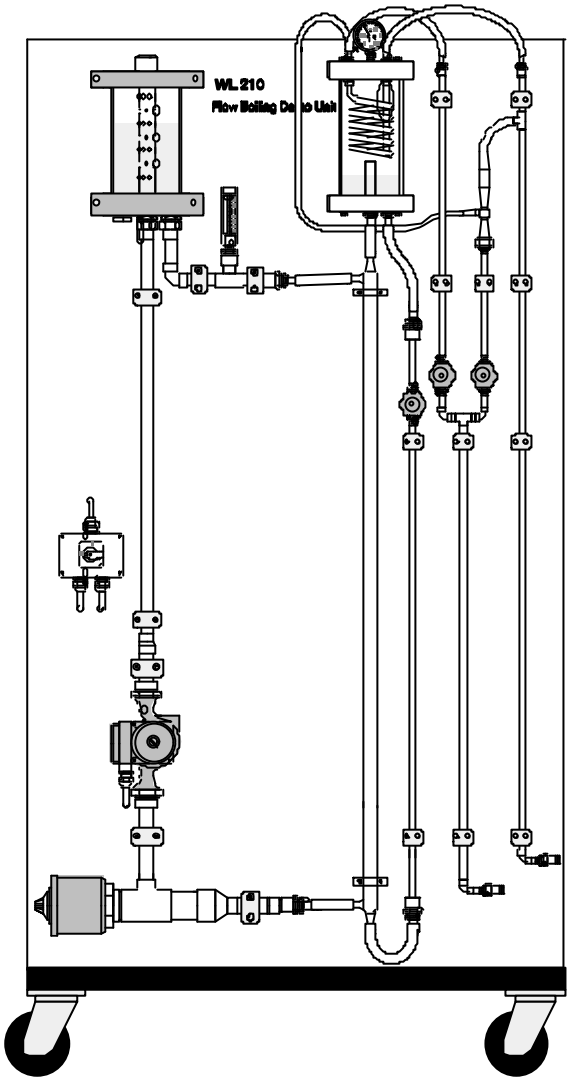
Operating Instructions

WL210 Flow Boiling Demonstration

WL 210 Demo Unit, Flow Boiling



Operating Instructions

Publication no: 916. 000 00A 210 12

05/96

WL 210 Demo Unit, Flow Boiling

Table of Contents

1 Introduction 1

2 Technical Description 3

2.1 Function 3

2.2 Layout 5

3 Operating and Safety Instructions 6

3.1 Safety. 6

3.2 Operating Instructions 8

4 Experiments 10

4.1 Object of the Experiment 10

4.2 Performing the Experiment 11

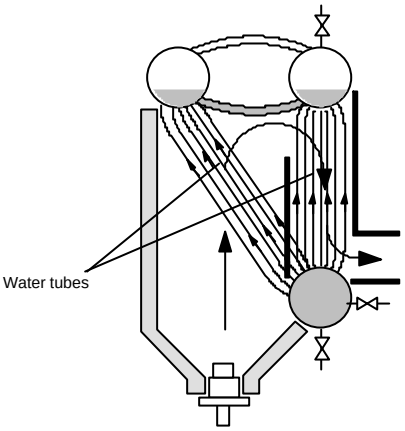
5 Appendix 13

5.1 Technical Data 13

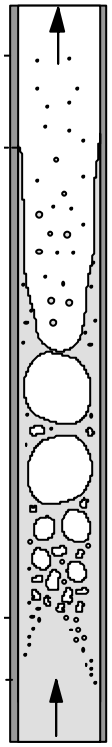
5.2 Index 15

WL 210 Demo Unit, Flow Boiling

1 Introduction



Water-tube steam generator



Evaporation process in a water tube

In the design and construction of steam generators knowledge of the evaporation process is essential.

With the test rig **WL 210 Demo Unit Flow Boiling,** the evaporation process in heated pipes, such as occurs in water-tube steam generators, can be demonstrated. The different phases of evaporation occurring in a water tube are seen particularly clearly.

The following concepts can be demonstrated:

- Single-phase liquid flow
- Sub-cooled boiling
- Bubbly flow
- Slug flow
- Annular flow
- Film boiling
- Mist flow
- Single-phase vapour flow
- Wet steam
- Superheated vapour

The influence of parameters such as flow rate, temperature and pressure on the evaporation process can also be examined experimentally.

The evaporation process takes place in a transparent, double-walled glass pipe. The pipe is heated with hot water in its outer shell.

The test rig is run by a low-boiling, non-toxic special fluid, so that the pressure and temperature level remains low and therefore safe. The low level of evaporation heat means that the heat output is low.

The test rig is designed for tutorial and experimental purposes.

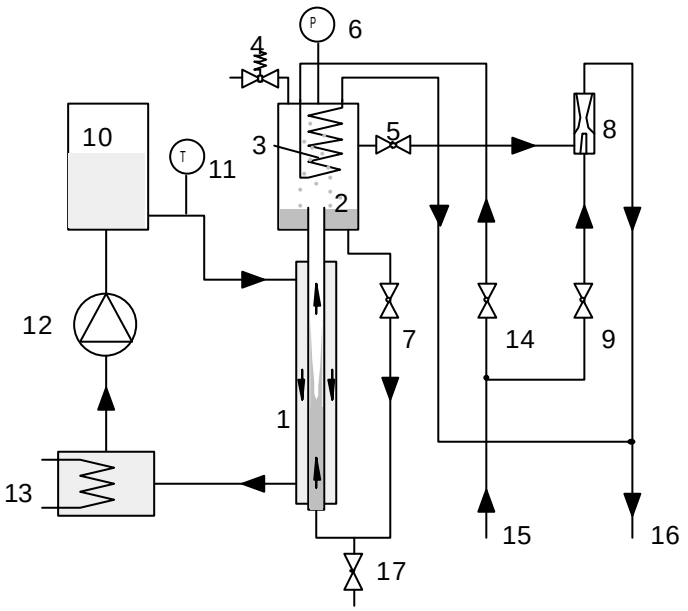
2 Technical Description

2.1 Function

The overall system is divided into 3 autonomous circuits.

- Evaporation circuit
- Heating circuit
- Cooling circuit

Evaporation circuit



1 Generating tube
2 Collector
3 Water cooled coil
4 Pressure-relief valve
5 Vent valve
6 Manometer
7 Circulation control valve
8 Water-jet air pump
9 Water-jet pump valve
10 Heating water expansion tank
11 Heating water inlet thermometer
12 Circulation pump
13 Elektric heater
14 Cooling water control valve
15 Cooling water inlet
16 Cooling water outlet
17 Refrigerant filling valve

The central component is the glass generating tube (1). The actual evaporation takes place inside the tube; the heating medium flows in the tube outer shell. The top of the generating tube opens into a glass container (2). This serves as a condenser and collector for the evaporation fluid. A water cooled coil (3) provides cooling.

In the top lid of the collector there is a pressure-relief valve (4) and a vent valve (5), and a manometer (6).

The evaporation fluid flows from the collector back to the generating tube. A flow control valve (7) controls the flow rate.

By means of a water-jet air pump (8) a defined vacuum can be generated in the evaporation circuit. The water-jet air pump is activated via the valve (9).

Heating circuit

The heating water is heated by the electric heater (13) and delivered by the pump (12) into the expansion tank (10). From there the water flows into the generating tuber (1). A thermometer (11) measures the intake air temperature. The water temperature is thermostatically controlled and can be adjusted on the heater.

Cooling circuit

The cooling water, like the water for the jet pump, is taken from the water main (15). After passing through the condenser pipe coil (3) the water is fed to an outlet (16). A valve (14) in the inlet allows the cooling power to be adjusted.

Evaporation fluid

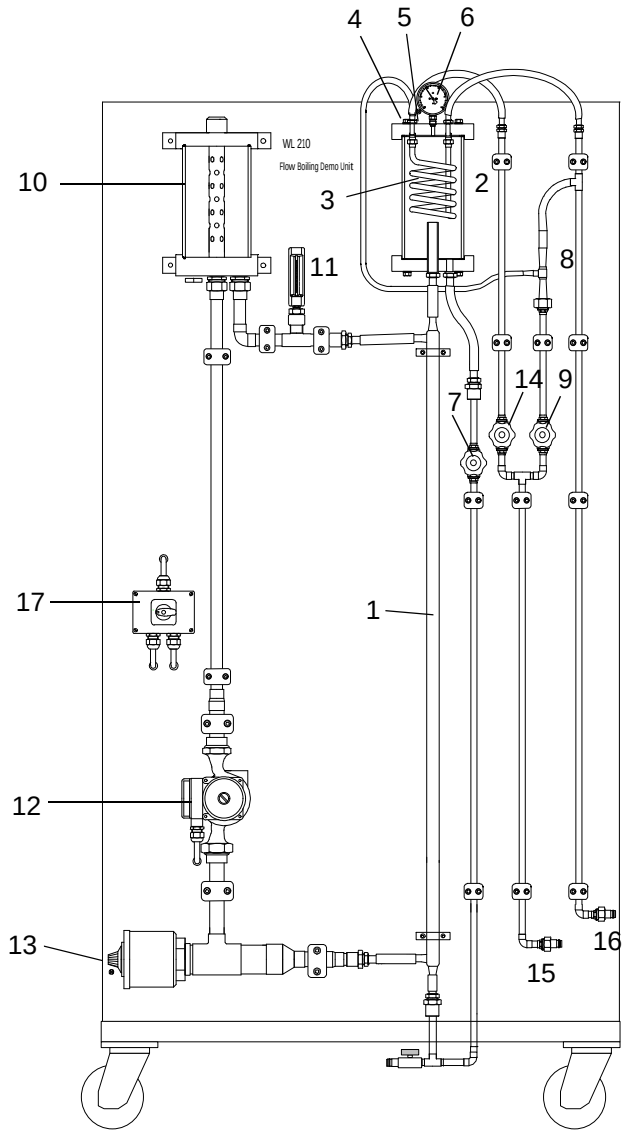
The evaporation fluid used is SES 36. This fluid has a number of advantageous properties:

- Low boiling point (36.7°C at ambient pressure)
- Low evaporation heat (118 kJ/kg)
- Non-hazardous substance, non-toxic
- Thermally stable
- In comparison with R11 very low impact on ozone (ODP value) and low level of greenhouse effect (GWP value)

2.2 Layout

All components are mounted on a white board. The board is fitted with castors, and is mobile.

The switch (17) activates the circulation pump and the heater. Cooling water is fed in and out by way of the connections (15) and (16).



1 Generating tube
2 Collector
3 Water cooled coil
4 Pressure-relief valve
5 Vent valve
6 Manometer
7 Circulation control valve
8 Water-jet air pump
9 Water-jet pump valve
10 Heating water expansion tank
11 Heating water inlet thermometer
12 Circulation pump
13 Elektric heater with thermostat
14 Cooling water control valve
15 Hose connection, cooling water inlet
16 Hose connection, cooling water outlet
17 Switch for heater and pump

3 Operating and Safety Instructions

The following safety instructions are essential to safe and proper operation.

You must read through the Test Instruction, in particular the safety instructions, before starting up the unit.

Participants must be instructed as to proper use of the equipment prior to taking part in the experiment.

3.1 Safety

DANGER! Electric shock

- Unit may only be connected to mains fused 16A
- Disconnect the unit and pull the mains plug before working on the electrics.
- In case of apparent faults, such as damaged insulation, shut down the system immediately and disconnect the power.
- Repairs must be carried out only by qualified personnel.
- Keep the electrical system away from contact with water.

DANGER! Burns

Pipes and tanks in the heating circuit can reach temperatures of up to 80°.

DANGER!

Do not adjust or modify safety installations and equipment, such as

- Safety valves
- Overheating protection
- Fuses
- Protective guards

IMPORTANT!

Operate the unit only in dry, enclosed rooms in which no combustible or aggressive gases, vapors or dusts are present.

When there is risk of frost, drain the heating water circuit.

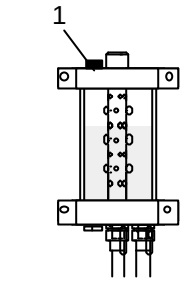
In storage keep the evaporation circuit vent valve closed, as otherwise evaporation fluid will be lost. Slight overpressure in the collector at high ambient temperatures is normal (40°C: 0.25 bar, 50°C: 0.8 bar).

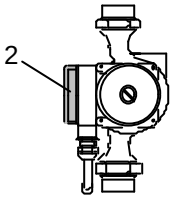
IMPORTANT!

Do not exceed the following limits:

- **Max. pressure in evaporation circuit :**
  1.5 bar
- **Max. water temperature :**
  70° C
- **Evaporation fluid level in collector:**
  2 - 3 cm
- **Water level in expansion tank:**
  cold: 50%
  warm: 75%

3.2 Operating Instructions





- **IMPORTANT!**
  Before starting up the heating circuit open the expansion tank screw plug (1).

- Before starting up the heating circuit connect the cooling circuit.

- Set circulation pump speed selector (2) to setting I.

- Pay attention to correct level of evaporation fluid and heating water.

  Evaporation fluid level in collector:
  2 cm

  Water level in expansion tank:
  cold: 50%

- Carry out any alterations to the valve settings slowly, and await thermal equilibrium.
- Cooling is very efficient; temperature and pressure drop very fast. Therefore: adjust the cooling circuit control valve (9) with care.
- Do not let off overpressure by opening the vent valve, or blow off the pressure-relief valve. This will cause evaporation fluid to be lost. It is better to reduce the pressure by increasing cooling.
- Reduce excess vacuum by opening the vent valve (5). To do this, detach the suction hose from the water-jet air pump (9) (jet pump has non-return valve).

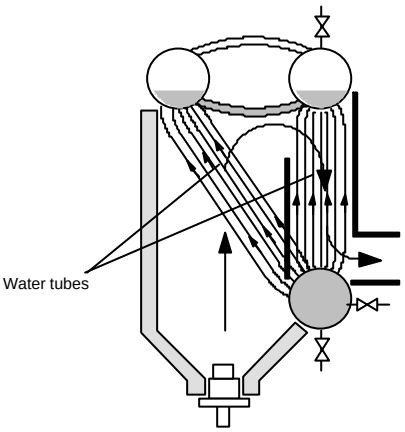
Filling in refrigerant

- Connect cooling water to 15 and 16
- Shut valve 14 completely
- Open valve 9 completely
- Start water-jet pump
- Open valve 5 on top of the collector and produce vacuum
- Connect valve 17 (lowest valve) and refrigerant supply with a hose in a way that refrigerant can flow in the collector. If necessary precool the refrigerant
- Open valve 17 and fill collector with refrigerant up to a level aprox. 2 cm below overflow tube
- Shut valve 17
- Shut valve 5
- Start heating circuit, if necessary bleed system via pressure-relief valve 4

If water-jet pump is not active, valve 5 has to be shut to avoid loss of refrigerant!

4 Experiments

4.1 Object of the Experiment



Water-tube steam generator

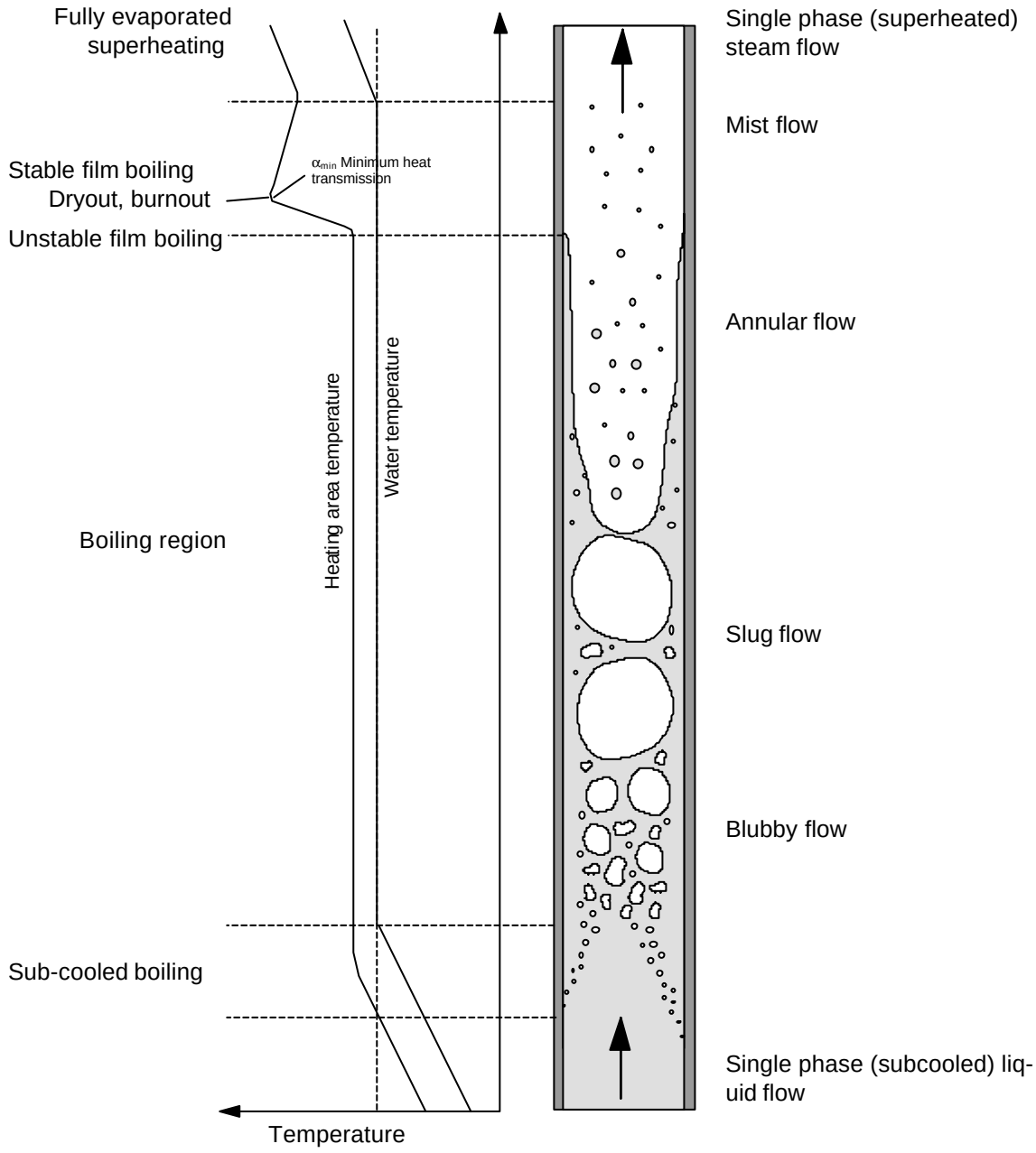
The object of the experiment is to demonstrate the various **phases of evaporation and boiling** in a water pipe heated from an external source.

Knowledge of these processes is important to the correct and safe design of a **water-tube steam generator**. For example, in certain phases of evaporation the heat exchange with the pipe walling may be impaired, so that the water pipe is insufficiently cooled on the water side and may burn out (dryout, burnout). Such zones should then not be exposed to full load on the furnace side.

The cold water first enters the pipe from below. As the temperature rises the first steam bubbles occur in nuclation points on the wall. The water temperature is still below boiling point (**sub-cooled boiling**). As soon as boiling point is reached steam bubbles occur in the center of the pipe, too, and so-called **bubbly flow** is created. The water temperature now remains constant. The small bubbles merge into large bubbles which shoot upwards. Since they fill almost the entire cross-section of the pipe, and deliver water upwards, this state is termed **slug flow**. Finally, the flow changes into a **annular flow**, in which the center of the pipe is filled only with steam and small drops of water. **Film boiling** occurs. At the end of the ring flow, when the water film becomes very thin, the heat transmission coefficient α falls, and the pipe walling may overheat (**burnout**). Then the water droplets still present evaporate in a **mist flow** or **spray flow** until, finally, pure saturated steam remains. As more heat is fed in, the steam temperature now rises; the steam becomes **superheated**.

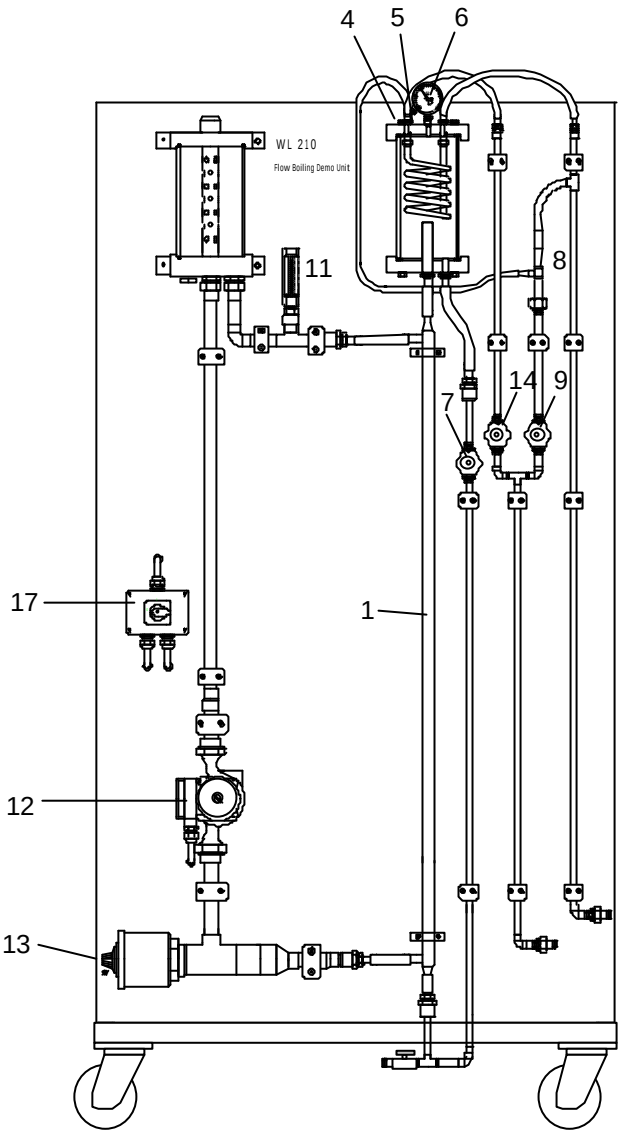
4.2 Performing the Experiment

- Set heater (13) to 60 °.
- Fully open cooling water control valve (14).
- Open circulation control valve (7) 1/2 a turn.
- Close vent valve (5).
- Switch on heater and pump (17).
- Water temperature (11) rises.



Evaporation phases in a water tube heated from an external source

- At around 40 - 50°C the first evaporation begins, and the pressure (6) in the collector rises.



- At around 60° and 0.2 - 0.4 bar the various boiling zones are formed in the evaporator pipe (1).
- By regulating the circulation and cooling, stable operation can be achieved with the typical phases of evaporation.

- The pressure can be increased by closing off the cooling; opening up the cooling reduces it. It will not generally be necessary to use the water-jet (8),(9) to generate vacuums.

5 Appendix

5.1 Technical Data

General

Dimensions:		
L x W x H	1000 x 600 x 1950	mm
Weight:	60	kg
Power supply:	230 V /	50Hz
Cold water supply		
Heating circuit		
Output:	2	kW
Temperature range:	5 - 80	°C
Thermometer:	0 - 100	°C
Circulation pump		
Delivery rate	3	m^3/h
Delivery head	5	m
Water-jet air pump		
Rec. water pressure:	0.5	bar
Water consumption:	330	liters/h
Final pressure:	12	mbar

Pipe evaporator

Length:	1200	mm
Inside diameter:	13.6	mm
Outside diameter	24	mm
Evaporation fluid volume	500	cm^3
Pressure range:	-1.0 ... 1.5	bar rel.

Evaporation fluid

Trade name: Solvay, Solkatherm SES36		
Molecular weight:	184.5	
Boiling point at p_o= 1013 mbar:	36.7	°C
Critical temperature:	177.4	°C
Critical pressure	2840	kPa
Density at 20°C	1.363	g/cm^3
Evaporation heat:	118	kJ/kg
Secific heat capacity	1.25	kJ/kg K
Non-flammable		

5.2 Index

A

Annular flow 9

B

Bubbly flow 9
Burnout 9

C

Circulation pump. 5
Collector 3
Cooling circuit 3, 4

D

Dryout 9

E

Electric heater 4
Evaporation circuit 3
Evaporation fluid 4, 13
Evaporation fluid level. 7

F

Film boiling 9, 10
Flow control valve 4
Function 3

G

Generating tube 3
Glass container 3

H

Heat transmission coefficient 9
Heating circuit 3, 4

L

Layout. 5
Limit values. 7

M

Manometer 3
Max. pressure 7
Max. water temperature 7
Mist flow 9

O

Operating instructions 8

P

Performing the experiment 10
Phases of evaporation 9
Pressure-relief valve 3
Process scheme 3

S

Safety instructions 6
Single phase liquid flow 10
Single phase steam flow 10
Slug flow 9
Sub-cooled boiling 9, 10
Superheated steam 9

T

Technical data 12
Thermometer 4

V

Vent valve 3

W

Water cooled coil 3
Water level 7
Water-jet air pump 5
Water-tube steam generator 9