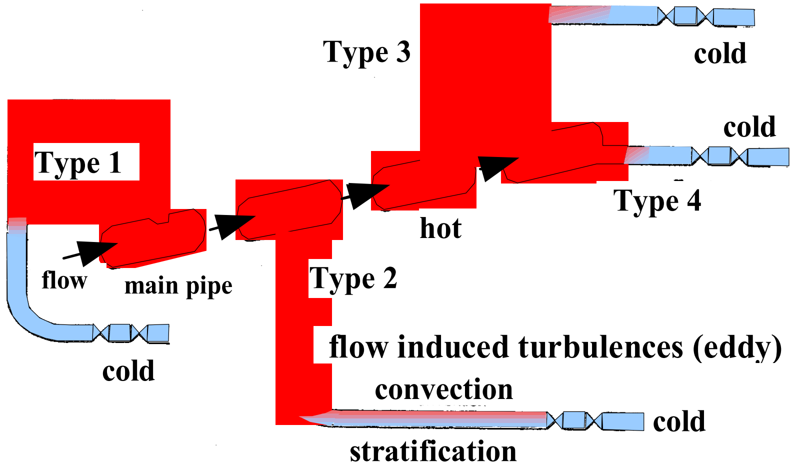
Thermal fatigue degradation effects occurred at austenitic T connections:

- cyclic feeding (Civaux, FR)
- valve leakage (GKN, DE)



Potential consequences?

- surface stresses
- crack initiation
- stresses in wall
- crack propagation

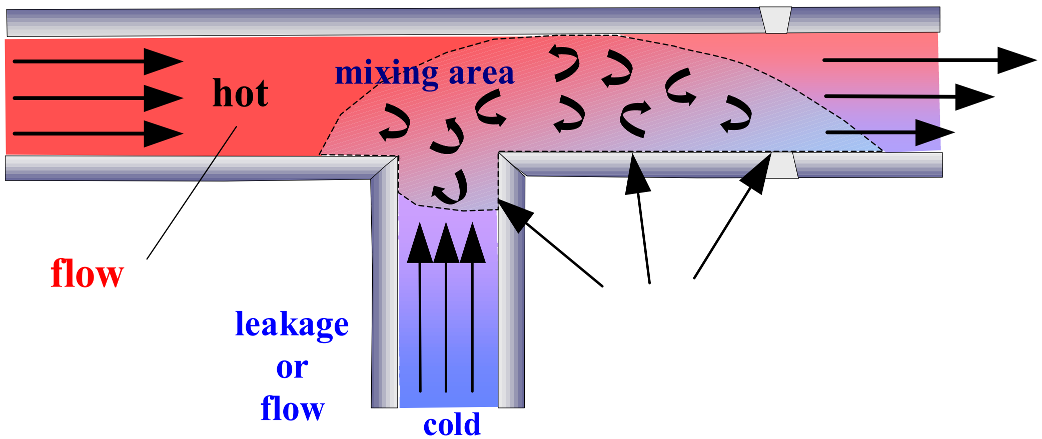


Figure 1: Turbulent mixing effects in piping system T connections

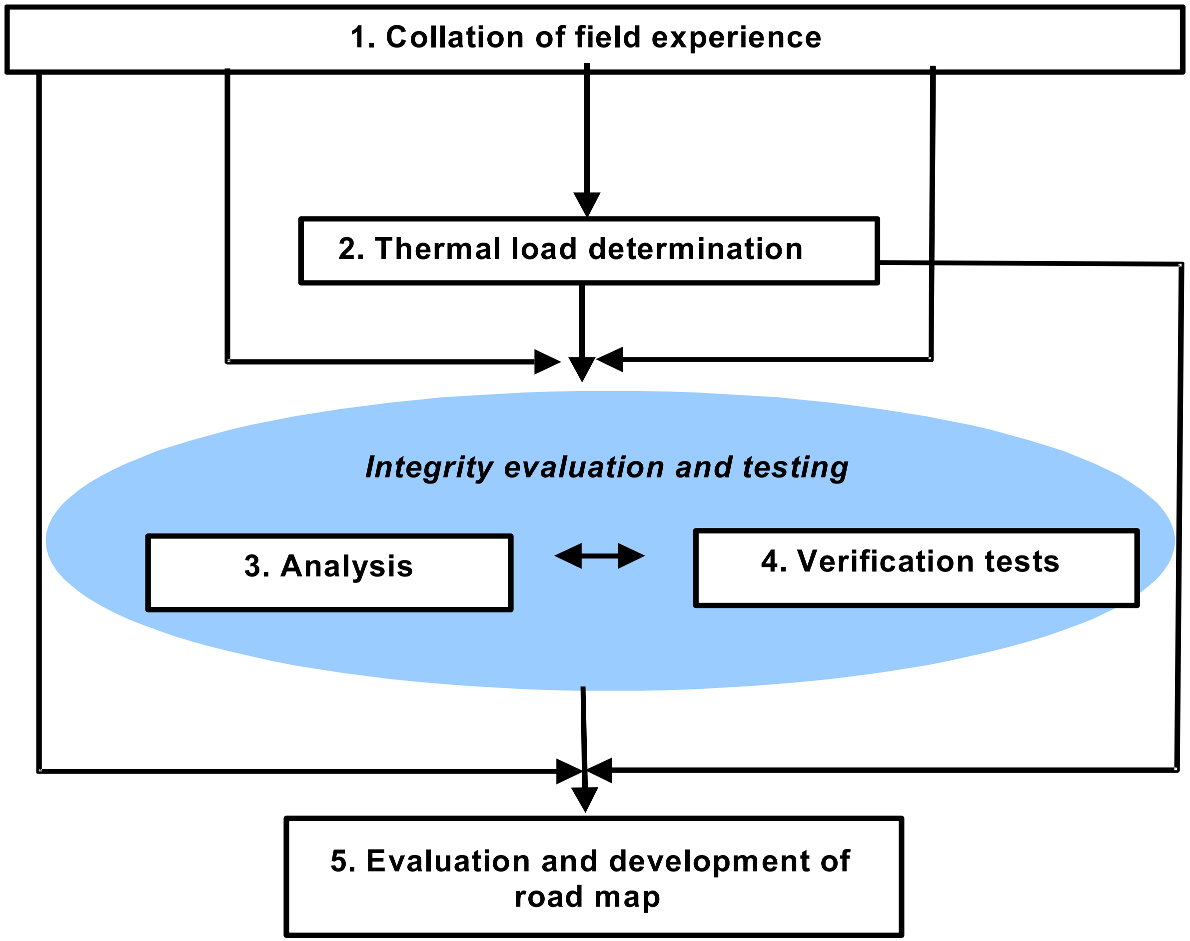


Figure 2: Work packages flow chart

Name	Country	Organisation
Wilke, U.	Germany	E.ON
Faidy, C.	France	EDF
Le Duff, J. A.	France	FANP-F
Braillard, O.	France	CEA
Cueto-Felgueroso, C.	Spain	Tecnatom
Varfolomeyev, I.	Germany	FHG
Solin, J.	Finland	VTT
Schippers, M.	Germany	FANP-D
Stumpfrock, L.	Germany	MPA
Nilsson, K.-F.	Netherlands	JRC
Vehkanen, S.	Finland	FNS
Seichter, J.	Germany	SPG
Abbas, T.	United Kingdom	CINAR
Figedy, S.	Slovakia	VUJE
Carmena, P.	Spain	ENDESA
Cizelj, L.	Slovenia	JSI

Figure 3: THERFAT consortium

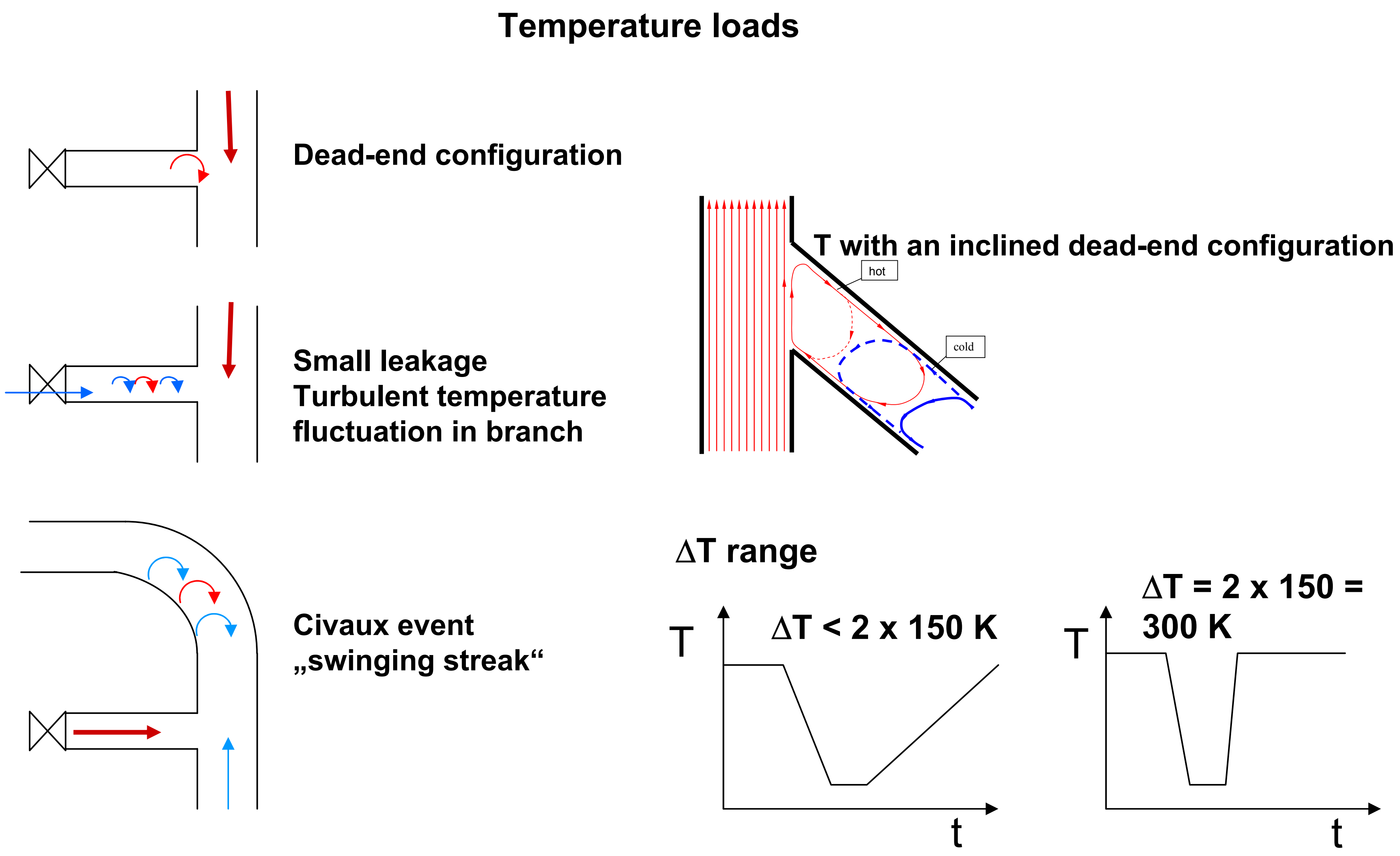
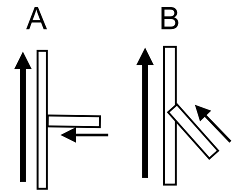
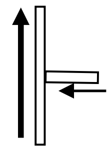


Figure 4: Field experience on high cyclic turbulent temperature mixing

Dimensions of T	Objective	Parameters	Remarks	Status
50 x 50 (90°-T)	Flow Visualisation	Various Flow Directions and Mass Flows	Tests at Room Temperature ➔ Variation of Fluid Density 	Tests finished
50 x 50 (45°-T)	Flow Visualisation	Various Flow Directions and Mass Flows		
70 x 24 (90°-T)	Flow Visualisation	Various Flow Directions and Mass Flows		
100 x 100 (90°-T)	Flow Visualisation	Flow Direction A Mass Flows see table below		Tests finished
50 x 50 (90°-T)	Electric Conductivity Measurement	Main Flow in kg/s: 2 and 4 Leak Flow in kg/s: 0.03, 0.06 and 0.12	Tests at Room Temperature ➔ Variation of Fluid Density 	Tests finished

	Main Mass Flow in kg/s	Leak Mass Flow in kg/s
DN 100 x 100 (d_i = 100)	20 10	0.015 0.03

Figure 5: SPG, glass models test matrix

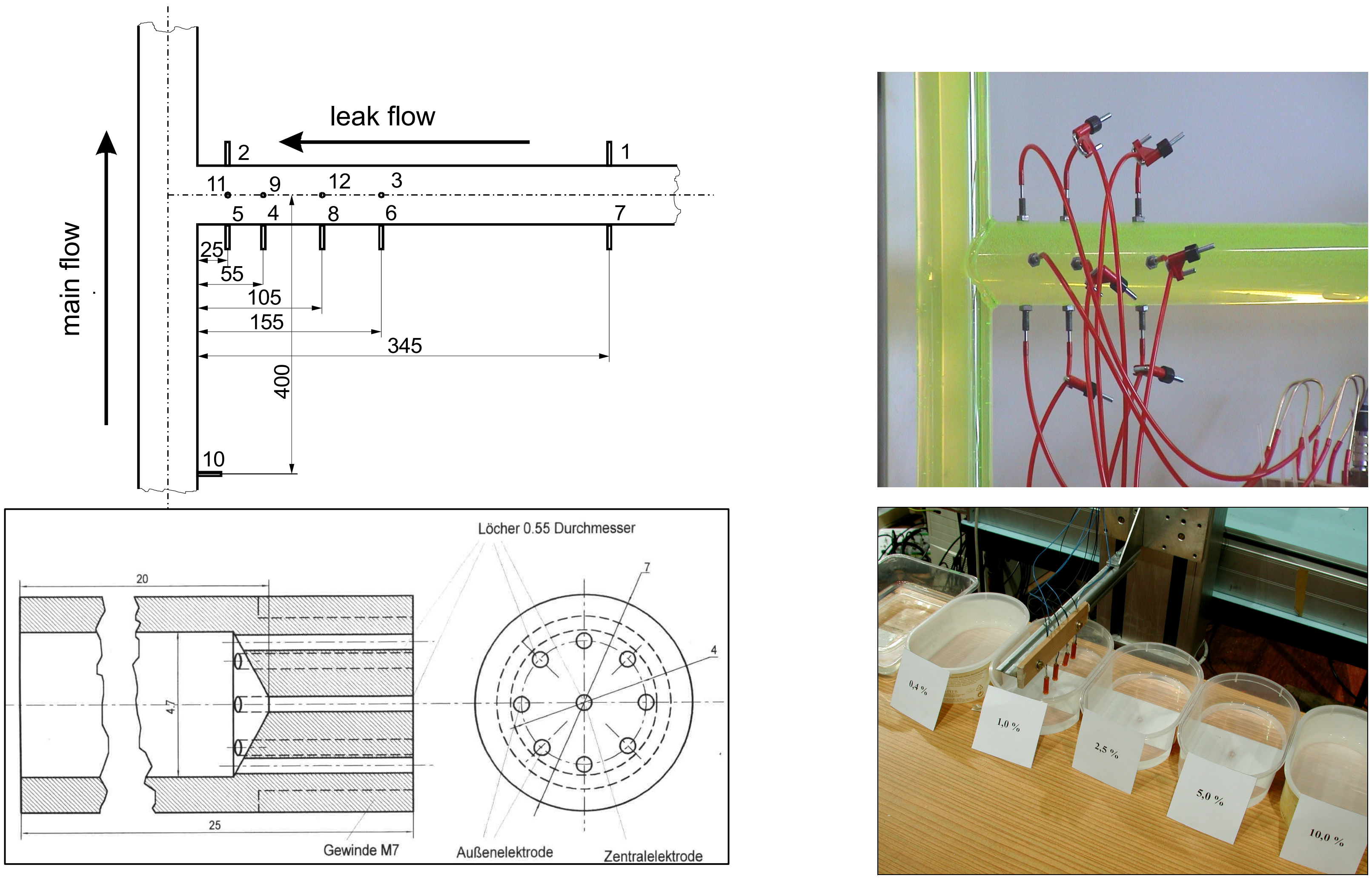


Figure 6: SPG, glass model, electrical conductivity measurement

Steel models (pipe wall thickness 1 mm)

Test matrix

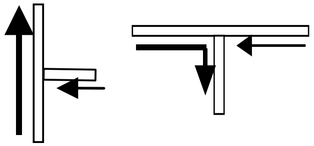
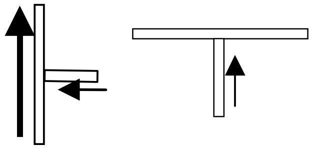
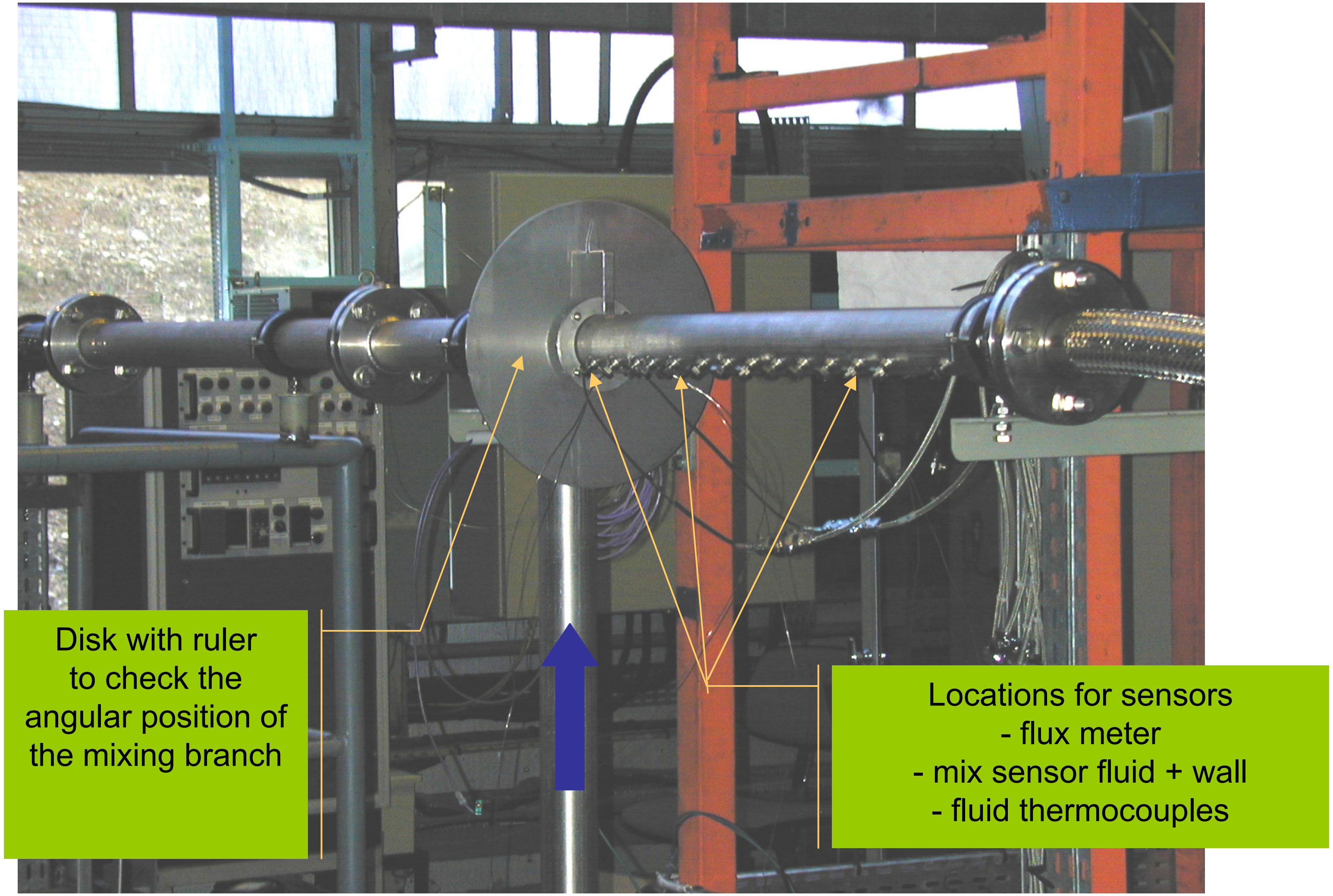
	T and flow orientation	Main mass flow $\dot{m}$ in kg/s	Leak mass flow $\dot{m}$ in kg/s	Temperature difference (hot – cold water) ΔT in K	Circumferential measurement position	Status
DN 50 x 50 (d_i = 48)	A B 	3,9 1,95	0.015 0.03 0.06 0.12 0.23	90 45	6 ... 12 o'clock	Tests finished
DN 80 x 20 (d_i = 78 x 20)		5,5 2,75	0.015 0.03 0.06 0.12	90 45	6 ... 12 o'clock	Tests finished

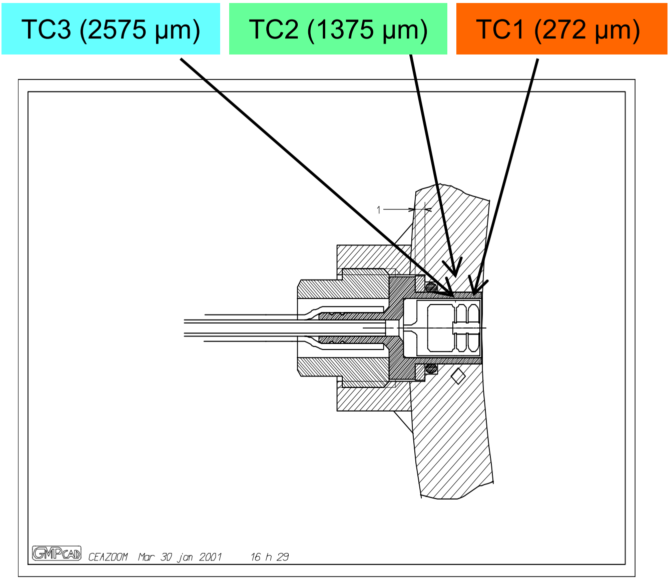
Figure 7: SPG, steel models, test matrix

The THERFAT mock-up

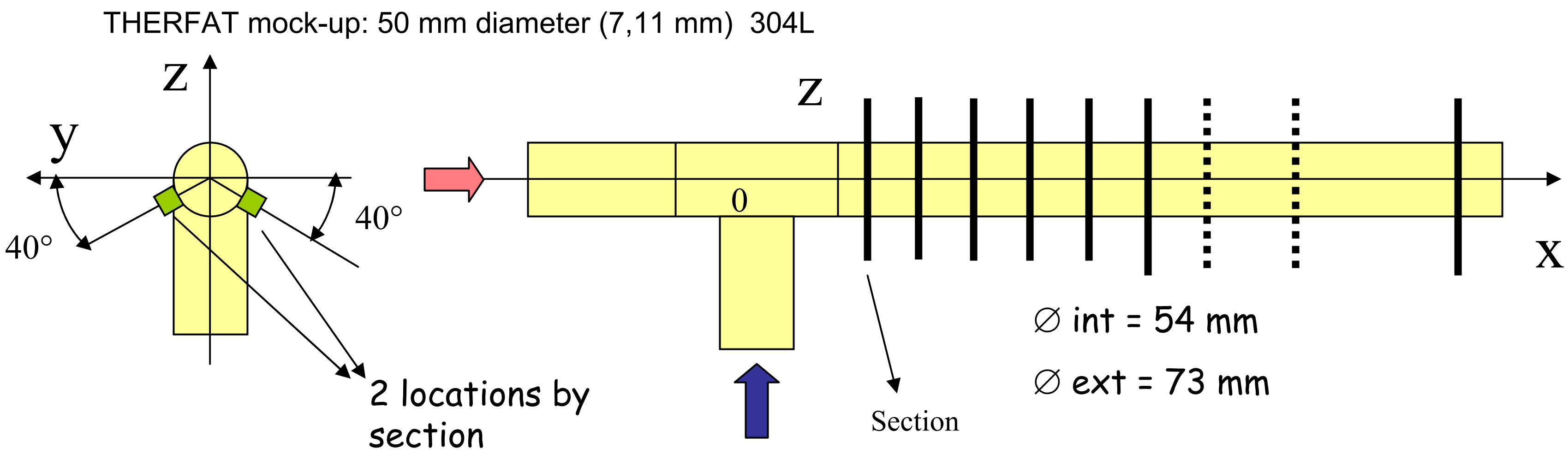


Fatherino facility overview

Figure 8: CEA, Fatherino II experiment, test rig



CEA flux meter



Fatherino II instrumentation

Figure 9: CEA, Fatherino II, test configuration

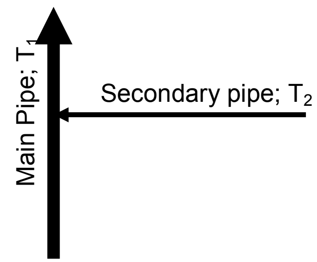
THERFAT
Example: turbulent-temperature load spectrum in branch

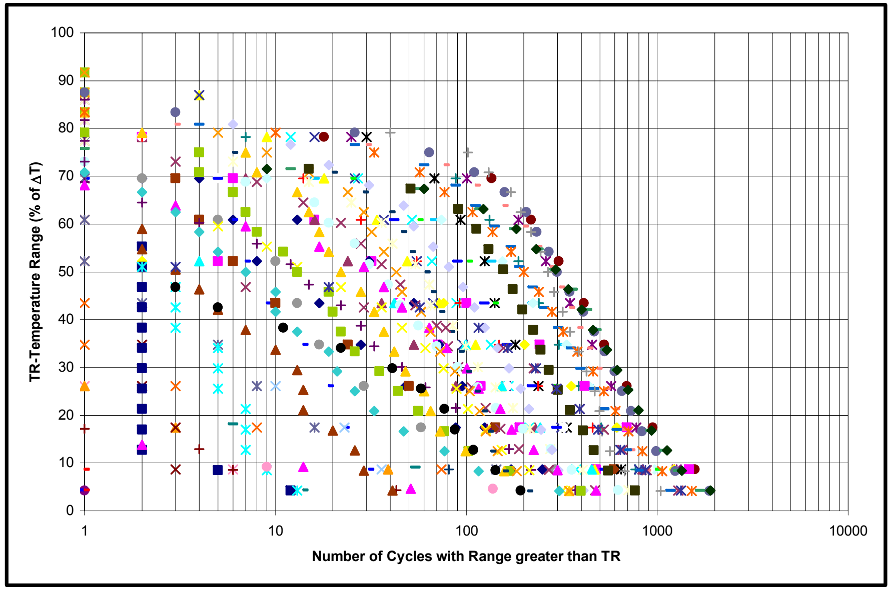
Measured temperature ranges – rain-flow evaluation

Vertical T 50 x 50 (wall thickness = 1 mm)

Measuring position 6 o'clock

Secondary pipe, fluid temperature





Measured temperature ranges – rain-flow evaluation

Vertical T 50 x 50 (wall thickness = 1 mm)

Measuring position 6 o'clock

Secondary pipe, outside wall temperature

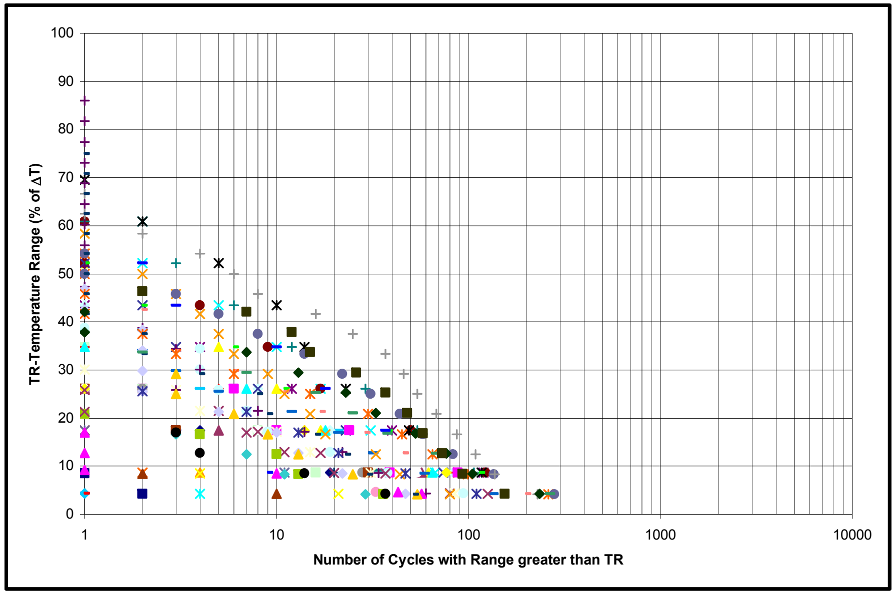


Figure 10: SPG, steel model, turbulent-temperature load spectrum

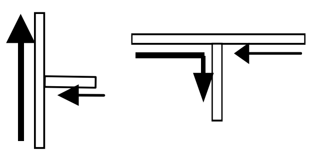
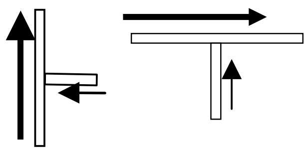
THERFAT – WP 2.2 Deliverable D8

Thermo-hydraulic tests on steel models (50 x 50 and 80 x 20)

- **Steady flow in main pipe - one leg locked (closed valve) but leakage**
- **Temperature difference ΔT (main flow – leakage) up to 90 K**
- **Temperature measurement outside and inside the wall (thickness 1 mm)**

Results

- **Temperature alterations, load spectra (percentage of ΔT)**
- **Mean heat-transfer coefficients found by inverse temperature calculation**
- **Report BLP-SB/27-04**

T and flow orientation		Temp. alterations	Heat-transfer coefficient
DN 50 x 50 (d_i = 48)	A B 	Dead leg: > 90 % Main flow: ≤ 70 %	Dead leg: ≤ 4000 W/m²K (A) ≤ 7000 W/m²K (B) Main flow: ≤ 6000 W/m²K (A) ≤ 10000 W/m²K (B)
DN 80 x 20 (d_i = 78 x 20)		Dead leg: negligible Main flow: ≤ 70 %	Dead leg: no relevant information Main flow: ≤ 10000 W/m²K

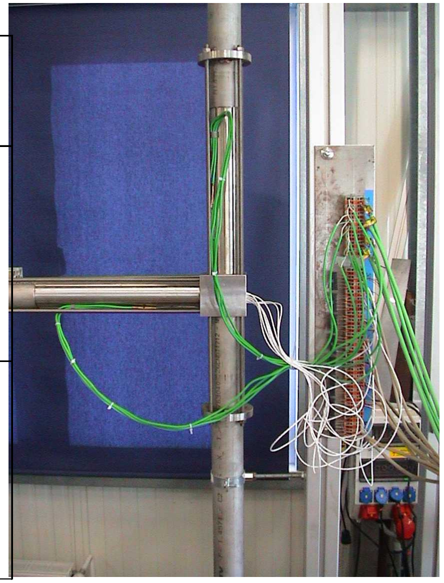


Figure 11: SPG, steel model, test results

Thermo-hydraulic tests with glass models (50 x 50 and 100 x 100)

- **Steady flow in main pipe - one leg locked (closed valve) but leakage**
- **Temperature difference ΔT simulated by different specific fluid densities**
- **Electrical conductivity measurement**

Results:
- **"Temperature" alterations (percentage of ΔT)**
- **Report BLP –SB/50-04**

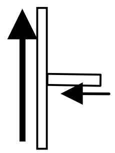
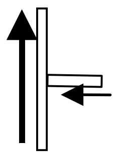
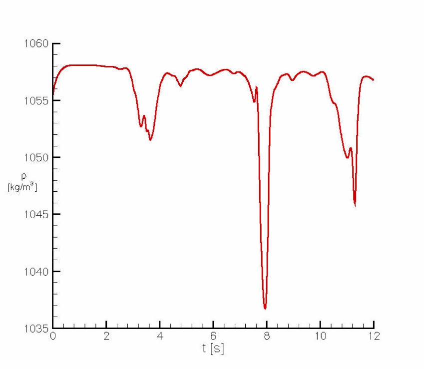
T and flow orientation		"Temp." alterations
DN 50 x 50		Dead leg: ≤ 80 %
DN 100 x 100		Dead leg: ≤ 40 %

Figure 12: SPG, glass model, test results

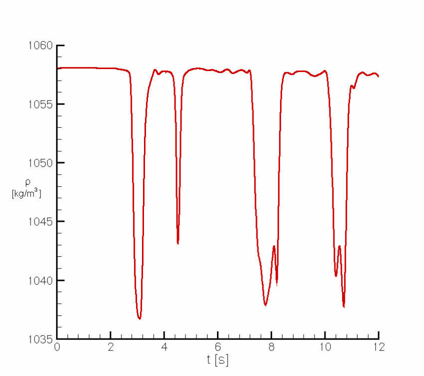
THERFAT – WP 2.3 Deliverable D10/D11

CFD benchmark calculation by Technical University of Dresden (TUD)

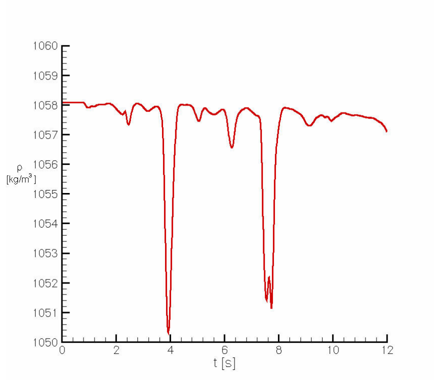
Density versus time in the leakage pipe at 6-o’clock position



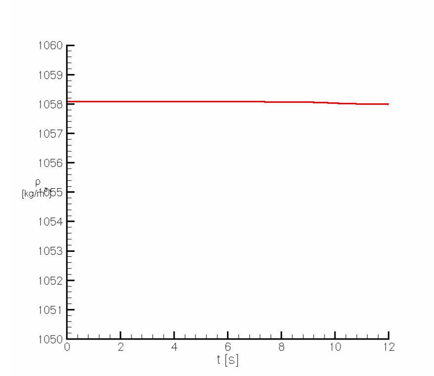
Distance 0.5 d



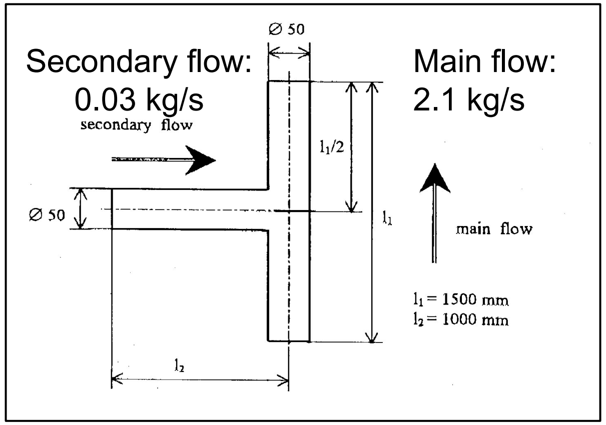
Distance d



Distance 2 d



Distance 3 d



Summary

- **Qualitative agreement with test results (large peaks at low frequency between small amplitudes)**
- **Time period covered by calculation: 12 s (decay time for start-up effects in tests about 100 s)**
- **Relation costs/benefit too large**

Figure 13: SPG, CFD benchmark analysis experiment/CFD analysis

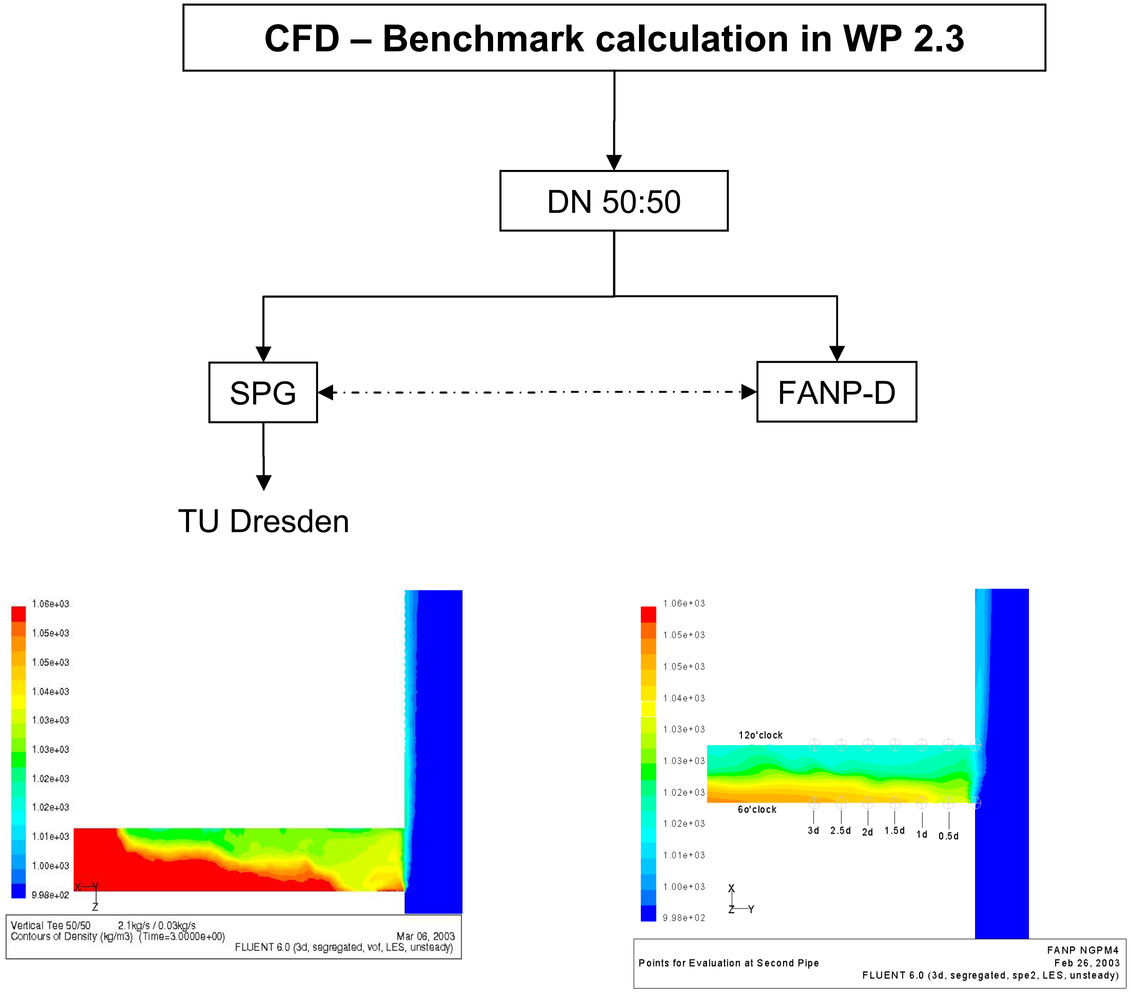


Figure 14: Benchmark of CFD analysis SPG, FANP-D