In-pile Test of a Small Scale Fuel Assembly Under Supercritical Water Conditions

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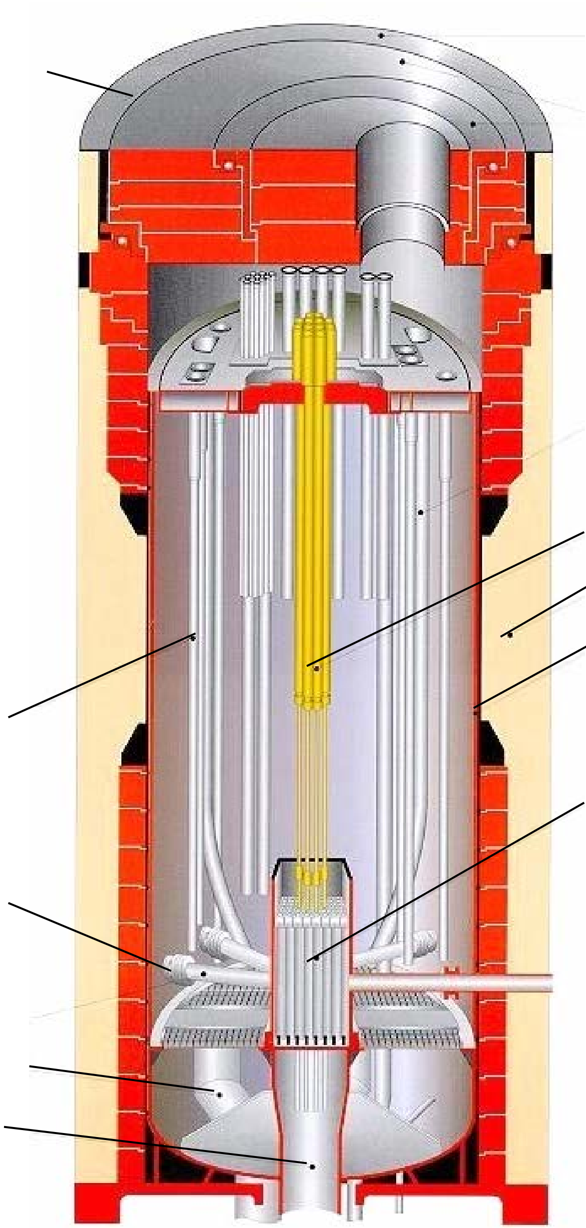
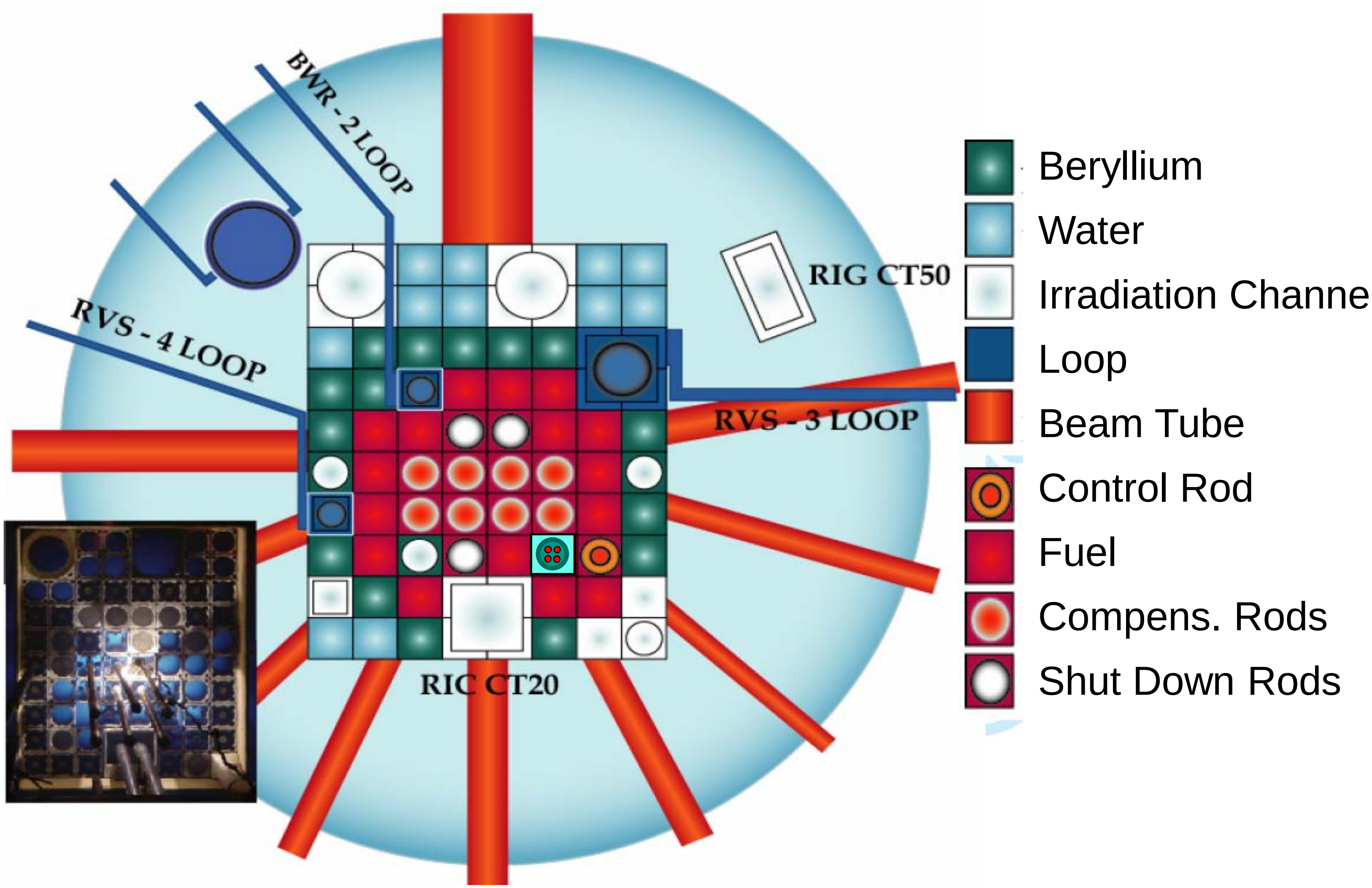
Cross Section of the LVR-15 Reactor in Řež



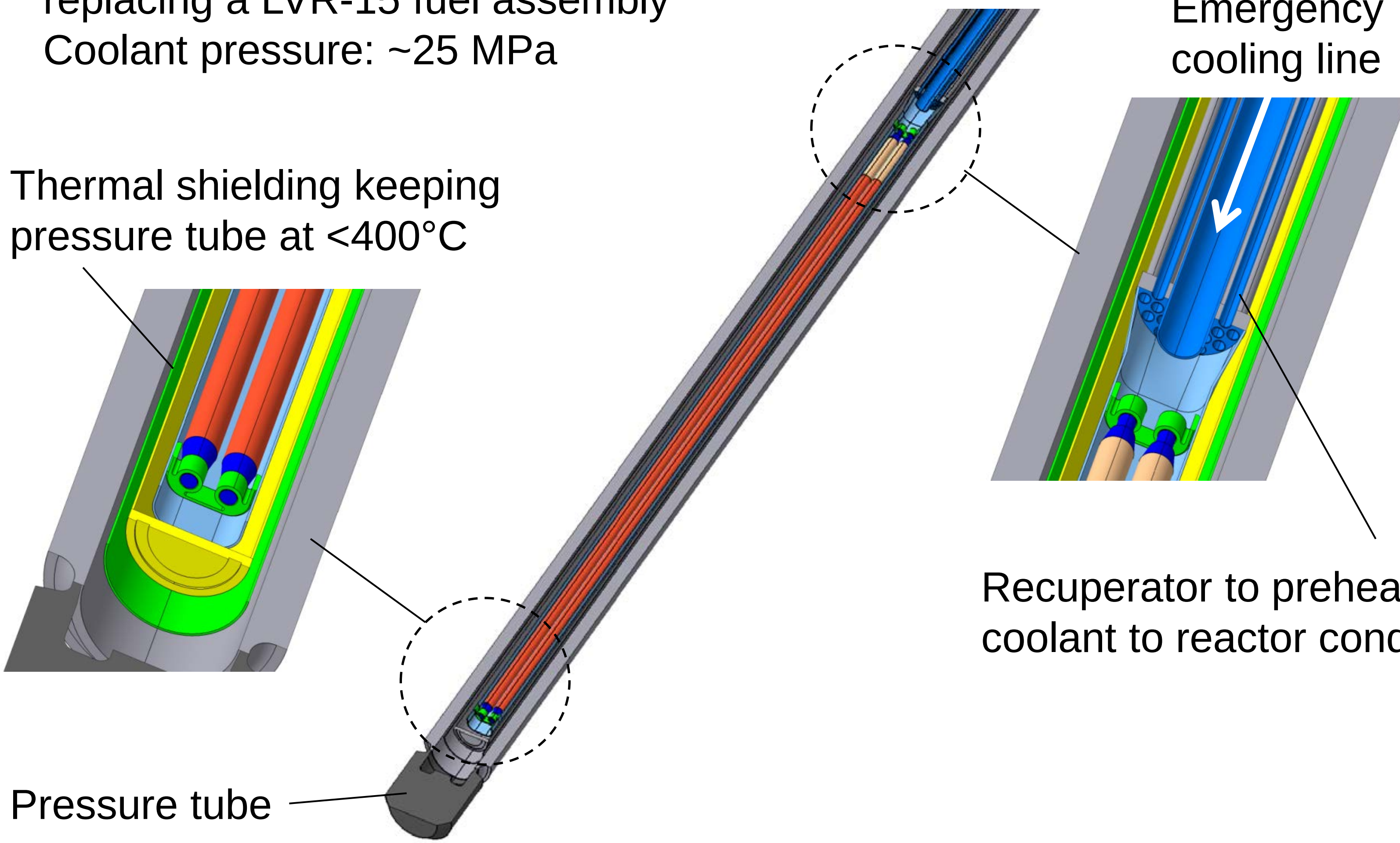
Nominal Power:	10 MW
Thermal Flux:	$1.5x10^{18}$ n/m^{2}s
Fast flux:	$2.5x10^{18}$ n/m^{2}s

LVR 15 Core Configuration



Test Fuel Assembly in Supercritical Water

4 fuel rods in a pressure tube replacing a LVR-15 fuel assembly
Coolant pressure: ~25 MPa



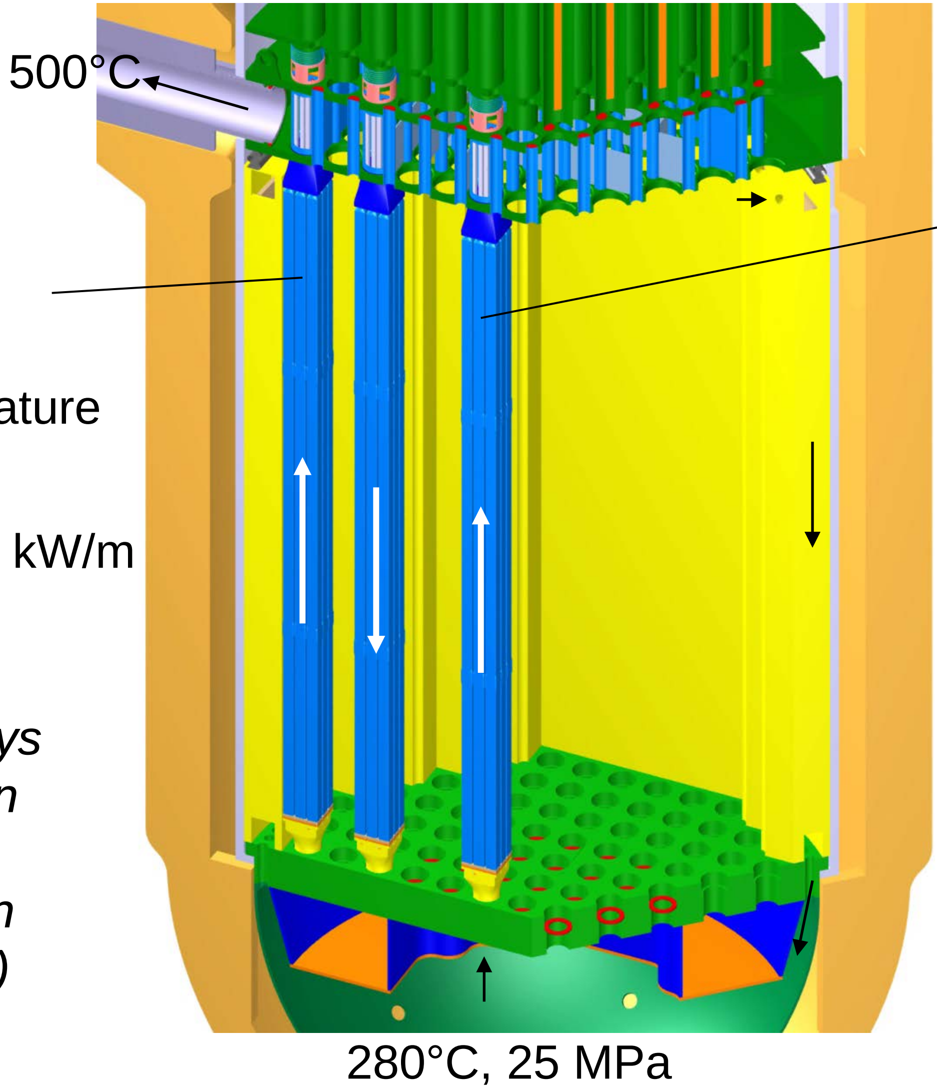
Predicted Conditions in HPLWR Core

Superheater Conditions:

Coolant temperature 500°C to 600°C

Lin. Power < 10 kW/m

Cladding alloys to be tested in Supercritical Water Loop in Řež (existing)



Evaporator Conditions:

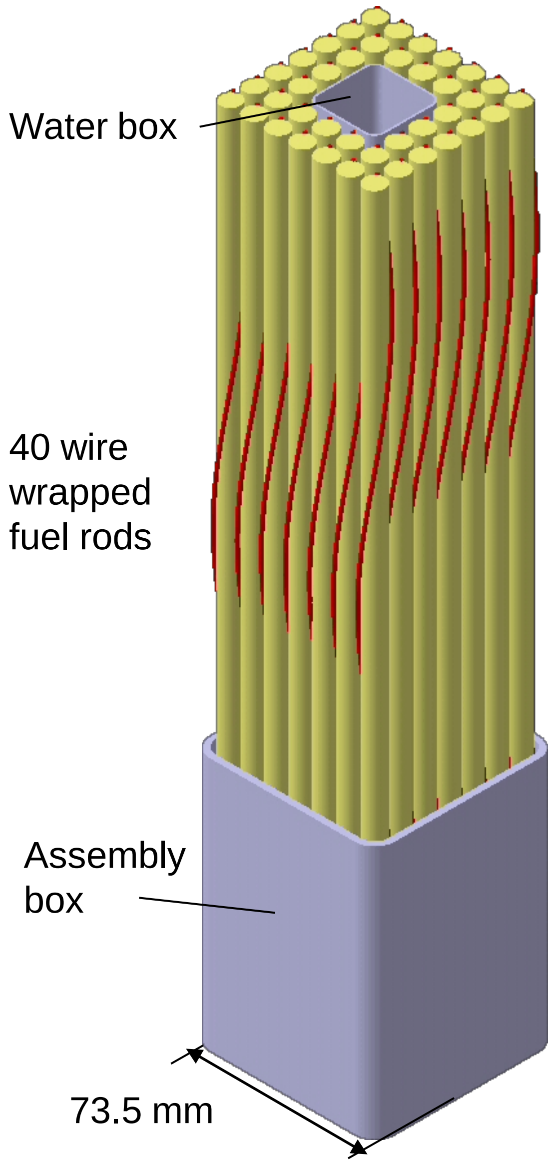
Coolant temperature 350°C to 400°C

Lin. Power < 39 kW/m

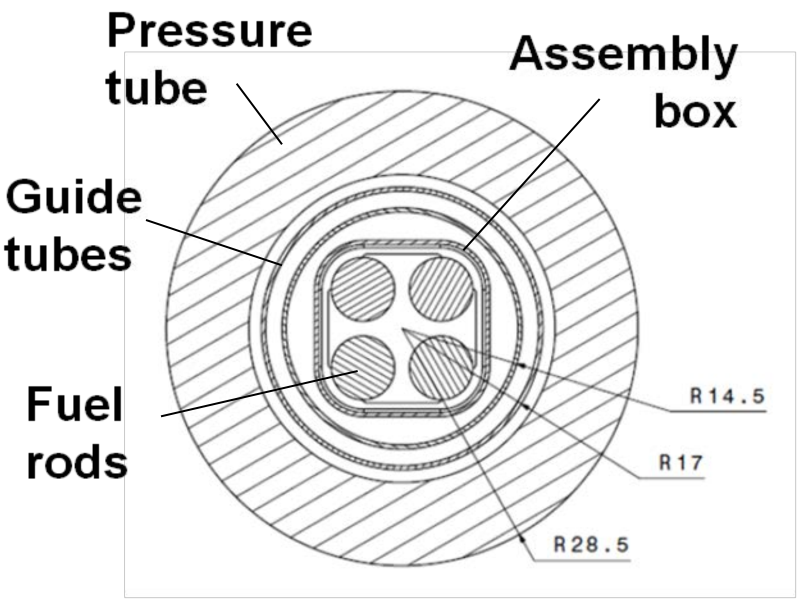
Fuel assembly to be tested in Fuel Qualification Test in Řež (new)

Fuel Assembly Design

HPLWR Assembly



Test Assembly



Use of

- Same fuel rod diameter (8mm)
- Same fuel rod pitch (9.44mm)
- Same wrapped wires (spacers)

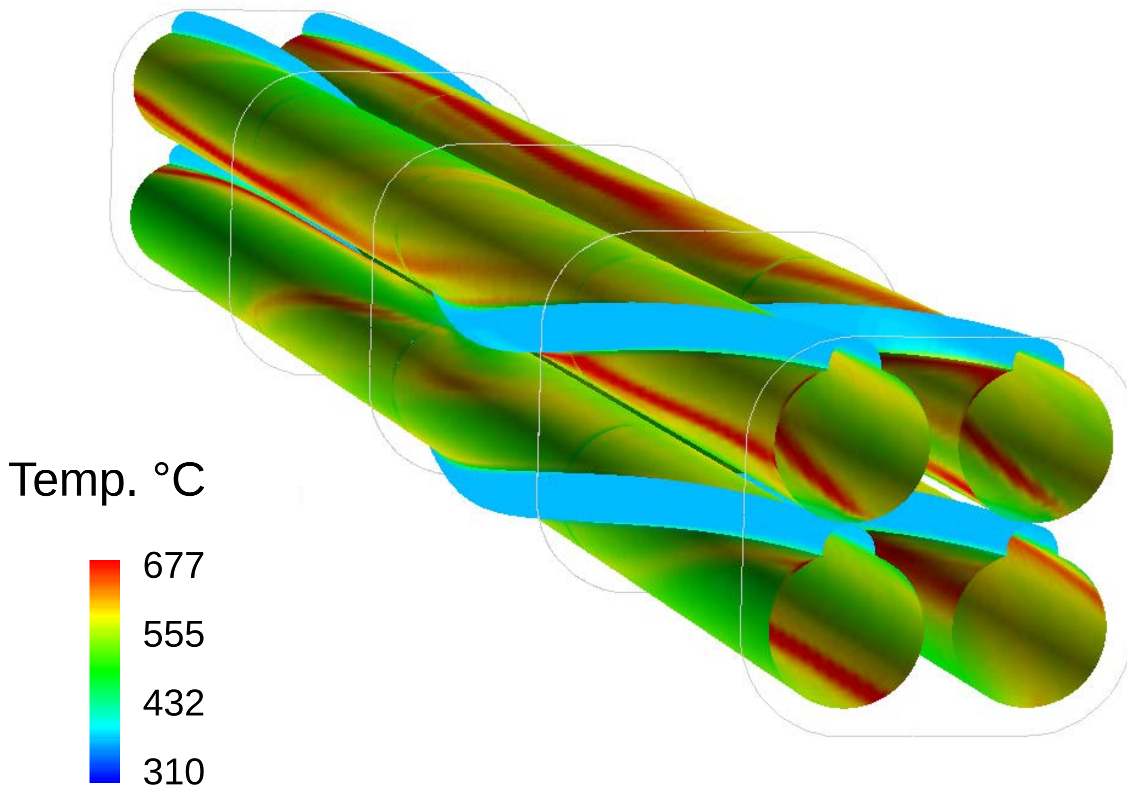
Technical Challenges under Evaporator Conditions

- Risk of local deterioration of heat transfer causing hot spots of the cladding at low mass flux

Predictions by Chandra et al. (2010)

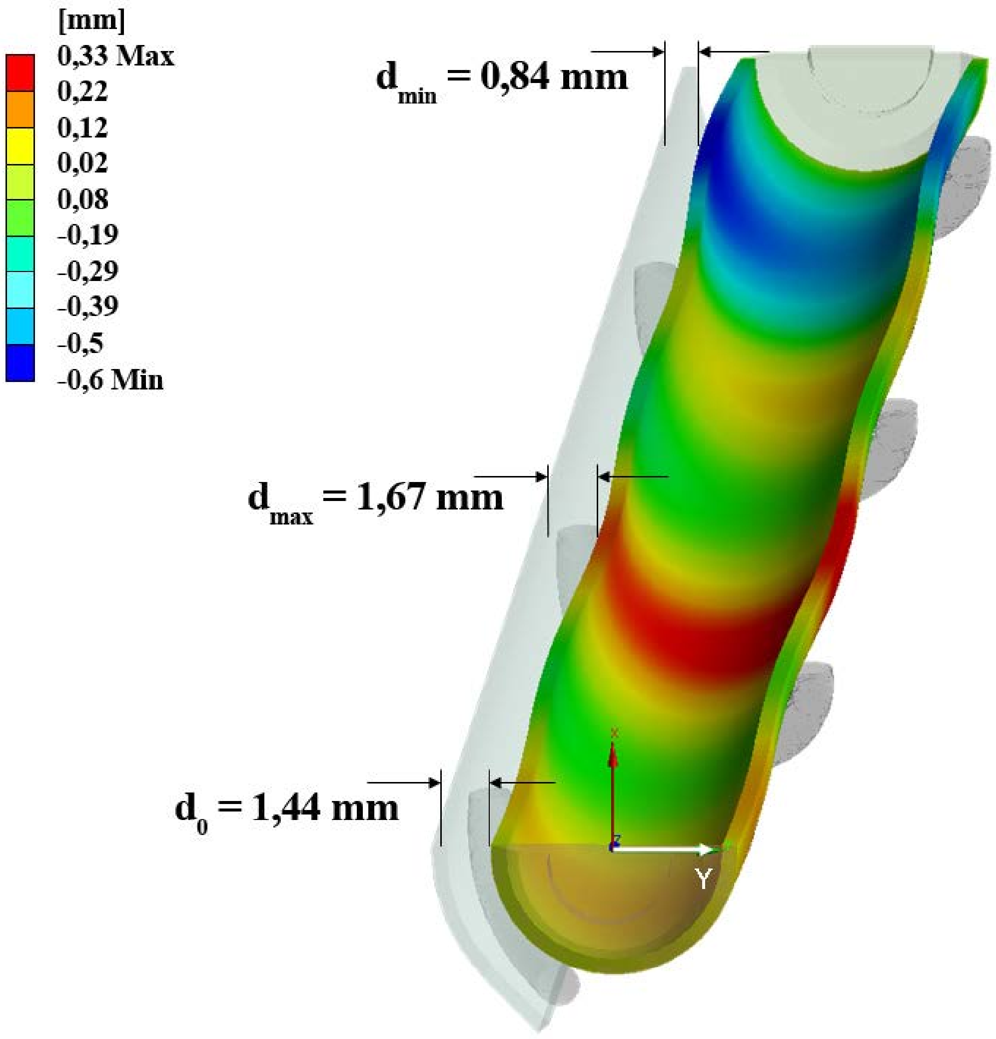
Coolant mass flux : $1332\ kg/m^2s$

Surface heat flux: $1375\ kW/m^2$



Technical Challenges under Evaporator Conditions

- Risk of deformations and thermal fatigue due to high heat flux

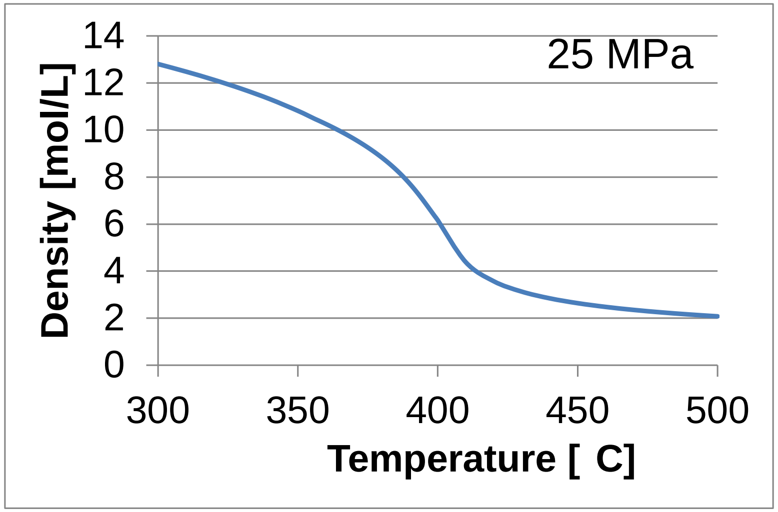


Predictions by Kremers et al. (2010)

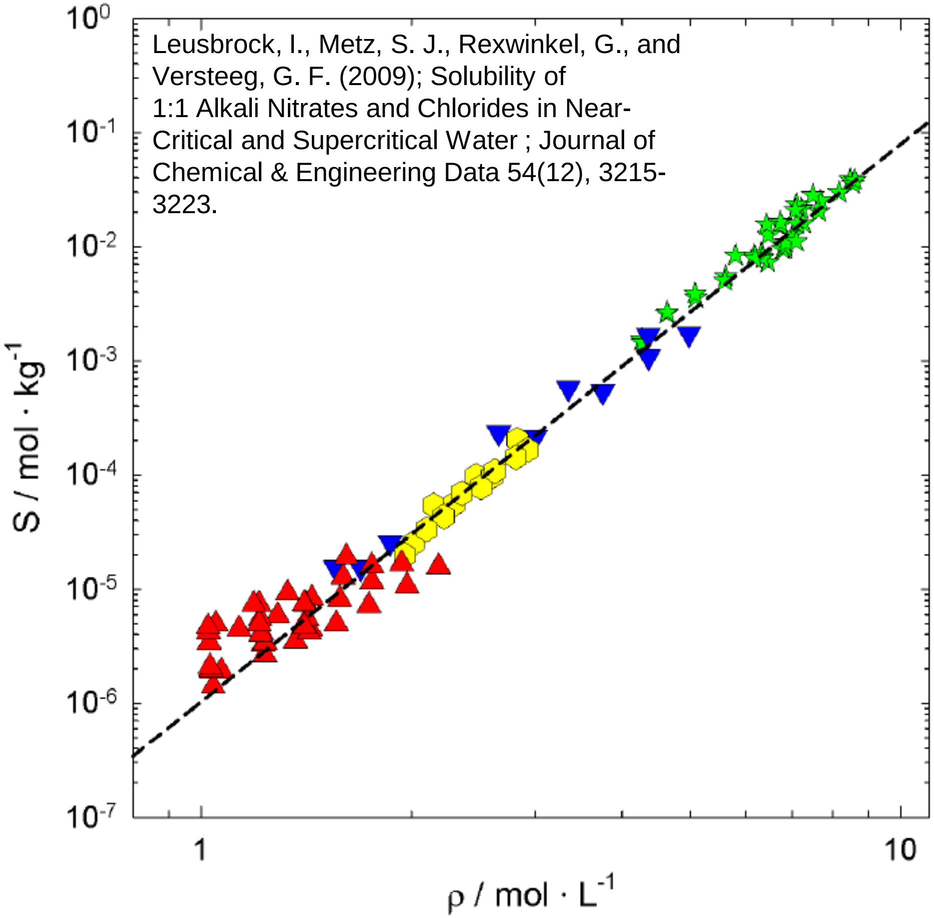
Surface heat flux:
1660 kW/m^2
Linear heat rate:
41.7 kW/m

Technical Challenges under Evaporator Conditions

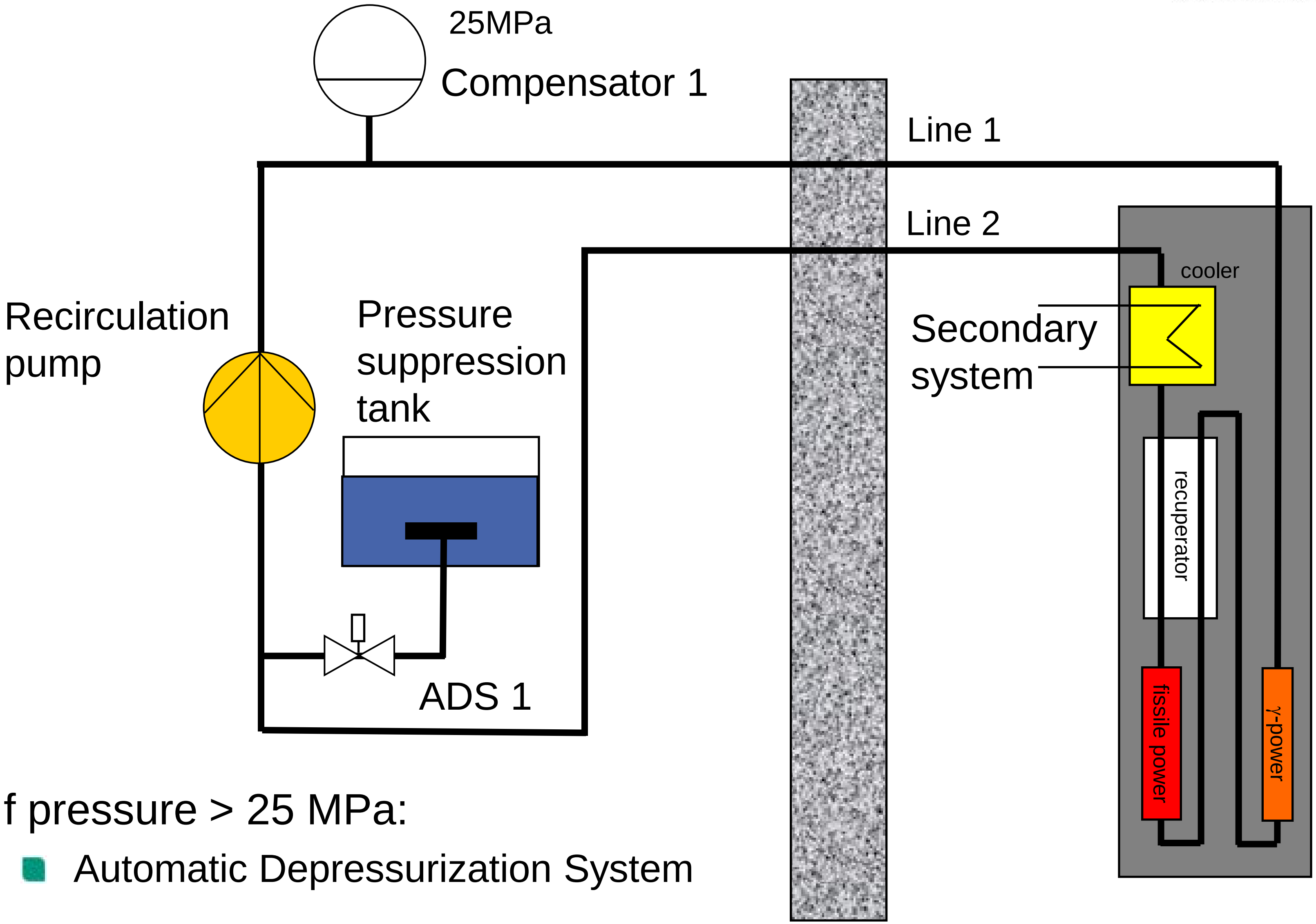
- Risk of deposits as solubility changes when passing the pseudo-critical temperature at 384°C



Example: Solubility of NaCl at 25 MPa

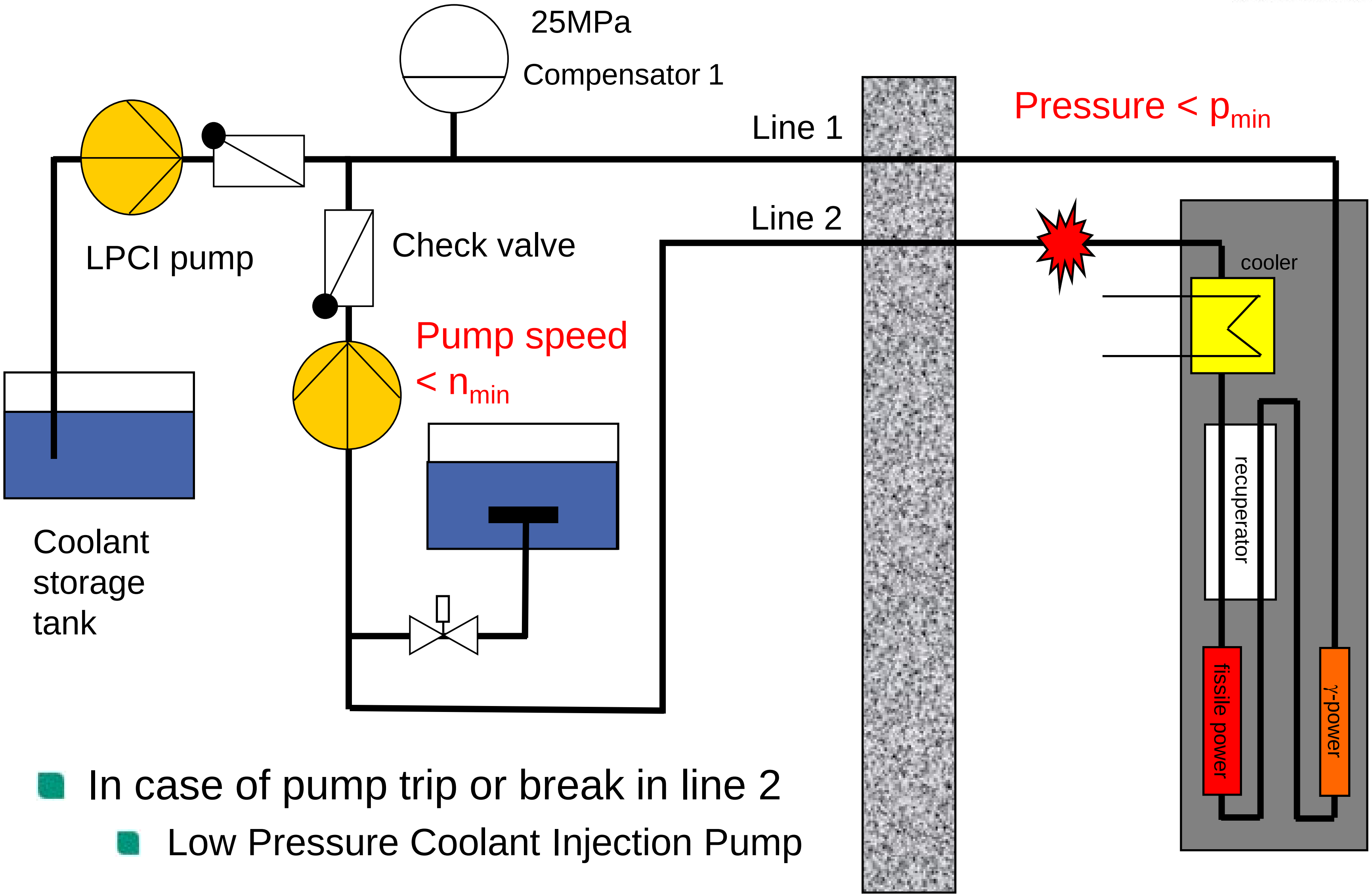


Supercritical Water Loop



- If pressure > 25 MPa:
  - Automatic Depressurization System

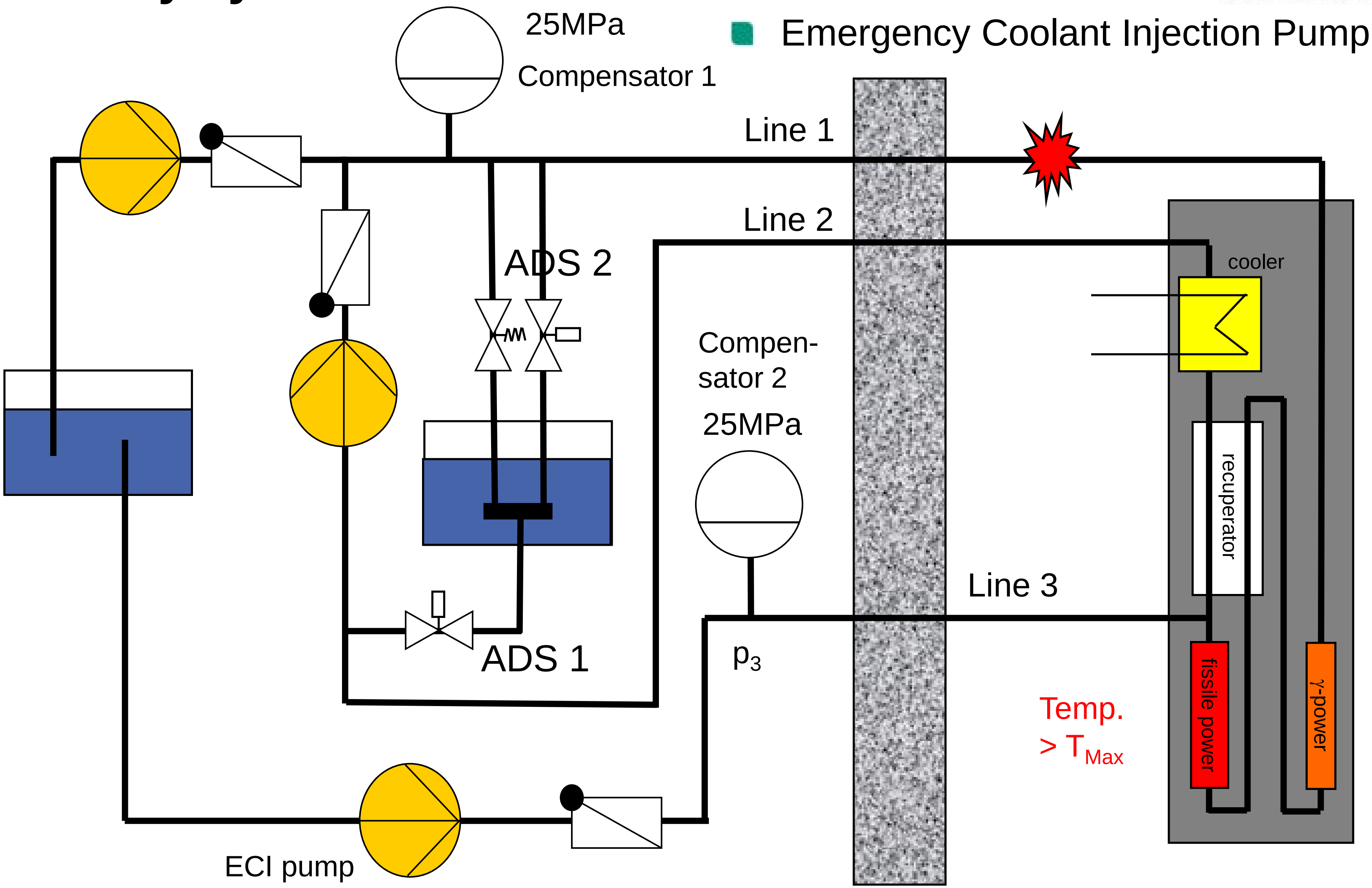
Safety system



- In case of pump trip or break in line 2
  - Low Pressure Coolant Injection Pump

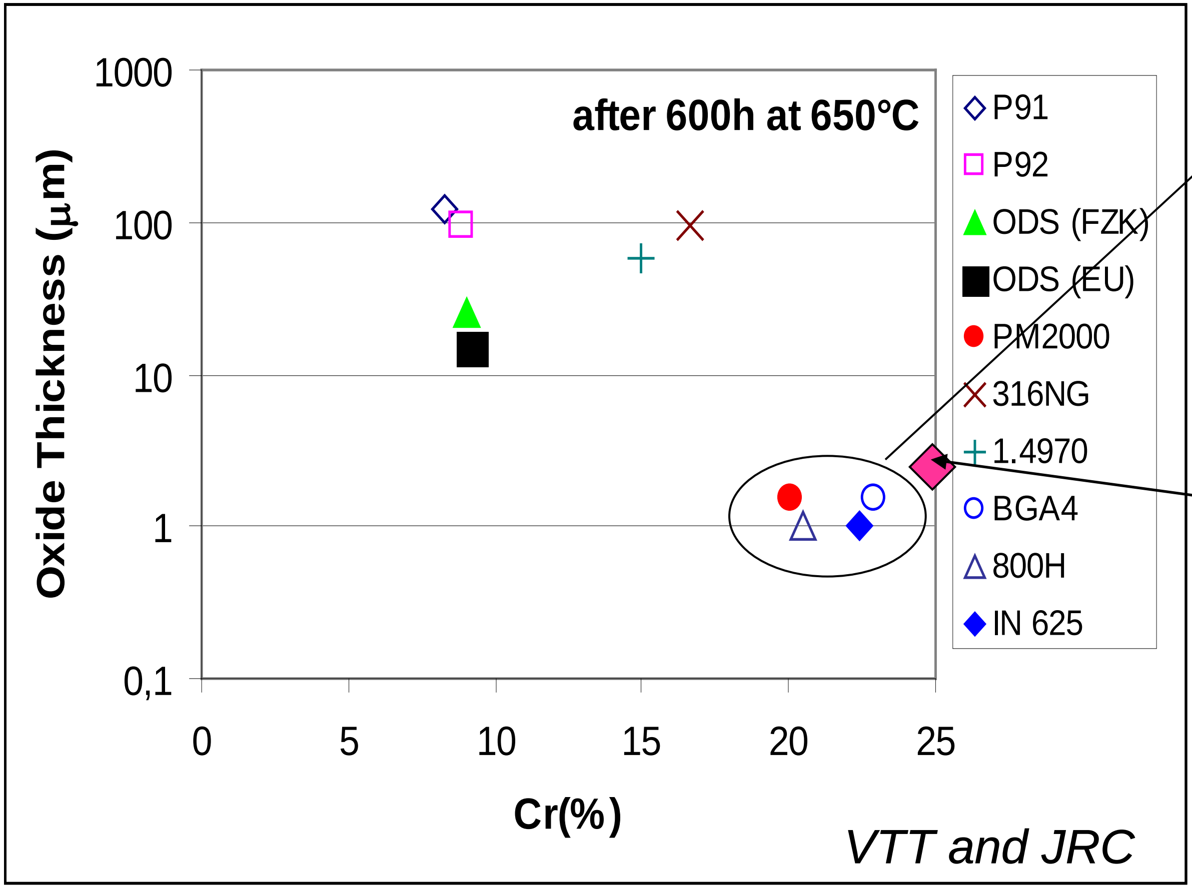
Safety system

- In case of break in line 1
  - Emergency Coolant Injection Pump



Material Options for Fuel Claddings

Test of available cladding alloys in the HPLWR Phase 2 project



Not applicable because of low strength or high Ni content

Very promising:

Modified stainless steel 310 developed and tested in Japan

Qualification of Cladding Materials

- Material Options: Stainless steels 1.4970, TP347H, 316L
- Corrosion experiments in low and high oxygen supercritical water environment at VTT and JRC Petten
- SCC tests using tensile specimen (SSRT)
- Welding tests of end caps and wires
- Material test in a fuel rod mock up

Autoclaves up to 650°C and 25 MPa at VTT and JRC Petten

Validation Tests

Out of pile validation test of the test section with 4 electrically heated fuel rods.

To be performed at Shanghai Jiaotong University, China.

Supercritical water loop SWAMUP at SJTU Shanghai, China

Project SCWR-FQT, Jan. 2011 to Dec. 2013

Objectives: Licensing the loop as a nuclear facility operated with supercritical water

- To design a test section, a loop and all safety and auxiliary systems required for operation of a fuel qualification test;
- To analyze the test facility under normal and accidental conditions to demonstrate safe operation;
- To build and operate an out-of-pile test assembly with supercritical water having the same test section geometry, but heated electrically;
- To validate codes for thermal-hydraulic predictions of the flow structure in SCWR fuel assemblies;
- To focus the material research on in-core materials which could be licensed in near future and to prepare a material database;
- To complete the required licensing documents;
- To teach and train young scientists in licensing procedures for nuclear facilities including the required quality management methods.

Partners of the SCWR-FQT Project

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KIT (Germany)
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