Internship Energy Technology

Fuel cells

Practical part

Faculty of Engineering

Chair of Energy Technology

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A calculator, drawing materials and colored pencils are needed.

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1. Breadboard construction

The fuel cell stack, consisting of 8 polymer electrolyte membrane fuel cells (PEMFC) connected in series, is powered by hydrogen (H2) on the anode side and ambient air on the cathode side. Before the reactant gases are fed into the fuel cell stack, they can either be humidified or fed directly (dry) to the fuel cell stack via a bypass (see Fig. 1.1).

For humidification, the reduct gases flow through glass containers filled with water. In this process, the reductant gases are fed into the glass containers with the help of a frit. The glass containers are heated continuously by heating plates, so that the water is heated to a temperature between 60 and 90°C. After the water has flowed through, with water vapor diffusing into the gas bubbles, the humidified gases are fed into the fuel cell stack. To prevent the water vapour from condensing, the gas supply lines to the fuel cell stack are insulated and heated by means of a heating wire that is wound around the supply line under the insulation (trace heating). Sensors can be used to monitor the relative humidity and temperature of the reactant gases before entering the fuel cell stack as well as the temperature before and after humidification.

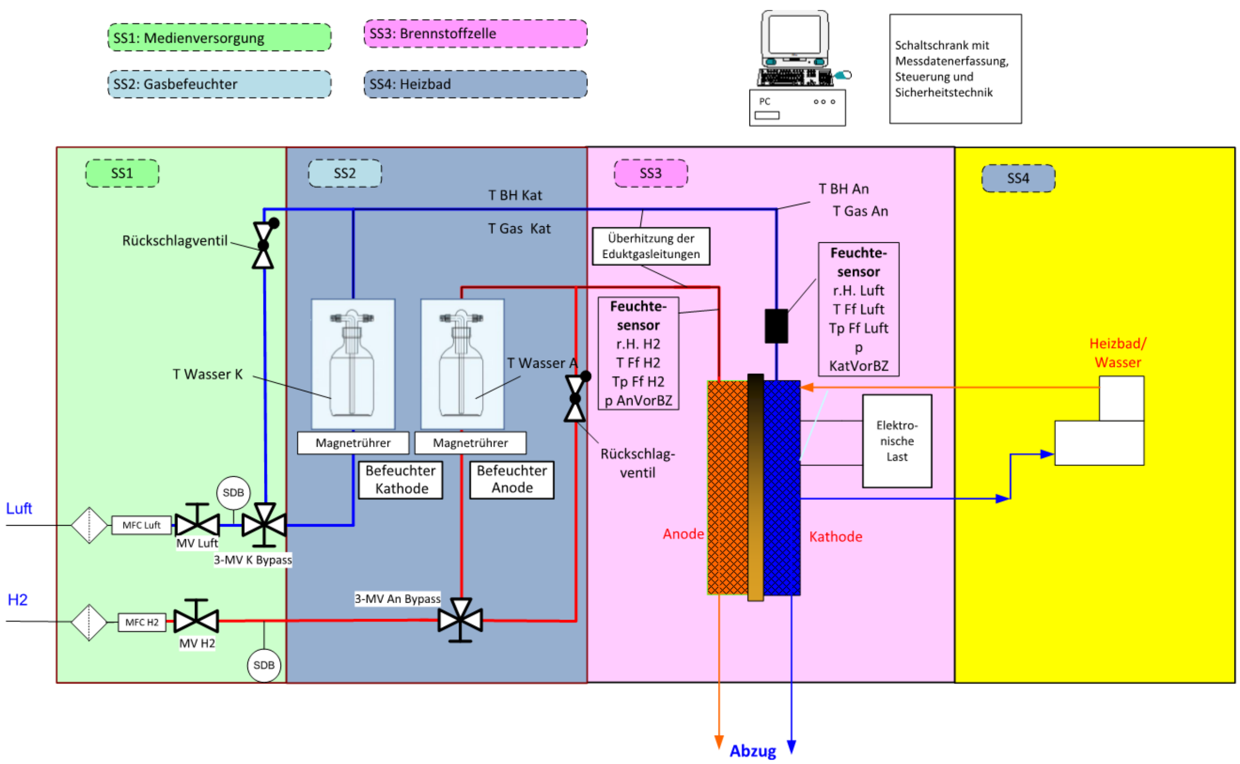

Fig. 1.1: Schematic experimental setup: fuel cell with peripheral devices

The inflow rates of the reductible gases can be regulated by means of two mass flow controllers (MFCs). The MFC is each equipped with a solenoid valve. Via another 3/2-way valve, the reductant gases can be fed either through the humidifiers or via a bypass directly into the fuel cell stack. The pressure of the reactant gases can also be controlled before and after the humidifiers via pressure sensors. The product gases are discharged via a flue.

The cell stack (see Fig. 1.2) is heated/cooled to the desired operating temperature during operation via an external heating bath. The cell voltages of the individual fuel cells are measured separately with the help of voltage meters. The current can be variably adjusted via a sink (electrical load). All measured and control variables can *be stored on a computer via* the LabView user interface and controlled or varied.

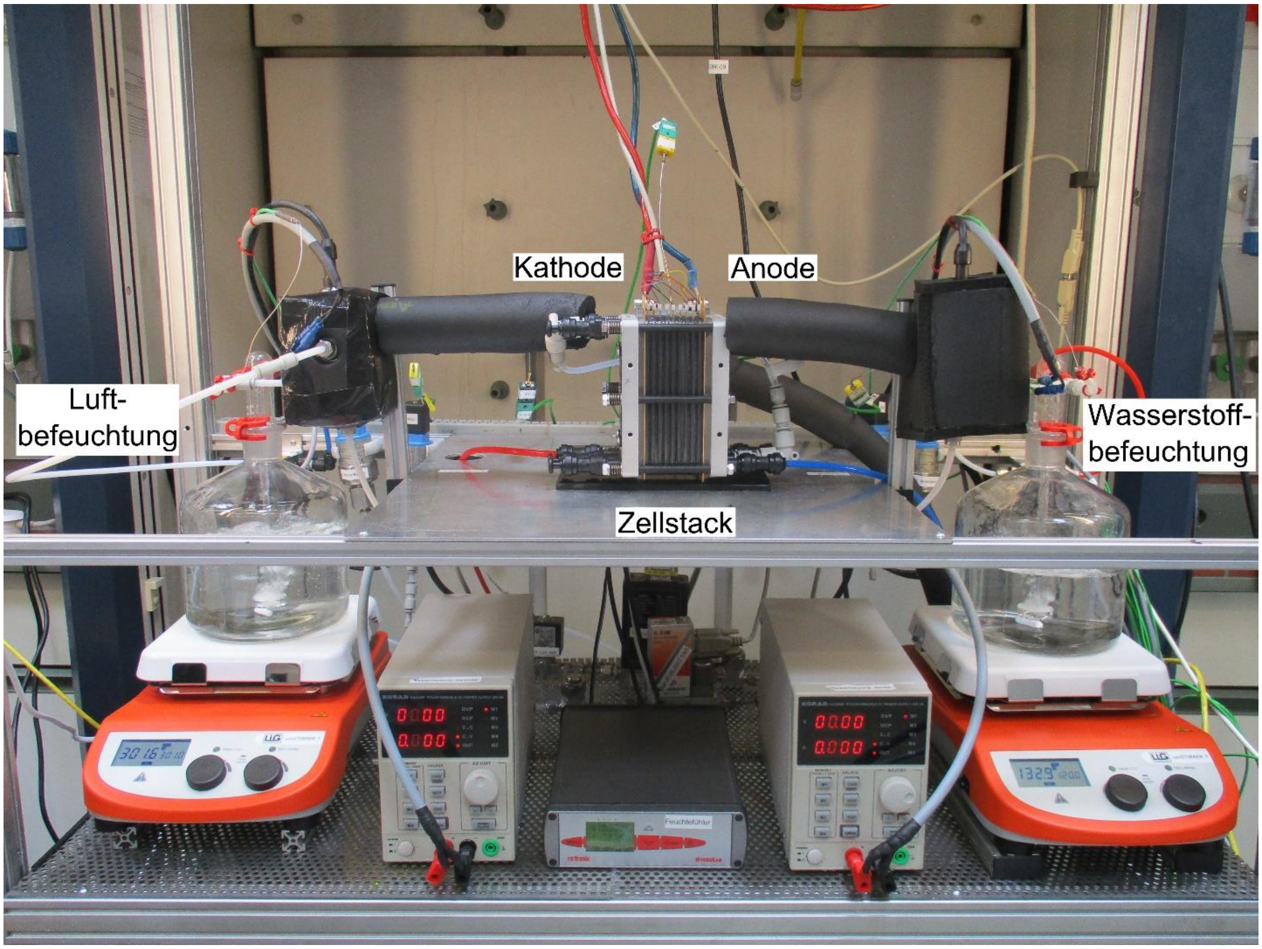

Fig. 1.2: Fuel cell test rig

2. Procedure

At the beginning of the experiment, all equipment (trace heating, heating bath, heating plate, pressure, humidity and temperature sensors, control cabinet, and the magnetic stirrers) is switched on. The heating plates should be set to a temperature of approx. 300°C at the beginning - due to the poor heat transfer. As soon as the water has reached a temperature of approx. 50°C (60°C), the heating plates should be regulated (between 150 and 200°C) so that the water temperature remains constantly at approx. 50°C (60°C).

After that, the LabView program is started on the computer . With the help of this program, all other settings can be made directly via the computer connected to the control cabinet (see Figure 2.1). The heat tracing (heating wires) should be set to a temperature of approx. 55°C (65°C). It is important that the temperature of the trace heating is always higher than the temperature of the humidified reductant gases when exiting the glass containers. This is to prevent the condensation of the water vapour. The heating bath for heating/cooling the cell stack should also be set to 50°C (60°C).

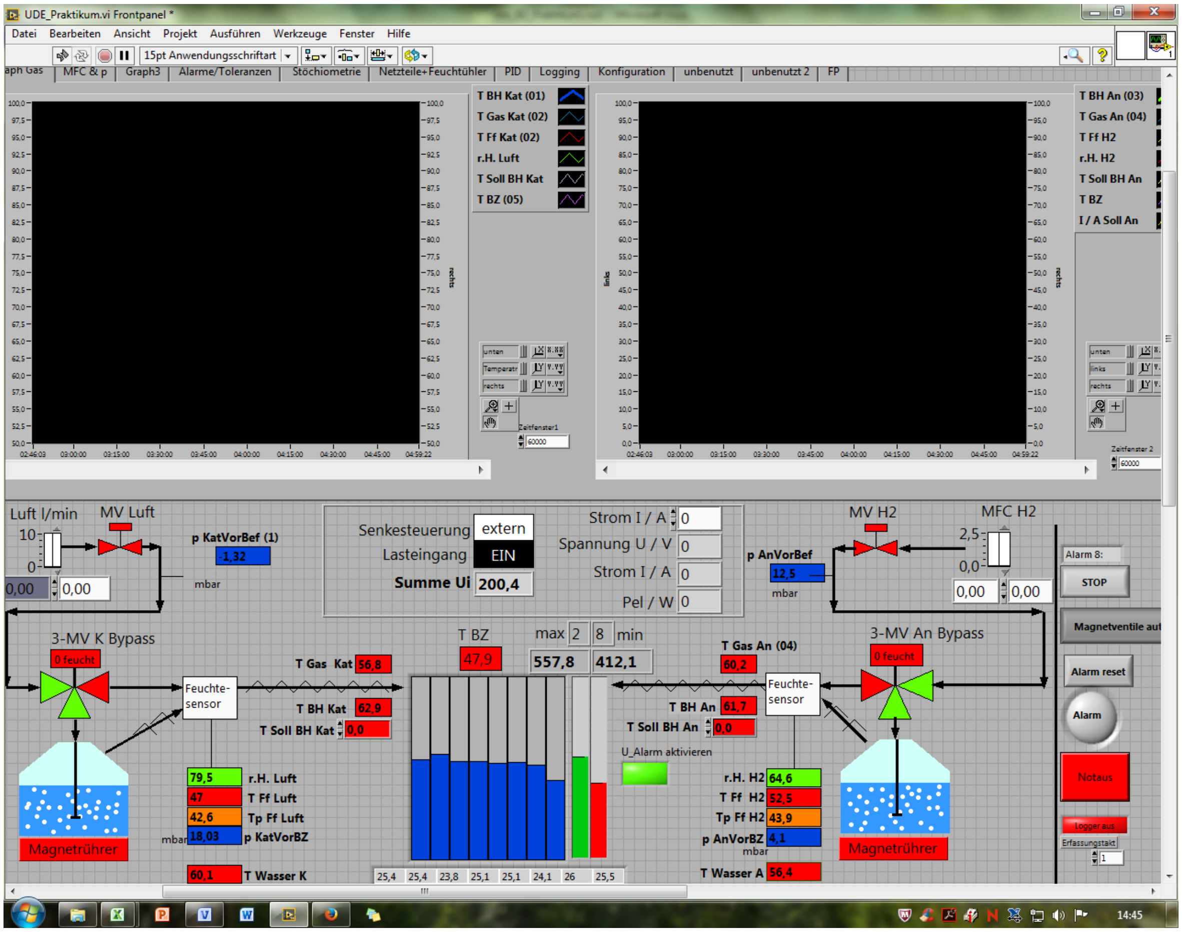

Fig. 2.1: LabView user interface

Once all temperatures have been set as desired, the gas supply (anode: hydrogen, cathode: ambient air) is opened by the solenoid valves. The gas flows are to be adjusted via the mass flow controllers in such a way that the fuel cells are operated via stoichiometry on the anode and cathode sides. At the operating point, a λ_{H2} of 1.25 and λO2 of 2.25 (based on the converted hydrogen) are to be achieved.

Ideally, a gas humidification of almost 100% (depending on residence time, temperature and bubble size) is measured. To prevent water vapour from condensing on the humidity sensors, wetting the sensors and thus displaying falsified humidity values, the relative humidification of the gas should always be below 100%. In the event that the humidity is measured at 100%, the gas supply should be switched to bypass (dry) for a short time through the 3/2-way valve until the relative humidity value drops below 100% again.

After the gas supply has been regulated and all sensors have been checked for function, *the sink (electrical load) can be switched on* via the LabView user interface.

3. Task/Experiments/Evaluation

1. For the **first test**, two operating points (I1 = 10 A, or I2 = 20 A) are to be set at a constant temperature (50°C) and compared with each other.

   To do this, use formula 2.4 to calculate the power of the fuel cell stack at operating point 1

(T = 50°C, I_1 = 10 A, λH2 = 1.25, λO2 = 2.25) at an average cell voltage of 0.72 V and at operating point 2 (T = 50°C, I2 = 20A, λH2 = 1.25, λO2 = 2.25) at an average cell voltage of 0.6V per cell.

Use formula 5.3 to calculate in advance the metabolic rate of hydrogen in the cell stack as well as the required volume flow of hydrogen for $\lambda_{H2=1.0}$ and λH2=1.25. Calculate the air volume flow rate to be set for λO2 = 2.25 in relation to the converted hydrogen (λH2=1.0) in the two operating points 1 and 2.

2. In the **second experiment,** the U-I characteristic curve of the fuel cell system is to be determined. For this purpose, different operating points are approached, held for at least 5 seconds and the corresponding data is recorded in Table 3.1. Sketch the U-I characteristic curve in Fig. 3.1.
3. For comparison**,** the U-I characteristic curve of the fuel cell stack at a changed temperature level (60°C) will be documented and evaluated in Table 3.1 in the third experiment. Sketch this U-I characteristic curve in Fig. 3.1.
4. Then calculate the **overall efficiency** of the fuel cell stack (related to H_u) in operating points 1 and 2.

Required equations

Power Stack: $$P = n \cdot U \cdot I$$

Mass turnover single cell: $$\dot{n} = \frac{I}{z \cdot F}$$

Substance turnover in the stack: $$\dot{n}_{Stack} = \lambda \cdot n \cdot \dot{n}$$

Volume flow in the stack: $$\dot{V}_{Stack} = \dot{n}_{Stack} \cdot V_m$$

Overall efficiency: $$\eta_{Stack} = \frac{P_{el}}{\dot{n} \cdot H_{u,H2}} = \frac{U_{Stack} \cdot I}{\dot{n} \cdot H_{u,H2}}$$

$$\eta_{Stack} = \frac{\overline{U}_{Zelle}}{U_{th,u}} \cdot FU = \frac{\overline{U}_{Zelle}}{U_{th,u}} \cdot \frac{1}{\lambda_{H2}}$$

Other information:

Number of cells in the stack: n = 8

Faraday constant: 96485.34 C/mol

Oxygen content in air: 21 vol-%

Nitrogen content in air = 79% by volume

Molvolumen Idealgas: $22{,}414 \cdot 10^{-3}$ m³/mol

Molar mass water: M_W = 18.0153 g/mol

Lower calorific value H2: 241.8 kJ/mol

Thermoneutral voltage: $U_{th,u}$ = 1.25 V

Number of electrons involved in the reaction: z=2 (H2); z=4 (O2)

50°C	Current	Voltage	Achievemen t
	[A]	[V]	[W]
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
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34			
35			

60°C	Current	Voltage	Achievemen t
	[A]	[V]	[W]
1			
2			
3			
4			
5			
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Table 3.1: Measured values U-I characteristic curve (50°C and 60°C)

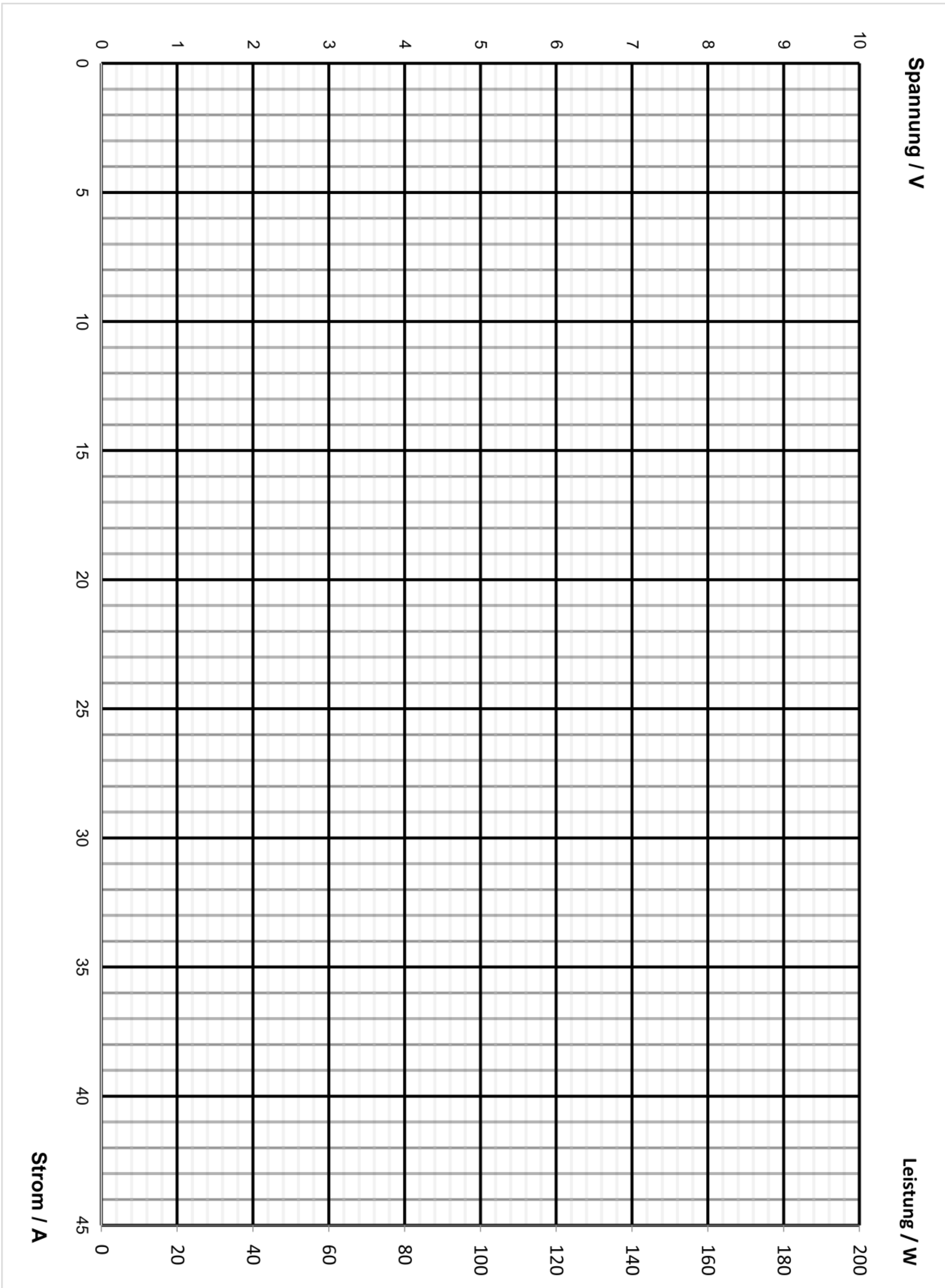

Fig. 3.1: Sketch of the U-I characteristic curve and performance

Excerpt from the laboratory regulations for the fuel cell practical course

The complete laboratory regulations remain unaffected by this.

The following laboratory regulations are intended to ensure general safety in the laboratory and on the test bench. Activities in the laboratory may only be carried out after appropriate instruction, so a short briefing on the following points will be carried out before the start of the experiment:

- Alerts
- Escape and rescue routes, assembly point
- First aid material
- Location of fire extinguishers and telephones

Signing the list of participants confirms that you have taken note of the safety instructions and the instruction that has been given.

1. Rules for the stay in the laboratory

The university is not liable for personal and material damage that can be proven to have been caused by negligent or intentional conduct. Claims for compensation against the department are excluded.

The following points must be observed during the entire laboratory stay:

- Eating and drinking is prohibited in the entire laboratory.
- No open flames, fire or open ignition sources.
- Sturdy and closed shoes must be worn.

2. Rules for conducting the internship experiment

- All instructions or Measures taken by the supervisor must be followed.
- Safety goggles may have to be worn during the experiment (will be provided).
- If it is determined that the equipment or aids are not in perfect safety terms, this defect must be reported immediately to the responsible supervisor.
- No changes are to be made to the test rig without being asked to do so by the supervisor.

Failure to observe these points can lead to exclusion from the internship.