

ASTRID

*Advanced Sodium Technological Reactor
for Industrial Demonstration*



DE LA RECHERCHE À L'INDUSTRIE

cea den



SFR R&D NEEDS

TOPIC 4

Energy Conversion System

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ESNII | 19/03/2015

PAGE 1

1- Rankine cycle – Water Sodium Reaction in Steam Generators

- Modeling and validation of sodium leak propagation in a SG tubes bundle (reaction jet, thermal and mechanical effects). Comparison with existing experimental database.
- Modeling of the leak self-evolution.

2- Brayton cycle – System loop

- Analysis of the scale effects, test facility specification for the ASTRID Gas PCS operation,
- Test facility development and tests,
- Analysis and validation of the CATHARE code.

Exothermic chemical reaction



SWR origins and effects

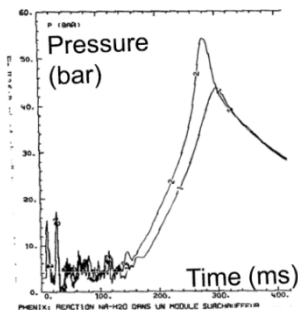
■ *SWR origins*

- **Tube corrosion:** loss of tube wall thickness due to generalized corrosion or stress corrosion cracking (mainly in welded zones) in case of aggressive chemical conditions
- **Thermal shocks:** when under-saturated water is injected at super-heater inlet, inducing thermal fatigue
- **Restraint tube expansion:** buckling, induced by differential expansion with envelope
- **Tube bundle vibrations:** hydraulic effect of Na flow, inducing tube wear



■ *SWR effects*

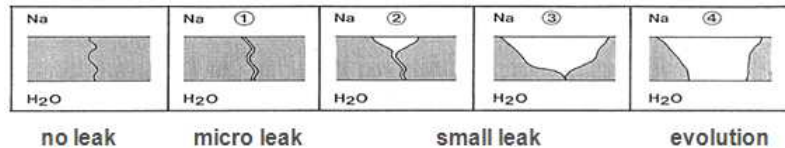
- **Chemical effects:** generalized corrosion due to oxides and stress corrosion cracking due to NaOH, and local erosion / corrosion due to propagation to surrounding structures
- **Mechanical effects due to large water leaks (>100 g/s),** leading to overpressure
- **Overheating effects due to large water leaks:** deformation, swelling, bursting



SWR wastage and overheating effects

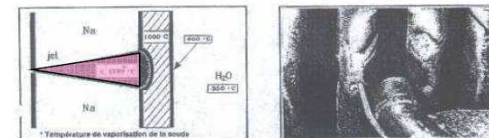
- Initiating defect (mainly in welded zones) leading to a crack, then a leak, plus a SWR leading to a reaction jet
- Growth of the leak orifice (self-wastage), and damage of the neighbouring tubes or wall by removal of material
- Perforation of adjacent tubes leading to secondary leaks. Under hot reaction products effects, tubes strongly become strained (swelling of tens of %) and can burst in tens of seconds by creating important breaks

Water leak self-evolution

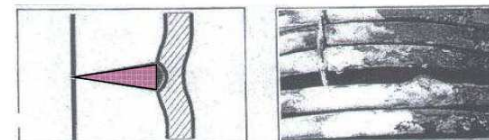


SWR thermal effects

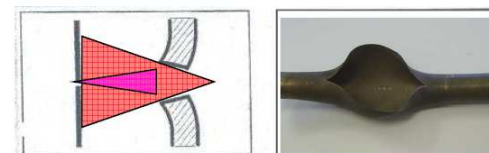
Wastage



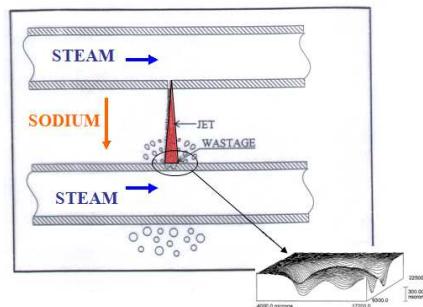
Overheating and swelling



Bursting



Wastage of surrounding tubes



for water leak rate > 80 g.s⁻¹

Secondary large leak

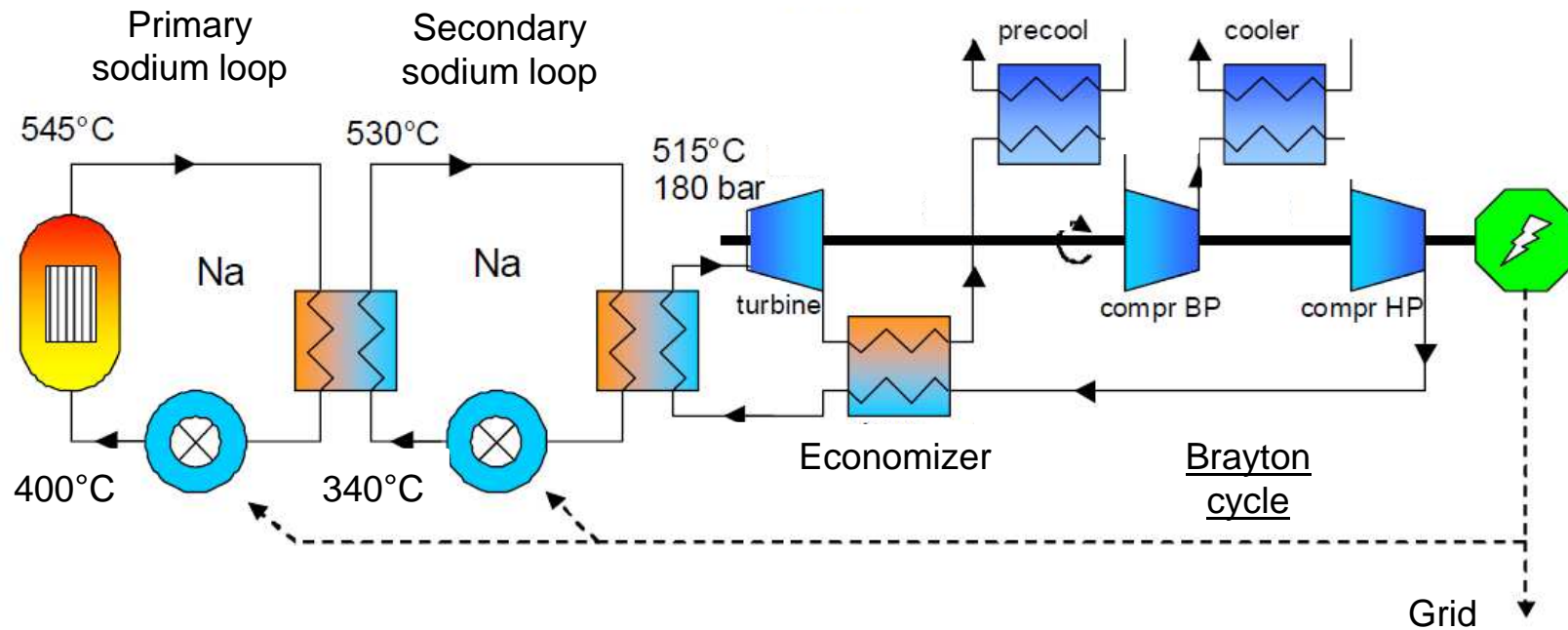
SWR modeling and validation

- Wastage and overheating models correlated with the SG tubes material (ferritic or ferritic-martensitic steels)
 - Distance between the leaking tube and the target wall, penetration time
 - Influence of the leak evolution and on the wastage rate and kinetics, behavior towards the overheating and bursting effects in the field of the high temperatures (up to 1200°C)

- Modeling of the leak self-evolution
 - Thermal and CFD coupling, multi-phase flow
 - Meshing deformation and evolution (solid cells to liquid cells depending on the wastage rate)

- Experimental data base analysis
 - Wastage tests
 - Bursting tests

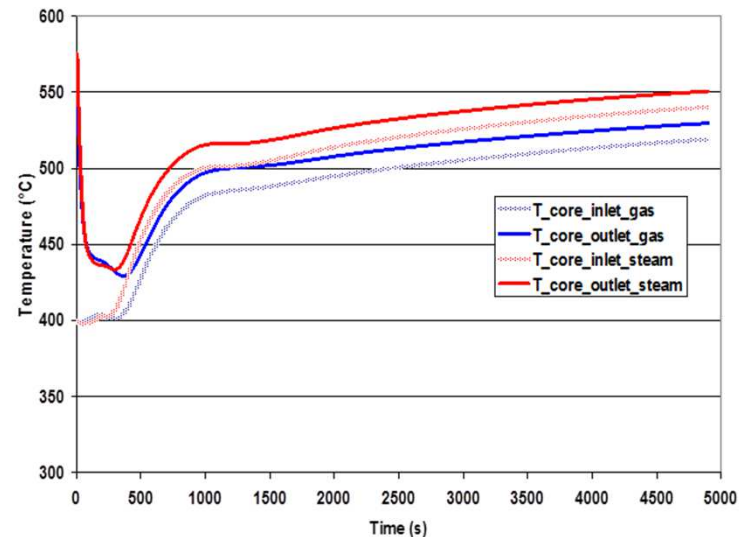
Gas power conversion system for SFR



CATHARE validation with gas PCS

- Coupling Na1/Na2/gas
- Transient calculation with initiating events on tertiary gas loop :
 Loss Of Heat Sink, Loss Of Station Power, by-pass valve opening, small gas leak, gas pipe break.
- Impact on primary and secondary loops

Example : Loss Of Station Power



CATHARE validation needs for ASTRID gas PCS

- Definition of similarity laws and representative scales for the phenomena to be simulated
- Test facility specification for the validation of the ASTRID Gas PCS operation,
- Construction and test program,
- Experimental data base analysis and Cathare Gas code validation
 - Transient incidental situations
 - Turbomachinery model and control system, general operating procedures (start-up/normal shut down, turbine bypass,...)

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