

Physics

Chemistry · Biology

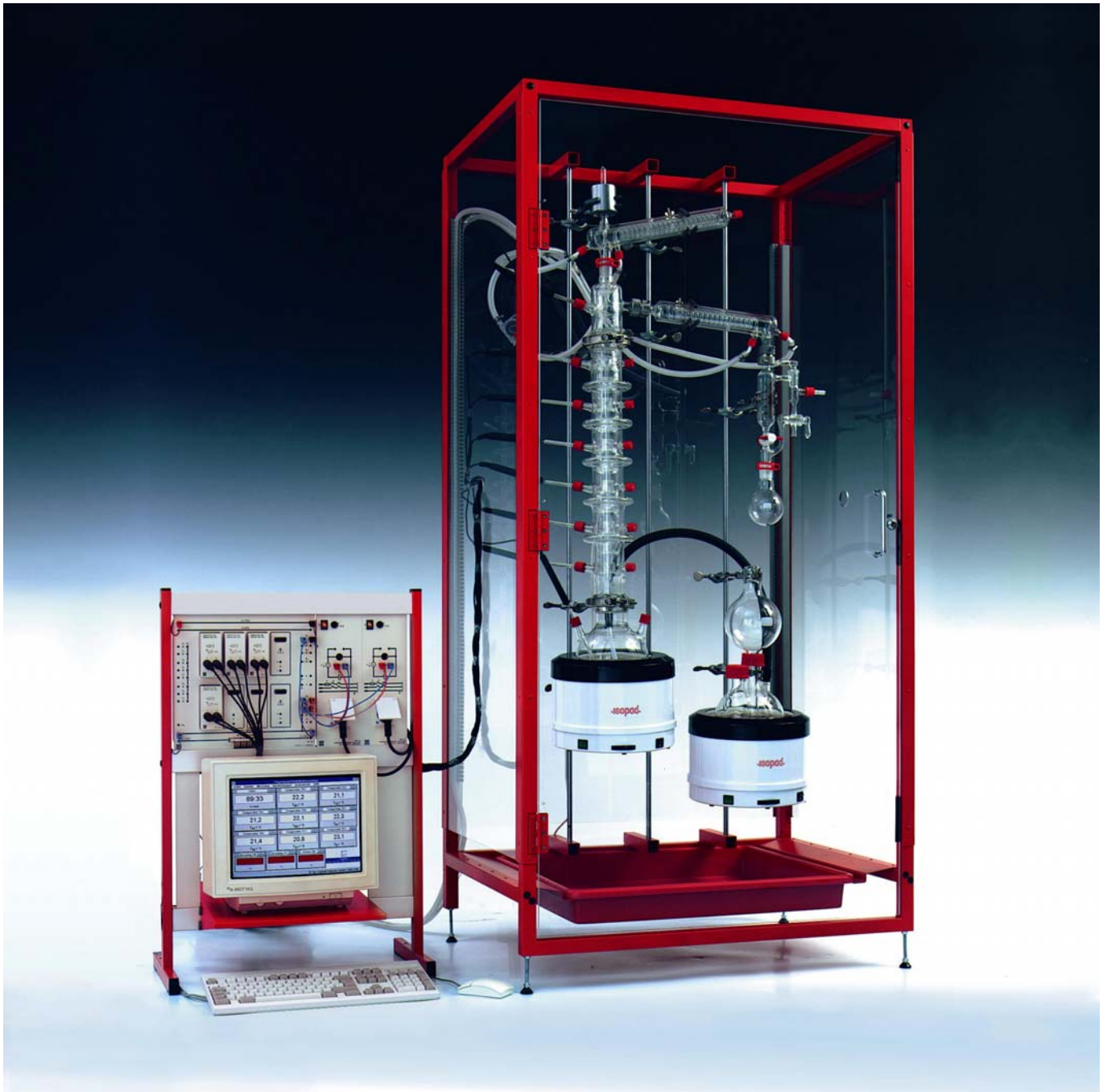
Technology



Lehr- und Didaktiksysteme  
LD Didactic GmbH  
Leyboldstrasse 1 · D-50354 Huerth

# Chemical Engineering

Industrial processes  
adapted for didactic education



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## Chemical Engineering

LD DIDACTIC offers corresponding training systems for all the relevant subjects in chemical engineering.

Thus there are training systems available in the following disciplines:

Chemical engineering, chemistry, physics, thermo-dynamics, fluid mechanics, electrical engineering, measurement and automatic control technology, applied computer-based process control and biotechnology.

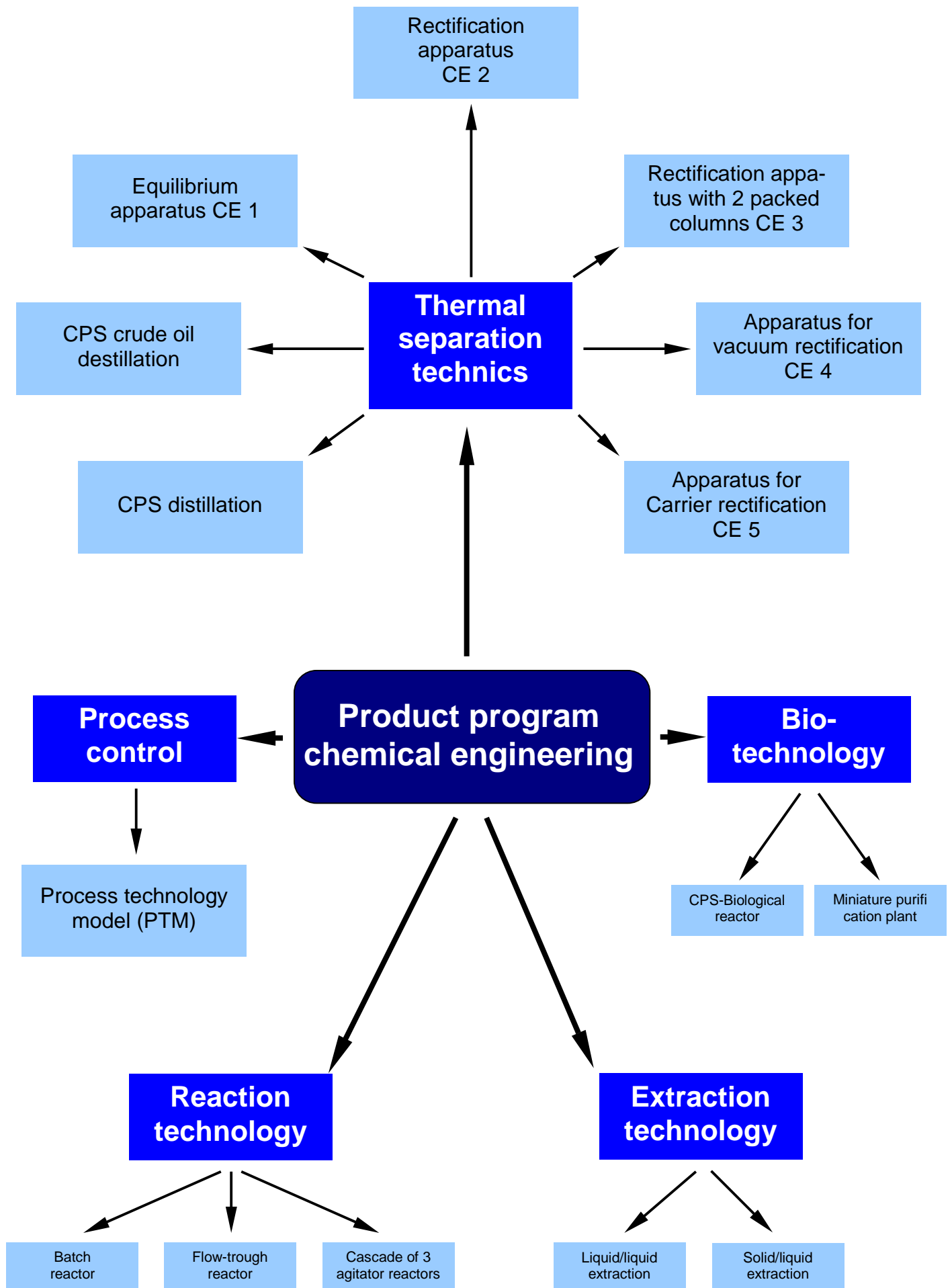
Chemical engineering is an important area of training in vocational schools, colleges and polytechnics, universities as well as company training centres.

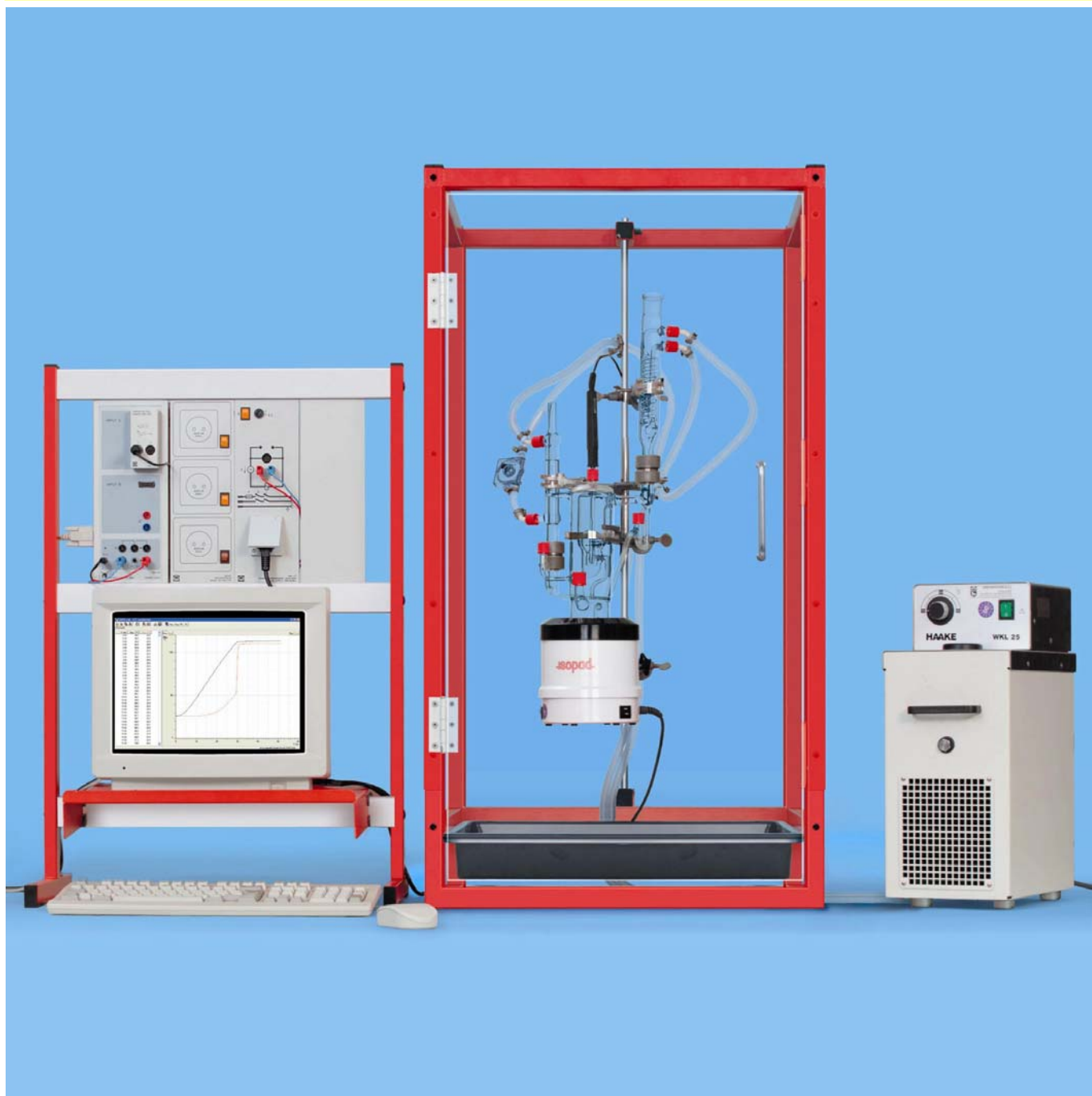
The range of experiments found in chemical engineering is broad: starting with simple model reactions of technical processes up to complex experiment set-ups on the laboratory scale, which are needed to satisfy university requirements.

LD DIDACTIC offers you a clearly structured, straightforward and didactically tested system design. All of the processes involved in thermal separation techniques are demonstrated and investigated using equipment with a maximum capacity of 2 l. The system has been designed for clear, unrestricted demonstration and has been deliberately streamlined on a single plane to eliminate any black-box effect. The data acquisition and system control is performed with the tried and tested CASSY interface. In conjunction with the user-friendly WINDOWS program CASSY Lab a system has been created which is easy to control and operate via a PC.

Most of the equipment has been designed in a modular fashion. Thus with supplementary sets the rectification apparatus can be expanded at low costs to accommodate apparatus for vacuum rectification or carrier rectification.

All of the systems supplied by LD DIDACTIC are accompanied by extensive literature. This literature includes not only introductory material on the theoretical background but also detailed experiment descriptions and valuable instructions on evaluating experiment results.





## Equipment list:

661 310	1	Equilibrium apparatus CE 1	501 44	1	Pair of connecting leads, 25 cm, red and blue
661 300	1	Frame CE 1	661 091	1	Boiling stones, 100 g
524 010USB	2	Sensor-CASSY, USB	666 467	2	Blank panels, 200 mm
524 200	1	CASSY Lab (software)	666 464	2	Blank panels, 100 mm
			665 963	2	Disposable syringes, 2 ml
			665 960	1	Disposable needles (10) for disposable syringes
524 045	1	Temperature box NiCr-Ni/NTC			
666193	1	Temperature sensor NiCr-Ni	1		PC (with Windows 98/Me/2000/XP) and free USB port
666 425	1	CPS panel frame, C 50, two level			
666 471	1	CPS mains power supply, switchable			

## Recommended accessories

667 355	1	Laboratory refractometer alternatively:
665 600	1	High-performance gas chromatograph with packed column and WLD
666 766	1	Circulation thermostat with refrigeration unit
665 009	1	Funnel, 75 mm diameter

Acquiring practical and theoretical knowledge of phase equilibria forms the basis of all techniques and principles of thermal separation. Rectification and azeotropic distillation remain incomprehensible until the basic principles of separation of binary mixtures are known.

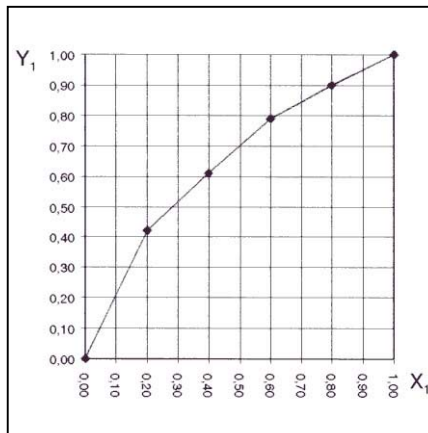
### 661 310 Equilibrium apparatus CE 1

For experimental determination of the equilibrium data of binary mixtures. For simultaneous determination of boiling temperature and mole fractions of the liquid and gaseous phase.

The measurement, recording and graphic representation of the boiling temperature and time are performed via CASSY (524 010USB) in conjunction with a personal computer and the program CASSY Lab (524 200).

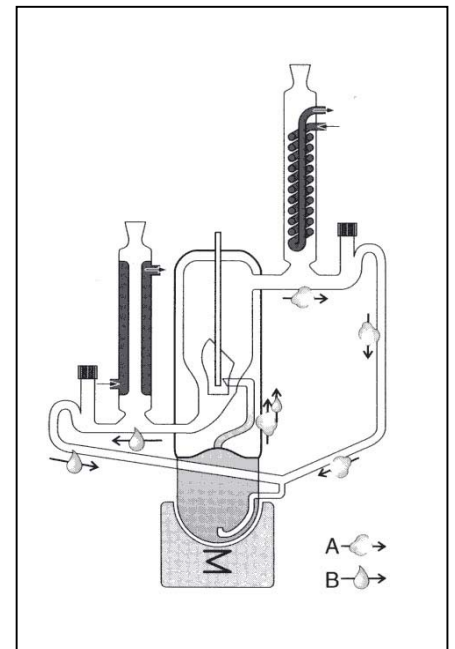
#### Scope of delivery:

- 1 Heating mantle, for 100 ml round-bottom flasks with integrated power controller and prefitted stand clamp, 230 V /50-60 Hz, 60 W
- 1 Stand rod, 15 cm
- 1 Glass section of the equilibrium apparatus, with evacuated double panes, (300 mm entire length), with reservoir, inside Cottrell pump, 1 phase separator, one sampling point each for the vapour phase and liquid phase, 1 protective sleeve for thermocouple
- 1 Liebig cooler, with 1 plane flange DN 15 (250 mm long)
- 1 Dimroth cooler, with 1 plane flange DN 15 (275 mm long)
- 4 Double bossheads
- 1 Chain clamp, 150 mm
- 2 Universal clamps
- 2 Sampling septa for GL 14 screw caps
- 2 Double couplings DN 15
- 2 Teflon seals DN 15
- GL Screw caps, some with seals



#### Phase equilibrium diagram

For representing the composition of the vapour phase of one component at equilibrium with respect to the composition of the corresponding liquid phase under the assumption that the working pressure remains constant. The illustration refers to the binary mixture methanol/ethanol. The relative amount of methanol in the vapour is plotted against the relative amount of methanol in the liquid.



#### Principle of the equilibrium apparatus

The liquid mixture is brought to the boil in the storage vessel by means of a heating mantle. When passing through the funnel-shaped taper of the Cottrell pump, the vapour bubbles (A) propel the liquid (B) which has not evaporated to the phase separator, where the gaseous and liquid phases are separated. The liquid phase (B) runs down the side as far as the sampling point, where samples can be taken through the septum of the GL threaded connection using a syringe. The vapour (A) passes through the phase separator and one of the side outlets to the Dimroth cooler, where it condenses. Drops of the condensate fall down and collect at the second sampling point. The reflux of liquid and condensate meet in a common tube in the storage vessel. The ascending flow of liquid in the middle of the storage vessel draws liquid out of the sample reflux tube. The liquid is subsequently heated once more.

### 661 300 Frame CE 1

The frame serves as a mount for the equilibrium apparatus CE 1 (661 310) and the plexiglass panelling offers the operator protection.

The front side forms a door. The frame is open to the top and the bottom side is completed by a plastic trough.

- Dimensions: 124 cm x 58 cm x 64 cm
- Weight: 15 kg

#### Scope of delivery:

- 1 Rear section with prefitted plexiglass panels, integrated stand rod as well as 4 prefitted cable ducts with 2 cold-water hoses branched at the top via connectors, also with 1 special adapter
- 1 Front section with plexiglass door
- 2 Plexiglass side panels
- 2 Connecting struts
- 2 Connecting struts with metal strips
- 1 Flow meter "Aquamobile" for checking the flow
- 1 Plastic trough
- 4 Feet
- 1 Hose clamp, set of 10
- Screwdriver and screws



### 668 912

#### Thermal Separation Methods, Part 1, Phase Equilibria

40 pages, DIN A4,

by Dr. U. Maerz and M. Raueiser

The book contains 11 practical experiments for examining binary mixtures with all the information necessary to perform and evaluate the experiments. It is subdivided into a theoretical section and an experimental section.

#### Topics:

- **Theoretical principles:**
  - Definition of phases and phase equilibria
  - The close/open system
  - Chemical potentials and coefficients
  - Checking the consistency of experimental data
  - Single-component and two-component systems
  - Presenting the phase equilibrium in a diagram
- **Experimental section:**
  - Mode of operation
  - Preparation
  - Procedure
  - Evaluation
  - Data on the experiments





## Equipment list:

661 311	1	Rectification apparatus CE 2
661 301	1	Frame CE 2
524 010USB	2	Sensor-CASSY, USB
524 200	1	CASSY Lab (software)
524 045	4	Temperature boxes (NiCr-Ni/NTC)
666 193	8	Temperature sensors NiCr-Ni
666 425	1	CPS panel frame, C 50, two level
666 471	1	CPS mains power supply, switchable
501 44	1	Pair of connecting leads, 25 cm, red and blue

665 963	2	Disposable syringes, 2 ml
665 960	1	Disposable needles (10) for disposable syringes
666 467	2	Blank panels, 200 mm
666 464	2	Blank panels, 100 mm
	1	PC (with Windows 98/Me/2000/XP) and free USB port

## Recommended accessories

667 355	1	Laboratory refractometer
alternatively:		
665 600	1	High-performance gas chromatograph with packed column and WLD
666 766	1	Circulation thermostat with refrigeration unit
665 009	1	Funnel, 75 mm diameter

## Extension sets for rectification apparatus CE 2 (661 311):

**661 332 Extension set for vacuum rectification CE 4/1**  
See page 11.

**661 342 Extension set for carrier rectification CE 5/1**  
See page 13.

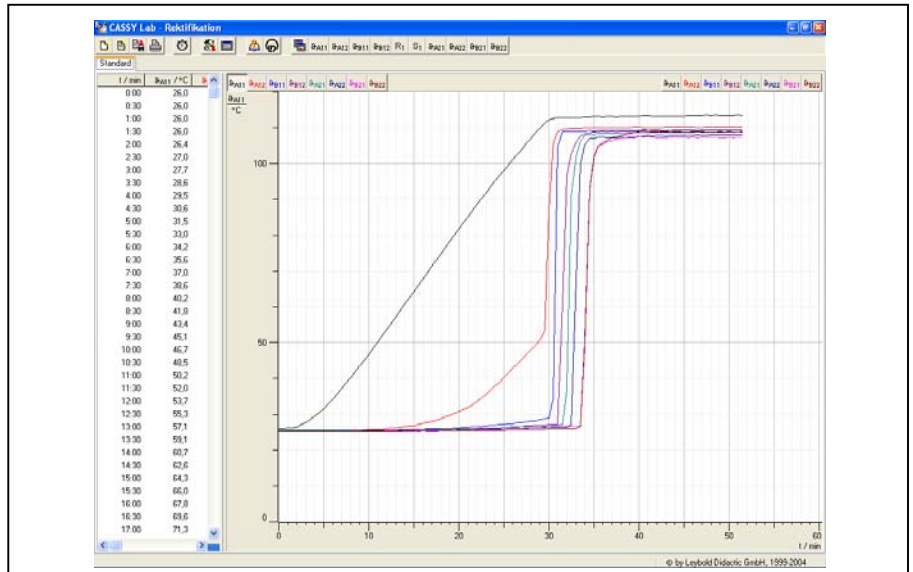
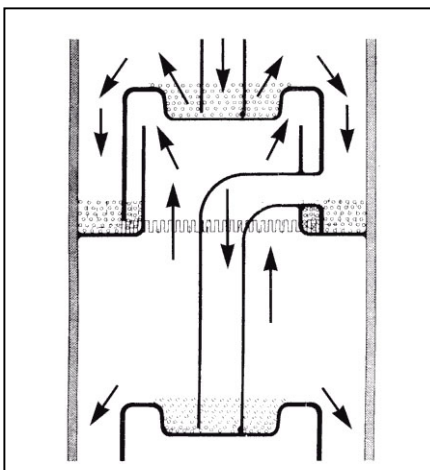
The treatment of reaction mixtures, e.g. via rectification, often involves high energy requirements and high investment costs. For economical reasons, when designing rectification columns a compromise is sought between investment costs and energy costs. The necessary parameters for understanding and planning rectification columns can be determined and evaluated with the following plants.

### 661 311 Rectification apparatus CE 2

Laboratory-scale pilot plant for experimental determination of equilibrium data of binary mixtures. With this plant it is possible to plot equilibrium curves and to calculate the number of theoretical plates and the amplification condensate reflux. Up to 7 fractions can be withdrawn simultaneously and analysed with regard to their composition and up to 8 temperatures can also be measured. In conjunction with a personal computer, the CASSY (524 010USB) controls the plant and also performs data collection and evaluation.

#### Scope of delivery:

- 1 Heating mantle, 2000 ml, with integrated power controller and fitted stand clamp, 230 V AC / 50 Hz, 500 W
- 1 Four-necked flask, 2000 ml, with 1 LF (laboratory flange) DN 60 and 3 GL 18 threaded connectors
- 1 Bubble-cap column in glass mantle with 11 trays, six GL 18 threaded connectors for temperature sensors, six GL 14 threaded connectors for taking samples and two LF DN 60
- 1 Lower section of vapour divider, with glass mantle, with 1 LF DN 60, 1 ST 29/32, 1 GL 18 threaded connector for temperature 1 side outlet with 1 plane flange DN 15
- 1 Vapour divider with 1 ST 29/32, with 1 oblique high-efficiency cooler, with two GL 14 threaded hose connectors and 1 glass ram with spherical ground joint and magnet for adjusting rate of reflux
- 1 Glass ram with spherical ground joint and magnet
- 1 Double coupling DN 15 with 1 Teflon seal
- 1 Conical dummy plug, glass, with plane ground joint DN 15
- 6 Double bossheads
- 1 Chain clamp
- 2 Clamping rings
- 2 Universal clamps
- 2 O-rings, silicone
- 1 Electric annular magnet, 24 V DC
- 10 Protective sleeves for temperature sensor
- 12 Sampling septa, GL 14
- 1 Joint clip ST 29/32
- Boiling stones, 100 g
- GL Screw caps, some with seals



The screen display shows a graph of 8 temperatures measured in the rectification apparatus plotted against time. The different boiling temperatures at equilibrium are easily recognisable after the initial heating phase. In the bubble-cap column, the fraction of the more volatile component in the vapour increases as it passes up from one tray to the next. As a result of the increased concentration of the more volatile component in the vapour: the further up the column, the lower the boiling point at equilibrium

### 661 301 Frame CE 2

The frame serves as a mount for the rectification apparatus CE2, CE3, CE4, CE5. The plexiglas panelling offers the operator protection.

The front side forms a door. The frame is open to the top and the bottom side is completed by a plastic trough.

- Dimensions: 90 cm x 185 cm x 65 cm
- Weight: 15 kg

#### Scope of delivery:

- 1 Rear section with prefitted plexiglass panel, three integrated stand rods
- 4 Cable ducts with 2 cold-water hoses and 1 special connection
- 1 Front section with plexiglass door
- 2 Plexiglass side panels
- 4 Connecting struts
- 1 Flow meter "Aquamobile" for checking the flow
- 1 Plastic through
- 4 Feet
- 1 Hose clamps, set of 10
- Screws and screwdriver

### 668 922

#### Thermal Separation Methods, Part 2, Rectification



60 pages, DIN A4, by Dr. U. Maerz and M. Raueiser. The book contains the data from 11 binary mixtures investigated in experiments. It contains all information necessary to perform and evaluate the experiments. It is subdivided into a theoretical section and an experimental section.

#### Topics:

- **Theoretical principles:**
  - Separation of binary mixtures by means of rectification - theoretical separation stage (plate)
  - Determination of the number of theoretical plates required at total reflux after McCabe and Thiele
  - HETP value
  - Minimum number of theoretical stages
  - Economical optimisation of stages and reflux ratio
- **Experimental section:**
  - Experiments for determining the number of theoretical plates in a column
  - Preparation
  - Procedure
  - Evaluation
  - Data on the experiments

### Flow sheet of a bubble tray

The illustration shows schematically the principle of a bubble tray. Under the bubbler, the ascending vapour is routed downwards into the condensate on the bubble tray. This ensures complete condensation of the vapour and repeated distillation. The condensate can flow back into the next lower tray via an overflow which is integrated into the bubble tray.



## Equipment list:

661 320	1	Rectification apparatus with two packed columns
661 301	1	Frame CE 2
524 010USB	1	Sensor-CASSY, USB
524 200	1	CASSY Lab (software)
524 045	2	Temperature boxes (NiCr-Ni/NTC)
666 193	4	Temperature sensors NiCr-Ni
666 425	1	CPS panel frame, C 50, two-level
666 471	2	CPS mains power supply switchable

501 44	4	Pair of connecting leads, 25 cm, red and blue
665 963	2	Disposable syringes, 2 ml
665 960	1	Disposable needles (10) for disposable syringes
666 467	2	Blank panels, 20 cm
666 464	1	Blank panel, 10 cm
	1	PC (with Windows 98/Me/2000/XP) and free USB port

## Recommended accessories

667 355	1	Laboratory refractometer alternatively:
665 600	1	High-performance gas chromatograph with packed column and WLD
666 766	1	Circulation thermostat with refrigeration unit
665 009	1	Funnel, 75 mm diameter



## 661 320 Rectification apparatus with 2 packed columns CE 3

Laboratory-scale pilote plant for simultaneous rectification with 2 packed columns with different packing material. With this plant, the number of theoretical plates can be determined for each packed column. Up to 4 fractions can be withdrawn simultaneously and analysed with regard to their composition and up to 4 temperatures can also be measured. In conjunction with the PC, the CASSY (524 010USB) controls the plant and also performs data collection and evaluation.

### Scope of delivery:

- 2 Heating mantles, 2000 ml, with integrated power controller and fitted stand clamp, 230 V AC / 50 Hz, 500 W
- 1 Four-necked flask, 2000 ml, with 1 LF (laboratory flange) DN 60 and 3 GL 18 threaded connectors
- 1 Packed column DN 60 with 2 LF DN 60
- 1 Packed column DN 100, bottom : LF DN 60, top: LF DN 100
- 2 Column heads as liquid separators, one with LF DN 100 at bottom, the other with LF DN 60, both with ST 20 on top, each with 1 thermometer holder GL 18 and one tube, 8 mm dia., for taking samples
- 2 High-efficiency reflux coolers with rocker, each with 1 ST 29/32 at top and bottom, each with 2 GL 14 threaded connectors for coolant supply
- 2 Double-necked round-bottom flasks, 100 ml, each with 2 GL 18 threaded connectors Raschig rings 4x4 mm high performance packing
- 2 Collection sieves for packing, 60 and 100 mm dia.
- 10 Double bossheads
- 2 Universal clamps
- 1 Clamping ring DN 100
- 1 Clamping ring DN 60
- 2 Chain clamps, 150 mm and 250 mm
- 2 Stand rods, 15 cm
- 1 O-Ring, silicone DN 100
- 3 O-Rings, silicone DN 60
- 2 Electric magnets, 24 V DC
- 2 Adapter cables for electric magnets, with 3-pole diode socket and two 4-mm plugs switches
- 1 Plug-in power supply, 24 V DC, each with two 4-mm jack plugs
- 5 Protective sleeves for temperature sensors
- 2 Sampling septa, GL 18
- 2 Joint clips ST 29/32
- 2 Teflon sleeves for ST 29/32
- Boiling stones, 100 g
- GL Screw caps, some with seals

## 661 322 Rectification apparatus with 1 packed column CE 3/1 (with Raschig rings)

Contains all parts and devices to build up a complete packed column with Raschig rings.

### Assembly of rectification plant with 1 packed column CE 3/1 (with Raschig rings)

#### Equipment list:

- |            |   |  |
|------------|---|--|
| 661 322    | 1 | Rectification apparatus with 1 packed column CE 3/1 (with Raschig rings) |
| 661 301    | 1 | Frame CE 2   |
| 524 010USB |   |  |
|            | 1 | Sensor-CASSY, USB  |
| 524 200    | 1 | CASSY Lab  |
| 524 045    | 1 | Temperatur box (NiCrNi)  |
| 666 193    | 2 | Temperatur sensors NiCrNi  |
| 666 425    | 1 | CPS panel frame, C50, two-level  |
| 666 471    | 1 | CPS mains power supply, switchable                                       |
| 501 44     | 3 | Pairs of connecting leads, 25 cm, red and blue                           |
| 666 467    | 2 | Blank panels, 200 mm   |
| 666 464    | 2 | Blank panels, 100 mm   |
|            | 1 | PC (with Windows 98/Me/2000/XP) and free USB port                        |

## 661323 Rectification apparatus with 1 packed column CE 3/2 with PP-packings)

Contains all parts and devices to build up a complete packed column with PP-packings.

### Assembly of rectification plant with 1 packed column CE 3/2 (with PP-packings)

#### Equipment list:

- |            |   |  |
|------------|---|--|
| 661 323    | 1 | Rectification apparatus with 1 packed column CE 3/2 (with PP-packings) |
| 661 301    | 1 | Frame CE 2   |
| 524 010USB |   |  |
|            | 1 | Sensor-CASSY, USB  |
| 524 200    | 1 | CASSY Lab  |
| 524 045    | 1 | Temperatur box (NiCrNi)  |
| 666 193    | 2 | Temperatur sensors NiCrNi  |
| 666 425    | 1 | CPS panel frame, C50, two-level  |
| 666 471    | 1 | CPS mains power supply, switchable                                     |
| 501 44     | 3 | Pairs of connecting leads, 25 cm, red and blue                         |
| 666 467    | 2 | Blank panels, 200 mm   |
| 666 464    | 2 | Blank panels, 100 mm   |
|            | 1 | PC (with Windows 98/Me/2000/XP) and free USB port                      |



## 668 922

### Thermal Separation Methods, Part 3, Optimisation of Separation Columns

38 pages, DIN A4, by Dr. U. Maerz, Dipl.-Ing. M. Metzbaure, Dipl.-Ing. M. Raueiser  
The book contains all the information necessary for preparing, performing and evaluating the experiments. It also gives sample measurements. The book is subdivided into a theoretical section and a experimental section.

### Topics:

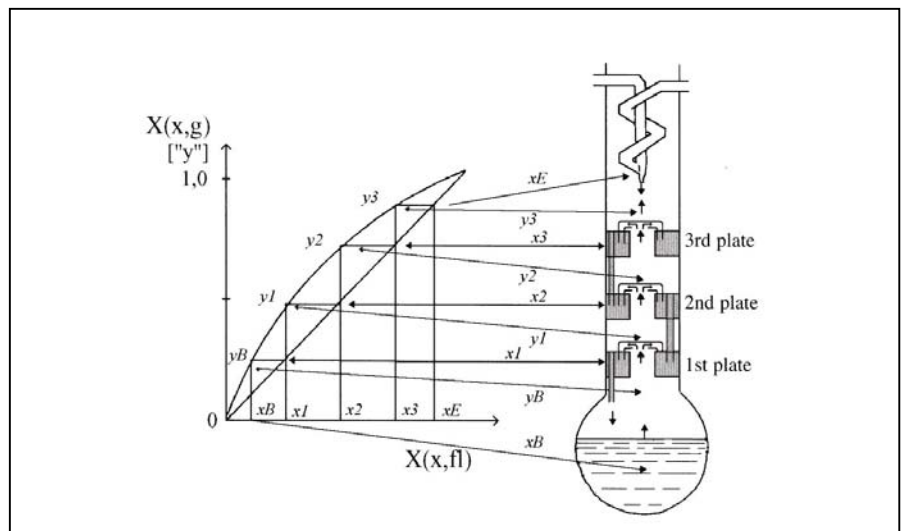
- **Theoretical principles:**
  - Separation effect of distillation columns
  - Theoretical separation stages (plates)
  - Distillation columns
- **Experimental section:**
  - Experiments on determining the theoretical plates of various types of columns
  - Preparation
  - Procedure
  - Evaluation
  - Data on the experiments
  - Worksheets

## 661 301 Frame CE 2

See page 7.

### Determination of the theoretical separation stages after McCabe/Thiele

The separation stages are drawn in the equilibrium diagram as shown in the illustration. For the determined mole fractions of the vapour phase  $Y_1$ , read off the number of "steps", i.e. the number of theoretical plates.





## Equipment list:

661 330	1	Apparatus for vacuum rectification CE 4	378 946	1	Diaphragm vacuum pump Divac 2.2 l	665 963	2	Disposable syringes, 2 ml
661 301	1	Frame CE 2	378 959	1	Gas ballast for DIVAG	665 960	1	Disposable needles (10) for disposable syringes
524 010USB	2	Sensor-CASSY, USB	378 965	1	Module SH	666 467	2	Blank panels, 200 mm
524 200	1	CASSY Lab (software)	378 509	1	Absolute pressure sensor	666 464	2	Blank panels 100 mm
524 045	4	Temperature boxes (NiCr-Ni/NTC)	667 186	1	Vacuum rubber tubing, 8 mm Ø, 1 m		1	PC (with Windows 98/Me/2000/XP) and free USB port
666 193	8	Temperature sensors NiCr-Ni	<i>Accessories for vacuum pump:</i>			<b>Recommended accessories</b>		
666 425	1	CPS panel frame, C 50, two-level	378 776	1	Variable leak valve DN 16 KF	667 355	1	Laboratory refractometer
666 471	1	CPS mains power supply, switchable	378 015	1	Cross DN 16 KF	alternatively:		
501 44	1	Pair of connecting leads, 25 cm, r/b	378 777	1	Fine vacuum ball valve DN 16 KF	665 600	1	High-performance gas chromatograph with packed column and WLD
			378 031	1	Small flange DN 16 with hose nozzle	666 766	1	Circulation thermostat with refrigeration unit
			378 065	1	Blank flange DN 16 KF	665 009	1	Funnel, 75 mm diameter
			378 045	1	Centering ring DN 16 KF			
			378 050	1	Clamping ring DN 10/16 KF			

In distillation technology it is often useful to rectify multicomponent mixtures under reduced pressure. This gentle process guarantees the separation of high-boiling components without much loss through thermal decomposition reactions. This aspect combined with the considerably lower energy expenditure resulting from the reduced heat requirements often compensate the additional costs that are incurred by upgrading the plant by a fractionation component and the vacuum generator.

### 661 330 Apparatus for Vacuum rectification CE 4

Laboratory-scale pilote plant for experimental determination of equilibrium data of binary mixtures. With this plant rectification can be performed under vacuum conditions and therefore at lower boiling temperatures. Up to 8 fractions can be withdrawn simultaneously and analysed with regard to their composition and up to 8 temperatures can also be measured.

In conjunction with a PC, the CASSY (524 010USB) controls the plant and also performs data collection and evaluation.

#### Scope of delivery:

- 1 Heating mantle, 2000 ml, with integrated power controller and fitted stand clamp, 230 V AC / 50 Hz, 500 W
- 1 Four-necked flask, 2000 ml, with 1 LF (laboratory flange) DN 60 and 3 GL 18 threaded connectors
- 1 Bubble-cap column in glass mantle with 11 trays, six GL 18 threaded connectors for temperature sensors, six GL 14 threaded connectors for taking samples and two LF DN 60
- 1 Lower section of vapour divider, with glass mantle, with 1 LF DN 60, 1 ST 29/32, 1 GL 18 threaded connector for temperature 1 side outlet with 1 plane flange DN 15
- 1 Vapour divider with 1 ST 29/32, with 1 oblique high-efficiency cooler, with two GL 14 threaded hose connectors
- 1 Glass ram with spherical ground joint and magnet for adjusting rate of reflux
- 1 Distilling bridge with integrated oblique efficiency cooler with two plane flange DN 15
- 1 Anschütz-Thiele attachment, 100 ml, straight, top plane flange DN 15, bottom ST 29/32, 2 Stopcocks ST, 1 Teflon stopcock
- 1 Round-bottom flask, 500 ml, 1 ST 29/32
- 1 Boiling capillary
- 2 Double couplings DN 15
- 2 Teflon seals DN 15
- 2 Double bossheads
- 1 Chain clamp, 150 mm
- 2 Clamping rings DN 60
- 3 Universal clamps
- 1 Universal clamp
- 2 O-rings, silicone DN 60
- 1 Electric annular magnet, 24 V DC
- 1 Plug-in power supply, 24 V DC
- 1 Adapter cable for electric magnet, with 3-pole diode socket and 4-mm plugs switches
- 10 Protective sleeves for temperature sensors
  - Vakuum hose, 2 m
  - Coolant hose, 1 m
- 2 Branching componets
- 1 Hose clamps, set of 10
  - GL screw caps, some with seals
- 12 Sampling septa, GL 14
- 2 Joint clips ST 29/32
- 2 Teflon sleeves ST 29/32

### 661 300 Frame CE 1

See page 7

### 661 332 Extension set for vacuum rectification CE 4/1

The extension set contains all necessary parts for upgrading the rectification apparatus CE 2 (661 311) to a fractional vacuum rectification unit CE 4 (661 330).

#### Scope of delivery:

- 1 Distillation bridge with integrated oblique high-efficiency cooler 2 TS DN 15, 2 GL 14
- 1 Anschütz-Thiele attachment, 100ml, straight top TS DN 15, bottom TS 29/32, 2 stopcock, 1 Teflon stopcock
- 1 Round bottom flask 500ml, 1 TS 29/32
- 1 Boiling capillary
- 1 Vacuum hose, 2 m
- 1 Coolant hose, 1 m
- 2 Branching components
  - Hose clips set of 10
- 1 Plug-in power supply, 24 V DC
- 1 Adapter cable for electric magnet, with 3-pole diode socket and two 4-mm plug switches
- 2 Double bossheads
  - 1 Universal clamp
  - 1 Universal clamp (666 555)
  - 1 Joint clip TS 29/32
  - 1 Double coupling DN 15
  - 1 Teflon seal DN 15
  - 1 Teflon sleeve TS 29/32
  - GL Screw caps



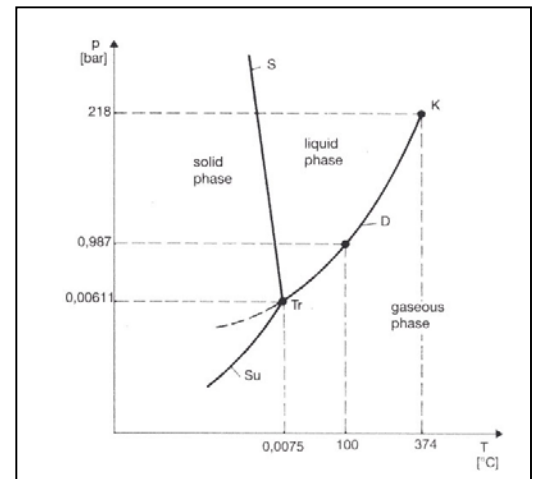
### 668 942 Thermal Separation Methods, Part 4, Fractional Vacuum Rectification

Approx. 36 pages DIN A4, by Dr. U. Maerz, Dipl.-Ing. M. Metzbaure, Dipl.-Ing. M. Raueiser

The book elucidates step by step how the experiments are prepared, performed and evaluated. It is subdivided into a theoretical section and an experimental section.

#### Topics:

- Theoretical principles:
  - Fractional rectification
  - Vacuum rectification
  - Method of fractional vacuum rectification
- Experimental section:
  - Experiments on fractional vacuum rectification
  - Preparation
  - Procedure
  - Evaluation
  - Worksheets



#### p,T diagram for water

D = vapour pressure curve

p = pressure

Su = sublimation curve

Tr = triple point

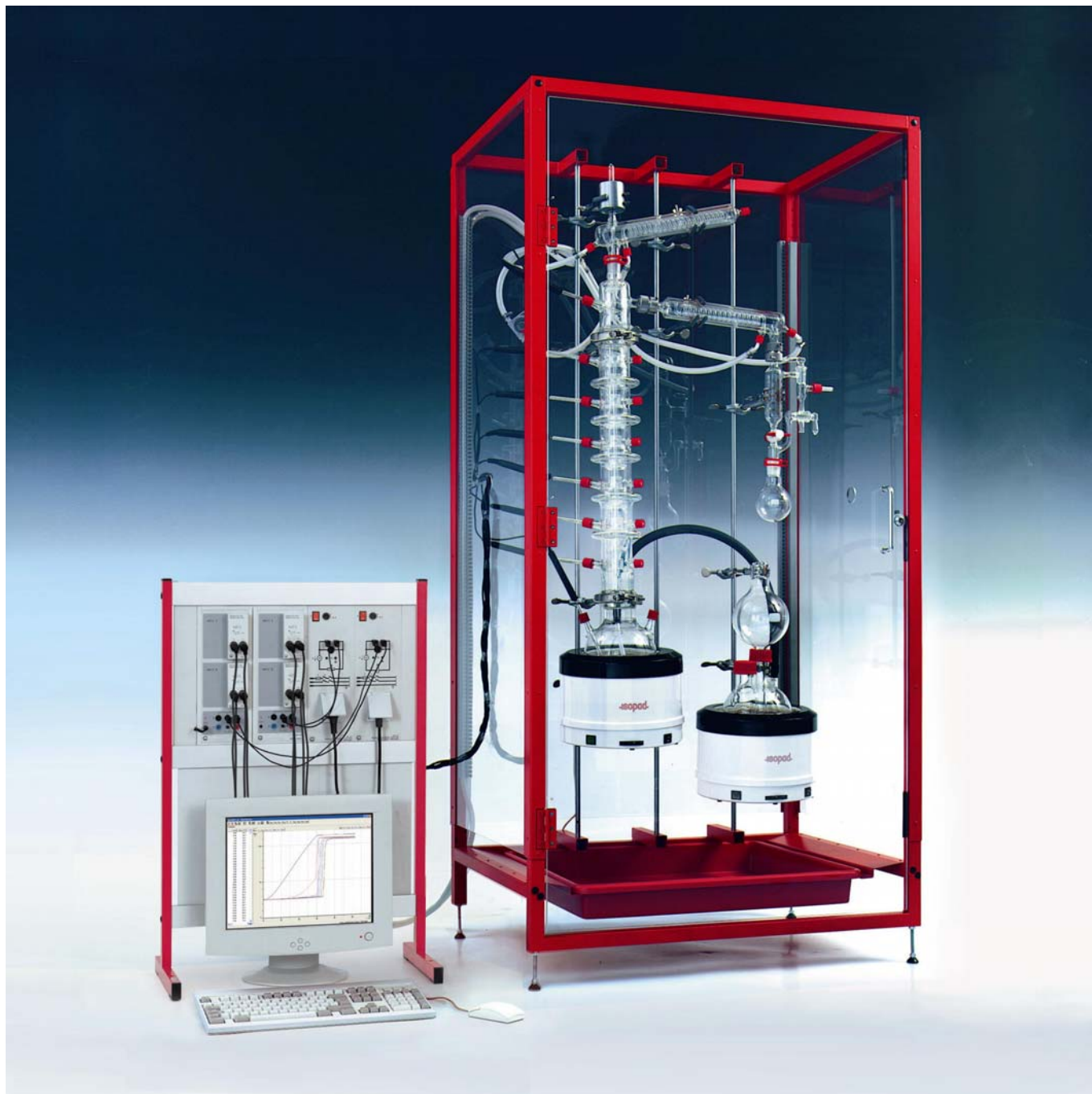
K = critical point

S = melting-point pressure curve

T = temperature

Among other things, the diagram elucidates the dependency of the boiling temperature on the pressure using water as an example. At a pressure of 0.987 bar, water boils at 100 °C. At a reduced pressure of 6.11 mbar, however, water boils at 0.0075 °C. If rectification is conducted under vacuum conditions, the mixture boils at a lower temperature than at standard pressure and enables a drastic reduction of the energy costs.




**Equipment list:**

661 340	1	Apparatus for carrier rectification CE 5
661 301	1	Frame CE 2
524 010USB	2	Sensor-CASSY, USB
524 200	1	CASSY Lab (software)
524 045	4	Temperature boxes (NiCr-Ni/NTC)
666 193	8	Temperature sensors NiCr-Ni
666 425	1	CPS panel frame, C 50, two level
666 471	2	CPS mains power supply, switchable
501 44	2	Pair of connecting leads, 25 cm, red and blue

665 963	2	Disposable syringes, 2 ml
666 467	2	Blank panels, 200 mm
666 464	1	Blank panel, 100 mm
665 960	1	Disposable needles (10) for disposable syringes
	1	PC (with Windows 98/Me/2000/XP) and free USB port

**Recommended accessories**

667 355	1	Laboratory refractometer alternatively:
665 600	1	High-performance gas chromatography unit with packed column and WLD
666 766	1	Circulation thermostat with refrigeration unit
665 009	1	Funnel, 75 mm diameter



The chemical industry often uses carrier rectification to separate high-boiling components. In this case, a current of carrier vapour is passed through the distillation mixture in the storage vessel. This generally lowers the boiling range of the mixture. Thus, under normal conditions, a very gentle separation of a component of the mixture can be obtained at a temperature much lower than its actual boiling point. Water-insoluble components with very high boiling points can be separated from ethanolic solutions at temperatures of below 100 °C using this method with water vapour as a carrier. In azeotropic rectification, an auxiliary compound is added to the azeotropic distillation mixture, either allowing one component of the mixture to be separated at a lower temperature, similar to carrier rectification, or changing the azeotropic point of the original mixture such that the purity of the mixture is increased.

### 661 340 Apparatus for Carrier Rectification CE5

Laboratory-scale pilot plant for performing carrier or azeotropic rectification.

Up to 8 fractions can be withdrawn simultaneously and analysed with regard to their composition and 8 temperatures can also be measured. In conjunction with a PC, the CASSY (524 010USB) controls the plant and also performs data collection and evaluation.

#### Scope of delivery:

- 2 Heating mantles, 2000 ml, with integrated power controller and fitted stand clamp, 230 V AC / 50 Hz, 500 W
- 2 Stand rods, 15 cm
- 1 Four-necked flask, 2000 ml, with 1 LF (laboratory flange) DN 60 and 3 GL 18 threaded connectors
- 1 Bubble-cap column in glass mantle with 11 trays, six GL 18 threaded connectors for temperature sensors, six GL 14 threaded connectors for taking samples and two LF DN 60
- 1 Lower section of vapour divider, with glass mantle, with 1 LF DN 60, 1 ST 29/32, 1 GL 18 threaded connector for temperature 1 side outlet with 1 plane flange DN 15
- 1 Vapour divider with 1 ST 29/32, with 1 oblique high-efficiency cooler, with two GL 14 threaded hose connectors
- 1 Glass ram with spherical ground joint and magnet for adjusting rate of reflux
- 1 Distilling bridge with integrated oblique high efficiency cooler, 2 DN 15, 2 GL 14
- 1 Anschütz-Thiele attachment, 100 ml, straight, top DN 15, bottom ST 29/32, 2 stopcocks ST, 1 Teflon stopcock
- 1 Round-bottom flask, 500 ml, 1 ST 29/32
- 1 Three-necked round-bottom flask, 2000 ml, 2 GL 45, 1 GL 18
- 1 Ascending tube with 1000 ml through
- 2 Double couplings DN 15
- 2 Teflon seals DN 15
- 11 Double bossheads
- 1 Chain clamp, 150 mm
- 2 Clamping rings DN 60
- 3 Universal clamps
- 3 Universal clamps
- 2 O-rings, silicone, DN 60
- 1 Electric annular magnet, 24 V DC
- 1 Plug-in power supply, 24 V DC
- 1 Adapter cable for electric magnet, with 3-pole diode and two 4-mm plug switches
- 10 Protective sleeves for temperature sensors
- Coolant hose, 1 m
- 2 Branching components
- 1 Hose clamps, set of 10
- 12 Sampling septa, GL 14
- 2 Joint clips ST 29/32
- 1 Teflon sleeve ST 29/32
- 1 Teflon sleeve with cellular rubber coating
- 2 Tubing clamps, GL 18
- Boiling stones, 100 g
- GL screw caps, some with seals

### 661 342 Extension set for Carrier Rectification CE 5/1

For rectification apparatus CE 2 (661 311, see page 6).

The extension set contains all the necessary parts for upgrading the rectification apparatus CE 2 (661 311) to a carrier rectification unit CE 5 (661 340).

#### Scope of delivery:

- 1 Heating mantle, 2000 ml, with integrated power controller, heating zone switch and fitted stand clamp, 230 V AC / 50 HZ, 500 W
- 1 Distillation bridge with integrated oblique high-efficiency cooler, 2 LF DN 15, 2 GL 14
- 1 Anschütz-Thiele attachment, 100 ml, straight, top LF DN 15, bottom ST 29/32, 2 ST-stopcocks, 1 Teflon stopcock
- 1 Round-bottom flask, 500 ml, 1 ST 29/32
- 1 Three-necked round-bottom flask, 2000 ml, 2 GL 45, 1 GL 18
- 1 Ascending tube with 1000 ml trough
- 1 Teflon hose with cellular rubber coating
- 2 Tubing clamps GL 18
- Coolant hose, 1 m
- 1 Branching components
- 1 Hose clamps, set of 10
- 1 Plug-in power supply, 24 V DC
- 1 Adapter cable for electric magnet, with 3-pole diode and two 4-mm plug switches
- 5 Double bossheads
- 3 Universal clamps (666 555)
- 1 Universal clamp
- 1 Joint clip ST 29/32
- 1 Double coupling DN 15
- 1 Teflon seal DN 15
- 1 Teflon sleeve ST 29/32
- GL screw caps, some with seals

### 661 301 Frame CE 2

See page 7



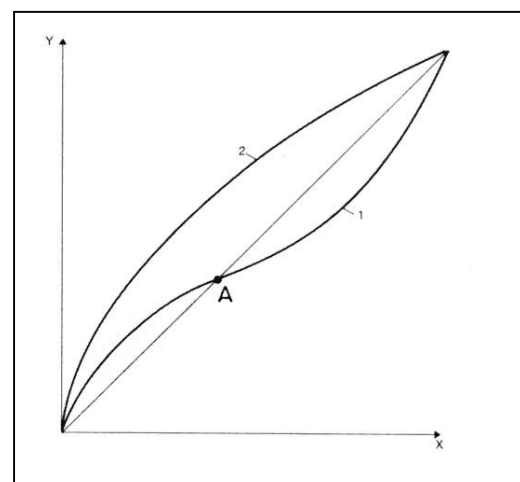
### 668 952 Thermal Separation Methods, Part 5, Carrier Rectification

Approx. 16 pages, DIN A4, by Dr. U. Maerz, Dipl.-Ing. M. Metzbaure, Dipl.-Ing. M. Raueiser

This book serves as a practical introduction to the topic and is subdivided into a theoretical section and an experimental section.

#### Topics:

- **Theoretical principles:**
  - Azeotropy
  - Influencing the azeotropic point
  - Effects of the carrier
  - Method of carrier and azeotropic rectification
- **Practical section:**
  - Experiments on carrier rectification and rectification
  - Preparation
  - Procedure
  - Evaluation
  - Worksheets



#### Azeotropy diagram

The schematic presentation of azeotropic distillation clearly illustrates the influence of an added substance on the azeotropic point.

**Curve 1:** Equilibrium curve without an added substance The equilibrium curve intersects the diagonal at point A. No further separation of the mixture is possible by means of distillation.

**Curve 2:** Equilibrium curve with added substance

By adding another substance, the equilibrium curve is above the diagonal for the entire range of concentration. The mixture can be separated without limitations by means of distillation.

**666442 CPS-Distillation**

Complete with standardized spacers and attachment components.

Suitable for:

- Standard-pressure distillation
- Vacuum distillation (after addition of some components)

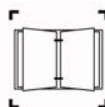
- Dimensions: 400 x 297 x 185 mm  
Experiment panel: 400 x 297 mm
- Weight: 1.6 kg

Scope of delivery:

- 1 Round-bottom flask, ST 29, 500 ml
- 1 Distillation bridge after Claisen, 2 GL 18, cooling jacket with 2 nipples for the water connection, 1 nipple for the vacuum connection.
- 1 Round-bottom flask, ST 29, 250 ml
- 1 Experiment panel
- Attachment components

**Equipment list:**

666 442	1	CPS-Distillation
666 753	1	Heating mantle, 500 ml
666 161	1	Chemical thermometer
666 425	1	CPS-Panel frame, C50
666 441	1	CPS-Pedestal
665 392	2	Joint clips
667 180	2	Rubber tubings, 1 m
666 467	1	Blank panel, 200 mm
666 464	1	Blank panel, 100 mm

**668 802****Book: Demonstration experiments****"General chemistry"**

216 pages, DIN A4, by Frank Römer  
44 experiments introducing the important topics of general chemistry.

The experiments can be performed both with the Chemistry Panel System (CPS) and also with conventional stand material and glassware.

The book contains comprehensive experiment series on all topics with instructions, master copies for foils and worksheets. The experiments have been selected such that the quantities of chemicals for disposal are kept to a minimum. This is ensured by the fact that the final products of one experiment are the starting material of the next.

- Separation methods
- Methods of classifying substances
- Physical and chemical principles
- Chemical reactions

### Assembly of a CPS-Distillation plant with CPS-Panel frames and accessories



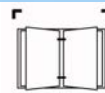
#### Crude oil distillation

This experiment assembly offers excellent teaching options for investigating the production process known as fractional distillation in an experimental procedure.

A number of gasoline fractions are derived from the crude oil mixture; these fractions are collected individually. The special bubble.cap column allows for the separation of fractions where there are only small differences in their boiling points. Temperature sensors in the assembly enable direct determination of the boiling points of individual fractions. This feature permits continuous process monitoring.

#### Equipment list

666 447	1 CPS-Crude oil distillation
524 010USB	1 Sensor-CASSY, USB
524 200	1 CASSY Lab (software)
524 045	2 Temperature boxes, NiCr-Ni/NTC
666 193	4 Temperature sensors, NiCr-Ni
666 754	1 Heating mantle 1000 ml
666 428	1 CPS-Panel frame C 100
661 099	1 Crude oil 1 l
666 583	1 Labjack
667 180	2 Rubber tubings, 1 m
666 467	3 Blank panels, 200 mm
666 464	2 Blank panels, 100 mm
	1 PC (with Windows 98/Me/2000/XP) and free USB port



**668 222**

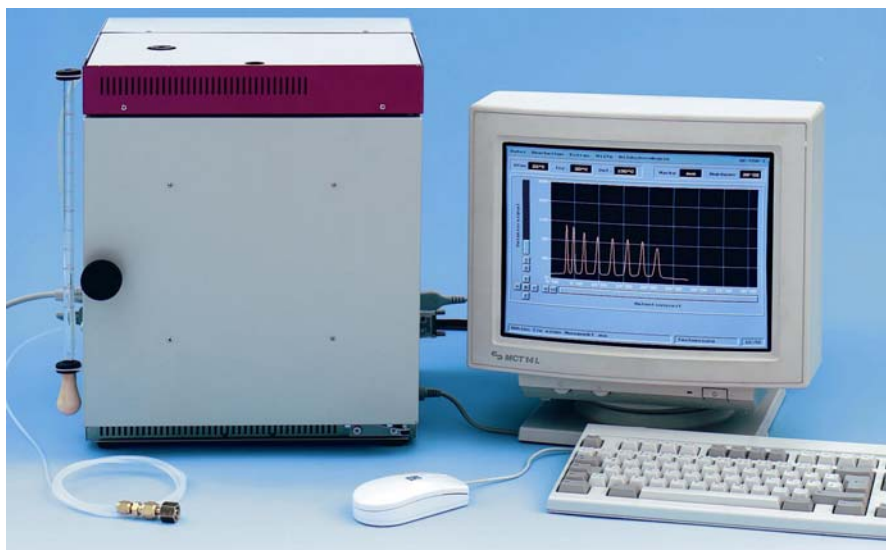
#### From crude oil to fuels and lubricants

74 pages, DIN A4, by K. Biedermann. Six experiments and a detailed theoretical discussion on the composition and processing of crude oil.



This new generation of gas chromatographs is a winner because it combines compact design with high performance. These modern devices are designed for training in schools, universities and industrial-use and offer excellent value for the money.

Gas chromatograph, computer and software are integrated into a single device for carrying out measurements and evaluations. Used in conjunction with definable temperature programs and the automatic amplification switchover, this unit permits analysis to be performed accurately and reliably.



## 665 600 High-performance gas chromatograph with packed column and HDC

### Main features:

- Flame ionization detector (FID), with high sensitivity, low dead volume and high stability
- Integrated operating system and software
- Heat conduction detector (HDC) in heated detector block
- Integrated operating system and software
- Graphics user interface with mouse control for parameter input and conducting measurement and evaluations:
  - determination of retention times and peak areas
  - comparison of two chromatograms
  - referencing, i.e. comparison of reference peaks and measurement peaks for determining absolute quantities
  - report generator
- Automatic baseline calibration before every measurement
- Excellent separation performance with packed columns 2 m long (1/8"); OV-1
- Carrier gas supply via steel gas bottles

### Gas chromatograph:

- Oven chamber: with motor-driven air circulation
- Heating power: max. 400 W
- Temperature sensor: Pt 500
- Temperature control: closed-loop PID control, 4 programmable via integrated computer, complete temperature program with heating speeds between 1 and 10 K/min
- Accuracy: 1 K
- Separately heated injector and detector block
- Carrier gas: helium

### Computer:

- CPU: 16 bit, 20 MHz clock speed
- RAM: 1 MB, EEPROM 512 KB
- Video adapter: VGA-compatible, resolution 640 x 480 pixels
- Mouse, keyboard and printer connectors
- Disk drive: 3.5", 1.44 MB
- Mains voltage: 220...240 V/50...60 Hz
- Dimensions: 33 cm x 42 cm x 34 cm
- Weight: 19 kg

### Scope of delivery:

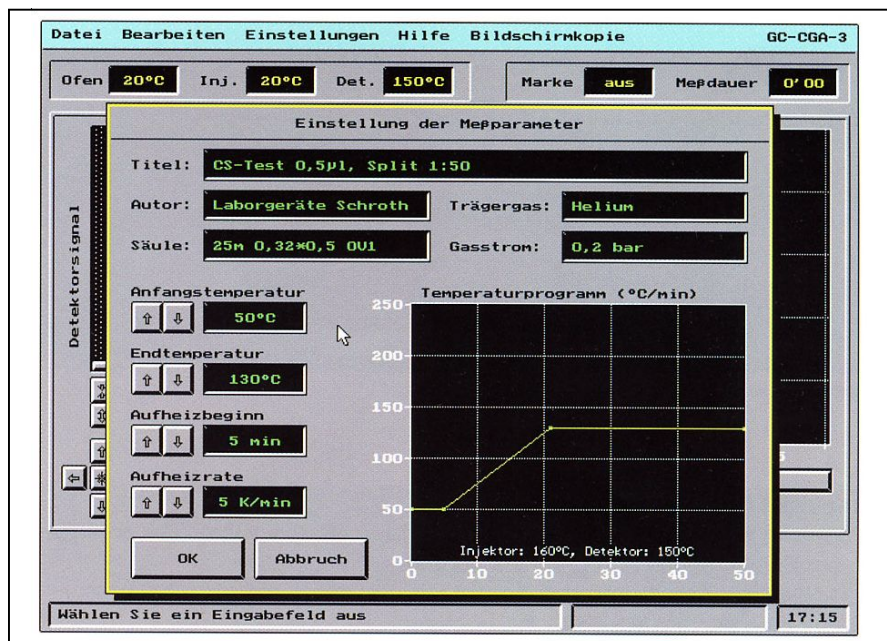
- 1 Gas chromatograph with heat conductivity detector and integrated computer
- 1 Packed separating column
- 1 Soap-bubble flow meter (for adjusting the carrier-gas flow)
- 1 Mouse
- 1 Gas connector set, with Teflon tubing and crimp connectors
- 1 Power lead for gas chromatograph
- 1 User's manual
- 1 Working disk

### Equipment list:

- |           |   |
|-----------|---|
| 665 600 1 | High performance gas chromatograph with packed column and HDC |
| 661 023 1 | Pressure reducing valve for helium                            |
| 665 616 1 | Steel pressure bottle, helium                                 |
| 661 019 1 | Trolley   |
| 665 615 1 | Microliter syringe  |

### Recommended accessories

- |           |  |
|-----------|--|
| 665 616 1 | Replacement canula for 665 515, set of 3 |
| 1         | Computer keyboard                        |
| 1         | VGA screen with connecting cable         |



## Peak allocation and determination of absolute mass using graphic evaluation

The integrated software is easy to use. Not only can you determine retention times and integrate peaks, you can also make direct comparisons with other measurements e.g. standard values. Consequently, measurement peaks can easily be allocated and absolute masses are determined.

The measurements can be saved to floppy disk and/or stored in a database for subsequent evaluations or be exported into other programs, such as Excel or Word for Windows on a separate PC.



## 665 601 High-performance gas chromatograph with capillary column and FID

### Main features:

- Flame ionization detector (FID), with high sensitivity, low dead volume and high stability
- Integrated operating system and software
- Graphical user interface with mouse control for parameter input and conducting measurement and evaluations:
  - determination of retention times and peak areas
  - comparison of two chromatograms
  - referencing, i.e. comparison of reference peaks and measurement peaks for determining absolute quantities
  - report generator
- Automatic baseline calibration before every measurement
- Excellent separation performance with capillary columns, 25 m long, inside diameter 0.32 mm, granular size 0.6 µm, OV-1
- Carrier gas supply via steel gas bottles

### Gas chromatograph:

- Oven chamber: with motor-driven air circulation
- Heating power: max. 400 W
- Temperature sensor: Pt 500
- Temperature control: closed-loop PID control, programmable via integrated computer, complete temperature program with heating speeds between 1 and 10 K/min
- Accuracy: 1 K
- FID gas supply: hydrogen
- Separately heated injector and detector block
- Carrier gas: H<sub>2</sub>, He or N<sub>2</sub>

### Detector:

- FID, with thermostat, electrically isolated microprocessor-controlled evaluation electronics, 12 bit resolution, built-in supply with purified combustion air, cleaned by replacement of activated-charcoal filter

### Computer:

- CPU: 16 bit, 20 MHz clock speed
- RAM: 1 MB, EEPROM 512 KB
- Video adapter: VGA-compatible, resolution 640 x 480 pixels
- Mouse, keyboard and printer connectors
- Disk drive: 3.5", 1.44 MB
- Mains voltage: 220...240 V/50...60 Hz
- Dimensions: 33 cm x 42 cm x 34 cm
- Weight: 19 kg

### Scope of delivery:

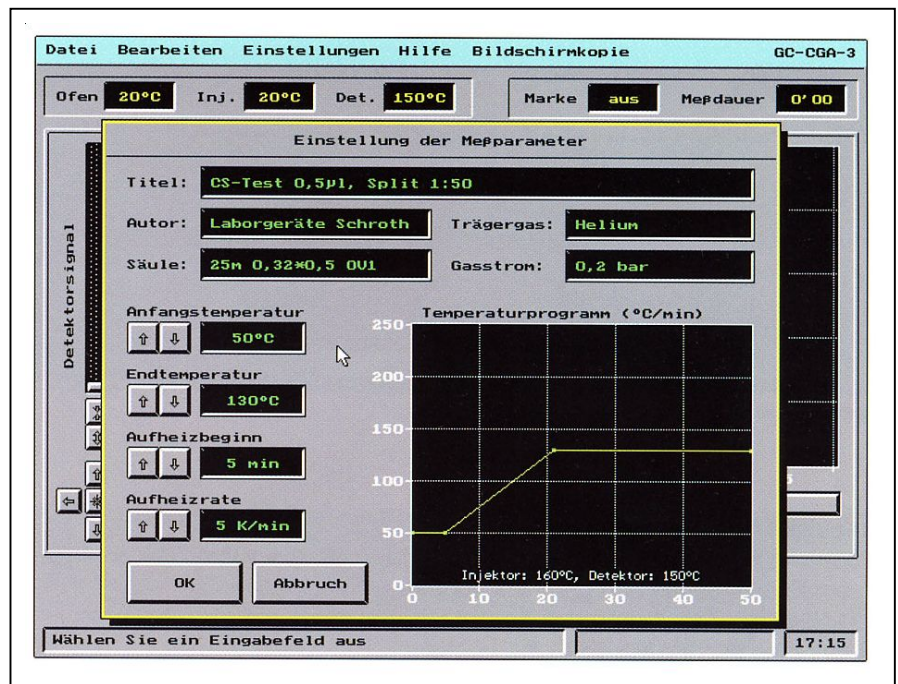
- 1 Gas chromatograph with flame ionization detector and integrated computer
- 1 Capillary separating column
- 1 Soap-bubble flow meter (for adjusting the gas flow)
- 1 Mouse
- 2 Gas connectoin sets, with Teflon tubing and crimp connectors
- 1 T-connector (for connecting a single gas bottle when using hydrogen as the carrier gas and FID supply gas)
- 1 Power lead for gas chromatograph
- 1 User's manual
- 1 Working disk

### Equipment list for 665 601: (Hydrogen used both as carrier gas and FID supply gas)

665 601	1	High-performance gas chromatography unit with capillary column and FID
661 015	1	Pressure reducing valve, hydrogen
661 010	1	Steel pressure bottle, hydrogen
661 019	1	Trolley
665 615	1	Microliter syringe
	1	VGA-Screen with connecting cable

### Recommended accessories:

665 616	1	Replacement canula for 665 615, set of 3
	1	Computer keyboard



### Temperature program which can be set via the graphical user interface

If the boiling temperatures of several components of a sample differ radically from each other, separation at a constant temperature is frequently almost impossible. Only a reproducible, continuous temperature increase in the form of a temperature program permits optimum separation of the sample components. Temperature programs up to 280 °C with heating rates of 1 to 10 °C per minute are possible with these two gas chromatographs.



✓  
✓  
**Compatible  
... all CASSY sensor  
boxes and sensors  
can be used with  
CASSY**

**With  
serial interface  
or USB port**

**Scope of delivery:**

- 1 Sensor-CASSY
- 1 CASSY Lab software, without activation code, with comprehensive help function (20 sessions free, then usable as demo version)
- 1 USB cable
- 1 Plug-in supply unit 12 V/ 1.6 A

**524 010USB Sensor-CASSY® USB**

Cascadable interface for measured-value recording.

- for connection to the USB port of a computer (WINDOWS 98/2000/XP), another CASSY module or the CASSY display
- Sensor-CASSY and Sensor-CASSY USB can be used mixed
- fourfold electrically isolated (inputs A and B, relay R, voltage source S).
- cascading of up to 8 CASSY modules possible (to multiply the inputs and outputs)
- up to 8 analog inputs per Sensor-CASSY retrofittable using sensor boxes
- automatic sensor box detection by CASSY Lab (plug and play) (524 200)
- microprocessor-controlled via the CASSY operating system (complete with software update functionality for fast, easy performance enhancements)
- can be set up as a benchtop, console or demonstration unit (also suitable for CPS/TPS panel frames)
- voltage supply 12 V AC/DC via cannon plug or an adjacent CASSY module

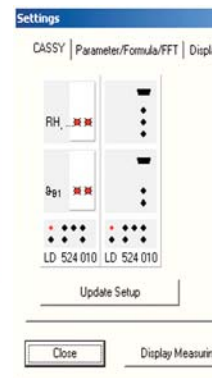
**Note:** also available with serial interface (524 010)

- **5 analog inputs** (any two inputs A and B usable simultaneously)  
**2 analog voltage inputs A and B** on 4-mm safety sockets  
 Resolution: 12 bits  
 Measuring ranges:  $\pm 0.3/1/3/10/30/100$  V  
 Measurement error:  $\pm 1$  % plus 0.5 % of range end value  
 Input resistance: 1 M $\Omega$   
 Scanning rate: max. 200,000 values/s (= 100,000 values/s per input)  
 Number of measured values: nearly unlimited (depends on PC) up to 100 values/s, at higher measuring rate max. 32,000 values (= 16,000 values per input)
- **1 analog current input A** on 4-mm safety sockets  
 Measuring ranges:  $\pm 0.1/0.3/1/3$  A  
 Measurement error: voltage error plus 1 %  
 Input resistance:  $<0.5$   $\Omega$  (except under overload)  
 See voltage inputs for further data
- **2 analog inputs at sensor box connector sites A and B**  
 (All CASSY sensor boxes and sensors can be connected)  
 Measuring ranges:  $\pm 0.003/0.01/0.03/0.1/0.3/1$  V  
 Input resistance: 10 k $\Omega$   
 See voltage inputs for further data  
 The technical data will change according to a connected sensor box. In this case, the CASSY Lab automatically detects the possible measurement quantities and ranges when a sensor box is attached
- **4 timer inputs** with 32-bit counters at sensor box site (e.g. for BMW box, GM box or timer box)  
 Counting frequency: max. 100 kHz; time resolution: 0.25  $\mu$ s  
 Measuring time between two events at same input: min. 100  $\mu$ s  
 Measuring time between two events at different inputs: min. 0.25  $\mu$ s  
 Memory: max. 10,000 time points (= 2,500 values per input)
- **1 changeover relay** (with LED to indicate switching state)  
 Range: max. 100 V / 2 A
- **1 analog output** (PWM-output) (pulse-width modulated, switchable voltage source, LED switching state indicator, e.g. for holding magnet or supplying the experiment)  
 Variable voltage range: max. 16 V / 200 mA (load  $\geq 80$   $\Omega$ )  
 PWM range: 0% (off), 5-95% (1% resolution), 100% (on)  
 PWM frequency: 100 Hz
- **12 digital inputs** (TTL) on sensor box sites A and B (at present only used for automatic sensor box detection)
- **6 digital outputs** (TTL) on sensor box sites A and B (at present only used for automatic switching of the measuring range of a sensor box)
- **1 USB port** for connection to a computer
- **1 CASSY bus** for connecting additional CASSY modules
- Dimensions: 115 mm x 295 mm x 45 mm
- Weight: 1 kg

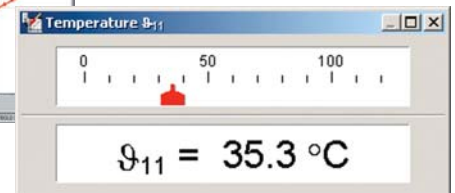
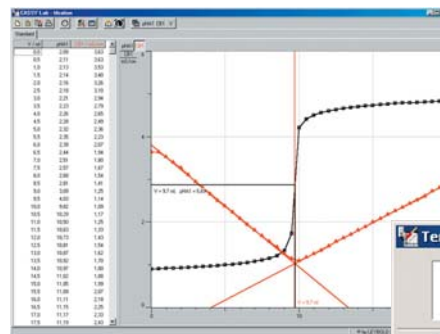
## 524 200 CASSY® Lab

Software for recording and evaluating measurement data acquired using the CASSY family, with comprehensive integrated help functionality.

- supports up to 8 Sensor- and Power-CASSYs on one USB port or serial interface
- supports alternatively up to 8 Pocket-CASSYs or Mobile-CASSYs at different USB ports
- supports all CASSY sensor boxes
- "plug and play" enabled for easy use: the software automatically detects the connected CASSYs and sensor boxes and displays these graphically, inputs and outputs are activated simply by pointing and clicking and typical experiment parameters are automatically loaded (depending on the connected sensor box)
- powerful evaluation functions including various fits (straight line, parabola, hyperbola, exponential function, free fit), integrals, diagram labeling, calculation of user-definable formulas, differentiation, integration, Fourier transforms
- convenient exporting of measurement data and diagrams via the clipboard
- free update at <http://www.leybold-didactic.com>
- graphical display of CASSY, sensor box and connector allocation when the experiment file is loaded
- hardware configuration (serial): Pentium class with Windows 95/98/Me/NT/2000/XP, free serial interface (RS232)
- hardware configuration (USB): Pentium III with Windows 98/Me/2000/XP, free USB port



**Plug and play**  
... automatic detection  
and configuration of  
CASSY and sensor  
boxes



## 524 045 Temperature box (NiCr-Ni, NTC)

For temperature measurement with up to two NiCr-Ni or NTC temperature sensors (666 193 or 666 212).

- Measurement ranges:  
NiCr-Ni: -200 ... +1100 °C  
NTC: -20 ... +120 °C



## 524 202 Software manual for CASSY Lab

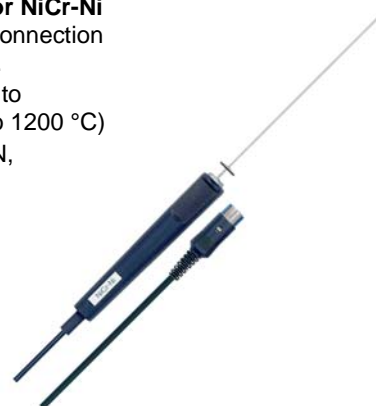
All information on using CASSY Lab, plus all experiment examples, in a single ring binder.



## 666 193 Temperature sensor NiCr-Ni

NiCr-Ni thermocouple. With connection cable (1.5 mm) and DIN plug.

- Measurement range: -200 to +1100 °C, (intermittently to 1200 °C)
- Tolerance classes: 1/3 DIN, (DIN IEC 584 Part 2)
- Diameter: 1.5 mm
- Overall length: 200 mm





# www.ld-didactic.com

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Visit our website for the latest special offers and exciting information about our products. Plus, our Online Center is waiting to help you with technical questions.



**++ 49 (0) 2233 – 604 - 0**

**LD Didactic GmbH**  
**Leyboldstraße 1**  
**D – 50354 Huerth - Germany**

**++ 49 (0) 2233 – 604 - 222**

**info@ld-didactic.de**

**www.ld-didactic.com**

