ESFR-SMART
sodium fast reactor safety

WP:	**WP2.2: New experiments for safety**
Task:	**2.2.1 and 2.2.2**
Speaker:	Wolfgang Hering
Affiliation:	Karlsruhe Institute of Technology, INR, Germany
Event:	Kick-off Meeting
When:	September 11-12, 2017
Where:	Euratom, Brussels, Belgium

TOC on New experiments for safety

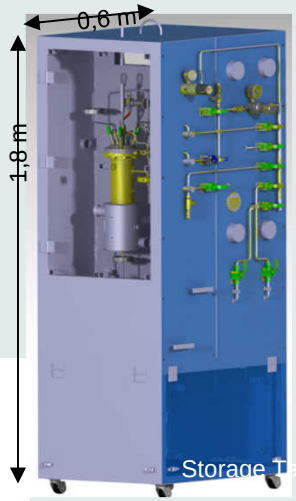
- Overview to HAC experimental capabilities
- Task 2.2.1: KASOLA tests on transitional conditions
- Task 2.2.2: Sodium boiling related tests

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 754501.

Experimental facilities at HAC

Basic physics (Electro-chemistry)

AMTEC
ATEFA

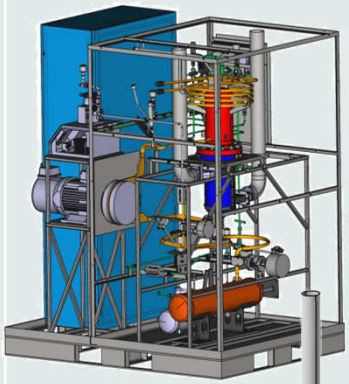


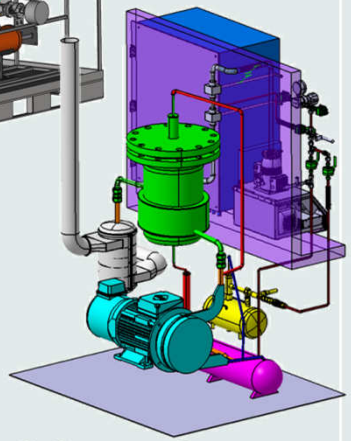
← DITEFA

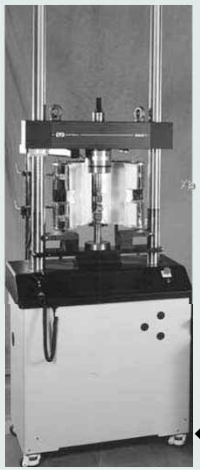
Na-Infrastructure

System level (Materials)

„Energy“ - materials
SOLTEC $1_{AWP} – 2_{IHM}$





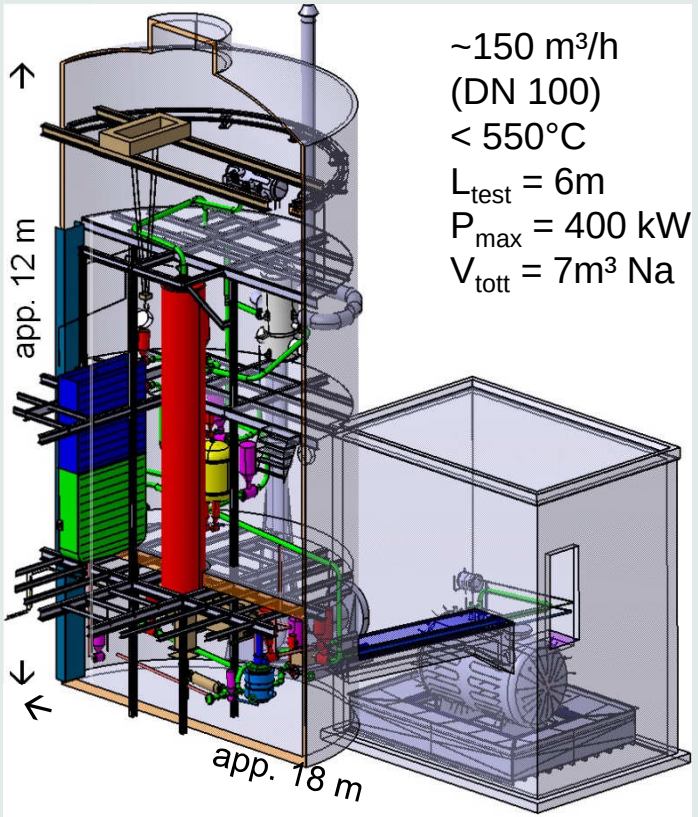


SOLTEC 3_{INR}

←CORTINA $_{AWP}$

Medium Scale / Demonstrator (Systems)

Thermal storage
KASOLA facility



~150 m³/h
(DN 100)
< 550°C
L_{test} = 6m
P_{max} = 400 kW
V_{tott} = 7m³ Na

Capabilities and Scientific Program

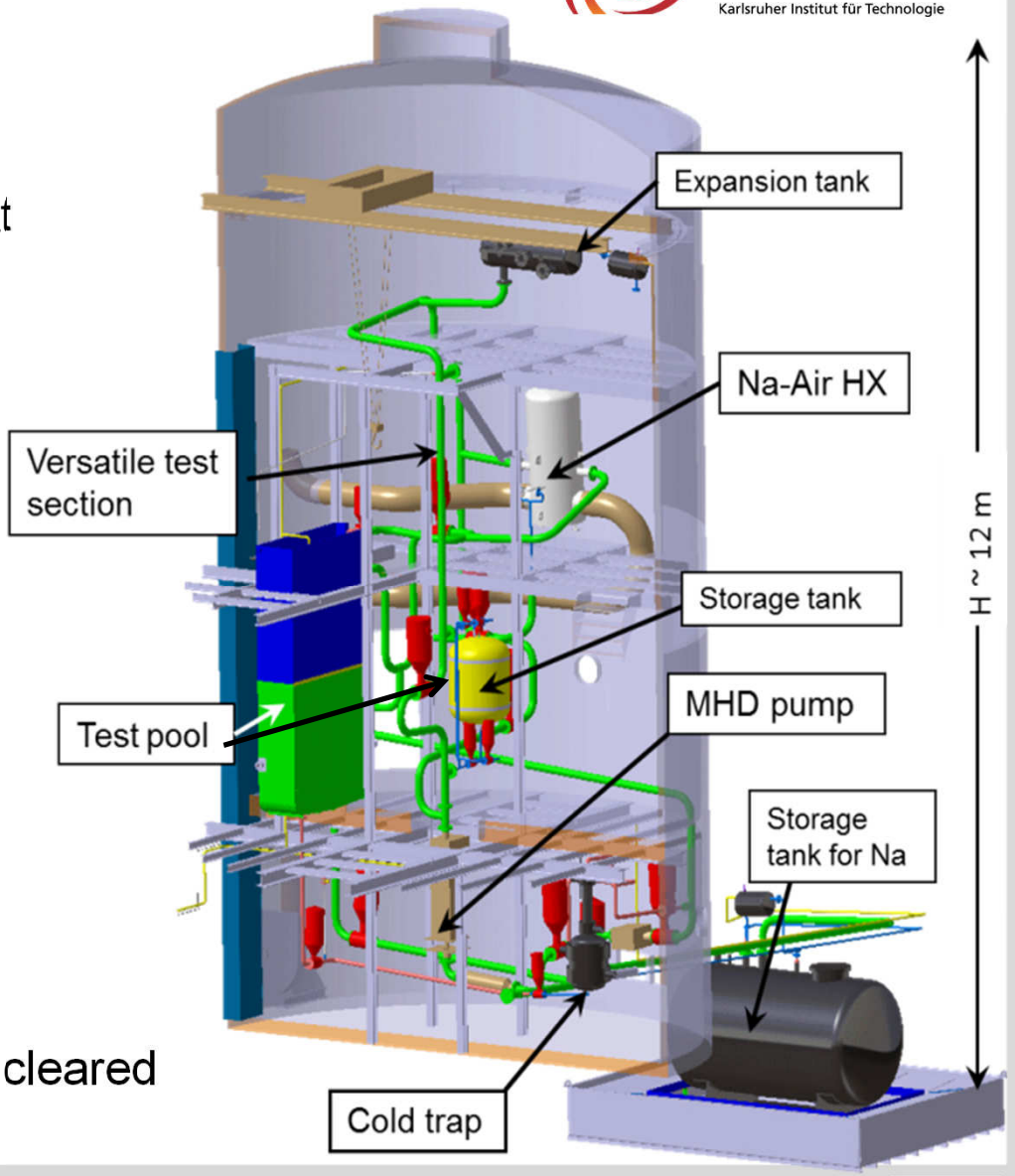
- **KASOLA:** 150m³/h, 7 m³ Na, 550°C
  contributes to safety oriented EU-programs: ESNII+, SESAME, ESFR_*smart*
  → Qualification of CFD and system codes
  → Component and safety tests under real conditions
  → Backbone of KIT-sodium infrastructure (Na-storage, purification, distribution)
- **SOLTEC-1:** IAM-AWP/INR: material qualification in flowing sodium up to 750°C (in oven), LCF (ESFR_*smart*)
- **SOLTEC-2:** IHM: material qualification in flowing sodium under fast thermal transient conditions up to 900°C (in test section)
- **SOLTEC-3:** High temperature loop for direct energy conversion (AMTEC) phase change experiments (ESFR_*smart*) up to 1000 °C
- **ATEFA:** Facility in operation to investigate AMTEC up to 1000 °C
- **DITEFA:** Education and training on liquid metals at room temperature Pre-tests for KASOLA, flow transitions, backward facing step
- **CORTINA:** Infrastructure for corrosion studies in sodium in final built phase
- **AMTEC Laboratory** @INR: in operation

KASOLA

- **Projected for:**
  - Research on liquid metal
  - Development of turbulent LM heat transfer models for CFD tools
  - Component tests (900l pool)
  - LM for CSP 2.0

Status (SiO, QE)

- Cold SIO (set-into-operation) phase finished
- Hot (SiO) in progress:
  - Na liquefied, components tested
  - Check of safety provisions (unexpected behavior detected → correction in work)
- Continuation in KW37/38
- After ISS test (TueV) → Operation cleared

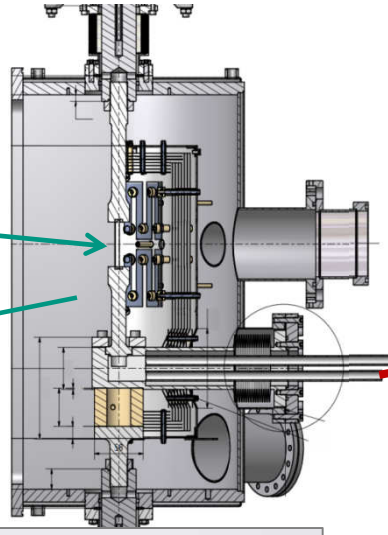


Qualification of Innovative Materials: SOLTEC – 1

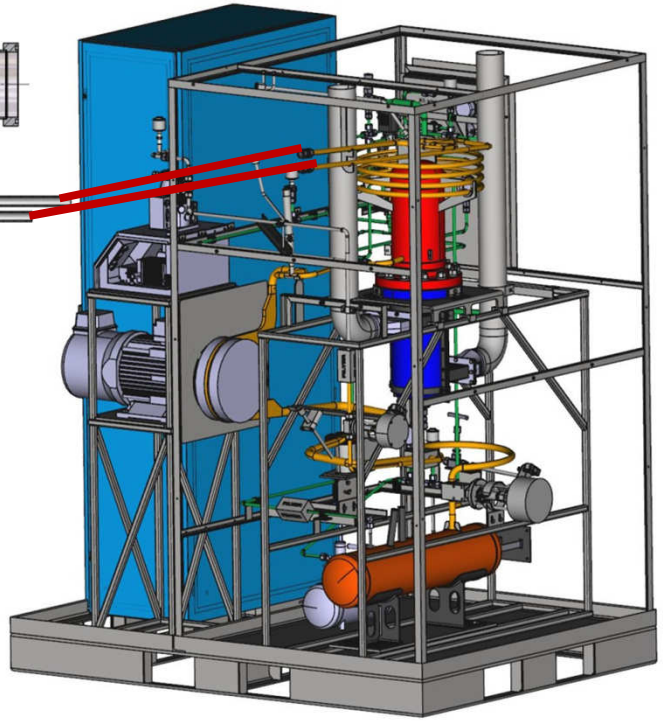
Sodium Loop to TEst materials and Corrosion: for Low Cycle Fatigue (LCF) tests

- Materials for tube receiver in CSP
- Ductile refractory metals (W, Mo) (ex. behavior at HT versus LM)
- Ductile behavior of W und Mo via innovative transformation processes (2 positiv evaluated DFG-Projects)

Test sample in
Maytec oven

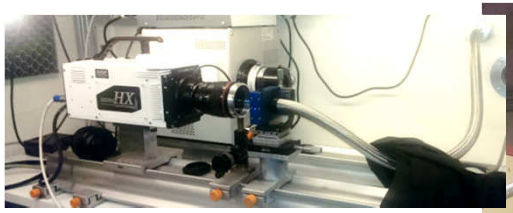


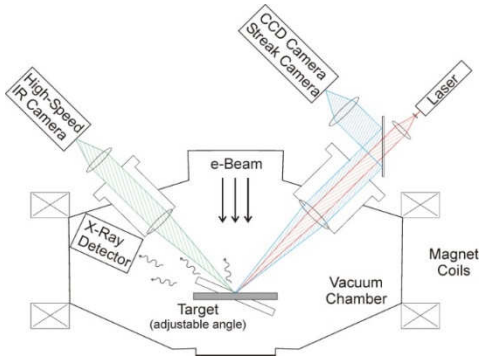
Interface
SOLTEC - Maytec

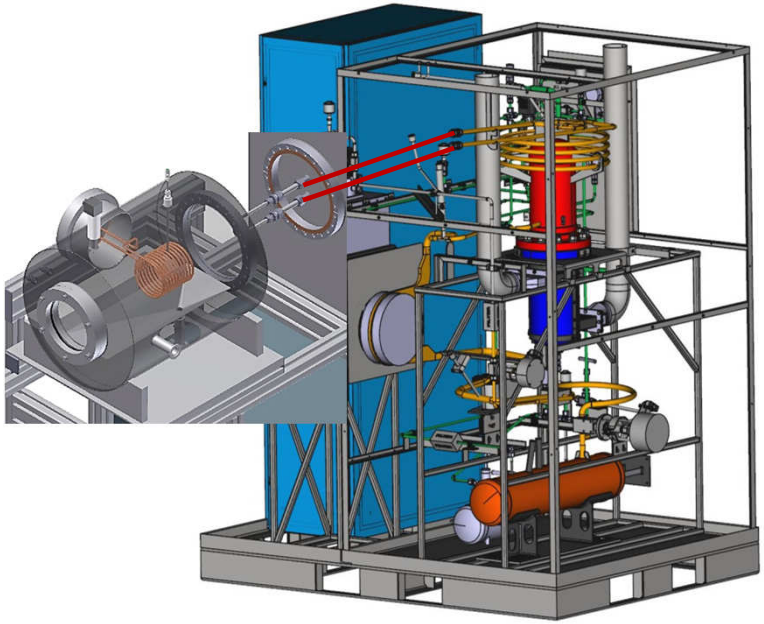


Material challenges: protective coatings: SOLTEC-2

- Material compatibility at high temperatures in contact with liquid PbBi, Sn and **Na**
- and under rapid temperature transients (SOLTEC-2) – Thermal cycling tests at high temperature - ΔT: 650 – 900°C
- Long term stability of protective surface coatings (in/outer surface) using pulsed electron beams (GESA-SOFIE) – **S**urface **O**ptimization facility with **F**ast **I**n-situ diagnostic **E**quipment

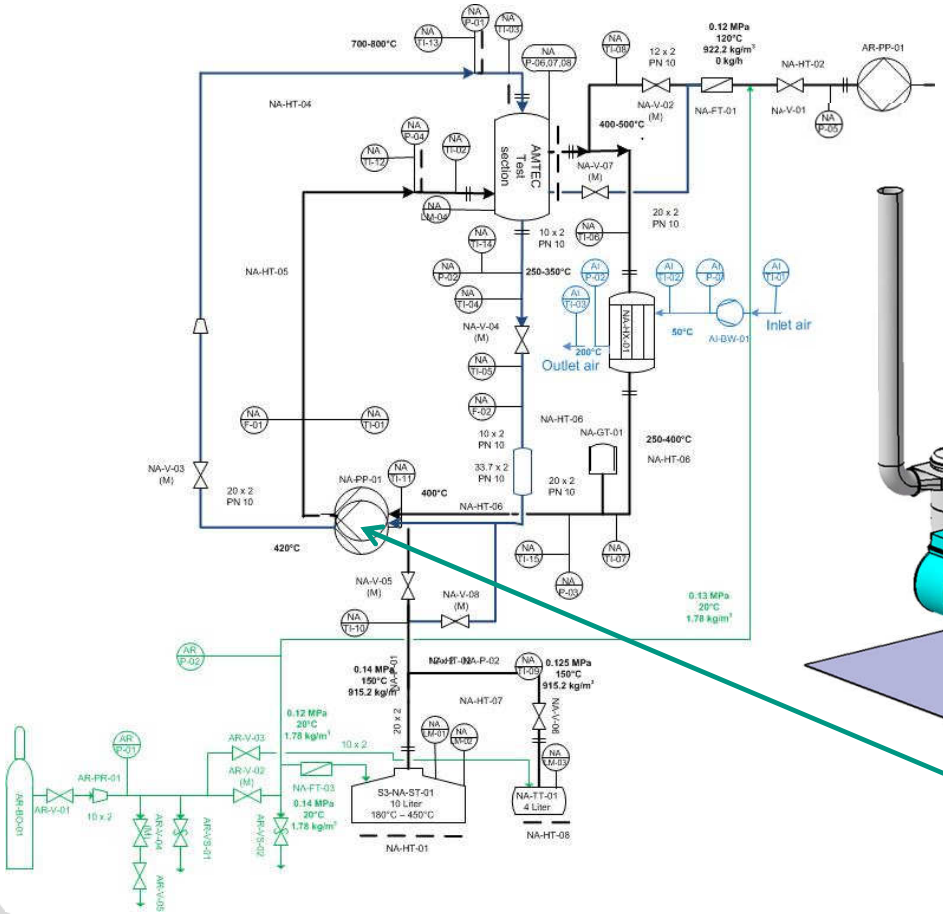


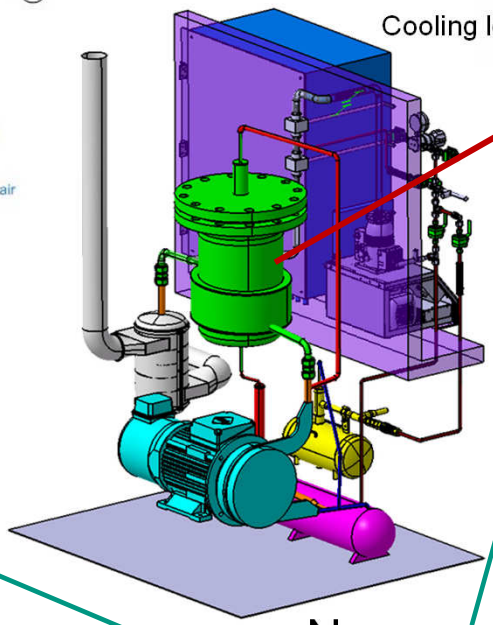


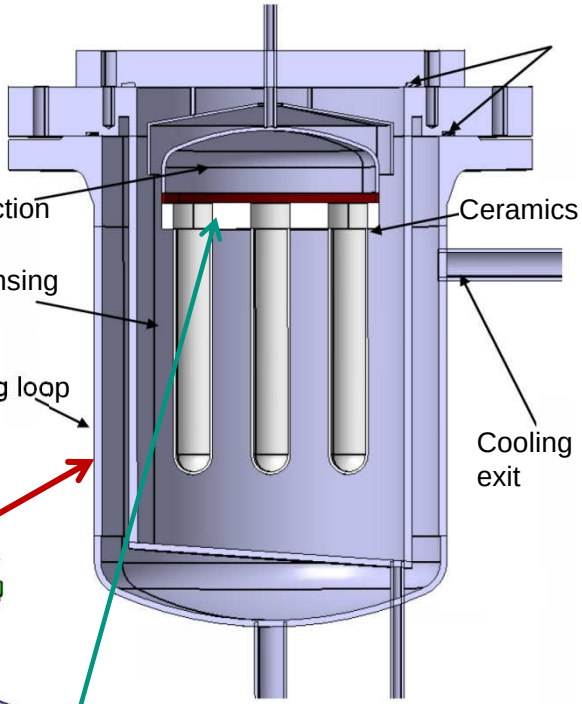


Qualification of Innovative Materials: SOLTEC-3

- Long term and transient test of AMTEC cells and cluste
  1. single cell (extending ATEFA)
  2. small module (3-7 cells)
  3. stacked modules

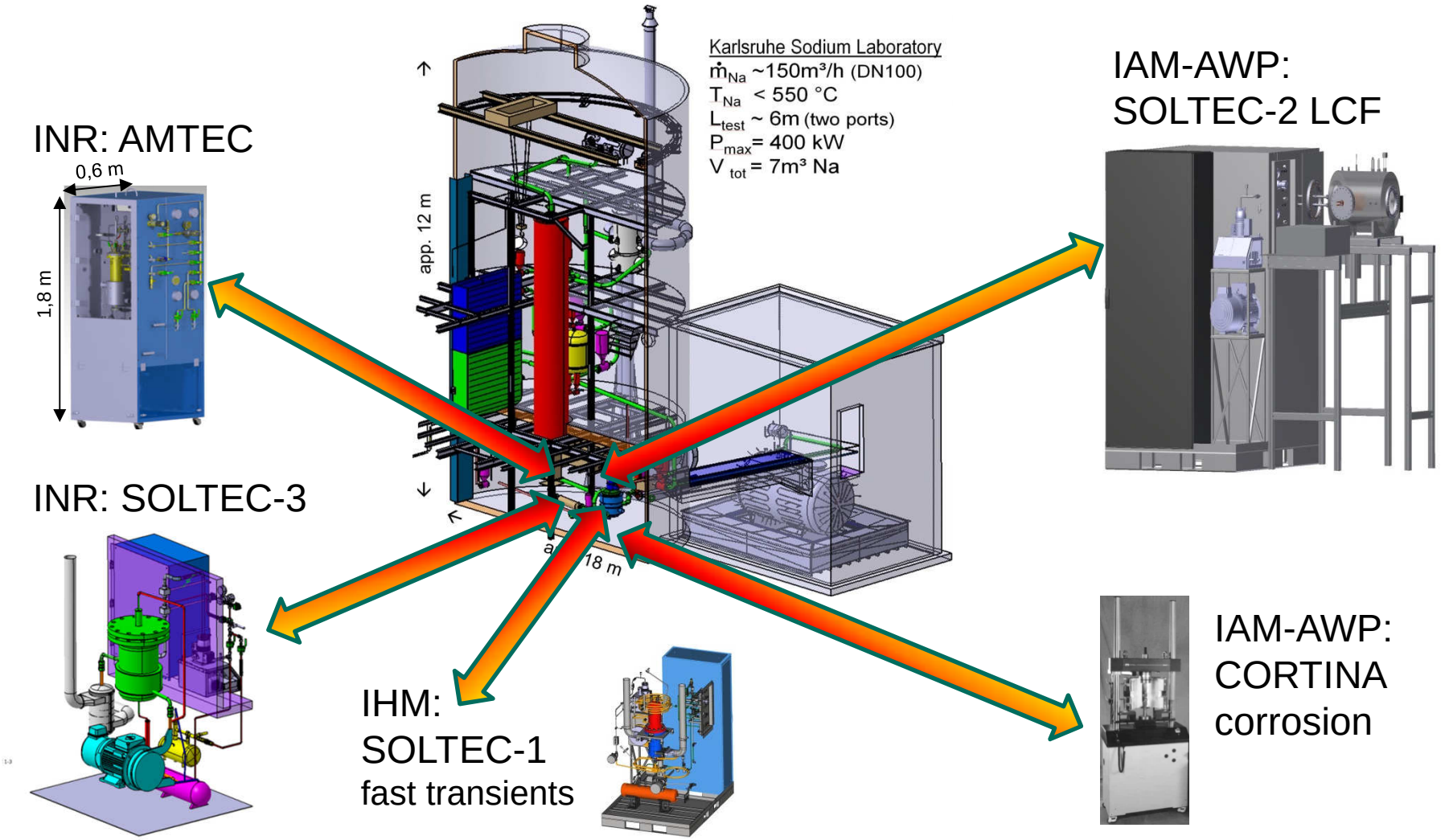






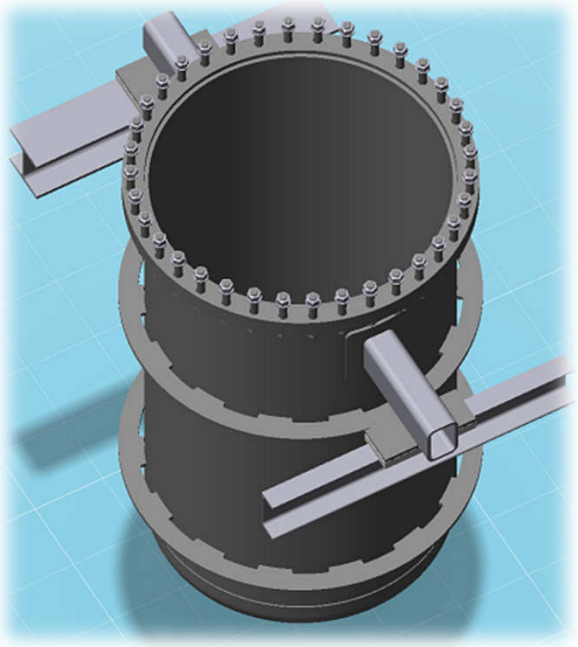
+ New ceramic base plate
+ EMP with two independent loops

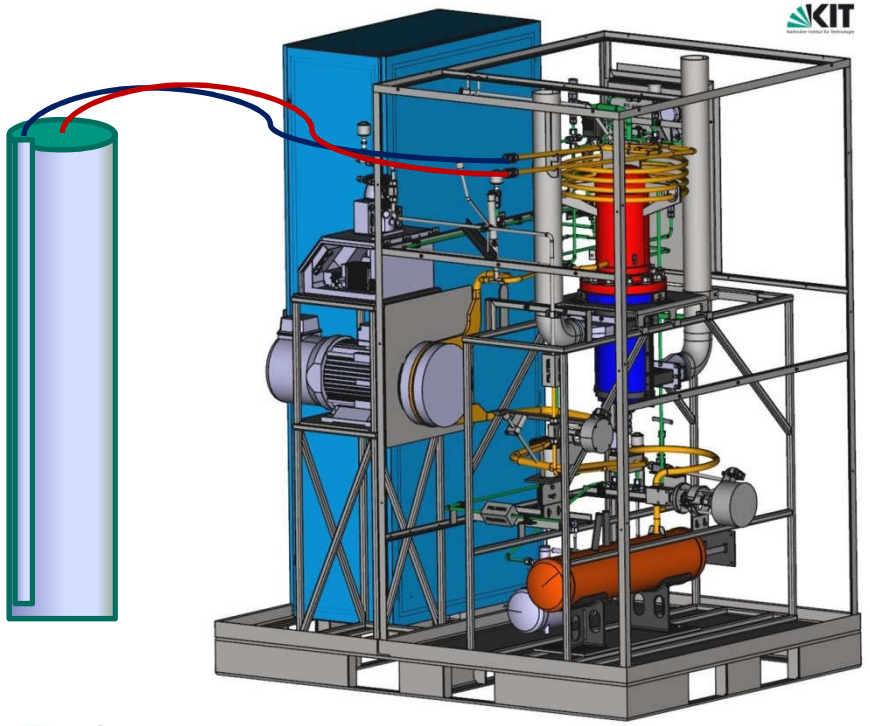
KIT-wide Sodium Infrastructure sharing



Qualification of Innovative Sensors

- Small sensors: SOLTEC -1/-2
  - up to 720°C
  - Up to 8 m/s (depending on Δp)
  - Direct attachable by SWAGELOC HT joints
    (qualified by KIT for Sodium up to 800°C)





- 3D-sensor arrays: KASOLA FlexStor
  - DN 900
  - Height of ~1,5 m (~1 m³)
  - Integrated in 2018 available in 2019

WP2.2: New experiments for safety

Output:

1. WP 2.2 will create new experimental data to calibrate and validate the computational tools for each defence-in-depth level.
2. At the end of the ESFR-SMART these data will be made available for the other SFR-related programs.

- Task 2.2.1: KASOLA test on transitional conditions
- Task 2.2.2: Sodium boiling related tests in/with SOLTEC

2.2.1: KASOLA test on transitional conditions

Task 2.2.1 uses the existing test sections in the KASOLA facility available in 2018 -2020. Initially a simple straight test section of app 6 m is installed with a heating system at the bottom. In 2018 this test section will be replaced by the backward-facing test section (BFS) with a very detailed instrumentation allowing to monitor flow pattern down-streams the step.

- Task 2.2.1.a: KASOLA test on transitional conditions:
  - Use set into operation experiments for model qualification
  - Get input for experimental conditions from Task 2.1.2
  - Results to be used in Task 2.1.2 for code validation
- Task 2.2.1.b: KASOLA using BFS test section
  passive shut down systems have to act fast enough to shut down the reactor safely before energetic action start
  - Assessment of scaling using BFS test section
  - Perform blind simulations to support experiments
  - Qualification of codes

2.2.2: Sodium boiling related tests

Task 2.2.2. will design and perform dedicated experiment to support water experiments at PSI on single droplet behavior to qualify 2-phase codes. A first concept foresees Laser heating to a single channel. The results is strongly dependent on high qualified instrumentation to detect bubble motion effects.

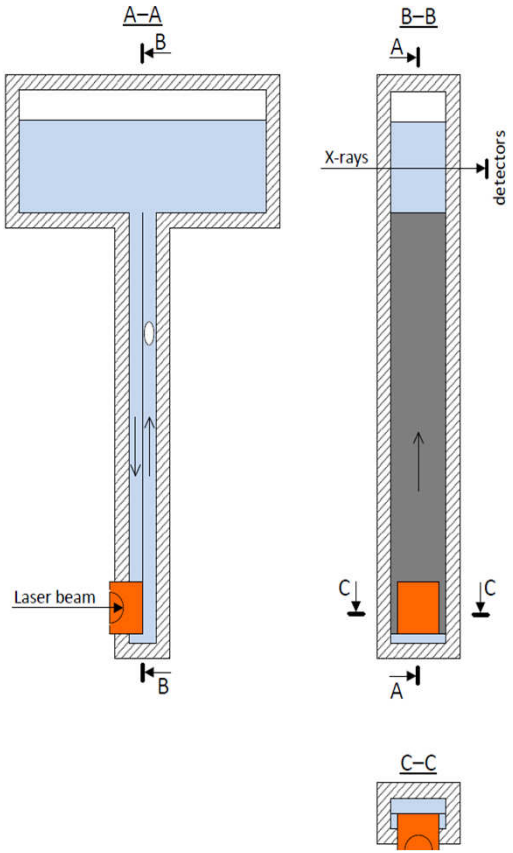
- Task 2.2.2:
  - Define experimental conditions and possible constraints
  - Built stand-alone test section or connect to SOLTEC
  - Document results

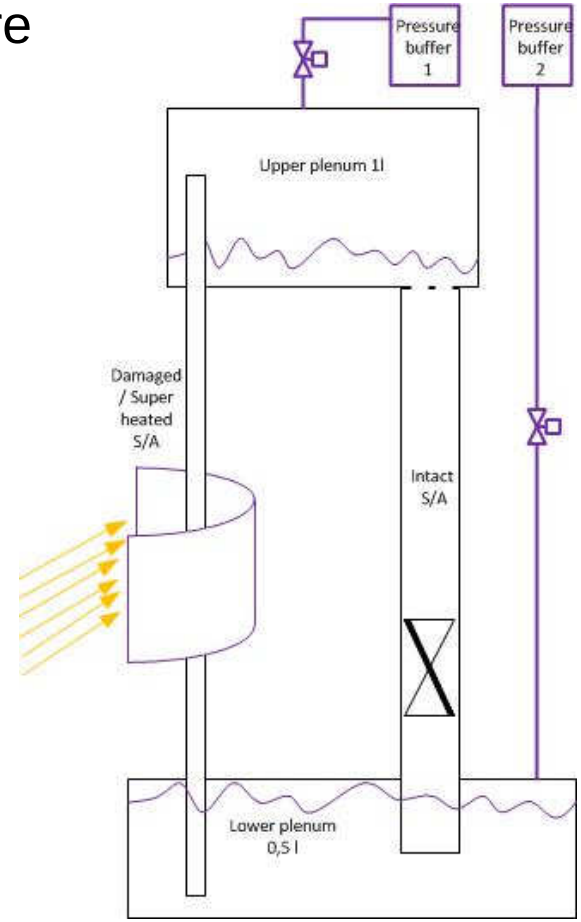
- Support of Task 1.4.5
  - Test of new instruments for safety (ECFM) developed at HZDR

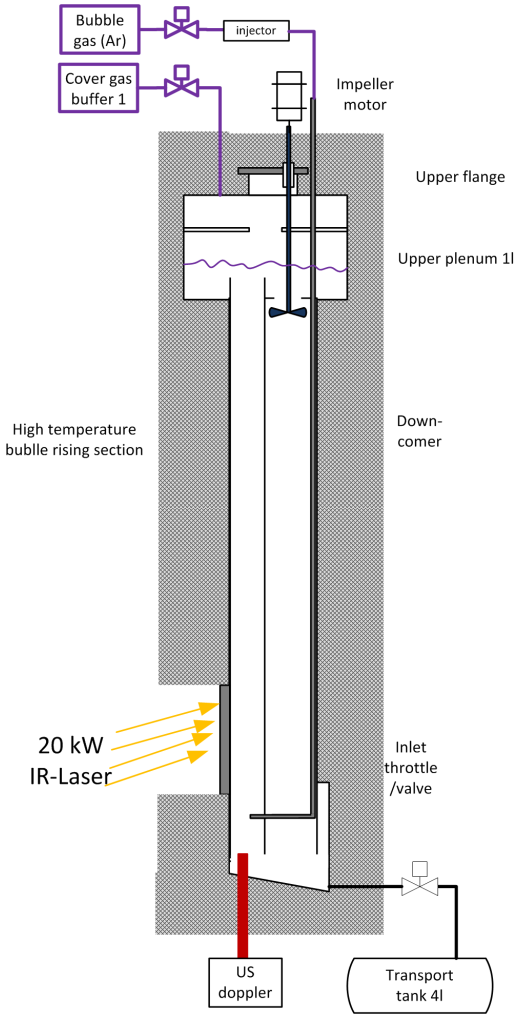
D2.2.5 New test section for sodium boiling at the SOLTEC facility 2,2 T2.2.2
KIT R CO ~~24~~ t.b.d → 36 (?)

2.2.2: Sodium boiling related tests

- Several concept is discussion using HAC infrastructure







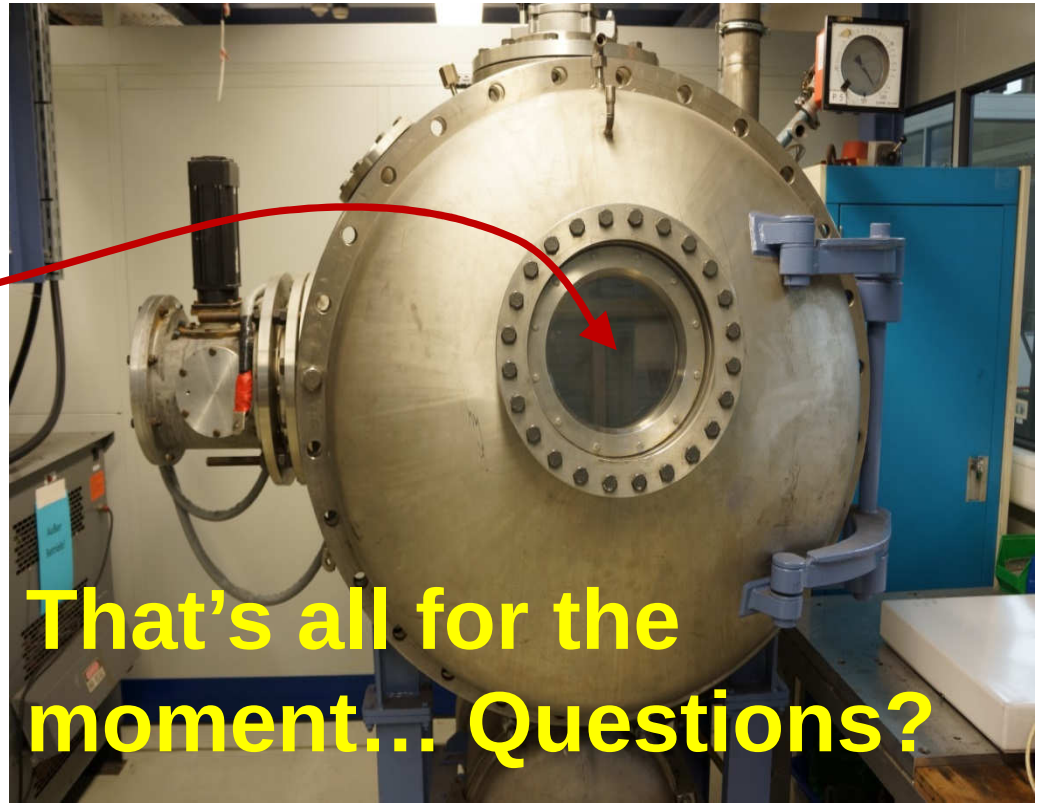
Outlook 2019/2020:

Striving for prototypic materials and flow structures

Laser heating (up to 500 kW/m²) for sodium vapour bubble production

Looking for adequate instrumentation

IR-Laser power ~20 kW



ESFR-SMART
sodium fast reactor safety

WP:	**WP2.1: Codes calibration and validation**
Task:	**2.1.2 KASOLA TH data**
Speaker:	Wolfgang Hering, Wadim Jäger
Affiliation:	Karlsruhe Institute of Technology, INR, Germany
Event:	Kick-off Meeting
When:	September 11-12, 2017
Where:	Euratom, Brussels, Belgium

TOC KASOLA

- Status KASOLA
- Task 2.1.2: KASOLA experiments

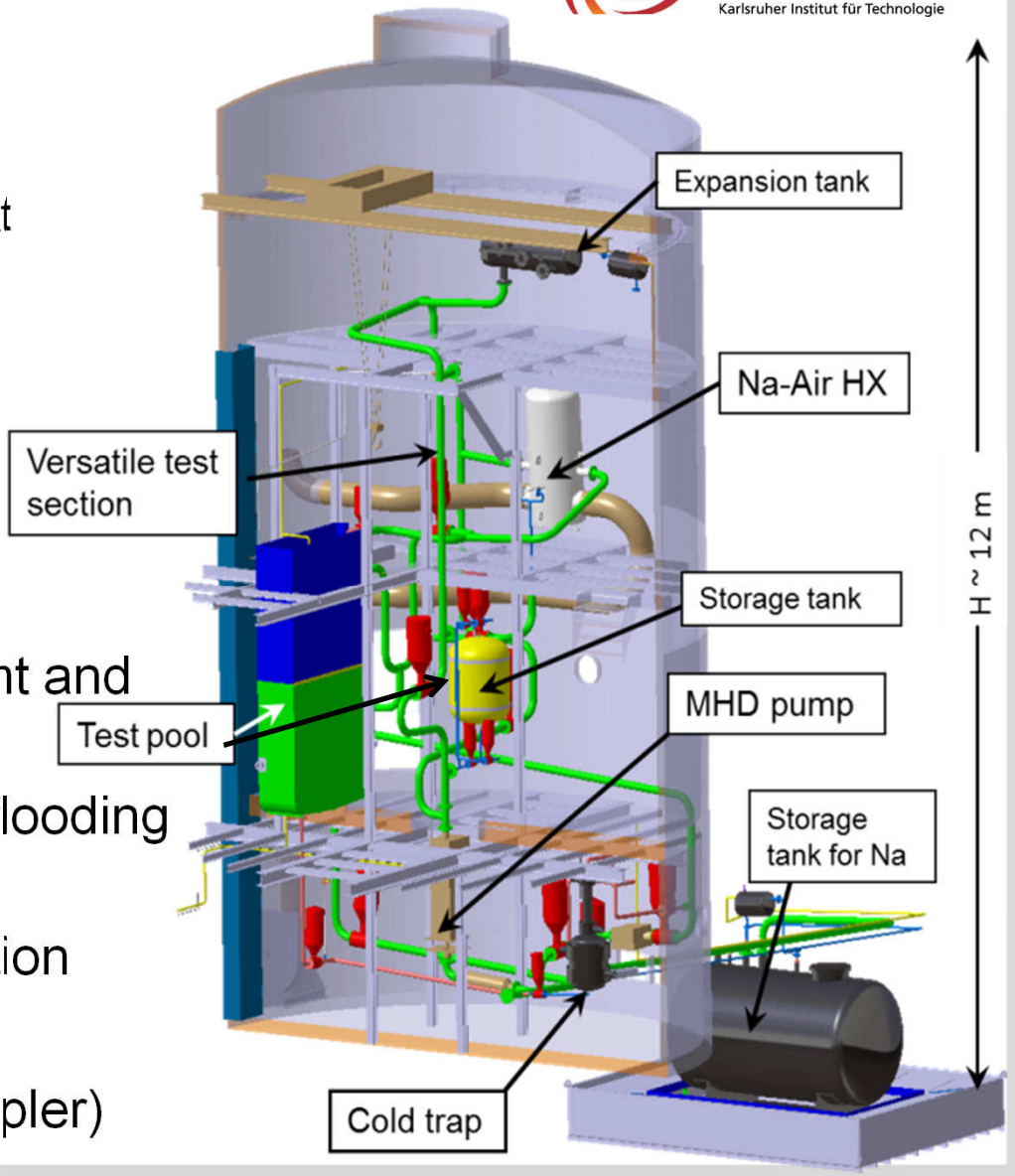
This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 754501.

KASOLA status

- **Projected for:**
  - Research on liquid metal
  - Development of turbulent LM heat transfer models for CFD tools
  - Component tests (900l pool)
  - LM for CSP 2.0

Safety features

- Fast draining of test sectiong and base loop
- Leak detection on all component and structures
- Fire extinguishing by inert gas flooding
- Remote operation, no personal allowed in case of pump operation
- Video supervision
- Catch pan at storage tank (Peppler)

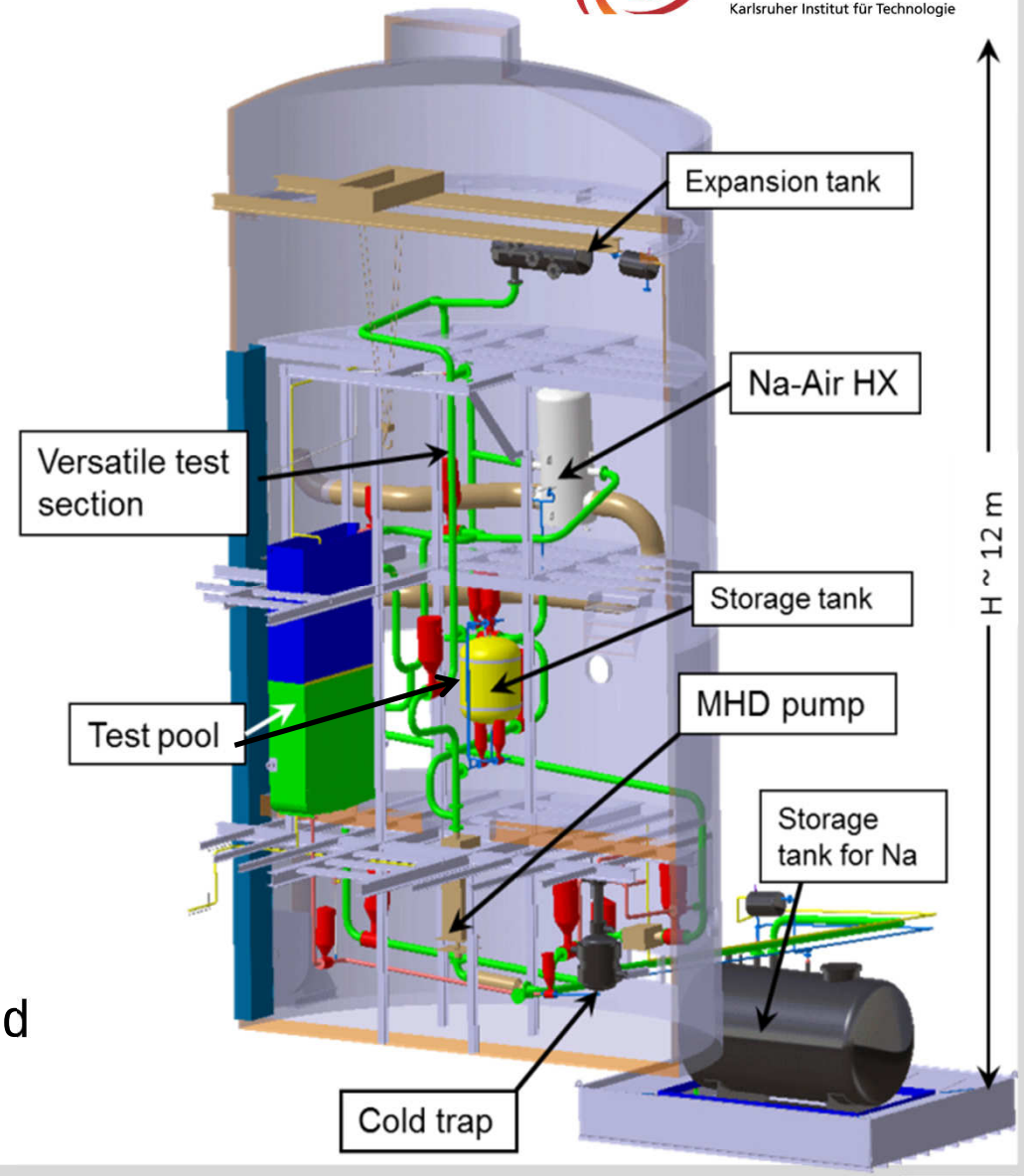


KASOLA status

Status (SiO, QE)

- Cold SIO (Set-Into-Operation) phase finished
- Hot (SIO) in progress:
  - Na liquefied, components tested
  - Check of safety provisions (unexpected behavior detected → correction in work)
- After ISS test (TueV) KW 38 → Operation cleared
- Qualification Experiments (QE) in spring 2018

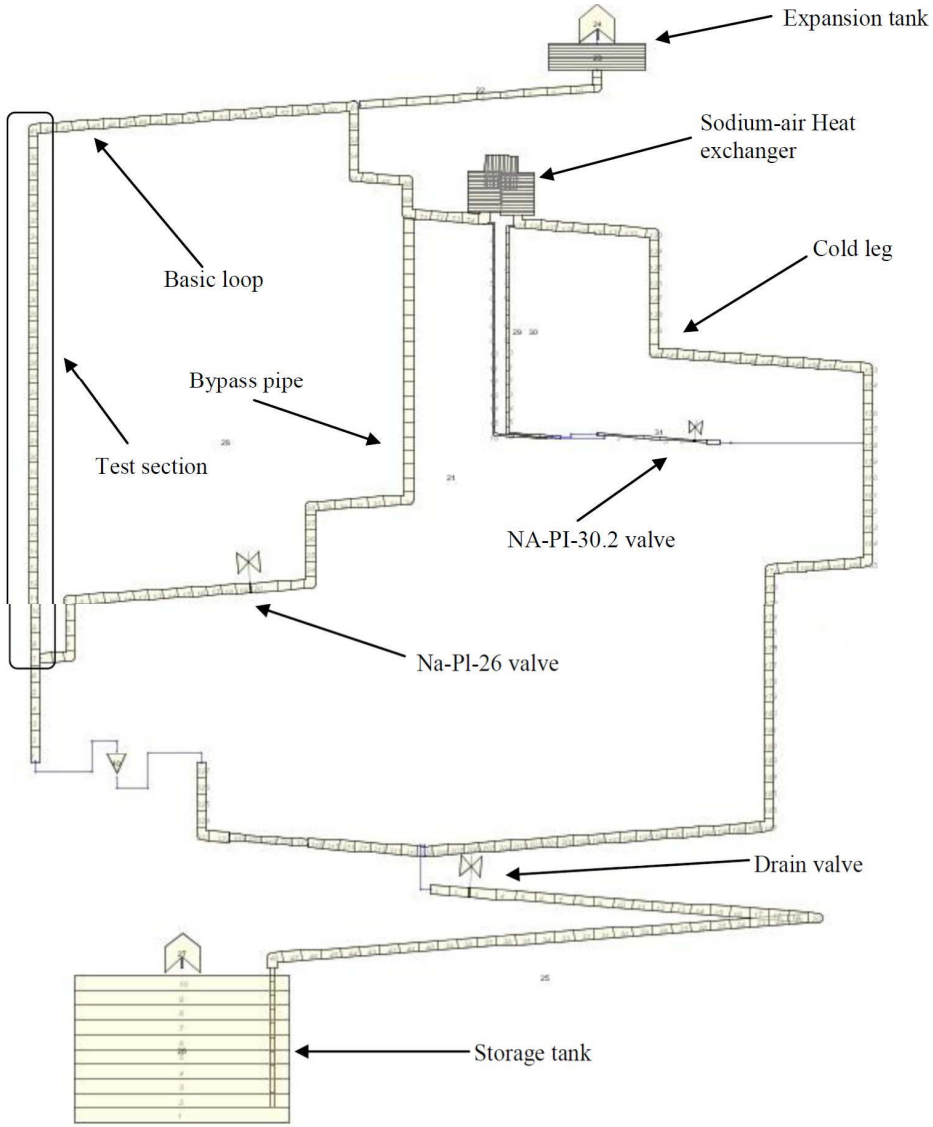
→ invite partners to participate in pre-calculations, sharing ideas and qualifying KASOLA



Preparations outside ESFR_smart

- Pre-ESFR_smart work done in JASMIN and SESAME:
- ASTEC-Na,
- RELAP5,
- FRED,
- TRACE, …

- Release of updated KASOLA Sheet after first set of SiO



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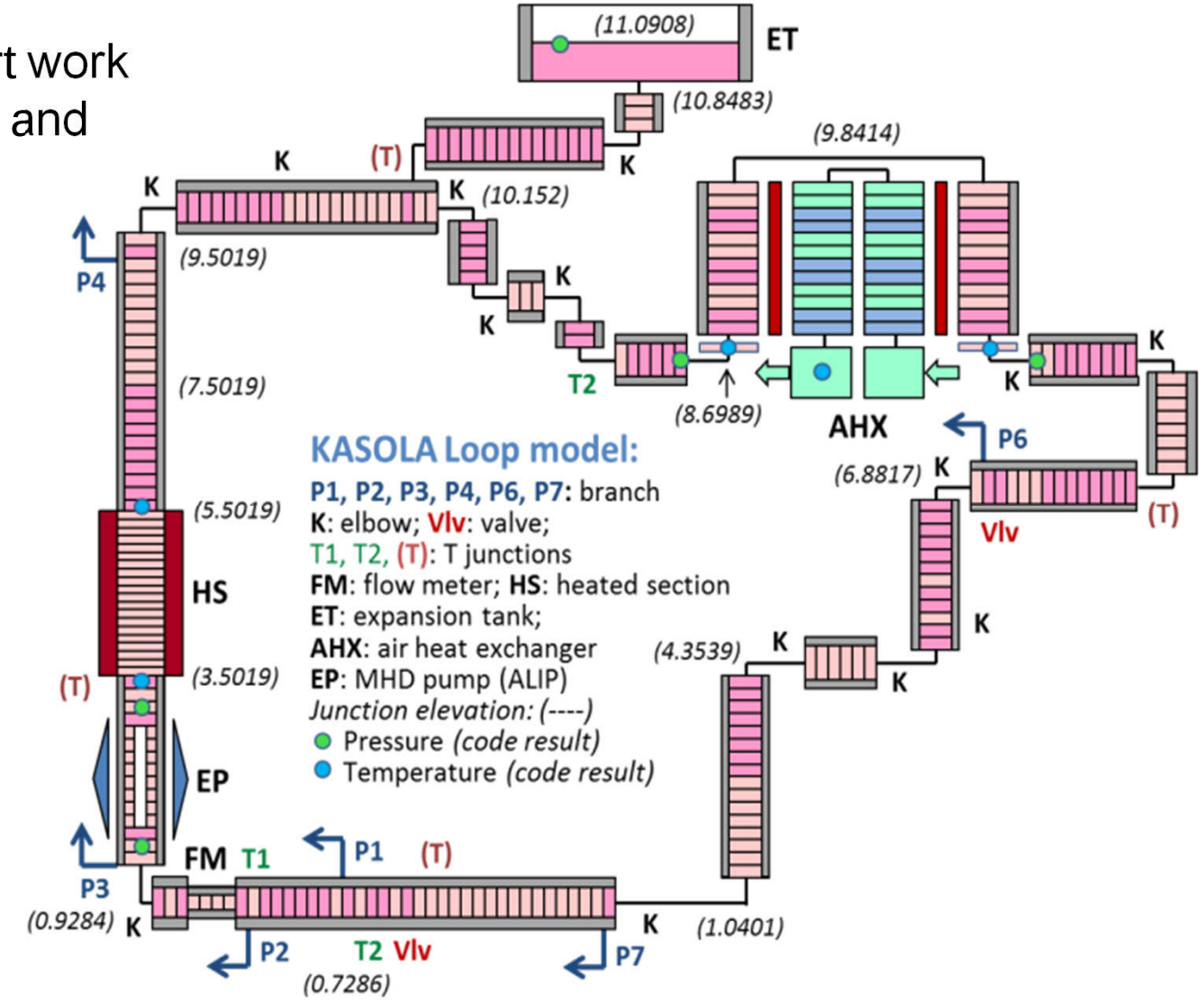
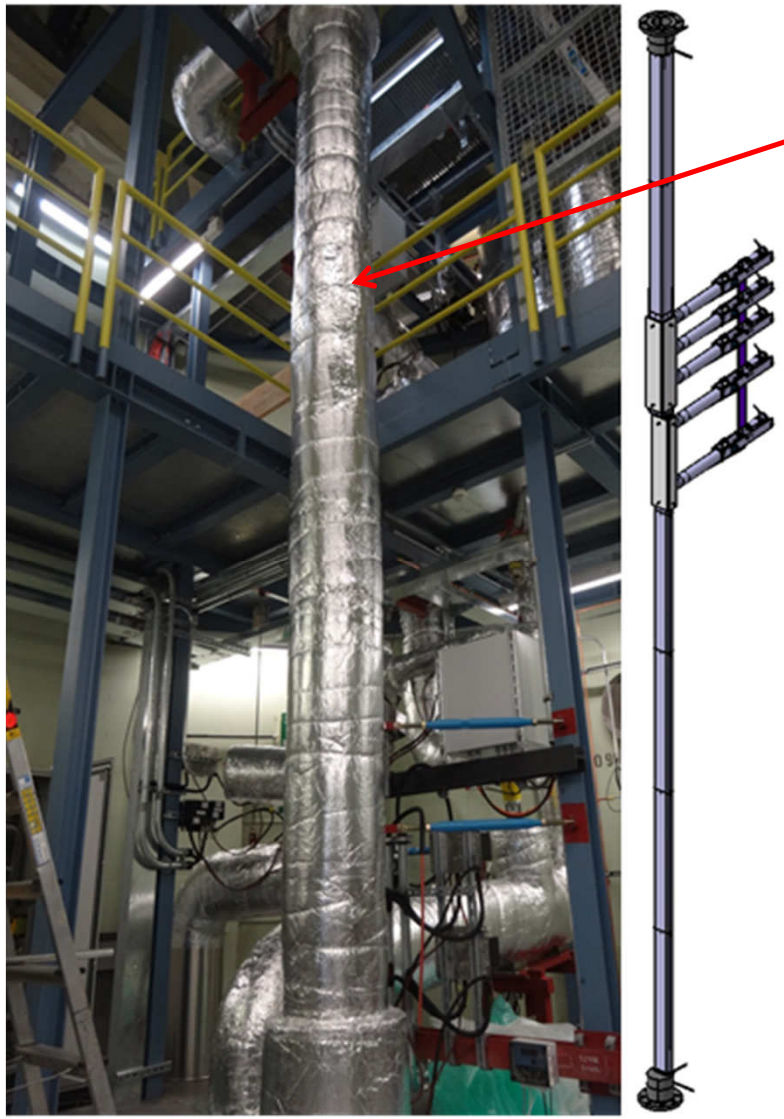


Status KASOLA



Test section for SiO

Test section for BFS

KASOLA SiO and QE

SiO

- Safety oriented test: Fast release of sodium under different conditions up to 300°C (avoidance of thermal shock)
- Overpressure/ overfilling provisions
- Cleaning / Wetting
- Flow meter calibration
- System review: component limits

→ Documentation

QE

- Static tests for heat balance
- Pump operation forward/reverse
- Test of test section 1 heating
- Dynamic loop operation

2.2.1: KASOLA test on transitional conditions

Task 2.2.1 uses the existing test sections in the KASOLA facility available in 2018-2020. Initially a simple straight test section of app 6 m is installed with a heating system at the bottom. In 2018/19 this test section will be replaced by the backward-facing test section (BFS) with a very detailed instrumentation allowing to monitor flow pattern down-streams the step.

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  - Use set into operation experiments for model qualification
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  passive shut down systems have to act fast enough to shut down the reactor safely before energetic action start
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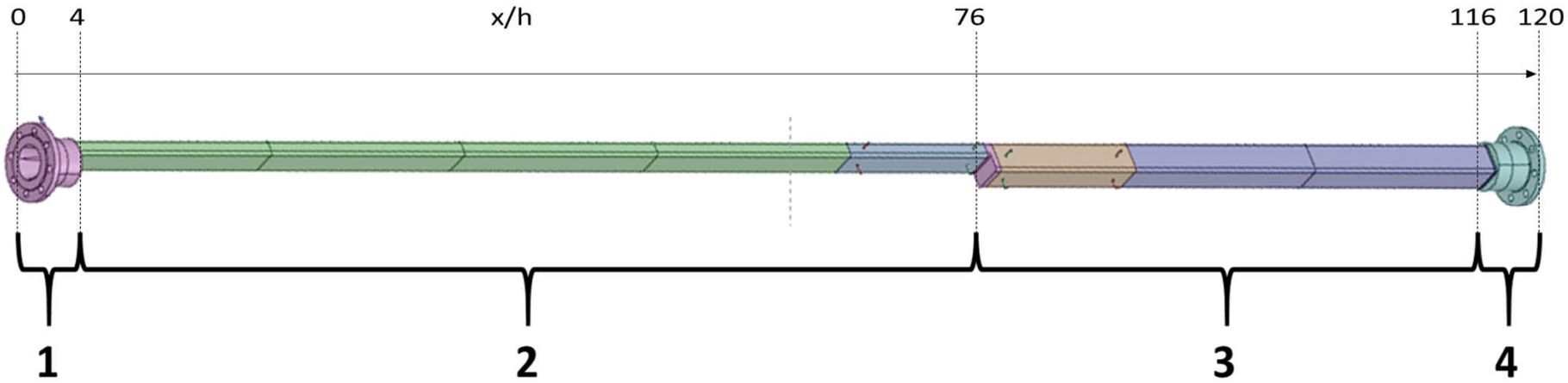
BFS: Backward Facing Step: Design

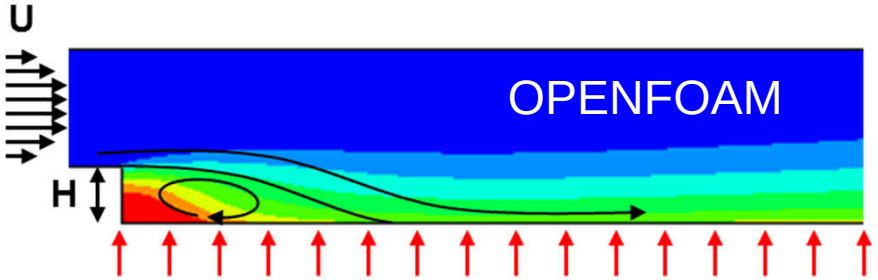


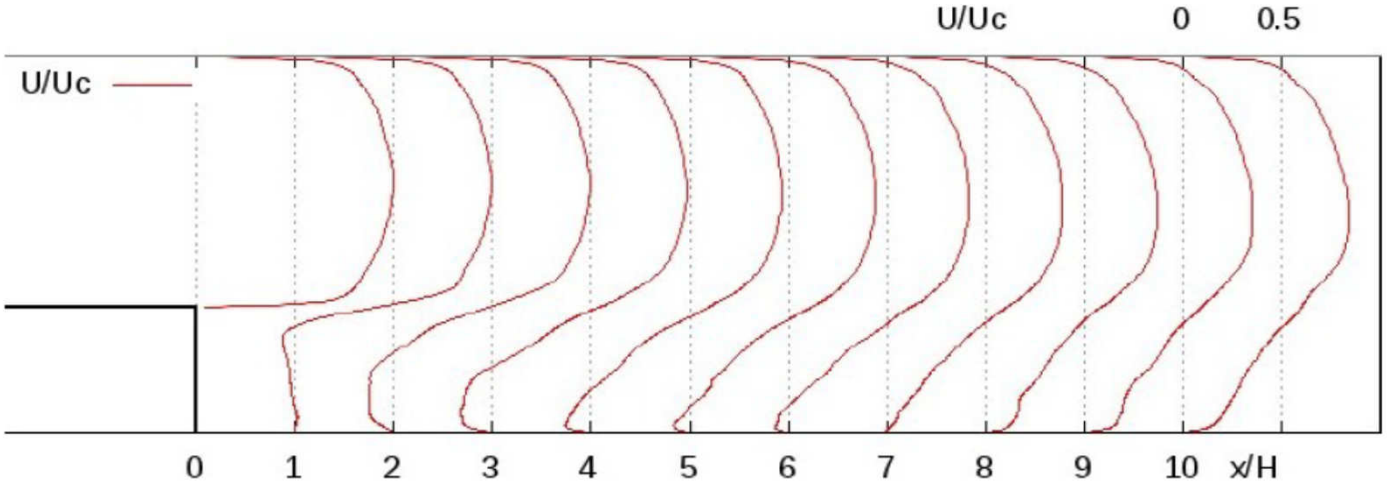
1. Inlet section (transition from circular to rectangular cross section):
   4 x/h = 200 mm
2. Rectangular section: 72 x/h = 3600 mm (40 x 40)
3. Quadratic section: 40 x/h = 2000 mm (90 x 40)
4. Outlet section (transition from quadratic to circular cross section)
   4 x/h = 200 mm

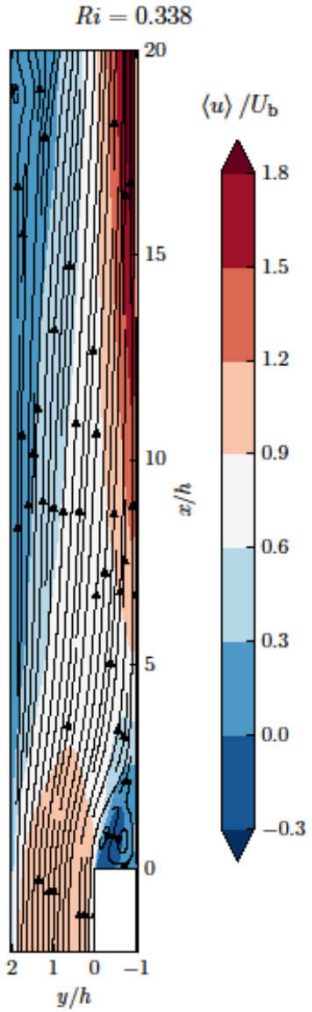
	Empirical correlations		Sharp 90° corners		Rounded corners	
	Techo	Colebrook	SST	BSLRSM	SST	BSLRSM
Δp [Pa]	40.9	41.8	39.7	41.7	40.8	43.1
U [m/s]	-	0.286	0.290	0.280	0.294	0.284

Analytical support (LIMTECH)

- CFD support by different institutions as part of the Helmholtz Alliance on Liquid Metal Technology (LIMTECH)
- RANS
- DNS
- LES







Milestones - Deliverables

- Spring 2018: updated KASOLA documentation
- Q1 deliverable of FlexStor vessel
- Q2/Q3 2018 Performance of QE experiments
- Q4 Maintenance, replace test section → BFS integration of FlexStor for CSP

MS2.1.3 Availability of new KASOLA data 2,1	T2.1.2	KIT Proj-Meeting	1. 12
MS2.2.1 KASOLA Phase I test data available 2,2	T2.2.1	KIT Proj-Meeting	1 12
MS2.2.2 KASOLA Phase II test data available 2,2	T2.2.1	KIT Proj-Meeting	2 24

D2.2.1 Experimental results from the KASOLA Phase I test on thermal-hydraulics of transitional flow 2,2	T2.2.1	KIT R CO	~~12~~ 14
D2.2.2 Experimental results from the KASOLA Phase II test on thermal-hydraulics of abrupt channel change 2,2	T2.2.1	KIT R CO	~~24~~ 26

That's all for the moment…. **Questions?**