ET 910
Training in refrigeration

Vocational training in refrigeration:
planning, design and testing of different refrigeration system configurations

The ideal training system for practice-oriented teaching

Instructional design and subject areas

The modular training system can be used to construct various refrigerant circuits thanks to a comprehensive selection of refrigeration components. Refrigeration solutions and real-world problems are worked out didactically in experiments.

The training system offers practical experiments to accompany the areas of learning relevant to training as a mechatronics technician for refrigeration. The scope of experiments can be extended by using temperature measurements. Consequently, the device offers various qualitative experiments and can therefore also be used to great success in university level education for practical course experiments in the field of energy engineering/refrigeration technology.

By combining the components, it is possible to simulate many industrial refrigeration circuits. By incorporating bypasses, the system behaviour with or without the use of a specific component can be demonstrated directly. The result is lasting understanding of how the components work together.

The training system is ideal for independent group work with two to three trainees or students. In contrast to experimental setups with fixed piping, changes in the refrigeration circuit can be made quickly and easily and their effects experienced directly. This immediate feedback ensures lasting learning success. By independently converting the system diagram into a real, functioning system, the trainees/students quickly achieve success.

The ET 910 training system uses standard industrial components from refrigeration technology. This ensures the necessary practical relevance making knowledge easier to recall. When selecting the components, care has been taken to ensure that as many training topics as possible can be covered.

Module plates mean the experiments can be designed flexibly and clearly. Using hoses that can be shut off minimises refrigerant losses when modifying experiments.

Even today, ET 910 alumni tell us that they apply the knowledge they learned – even many years later – when it comes to understanding complex systems.

Covering subject areas in the training as a mechatronics engineer for refrigeration by experimental work with the training system ET 910

Refrigeration	Air conditioning technology	Electrical engineering in refrigeration and air conditioning technology
Functional interrelationships in the refrigeration circuit	Investigation of the states of the air	**Principles of electrical engineering**
Production of mechanical subsystems	Basic interrelationships in ventilation and room air conditioning	**Consumers of single phase alternating current**
Thermodynamics, log p-h diagram	Construction elements and function of the air conditioning system	**Protection against electrical hazards**
Refrigerants and lubrication oils	Air conditioning, h-x diagram	**Simple refrigeration controls**
Primary and secondary controllers	Air circuit in the duct system	Consumers of three phase alternating current
Heat exchangers	Fire protection measures	Electrical drives and fault finding
Compressors	Energy saving	**Control of refrigeration systems**
Piping		Building automation
Troubleshooting, maintenance and disposal		

■ applications for the ET 910 training system

Experimental range

Different expansion elements – function and properties

- manually operated expansion valve
- pressure-controlled expansion valve
- capillary tube
- thermostatic expansion valve with internal pressure compensation

Different temperature controllers – function and properties

- control of the evaporation temperature via evaporation pressure controller KVP (normal cooling stage)
- control of the cold storage temperature via thermostatic switch with compressor control
- control of the cold storage temperature via electric temperature controller with compressor control

Different capacity controllers – function and properties

- capacity controller KVC
- capacity controller KVC with post-injection
- electrical refrigeration controller with solenoid valve and pump-down control

Different defrost circuits in the freezing stage – function and properties

- shut-down of the compressor via defrost timer
- shut-down of the compressor via evaporator thermostat
- electric defrost heater via defrost timer
- hot gas defrosting via reversing valve and defrost timer

Different extensions of the refrigeration circuit – function and properties

- influence of a heat exchanger - supercooling and superheating
- pressure-compensated compressor start via time-delayed bypass valve
- intake pressure control via start-up controller KVL
- liquid separator in the intake pipe
- operation with and without collector

Different extensions of the refrigeration circuit – troubleshooting and maintenance

- opening of the refrigeration circuit with refrigerant displacement
- opening of the refrigeration circuit by extraction off the refrigerant
- evacuation of the refrigeration circuit
- filling of the refrigeration circuit
- leak detection
- setting of thermostats and controllers
- check electrical function

ET 910 – ET 910.13 Design of the training system

Modular design of the device

The ET 910 Refrigeration training system, base unit used in conjunction with the additional units:

- ET 910.05 Refrigeration laboratory workplace
- ET 910.10 Refrigeration components for basic experiments
- ET 910.11 Refrigeration components for advanced experiments
- ET 910.12 Set of accessories, and
- ET 910.13 Maintenance set

represents a modular compression refrigeration system.

The basic configuration alone fulfils many tasks. The system can be extended with ET 910.11 and ET 910.13 for a more in-depth treatment of the topic.

The modular aspect of the system allows trainees / students to independently construct refrigeration circuits of varying degrees of difficulty. The individual components are connected to each other with flexible hoses. The modularity means multi-user systems can also be designed at low cost.

Basic configuration ET 910.10

Fundamentals of the refrigeration circuit

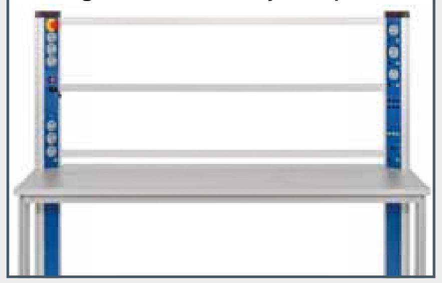
- simple refrigeration circuit, consisting of compressor, condenser, receiver, filter / drier, expansion valve, evaporator
- function of the individual components
- pressures and temperatures in the cyclic process
- behaviour under different cooling loads
- behaviour under different cold storage room temperatures
- behaviour with different mass flow rates

Advanced considerations of the refrigeration circuit

- function of the evaporator (evaporation pressure, superheating)
- difference between vented / unvented evaporator, frosting in the evaporator
- function of condenser and receiver (condensing pressure)
- function of heat exchanger, supercooler / superheater
- function of liquid separator
- effect of pressure losses in the piping system, simulation via manual valve
- effect of overfilling / underfilling
- function of filter / drier and sight glass
- electrical connection of a consumer

ET 910
Refrigeration training system, base unit

ET 910.05
Refrigeration laboratory workplace



ET 910.12
Set of accessories

ET 910.10
Refrigeration components for basic experiments

Minimum configuration for a functional workstation, consisting of **ET 910** Base unit, **ET 910.10** Refrigeration components for basic experiment, **ET 910.05** Refrigeration laboratory workplace and **ET 910.12** Set of accessories.

Extension set ET 910.11

Primary and secondary controllers in the refrigeration circuit

- various expansion elements: manually operated flow control valve, capillary tube, pressure-controlled expansion valve, thermostatic expansion valve
- various capacity controllers: KVP evaporation pressure controller, KVL start-up controller, KVC capacity controller with post-injection, electric thermostat with solenoid valve, refrigeration controller with solenoid valve
- compressor pump-down control system
- compressor start-up relieved via time-delayed bypass valve
- electric defrost heater with defrost timer
- hot gas defrosting with 4-way reversing valve and defrost timer

Simple electrical control systems from refrigeration technology

- proficiency in the fundamentals of control engineering
- complete tasks relating to refrigeration technology: thermostatic control, self-holding, alternating operation, delay circuit, electronic refrigeration controller

ET 910.11
Refrigeration components for advanced experiments

Further experiments with primary and secondary controllers in the refrigeration circuit. Electrical components can also be used to study tasks in the field of electrical engineering.

Maintenance set ET 910.13

Troubleshooting and maintenance

- emptying and evacuating a system
- filling a system and checking for leaks
- opening a system with refrigerant displacement / pump-down
- adjusting expansion valves, thermostats, pressure controllers

The maintenance set essentially consists of

- selected tools
- leak detection device
- multimeter
- filling and evacuating device

ET 910.13
Maintenance set

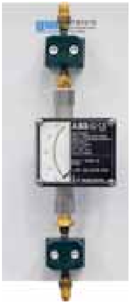
For filling and emptying the system. An ET 910.13 maintenance set can be used for several workstations. This can also be used to complete maintenance and troubleshooting tasks.

Overview of the modular components

ET 910.10 Refrigeration components for basic experiments

Sight glass with filter/drier

Flow meter



Manometer delivery side/intake side

Assembly aid

Heat exchanger

Pressure-controlled expansion valve

Thermostatic expansion valve

Circuit breaker, 3 pins

Electric thermostat 1

Electric thermostat 2

Liquid separator

ET 910.12 Set of accessories

Set of accessories

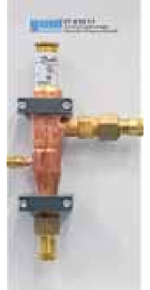
The ET 910.12 Set of accessories is required to establish the hydraulic and electrical connection from the components to each other and to the base unit. It contains refrigerant hoses in different lengths and diameters (some with shut-off valves), refrigerant filter/drier as an alternative, T-sections, couplings and laboratory cables. Two capillary tubes of different lengths, two distributors and a sufficient length of insulating tube are also included.

ET 910.11 Refrigeration components for advanced experiments

Manually operated valve

Temperature controller

Evaporation pressure controller



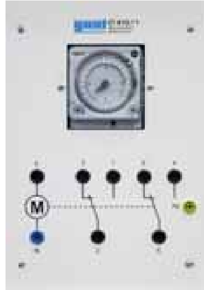
Intake pressure controller

Capacity controller

4-way reversing valve

Post-injection valve

Defrost timer

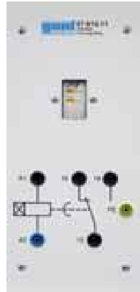


Refrigeration controller

Solenoid valve 1

Solenoid valve 2

Time relay



Main contactor

Auxiliary contactor

Example experimental setups

Some of the experimental setups that can be created with the training system are presented below as examples:

- simple refrigeration circuit with compressor, condenser, thermostatic expansion valve and evaporator
- understanding the function of a suction pressure controller in the refrigerant circuit
- hot gas defrosting process with a 4-way reversing valve

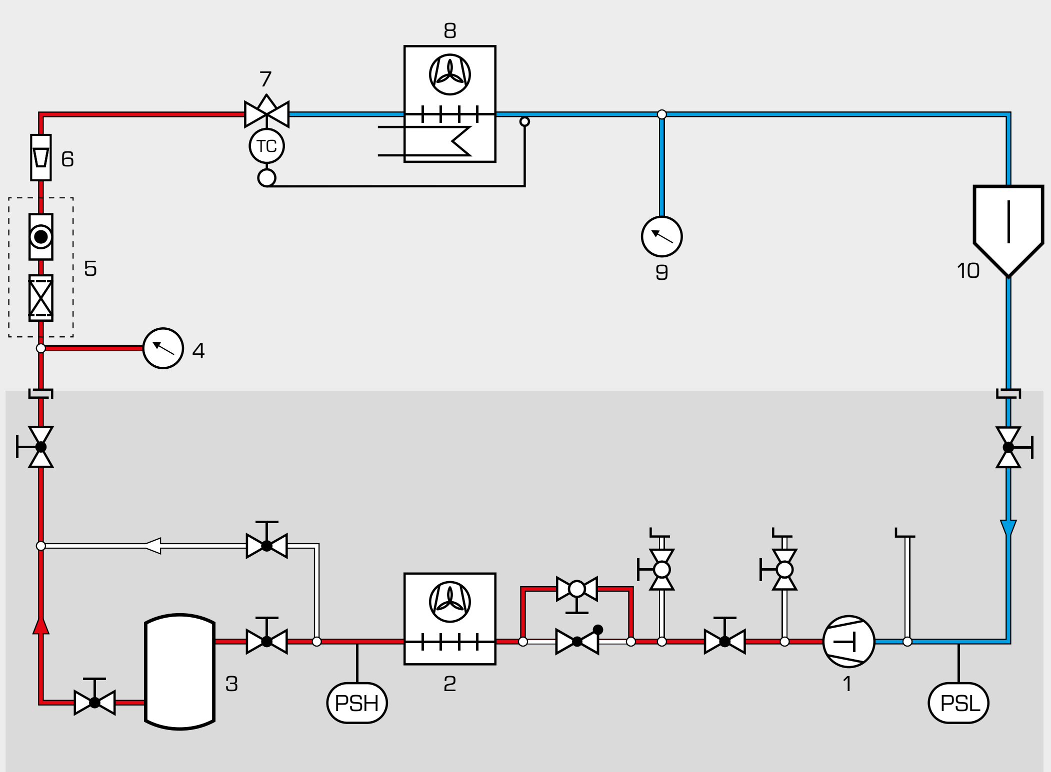
Before undertaking any practical work with the training system, the trainees/students first learn to read and understand refrigeration system diagrams or process schematics and simple electrical circuit diagrams.

When compiling the required experiment components, students can familiarise themselves with real refrigeration components used in the system diagrams.

During commissioning, practical activities such as evacuation, filling and leak testing are carried out. The relevant rules and regulations can be reviewed. In the subsequent experiment, students can get to grips with the function of the system in the truest sense of the word. The function is optimised by adjusting the controllers and expansion elements. The effects of external influences can be demonstrated, such as the change in the thermal load on the evaporator.

Laboratory workstation with base unit and components for experiment in the fundamentals

Example: simple refrigeration circuit with thermostatic expansion valve



Components

ET 910

3 receiver,
2 condenser,
1 compressor,
8 evaporator

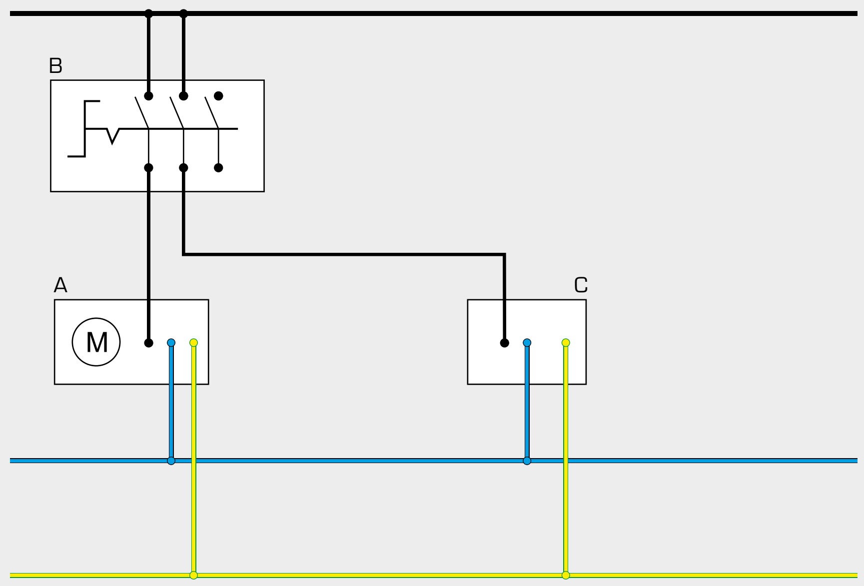
ET 910.10

7 thermostatic expansion valve,
6 flow meter,
5 sight glass with filter/drier,
4 intake side manometer,
9 pressure side manometer,
10 liquid separator

ET 910.12 Set of accessories with cables, hoses, etc.

In this introductory experiment, a simple refrigeration circuit is set up, consisting of a condensing unit (compressor **1**, condenser **2**, receiver **3**), refrigeration chamber with evaporator 8, thermostatic expansion valve **7** and sight glass with filter/drier **5**.

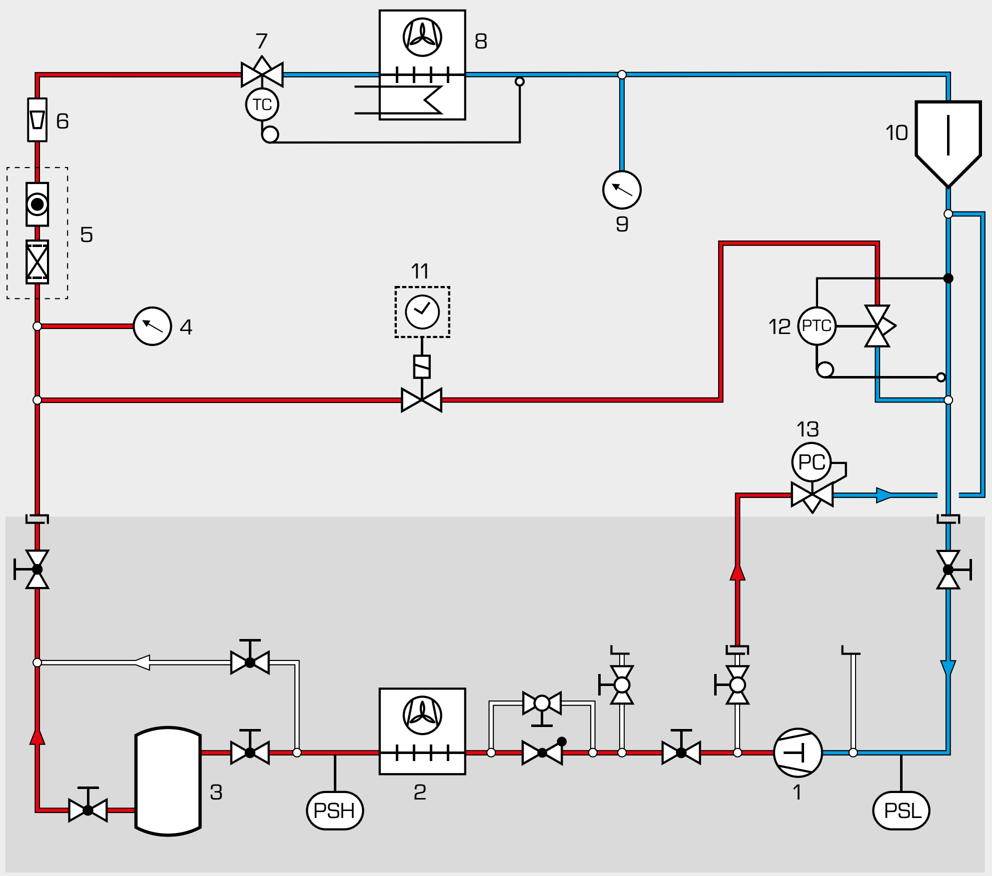
The control response of the expansion valve can be observed at the flow meter **6**. Manometers **4, 9** provide an insight to the pressure ratios in the circuit. The trainees/students learn about the elements and functions in the refrigeration circuit. The change of state of the refrigerant can be tracked and entered into the log p-h diagram using pressure and temperature measurements. A deeper understanding of the processes is gained by measuring the temperatures manually.



A condensing unit
B refrigeration chamber heater/fan
C circuit breaker, 3-pin
phase (L), neutral (N),
protective earth (PE)

Example experimental setups

Example: capacity control with post-injection



Components

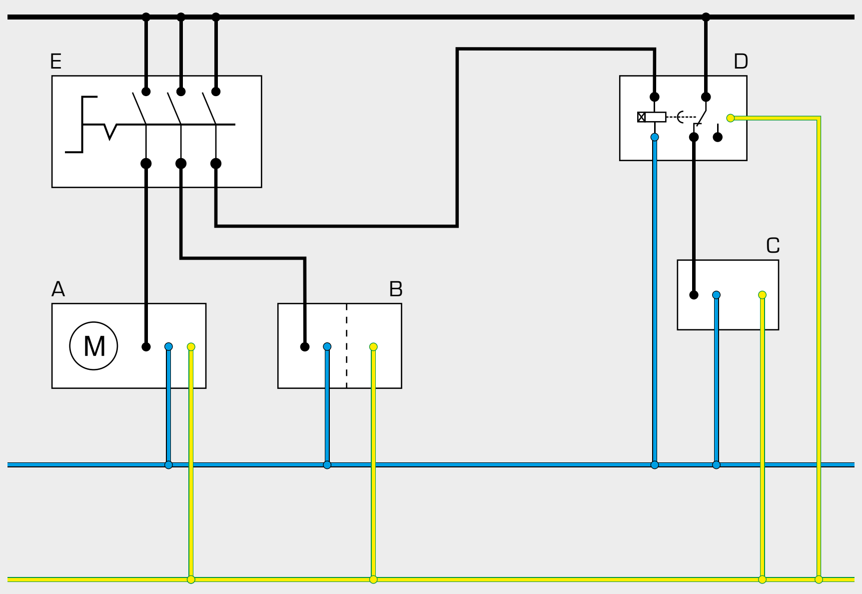
3 receiver,
2 condenser,
1 compressor,
8 evaporator
ET 910

10 liquid separator,
7 thermostatic expansion valve,
6 flow meter,
5 sight glass with filter/drier,
4 pressure side manometer,
9 intake side manometer
ET 910.10

13 KVC capacity controller,
12 post-injection valve,
11 solenoid valve with time relay
ET 910.11

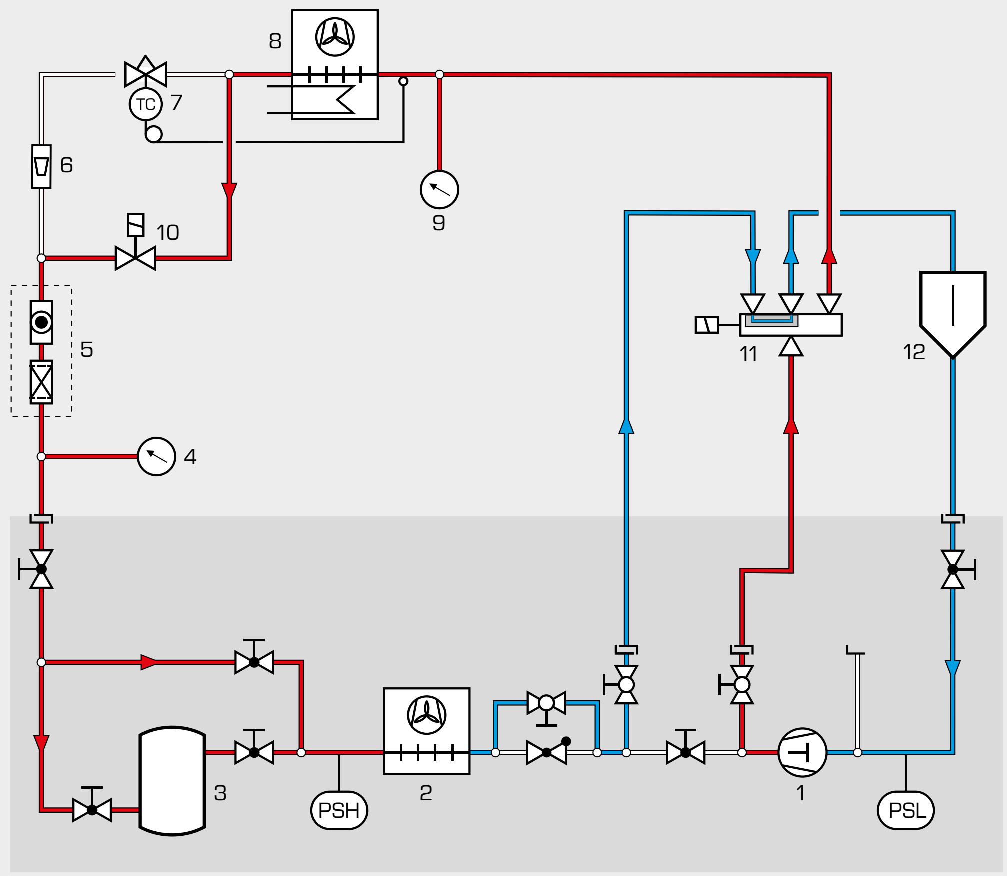
ET 910.12 Set of accessories with cables, hoses, etc.

This experiment demonstrates one type of capacity control for larger plants. Whereas in small systems the power output is usually controlled by the compressor switching on and off, in larger systems a KVC capacity controller **13** is used. If the pressure difference between the pressure side and the intake side of the compressor is too high, the KVC allows a partial flow of the compressed gas to flow back to the intake side. This reduces the effective mass flow of refrigerant. To prevent the compressor from overheating, a small amount of liquid refrigerant is injected directly into the intake line via the post-injection valve **12**. The refrigerant evaporates immediately, thereby cooling the intake gas. The post-injection can be intentionally deactivated via the solenoid valve **11** so that the effect can be observed immediately.



A condensing unit, **B** refrigeration chamber fan, **C** solenoid valve, **D** time relay, **E** 3-pin circuit breaker,
■ phase (L), ■ neutral (N), ■ protective earth (PE)

Example: hot gas defrosting process with 4-way reversing valve



Components

3 receiver,
2 condenser,
1 compressor,
8 evaporator
ET 910

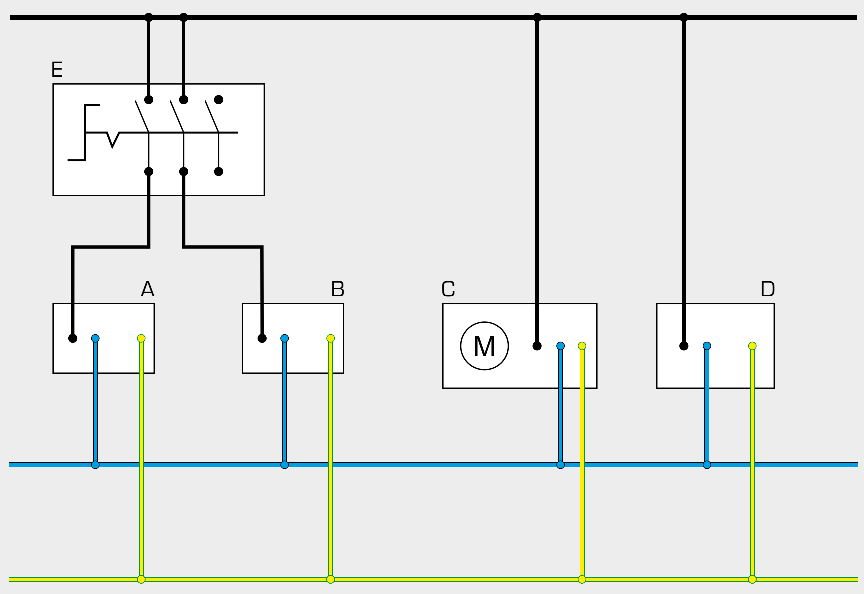
12 liquid separator,
7 thermostatic expansion valve,
6 flow meter,
5 sight glass with filter/drier,
4 pressure side manometer,
9 intake side manometer
ET 910.10

11 4-way reversing valve,
10 solenoid valve
ET 910.11

ET 910.12 Set of accessories with cables, hoses, etc.

At evaporation temperatures of less than 0°C, e.g. in deep-freeze systems, the air is cooled below its dew point temperature, causing condensate to escape and freeze on the surface of the evaporator. This layer of ice hinders convective heat transfer and reduces the heat transfer surface. In addition to the option of using a time-controlled defrost heater, ET 910 also offers hot gas defrosting.

The function of evaporator **8** and condenser **2** is exchanged via a 4-way reversing valve **11**, thus reversing the flow direction of the refrigerant. The frozen evaporator now receives the hot gas directly from the compressor outlet and defrosts very effectively.



A solenoid valve, **B** 4-way reversing valve, **C** condensing unit, **D** refrigeration chamber fan, **E** 3-pin circuit breaker,
■ phase (L), ■ neutral (N), ■ protective earth (PE)

Findings from the experiments

Measured Values Experiment 2			
Test run	1	2	3
Observation			
Evaporation Pressure $p_{1,4}$ in bar	1.5	1.9	2.1
Evaporation Pressure, absolute $p_{1,4}$ in bar	2.5	2.9	3.1
Evaporation Temperature in °C (Reading at the manometer)	-4.0	0.0	2.0
Condensation Pressure $p_{2,3}$ in bar	7.5	7.2	6.7
Condensation Pressure, absolute $p_{2,3}$ in bar	8.5	8.2	7.7
Condensation Temperature in °C (Reading at the manometer)	33.5	32.0	30.0
Temperature T_2 in °C at compressor outlet	45.6	47.3	43.0
Temperature T_3 in °C before expansion valve	24.8	24.0	22.5
Temperature T_4 in °C at evaporator inlet	-2.5	0.5	1.0
Temperature T_1 in °C at evaporator outlet	-1.2	2.5	5.0
Temperature T_1 in °C at compressor inlet	0.4	6.0	8.8
Refrigerant mass flow in kg/h	23	28	30

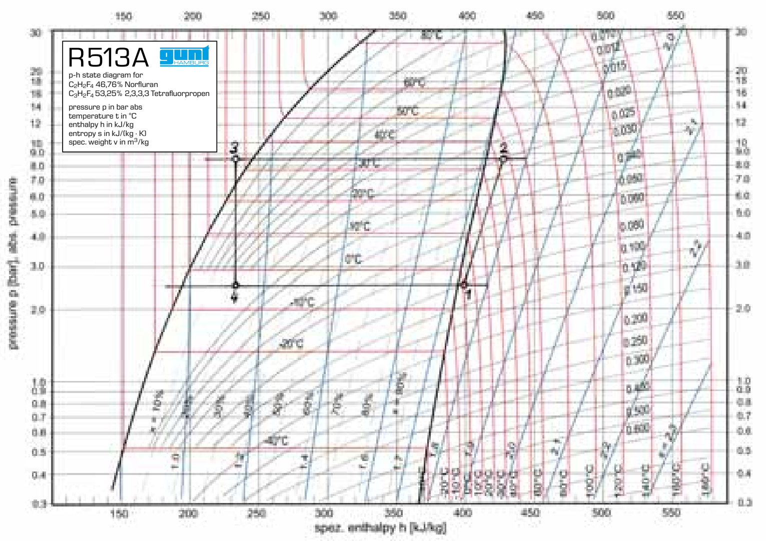
Recording measured values in a refrigerating plant

By measuring pressures and temperatures, it is possible to study the function of the individual components in the refrigeration circuit in detail.

Understanding the changes in state caused by placing the components themselves, students gain lasting knowledge of how refrigeration components work. In addition to practising the real-world ability to measure temperature correctly (correct measuring position and good contact between the sensor and the tube) or read a manometer properly, this unit also considers the matter of the steady state of the system.

The cyclic process can be displayed graphically by plotting the measured values in the log p-h diagram. The log p-h diagram is very important for refrigeration since it clearly shows how the main components work, allowing this to be discussed in detail.

The abstract concept of enthalpy is demonstrated by a balance of the exchanged energy flows. Basic properties of phase mixtures, condensation and evaporation can also be explained using the log p-h diagram.



Enter measured values in log p-h diagram and plot cyclic process

Calculations Experiment 2			
Test run	1	2	3
Enthalpies (Readings of the log p-h-diagram)			
h_1 in kJ/kg	398	402	405
h_2 in kJ/kg	428	426	428
h_3 in kJ/kg	233	229	228
h_4 in kJ/kg	233	229	228
Enthalpy differencies			
$h_1 - h_4$ in kJ/kg	165	173	176
$h_2 - h_3$ in kJ/kg	195	197	200
Mass flow $\dot{m}$ in kg/h	23	28	30
Calculation of Capacity			
Evaporator capacity $P_1 = \frac{\dot{m} \cdot (h_1 - h_4)}{3600}$ in kW	1.054	1.345	1.466
Condensor capacity $P_2 = \frac{\dot{m} \cdot (h_2 - h_3)}{3600}$ in kW	1.245	1.532	1.666
Theoretical coefficient of performance (COP)			
$\varepsilon = \frac{P_1}{P_2 - P_1}$	5.49	7.18	7.33

Calculate energy flows and determine coefficient of performance

Energy flows can be determined using simple thermodynamic calculations. Calculating the coefficient of performance allows statements to be made about the efficiency of the system; the calculation can be altered in a targeted manner by using different components. In addition, the influence of thermal loads or the pressure ratio on the coefficient of performance is effectively illustrated.

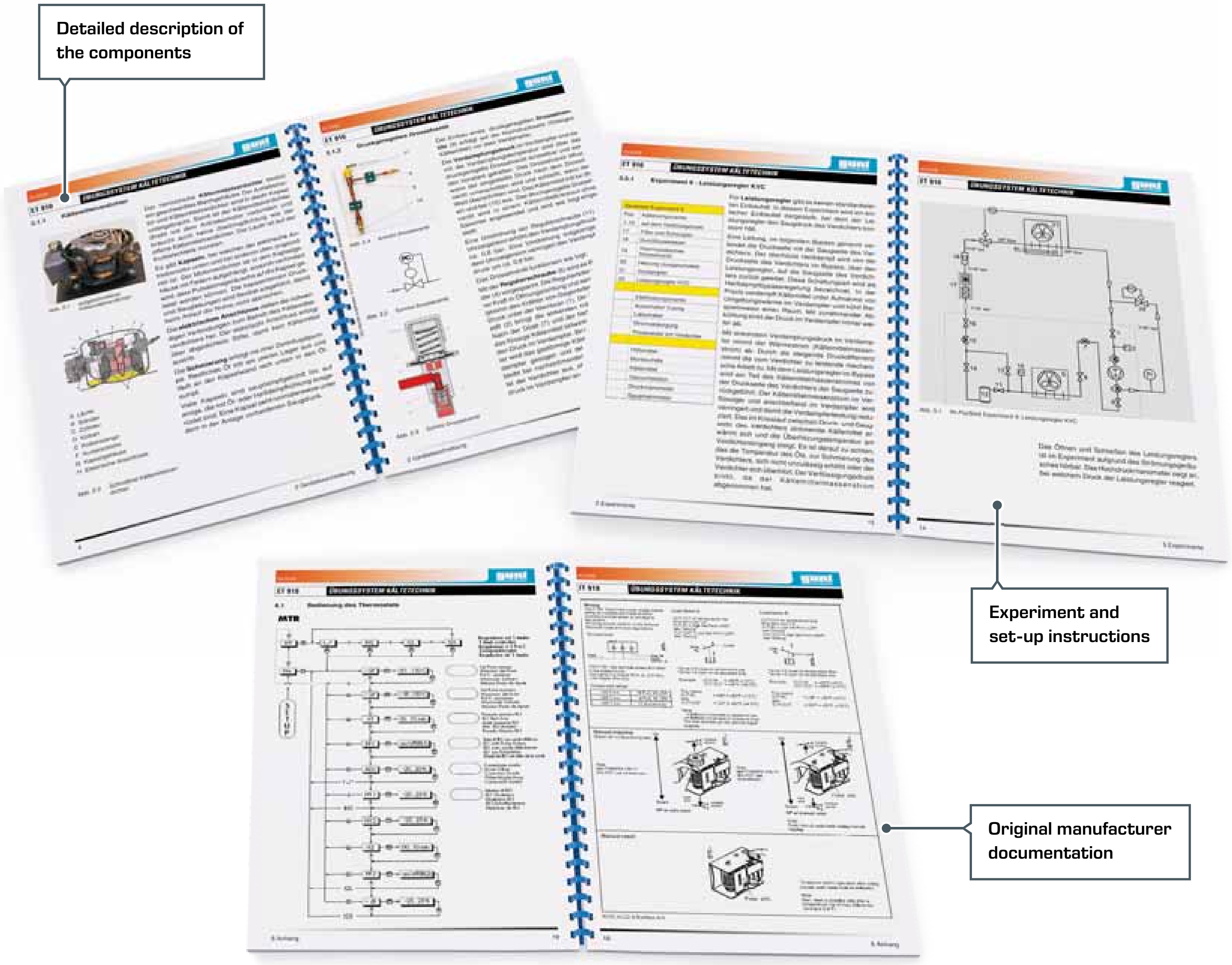
The instructional material

We have developed extensive instructional material for the training system ET 910. This makes the use of the system during your lessons easier.

The instructional materials consists in detail of:

- comprehensive system description ET 910
- extensive operating instructions
- detailed description of the design and function of the components used
- design instructions with system flow chart, electric circuit diagram and item list
- worksheets with instructions for the experiments for trainees
- original manufacturer documentation and assembly instructions for the most important components

Materials as printouts and additionally also as PDF files.



With the purchase of the training system ET 910 you receive a first class documentation and teaching aid