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Experimental Demonstration and Performance Evaluation of Passive Decay Heat Removal System of PFBR

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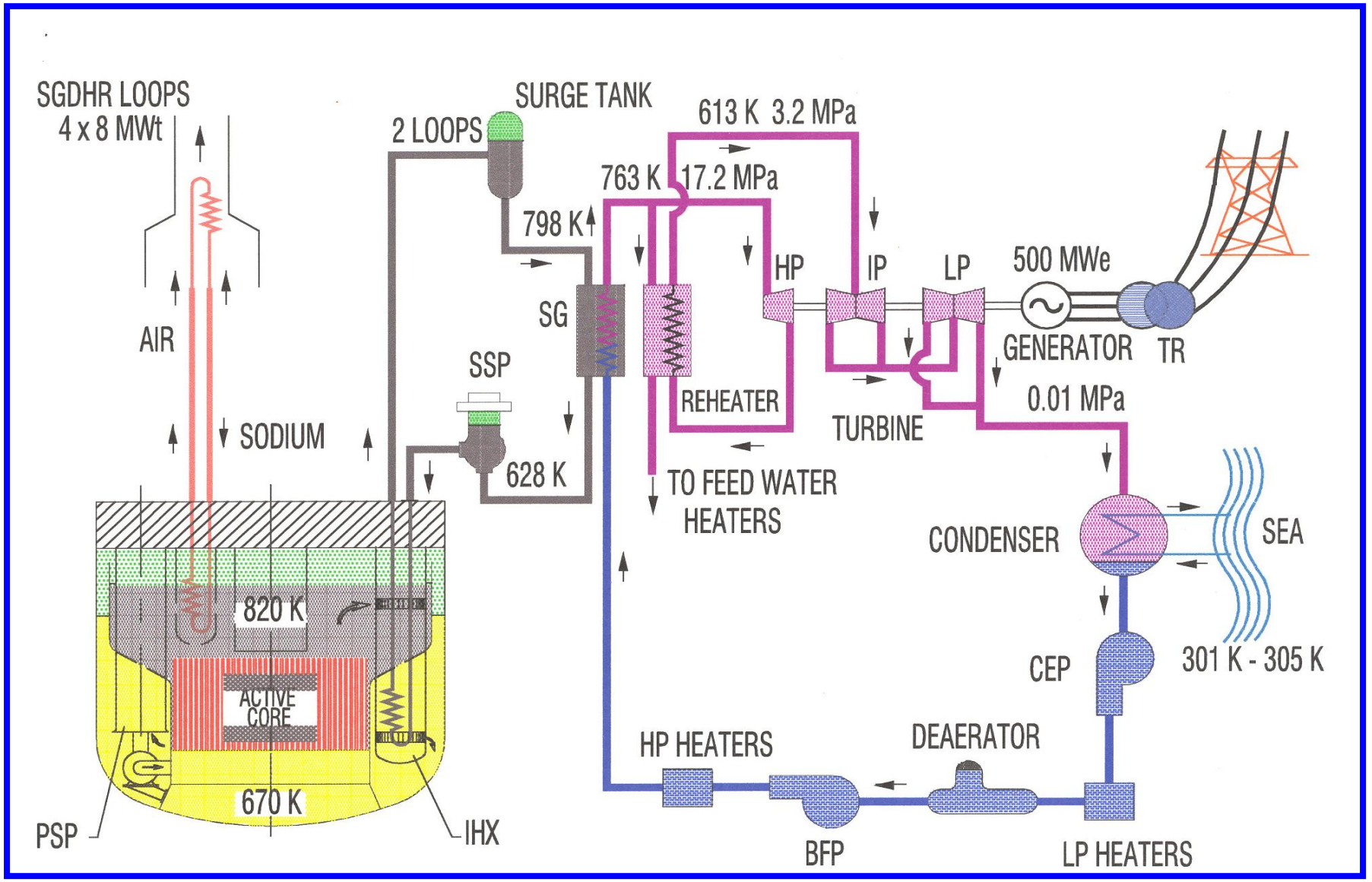
OUTLINE

- **INTRODUCION**
- **SAFETY GRADE DECAY HEAT REMOVAL (SGDHR) SYSTEM**
- **EXPERIMENTAL FACILITY**
  - **Simulation Criteria**
- **EXPERIMENTAL RESULTS**
  - **Steady State Scenarios**
  - **Transient Scenarios**
- **SUMMARY**

Introduction -PFBR Heat Transport Circuits

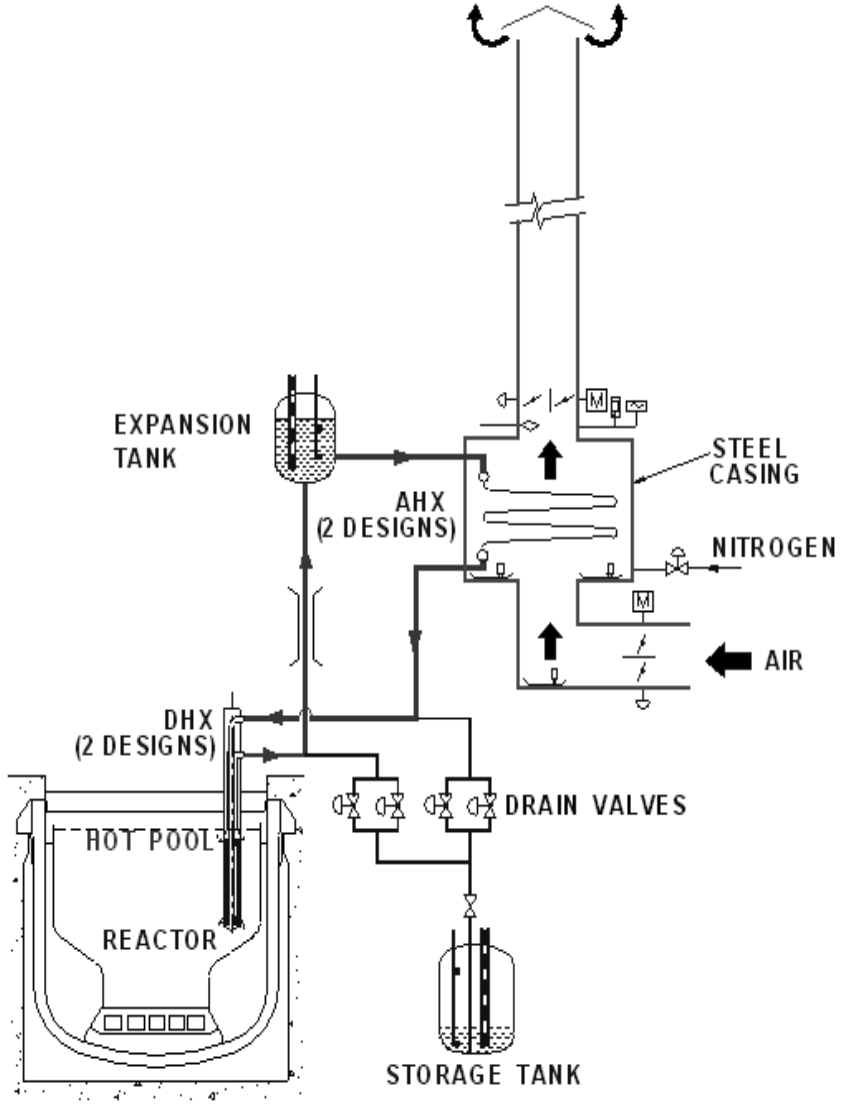


Decay Heat Removal System in PFBR

- **Controlled Shutdown:**
  - Decay heat removal through Operation Grade Decay Heat Removal (OGDHR) system.
  - OGDHR Capacity:4x5 MW.
- **SCRAM:**
  - Both OGDHRS and SGDHRS are initiated.
  - If OGDHRS is ensured, SGDHRS brought to poised state.
  - SGDHR Capacity: 4x8 MW
- **Events to initiate SGDHRS:**
  - SCRAM
  - Loss of both secondary sodium loops
  - Loss of steam – water system caused
    - Class IV power failure
    - Unavailability of all the BFP
    - Feedwater or steam pipe punctures or ruptures
  - Earthquakes
  - Failure of OGDHRS during shutdown state of the reactor

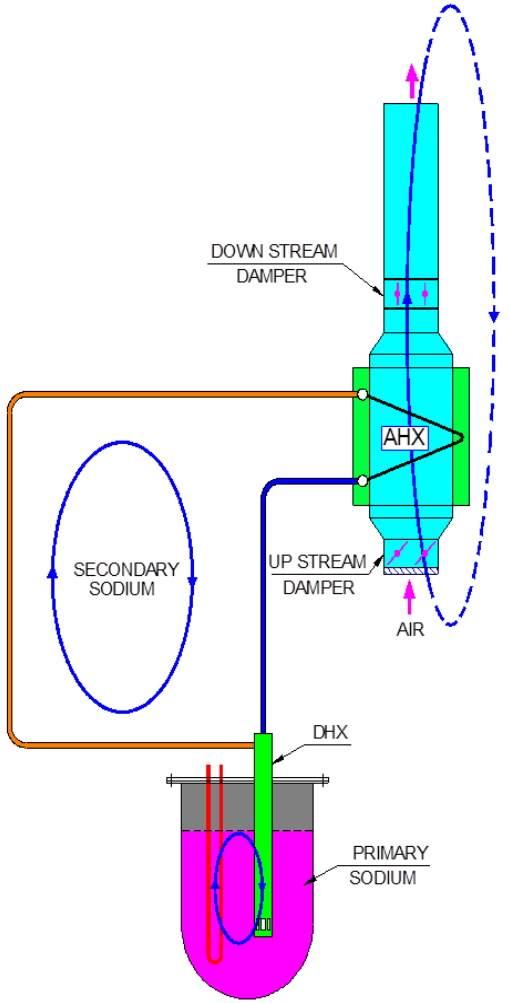
Summary of SGDHR System

- No. of Loops: 4 × 8 MW
- Temperatures: Pool 547 °C; Hot leg 495 °C; Cold leg 302 °C
- Thermal Center Difference: 40 m
- SGDHR System: Completely passive operation
- Design Safety: Diversity & redundancy in DHX, AHX & dampers
- Leak Event Safety: DHX shell side inlet & heat transfer area sized for vessel leak
- Air Dampers: Operated on demand by powered actuators



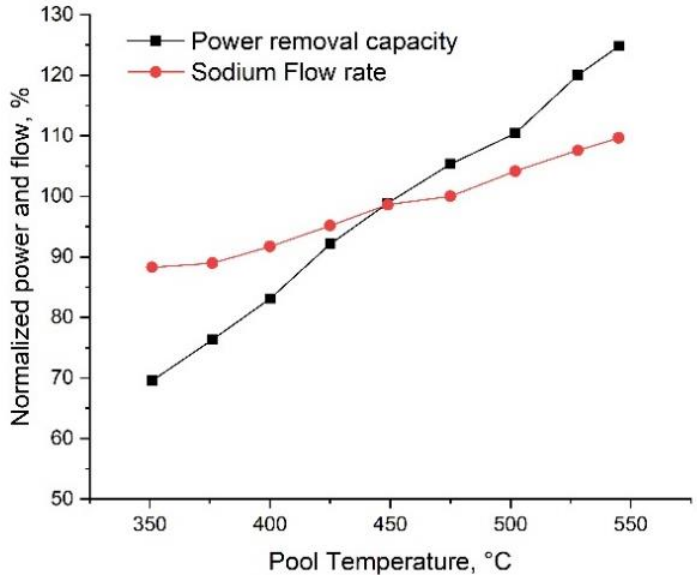
Experiments in Sodium Facility- SADHANA

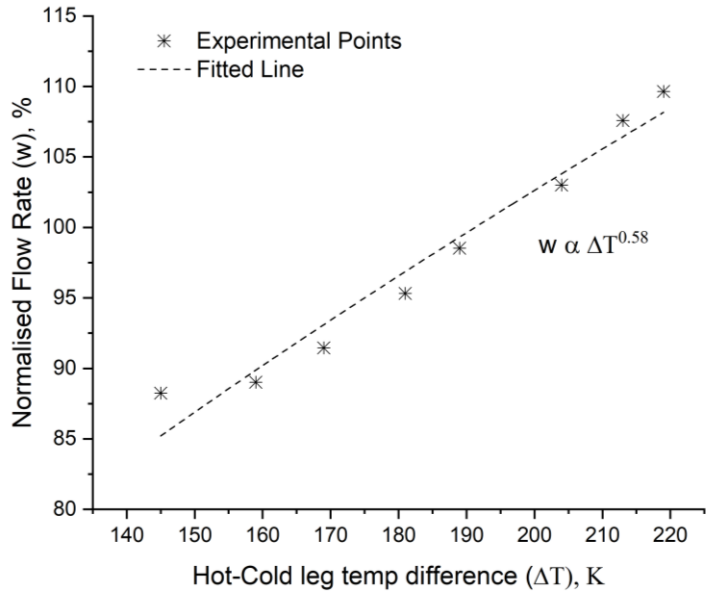
- Constructed to study thermal-hydraulic behavior of SGDHR system of PFBR
- Scaling: 1:22 (in power)
- Similarity basis: Richardson number (Ri)
- Temperature parameters: Maintained same as prototype
- Components: DHX & AHX similar to PFBR's SGDHR
- Thermal center difference: Half of prototype
- Test vessel: Designed to simulate hot pool of reactor

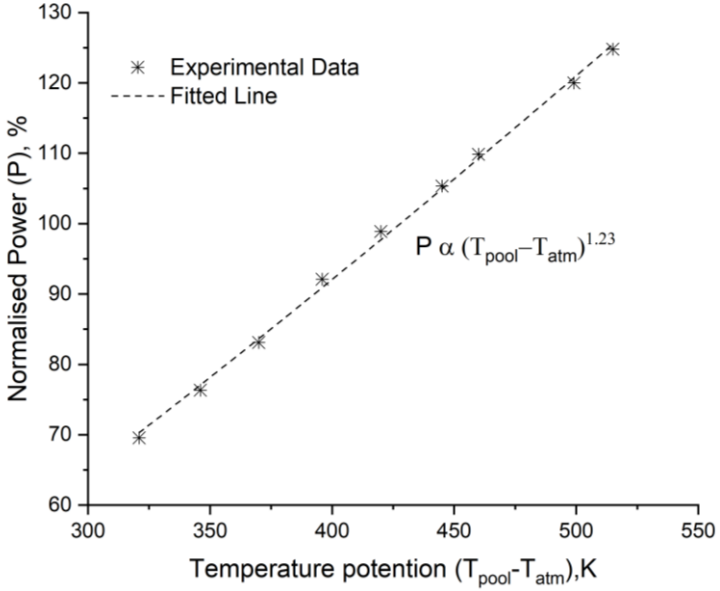


Demonstration -At Nominal Operating Condition

- **Nominal reactor operating condition during SGDHR is reproduced in test vessel.**
- **Air dampers: Kept full open during tests.**
- **Observation: Stable with no fluctuations in temperature or sodium flow.**
- **At 550 °C sodium pool temperature:**
  - **Heat removal capacity: 24.8% above nominal**
  - **Sodium flow rate in intermediate loop:9.7% above nominal**

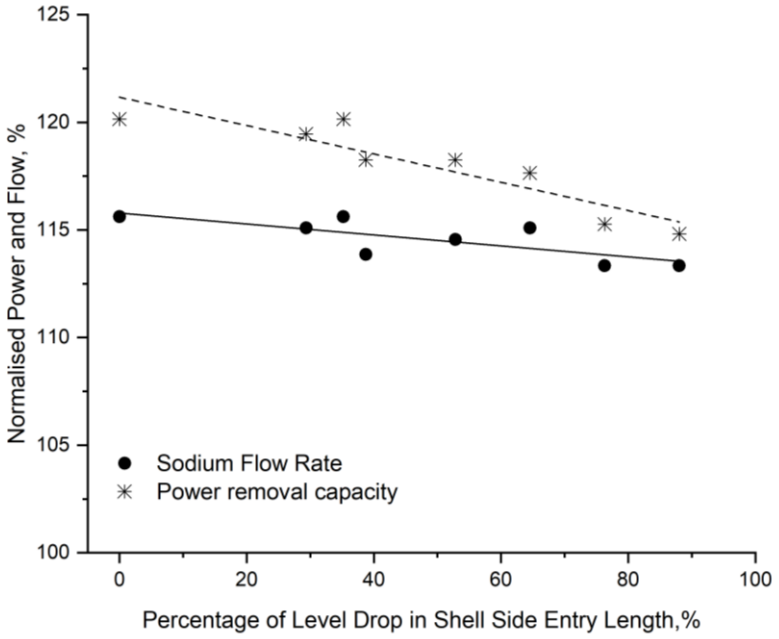


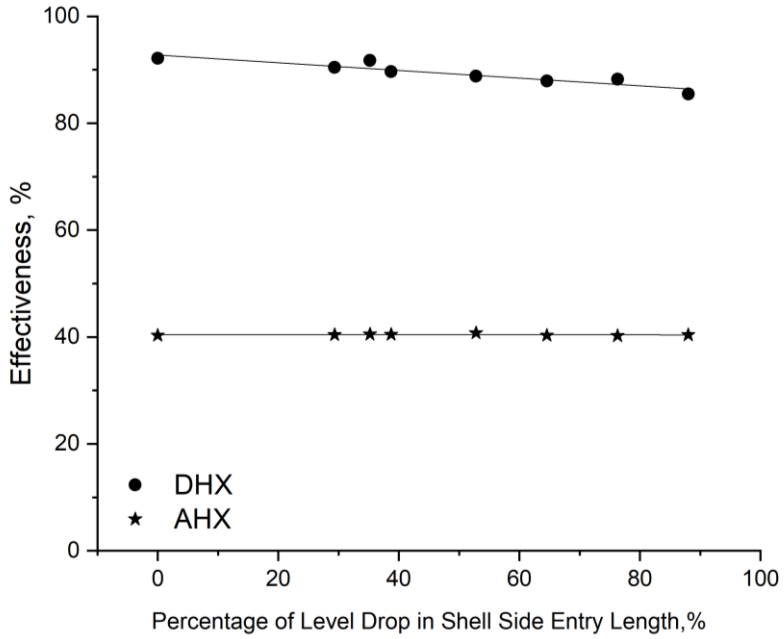




Demonstration -During Main Vessel Leak Event

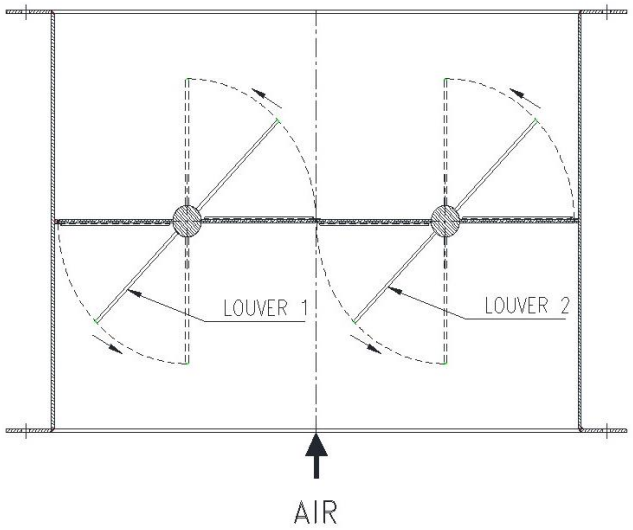
- **Shell-side inlet of DHX: Perforated to ensure availability during main vessel leak**
- **Design basis event (main vessel leak):**
  - **Primary side sodium entry area available: Only 10%**
  - **Effective heat transfer area available: 55% of initially provided**
- **Result: Heat removal capacity reduced by only 5%**

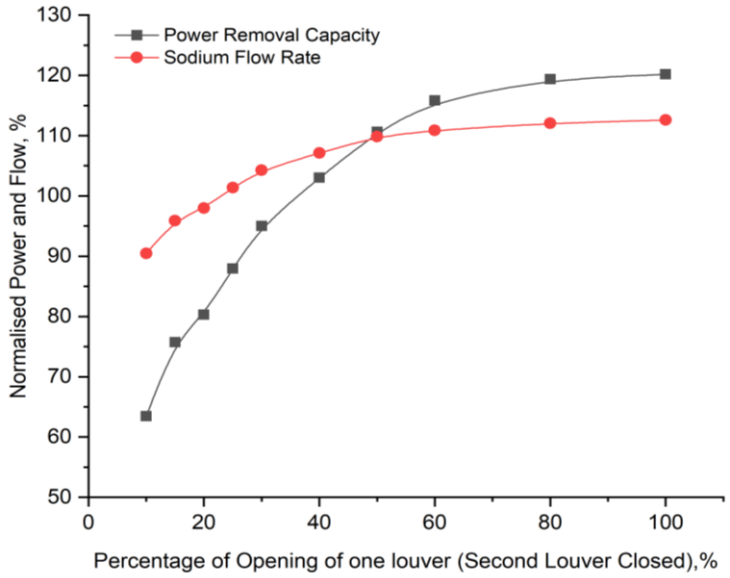




Demonstration -During Unfavorable Conditions

- The air dampers are provided with two lowers operated by diverse actuators. In case of failure of one of louver to open also,
  - Reduction in power removal capacity is just 1%.
  - Confirms the high reliability of the SGDHR system.

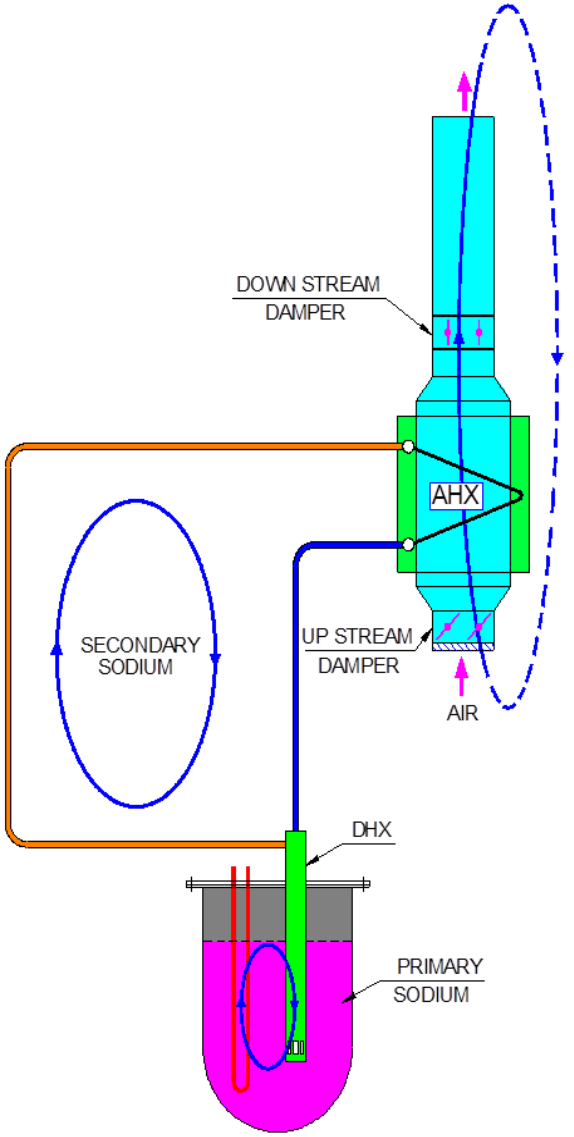




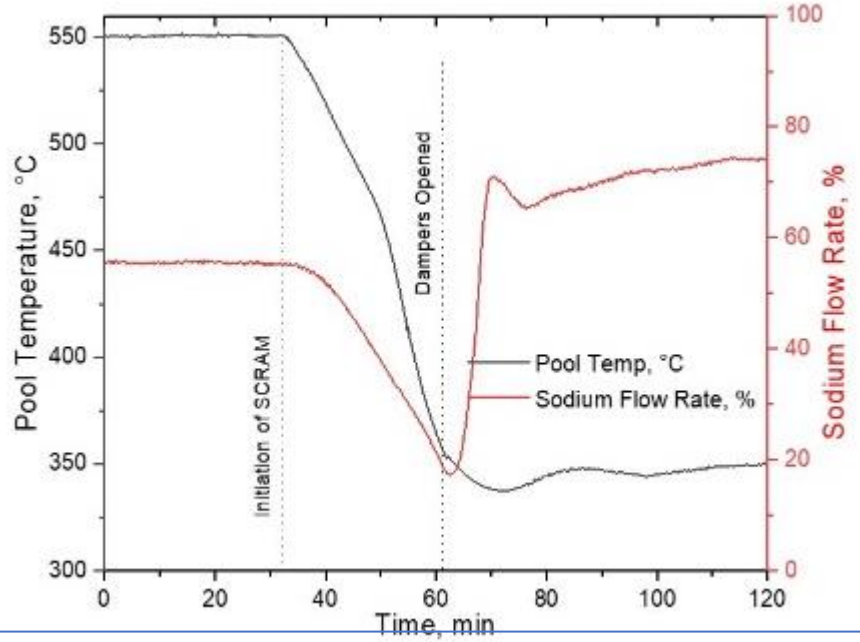
- The unfavorable (reversed flow) direction in intermediate sodium side of SGDHR system,
  - Heat exchangers perform as parallel heat exchangers
  - Reduction in power removal capacity of system was 46.6%.

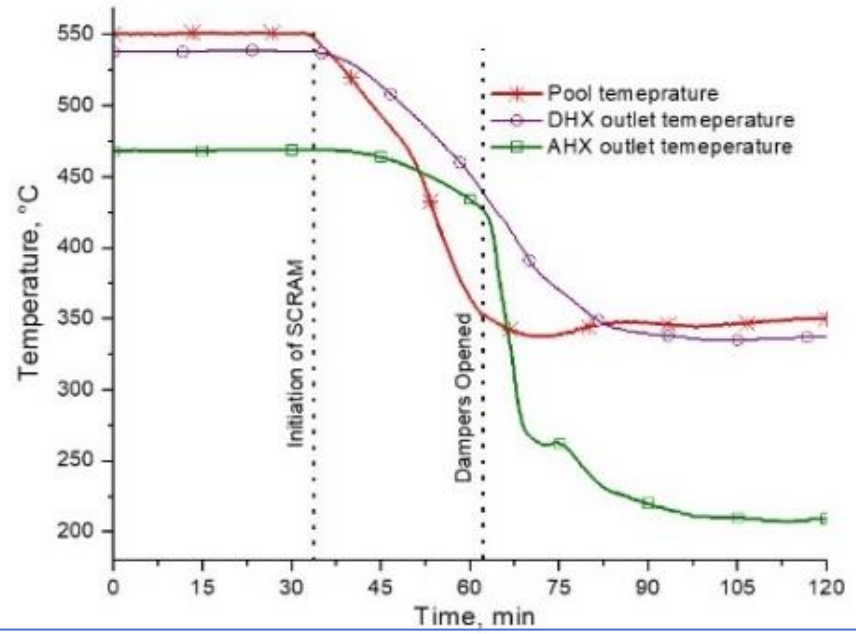
Response of SGDHR System During Transients

- **Heat removal capacity & flow stability depend on hot pool sodium temperature during various transients.**
  - **SCRAM: Maximum cooling rate of hot pool sodium**
  - **Extended SBO accident: Maximum heating rate of hot pool sodium**
- **Transient effects: Experimentally studied on SGDHR circuit in SADHANA facility**
- **Method:**
  - **Cooling: Injection of liquid sodium**
  - **Heating: Immersed electrical heaters**



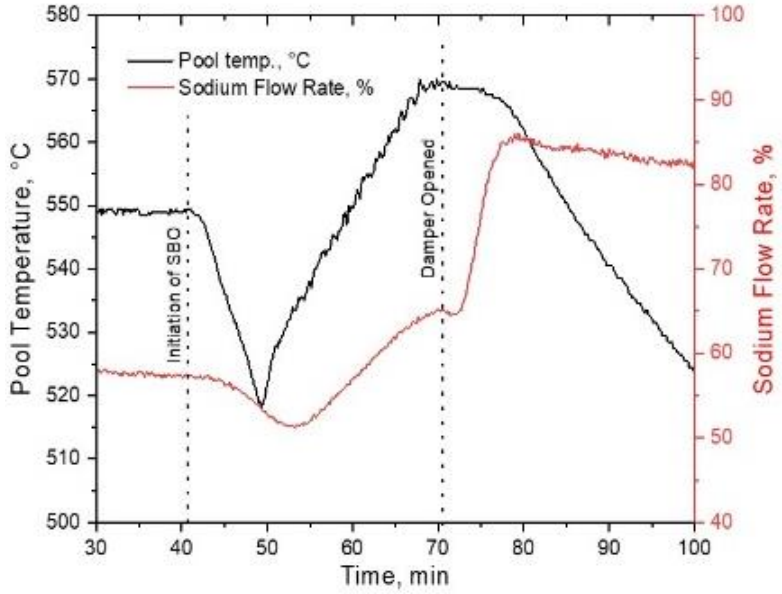
Response of SGDHR system-SCRAM

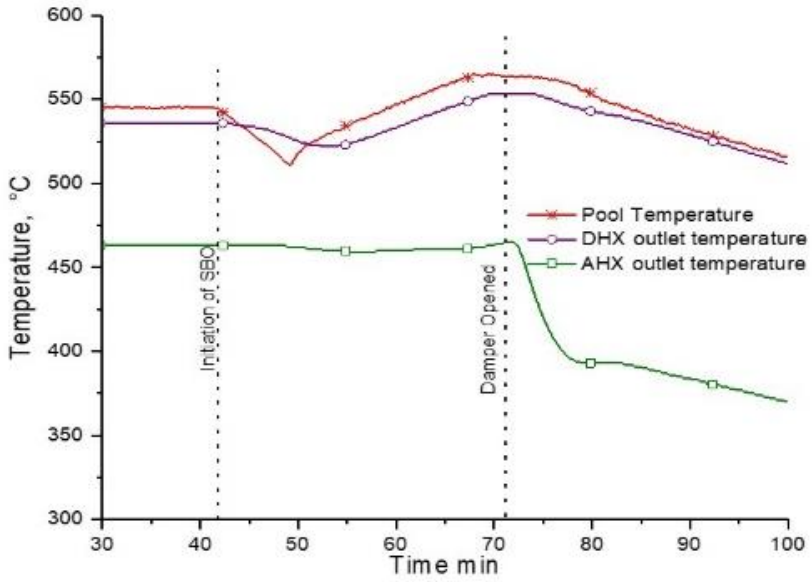




- **After initiation of SCRAM scenario,**
  - **Sodium flow rate reduced up to 17.5%.**
  - **Temperature of pool < temperatures of the intermediate circuit; about 15 minutes**
- **After 30 minutes,**
  - **Air dampers were opened; AHX reduced cold leg temperature below the pool temperature.**
  - **Sodium flow rate reached steady state (70.9%) in 8 minutes with minimal oscillations**

Response of SGDHR System-SBO



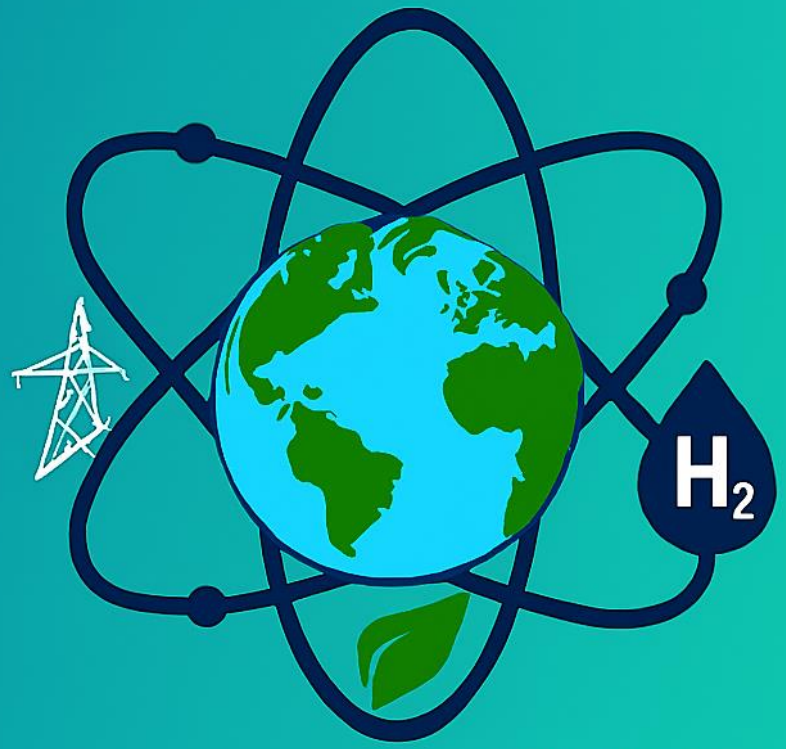


- **After initiation of SBO event: Sodium flow dropped to 51.4% (from 57.6% nominal).**
- **Flow was reaching a steady value 64.5% as hot pool temp stabilized at 570 °C.**
- **Air dampers opened at 30 minutes; Sodium flow reached maximum within 7 minutes.**
- **Temperature behavior: Hot pool sodium temp always > intermediate circuit sodium temp**
- **Flow dynamics: No oscillations or flow reversal observed**

Conclusion

- The SGDHR system of PFBR was thoroughly evaluated using the SADHANA experimental facility through steady-state and transient studies.
- Design philosophy, methodology, and stability of the system were validated under simulated operating and accident conditions.
- Even under main vessel leak conditions, heat removal capability was reduced only marginally, proving design adequacy and resilience.
- SCRAM: Demonstrated effective heat removal and flow stabilization without flow reversal under rapid cooling rate.
- SBO: Showed reliable performance under maximum heating rate conditions without oscillations or flow reversal.
- Overall, the SGDHR system exhibited high stability, availability, and reliability, ensuring passive safety of PFBR.

THANK YOU



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