Design Features of ACR in Severe Accident Mitigation

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ACR Process, Safety and Risk Assessment

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Presentation Outline

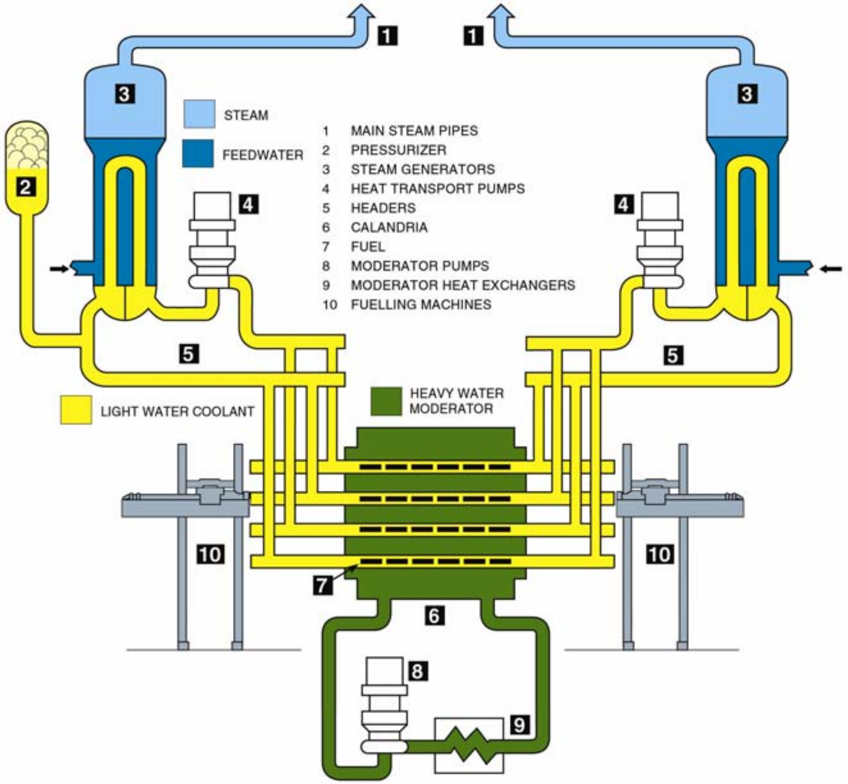
- Severe Accident Management (SAM)
- ACR Design
- ACR SAM-related design features
- Conclusions

Severe Accident Management (SAM)

- Actions to:
  - Prevent core damage, terminate progress of core damage and retain core within vessel
  - Maintain containment integrity
  - Minimize offsite releases
- ACR core damage characteristics different from pressure vessel reactors

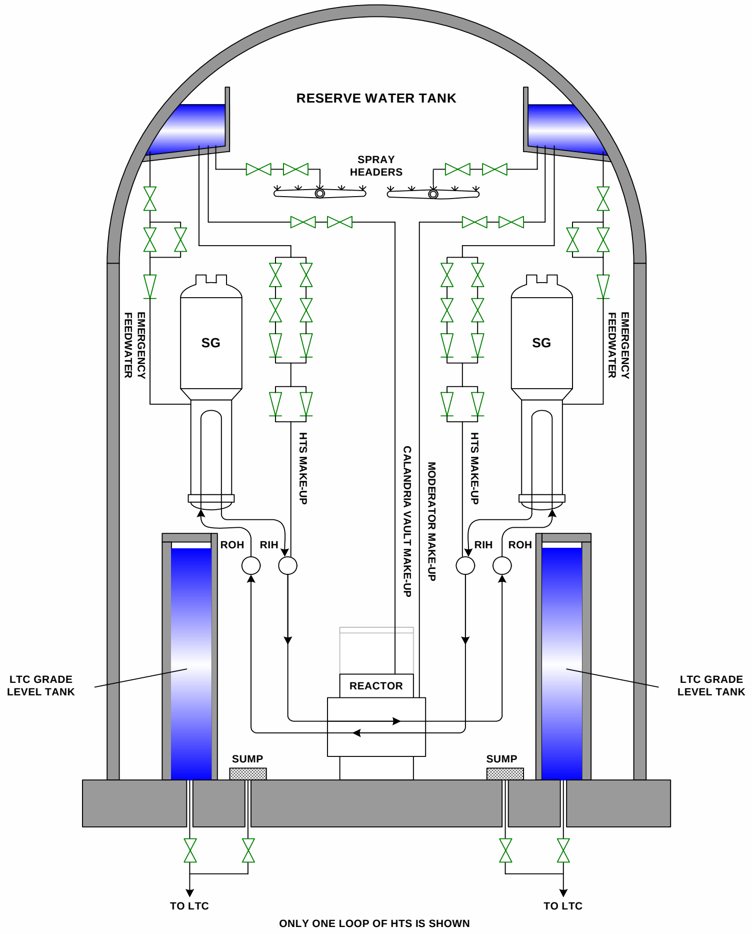
ACR Design Overview

- Horizontal fuel channels surrounded by heavy water moderator
- Slightly enriched uranium fuel and light water reactor coolant
- Two fast acting, fully capable, diverse and separate shutdown systems physically and functionally independent
- Emergency Core Cooling consists of emergency coolant injection (ECI) system and long term cooling system (LTC)



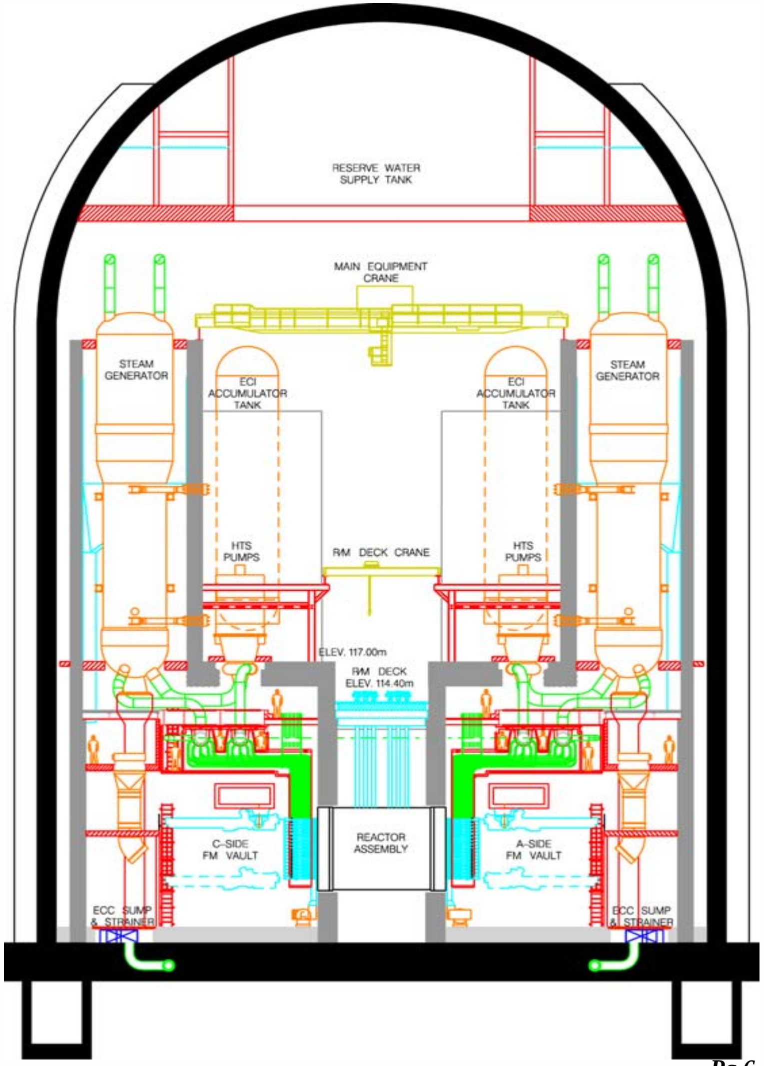
ACR Design Overview

- Reserve Water System
  - emergency source of water by gravity to the steam generators, moderator system, shield cooling and heat transport system
- Secondary control area
  - monitoring and control capability to shutdown reactor and maintain the plant in a safe shutdown state following events that render the main control room unavailable
- Electrical power systems supply
  - safety-related portions are seismically qualified and consist of redundant divisions of standby generators, batteries, and distribution to the safety-related loads.



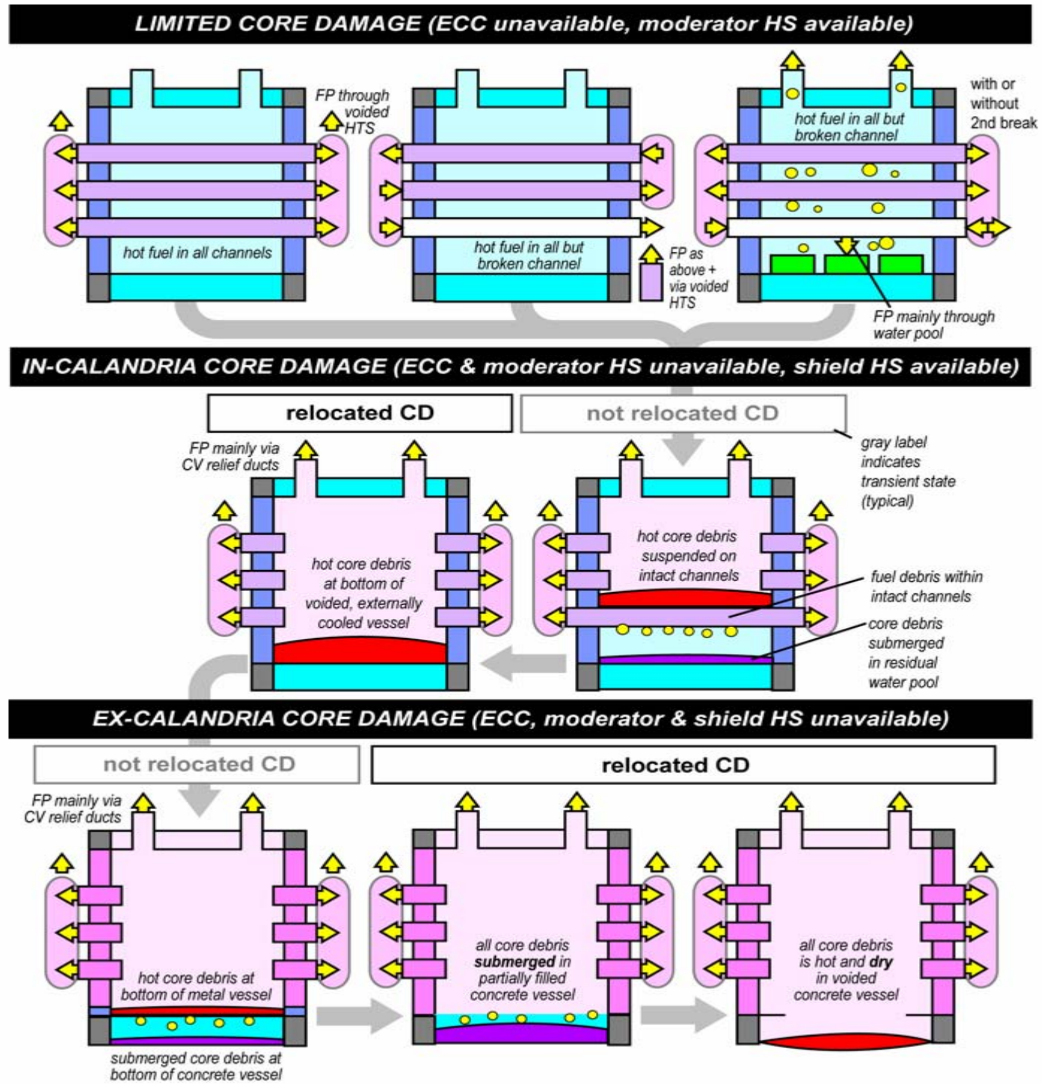
ACR Design Overview

- Containment system: strong structure, (steel lined and low leakage) with isolation, hydrogen control and heat removal



ACR Core Damage States

- Limited Core Damage (CANDU-specific)
- In-Calandria Core Damage (analogous to In-Vessel Core Damage in ALWRs)
- Ex-Calandria Core Damage (generic to all designs)



Prevention of Core Damage

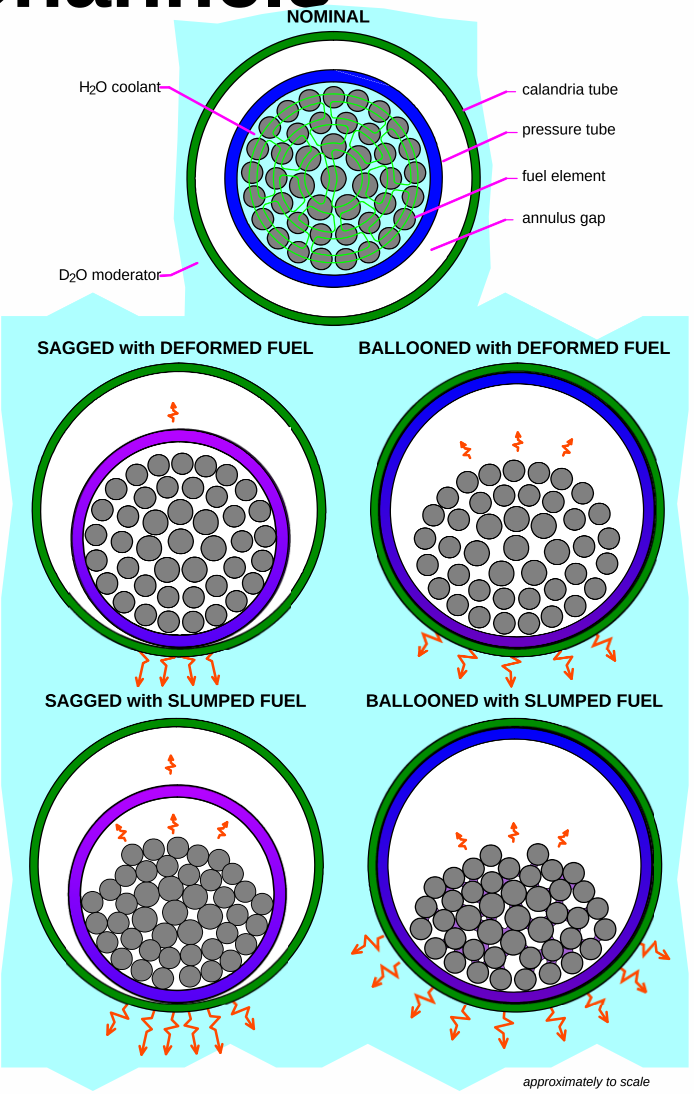
- Conventional AM provisions
  - Keep inside of pressure tubes flooded with liquid water to prevent fuel and pressure deformations
- HTS depressurization (Engineered and Inherent features)
  - Two independent, reliable, engineered systems to depressurize HTS to below ECIS injection pressure using MSSVs
  - Inherent “thermal fuse” (pressure tube failure) allows flooding of fuel by passive water supplies from ECIS or RWS
- SAMDA
  - Engineered emergency cross-connections of safety grade systems

Core Retention Design Provisions

- 2 vessels to retain hot core
  - Fuel channels
  - Calandria

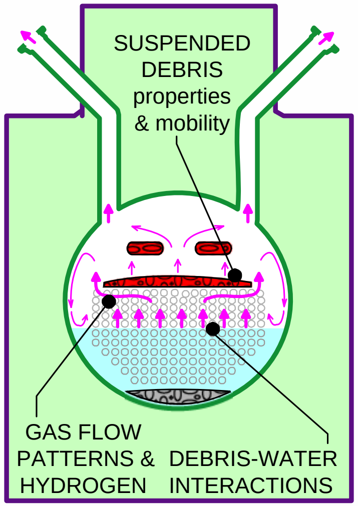
Retention in Fuel Channels

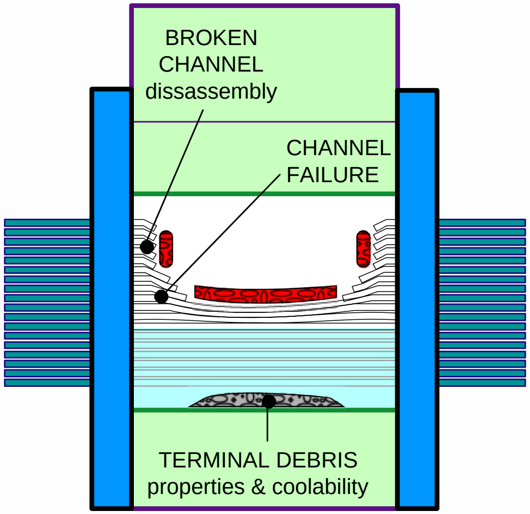
- Fuel channels depressurized before fuel heats up
- Heat rejection paths established by fuel and pressure tube deformations while the fuel is still solid
- Channels submerged in liquid water ensures retention of hot, solid fuel debris within the fuel channels.



SAM Design Provisions

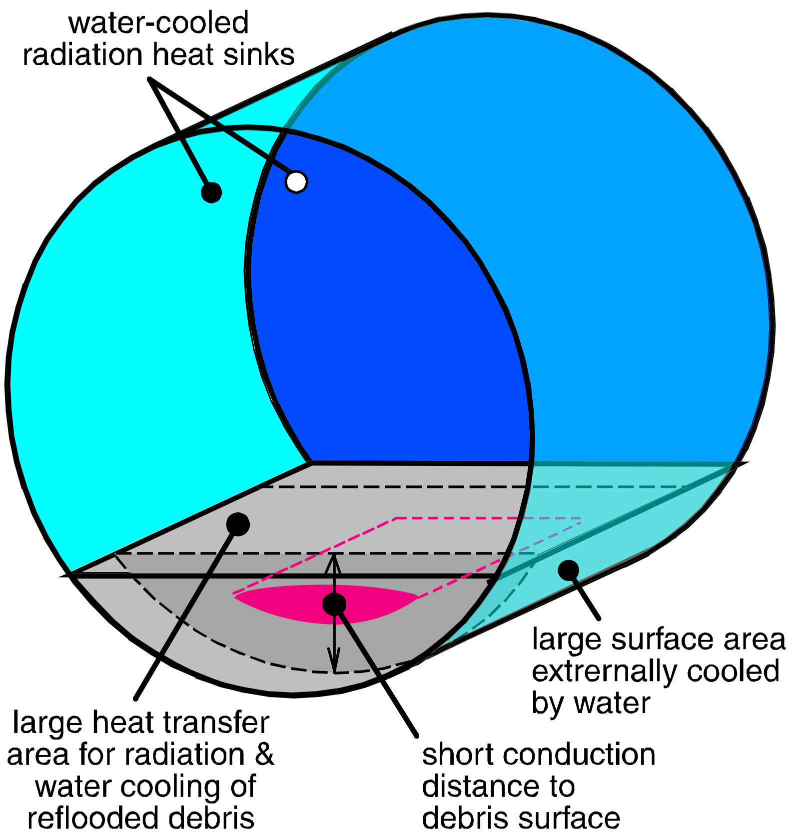
- 2 steam relief paths
- Water make-up by gravity from RWS
- Level measurement in calandria and RWS tank
- Means to control calandria water make-up
- Cross sections for alternate services
- SAMDA – calandria vessel design optimization to reject heat to shield water





Retention in Calandria Vessel

- Strong calandria vessel
- Outer walls in contact with water
- Passive heat sink provided by RWS



Core Damage Termination

- Termination by flooding core materials with water and keeping them flooded thereafter.
- Design provisions for termination in:
  - Fuel channels (LTC from sumps; RWS water by gravity)
  - Calandria vessel (RWS water by gravity)
  - Calandria vault (ACR layout meets EPRI core debris spreading criterion)
- SAMDA
  - Recirculate sump water through RWS tank

Containment Integrity Maintenance

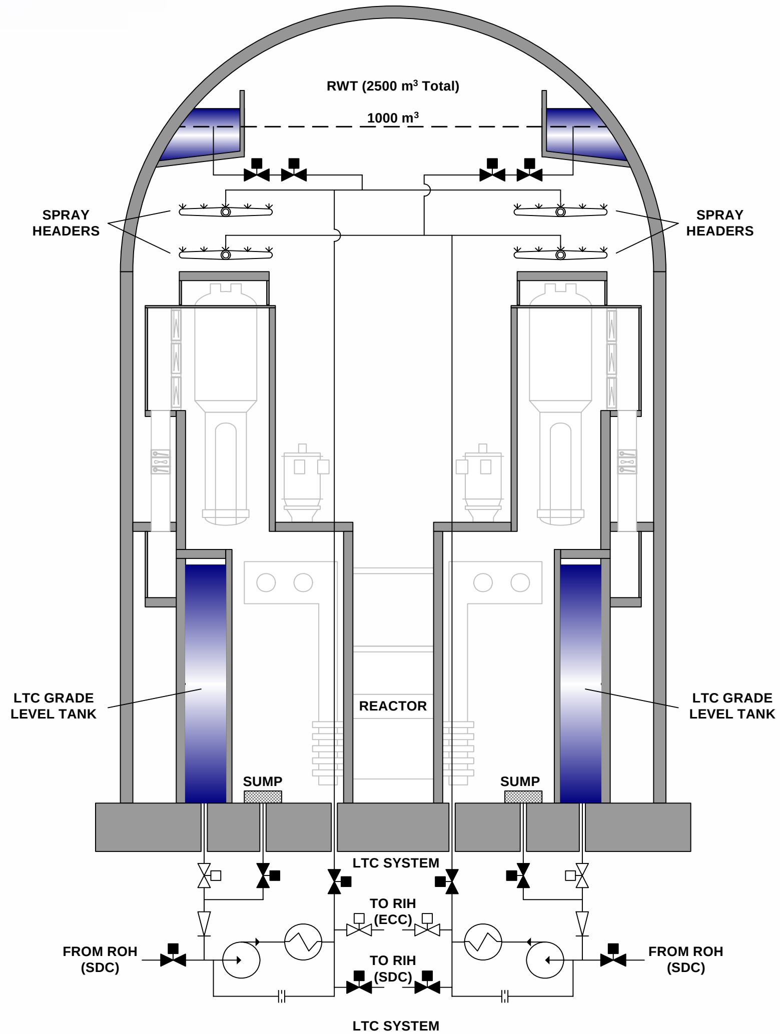
Challenges:

- Pressurization
- Flammable gas control
- Core concrete interaction

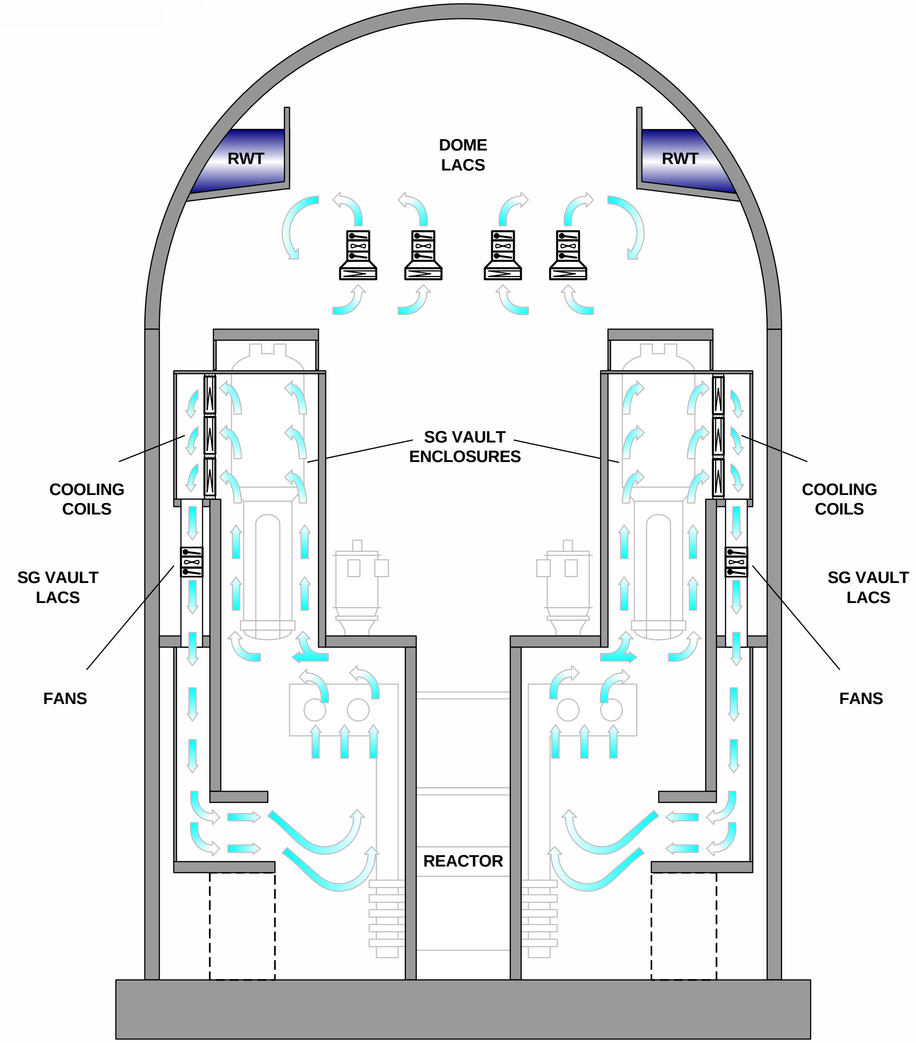
Prevention of Containment Pressurization

- Design features:
  - Strong containment
  - Containment sprays
  - Local Air Coolers to condense steam (SG vault, RB dome, moderator room and other locations)
  - Post-accident heat sinks for HTS, calandria vessel, and shield water to stop steaming into containment
- SAMDA
  - Containment venting

Prevention of Containment Pressurization Sprays



Prevention of Containment Pressurization
Local Air Coolers



Offsite Release Minimization

- Isolated ACR containment is leak tight (less than 0.2% per day at design pressure)
- Containment structure has a large margin (more than twice the design pressure)
- Fail safe design
- SAMDA
  - Containment venting

Flammable Gas Control

- Post-accident hydrogen control strategy
  - Remove hydrogen from containment atmosphere
  - Prevent hydrogen detonation
- Design provision
  - Passive autocatalytic recombiners and igniters
  - Containment structure designed to provide forced and natural circulation mixing

Conclusions

- Severe accident management design provisions ongoing from early stages of ACR design
- Active heat sinks for process vessels capable of operating under severe accident conditions
- Passive backup heat sinks will provide SAM more than 1 day to diagnose accident and establish ultimate heat sink
- Robust containment design

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