS4A/SASSYS-1 HEAT REJECTION SYSTEM MODEL

- PRIMAR-4 module used to model ARC-100 heat transport systems
  - Primary
  - Intermediate
  - DRACS
  - RVACS
METRICS & CRITERIA

Metrics

• Maintain coolable fuel pin geometry
• UTOP, USBO, ULOHS
• Expected to have frequencies of occurrence below $10^{-6}$ per reactor-year
• Conservatively evaluated against criteria for beyond design basis events
• Note: These metrics are preliminary and will depend on results of PRA

Criteria

• No sodium boiling
• No fuel melting
• No significant loss of cladding from FCCI
  – Threshold at 715°C
• Maintain reactor vessel integrity
  – Key structures below 704°C
RESULTS
**BOL UNPROTECTED STATION BLACKOUT**

- Loss of electrical power to all plant systems
- Primary pumps trip
- Intermediate pumps trip
- SG heat rejection to zero
- DRACS air baffles open
BOL UNPROTECTED STATION BLACKOUT

![Graphs showing temperature and power changes over time during a blackout scenario.](image_url)
BOL UNPROTECTED TRANSIENT OVERPOWER

- Single most reactivity control rod withdrawn from reactor
- BOL: 47¢ at 2¢/s

- Pumps remain on
- SG conservatively assumed to continue rejecting at 100%
BOL UNPROTECTED TRANSIENT OVERPOWER
BOL UNPROTECTED LOSS OF HEAT SINK

- Simultaneous trip of intermediate sodium pumps
- All heat rejection through the balance of plant is conservatively assumed lost
SUMMARY AND CONCLUSIONS
SUMMARY AND CONCLUSIONS

<table>
<thead>
<tr>
<th>Beginning of Life</th>
<th>Steady-State</th>
<th>USBO</th>
<th>UTOP</th>
<th>ULOHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Fuel Temp.</td>
<td>564°C</td>
<td>755°C</td>
<td>861°C</td>
<td>568°C</td>
</tr>
<tr>
<td>Fuel Melting Margin</td>
<td>659°C</td>
<td>468°C</td>
<td>362°C</td>
<td>655°C</td>
</tr>
<tr>
<td>Peak Cladding Temp.</td>
<td>548°C</td>
<td>752°C</td>
<td>836°C</td>
<td>554°C</td>
</tr>
<tr>
<td>Max. Clad Penetration</td>
<td>0%</td>
<td>0.1%</td>
<td>0.5%</td>
<td>0%</td>
</tr>
<tr>
<td>Peak Sodium Temp.</td>
<td>547°C</td>
<td>751°C</td>
<td>833°C</td>
<td>553°C</td>
</tr>
<tr>
<td>Sodium Boiling Margin</td>
<td>396°C</td>
<td>193°C</td>
<td>122°C</td>
<td>388°C</td>
</tr>
<tr>
<td>Peak Hot Pool Temp.</td>
<td>510°C</td>
<td>560°C</td>
<td>651°C</td>
<td>516°C</td>
</tr>
<tr>
<td>Reactor Vessel Margin</td>
<td>194°C</td>
<td>144°C</td>
<td>53°C</td>
<td>188°C</td>
</tr>
</tbody>
</table>

- Severe unprotected transient scenarios analyzed with SAS4A/SASSYS-1 to assess ARC-100 safety characteristics
  - Very unlikely double-fault events with an assumed failure of the highly reliable reactor protection system
- ARC-100 maintains large safety margins
  - Due to design features that utilize inherent passive responses to unanticipated conditions and equipment failures
  - Sodium coolant provides superior heat removal at near atmospheric pressures with large margins to boiling
  - Metallic fuel operates at relatively low temperatures due to its high thermal conductivity.
  - Pool-type primary system provides a large thermal capacity
    - Allows for shutdown heat removal through the RVACS and DRACS systems via natural circulation
    - Inherent reactivity feedbacks responsible for reducing power to match the total available heat rejection
- These results demonstrate the capability of the ARC-100 design to provide protection against reactor damage during low probability accident sequences resulting from multiple equipment failures
THANK YOU FOR YOUR ATTENTION