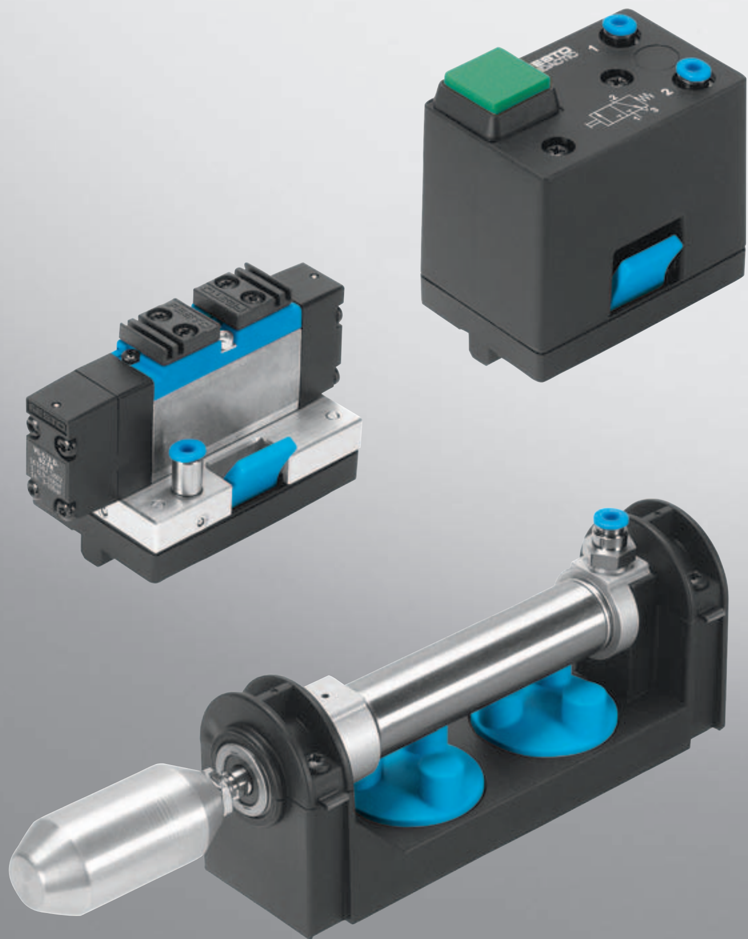
# Pneumatics
# Basic Level

Textbook TP 101



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## Section B: Theory

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## Section C: Solutions

## Notes on the layout of the book

This textbook forms part of the Learning System for Automation and Technology from Festo Didactic GmbH & Co. It has been designed for training courses and is also suitable for the purpose of self-tuition.

The book is divided into the following sections :

Part A: Course section,
Part B: Theory section,
Part C: Solutions to the exercises.

**Part A: Course**

The course provides the necessary information on the subject concerned using both examples and exercises, and is to be worked through in sequence. Subjects which are dealt with in greater depth in the Theory section are marked in the text.

**Part B: Theory**

This section contains detailed information on fundamentals. Topics are set out in a logical manner. The student can either work through this section chapter by chapter or use it for reference purposes.

**Part C: Solutions**

This section contains the solutions to the exercises in Part A.

A comprehensive index is provided at the end of the textbook.

The concept of this textbook supports training in key qualifications in the newly structured engineering and electro-technical vocations. Particular value is attached to the fact that students have the option of learning the subject concerned by working through the course section independently.

The book can be incorporated into an existing training program.

# Section A

# Course

# Chapter 1

# Characteristics and applications of pneumatics

### 1.1 Pneumatics in review

Pneumatics has long since played an important role as a technology in the performance of mechanical work. It is also used in the development of automation solutions.

In the majority of applications compressed air is used for one or more of the following functions:

- To determine the status of processors (sensors)
- Information processing (processors)
- Switching of actuators by means of final control elements
- Carrying out work (actuators)

To be able to control machinery and installations necessitates the construction of a generally complex logic interconnection of statuses and switching conditions. This occurs as a result of the interaction of sensors, processors, control elements and actuators in pneumatic or partly pneumatic systems.

The technological progress made in material, design and production processes has further improved the quality and diversity of pneumatic components and thereby contributed to their widely spread use in automation.

The pneumatic cylinder has a significant role as a linear drive unit, due to its

- relatively low cost,
- ease of installation,
- simple and robust construction and
- ready availability in various sizes and stroke lengths.

The pneumatic cylinder has the following general characteristics:

- Diameters 2.5 to 320 mm
- Stroke lengths 1 to 2000 mm
- Available forces 2 to 45000 N at 6 bar
- Piston speed 0.1 to 1.5 m/s

*Fig. 1.1*
*Single-acting cylinder*

Pneumatic components can perform the following types of motion:

- Linear
- Swivel
- Rotary

Some industrial applications employing pneumatics are listed below:

- General methods of material handling:
  – Clamping
  – Shifting
  – Positioning
  – Orienting
  – Branching of material flow
- General applications:
  – Packaging
  – Filling
  – Metering
  – Locking
  – Driving of axes
  – Door or chute control
  – Transfer of materials
  – Turning and inverting of parts
  – Sorting of parts
  – Stacking of components
  – Stamping and embossing of components

*Fig. 1.2*
*Points switch for two conveyor belts*

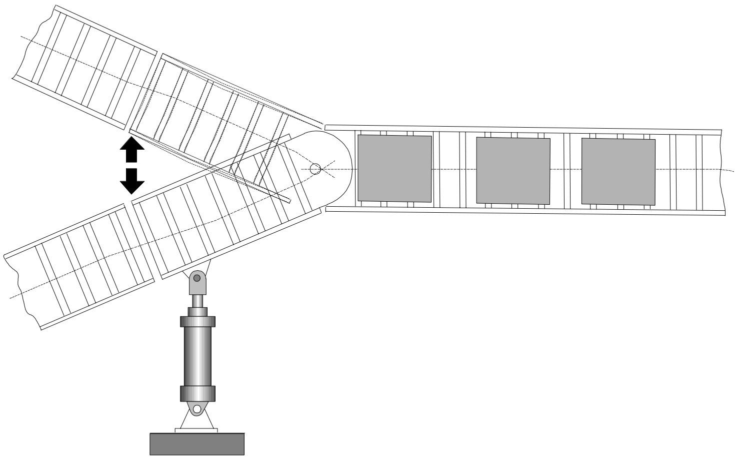
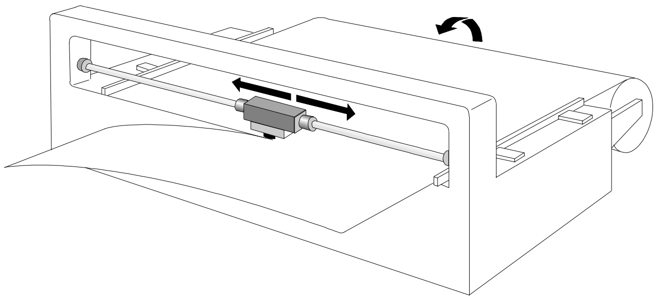


*Fig. 1.3*
*Pneumatic cutter*



Pneumatics is used in carrying out machining and working operations. For example:

- Drilling
- Turning
- Milling
- Sawing
- Finishing
- Forming
- Quality control

Advantages and distinguishing characteristics of compressed air:

| | |
|---|---|
| Availability | Air is available practically everywhere in unlimited quantities. |
| Transport | Air can be easily transported in pipelines, even over large distances. |
| Storage | Compressed air can be stored in a reservoir and removed as required. In addition, the reservoir can be transportable. |
| Temperature | Compressed air is relatively insensitive to temperature fluctuations. This ensures reliable operation, even under extreme conditions. |
| Explosion proof | Compressed air offers no risk of explosion or fire. |
| Cleanliness | Unlubricated exhaust air is clean. Any unlubricated air which escapes through leaking pipes or components does not cause contamination. |
| Components | The operating components are of simple construction and therefore relatively inexpensive. |
| Speed | Compressed air is a very fast working medium. This enables high working speeds to be attained. |
| Overload safe | Pneumatic tools and operating components can be loaded to the point of stopping and are therefore overload safe. |

*T 1.1 Advantages and distinguishing characteristics of compressed air*

In order to accurately define the areas of application of pneumatics, it is also necessary to be acquainted with the negative characteristics:

*T 1.2 Disadvantages of pneumatics*

| | |
|---|---|
| Preparation | Compressed air requires good preparation. Dirt and condensate should not be present. |
| Compression | It is not always possible to achieve uniform and constant piston speeds with compressed air. |
| Force requirement | Compressed air is economical only up to a certain force requirement. Under the normal working pressure of 600 to 700 kPa (6 to 7 bar) and dependent on the travel and speed, the output limit is between 40 000 and 50 000 Newtons. |
| Noise level | The exhaust air is loud. This problem has now, however been largely solved due to the development of sound absorption material and silencers. |

A comparison with other forms of energy is an essential part of the selection process when considering pneumatics as a control or working medium. This evaluation embraces the total system from the input signal (sensors) through the control part (processor) to the control elements and actuators. All factors must be considered such as:

- Preferred control methods
- Available resources
- Available expertise
- Systems currently installed which are to be integrated with the new project

*Criteria for a working medium*

Choice of working media:

- Electrical current (electricity)
- Fluids (hydraulics)
- Compressed air (Pneumatics)
- A combination of the above

Selection criteria for the working section:

- Force
- Stroke
- Type of motion (linear, swivelling, rotating)
- Speed
- Service life
- Safety and reliability
- Energy costs
- Controllability
- Storage

*Criteria for a control medium*

Choice of control media:

- Mechanical connections (mechanics)
- Electrical current (electrics, electronics)
- Fluids (hydraulics)
- Compressed air (pneumatics, low pressure pneumatics)

Selection criteria for the control section:

- Reliability of components
- Sensitivity to environmental influences
- Ease of maintenance and repair
- Switching time of components
- Signal speed
- Space requirements
- Service life
- Modification of the control system
- Training requirements of operators and maintenance personnel

### 1.2. Pneumatics and control system development

The product development in pneumatics can be considered in a number of areas:

- Actuators
- Sensors and input devices
- Processors
- Accessories
- Control systems

The following factors must be taken into account in the development of pneumatic control systems:

- Reliability
- Ease of maintenance
- Cost of spare parts
- Assembly and connection
- Maintenance and repair costs
- Interchangeability and adaptability
- Compact design
- Economic efficiency
- Documentation

## 1.3 Structure and signal flow of pneumatic systems

Pneumatic systems consist of an interconnection of different groups of elements.

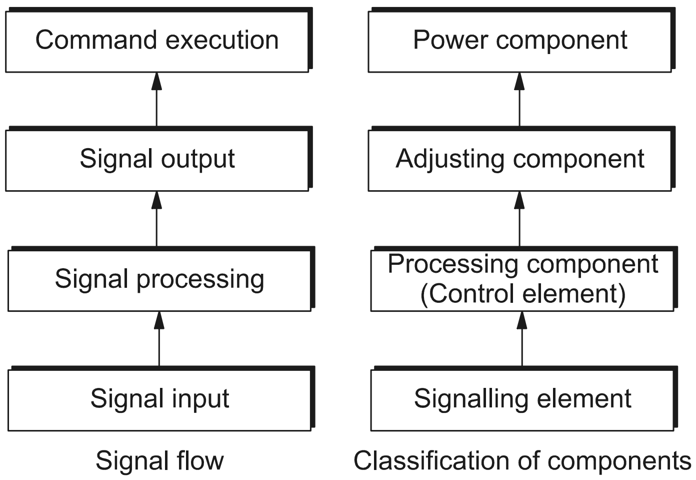



*Fig. 1.4*
*Signal flow*

This group of elements forms a control path for signal flow, starting from the signal section (input) through to the actuating section (output).

Control elements control the actuating elements in accordance with the signals received from the processing elements.

The primary levels in a pneumatic system are:

- Energy supply
- Input elements (sensors)
- Processing elements (processors)
- Control elements
- Power components (actuators)

The elements in the system are represented by symbols which indicate the function of the element.

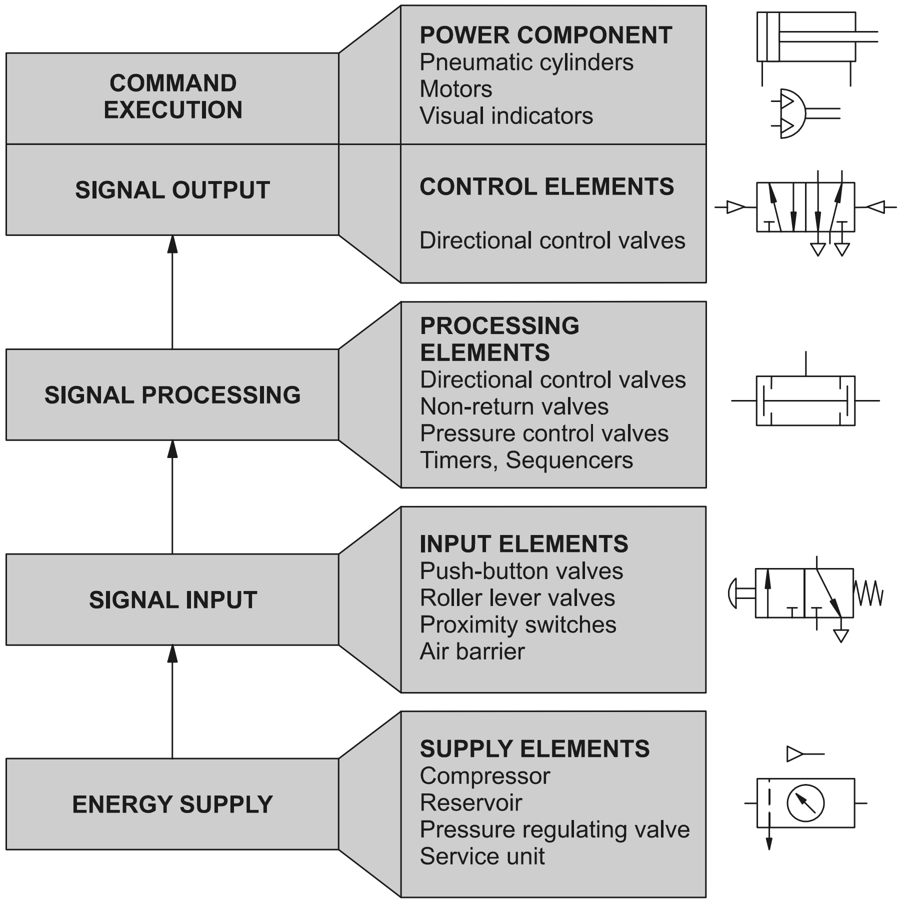



*Fig. 1.5*
*Pneumatic control system*

A directional control valve can be used as an input, processing or control element. The distinguishing feature for the allocation of the individual components to the respective groups of elements is the configuration within a pneumatic system.

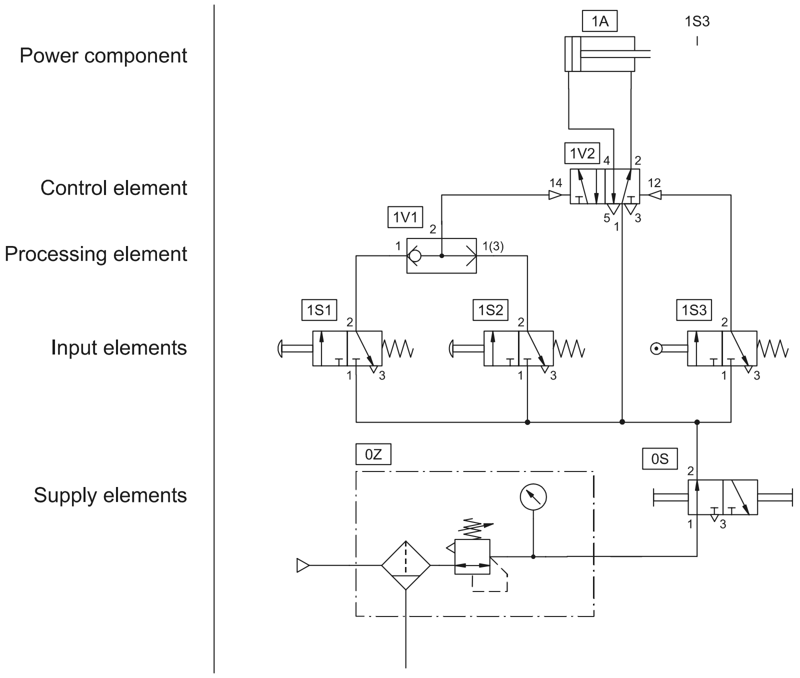



*Fig. 1.6*
*Circuit diagram and pneumatic elements*

# Chapter 2

# Components of a pneumatic system

### 2.1 Air generation and distribution

The compressed air supply for a pneumatic system should be adequately calculated and made available in the appropriate quality.

Air is compressed by the air compressor and delivered to an air distribution system in the factory. To ensure the quality of the air is acceptable, air service equipment is utilised to prepare the air before being applied to the control system.

Malfunctions can be considerably reduced in the system if the compressed air is correctly prepared. A number of aspects must be considered in the preparation of the service air:

- Quantity of air required to meet the demands of the system
- Type of compressor to be used to produce the quantity required
- Pressure requirements
- Storage required
- Requirements for air cleanliness
- Acceptable humidity levels to reduce corrosion and sticky operation
- Lubrication requirements, if necessary
- Temperature of the air and effects on the system
- Line sizes and valve sizes to meet demand
- Material selection to meet environmental and system requirements
- Drainage points and exhaust outlets in the distribution system
- Layout of the distribution system to meet demand.

As a rule pneumatic components are designed for a maximum operating pressure of 800-1000 kPa (8 - 10 bar) but in practice it is recommended to operate at between 500-600 kPa (5 and 6 bar) for economic use. Due to the pressure losses in the distribution system the compressor should deliver between 650-700 kPa (6.5 and 7) bar to attain these figures.

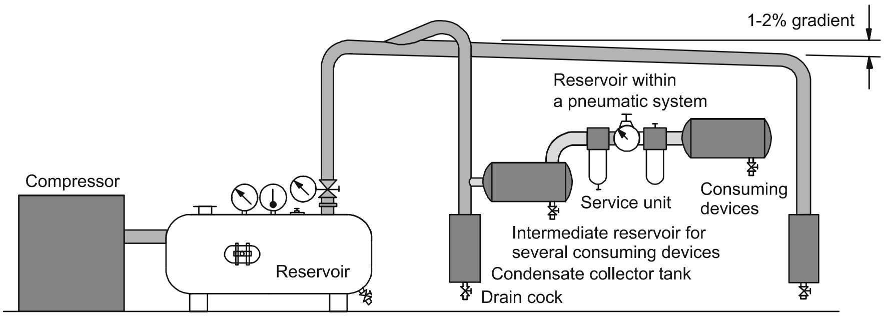
A reservoir should be fitted to reduce pressure fluctuations. In some cases, the term ‘receiver’ is also used to describe a reservoir.

The compressor fills the reservoir which is available as a storage tank.

The pipe diameter of the air distribution system should be selected in such a way that the pressure loss from the pressurised reservoir to the consuming device ideally does not exceed approx. 10 kPa (0.1 bar). The selection of the pipe diameter is governed by:

- Flow rate
- Line length
- Permissible pressure loss
- Operating pressure
- Number of flow control points in the line

*Fig. 2.1*
*Air distribution system*




Ring circuits are most frequently used as main lines. This method of installing pressure lines also achieves a constant supply in the case of high air consumption. The pipe lines must be installed in the direction of flow with a gradient of 1 to 2%. This is particularly important in the case of branch lines. Condensate can be removed from the lines at the lowest point.

Any branchings of air consumption points where lines run horizontally should always be installed on the upper side of the main line.

Branchings for condensate removal are installed on the underside of the main line.

Shut-off valves can be used to block sections of compressed air lines if these are not required or need to be closed down for repair or maintenance purposes.

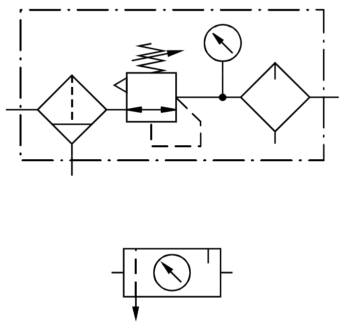
The air service unit is a combination of the following :

- Compressed air filter (with water separator)
- Compressed air regulator
- Compressed air lubricator

However, the use of a lubricator does not need to be provided for in the power section of a control system unless necessary, since the compressed air in the control section does not necessarily need to be lubricated.

The correct combination, size and type of these elements are determined by the application and the control system demand. An air service unit is fitted at each control system in the network to ensure the quality of air for each individual task.

*Fig. 2.2*
*Air service unit*



*Compressed air filter*

The compressed air filter has the job of removing all contaminants from the compressed air flowing through it as well as water which has already condensed. The compressed air enters the filter bowl through guide slots. Liquid particles and larger particles of dirt are separated centrifugally collecting in the lower part of the filter bowl. The collected condensate must be drained before the level exceeds the maximum condensate mark, as it will otherwise be re-entrained in the air stream.

*Compressed air regulator*

The purpose of the regulator is to keep the operating pressure of the system (secondary pressure) virtually constant regardless of fluctuations in the line pressure (primary pressure) and the air consumption.

*Compressed air lubricator*

The purpose of the lubricator is to deliver a metered quantity of oil mist into a leg of the air distribution system when necessary for the operation of the pneumatic system.

### 2.2 Valves

The function of valves is to control the pressure or flow rate of pressure media. Depending on design, these can be divided into the following categories:

- Directional control valves
  – Input/signalling elements
  – Processing elements
  – Control elements
- Non-return valves
- Flow control valves
- Pressure control valves
- Shut-off valves