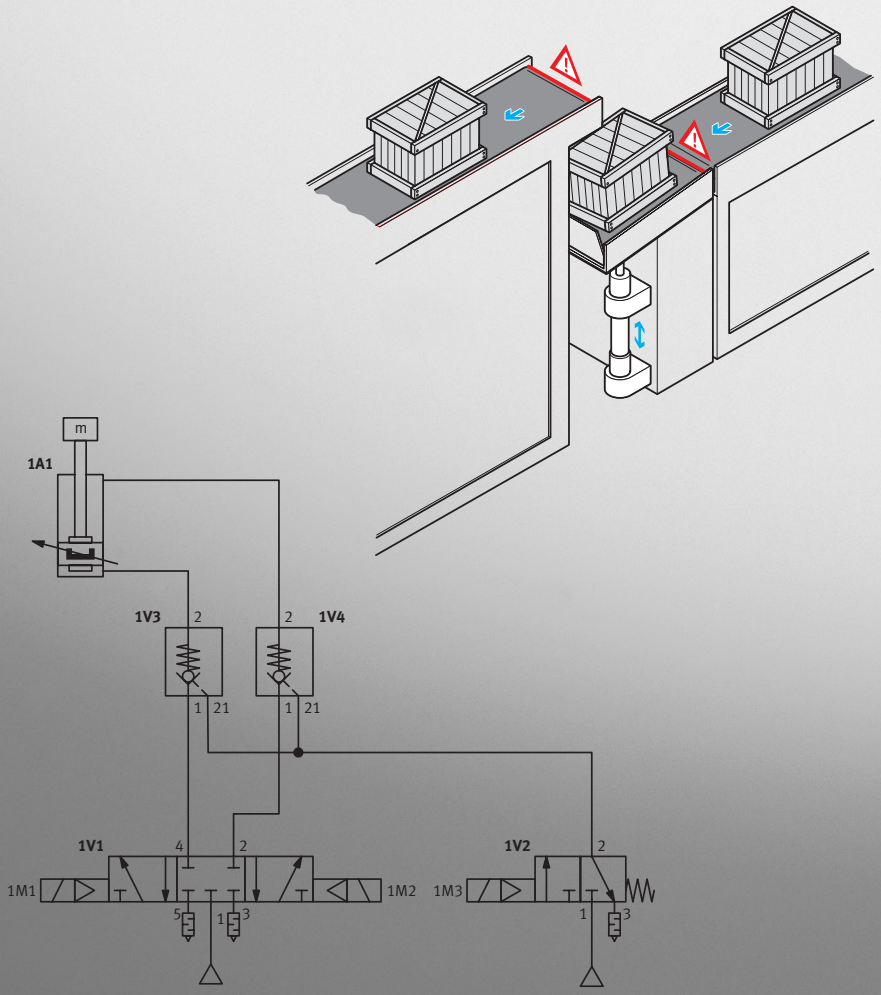
Safety in pneumatic systems

FESTO

Workbook
TP 250

CD-ROM included



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Basics: safety in pneumatic systems

Use for intended purpose

The training package for safety in pneumatic systems may only be used:

- For its intended purpose in teaching and training applications
- When its safety functions are in flawless condition

The components included in the training package are laid out in accordance with the latest technology, as well as recognised safety rules. However, life and limb of the user and third parties may be endangered, and the components may be impaired, if they are used improperly.

The training system from Festo Didactic has been developed and manufactured exclusively for training and vocational education in the fields of automation and technology. The respective training companies and/or trainers must ensure that all trainees observe the safety precautions which are described in this workbook.

Festo Didactic hereby excludes any and all liability for damages suffered by trainees, the training company and/or any third parties, which occur during use of the equipment set in situations which serve any purpose other than training and/or vocational education, unless such damages have been caused by Festo Didactic due to malicious intent or gross negligence.

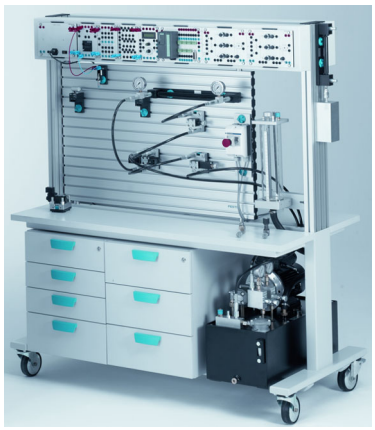
Preface

Festo Didactic's learning system for automation and technology is geared towards various educational backgrounds and vocational requirements. Correspondingly, the training system is broken down as follows:

- Technology oriented training packages
- Mechatronics and factory automation
- Process automation and control technology
- Mobile robotics
- Hybrid learning factories

The training system for automation and technology is continuously updated and expanded in accordance with developments in the field of education, as well as actual professional practice.

The technology packages deal with various technologies including pneumatics, electro-pneumatics, hydraulics, electro-hydraulics, proportional hydraulics, programmable logic controllers, sensor technology, electrical engineering, electronics and electric drives.



The modular design of the training system allows for applications which go above and beyond the limitations of the individual training packages. For example, PLC actuation of pneumatic, hydraulic and electric drives is possible.

All training packages are comprised of the following elements:

- Hardware
- Media
- Seminars

Hardware

Hardware included in the training packages consists of industrial components and systems that are specially designed for training purposes. The selection and design of the components encompassed by the training packages are especially well matched to the projects included in the accompanying media.

Media

The media provided for the individual groups of topics are allocated to the teachware and software categories. The practically oriented teachware includes:

- Technical books and textbooks (standard works for imparting basic knowledge)
- Workbooks (practical exercises with supplementary instructions and sample solutions)
- Lexicons, manuals, technical books (which provide technical information on groups of topics for further exploration)
- Transparency sets and videos (for easy-to-follow, dynamic instruction)
- Posters (for clear-cut representation of facts)

From the software category, programmes are made available for the following applications:

- Digital training programmes (didactically and medially prepared learning content)
- Simulation software
- Visualisation software
- Software for measurement data acquisition
- Project engineering and design engineering software
- Programming software for programmable logic controllers

The teaching and learning media are available in several languages. They are intended for use in classroom instruction, but are also suitable for self-study.

Seminars

Comprehensive seminar offerings covering the contents of the training packages round out the programme for training and vocational education.

Do you have suggestions or criticism regarding this manual?

If so, send us an e-mail at did@de.festo.com.
The authors and Festo Didactic look forward to your feedback.

Introduction

This workbook is part of the training system for automation technology from Festo Didactic GmbH & Co. KG. The system provides a solid basis for practice oriented training and vocational education. The TP 205 training package for safety in pneumatic systems coves the following topics:

- Pneumatic safety circuits
- Electrical safety circuits
- Use of safety switching devices
- Use of a safety door

The workbook for TP 250, safety in pneumatic systems, provides an introduction to the issue of safe machines. Emphasis is placed upon imparting knowledge regarding basic pneumatic and electrical circuits which are used to increase safety in electro-pneumatic controllers. A Learnline laboratory workstation with compressed air supply must be available in order to set up the circuits.

As a prerequisite for using the TP 250 supplementary equipment set, components from the equipment sets TP 101 (fundamentals of pneumatics) and TP 201 (fundamentals of electro-pneumatics) must be available. The circuits for the 8 exercises targeted at increasing the safety of the pneumatic section of a lift and use of electrical safety switching devices are set up with equipment set TP 205. The theoretical fundamentals are an essential part of this workbook.

Work and safety instructions

General

- Trainees may only work with the controllers under the supervision of a trainer.
- Observe specifications included in the data sheets for the individual components, and in particular all safety instructions!

Mechanical system

- Mount all of the components securely onto the slotted profile plate.
- Limit switches may not be actuated frontally.
- Danger of injury during troubleshooting!
  Use a tool to actuate the limit switches, for example a screwdriver.
- Only reach into the setup when it's at a complete standstill.

Electrical specifications

- Electrical connections may only be established and interrupted in the absence of voltage!
- Use connector cables with safety plugs only for electrical connections.
- Use low voltage only (max. 24 V DC).

Pneumatics

- Do not exceed the maximum permissible pressure of 600 kPa (6 bar).
- Do not activate compressed air until all of the tubing connections have been completed and secured.
- Do not disconnect tubing while under pressure.
- Danger of injury when switching compressed air on!
  Cylinders may advance and retract automatically.
- Danger of accident due to tubing slipping off!
  - Use shortest possible tubing connections.
  - Wear safety glasses.
  - In the event that tubing slips off:
    Switch compressed air supply off immediately.
- Pneumatic circuit setup:
  Connect the devices with plastic tubing with an outside diameter of 4 or 6 mm. Push the tubing into the push-in connector as far as it will go.
- Switch compressed air supply off before dismantling the circuit.
- Pneumatic circuit dismantling:
  Press the blue release ring down, after which the tubing can be pulled out.

The mounting boards for the components are equipped with mounting variant A, B or C:

Variant A, snap-in system
Lightweight components that are not load-bearing (e.g. directional control valves). Simply clip the components into the slot on the profile plate. Release the components from the slots by turning the blue lever.

Variant B, bolt system
Components with medium load capacity (e.g. actuators). These components are clamped onto the profile plate using T-head bolts. The blue, knurled nut is used for clamping and loosening.

Variant C, screw system
For components with high load capacity and components which are seldom removed from the profile plate (for example on-off valve with filter regulator). The components are secured with socket head screws and T-head bolts.

Observe specifications in the data sheets regarding the individual devices.

A stopwatch is required in order to evaluate the controllers after setting them up. The stopwatch is used to:
- Adjust the one-way flow control valves such that cylinder stroke times comply with the specified values
- Adjust time delay valves

Training package for safety in pneumatic systems (TP 250)

The TP 250 training package consists of a multitude of individual training materials. The subject of this part of the TP 250 training package is safety technology.

Important components of TP 250

- Permanent workstation with Festo Didactic slotted profile plate
- Compressor (230 V, 0.55 kW, max. 800 kPa = 8 bar)
- Equipment sets or individual components (e.g. cylinders, directional control valves, preset counters, stepper modules, logic components, pneumatic proximity switches)
- Optional learning materials (e.g. optical displays, 5/3-way valve, pulling/pushing load)
- Practical training models
- Complete laboratory setups

Media

The teachware for the TP 250 training package consists of a workbook and a book of exercises. The workbook includes exercise sheets for each exercise, the solutions to each individual worksheet and a CD-ROM. A set of ready-to-use exercise sheets and worksheets is included in each workbook for all of the exercises.

Data sheets for the hardware components are made available along with the equipment set.

Training documentation	
Textbooks	Pneumatics Electropneumatics Fundamentals
Workbooks	Safety in pneumatic systems
Optional teachware	FluidSIM® pneumatic simulation software Web-based training for safety technology

Seminars	
SEP-PILZ	Safe pneumatic and electrical design of machines and equipment
P141	Safe circuit technology for maintenance personnel
SAFETY-AL	Safety relevant circuits in pneumatics and electro-pneumatics for vocational training
SAFETY2	Safety in pneumatics and electro-pneumatics for design engineers
SAFETY3	Laying out safety circuits in accordance with DIN EN ISO 13 849-1 with the help of SISTEMA software

Please refer to the current seminar schedule for event locations, dates and prices.

You'll find further training materials in our catalogue and on the Internet. The training system for automation technology is continuously updated and expanded. Transparency sets, videos, CD-ROMs and DVDs, as well as textbooks, are offered in several languages.

Learning objectives

Learning objectives

- Be able to select the most important standards for the safety of a machine.
- Be able to conduct a risk assessment for a simple machine.
- Gain experience in setting up and commissioning a lift.
- Gain experience in recognising points of danger at the lift and sketching them into the layout drawing.
- Gain experience in reducing hazards associated with the lift.
- Gain experience in assuring safe, optimised operation of the no-load and working strokes.
- Know how to safeguard implemented safety measures from manipulation.
- Be able to reduce risk by regulating speed.
- Be able to name possible disadvantages associated with the use of the lift.
- Gain experience in recognising, executing and ideally adjusting the required changes to the lift.
- Gain experience in selecting an emergency stop function which is appropriate for the lift.
- Be familiar with various ways of implementing this function.
- Be able to set up a 2-channel pneumatic emergency stop function.
- Be able to integrate a safety mushroom actuator into the electrical controls.
- Be able to properly restart operation.
- Be able to indicate the emergency stop status of a system.
- Be able to determine how a system should perform in the event that compressed air supply should fail.
- Be able to make use of sensors for detecting compressed air supply failure.
- Be able to assure safe reactivation of compressed air supply.
- Be familiar with required system performance in the event of electrical power failure.
- Be able to make use of suitable valves in order to assure a safe emergency stop status for a system.
- Be able to make use of a safety switching device and be familiar with its mode of operation.
- Be able to indicate the operating state of the lift.
- Be able to detect overloads by means of condition monitoring.
- Be able to implement suitable measures for eliminating the cause.
- Be familiar with additional ways of triggering an emergency stop.
- Be able to increase the performance level of the lift by increasing its diagnostic coverage.
- Be able to integrate an additional component into the system in order to increase safety.
- Be familiar with additional ways of triggering an emergency stop.

Allocation of learning objectives to exercises

Exercise / Learning objectives	1	2	3	4	5	6	7	8
Be able to select the most important standards for the safety of a machine.	•							
Be able to conduct a risk assessment for a simple machine.	•							
Gain experience in setting up and commissioning a lift.	•							
Gain experience in recognising points of danger at the lift and sketching them into the layout drawing.		•						
Gain experience in reducing hazards associated with the lift.		•						
Gain experience in assuring safe, optimised operation of the no-load and working strokes.		•						
Know how to safeguard implemented safety measures from manipulation.			•					
Be able to reduce risk by regulating speed.			•					
Be able to name possible disadvantages associated with the use of the lift.			•					
Gain experience in recognising, executing and ideally adjusting the required changes to the lift.			•					
Gain experience in selecting an emergency stop function which is appropriate for the lift.				•				
Be familiar with various ways of implementing this function.				•				
Be able to set up a 2-channel pneumatic emergency stop function.				•				
Be able to integrate a safety mushroom actuator into the electrical controls.				•				

Exercise Learning objectives	1	2	3	4	5	6	7	8
Be able to properly restart operation.				•				
Be able to indicate the emergency stop status of a system.				•				
Be able to determine how a system should perform in the event that compressed air supply should fail.					•			
Be able to make use of sensors for detecting compressed air supply failure.					•			
Be able to assure safe reactivation of compressed air supply.					•			
Be familiar with required system performance in the event of electrical power failure.						•		
Be able to make use of suitable valves in order to assure a safe emergency stop status for a system.						•		
Be able to make use of a safety switching device and be familiar with its mode of operation.						•		
Be able to indicate the operating state of the lift.						•		
Be able to detect overloads by means of condition monitoring.							•	
Be able to implement suitable measures for eliminating the cause.							•	
Be able to integrate an additional component into the system in order to increase safety.								•
Be familiar with additional ways of triggering an emergency stop.								•

Equipment set

The workbook for safety in pneumatic systems imparts knowledge for improving safety by means of pneumatic circuits, as well as through the use of special pneumatic components, electrical safety switching devices and a safety door.
The TP 250 equipment set for safety in pneumatic systems includes the components which are necessary for mastering the predefined learning objectives. Components from the TP 101 and TP 201 equipment set plus a Learnline laboratory workstation are required in order to set up the circuits.

TP 250 equipment set for safety in pneumatic systems, order number 567264

Component	Order no.	Quantity
Air reservoir, 0.1 litres	573281	1
Non-return valve, piloted non-return function	540715	2
5/3-way solenoid valve, normally closed	567201	1
Non-return valve	153462	1
Weight for cylinder, 2 kg	572778	1
Cylinder cover	572777	1
Operating mode indicator	567263	1
Safety mushroom actuator	567261	1
Safety switching device for emergency stop and safety door	567262	1

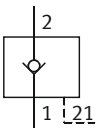
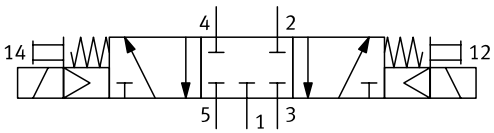
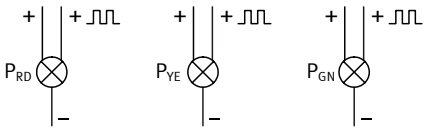
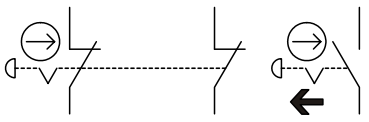
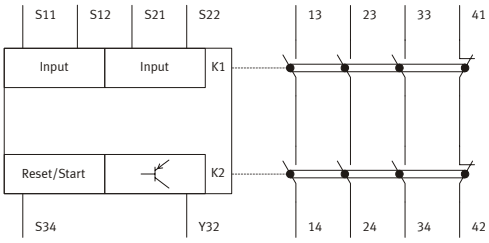
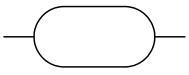
Components required from the TP 201 equipment set for electro-pneumatics, basic level 540712

Component	Order no.	Quantity
Signal input, electrical	162242	1
Relay, 3-off	162241	2
Electrical limit switch, actuated from left	183322	1
Electrical limit switch, actuated from right	183345	1
2 x 3/2-way solenoid valve with LED, normally closed	567198	1
5/2-way solenoid valve with LED	567199	1
Pressure sensor with display	572745	1
One-way flow control valve	193967	1
Double-acting cylinder	152888	1
Electronic proximity switch with cylinder mounting	540695	2
On-off valve with filter-regulator	540691	1
Distributor block	152896	1
Plastic tubing, 4 x 0.75, silver, 10 m	151496	1

Components required from the TP 101 equipment set for pneumatics, basic level 540710

Component	Order no.	Quantity
Pressure regulator with pressure gauge	539756	1

Graphic symbols, equipment set

Component	Graphic symbol
Non-return valve, piloted non-return function	
5/3-way solenoid valve, normally closed	
Non-return valve	
Weight for cylinder, 2 kg	
Operating mode indicator	
Safety mushroom actuator	
Safety switching device for emergency stop and safety door	
Air reservoir, 0.1 litres	

Allocation of components to exercises

Exercise	1	2	3	4	5	6	7	8
Double-acting cylinder	1	1	1	1	1	1	1	1
Weight for cylinder, 2 kg	1	1	1	1	1	1	1	1
On-off valve with filter-regulator	1	1	1	1	1	1	1	1
Distributor block	1	1	1	1	1	1	1	1
Electronic proximity switch with cylinder mounting	2	2	2	2	2	2	2	2
Signal input, electrical	1	1	1	1	1	1	1	1
Relay, 3-off	1	1	1	2	2	2	2	2
5/2-way solenoid valve with LED	1	1	1					
Pressure regulator with pressure gauge		1	1	1	1	1	1	1
One-way flow control valve			2	2	2	2	2	2
Non-return valve, piloted non-return function				2	2	2	2	2
2 x 3/2-way solenoid valve with LED, normally closed				1	1	1	1	1
5/3-way solenoid valve, normally closed				1	1	1	1	1
Safety mushroom actuator				1	1	1	1	
Pressure sensor with display					1	1	1	1
Air reservoir, 0.1 litres					1	1	1	1
Non-return valve					1	1	1	1
Safety switching device						1	1	1
Cylinder cover								1
Electrical limit switch, actuated from left								1
Electrical limit switch, actuated from right								1
Operating mode indicator						1	1	1

Notes for the teacher/trainer

Learning objectives
The basic learning objective of this workbook is to continuously increase safety for an electro-pneumatic system. This knowledge is gained by means of theoretical questions and by actually setting up the circuits. This direct interaction involving both theory and practice ensures faster progress and longer-lasting learning. The more specific learning objectives are documented in a matrix. Concrete, individual learning objectives are assigned to each exercise.

Required time
The time required for working through the exercises depends on the learner's previous knowledge of the subject matter. A time of roughly 1 to 1½ hours can be assumed for each exercise.

Equipment set components
The workbook and the equipment set are matched to each other. You will need components from equipment sets TP 101, TP 201 and TP 250 for the eight exercises.

Standards
The following standards are used in this workbook:

DIN EN ISO 12100:	Safety of machinery
DIN EN 983	Safety requirements for fluid power systems and their components – Pneumatics
DIN EN 1037	Prevention of unexpected start-up
DIN EN ISO 13 849-1	Safety-related parts of a control system – Basic concepts

Identification within solutions
Solution texts and supplements in graphics or diagrams appear in red.

Identification within the working sheets
Texts which require completion are identified with a grid or grey table cells.
Graphics which require completion include a grid.

Training notes
Solutions for the circuit diagrams for all exercises can be found on the included CD-ROM in the "Circuit diagrams" folder as PDF files. Comprehensive circuit diagrams, provided as solutions and as exercises for trainees, are also available in A3 format for better legibility.

Exercise 1
Commissioning and risk assessment for a lift

Learning objectives

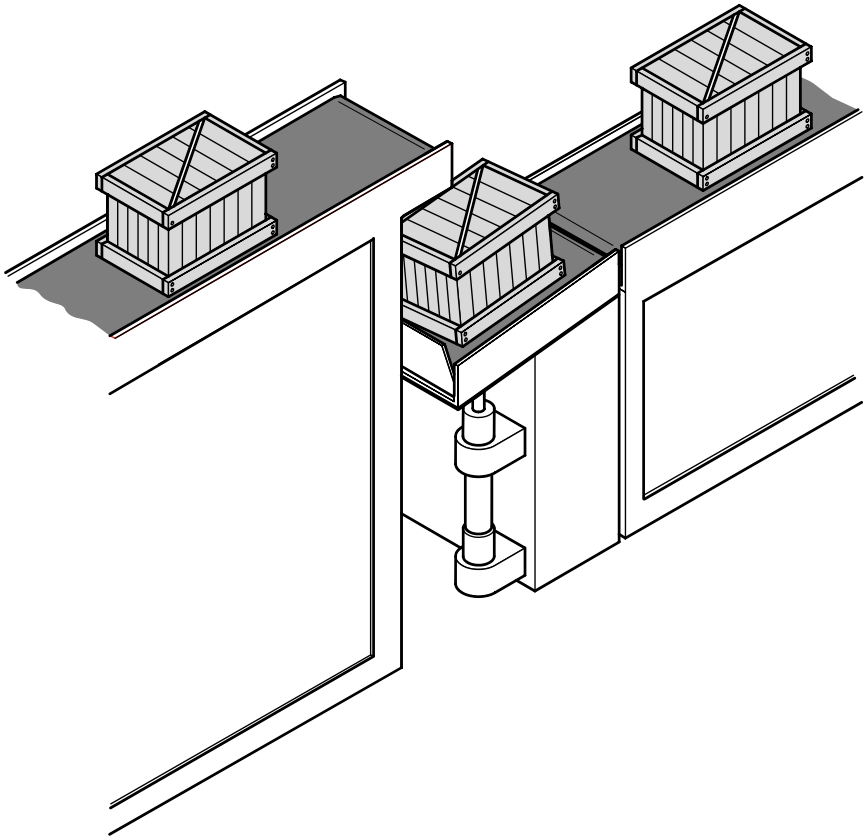
After completing this exercise:

- You will be able to select the most important standards for the safety of a machine.
- You will be able to conduct a risk assessment for a simple machine.
- You will be experienced in setting up and commissioning a lift.
- You will be experienced in recognising points of danger at the lift and sketching them into the layout drawing.

Problem description

You need to set up, commission and assess a lift, and assure its safe design. Due to the fact that the lift will be used in production, you are obligated to examine it in light of applicable safety directives, and to minimise hazards during its use.

Layout



Lift

Prerequisites

- Equipment sets TP 250, TP 201 and a laboratory trolley with slotted profile plate must be available.

Assignments

1 Select standards which deal with safety technology and safety concepts.
2 Set up the lift and place it into service.
3 Complete a risk analysis for the system.
4 Determine possible technical means in order to reduce danger resulting from the machine.

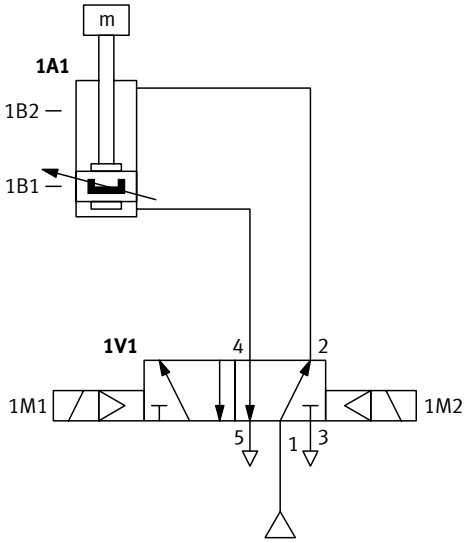
1 Selecting standards regarding safety technology

a) Select the standards which apply to machines. Tick the appropriate standards in the table below.

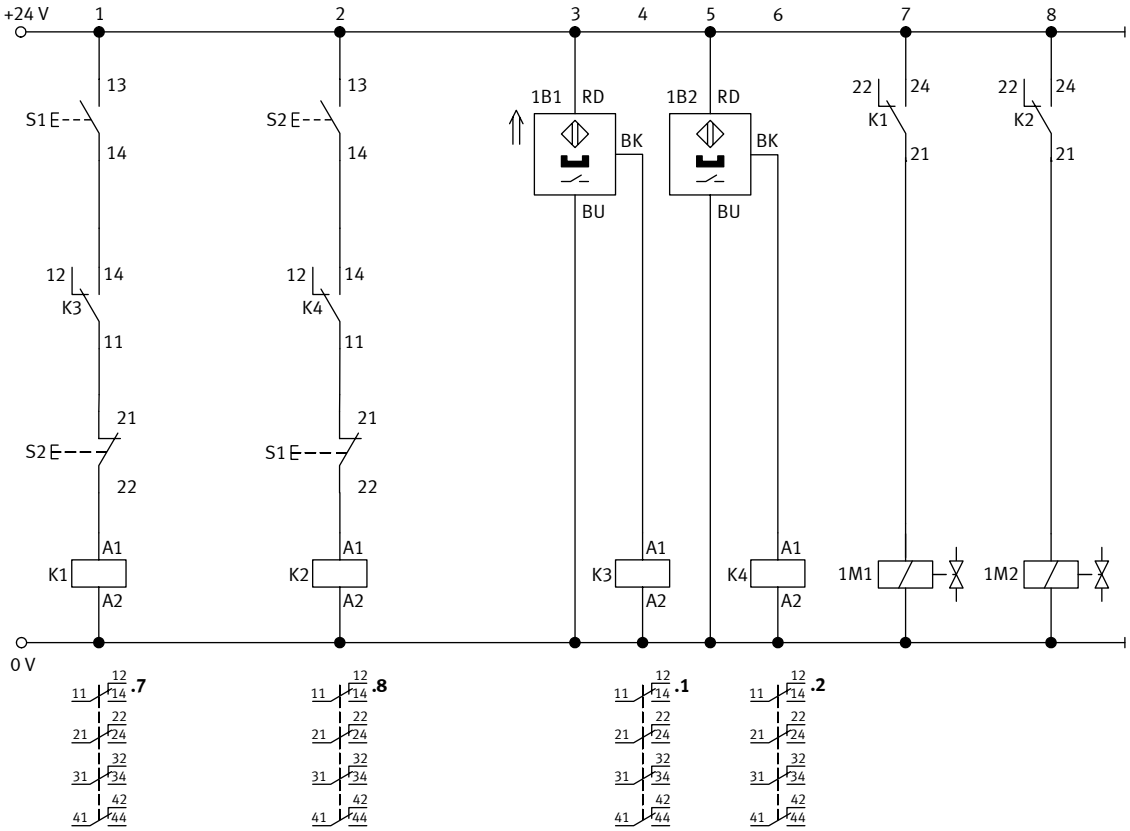
	Standard
☐	DIN EN 60617, part 5
☑	EN-ISO 13849, part 1
☑	EN-ISO 13849, part 2
☐	DIN ISO 1219, part 1
☑	DIN-ISO 4414

2 Setting up and commissioning the lift

a) Set up the required system in accordance with the following circuit diagrams.



Pneumatic circuit diagram



Electrical circuit diagram

Note
Mount the cylinder and weight to one of the vertical columns on the laboratory trolley.
Make sure that there is an additional mounting slot to the right of the cylinder for mounting other required components.

b) Commission the lift and describe the operating sequence.

When switch S1 is activated, solenoid valve 1V1 enables flow from 1 to 4. The piston side of the double-acting cylinder is pressurised with compressed air and the piston rod advances.
When switch S2 is activated, solenoid valve 1V1 enables flow from 1 to 2. The piston rod side of the double-acting cylinder is pressurised with compressed air and the piston rod retracts.