

Workgroup „Thermohydraulics“

The thermohydraulic laboratory

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Dresden, 2014



DRESDEN
concept
Exzellenz aus
Wissenschaft
und Kultur

Outline

- I. Education
- II. Thermohydraulic laboratory
- III. Test facilities and projects
- IV. Codes

I. Education

Lecture „Nuclear and thermohydraulic design of nuclear reactors“

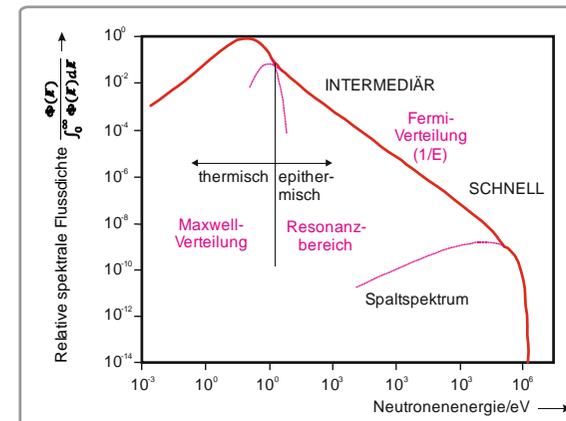
- Introduction
- Neutron physics (steady-state reactor)
- Reactor heat transfer
- Reactor technology
- Safety related rules

Exercises: Applying the equations ...

Practical training:

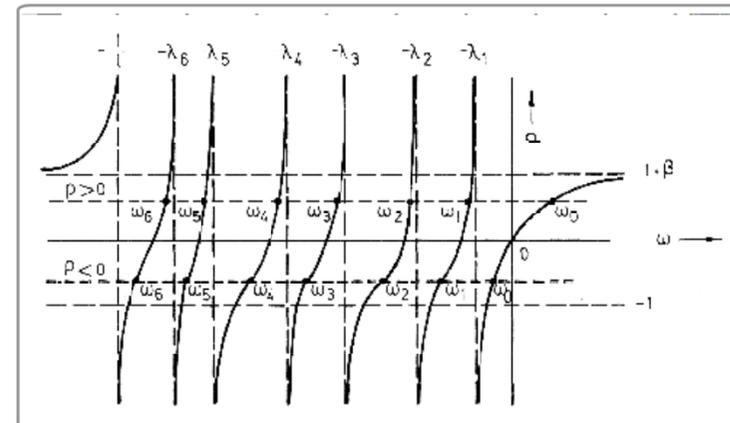
Experiments at the Nuclear Education Reactor AKR-2

- Reactor start-up
- Neutron flux
- Critical experiment



Lecture „Transient behaviour of nuclear power plants“

- Introduction
- Neutron kinetics
- Reactivity effects
- Reactivity coefficients
- Short time behaviour



Exercises: Applying the equations ...

Practical training:

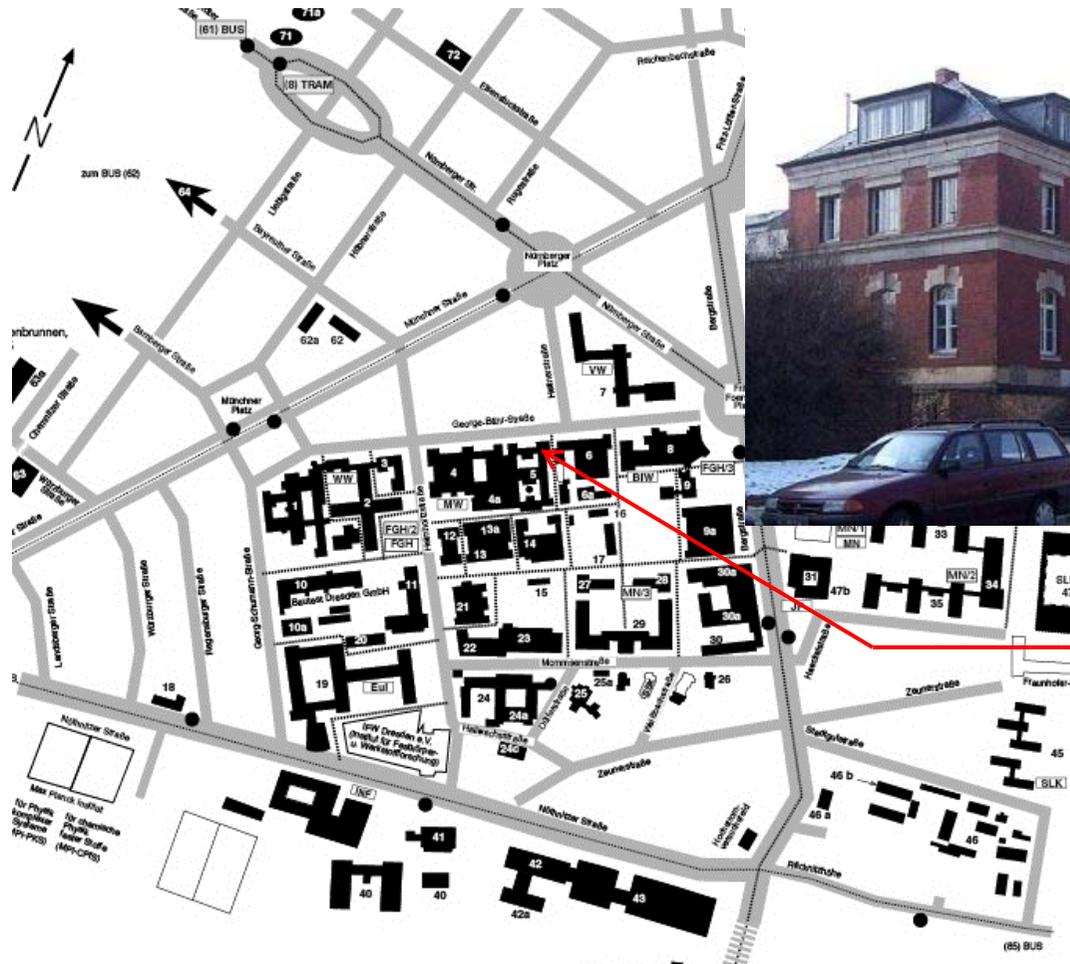
- a. Experiments at the Nuclear Education Reactor AKR-2
 - Reactor start-up
 - Influence function
- b. PWR simulator
- c. BWR feedback control

Student research projects

- Multidisciplinary project thesis: 6 month in 7th semester
- Course work: 500 hours
- Diploma thesis: 4 month (regular in 10th semester)

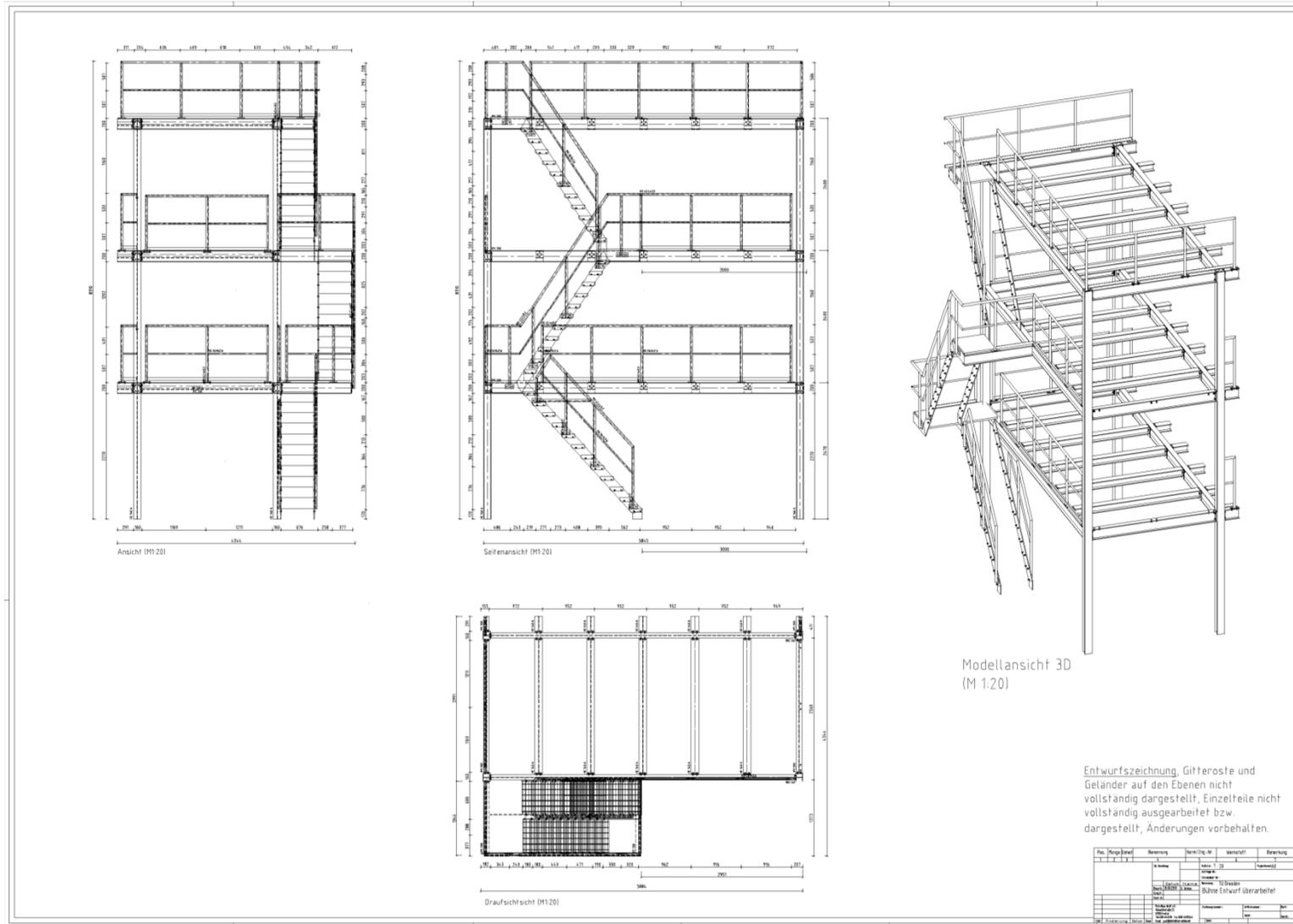
All thesis are in close relationship to prevailing applied research topics (industry, research institutes, university)!

II. Thermohydraulic laboratory



Mollierbau

George-Bähr-Str. 3
01069 Dresden



- 18 m² area for experiments at 3 platforms
- Up to 9,6 m height
- 150 kW electrical power
- 120 kW steam generator power up to 6 bar
- Cooling pond as heat sink
- > 25 years of experience in medium/large scale thermohydraulic experiments



III. Test facilities and projects

DANTON

.....DANTON-GT

.....DANTON-II

.....BORAN (2006-2009)

.....ISOTRAN (2010/2011)

.....ERKO (2011)

.....ADELA-I (2007)

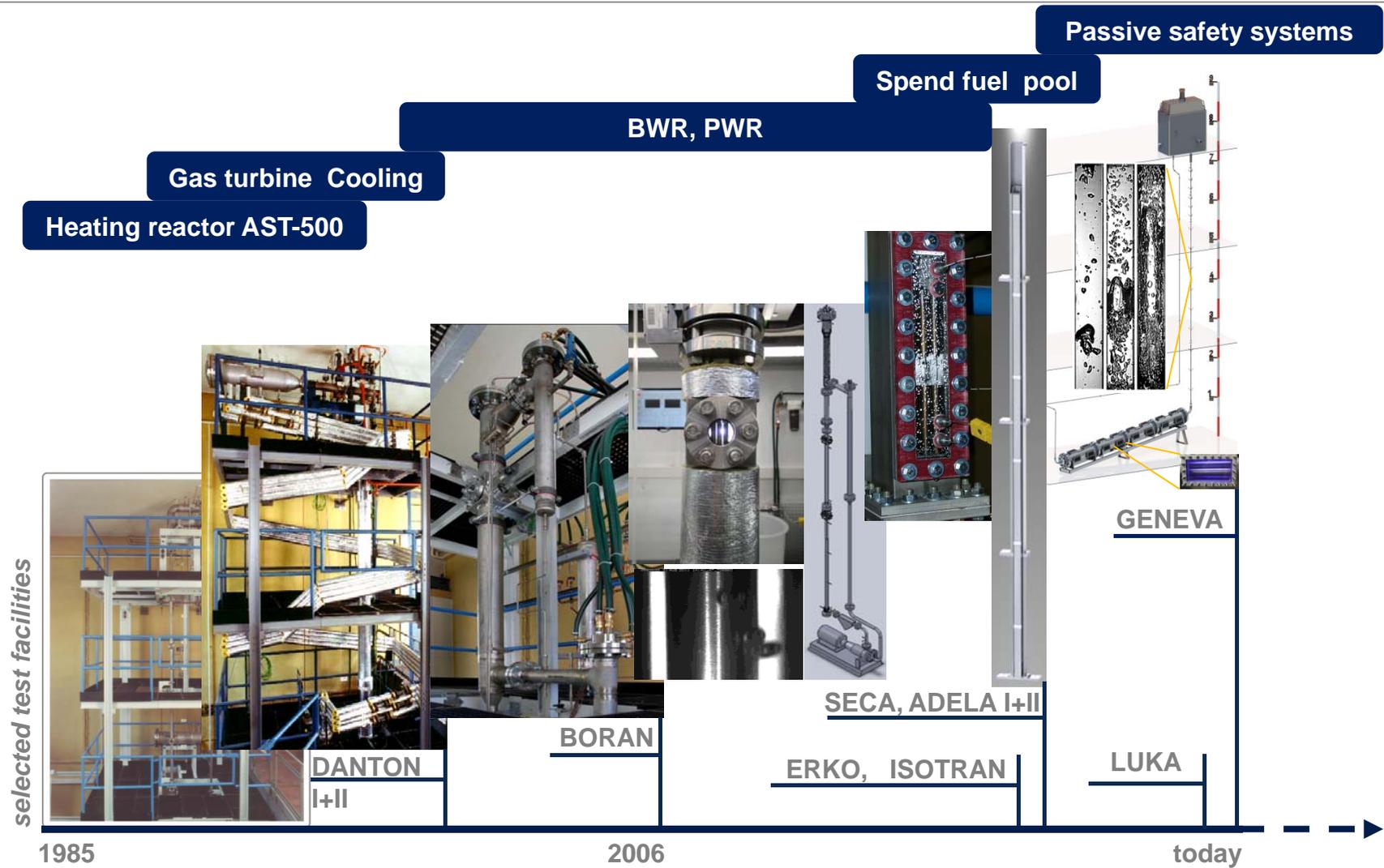
.....ADELA-II (2013)

.....SECA (2013)

.....LUKA

.....GENEVA

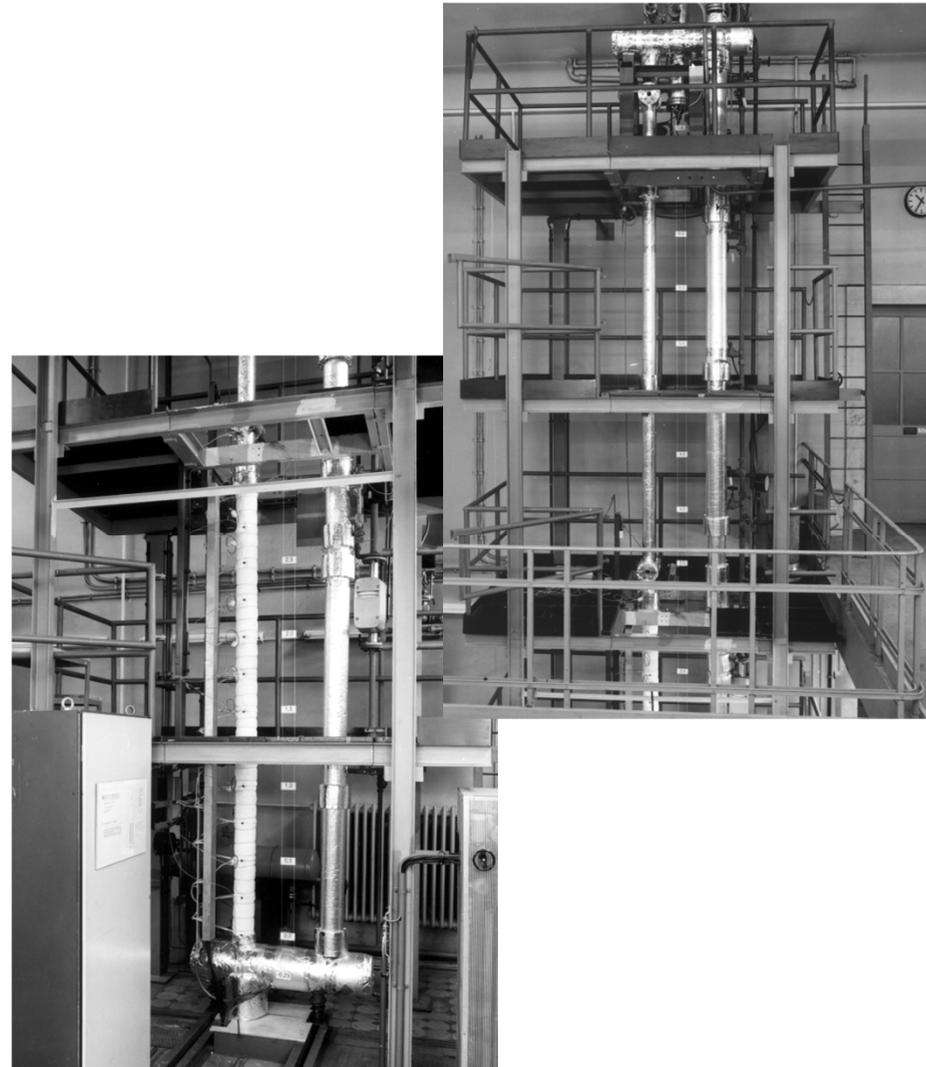
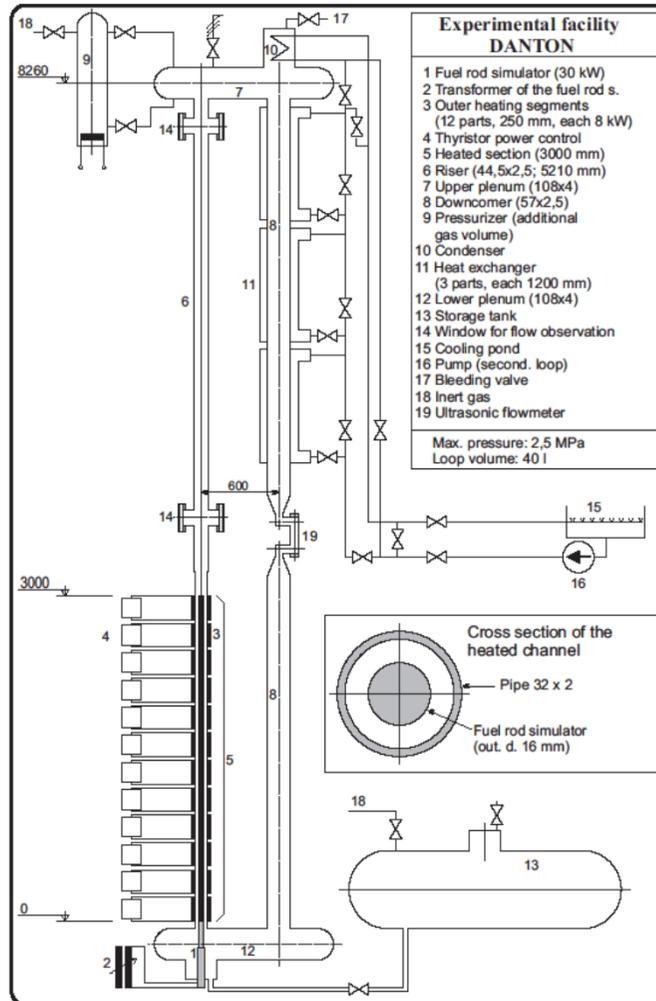
.....ALADIN



DANTON

Test facility	DANTON			
Project	Thermohydraulic properties of the primary loop of district heating nuclear reactors			
Commissioning	1985	Decommissioning	1999	
Parameter	Power/kW	100	Heater length/m	3,0
	Temperature/°C	225	Riser length/m	5,26
	Pressure/MPa	2,5	Heater	Central rod + 12 outer sections (axial profiling)
	Height/m	8,7	Special data acquisition	Conductivity needle probes for local void fraction at riser inlet and outlet (3 radial positions)
Primary loop volume/l	40			
Short description	Natural circulation loop with self-pressurization; integral facility for the investigation of the Russian nuclear heating reactor AST-500; single- and two-phase flow in the heater and riser; stable and unstable loop mass flow			

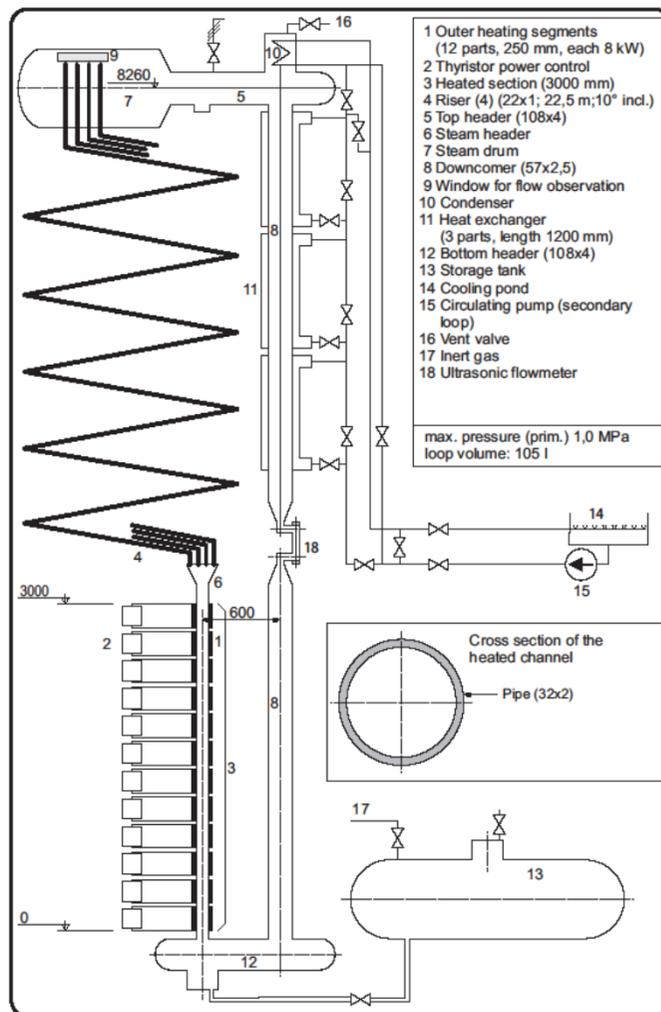
Configuration



DANTON

Test facility	DANTON-GT			
Project	Simulation of parallel risers in the cooling-air cooler system of Siemens model Vx4.3 gas turbines			
Commissioning	12/1995	Decommissioning		06/1997
Parameter	Power/kW	50	Heater length/m	3,0
	Temperature/°C	180	Riser length/m	23 (inclination angle 10°)
	Pressure/MPa	1,0	Heater	12 outer sections (axial profiling)
	Height/m	8,7	Special data acquisition	Conductivity probes for void detection at riser inlet and outlet
Primary loop volume/l	105			
Short description	Natural circulation loop with self-pressurization; thermohydraulic behaviour of 4 parallel slightly inclined adiabatic risers at two-phase flow conditions; flow stability in the loop, flow distribution to the parallel risers			

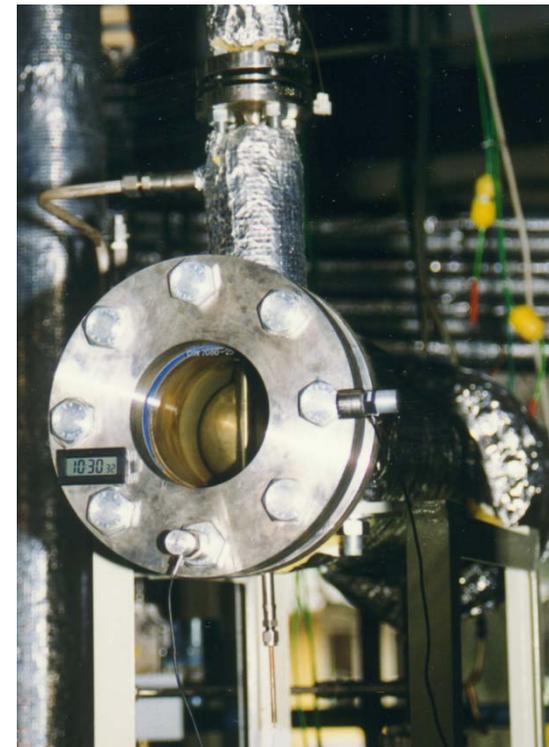
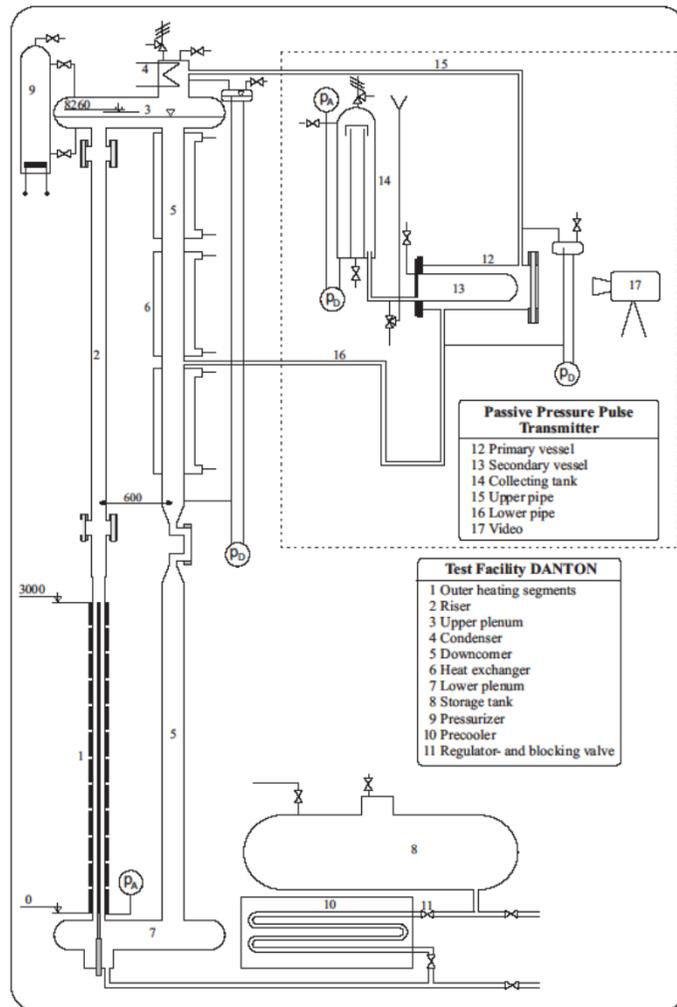
Gas turbine cooling-air cooler configuration



DANTON

Test facility	DANTON-PPPT			
Project	Investigation of the operation mode of passive pressure pulse transmitters (PPPT)			
Commissioning	07/1997	Decommissioning	07/1999	
Parameter	Power/kW	100	Heater length/m	3,0
	Temperature/°C	225	Riser length/m	5,26
	Pressure/MPa	2,5	Heater	Central rod + 12 outer sections (axial profiling)
	Height/m	8,7	Special data acquisition	Video recording of condensation and level transition in PPPT
Primary loop volume/l	43			
Short description	Natural circulation loop with self-pressurization used as steam source for PPPT experiments; simulation of water level drop in SWR-1000 BWR, pressure pulse signal as function of water level position			

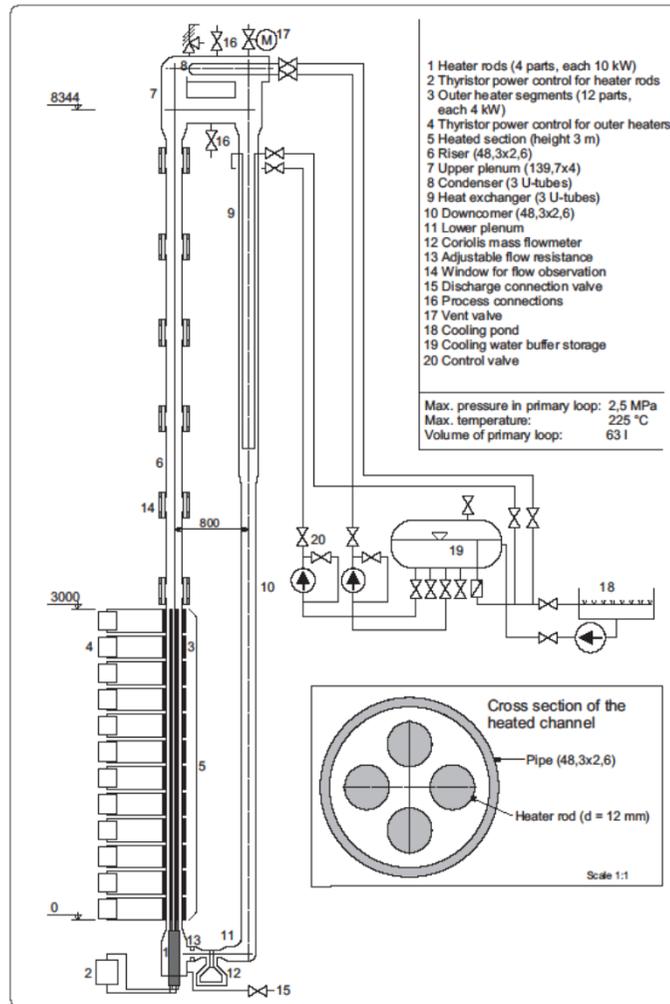
Passive pressure pulse transmitter configuration



DANTON-II

Test facility	DANTON-II			
Project	Generic investigations of natural circulation loop behaviour at two-phase flow conditions			
Commissioning	2000	Decommissioning		05/2005
Parameter	Power/kW	88	Heater length/m	3,0
	Temperature/°C	225	Riser length/m	5,34
	Pressure/MPa	2,5	Heater	4 rods + 12 outer sections (axial profiling)
	Height/m	9,5	Special data acquisition	Light barrier probes for local void fraction at 6 riser levels; Coriolis mass flow meter
Primary loop volume/l	63			
Short description	Natural circulation loop with self-pressurization; integral facility for the investigation of single- and two-phase flow in the heater and riser; stable and unstable loop mass flow, flashing and geysering phenomena			

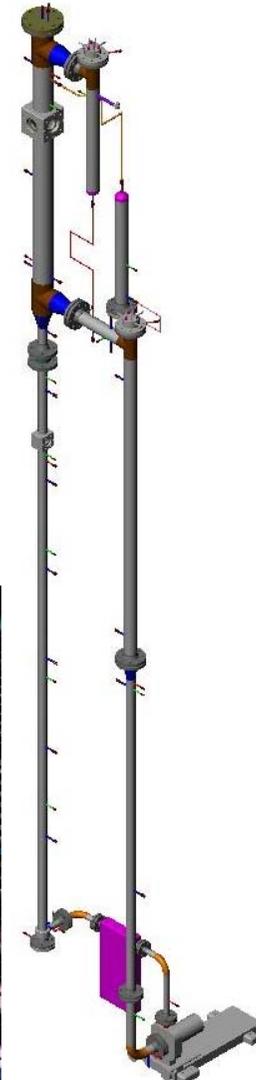
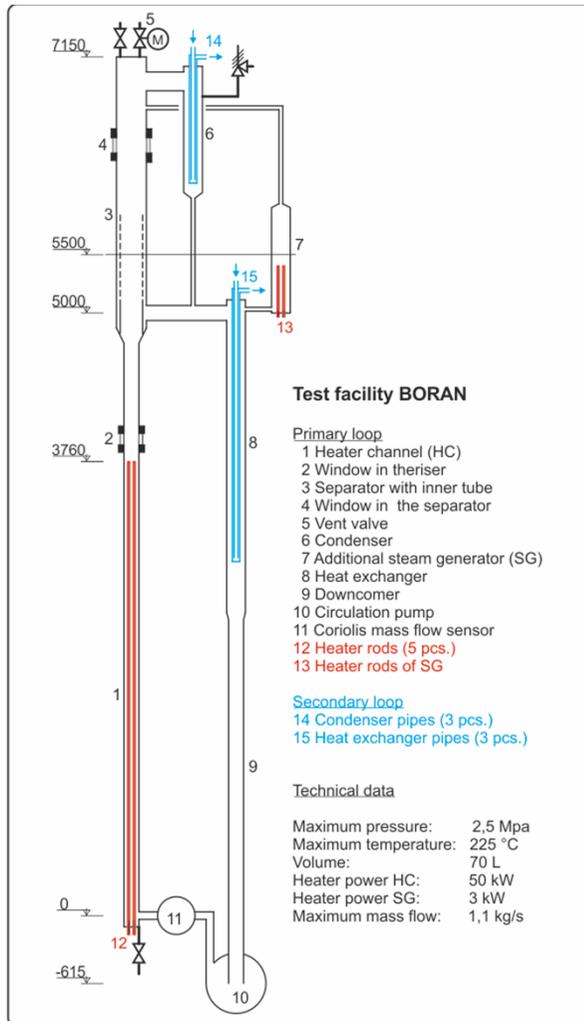
Configuration



BORAN

Test facility	BORAN			
Project	Analysis of the reactivity effectiveness of boron injection into BWR fuel elements during transient core conditions			
Commissioning	07/2007	Decommissioning	08/2010	
Parameter	Power/kW	50	Heater length/m	3,76
	Temperature/°C	225	Riser length/m	1,8
	Pressure/MPa	2,5	Heater	5 rods
	Height/m	8,2	Special data acquisition	12 two-point conductivity probes for boron slug detection; 16x16 wire mesh sensor for local void fraction; Coriolis mass flow meter
Primary loop volume/l	70			
Short description	Forced circulation loop with self-pressurization (optional with electrically heated pressurizer); integral facility for the investigation of boron volatility with steam from two-phase flow; simulation of boron dilution transients in BWR accidents			
Supported by	Vattenfall Europe Nuclear Energy GmbH			

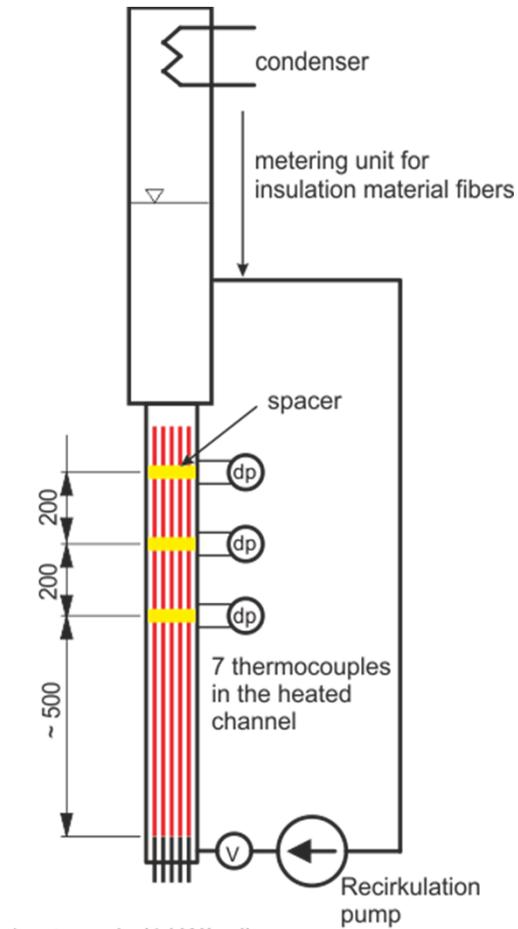
Configuration



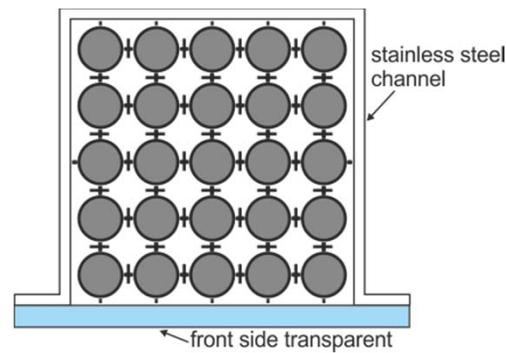
ISOTRAN

Test facility	ISOTRAN			
Project	Investigation of insulation fibres transport through BWR spacers during transition to two-phase flow			
Commissioning	03/2010	Decommissioning		
Parameter	Power/kW	25	Heater length/m	1,0
	Temperature/°C	100	Bundle length/m	1,56
	Pressure/MPa	0,1	Heater	25 rods (10 mm diam.)
	Height/m	2,76	Special data acquisition	Video recording of spacer flow behaviour at 3 windows
Primary loop volume/l	15			
Short description	Forced circulation loop at ambient pressure; insertion of fine-grained insulation fibres into the back flow pipe; investigation of fibre bed formation below original BWR spacers and their behaviour during transition to two-phase flow; confirmation of free fluid passage			
Supported by	Vattenfall Europe Nuclear Energy GmbH			

Configuration



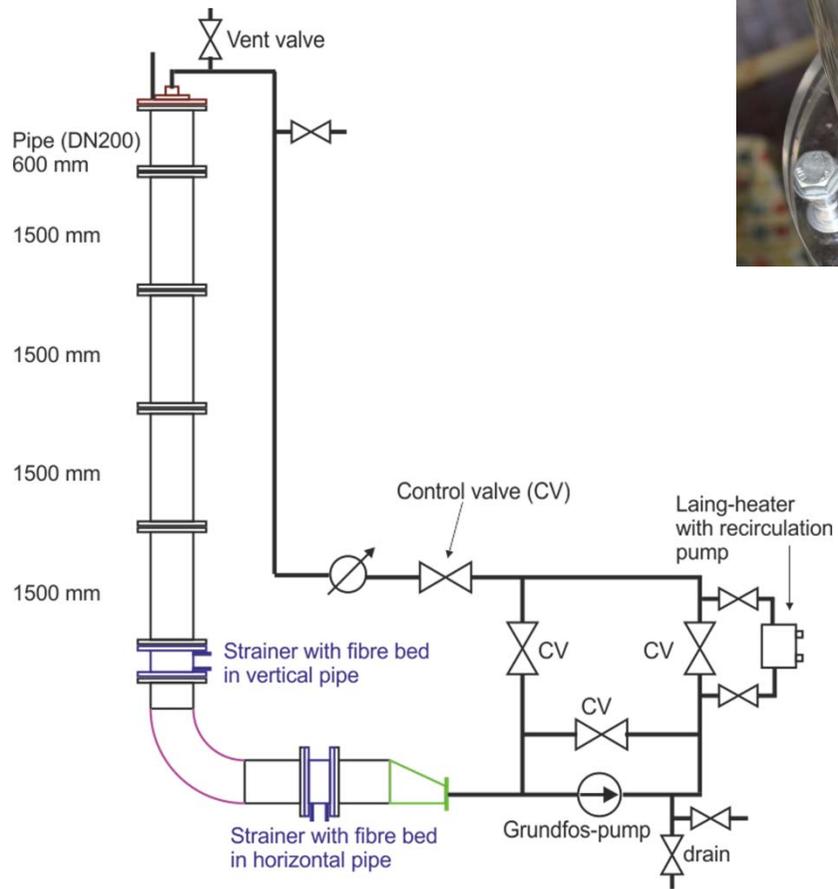
heater rods (1 kW/rod):
 heated
 unheated



ERKO

Test facility	ERKO			
Project	Investigation of erosion corrosion at zinc coated gratings			
Commissioning	06/2010	Decommissioning	03/2011	
Parameter	Power/kW	12	Jet velocity/m/s	26
	Temperature/°C	80	Flow rate/m ³ /h	25
	Pressure/MPa	0,1	Heater	Continuous-flow heater
	Height/m	8,2	Special data acquisition	ICP-MS analysis of concentration in fluid and fibre bed
Primary loop volume/l	300			
Short description	Forced circulation loop at ambient pressure; long-term water jet on zinc coated gratings; investigation of pressure drop at insulation fibre bed due to reposition of corrosion products			
Supported by	Vattenfall Europe Nuclear Energy GmbH			

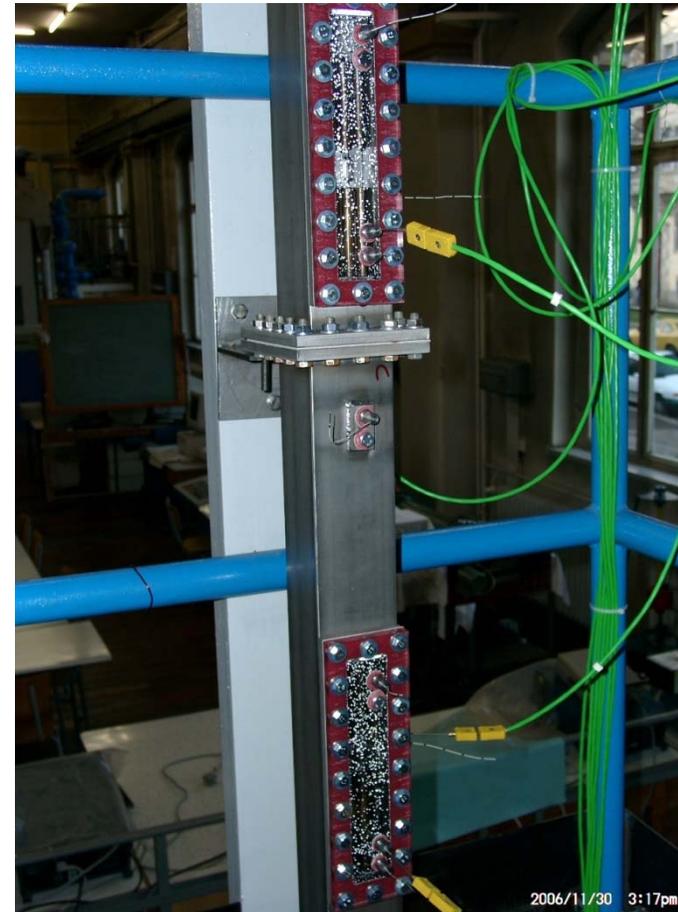
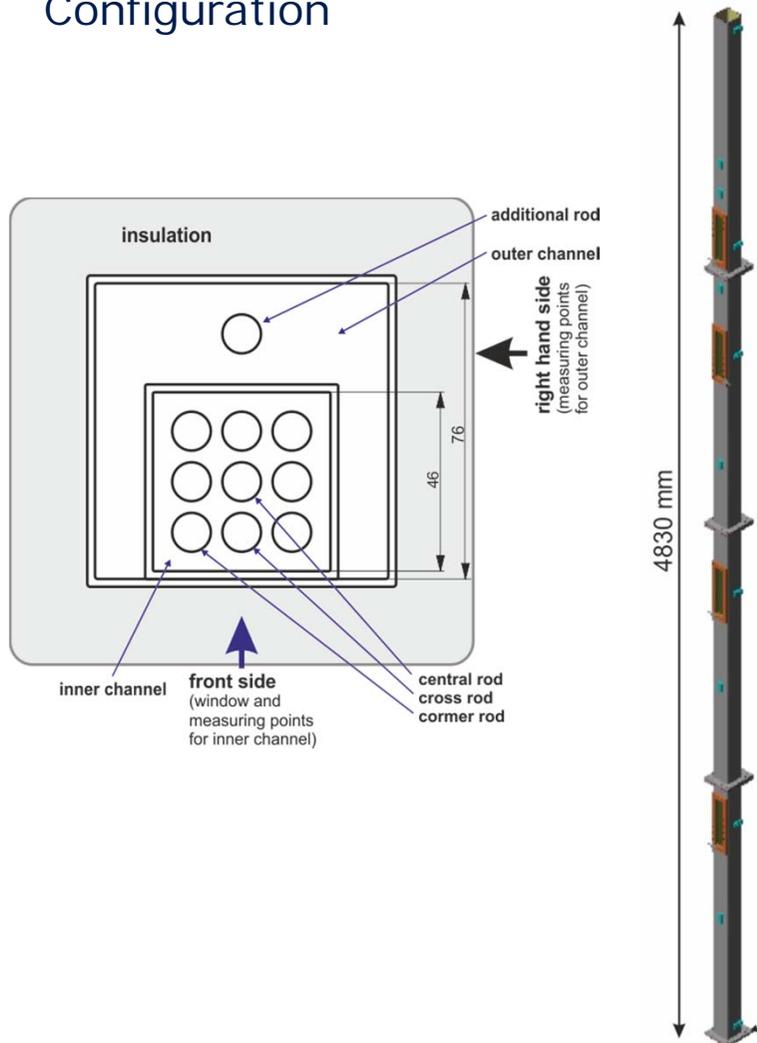
Configuration



ADELA

Test facility	ADELA-I			
Project	Experimental investigation of a nuclear fuel storage pond boil-off scenario			
Commissioning	11/2006	Decommissioning	06/2007	
Parameter	Power/kW	20	Number of spacers	7 (original BWR)
	Temperature/°C	600	Heated length/m	3,76
	Pressure/MPa	0,1	Heater	10 rods, 10 mm diam.
	Height/m	4,85	Special data acquisition	Video recording at two-phase transition region; conductivity probes for water level detection
Volume/l	22			
Short description	Simulation of a BWR fuel element with axial 1:1 scaling in a fuel storage pond during boil-off scenario; velocity of water level decrease; heater rod wall and fluid temperature			
Supported by	Vattenfall Europe Nuclear Energy GmbH			

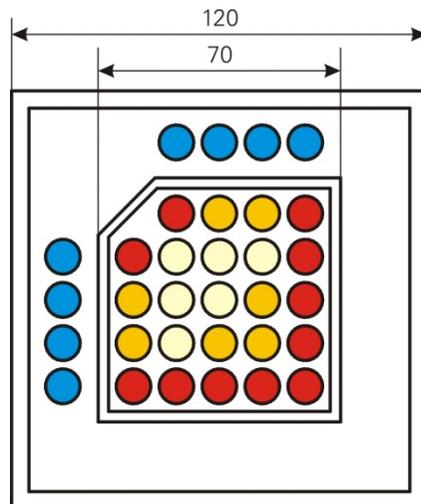
Configuration



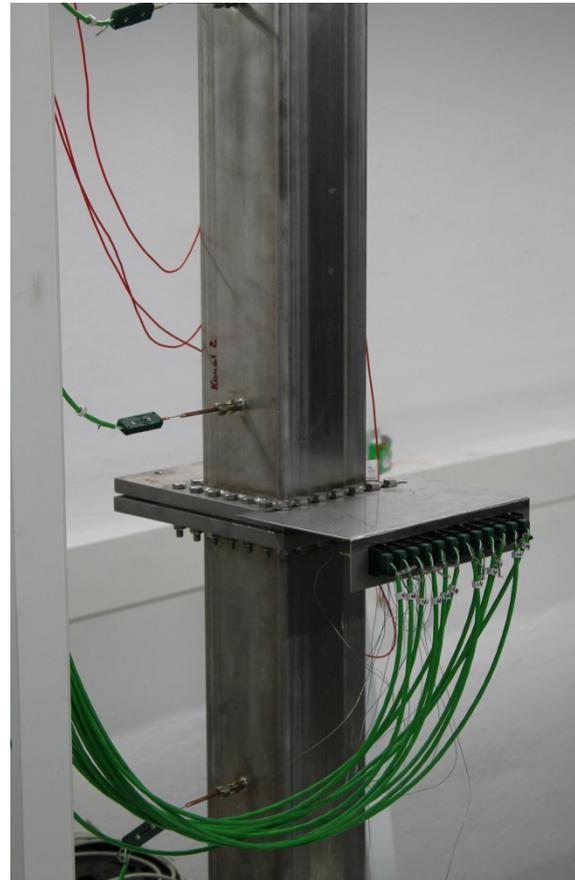
ADELA

Test facility	ADELA-II			
Project	Investigation of rod loading during vessel boil-off			
Commissioning	04/2011	Decommissioning		
Parameter	Power/kW	37,5	Number of spacers	6 (original BWR)
	Temperature/°C	600	Heated length/m	3,76
	Pressure/MPa	0,1	Heater	24 + 8 rods, 10 mm diam.
	Height/m	4,9	Special data acquisition	110 thermocouples for wall and fluid temperature measurement
	Volume/l	70		
Short description	Simulation of a BWR fuel element with axial 1:1 scaling in a fuel storage pond during boil-off scenario; velocity of water level decrease; heater rod wall and fluid temperature			
Supported by	Vattenfall Europe Nuclear Energy GmbH			

Configuration



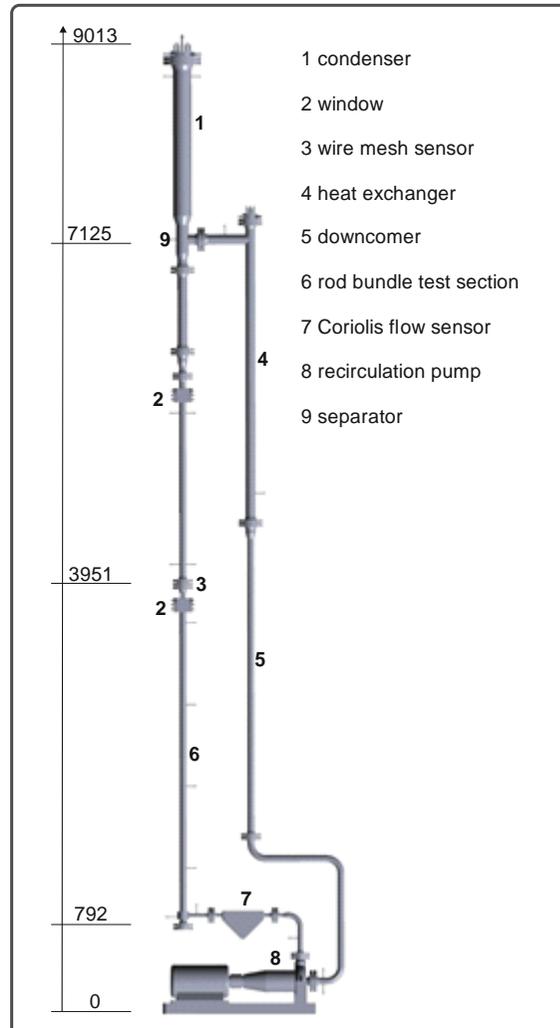
-  Power range 1
-  Power range 2
-  Power range 3
-  Power range 4



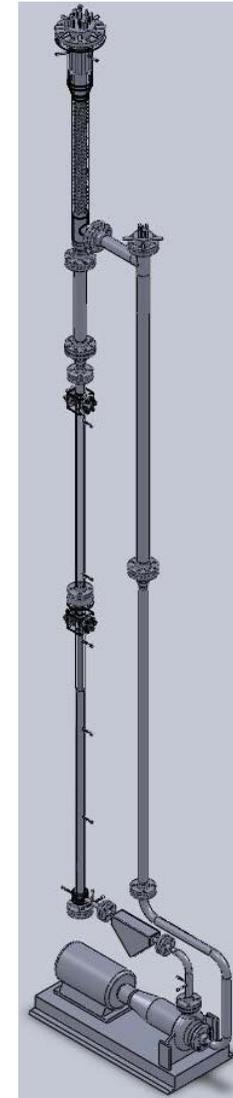
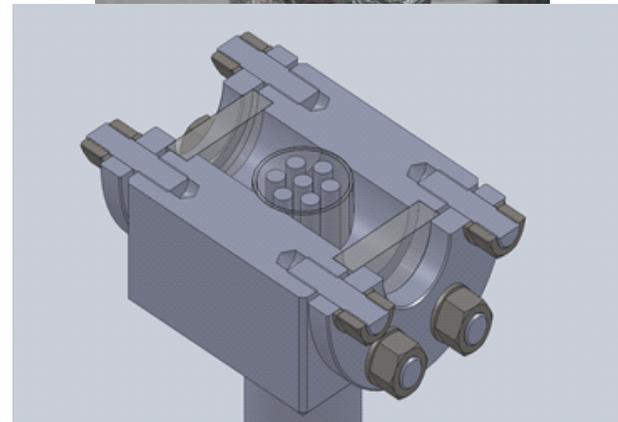
SECA

Test facility	SECA-I			
Project	Experimental investigation of the influence of reactor specific coolant additives on the boiling process (part of <u>joint project</u> : „Modelling, simulation and experiments on boiling phenomena in PWR“)			
Commissioning	04/2011	Decommissioning		
Parameter	Power/kW	60	Heater length/m	2,5
	Temperature/°C	250	Riser length/m	3,5
	Pressure/MPa	4,0	Heater	5 rods
	Height/m	9,1	Special data acquisition	16x16 wire mesh sensor for local void fraction; high speed camera; Coriolis mass flow meter
Primary loop volume/l	67			
Short description	Forced circulation loop with self-pressurization; integral facility for the investigation of boric acid influence on boiling at rod surface and two-phase flow behaviour			
Supported by	Federal Ministry of Education and Research			

Rod bundle configuration



2014

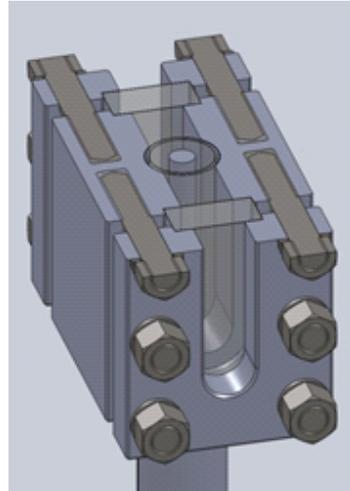
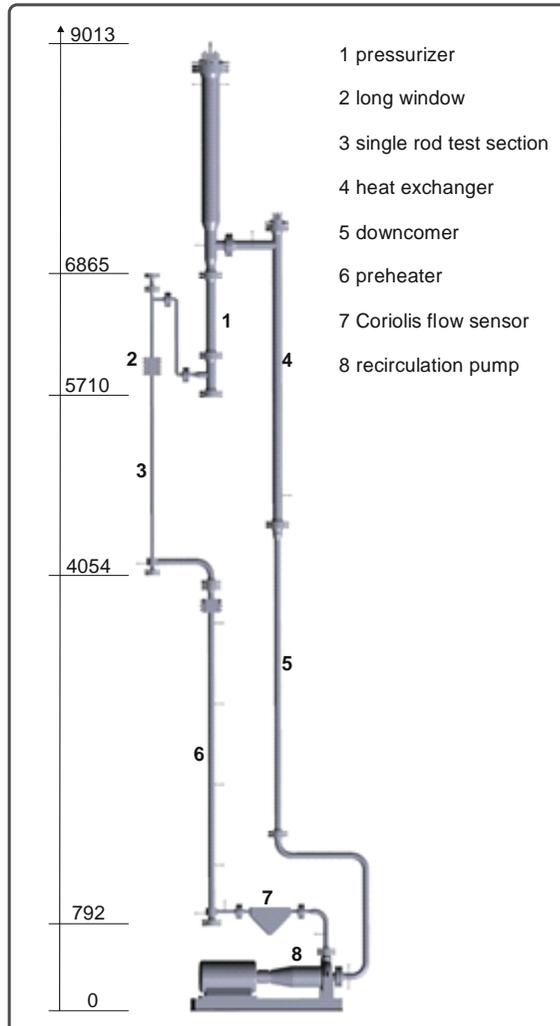


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SECA

Test facility	SECA-II			
Project	Experimental investigation of the influence of reactor specific coolant additives on the boiling process (part of <u>joint project</u> : „Modelling, simulation and experiments on boiling phenomena in PWR“)			
Commissioning	04/2011	Decommissioning		
Parameter	Power/kW	20	Heater length/m	0,1
	Temperature/°C	250	Riser length/m	3,5
	Pressure/MPa	4,0	Heater	Single rod, direct heating
	Height/m	9,1	Special data acquisition	16x16 wire mesh sensor for local void fraction; high speed camera; Coriolis mass flow meter
Primary loop volume/l	67			
Short description	Forced circulation loop with with electrically heated pressurizer; integral facility for the investigation of boric acid influence on boiling at single rod surface; subcooled boiling, nucleate boiling, critical heat flux			
Supported by	Federal Ministry of Education and Research			

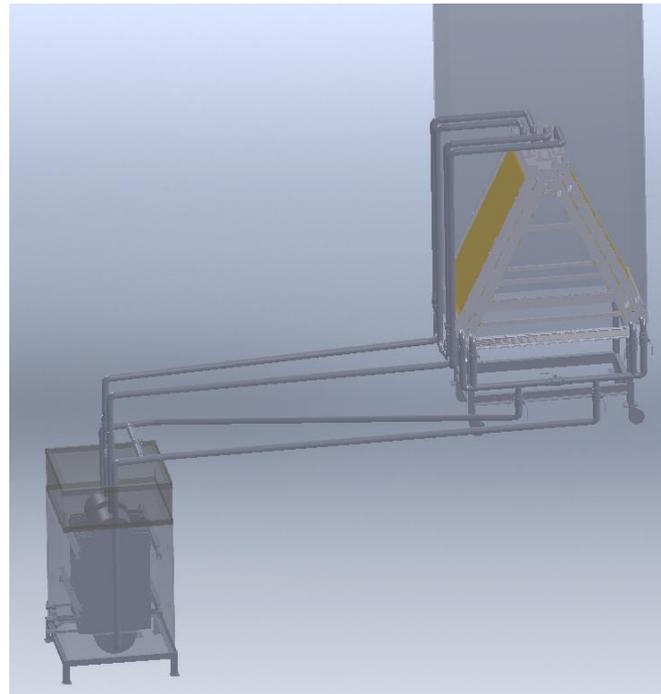
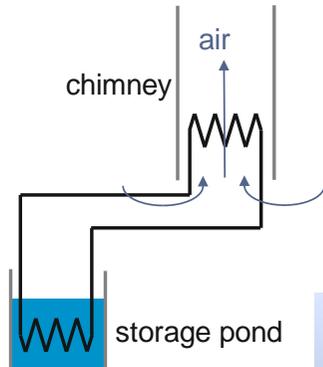
Single rod configuration



LUKA

Test facility	LUKA-I ... -V			
Project	Passive heat removal from spent fuel pond			
Commissioning	04/2010	Decommissioning		05/2014
Parameter	Power/kW	25	Heat exchanger tubes	40
	Temperature/°C	80		
	Pressure/MPa	0,1		
	Chimney height/m	7,5	Special data acquisition	Ultrasonic flow meter for air velocity
Water loop height/m	4,2			
Short description	Natural circulation driven loop flow; optimization of water-air heat exchanger; heat transfer to a 1:1 scaled chimney			
Supported by	AREVA GmbH			

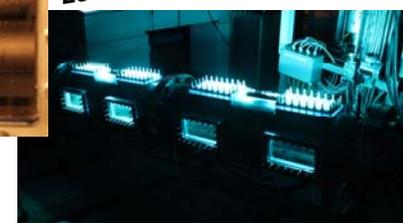
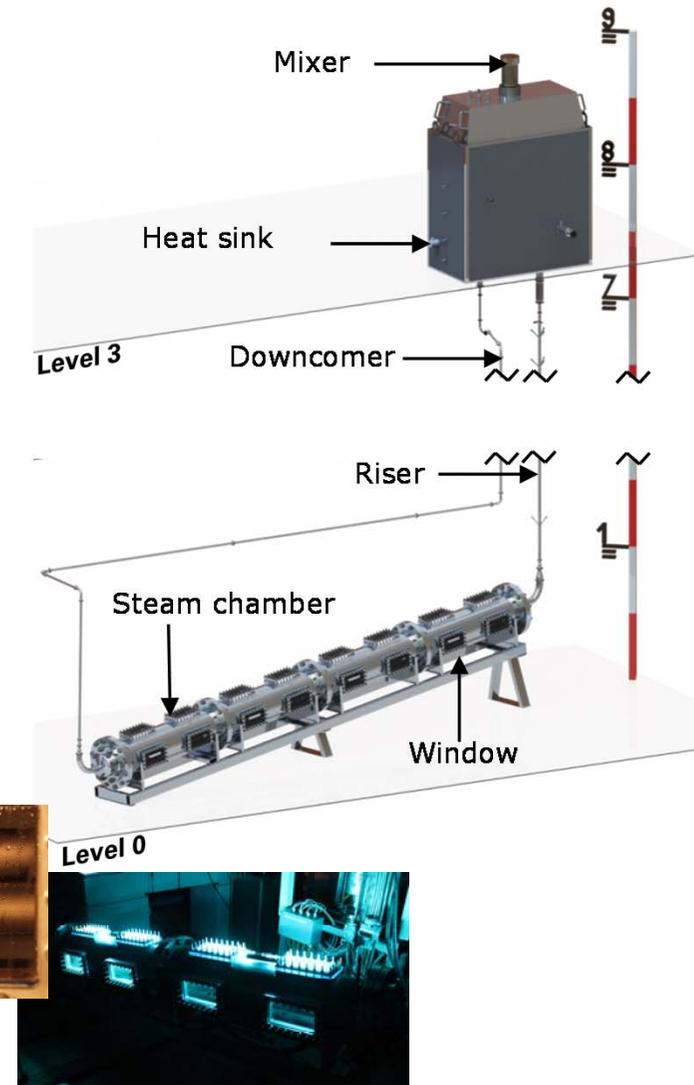
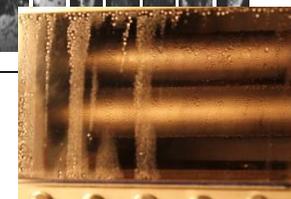
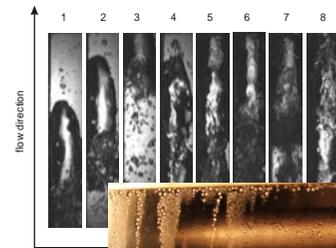
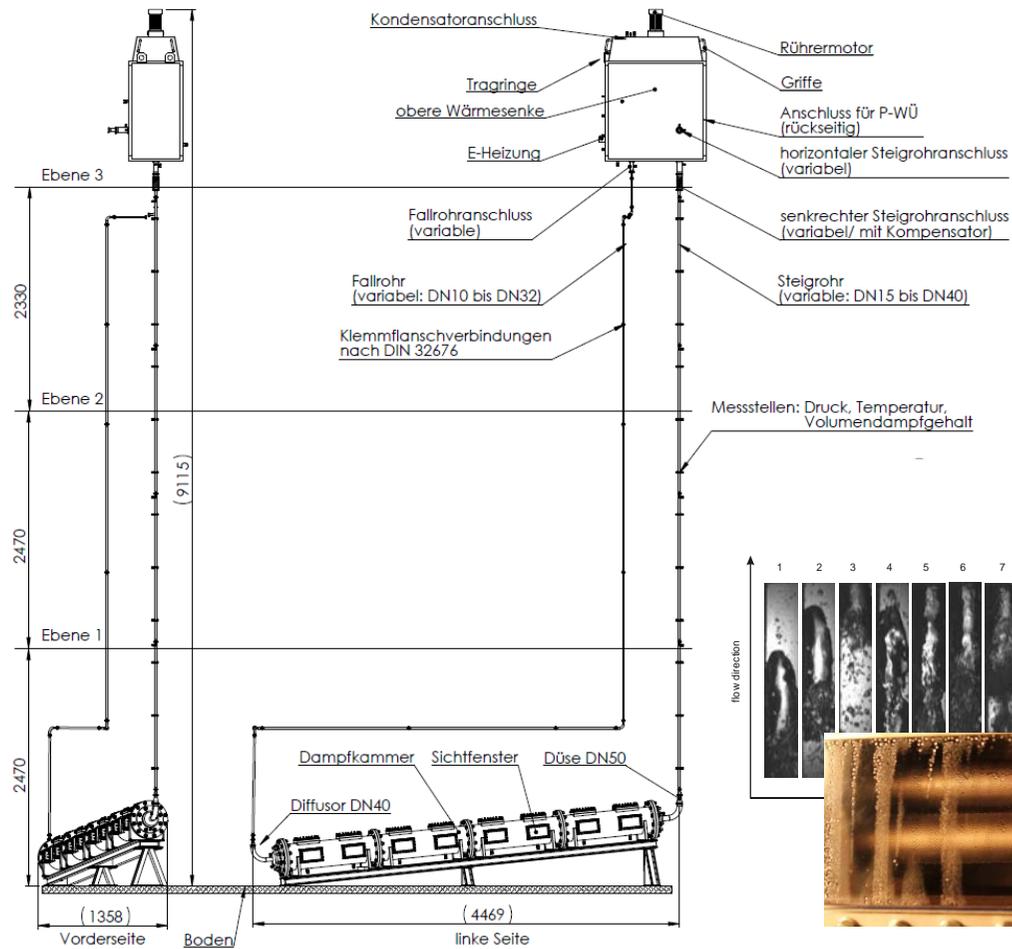
Configuration



GENEVA

Test facility	GENEVA			
Project	Generic studies about the operating behaviour of passive heat removal systems			
Commissioning	06/2013	Decommissioning		
Parameter	Power/kW	120	Steam supply	2 steam generators (each 60 kW; 3,0 bar)
	Temperature/°C	108	Condensation tubes	1 ... 4
	Pressure/MPa	0,1	riser	7,5 m; ID 20 mm, 40 mm
	Height/m	9,0	Special data acquisition	Needle shaped conductivity probes for local void fraction; high speed camera; Coriolis mass flow meter
Primary loop volume/l	400			
Short description	Natural circulation loop at ambient pressure; heat supply by saturated steam to condensation tubes inside a steam chamber; investigation of two-phase flow instabilities (geysering, flashing)			
Supported by	E.On Kernkraft GmbH			

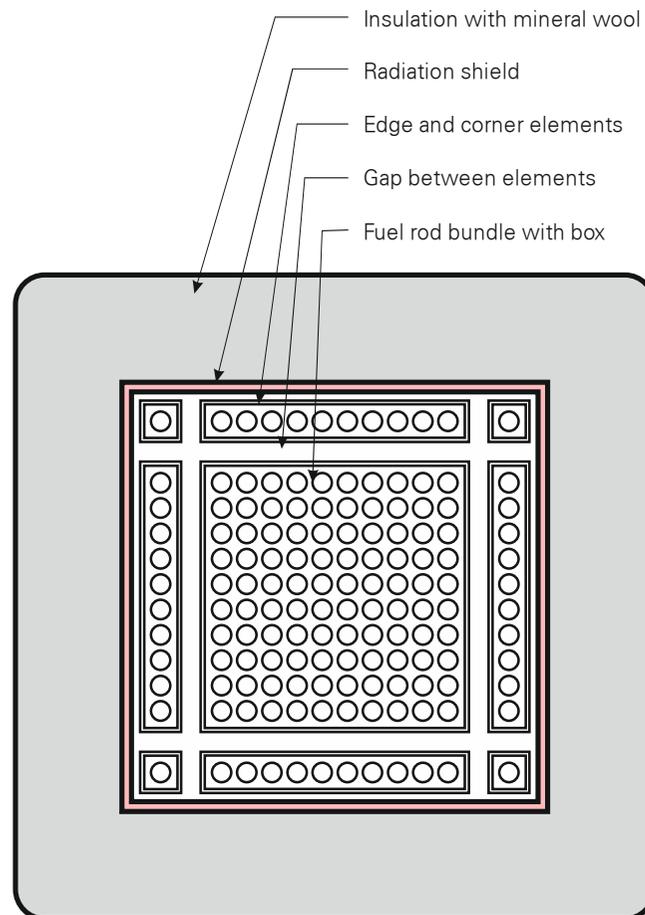
Configuration



ALADIN

Test facility	ALADIN			
Project	Fuel rod behaviour in spent fuel pool boil-off scenarios			
Commissioning	11/2014	Decommissioning		
Parameter				
Short description	Experimental investigation of fuel rod in spent fuel pools; full-scale BWR fuel element; boil-off scenarios and cooling by air			
Supported by	Federal Ministry of Education and Research			

Configuration



IV. Codes

Integral code ATHLET

Analysis simulator ATLAS