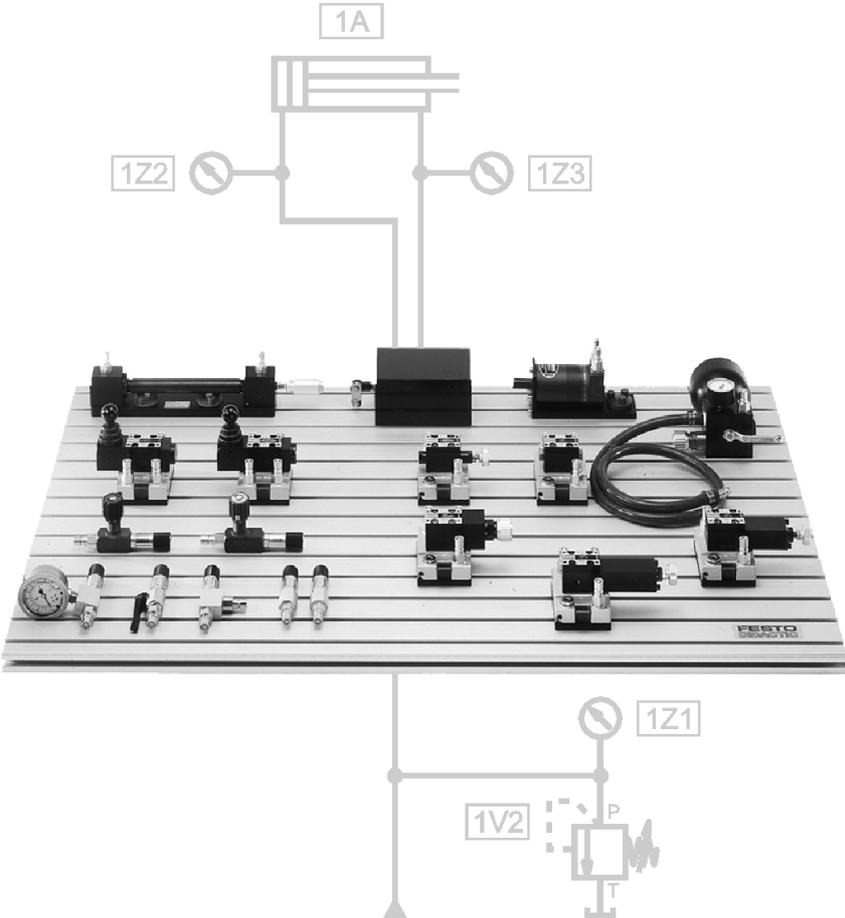


Hydraulics

Workbook Basic Level



FESTO

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Preface

Festo Didactic's Learning System for Automation and Communications is designed to meet a number of different training and vocational requirements. The Festo Training Packages are structured accordingly:

- Basic Packages provide fundamental knowledge on a wide range of technologies.
- Technology Packages deal with important areas of open-loop and closed-loop control technology.
- Function Packages explain the basic functions of automation systems.
- Application Packages provide basic and further training closely oriented to everyday industrial practice.

Technology Packages deal with the technologies of pneumatics, electropneumatics, programmable logic controllers, automation with PCs, hydraulics, electrohydraulics, proportional hydraulics and application technology (handling).

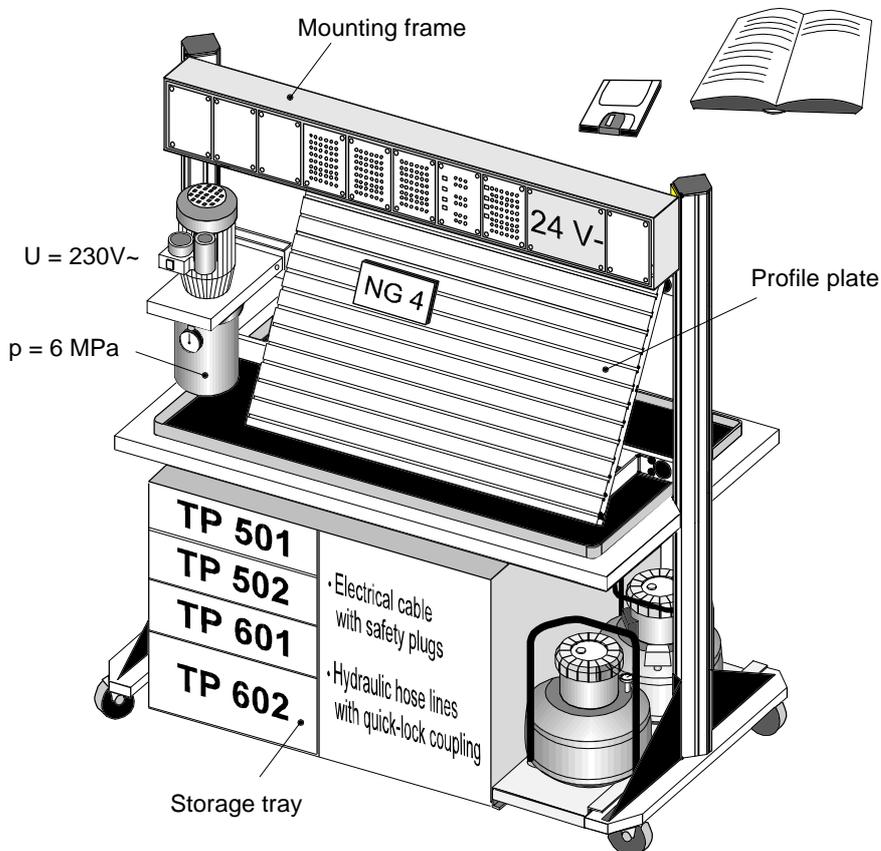


Fig. 1:
Hydraulics 2000 –
i.e. mobile workstation

The modular structure of the Learning System permits applications to be assembled which go beyond the scope of the individual packages. It is possible, for example, to use PLCs to control pneumatic, hydraulic and electrical actuators.

All training packages have an identical structure:

- Hardware
- Courseware
- Software
- Courses

The hardware consists of industrial components and installations, adapted for didactic purposes.

The courseware is matched methodologically and didactically to the training hardware. The courseware comprises:

- Textbooks (with exercises and examples)
- Workbooks (with practical exercises, explanatory notes, solutions and data sheets)
- OHP transparencies and videos (to bring teaching to life)

Teaching and learning media are available in several languages. They have been designed for use in classroom teaching but can also be used for self-study purposes.

In the software field, computer-based training programs and programming software for programmable logic controllers are available.

Festo Didactic's range of products for basic and further training is completed by a comprehensive selection of courses matched to the contents of the technology packages.

Latest information about the technology package **TP501**.

New in Hydraulic 2000:

- Industrial components on the profile plate.
- Exercises with exercise sheets and solutions, leading questions.
- Fostering of key qualifications:
Technical competence, personal competence and social competence form professional competence.
- Training of team skills, willingness to co-operate, willingness to learn, independence and organisational skills.

Aim – **Professional competence**

Content

Part A	Course	Exercises
Part B	Fundamentals	Reference to the text book
Part C	Solutions	Function diagrams, circuits, descriptions of solutions and equipment lists
Part D	Appendix	Storage tray, mounting technology and datasheets

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Introduction

This workbook forms part of Festo Didactic's Learning System for Automation and Communications. The Technology Package "Hydraulics", TP500, is designed to provide an introduction to the fundamentals of hydraulic control technology. This package comprises a basic level and an advanced level. The basic level package TP501 teaches basic knowledge of hydraulic control technology, while the advanced level package TP502 builds on this.

The basic level hydraulic exercises are designed to be carried out with manual actuation. It is, however, also possible to use electrical actuation. The hydraulic components have been designed to provide the following:

- Easy handling
- Secure mounting
- Environmentally-friendly coupling system
- Compact component dimensions
- Authentic measuring methods

We recommend the following for the practical execution of the exercises:

- Hydraulic components: Equipment set TP501
- One hydraulic power pack
- A number of hose lines
- A profile plate or a suitable laboratory trolley
- A measuring set with the appropriate sensors

This workbook provides knowledge of the physical interrelationships and the most important basic circuits in hydraulics. The exercises deal with the following:

- Plotting of characteristics for individual components
- Comparison of the use of different components
- Assembly of various basic circuits
- Use of basic hydraulics equations

The following technical equipment is required for safe operation of the components:

- A hydraulic power pack providing an operating pressure of 60 bar and a flow rate of 2 l/min
- An electrical power supply of 230V AC for the hydraulic power pack
- A power supply unit with an output of 24V DC for solenoid-actuated valves
- A Festo Didactic profile plate for mounting the components

The theoretical background is described in the “Hydraulics Basic Level” textbook TP501. Technical descriptions of the components used are given in the data sheets in Part D of this workbook.

Festo Didactic offers the following further training material for hydraulics:

- Magnetic symbols
- Hydraulics slide rule
- Set of OHP transparencies
- Transparent models
- Interactive video
- Symbol library

Notes on safety



Observe the following in the interests of your own safety:

- Exercise care when switching on the hydraulic power pack. Cylinders may advance unexpectedly!
- Do not exceed the maximum permissible operating pressure (see data sheets).
- Observe all general safety instructions (DIN 58126 and VDE 100).

Notes on operation



Always work in the following sequence when assembling a hydraulic circuit.

1. The hydraulic power pack and electrical power supply must be switched off during the assembly of the circuit.
2. All components must be securely fitted to the profile plate, i.e. securely snap-fitted or bolted down.
3. Check that all return lines are connected and all hose lines are securely fitted.
4. Switch on the electrical power supply first and then the hydraulic power pack.
5. Before dismantling the circuit, ensure that pressure in hydraulic components has been released:

Couplings must be connected and disconnected only under zero pressure!

6. Switch off the hydraulic power pack first and then the electrical power supply.

Technical notes

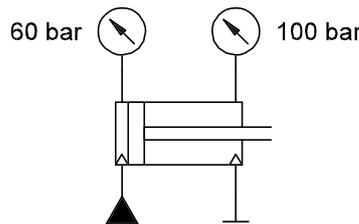
Observe the following in order to ensure safe operation.

- The hydraulic power pack PN 152962 incorporates an adjustable pressure relief valve. In the interests of safety, the pressure is limited to approx. 60 bar (6 MPa).
- The maximum permissible pressure for all hydraulic components is 120 bar (12 MPa).

The operating pressure should not exceed 60 bar (6 MPa).

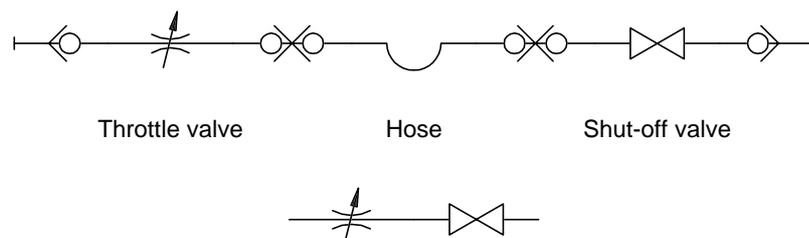
- In the case of double-acting cylinders, the pressure intensification effect may produce an increased pressure proportional to the area ratio of the cylinder. With an area ratio of 1:1.7 and an operating pressure of 60 bar (6 MPa), this increased pressure may be over 100 bar (10 MPa)!

Fig. 2:
Pressure intensification



- If connections are detached under pressure, the non-return valve in the coupling may cause pressure to become trapped in the valve or other component concerned. The pressure relieving device PN 152971 can be used to release this pressure. Exception: This is not possible in the case of hose lines and non-return valves.
- All valves, other components and hose lines are fitted with self-closing quick-release couplings. This prevents the accidental spillage of hydraulic fluid. In the interests of simplicity, these couplings are not shown in circuit diagrams.

Fig. 3:
Simplified drawing of
self-closing couplings



- It is frequently necessary when assembling a control circuit to modify the given circuit diagram. Within the scope of the equipment set in this Training Package, the following alternative solutions are possible:
- Plugs can be used to change the function of directional control valves (Figs. 4 and 5).
- Directional control valves with different normal positions can be used (Fig. 6).
- Solenoid-actuated valves can be used in place of hand lever valves (Fig. 7).

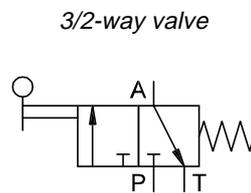
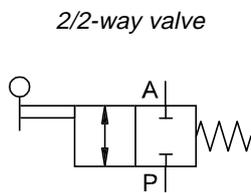


Fig. 4:
Circuit diagram

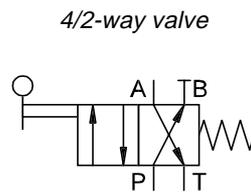
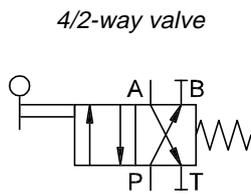


Fig. 5:
Practical assembly

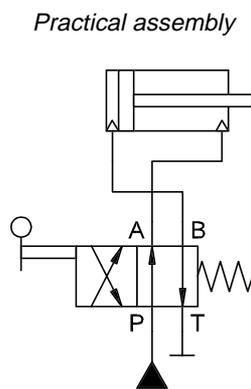
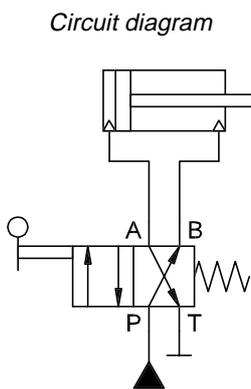


Fig. 6:
Directional control valves
with various
normal positions

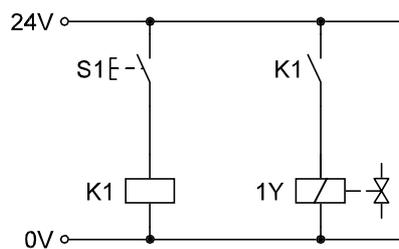
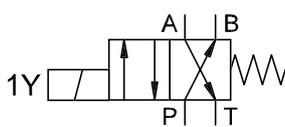


Fig. 7:
Solenoid-actuated
directional control valve

Flow rate sensor

The flow rate sensor consists of:

- A hydraulic motor, which converts the flow rate q into a rotary speed n .
- A tachogenerator, which produces a voltage V proportional to the rotary speed n .
- A universal display unit, which converts the flow rate q into l/min. The universal display should be set to sensor no. 3 for this purpose.

Fig. 8:
Block circuit diagram

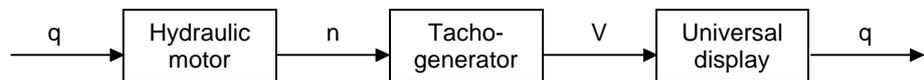
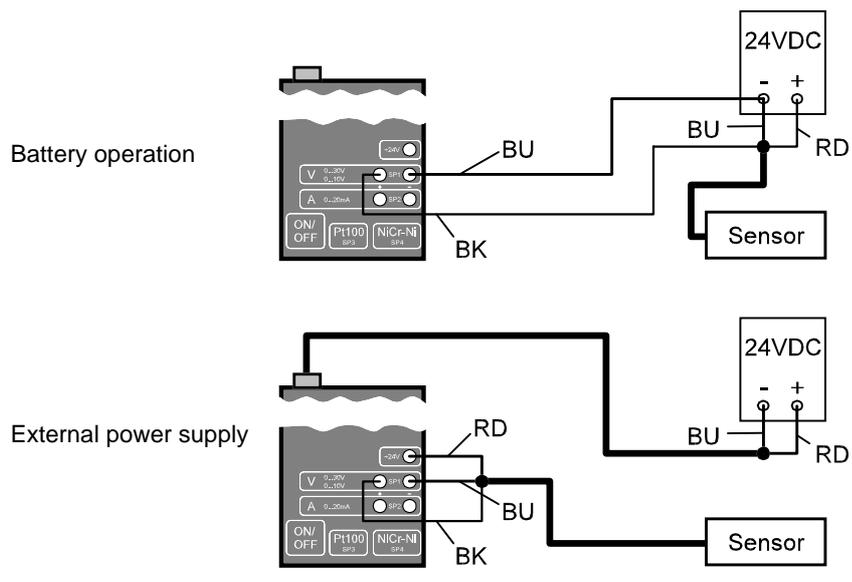


Fig. 9:
Circuit diagrams,
hydraulic and electrical



Fig. 10:
Connecting up the
universal display



Training contents

- Characteristics of valves and other components.
- Uses of individual valves and other components.
- Comparison of uses and functions of different valves and other components.
- Measurement of variables such as pressure, flow rate and time.
- Control of pressure and speed.
- Calculations of area ratios, forces, power and speed.
- Basic physical principles of hydraulics.
- Use of basic hydraulics equations.
- Understanding and drafting of circuit diagrams.
- Drafting of displacement/step diagrams.
- Use of symbols in accordance with DIN/ISO 1219.
- Assembly and commissioning of control circuits, including fault-finding.
- Assessment of energy consumption.
- Basic hydraulic circuits such as a pressure sequence circuit, a bypass circuit to the pump, a differential circuit, circuits with flow control valves in the inlet, outlet and bypass, circuits with counter-holding and bypass circuits with a non-return valve.

List of training aims

<i>Exercise</i>	<i>Training aims</i>
1	Drawing a pump characteristic.
2	Drawing a characteristic for a pressure relief valve.
3	Measuring flow resistances.
4	Application of a non-return valve. Use of a 2/2-way valve to control a single-acting cylinder.
5	Application of a 3/2-way valve. Determination of times
6	Application of a 4/2-way valve. Determination of times
7	Application of a 4/3-way valve. Use of a pilot-operated non-return valve.
8	Use of a hydraulic accumulator as a power source. Use of accumulator to power advance and return strokes of cylinder after pump is switched off.
9	Application of a 2-way flow control valve. Assembly of a counter-pressure circuit.
10	Plotting of characteristic for a 2-way flow control valve. Comparison between this valve and a throttle valve.
11	Application of a one-way flow control valve. Difference between flow control valve and throttle valve on the basis of a concrete application.
12	Design and mode of operation of a differential circuit. Influence of piston areas on pressures
13	Design of a control circuit with reduced output pressure. Explanation of mode of operation of a 3-way pressure regulator.
14	Hydraulic clamping with a double-acting cylinder. Comparison of circuits with and without counter-holding.
15	Speed control circuit with tractive load. Comparison of circuits with flow control valves in the inlet line and outlet line respectively.
16	Circuit for a double-acting cylinder with a varying load.
17	Specification of pressure for a double-acting cylinder. Choice of either a pressure relief valve or a pressure regulator
18	Pressure sequence circuit. Drawing of a displacement/step diagram
19	Calculation of forces associated with a double-acting cylinder Calculation of advance-stroke time of a cylinder piston.
20	Electrohydraulic control circuit.

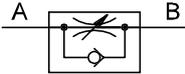
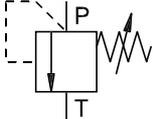
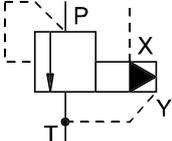
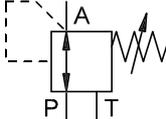
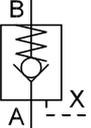
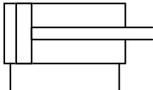
Equipment set for “Hydraulics Basic Level”

<i>Description</i>	<i>Order No.</i>	<i>Qty.</i>
Pressure gauge	152841	3
Throttle valve	152842	1
One-way flow control valve	152843	1
Shut-off valve	152844	1
Non-return valve, opening pressure 1 bar	152845	1
Non-return valve, opening pressure 5 bar	152846	1
Branch tee	152847	7
Pressure relief valve	152848	1
Pressure relief valve, piloted	152849	1
Pressure regulator	152850	1
Flow control valve	152851	1
Non-return valve, hydraulically piloted	152852	1
Double-acting cylinder	152857	1
Hydraulic motor	152858	1
Diaphragm accumulator	152859	1
Loading weight, 9 kg	152972	1
4/2-way hand lever valve	152974	1
4/3-way hand lever valve, recirculation mid-position	152977	1

TP501, PN 080246

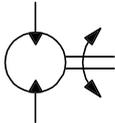
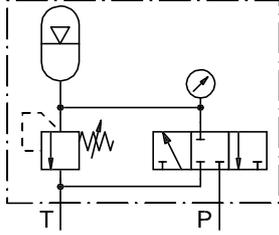
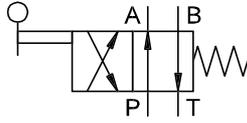
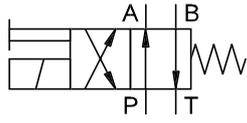
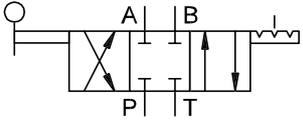
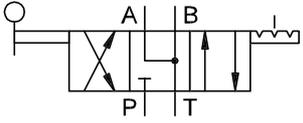
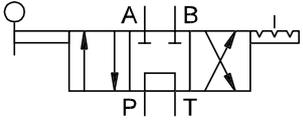
<i>Additional equipment</i>	<i>Description</i>	<i>Order No.</i>	<i>Qty.</i>
	Stop-watch	151504	1
	4/3-way hand lever valve, closed in mid-position	152975	1
	4/3-way hand lever valve, relieving mid-position	152976	1
	Relay, 3-fold	162241	1
	Signal input unit, electrical	162242	1
	Flow-rate sensor	183736	1
	4/2-way solenoid valve	167082	1
	4/3-way solenoid valve, closed in mid-position	167083	1
	4/3-way solenoid valve, relieving mid-position	167084	1
	4/3-way solenoid valve, recirculating mid-position	167085	1
	Universal display	183737	1
	Pressure sensor	184133	1

<i>Accessories</i>	<i>Description</i>	<i>Order No.</i>	<i>Qty.</i>
	Profile plate, large	159411	1
	Schlauchleitung, 600 mm	152960	12
	Hydraulik-Aggregat	152962	1
	Hose line, 1000 mm	152970	4
	Pressure relieving device	152971	1
	Protective cover (for weight, 9kg)	152973	1
	Power supply unit, 24 V, 4.5 A	162417	1
	Cable set with safety plugs	167091	1

Description	Symbol
Pressure gauge	
Throttle valve	
One-way flow control valve	
Shut-off valve	
Non-return valve	
Branch tee	
Pressure relief valve	
Pilot-operated pressure relief valve	
Pressure regulator	
Flow control valve	
Piloted non-return valve	
Double-acting cylinder	

Symbols for equipment set TP501

*Symbols for
equipment set TP501*

<i>Description</i>	<i>Symbol</i>
Hydraulic motor	
Diaphragm accumulator, detailed	
Diaphragm accumulator, simplified	
Weight	
4/2-way hand lever valve	
4/2-way solenoid valve	
4/3-way hand lever valve, closed in mid-position	
4/3-way hand lever valve, relieving mid-position	
4/3-Wege-Handhebelventil mit Umlaufstellung	

Description	Symbol
4/3-way solenoid valve, closed in mid-position	
4/3-way solenoid valve, relieving mid position	
4/3-way solenoid valve, recirculating mid-position	
Hose line	
Hydraulic-power pack, detailed	
Hydraulic power pack, simplified	
Pressure sensor	
Flow rate sensor	
Hydraulic motor with tachogenerator	

Symbols for equipment set TP501

Component / exercise table for TP 501

Description	Exercises																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pressure gauge	1	1	3	1	3	1	1	2	5	3	5	3	4	3	3	3	3	2		
Throttle valve			1							1										
One-way flow control valve								1			1		1	1						
Shut-off valve	1	1	1	1			1		1	1	1	1	1	1	1		1	1		
Non-return valve, 1 bar								1	1		1		1	1	1	1		1		
Non-return valve, 5 bar				1	1				1							1	1		1	
Branch tee		2	3	4	3	2	3	3	6	2	4	4	5	4	4	4	5	7		2
Pressure relief valve *)		1	2	1	1	1	1	1	2	2	2	1	1	2	2	3	2	3		1
Pressure relief valve, piloted		(1)	(1)						(1)	(1)	(1)			(1)	(1)	(1)	(1)	(1)		
Pressure regulator													1				1			
Flow control valve			1						1	1		1			1			1		
Piloted non-return valve							1													1
Cylinder, double-acting				1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Hydraulic motor																			1	
Diaphragm accumulator								1												
Weight				1	1										1	1				
4/2-way hand lever valve			1		1	1		1			1	1		1						
4/3-way hand lever valve recirculating mid-position			1				1		1				1		1	1	1	1		
Hydraulic power pack	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hose line, 600 mm	3	5	5	6	5	4	7	5	9	4	12	5	12	10	11	8	5	12		4
Hose line, 1000 mm			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	4		2
Stop-watch					1	1	1		1		1	1		1	1					
Pressure sensor			(2)			2	2													
Flow-rate sensor	1	1	1							1									1	
Universal display	1	1	1							1									1	
Power supply unit	1	1	1							1									1	1

*) If a sufficient number of directly-controlled pressure relief valves is not available, the pilot-operated pressure relief valve can also be used.

Electrical equipment for exercise 20

<i>Description</i>	<i>Order No.</i>	<i>Qty.</i>
4/3-way solenoid valve, relieving mid-position	167084	1
Signal input unit, electrical	162242	1
Relay, 3-fold	162241	1
Cable set	167091	1

The exercises appear in Section A of the workbook, with solutions to these in Section C. The methodological structure is the same for all exercises.

Methodological structure of exercises

The exercises in Section A are structured as follows:

- Subject
- Title
- Training aim(s)
- Problem definition
- Exercise
- Positional sketch

A worksheet then follows for use in carrying out the exercise.

The solutions in Section C contain the following:

- Hydraulic circuit diagram
- Practical assembly
- Component list
- Solution description
- Evaluation
- Conclusions