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Programmable Logic Controllers

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OBJECTIVE

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To enable the participants to understand the design and principle of operation of Programmable Logic Controllers (PLC), write and implement simple programs and be familiar with applications of PLC’s in industries.

Topic Outline

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- Advantage of a PLC compared to conventional controls such as electrical, electro-pneumatic or electro-hydraulic controls
- Function of the system components of a PLC
- Commissioning of a Programmable Logic Controller
- Criteria for the use of mechanical, optical, capacitive and proximity sensors
- Circuit development/diagram design
- Development of logic control system
- Development of sequence control system
- Defining appropriate control system for a given task
- Control using timers and counters

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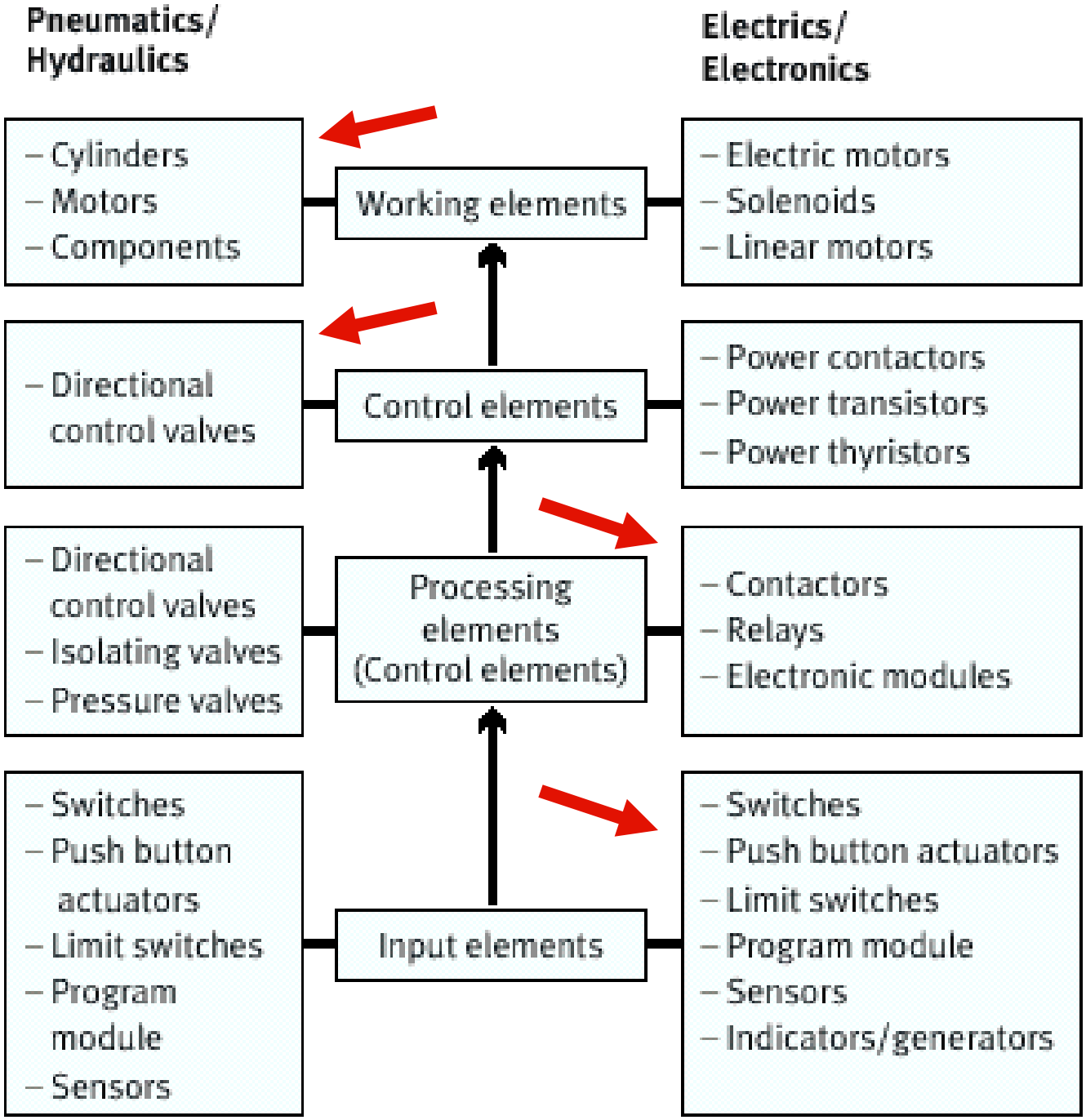
Pneumatic Control System


Pneumatics/
Hydraulics
Electrics/
Electronics
– Cylinders
– Motors
– Components
Working elements
– Electric motors
– Solenoids
– Linear motors
– Directional
control valves
Control elements
– Power contactors
– Power transistors
– Power thyristors
– Directional
control valves
– Isolating valves
– Pressure valves
Processing
elements
(Control elements)
– Contactors
– Relays
– Electronic modules
– Switches
– Push button
actuators
– Limit switches
– Program
module
– Sensors
Input elements
– Switches
– Push button actuators
– Limit switches
– Program module
– Sensors
– Indicators/generators

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PNEUMATIC ACTUATORS

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LINEAR CYLINDERS

- Single-acting Cylinder
- Double-acting Cylinder

ROTARY CYLINDERS

- Rotary vane Cylinder
- Pneumatic motors

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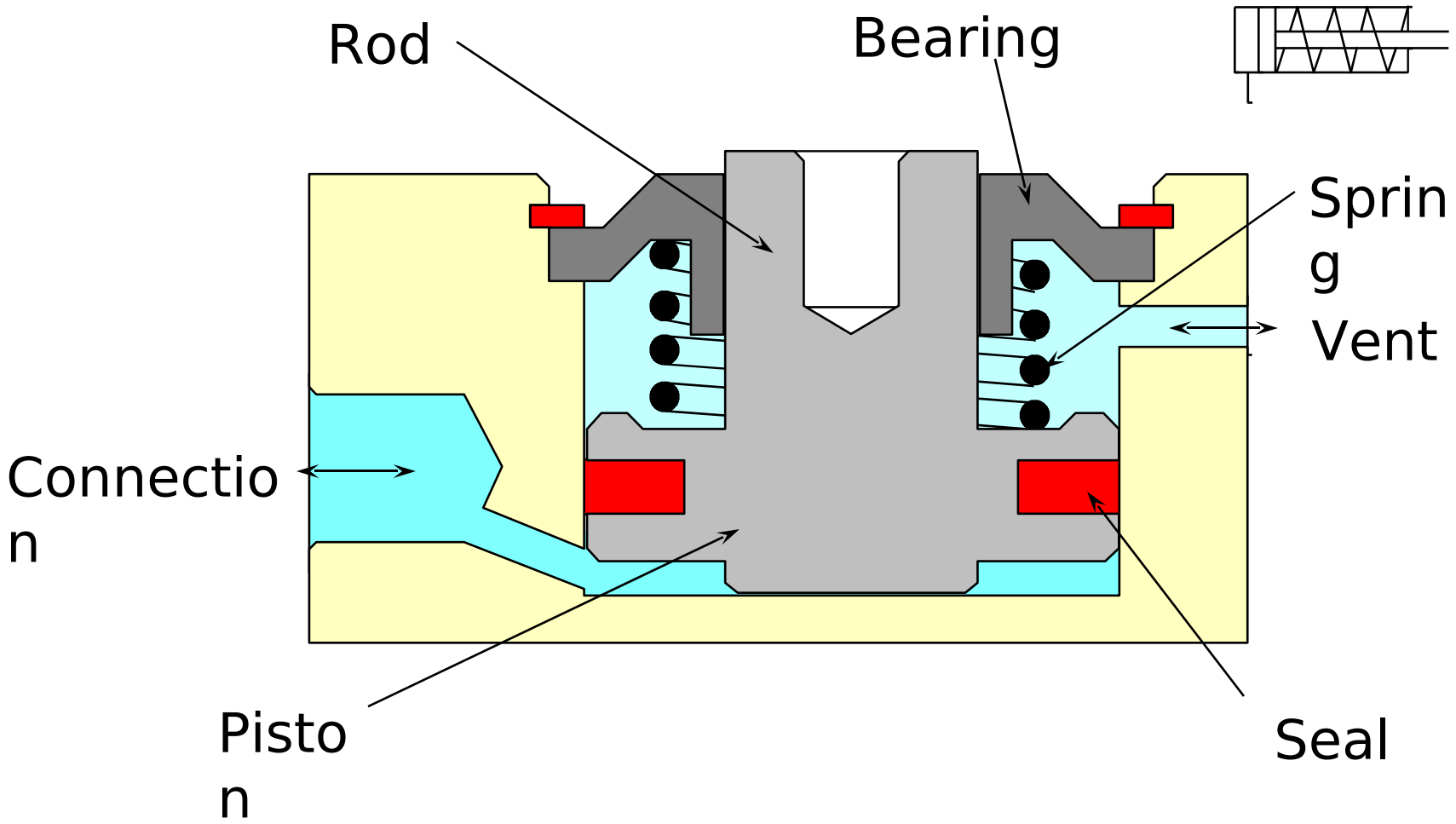
Single acting cylinder


Rod
Bearing
Sprin
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Vent
Connectio
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Pisto
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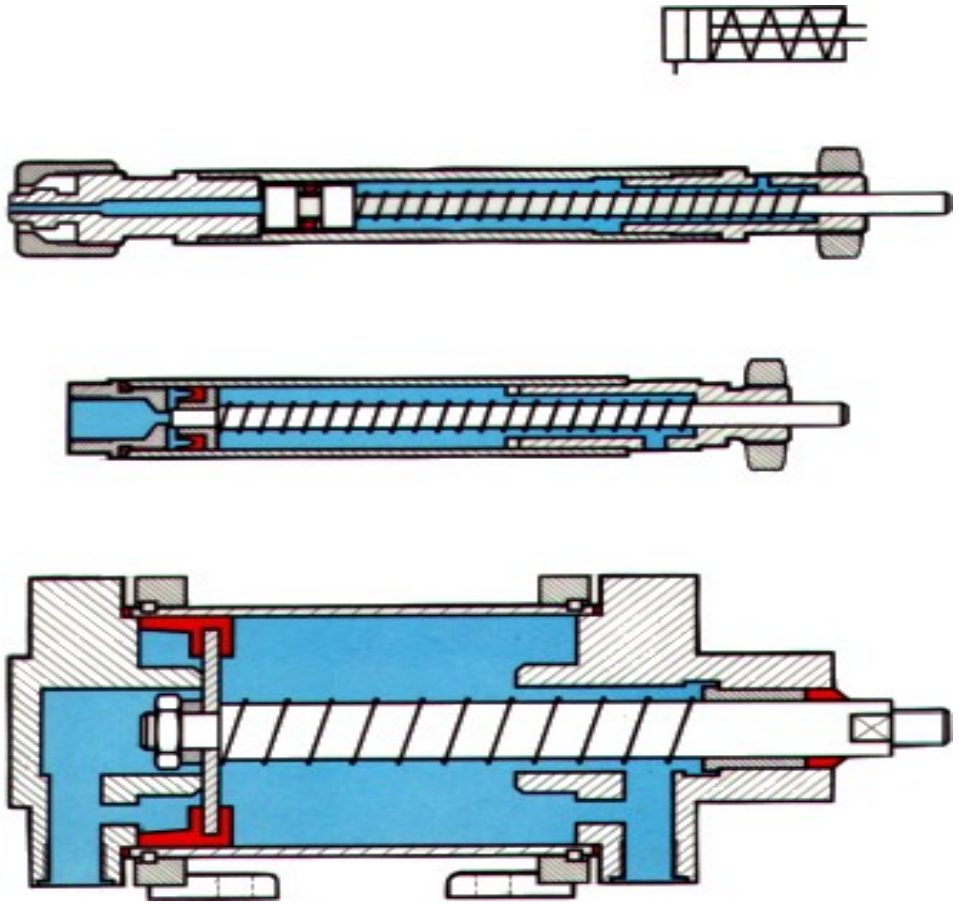
Seal

Single Acting Cylinders



If compressed air is supplied, air hits the piston surface and the piston rod moves out. When air is released, the return spring moves the piston to its initial position.

Single acting cylinders do work in one way, therefore they are ideal for tensioning, ejecting, compressing etc.

Operation of Single Acting Cylinders

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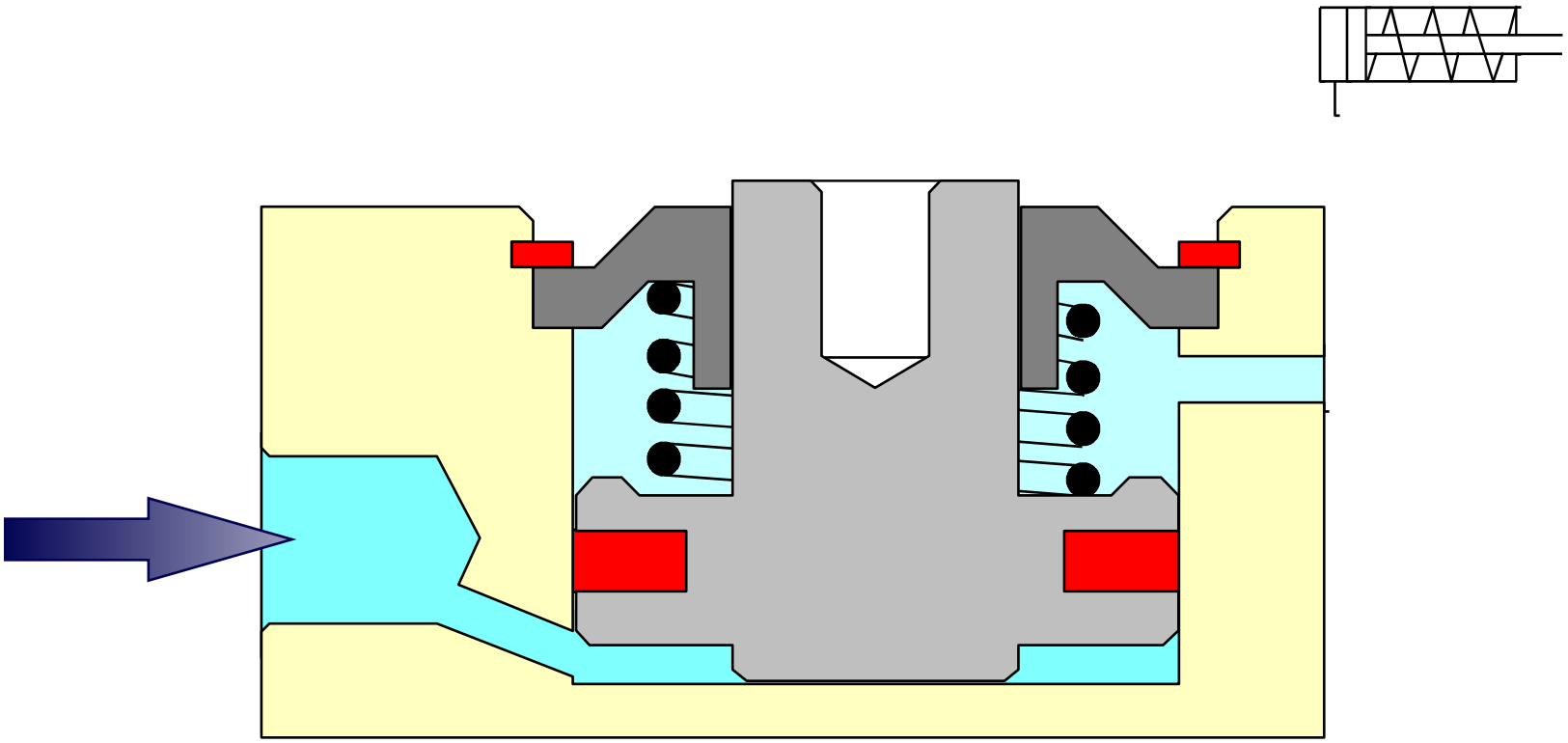

Operation of Single Acting Cylinders

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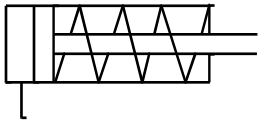
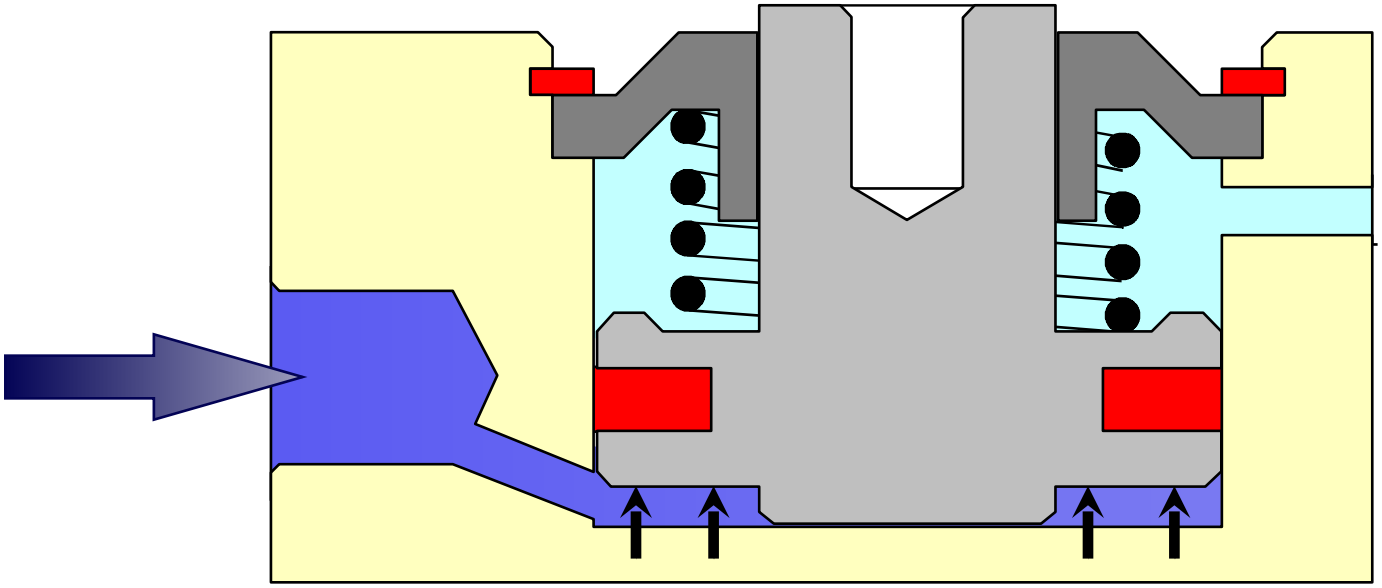
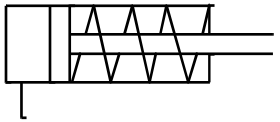


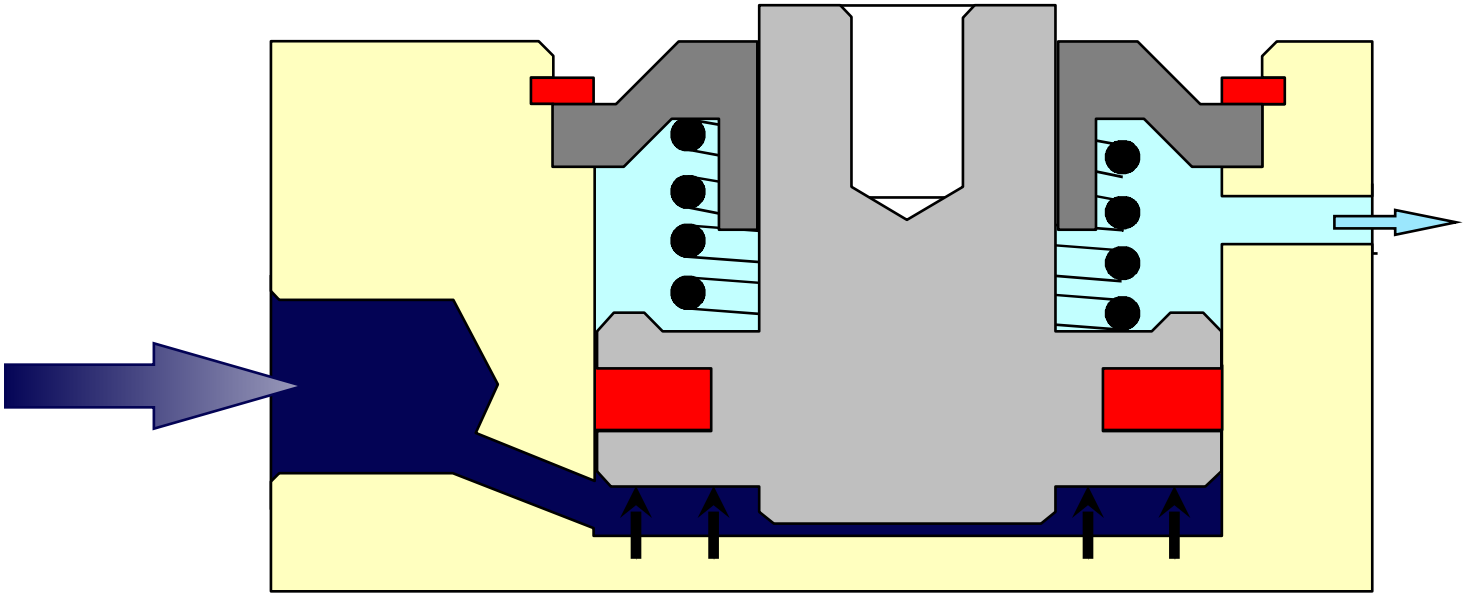


Force = Pressure x Area (piston)

Operation of Single Acting Cylinders

FESTO





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Operation of Single Acting Cylinders

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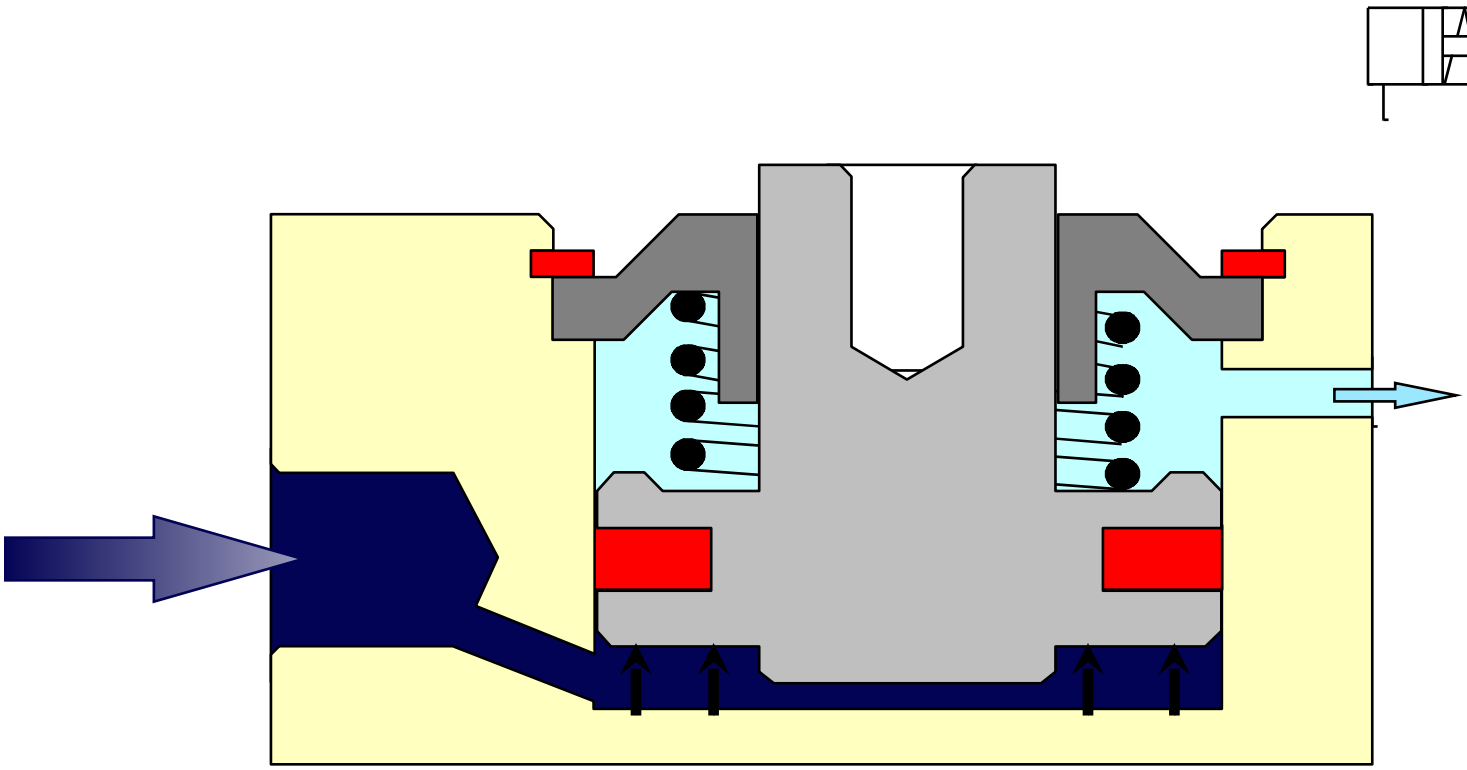

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Operation of Single Acting Cylinders

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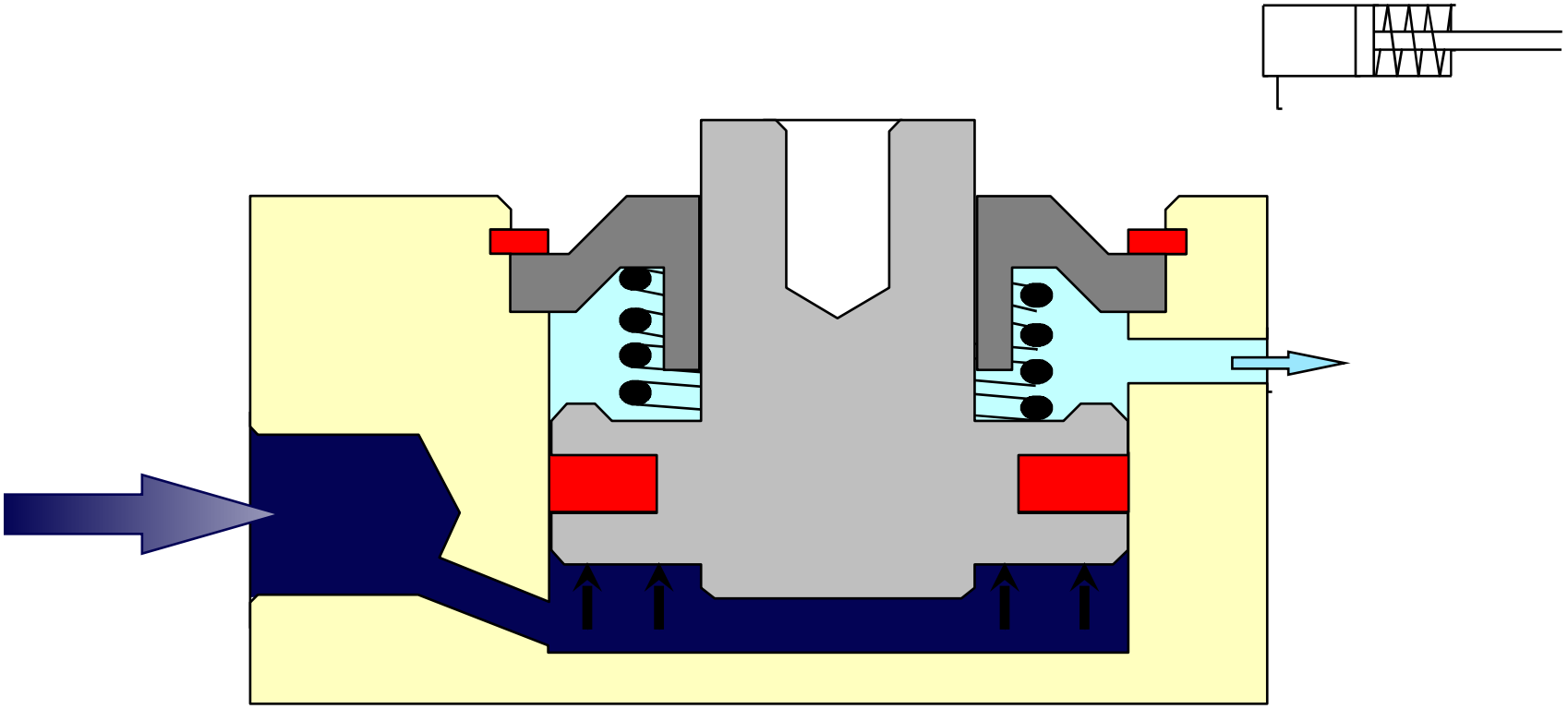

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Operation of Single Acting Cylinders

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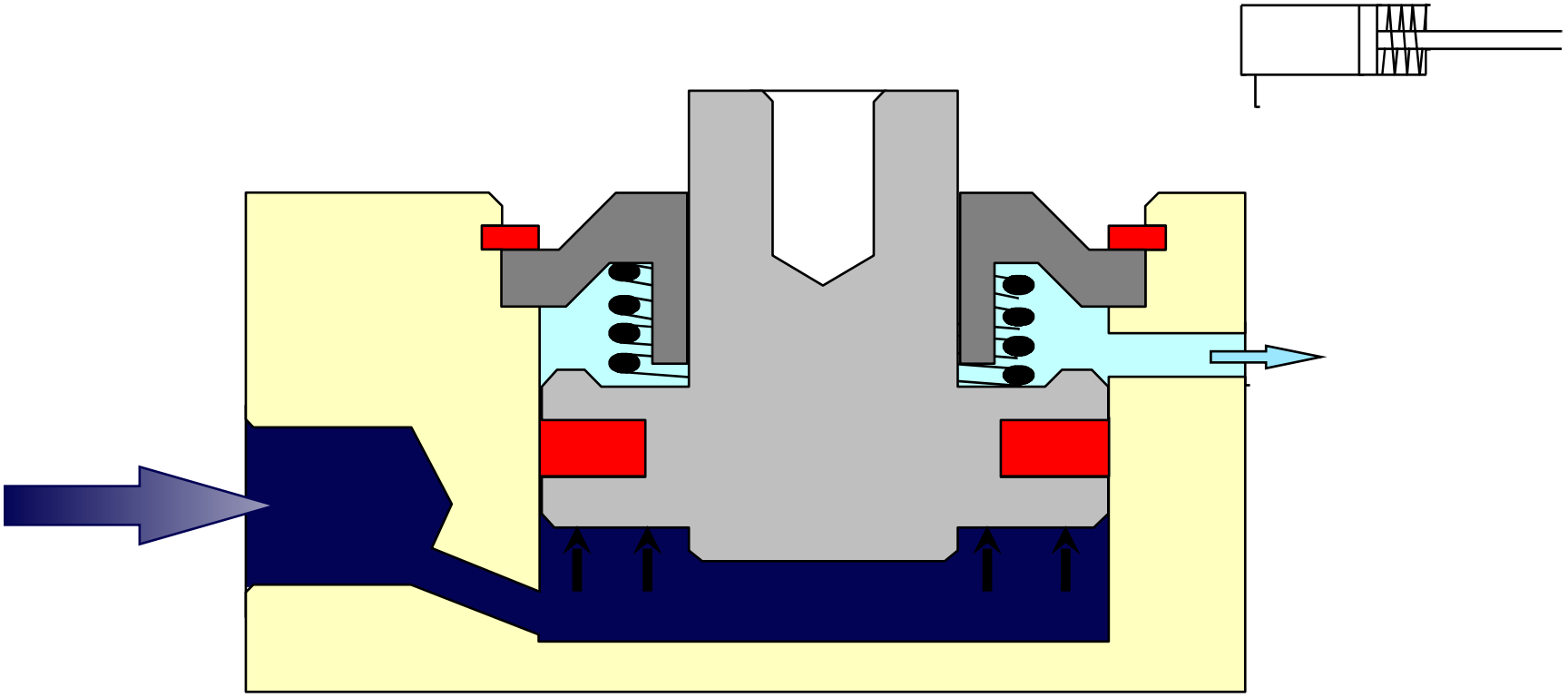

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Operation of Single Acting Cylinders

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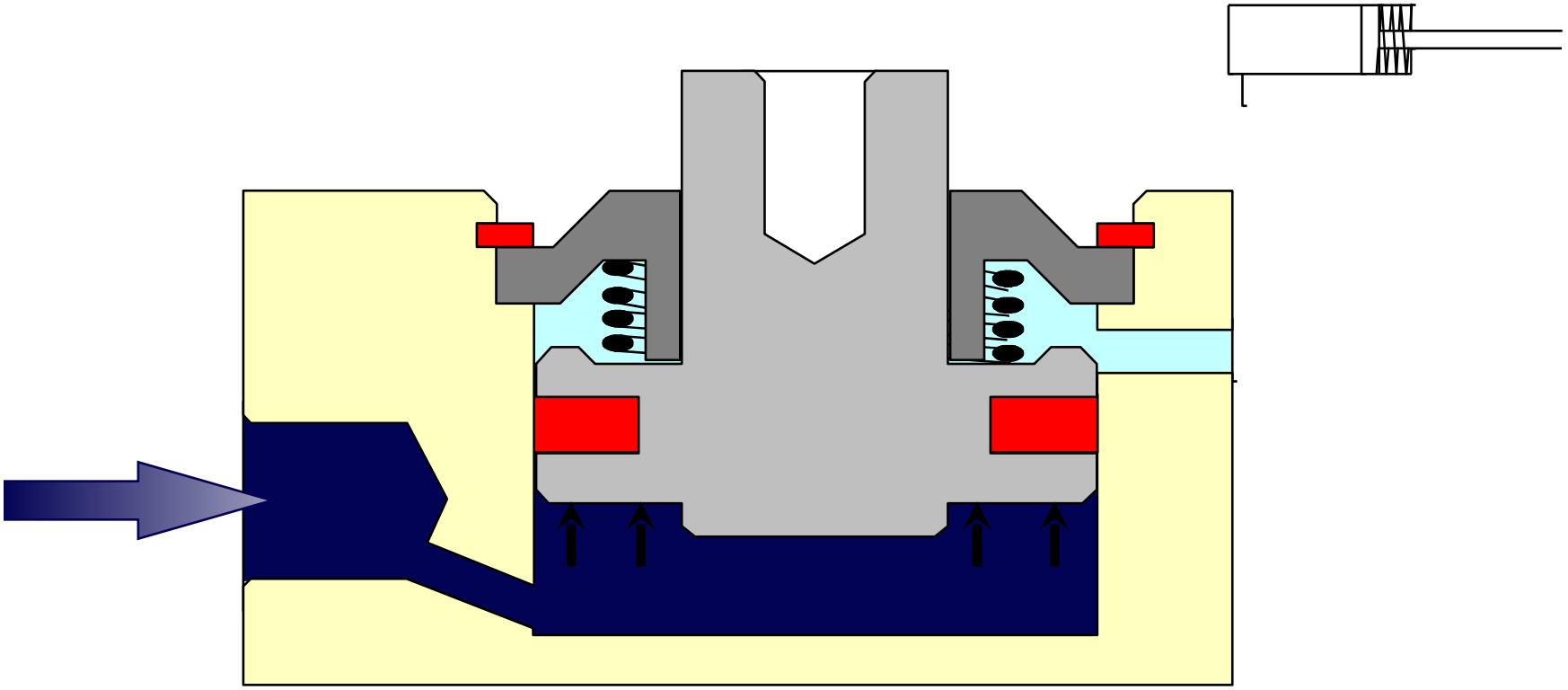

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Operation of Single Acting Cylinders

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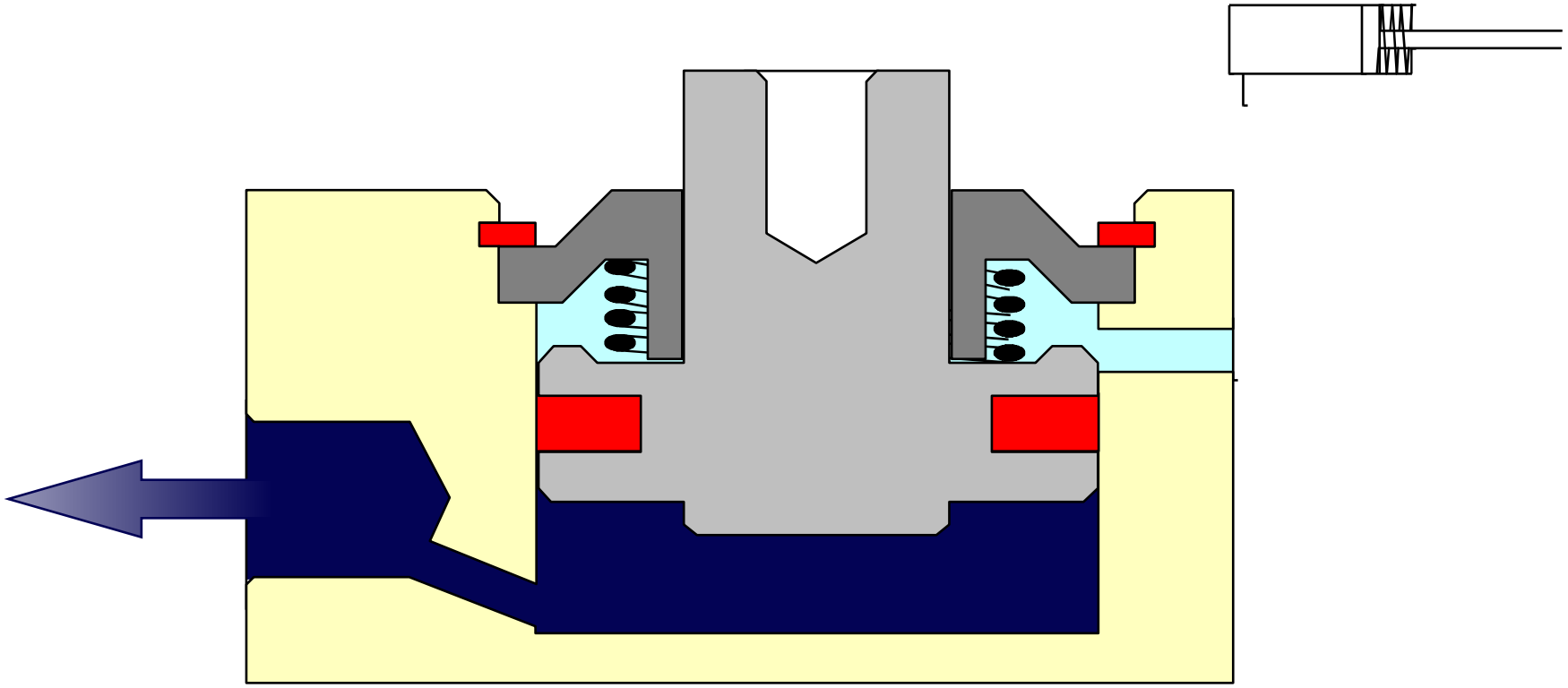

Operation of Single Acting Cylinders

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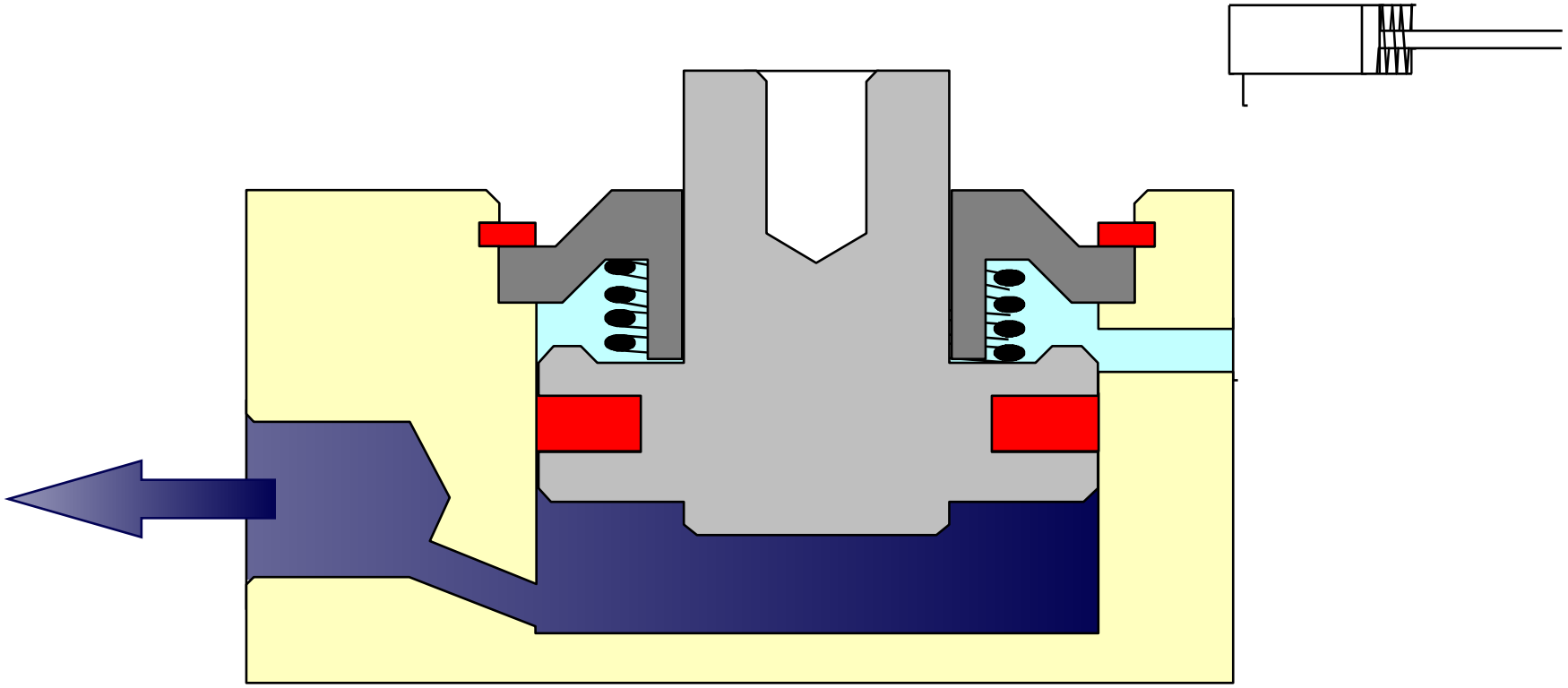

Operation of Single Acting Cylinders

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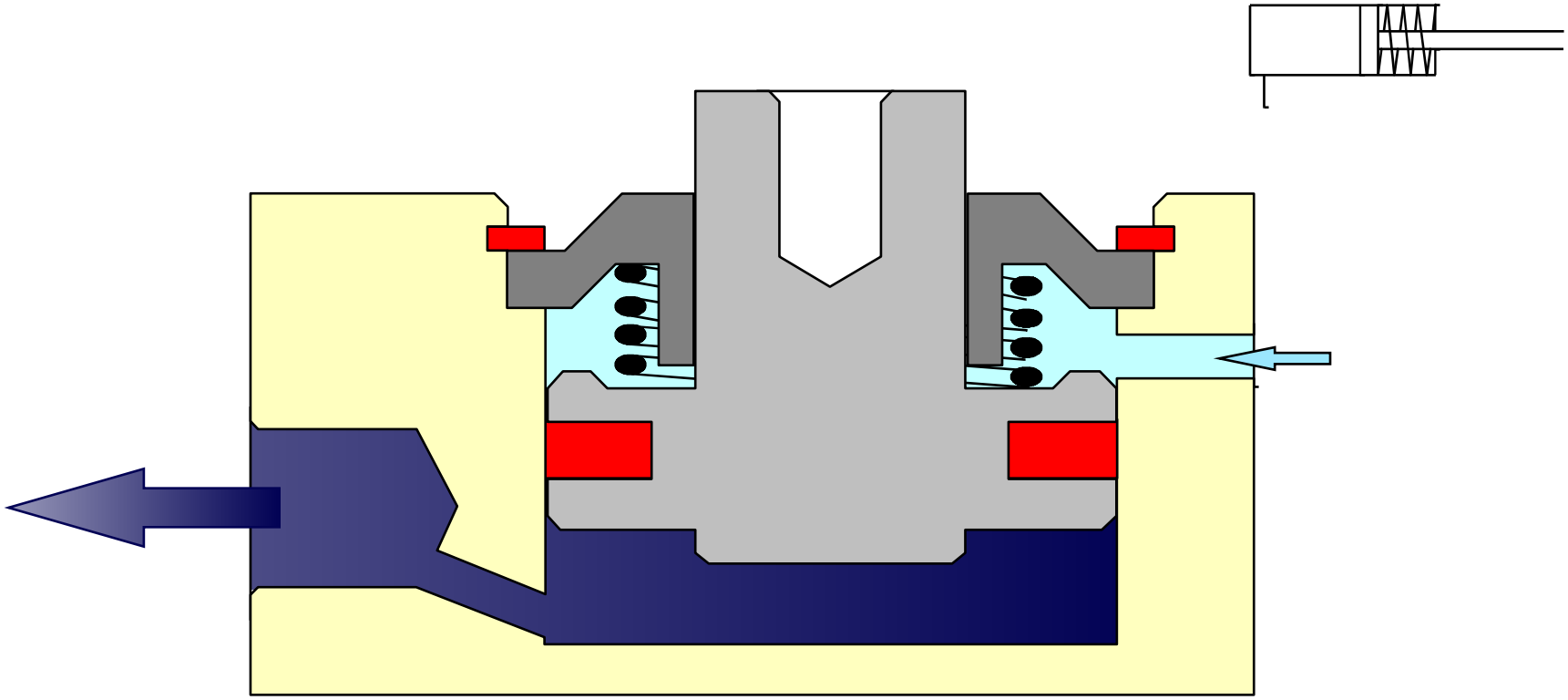

Operation of Single Acting Cylinders

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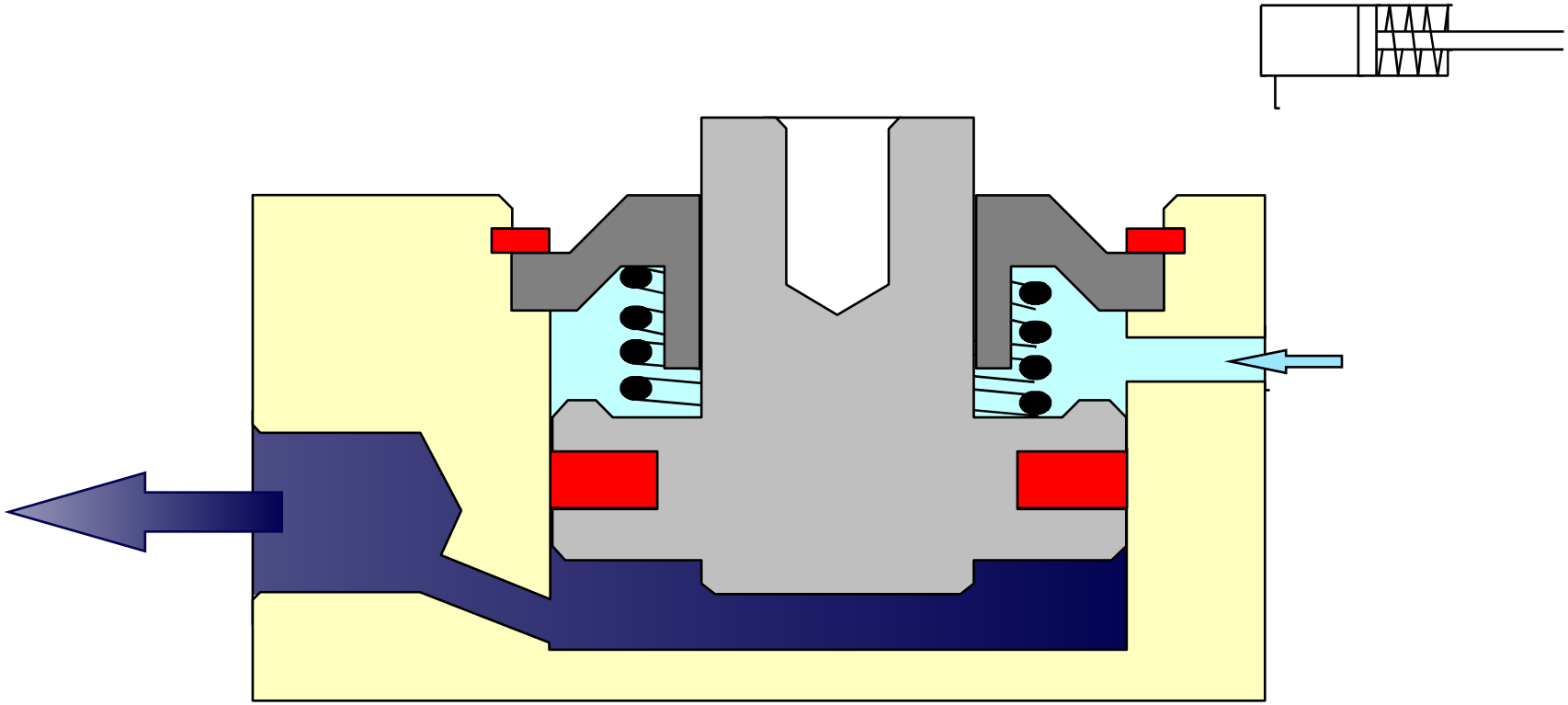

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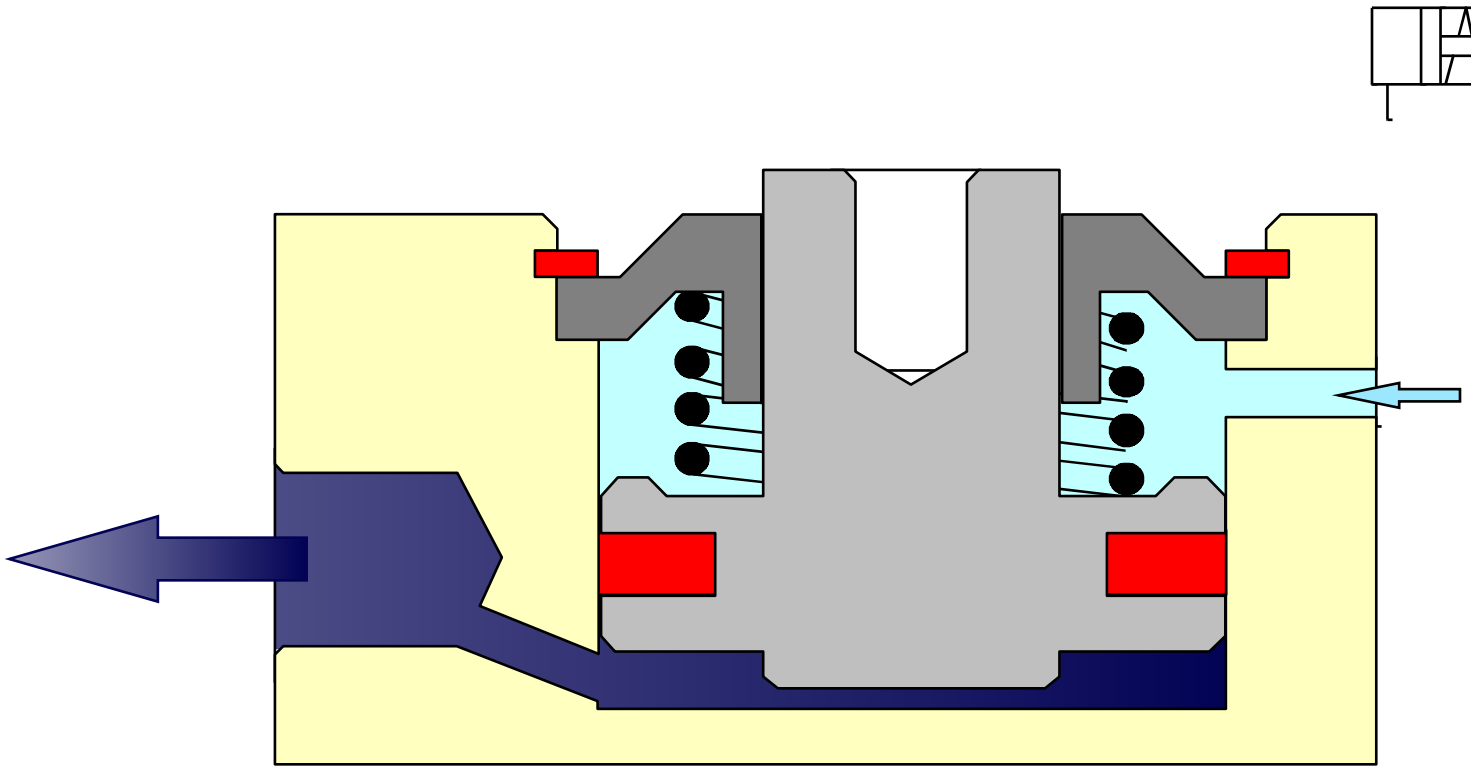

Operation of Single Acting Cylinders

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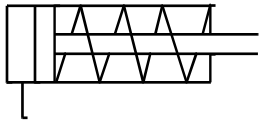

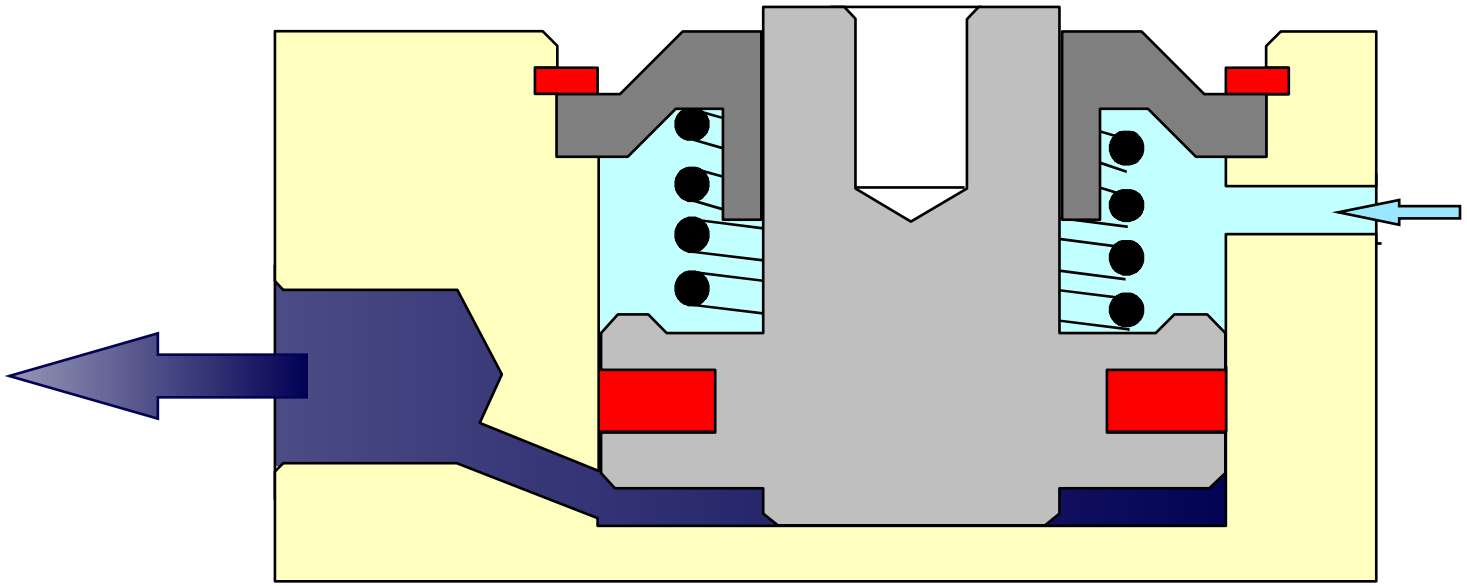

Operation of Single Acting Cylinders

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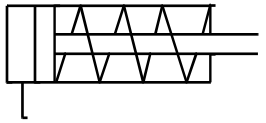

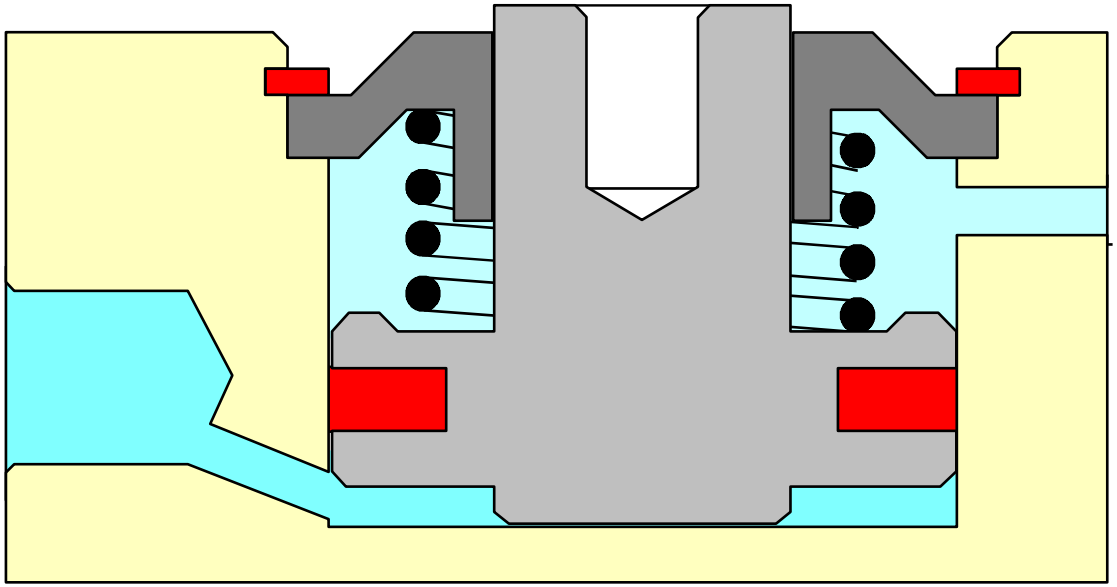

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Double acting cylinder

Double Acting Cylinder

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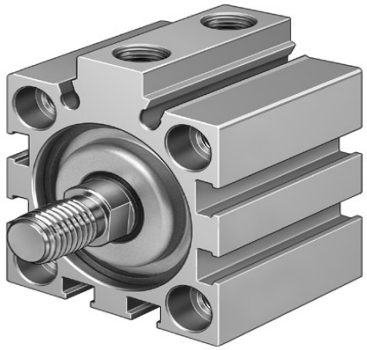
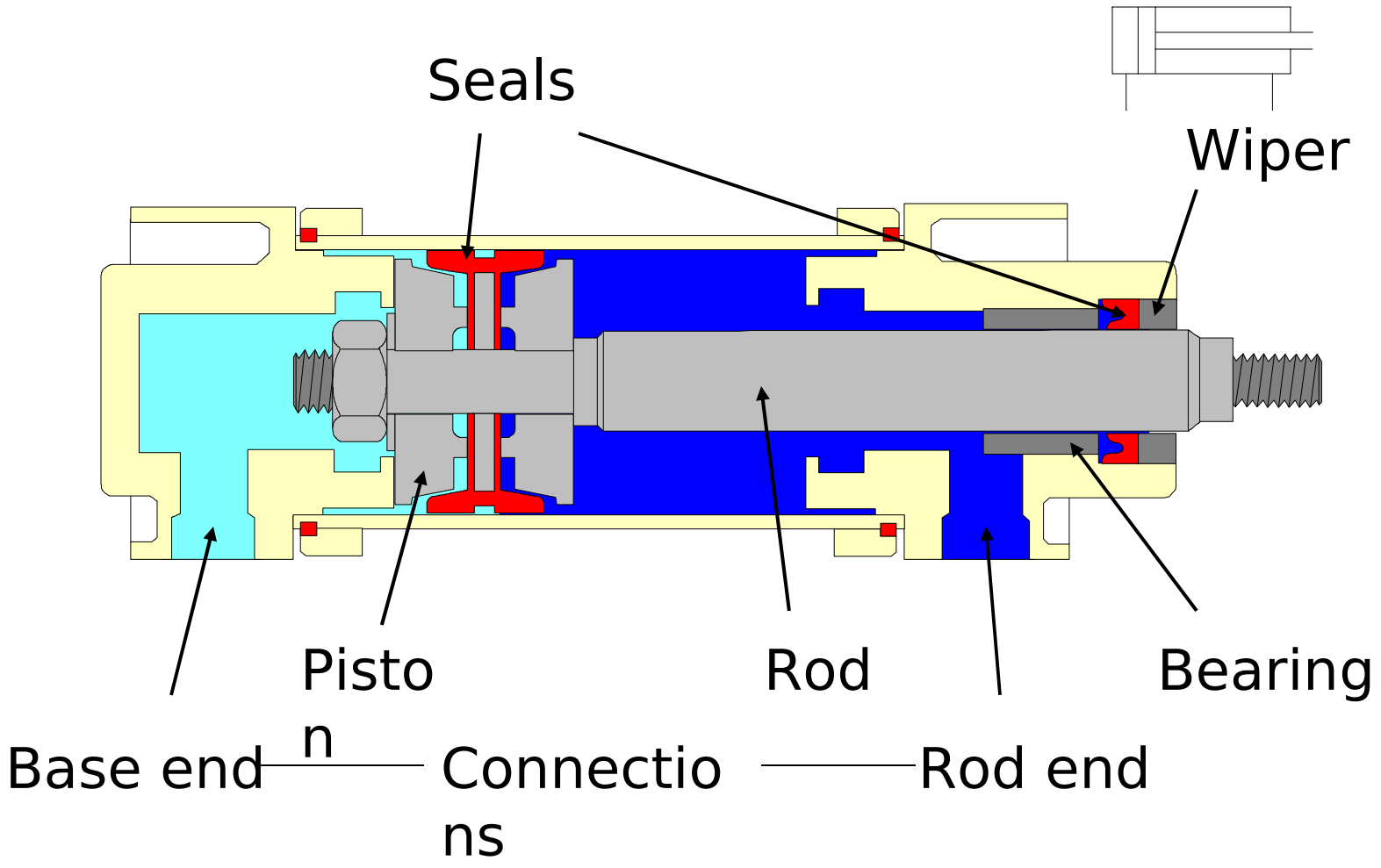
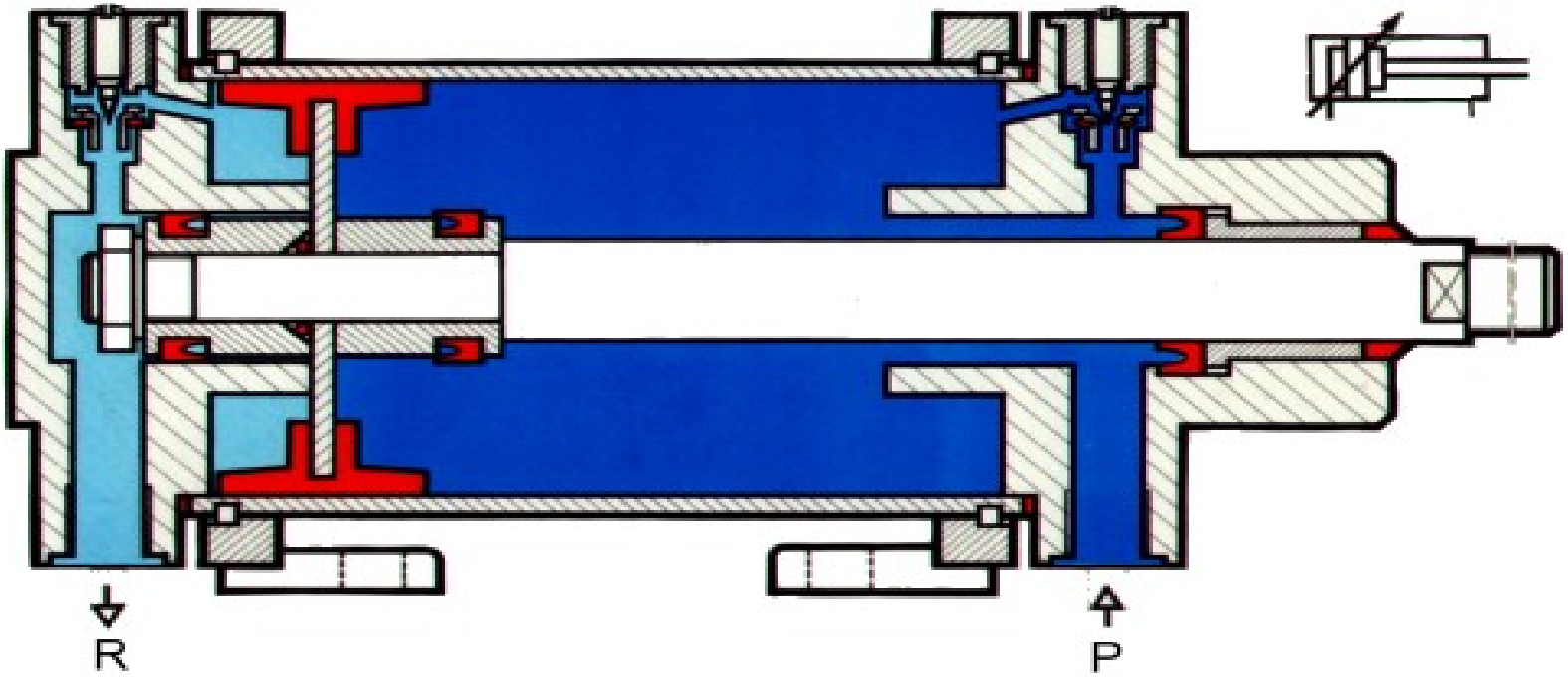



Seals
Wiper
Piston
Rod
Bearing
Base end
Connections
Rod end

Double Acting Cylinders with Air Cushioning

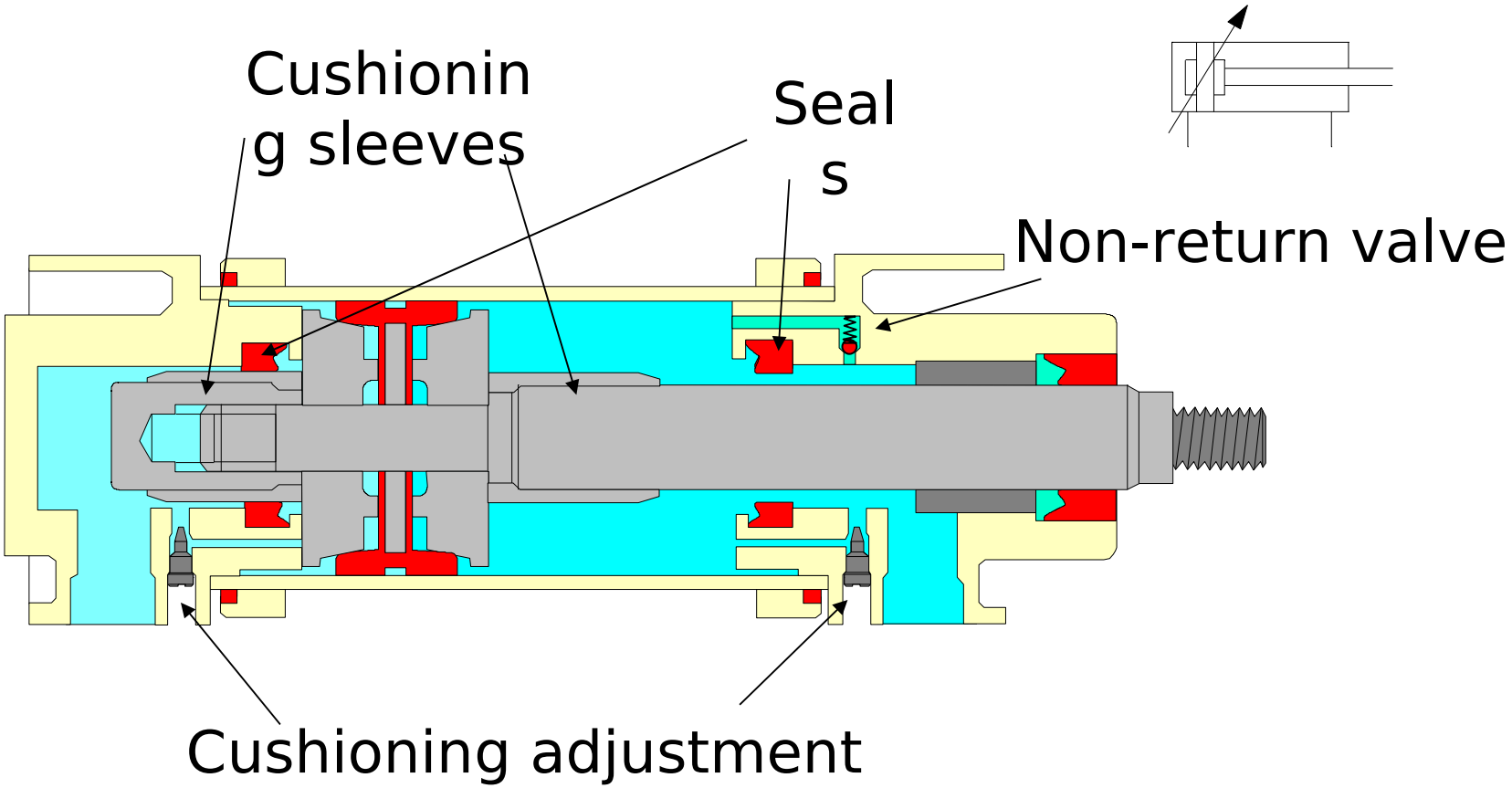
FESTO



When the piston approaches its final position, the damping piston shuts off the direct air-outlet. Excess pressure sets up an air-cushion in the remaining cylinder volume and kinetic energy is converted into pressure. At this stage, air may only leave the cylinder through a controlled cross section of stream discharge.

Operation of Double Acting Cylinders with Air Cushioning

FESTO



Operation of Double Acting Cylinders with Air Cushioning

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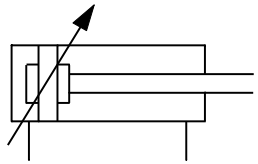

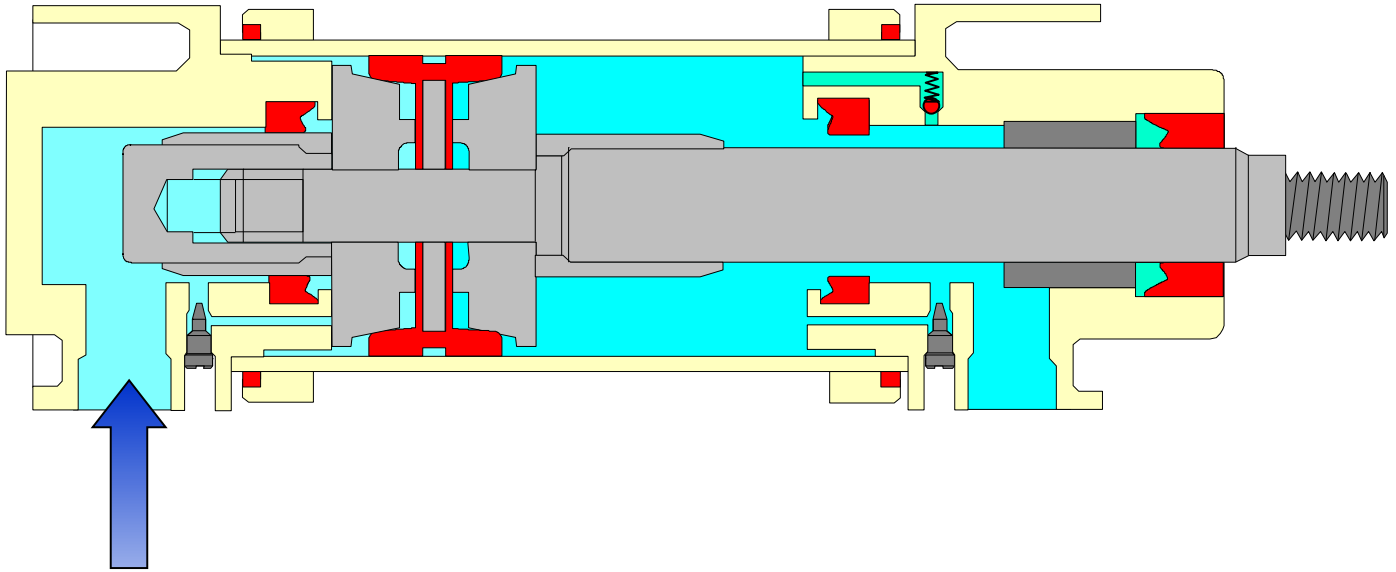

Operation of Double Acting Cylinders with Air Cushioning

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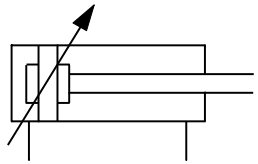

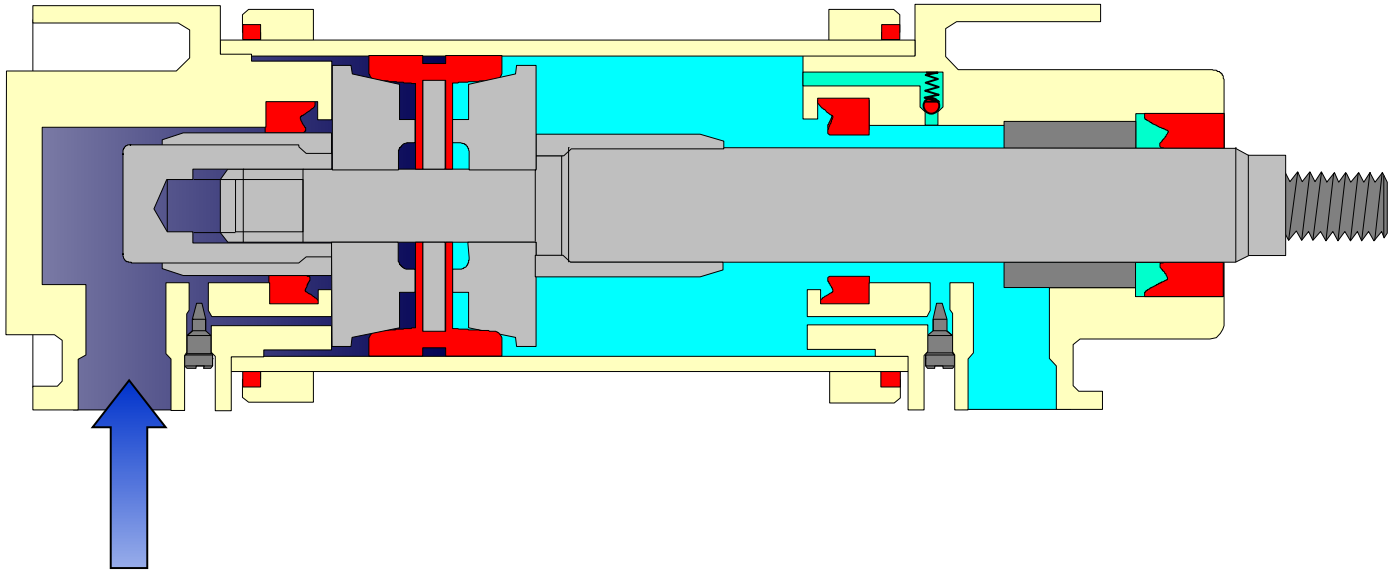

Operation of Double Acting Cylinders with Air Cushioning

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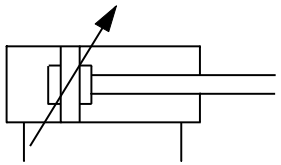

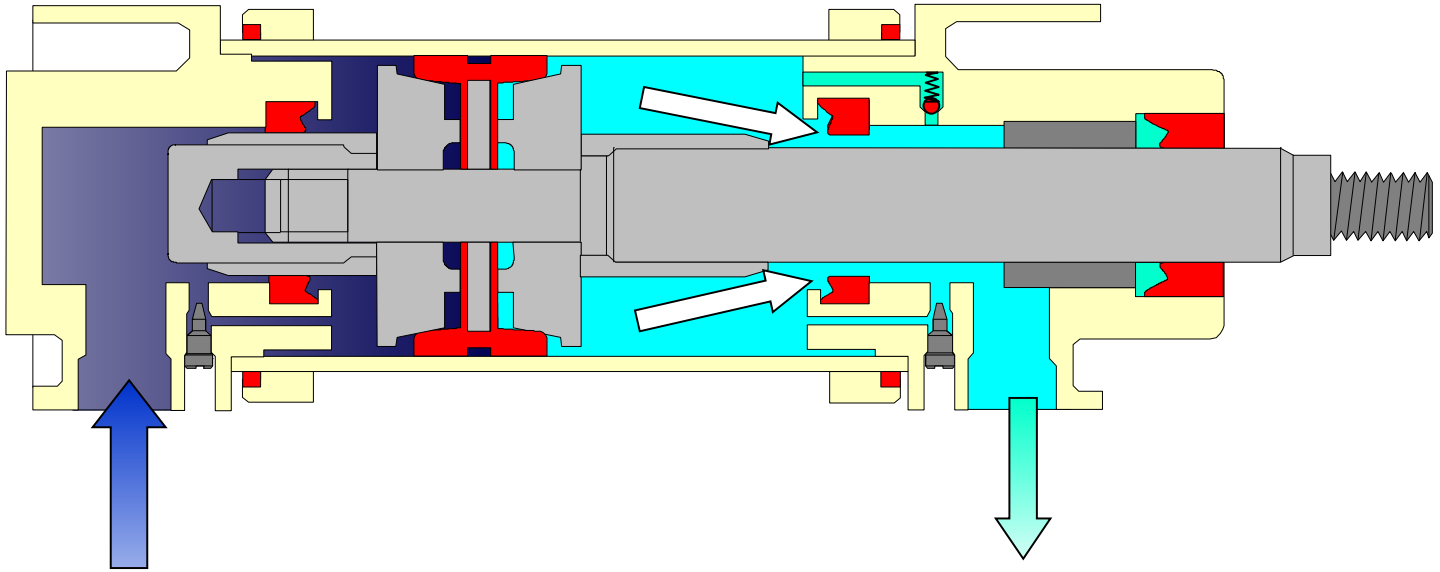

Operation of Double Acting Cylinders with Air Cushioning

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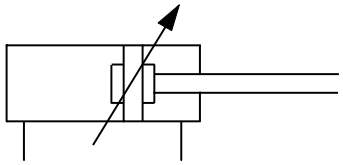

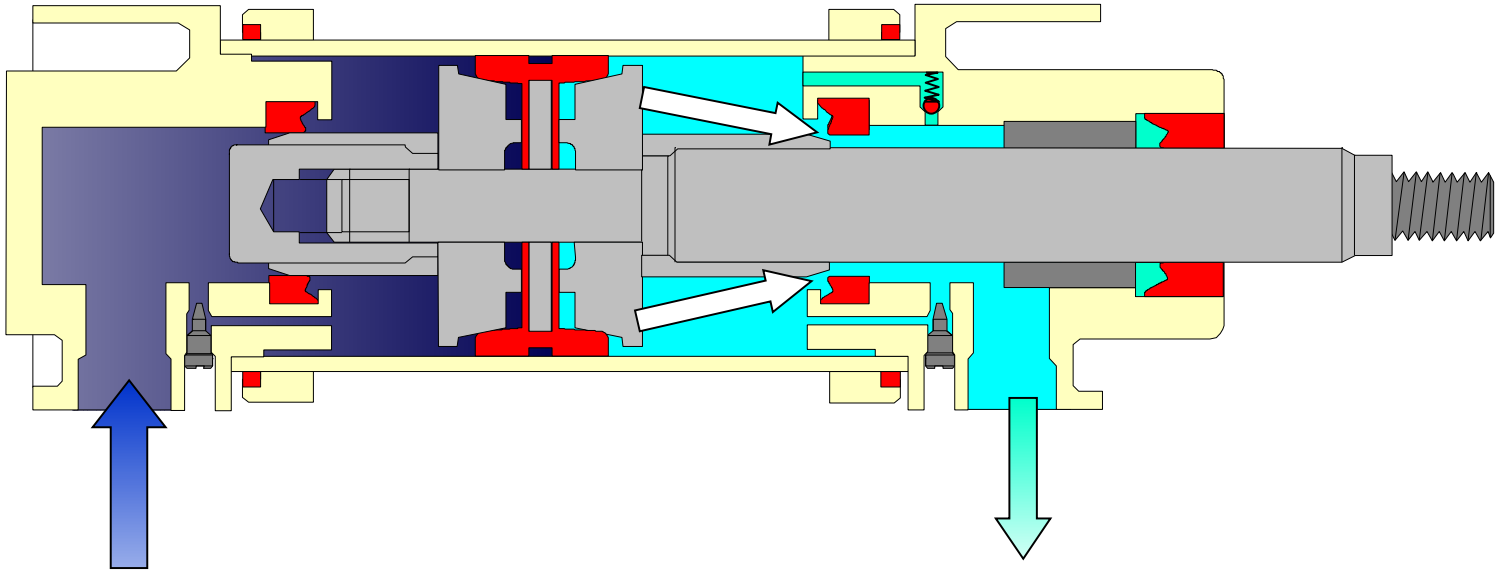

Operation of Double Acting Cylinders with Air Cushioning

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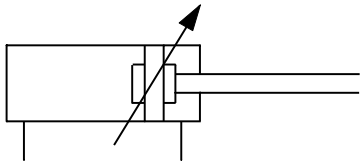

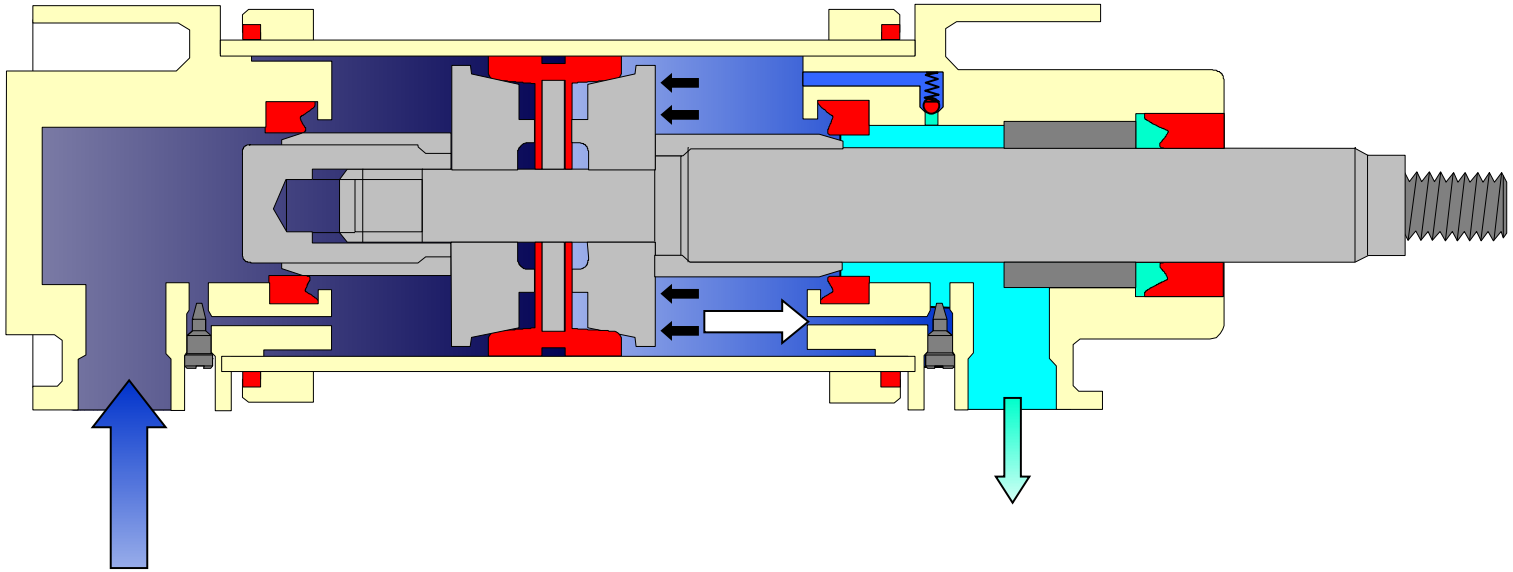

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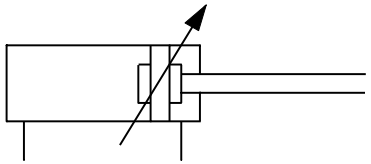

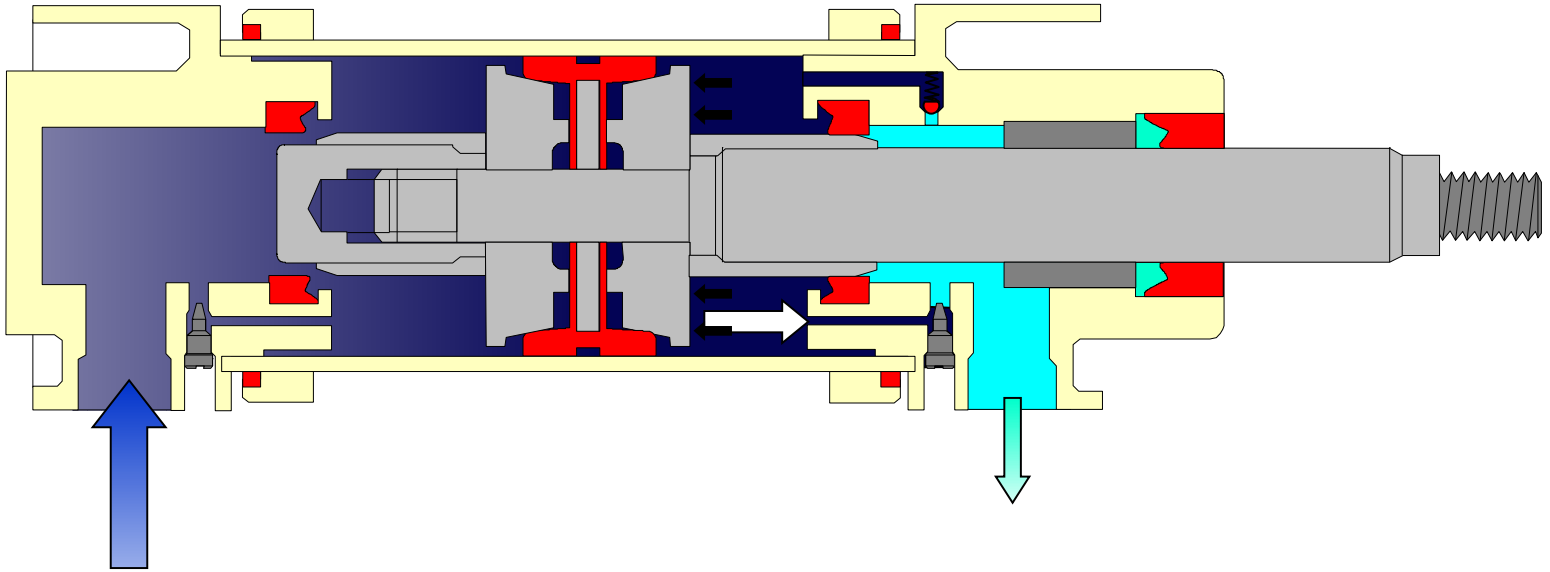

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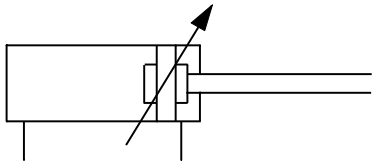

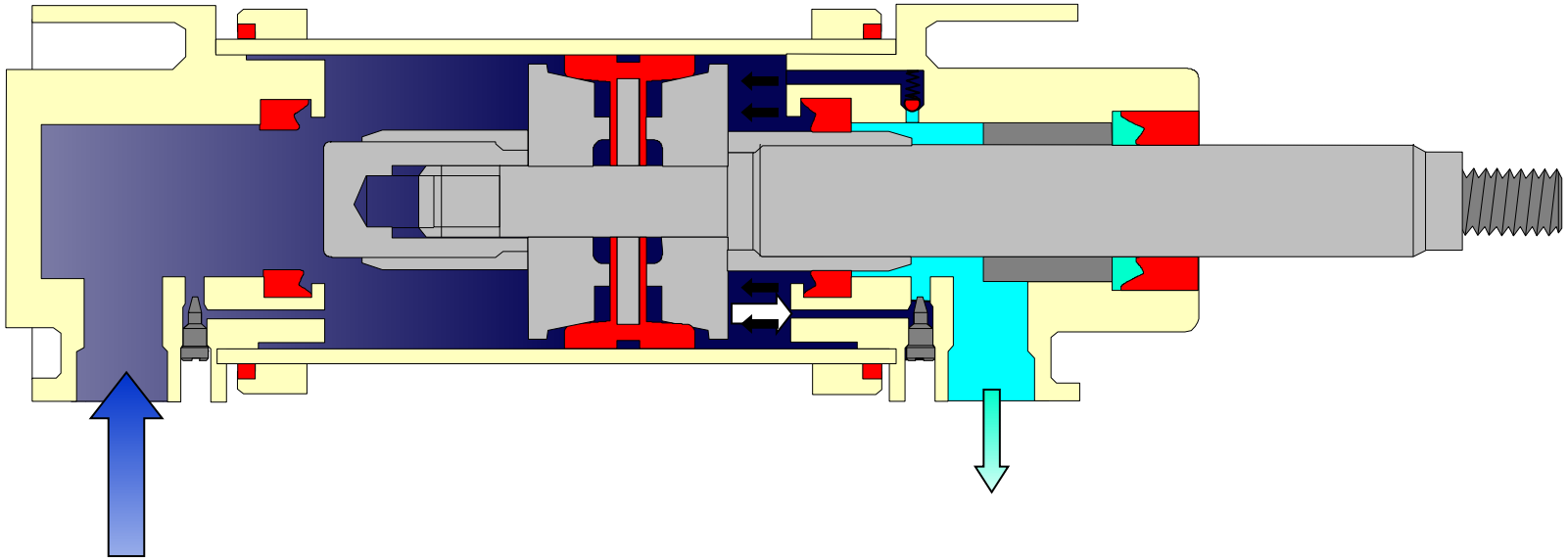

Operation of Double Acting Cylinders with Air Cushioning

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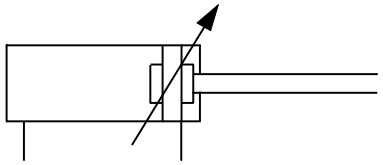

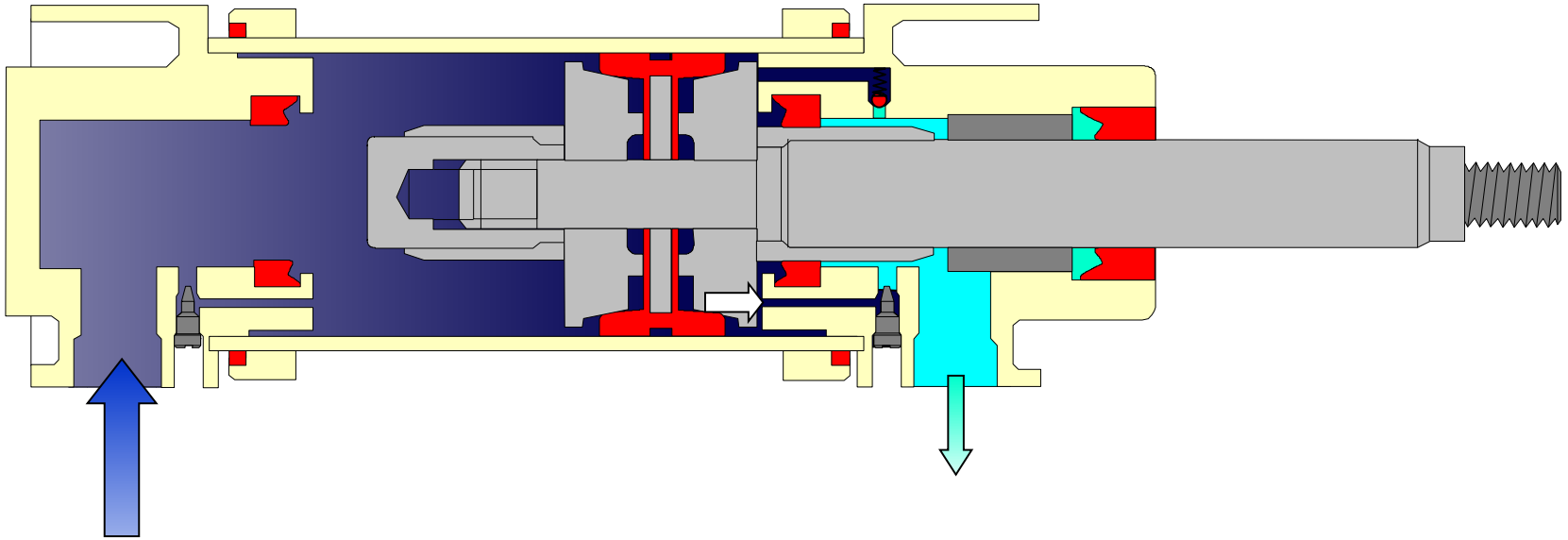

Operation of Double Acting Cylinders with Air Cushioning

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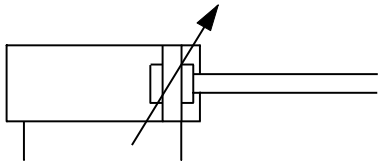

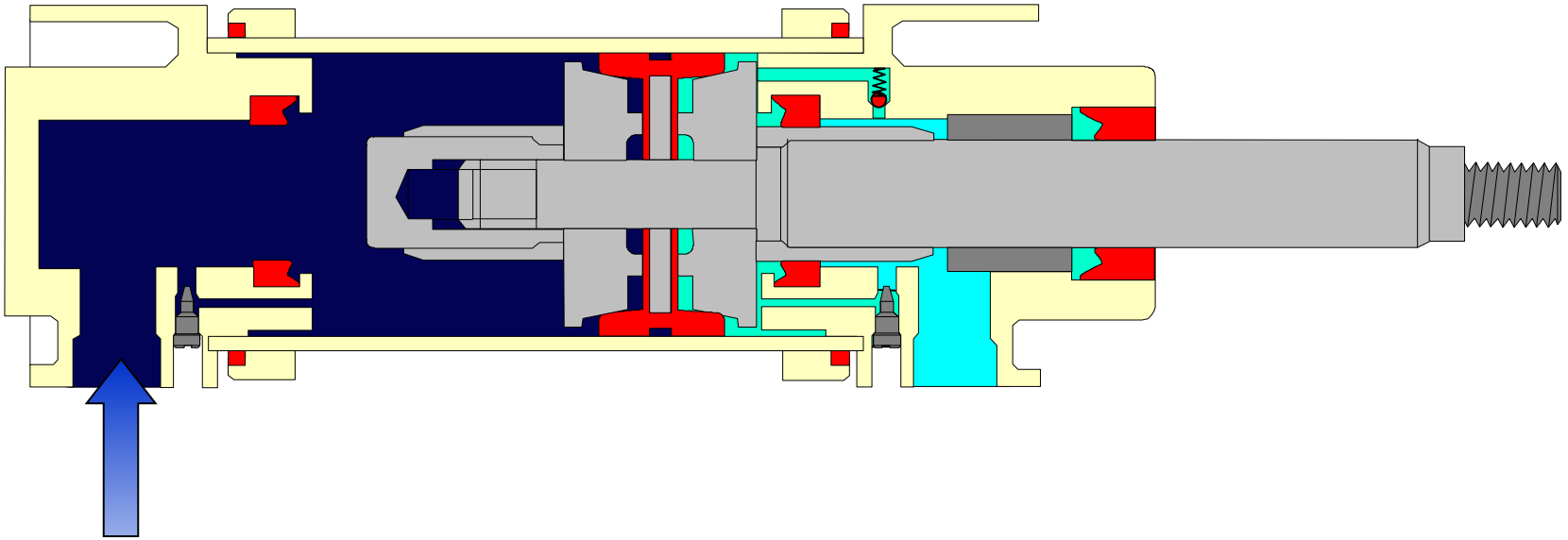

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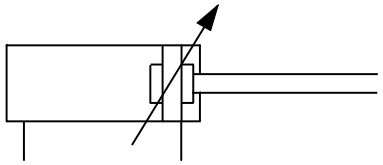

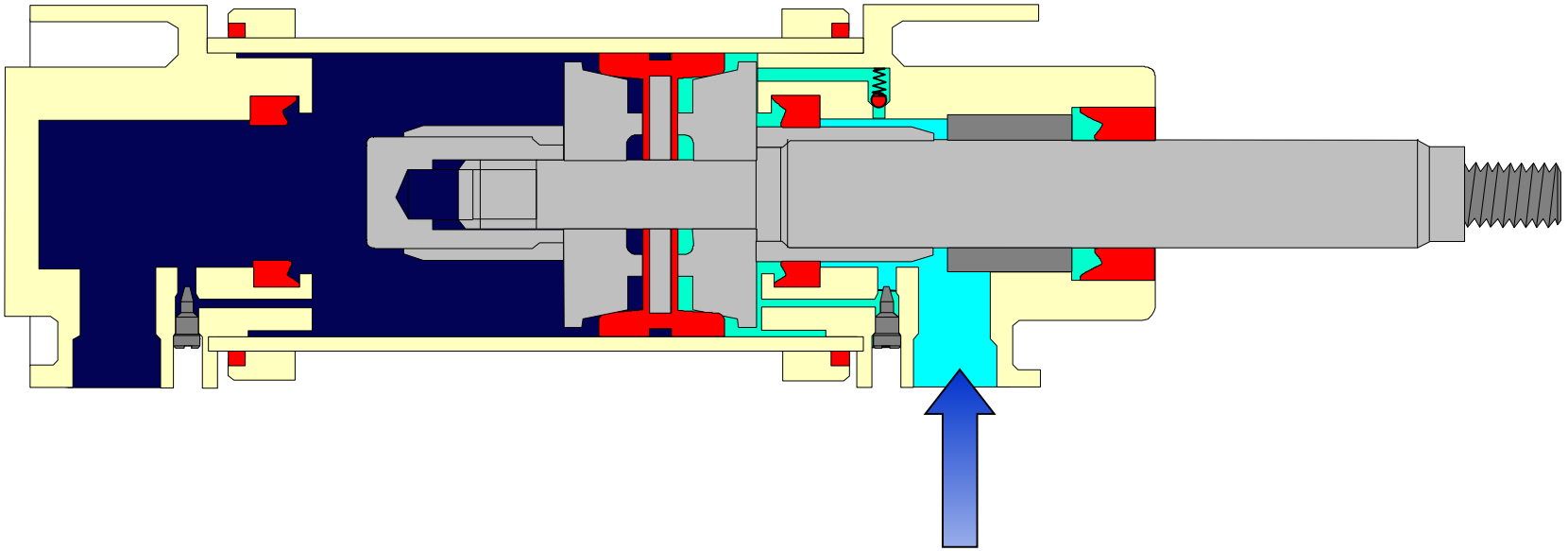

Operation of Double Acting Cylinders with Air Cushioning

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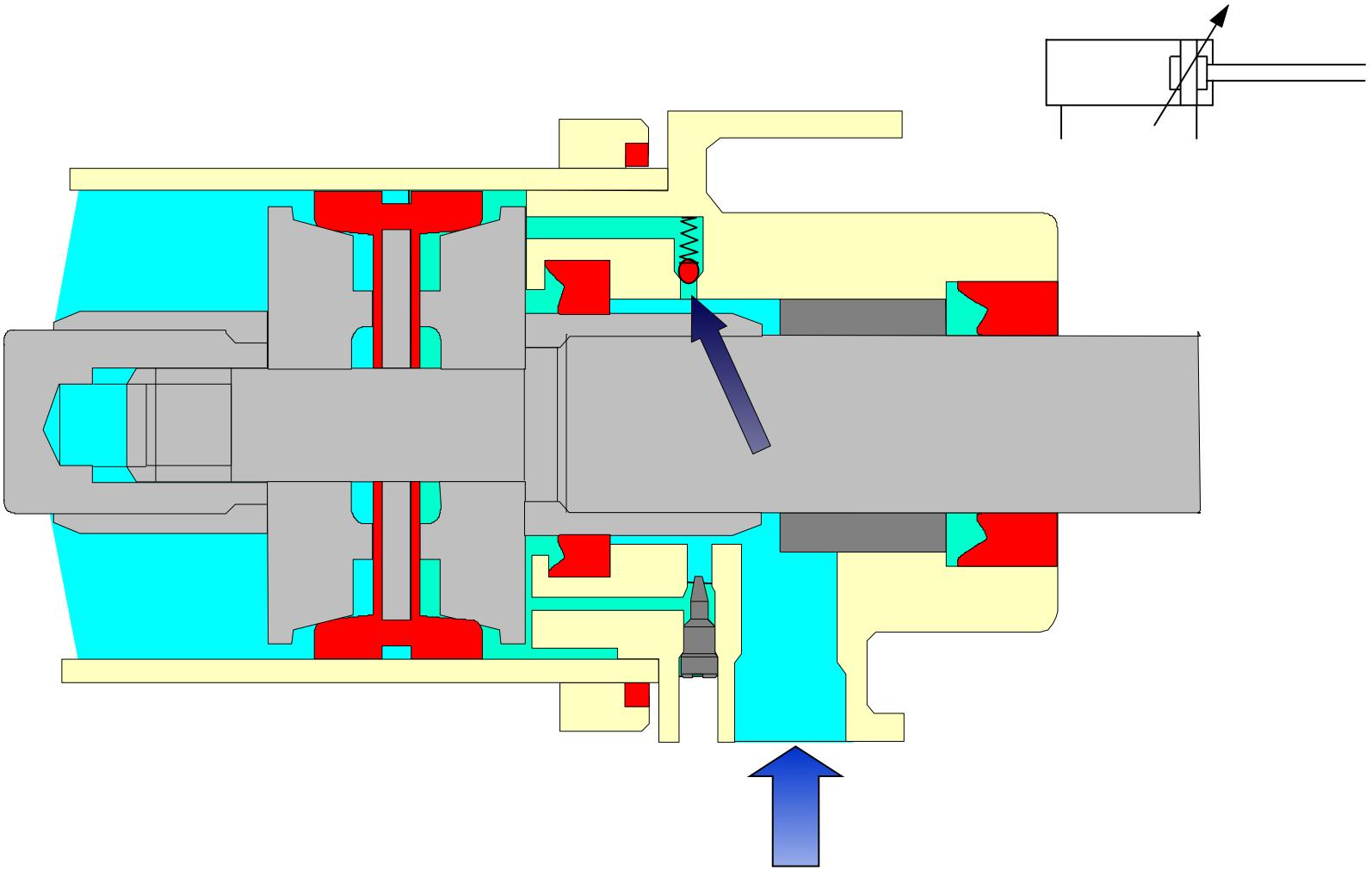

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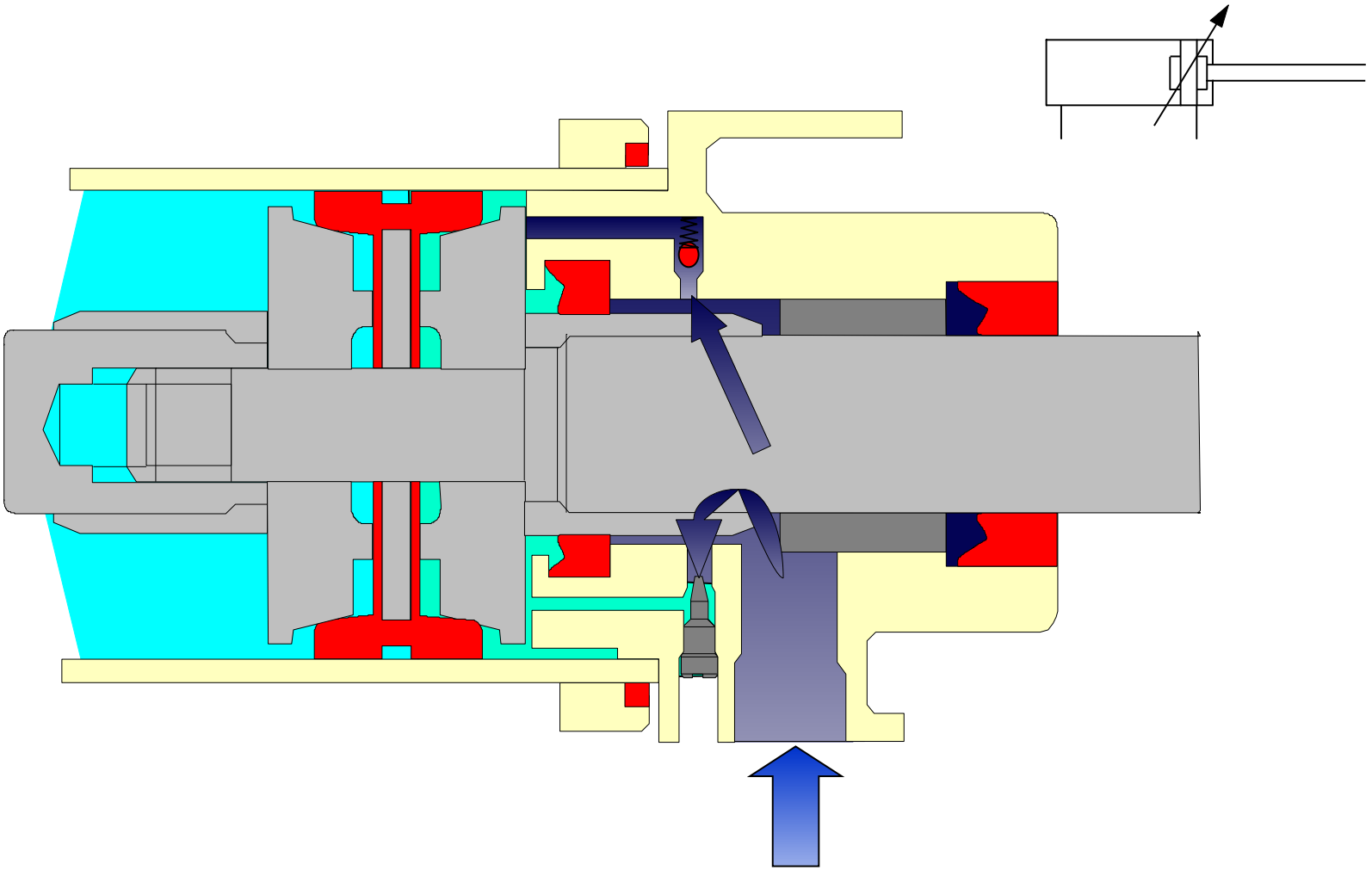

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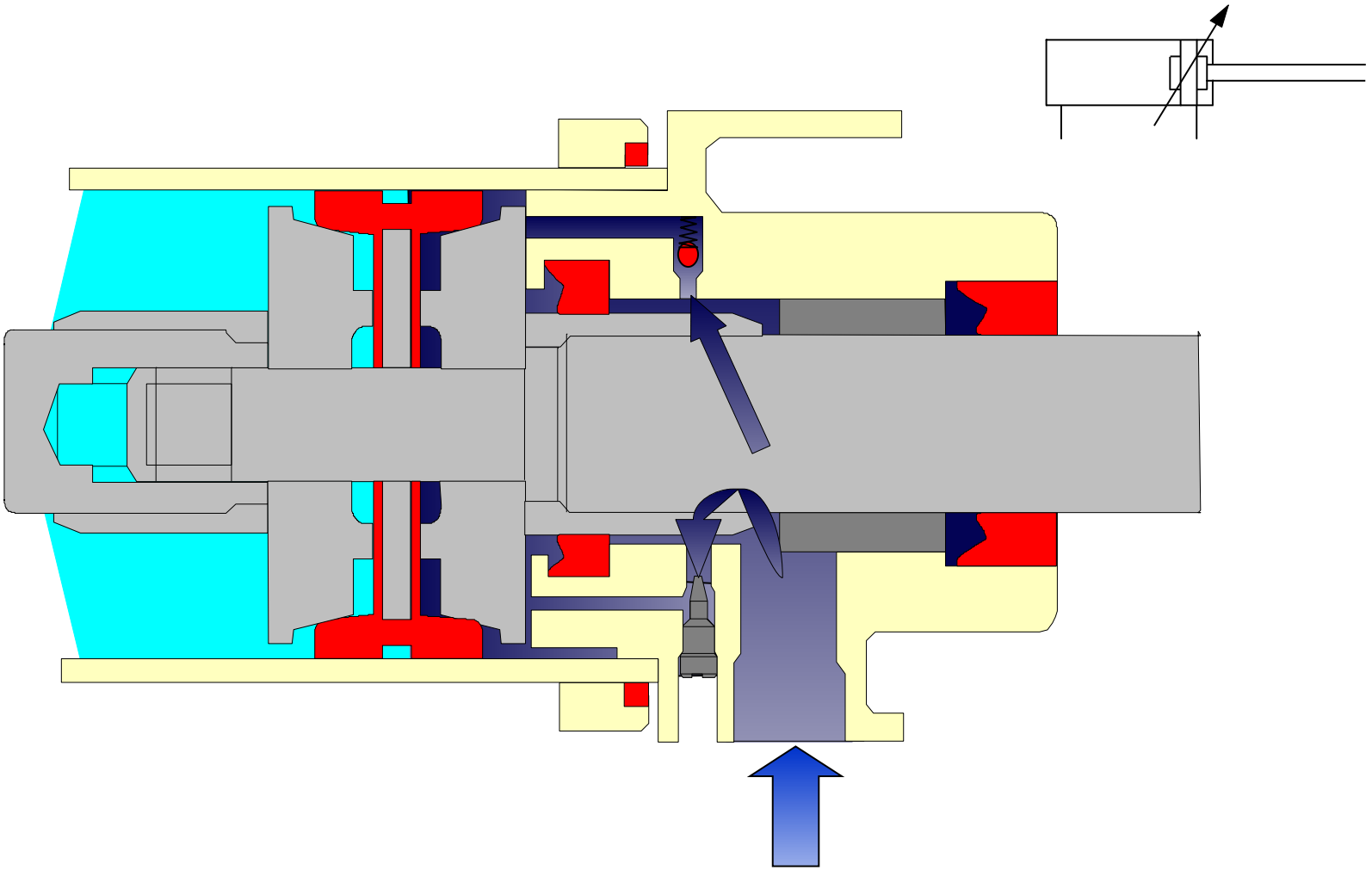

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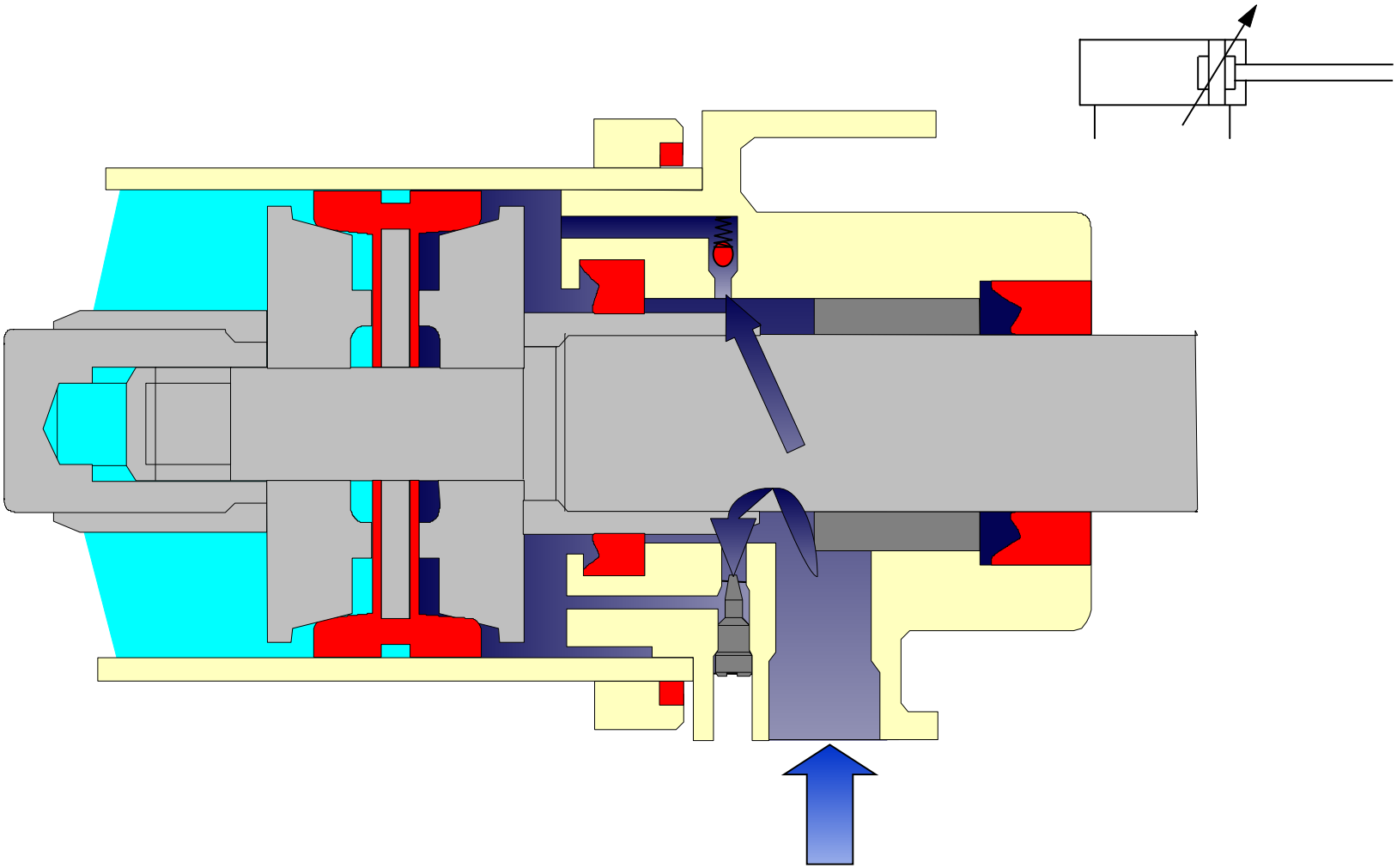

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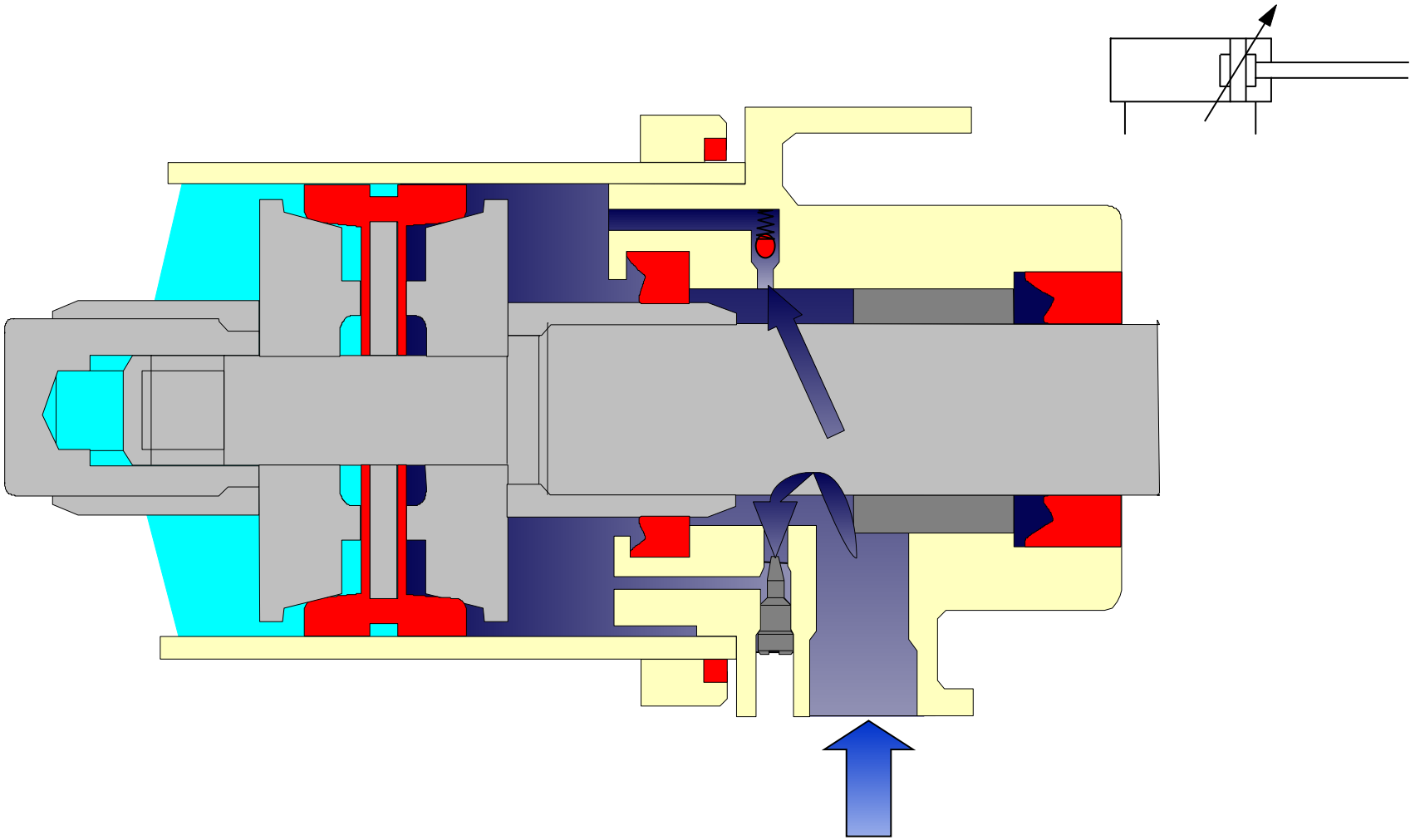

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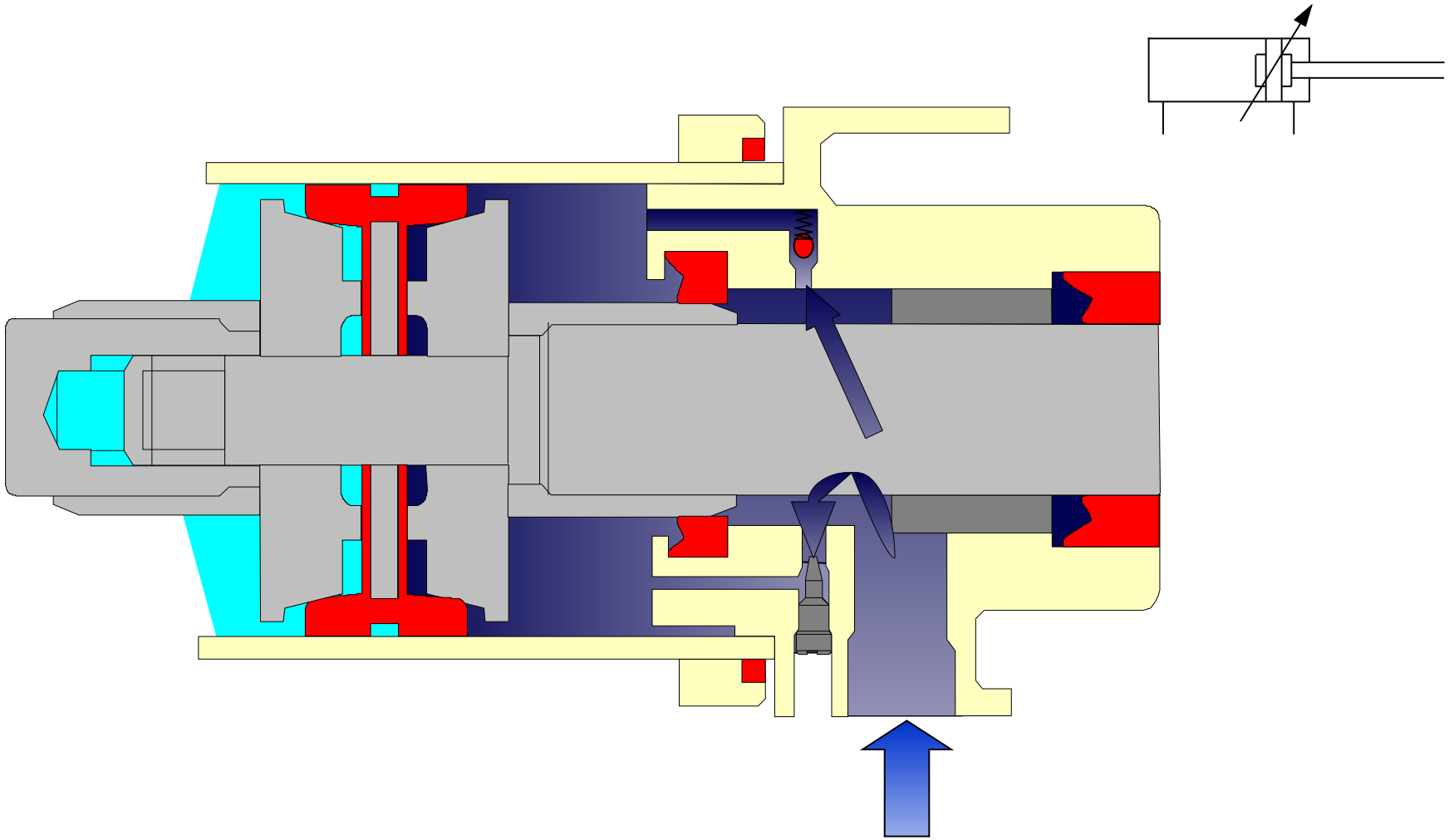

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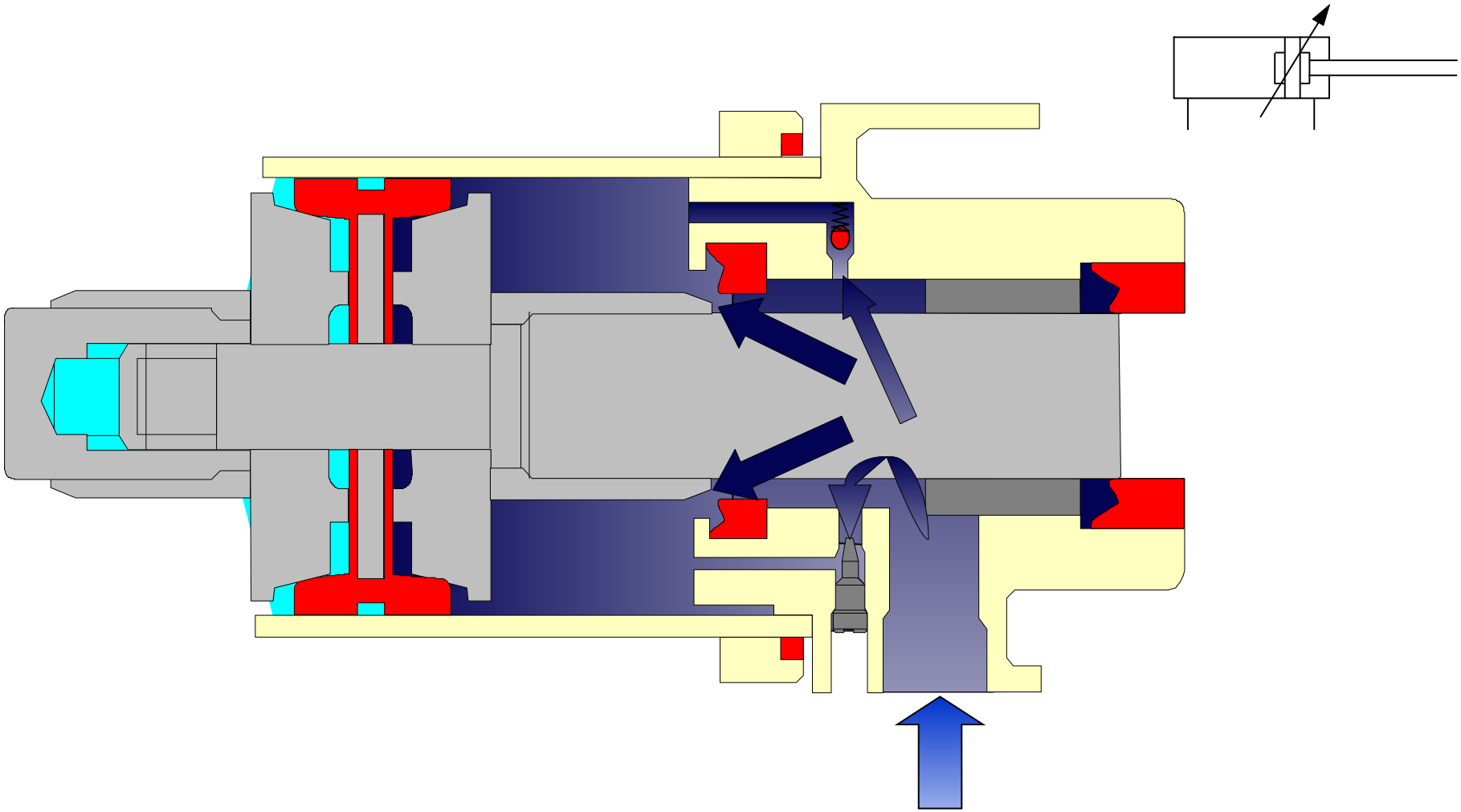
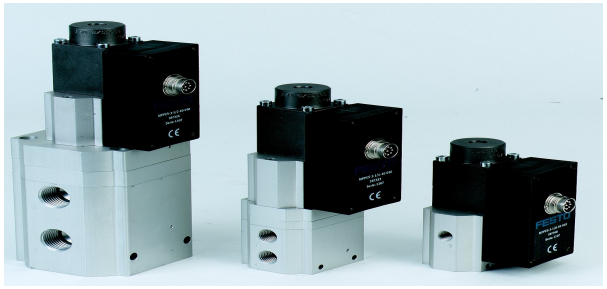


PNEUMATIC VALVES

FESTO

FUNCTIONS :

- open and close flow paths
- regulate pressure
- directs flow to various paths
- adjust flow volume

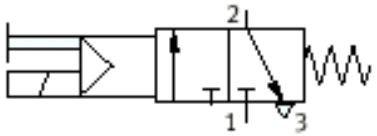


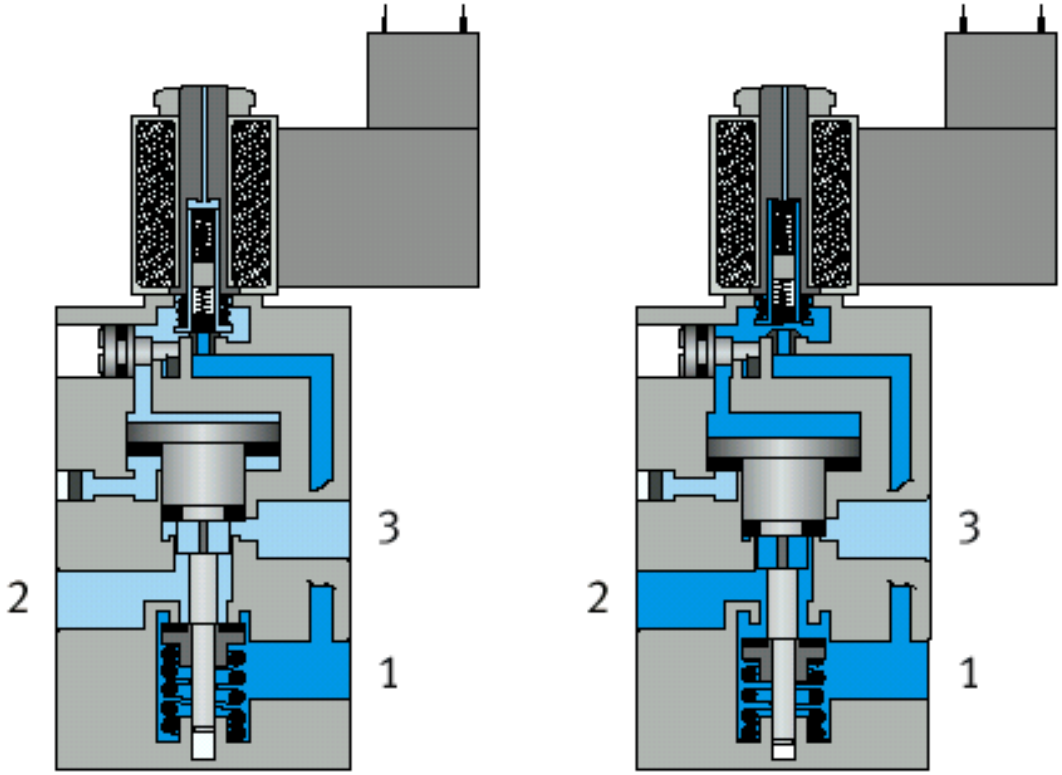
FESTO

Directional control valves

3/2 - way Directional Control Valve, Solenoid Actuated, Spring Returned

FESTO

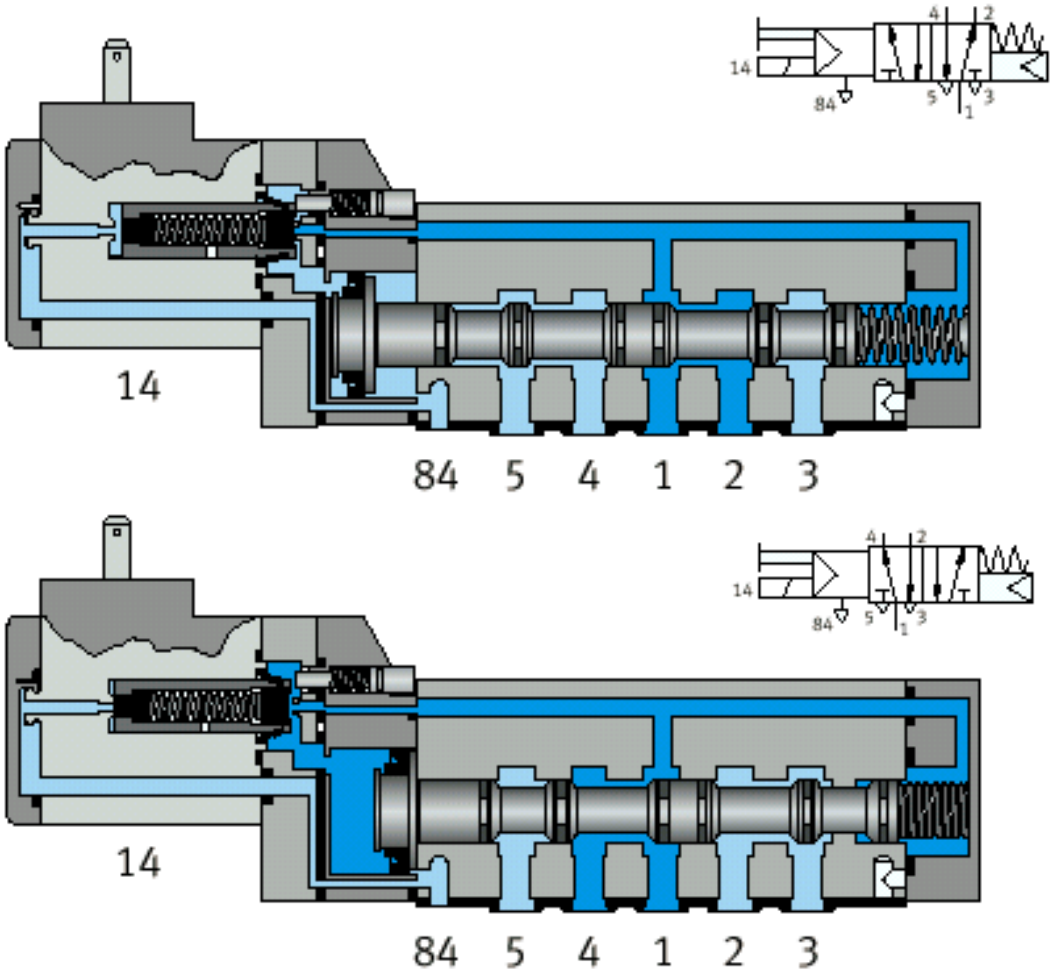




When an electric current is applied to the coil, an EMF is generated which lifts the lower sealing lips of the armature and opens the passage for pilot air. Pilot air then applies pressure on the diaphragm which then causes the valve to switch its position.

Upon removal of the current, the pilot air passage closes and a spring returns the valve to its normal switching position.

5/2 - way Directional Control Valve, Solenoid Actuated, Spring

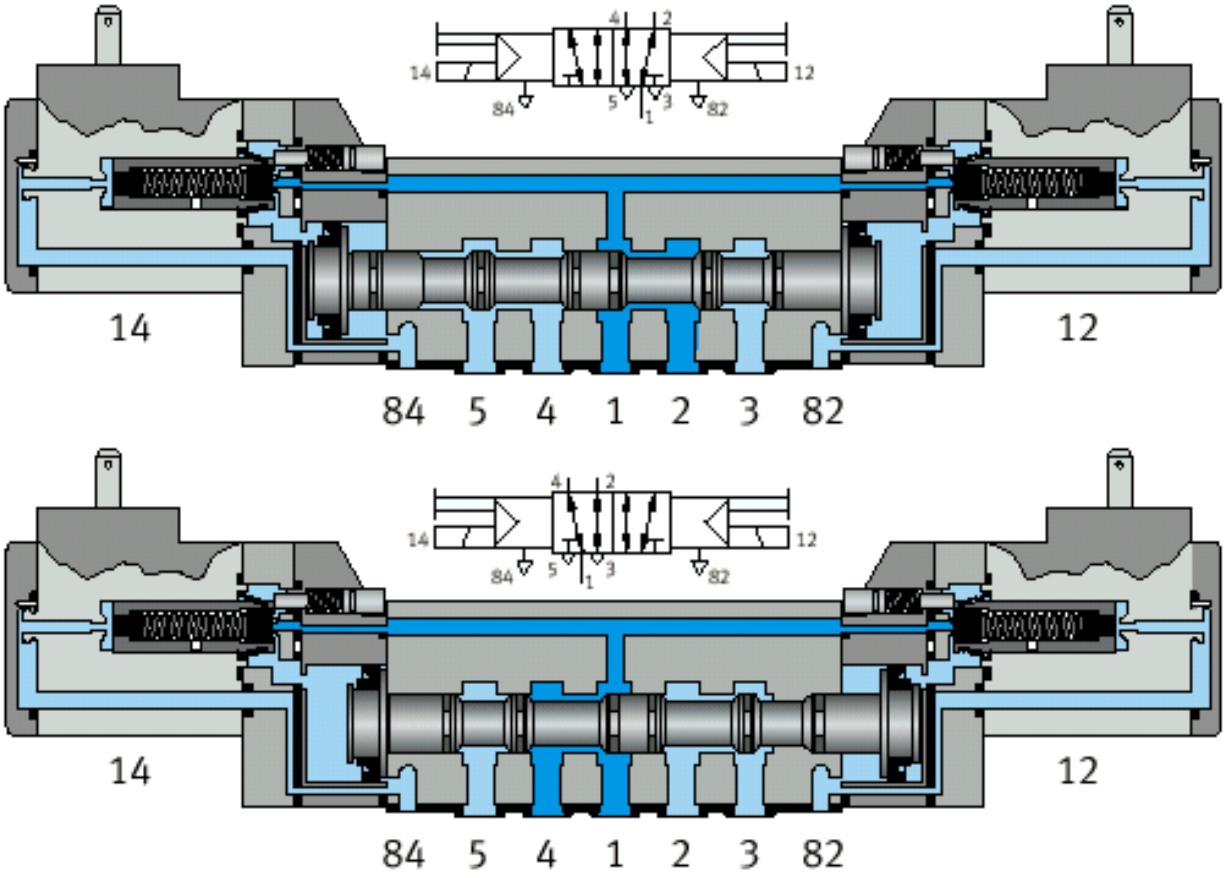


When the solenoid is energized, the armature moves and the pilot air passage opens. The pilot air applies pressure to the left side of the valve piston resulting to the valve switching its position.

Upon removal of the electrical signal, a spring returns the valve to its neutral switching position.

Used for the control of double acting cylinders.

5/2 - way Directional Control Valve, Double Solenoid Actuated

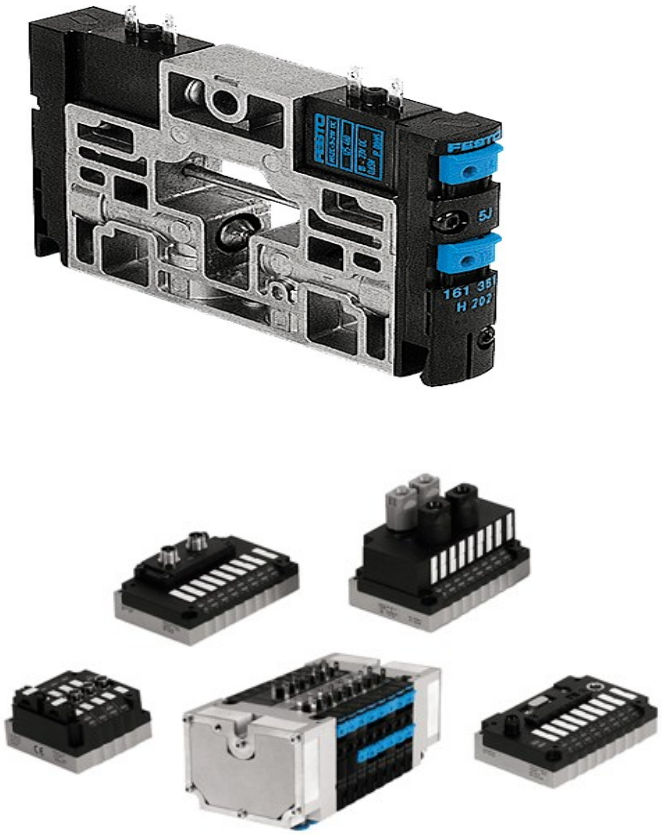


Because of the absence of a return spring, double solenoid actuated valves retain the last signal administered to them. They remain in their last switched position even with power removed from both solenoids.

Effectively, this means that this valve has **“memory characteristic”**.

Compact Performance Valve

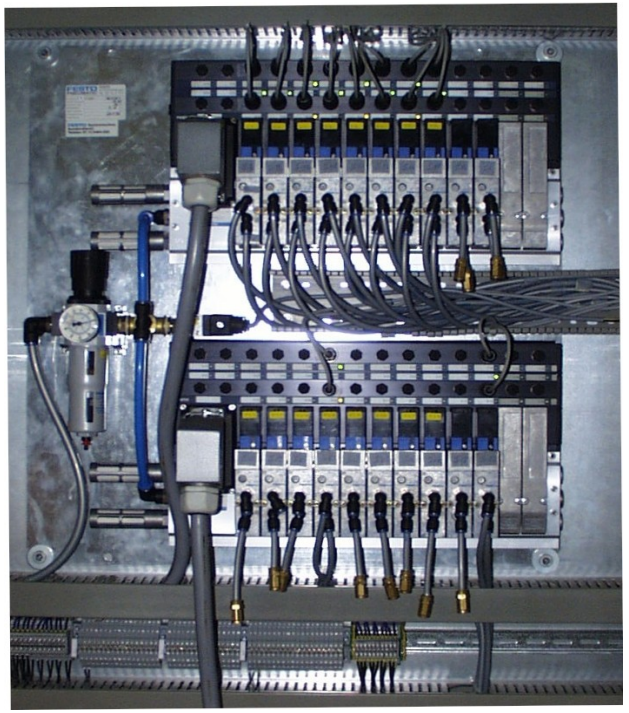
FESTO

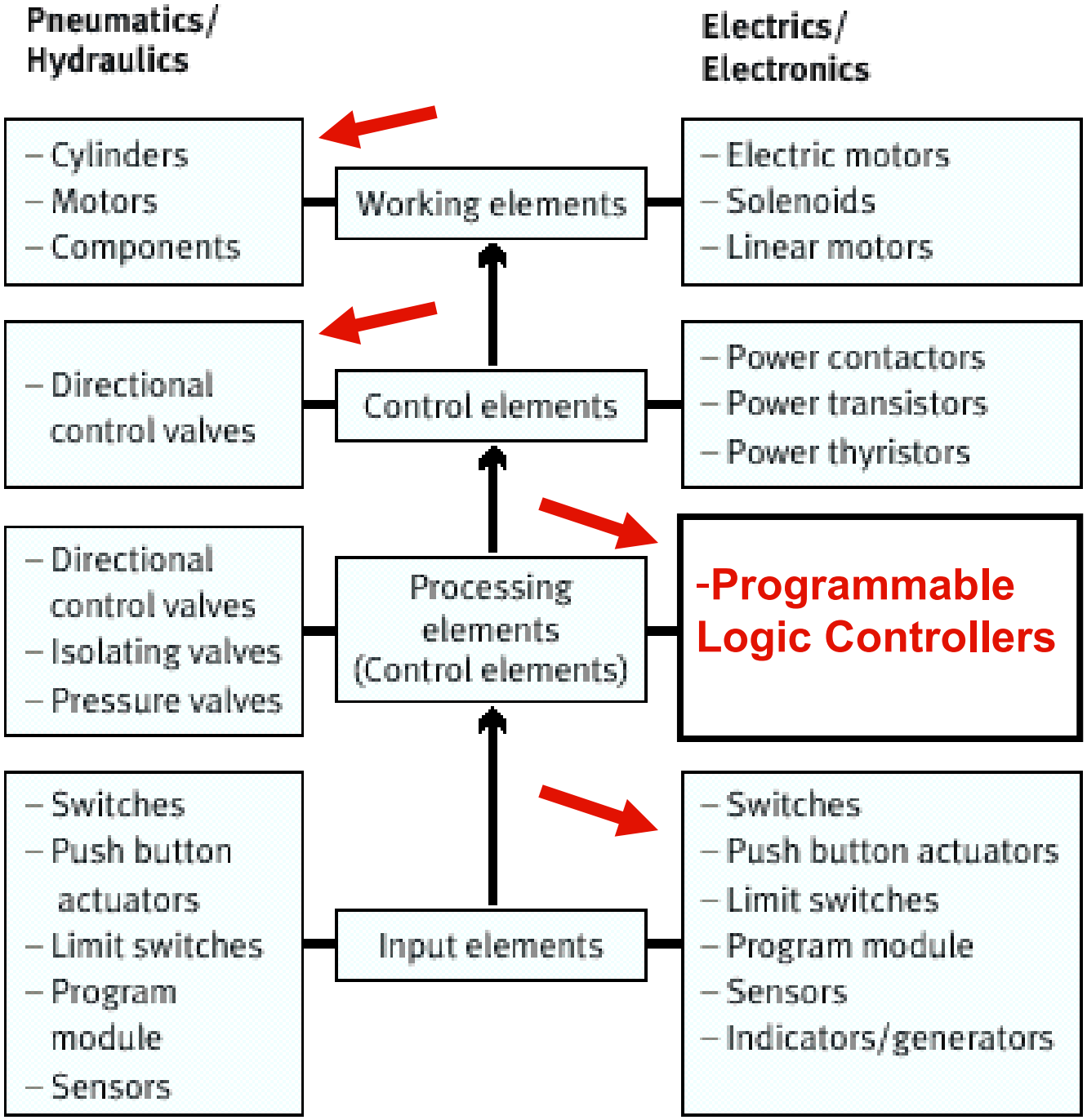


CP stands for compact performance, and thus for maximum performance in the smallest of spaces. Flow rates ranging from 400 to 1600 liters per minute combined with minimal weight and installation space requirements predestine CPV valve terminals for use in direct proximity to the pneumatic drive, assuring shortest possible response times and increased productivity. A wide range of additional valve and pneumatic functions allow for individualized, custom tailored design solutions. Flexibility is also trump where mounting options (top-hat rail mounting right on up to pneumatic multi-connector plate) and electrical connection options are concerned.

FESTO

Process Automation




Pneumatics/
Hydraulics
Electrics/
Electronics
– Cylinders
– Motors
– Components
Working elements
– Electric motors
– Solenoids
– Linear motors
– Directional control valves
Control elements
– Power contactors
– Power transistors
– Power thyristors
– Directional control valves
– Isolating valves
– Pressure valves
Processing elements (Control elements)
-Programmable Logic Controllers
– Switches
– Push button actuators
– Limit switches
– Program module
– Sensors
Input elements
– Switches
– Push button actuators
– Limit switches
– Program module
– Sensors
– Indicators/generators

FESTO

Definition

FESTO

A digitally operating electronic system, designed for use in an industrial environment, which uses memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic to control, through digital or analog inputs and outputs, various types of machines or processes.

FESTO

What is a PLC?

A programmable logic controller (PLC) is a specialized computer to perform logic functions for machine control.

PLCs are used to implement logic functions such as not allowing a drill press to start unless the operator has one hand on each of the two start switches.

Such control functions used to be implemented using relays. PLCs revolutionized this by allowing the control logic to be implemented using software.

Advantages of using PLC's

FESTO

- Highly reliable
- Highly versatile (universal applicability)
- Simple troubleshooting
- Simple installation
- Quick modification of the program (highly flexible)
- Capable of task not possible with relays before as indicated by the ff:
  - calculation
  - information exchange
  - text and graphic display
  - data processing
  - networking
- Low space requirement
- Low power consumption
- High processing speed
- No moving parts, hence no wearing parts

Disadvantages of using PLC’s

FESTO

- High initial cost (for a simple process)
- Sensitive to dust, high temperature and high humidity
- Repair must be made by a qualified personnel
- Not very widespread
- No uniform programming language

FESTO
DIDACTIC

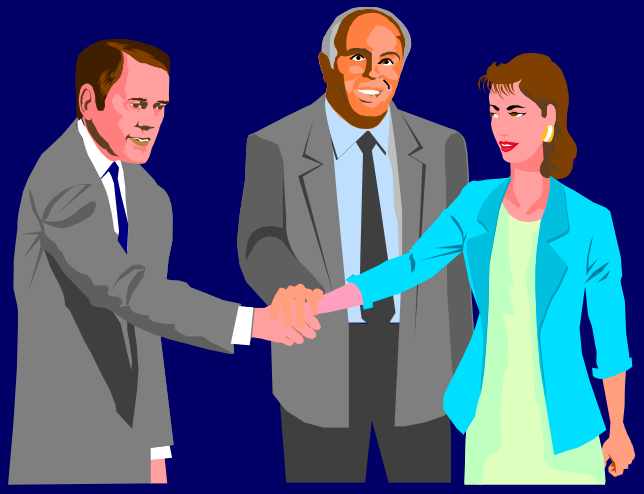
IEC 1131 - International Standard for PLC

Principles:

- The new standard takes into account as many as possible aspects of manufacturing and application of PLC systems.
- The manufacturers must conform with the instructions regarding the technical requirements of a PLC as well as the programming.
- Any deviations must be fully documented for the user.

AIMS :

- Uniform standard program languages
- Manufacturer-independent
- Open interfaces in the program systems Ideally, download of programs to different hardware systems



Selecting a PLC

Number of I/O’s

Kind of signals : digital or analog

Fieldbus system or standalone

Modular or compact

Operating voltage

Positive or negative triggerred input

Relay or transistor output

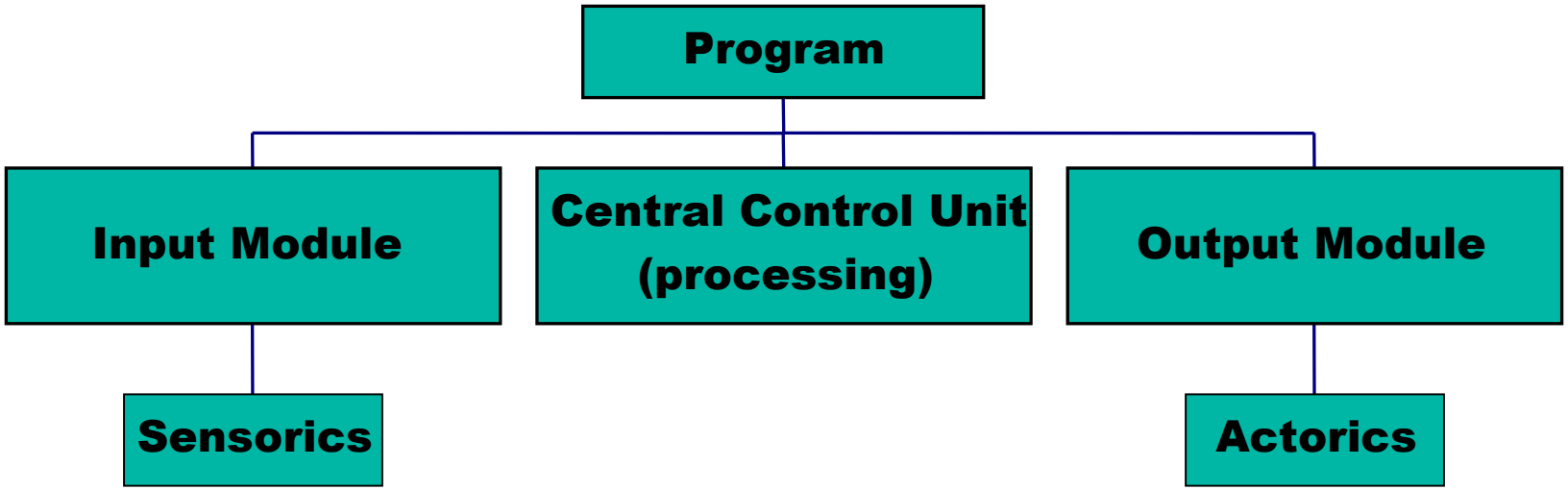
Operating systems

FESTO

PLC System

System Components

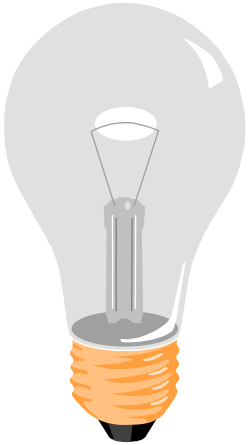
FESTO



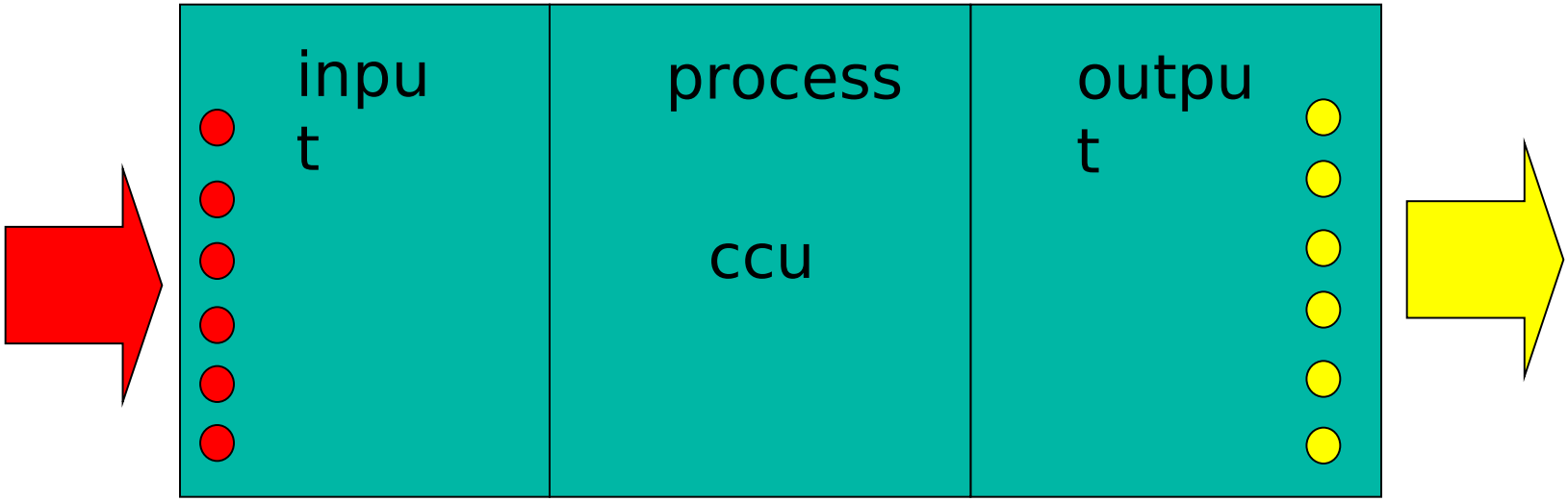
PLC SYSTEM

FESTO

INPUTS PROCESSOR OUTPUTS



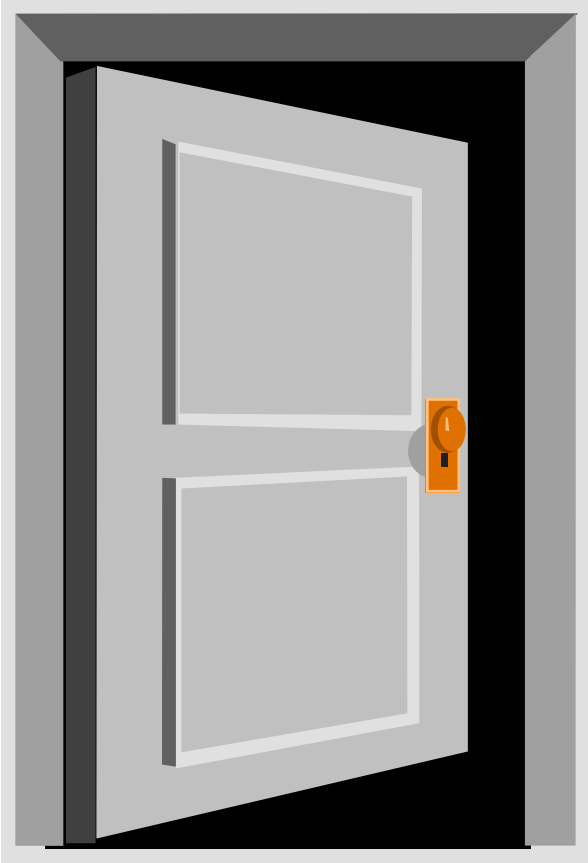
The PLC System



- Input devices send intelligible signals into the PLC
- Output devices receive intelligible signals from the output terminals

INPUTS

FESTO



- Acknowledging
- Limit switches
- Sensors
- Pushbuttons
- Relays
- Transmitters
- Signal Generators

Input Module : Functions

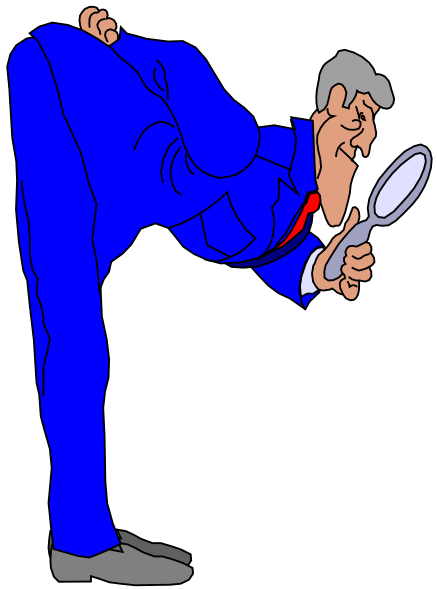
FESTO

The input module of a PLC is the module to which sensors are connected to. The sensor signals are to be passed on to the central control unit. The important functions of an input module are as follows:

- Reliable signal detection
- Voltage adjustment of control voltage to logic voltage
- Protection of sensitive electronics from external voltages
- Screening of signals

PROCESSORS

FESTO



Central Control Unit CCU

- the most important component of the PLC
- it directs the operation of the system
- it contains the arithmetic logic unit
- it processes input signals to produce the necessary output signal
- it has memory to store programs and data to be processed
- it allows communication with external peripherals
- it is interfaced with sensors and actuators using the input and output modules respectively

Output Module : Functions

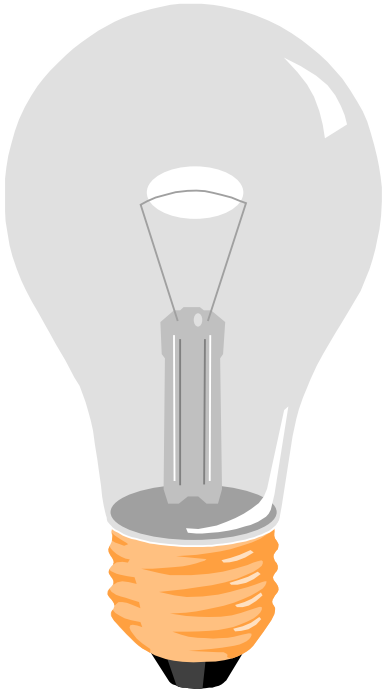
FESTO

Output modules conduct the signals of the central control unit to final control elements, which are actuated according to the task. The functions of the output module, as seen from the application of the PLC, include the following:

- Voltage adjustment of logic voltage to control voltage
- Protection of sensitive electronics from spurious voltages from the controller
- Power amplification sufficient for the actuation of major final control elements
- Short circuit and overload protection of output

OUTPUTS

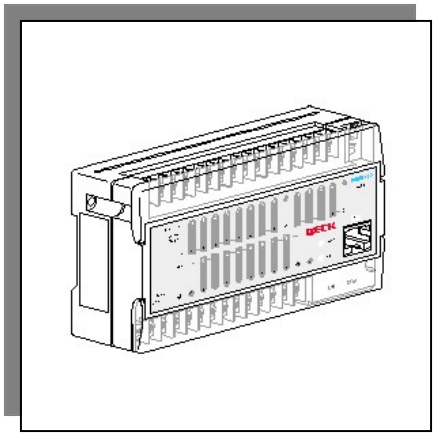
FESTO



- Final control elements
- Relays
- Electrical loads
- Solenoid coils
- Lamps
- Indicators
- Alarms / buzzers

Construction of a PLC

Fixed I/O



FEC34 PLC in Distribution Station

Modular

FESTO
DIDACTIC

FESTO FPC 101B

- Operating Voltage
  - Nominal Voltage : 24Vdc
  - Permissible Range : 17 to 30Vdc
- Inputs : 21
- Outputs : 16
- Registers : 64
- Timers : 32
- Counters : 16
- Programming Languages : STL, LDR.
- Arithmetic Commands : +, -, *, /
- Bit/Word Processing : Yes
- Program Structure : 1 User Program
  - incorporation of 8 program modules
  - incorporation of up to 16 function modules
- User Program Memory : 12Kbytes (RAM or EPROM)
- Delay Time : 5ms - input
  10ms - output

FESTO
DIDACTIC

FESTO FEC-20-DC

- Operating Voltage
  - Nominal Voltage : 24Vdc
  - Permissible Range : 17 to 30Vdc
- Inputs : 12
- Outputs : 8
- Registers : 256
- Timers : 256
- Counters : 256
- Programming Languages : STL, LDR
- Arithmetic Commands : +, -, *, /
- Bit/Word Processing : Yes
- Program Structure : 8 User Program
  - incorporation of 8 program modules
  - incorporation of up to 256 function modules
- User Program Memory : 32Kbytes (RAM or EPROM)
- Delay Time : 5ms - input
  10ms - output

Compact PLC

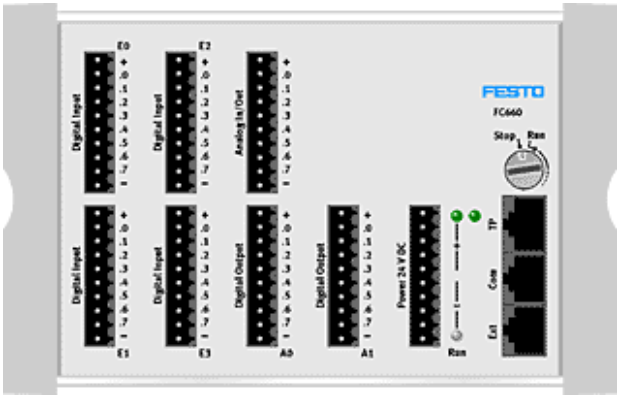
IPC FEC Compact

IPC FEC Standard

FED – Front End Display

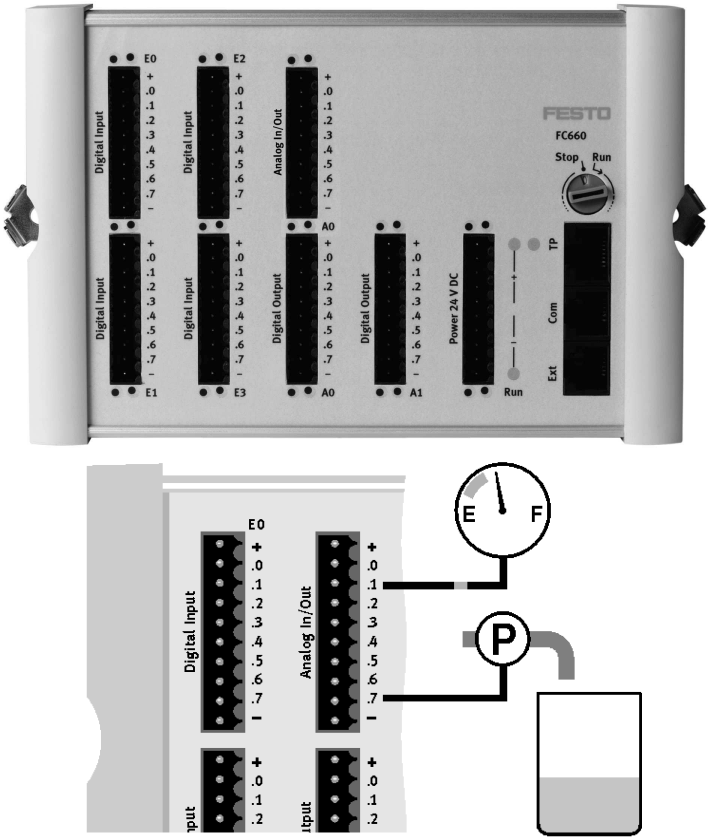
FST – Festo Software Tool

IPC FEC Standard - The 600 line



FEC- FC600	32/16 digital I/Os
FEC- FC620	32/16 digital I/Os + 3/1 analog I/Os
FEC- FC640	32/16 digital I/Os + Ethernet
FEC- FC660	32/16 digital I/Os + 3/1 analog I/Os + Ethernet

FEC Standard – systematically more intelligent



FEC + Ethernet = FC34

FC34 - Hardware Features

PROGRAMMING SOFTWARE
FST4, FST IPC 3.21
MULTIPROG

- **12 digital Inputs (PNP/NPN)**
- **24 V DC**
- **Run / Stop Switch**
- **2 Relay / 6 Transistor Outputs**
- **COM and EXT Interfaces**
- **Ethernet**
  - Twisted Pair
  - RJ45 connector
  - 10 MBit/s
- **256 timers, 256 counters**
- **256 registers**
- **160,000 flag**

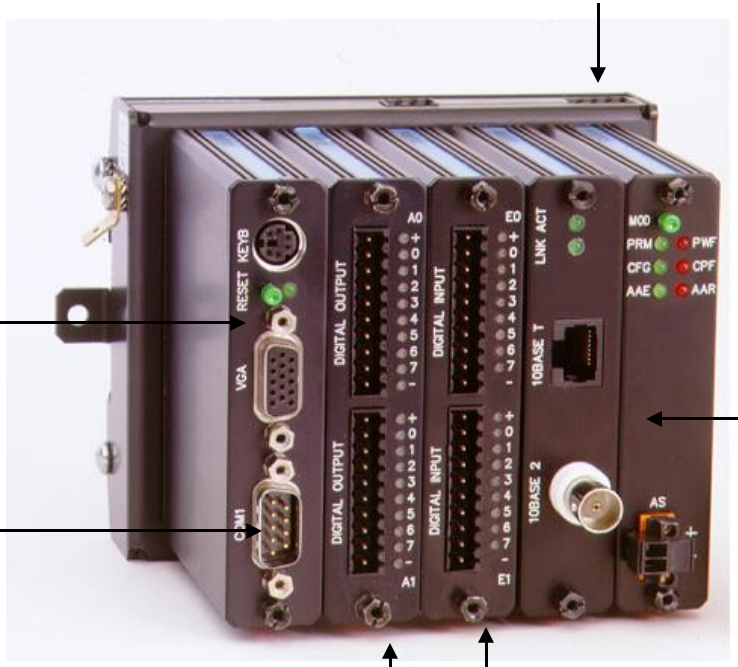
PLC & Mobile Phone

- Remote control and diagnostic of test stations
- Hardware is FEC FC38 (FEC with GSM modem)
- Software written in FST

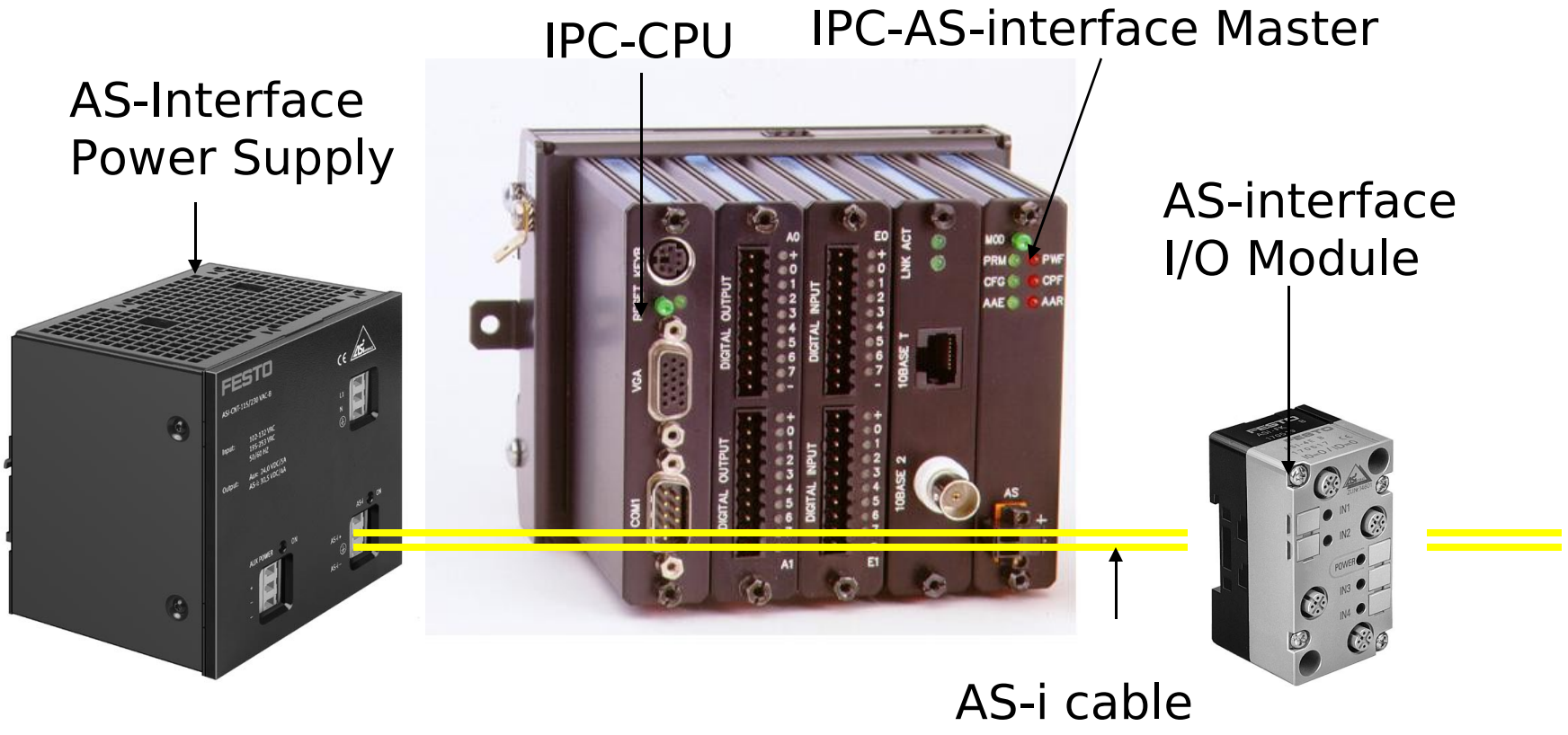
SMS PLC

FESTO

S-Interface – CPU and AS-i Master



AS-Interface - Hardware



FESTO

FESTO PLC : Optimum Control

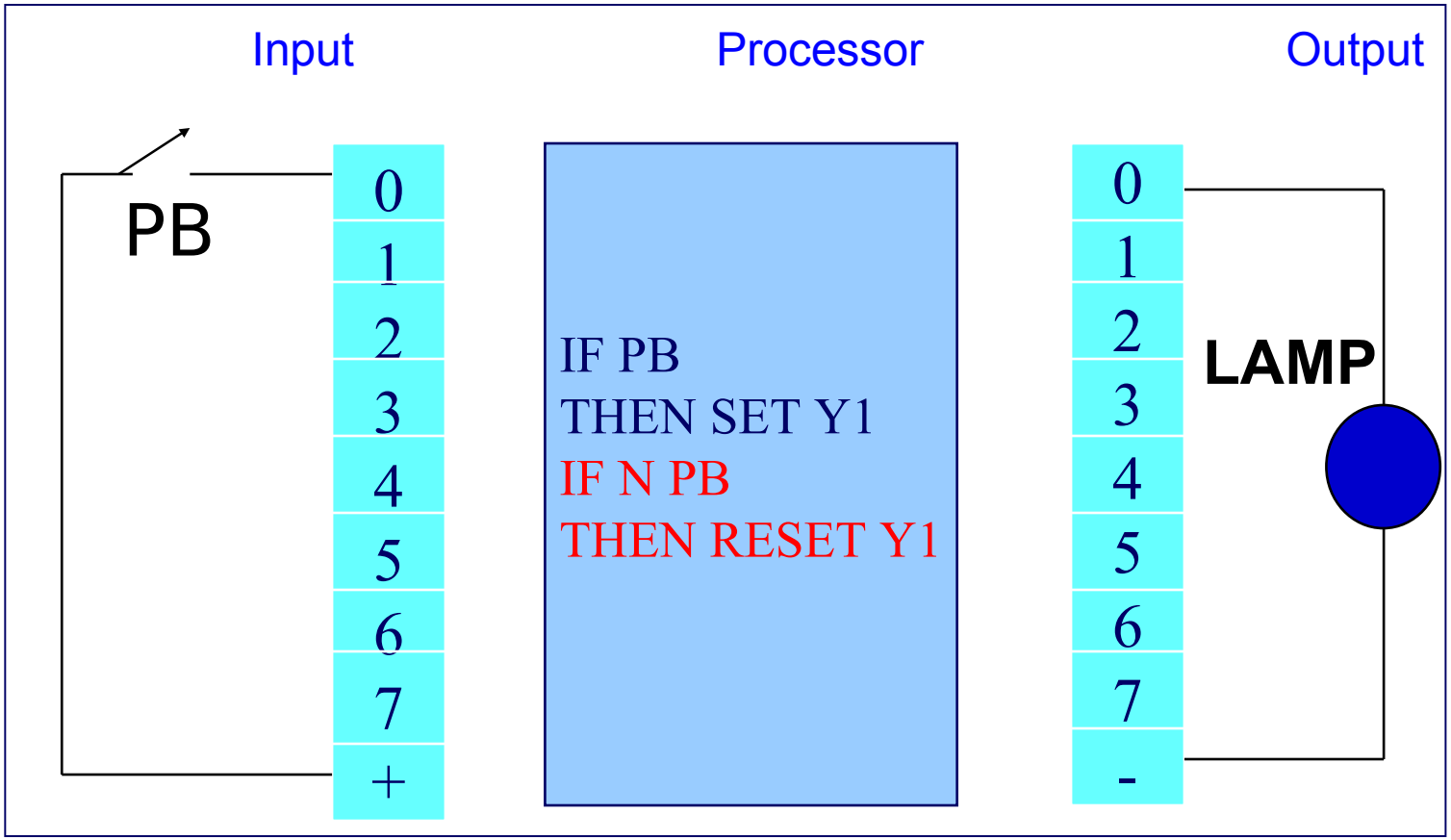
Festo FPC 400
- the multi-functional one

Festo IPC
- the allrounder

FESTO

PLC Programming

Sample setup



FESTO

PLC Programming

FESTO SOFTWARE TOOL

(FST)

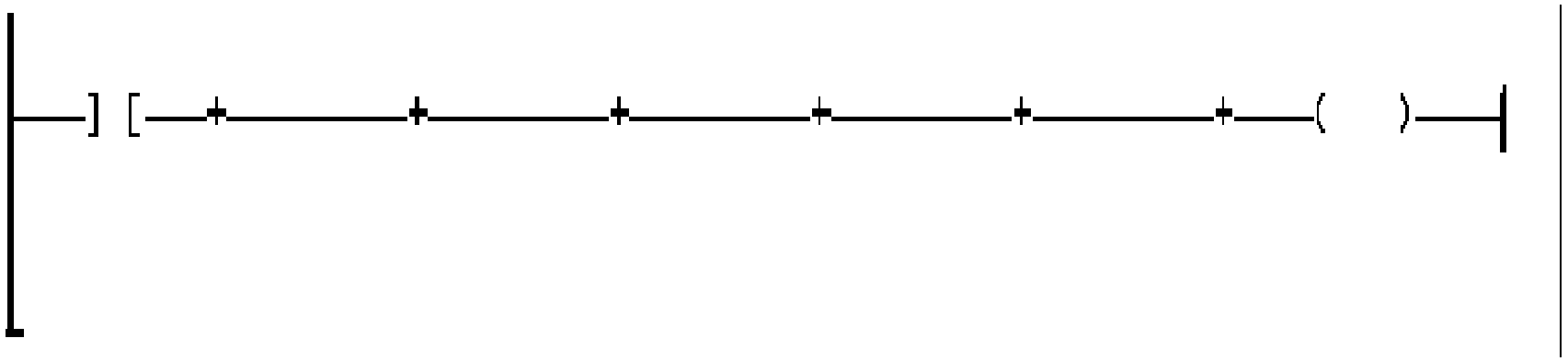
FESTO

Ladder Diagram

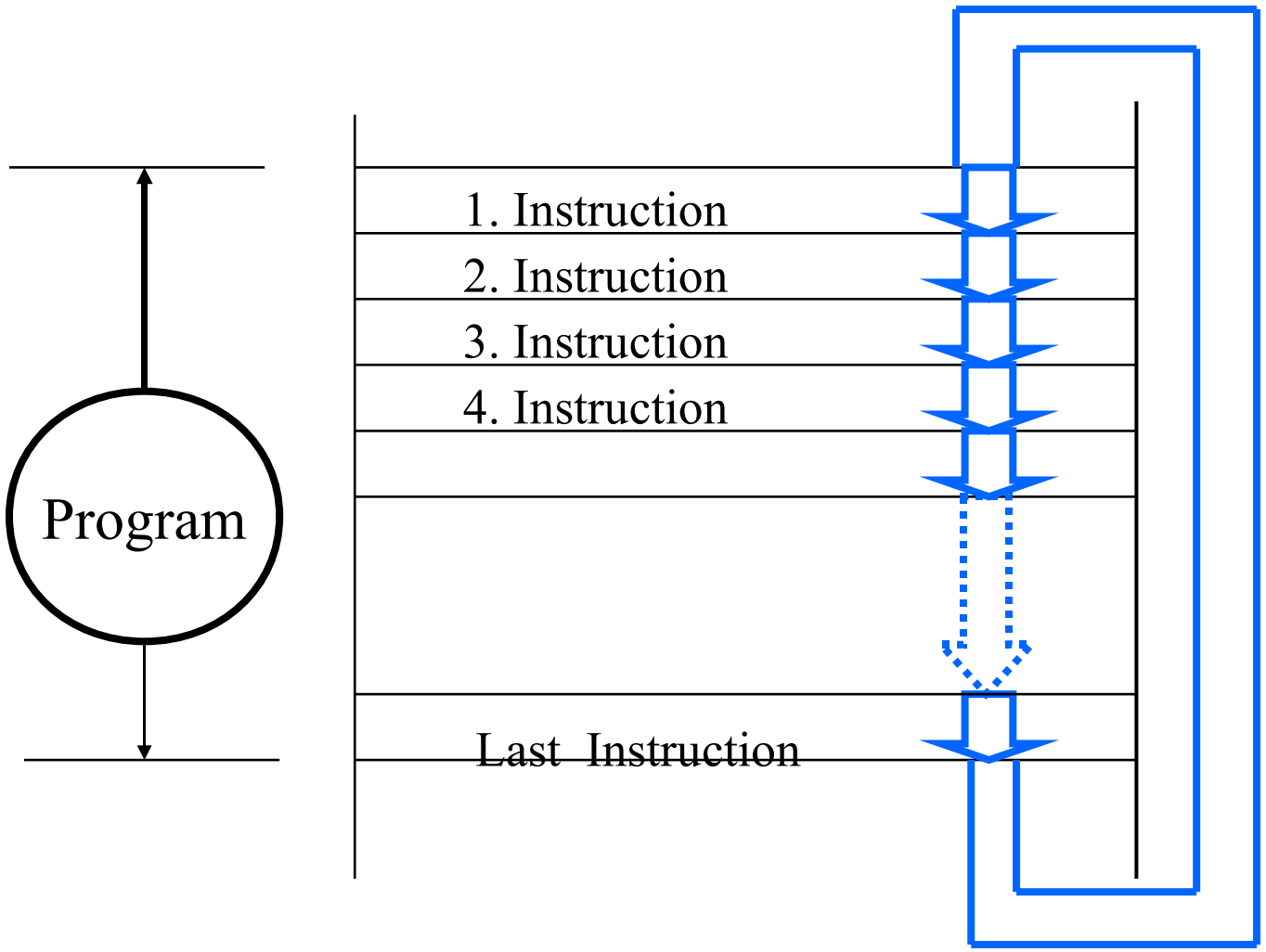
Ladder Diagram

FESTO

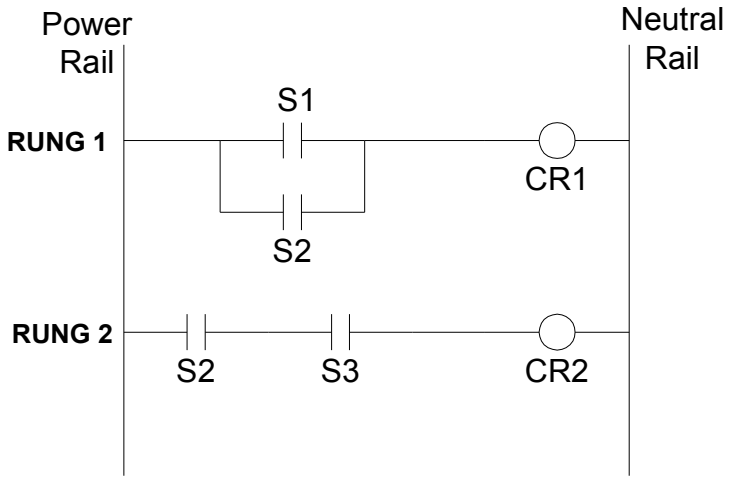
- The ladder diagram describes the program in graphic form. It was developed from the relay ladder but is structured in diagrammatic form. It is made up of two vertical lines of which the left one is connected to the voltage source and the right is zero voltage source. The various current paths(rungs) run horizontally between the two (from left to right).



Program processing by PLC



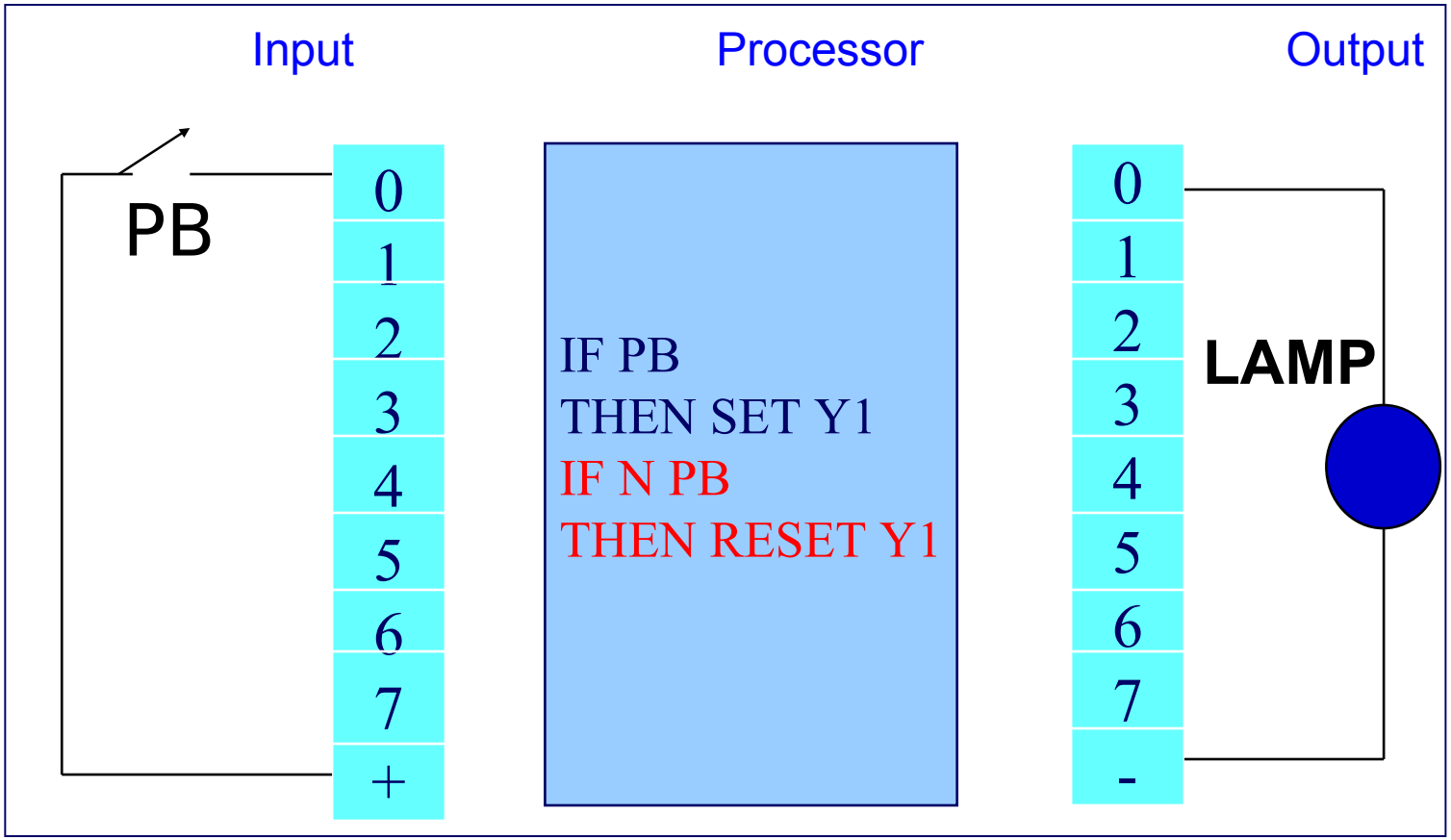
Ladder Diagram



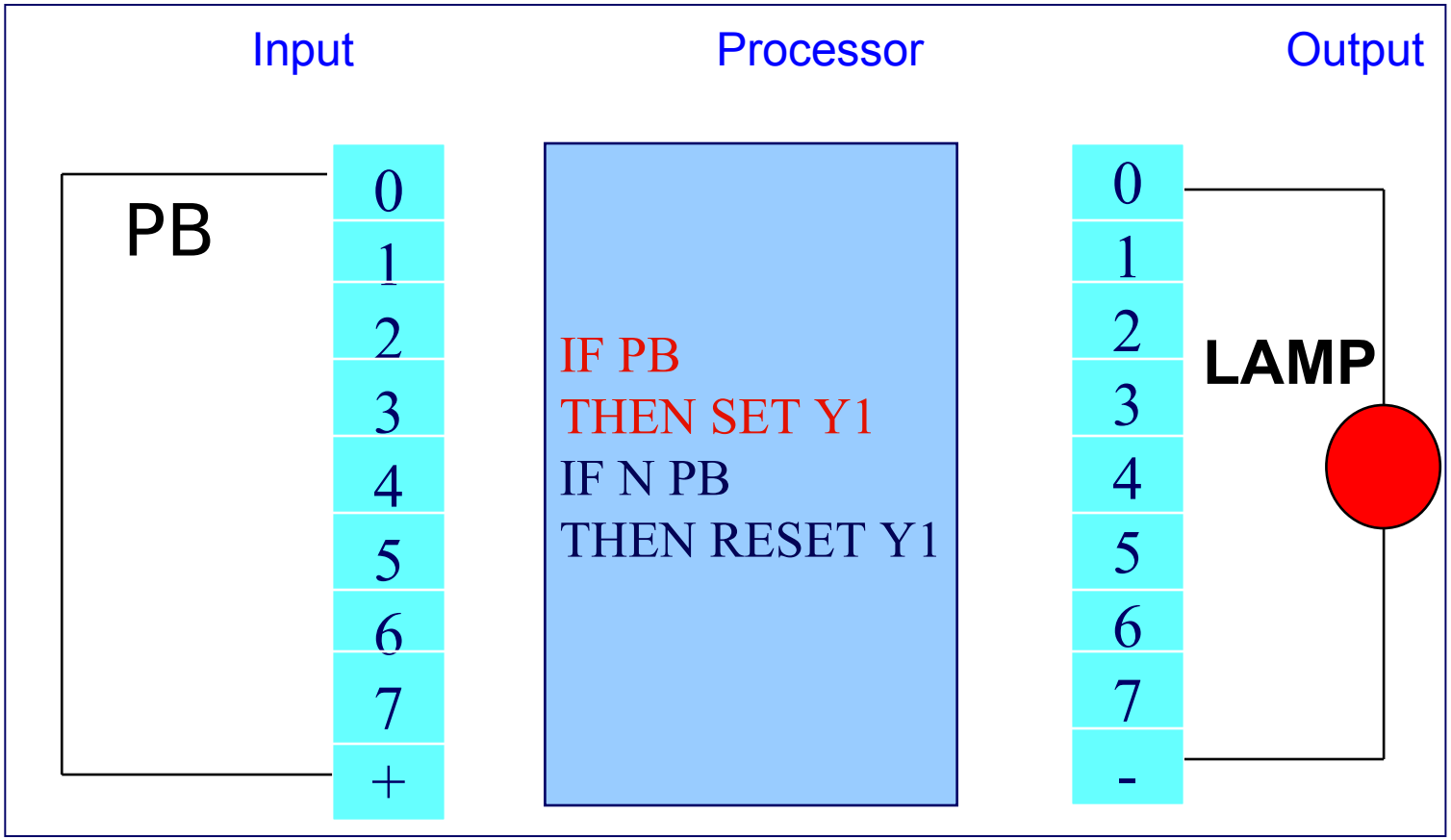
Ladder diagram is a drawing showing all the switches, sensors, motors, valves, and relays that are used in the control circuit.

Today, many PLCs are programmed using **ladder logic programming**.

Sample setup

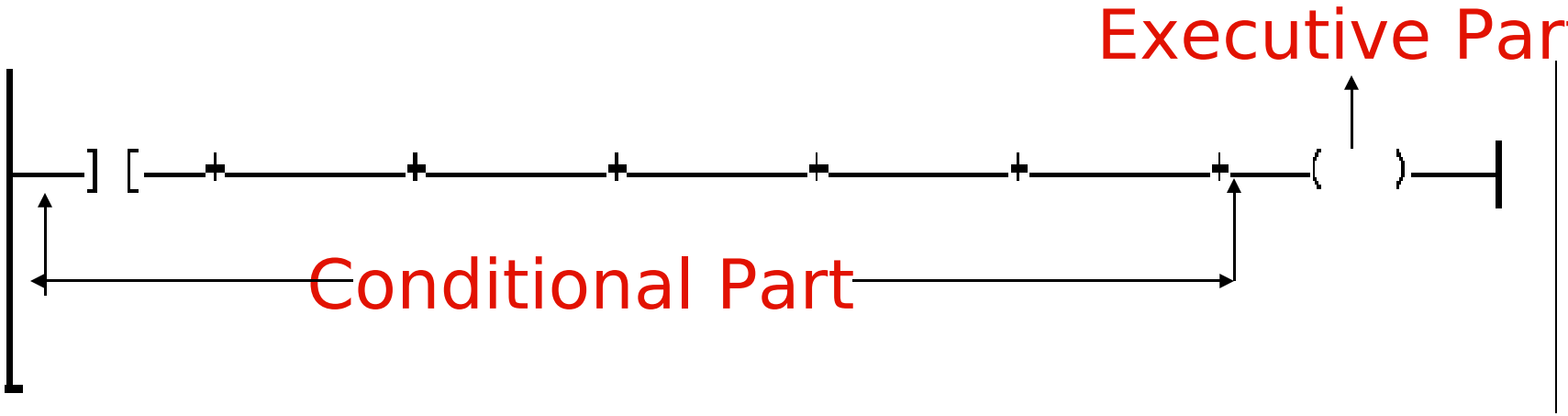


Sample setup



Ladder Diagram

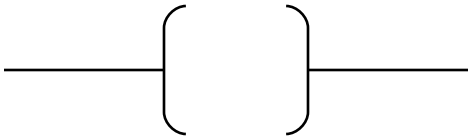
FESTO



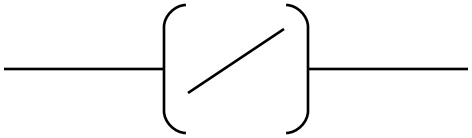
- Language Elements
  - inputs]N[
    normally closed]/[
    normally open] [
  - outputs

Coil Operations

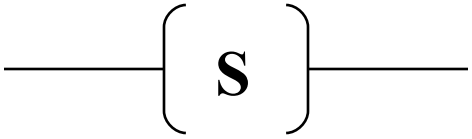
FESTO



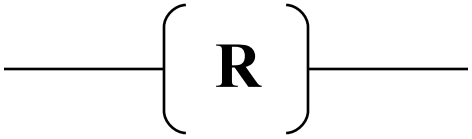
Non-Latching Coil: O0.0 is energized if signal reaches the coil, de-energized if the signal does not.



Inverse Non-Latching Coil: O0.0 is energized if signal does not reach the coil, de-energized if the signal does.



Set & Hold Coil: O0.0 is energized once signal reaches the coil, remains energized until Reset Coil is activated.(**Memorized ON**)



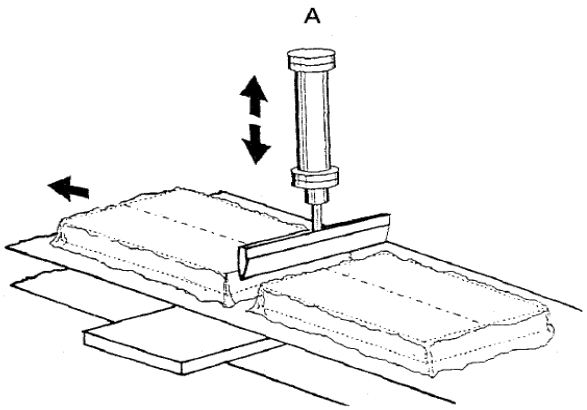
Reset Coil: O0.0 is de-energized once signal reaches the coil, remains de-energized until Set & Hold Coil is activated.(**Memorized OFF)**

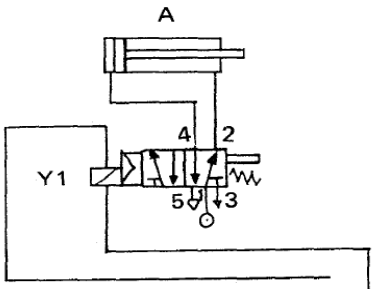
Exercise 1

SETTING AND RESETTING AN OUTPUT

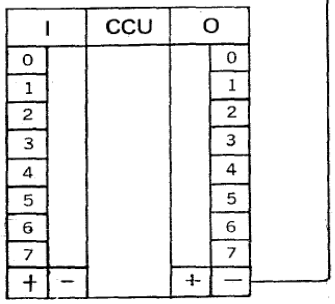
A double-acting cylinder is used to cut packaging material between boxes. When the boxes are in position, the operator presses a pushbutton (PB) to cut the material. Upon release of the button, the cylinder returns to its initial position.

Positional Sketch





Circuit Diagram



Allocation List Sample

Absolute	Symbolic	Comments
O0.0	CYLLIFT	Lifting cylinder
O0.1	CYLFEED	Feeding cylinder
O0.4	ALRMON	Alarm for level of coolant
O0.7	CLMPCYL	Cylinder for clamping workpiece
O1.0	MTRMN	Main Motor
O1.3	MTRCOOL	Motor for Coolant
I0.0	PBSTRT	Pushbutton Start Function
I0.1	PBSTP	Pushbutton Stop Function
I0.2	PBRST	Pushbutton Reset Function
I0.3	CLMPSEN	Sensor for Clamping cylinder Clamp on
I0.5	CYLUP	Lifter up
I0.7	CYLDN	Lifter down
I1.1	SENWKPC	Sensor for workpiece

Allocation List

FESTO

- The items of equipment associated with the FEC are addressed via operands in the control programs. An operand consists of an abbreviation identifying the equipment group and an address specifying a level within the group. Output 3 in output word 5, for example, is identified as O5.3

Symbolic operands

FESTO

- The FST software also allows you to use symbolic designations for the equipment: O5.3 may switch a motor on and off.
- For Example, in which case you can refer to it as ‘MotorOn’ in your programs.
- In this way you can make the programs more easily comprehensible, and also retain a clear overview even when there are a large number of operands. You are largely free to decide on the names of the symbolic operands yourself.

Absolute operands

FESTO

- In the following the direct entry of an operand (such as O5.3) is referred to as an absolute operand, whereas entry in symbolic form (MotorOn) is referred to as symbolic operand.
- The assignment of symbolic operands to absolute operands is defined in the allocation list.
- It is advisable to create the allocation list before program entry and then only to use the symbolic operand designations in the control programs.

Basic Electronics -- E311
Programmable Logic Controller I

FESTO DIDACTIC

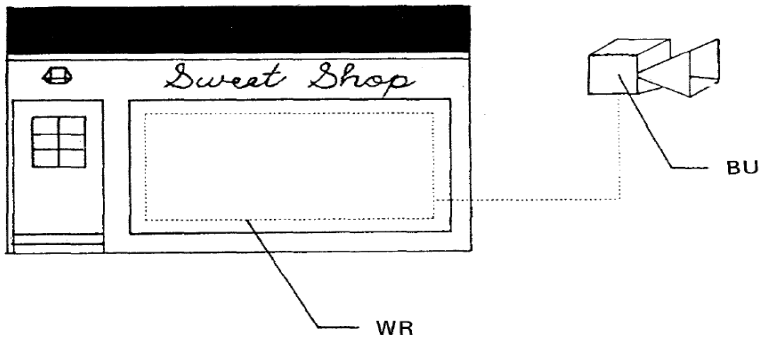
FESTO

Exercise 2

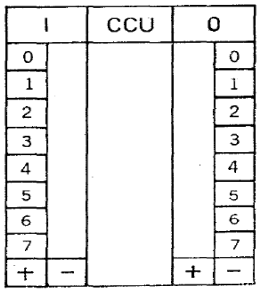
BURGLAR ALARM

A thin wire (WR) is stretched behind a pane of glass in a shop window. If there should be an attempt to break in, the wire will break and interrupt the closed circuit; thus, activating a buzzer (BU).

Positional Sketch

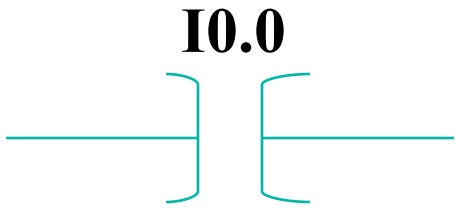


Circuit Diagram



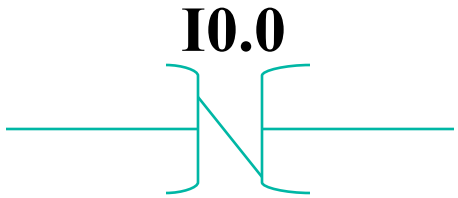
Ladder Diagram Contacts

FESTO



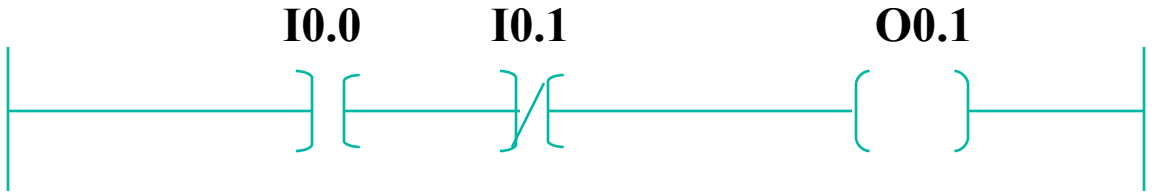
Normally Open Contact:**Yes Logic**

Closes when a signal is present at I0.0



Normally Close Contact:**Not Logic**

Opens when a signal is present at I0.0

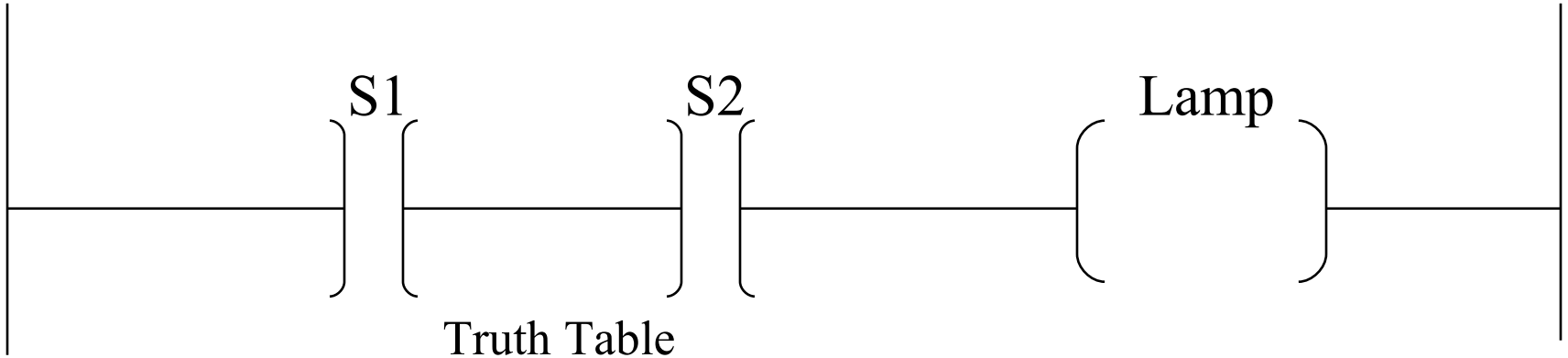


Output O0.1 is energized when a signal is present at I0.0 and not present at I0.1.

Logic Operations

FESTO

- **AND OPERATION**
  - realized by series connection of two NO contacts



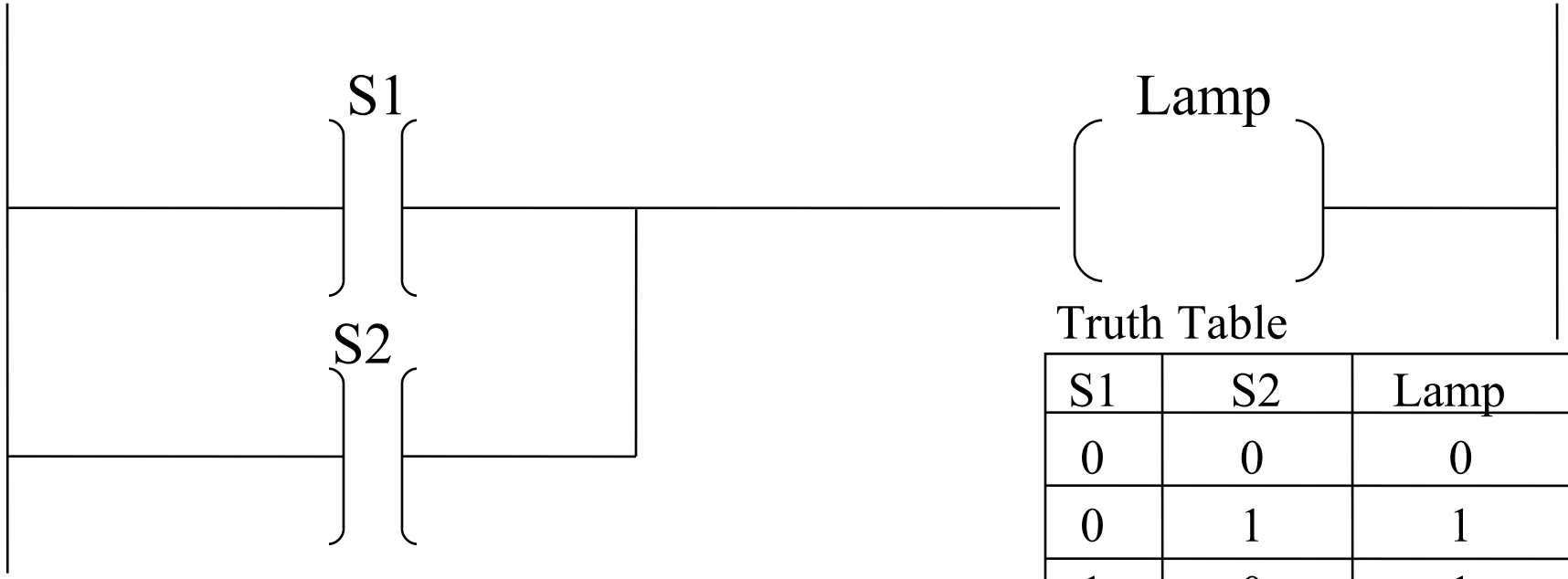
Truth Table

S1	S2	Lamp
0	0	0
0	1	0
1	0	0
1	1	1

Logic Operations

FESTO

- **OR OPERATION**
  - realized by parallel connection of two NO contacts



Truth Table

S1	S2	Lamp
0	0	0
0	1	1
1	0	1
1	1	1

.6 PLC Programming using STL

Statement list (STL) language is another language used in PLC programming besides the ladder programming.

STL allows the programmer to solve control tasks using simple English statements to describe the desired operation of the controller.

SENTENCE 1
    Conditional part THEN
    Executive part
SENTENCE 2
    Conditional part THEN
    Executive part

SENTENCE 1
    Conditional part THEN ....

Commonly used commands in STL

FESTO

- **IF -** always introduces a conditional part. Operands can be interrogated and linked by logical associations within the statement.
- **THEN -** introduces the executive part. This part is executed if the condition is true. The statement may contain commands to modify outputs or flags etc., to carry out arithmetic operations, to activate timers or counters, or to call other programs or program modules.
- **OTHRW -** introduces a second, alternative executive part. This part is executed if the result of the conditional part of the step is not true and hence the THEN clause cannot be executed.
- **STEP -** The STEP statement is very important in sequence programs as it determines the structure of the program or, if branches are used, the sequence of processing.

STL conditional part

FESTO

- **AND -** This is the logical operator AND. It allows logical “AND”-ing of a number of input conditions. The condition is fulfilled when all “AND”-ed input conditions are true.
- **OR -** This is the logical operator OR. This operator allows you to create a logical expression with several input conditions. The condition is fulfilled when at least one of the conditions is true.
- **NOP -** NOP means “No operation”. You can use this statement when you want to carry out an executive part without an input condition.
- **N -** This is a negation. It allows you to invert an input condition.

STL executive part

FESTO

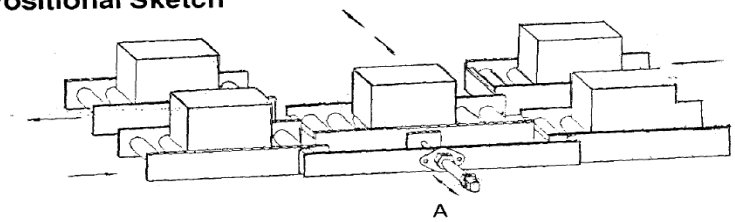
- **SET -** activates a one-bit operand. You can use this for setting outputs, flags, timers, counters and programs to logical one.
- **RESET -** is the opposite of SET. It deactivates one-bit operands, used, for example, for setting an output to logical zero.
- **LOAD -** A LOAD statement reads a register or a multibit operand, i.e. its value is written to a multibit accumulator. Normally this statement is followed by the keyword TO, indicating the destination of the operation.
- **TO -** A TO statement assigns a value to a word operand. TO specifies the destination of the operation.
- **JMP TO -** A JMP TO statement causes the program to branch to a specific program step.

Exercise 3

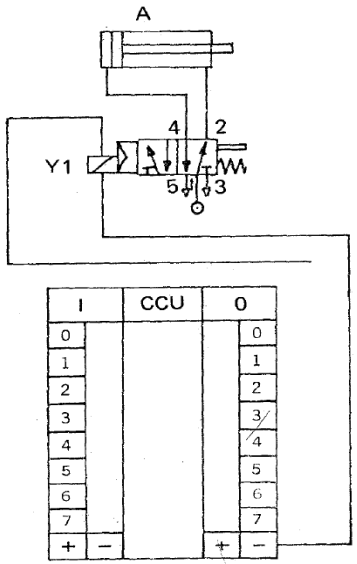
TURNING DEVICE

A turning device transfers parts from one conveyor belt to another which are running in opposite directions. When pushbutton (PB1) is pressed, the frame of the turning device is pushed forward by cylinder A. When the pushbutton (PB2) is pressed, the frame is pulled back towards its initial position.

Positional Sketch



Circuit Diagram



FESTO DIDACTIC

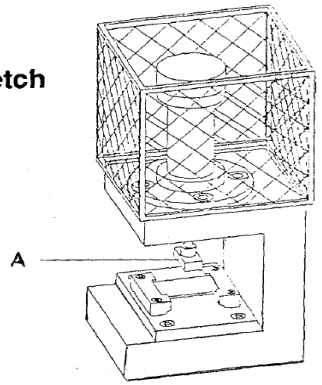
FESTO

Exercise 4

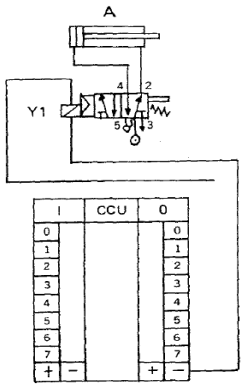
PRESSING DEVICE

A pressing cylinder is to extend only if the START pushbutton (PB1) is actuated and the protective guard is lowered down. Limit switch (LS) is actuated if the protective guared is lowered. If this condition is not met, the pressing cylinder must retract at once.

Positional Sketch



Circuit Diagram



FESTO

Sensors

FESTO

What are sensors?

A sensor is a technical converter, which converts a physical value such as temperature, distance or pressure, into a different value which is easier to evaluate. This is usually an electrical signal such as voltage, current, resistance or frequency of oscillation.

Basic Functions of Sensors

FESTO

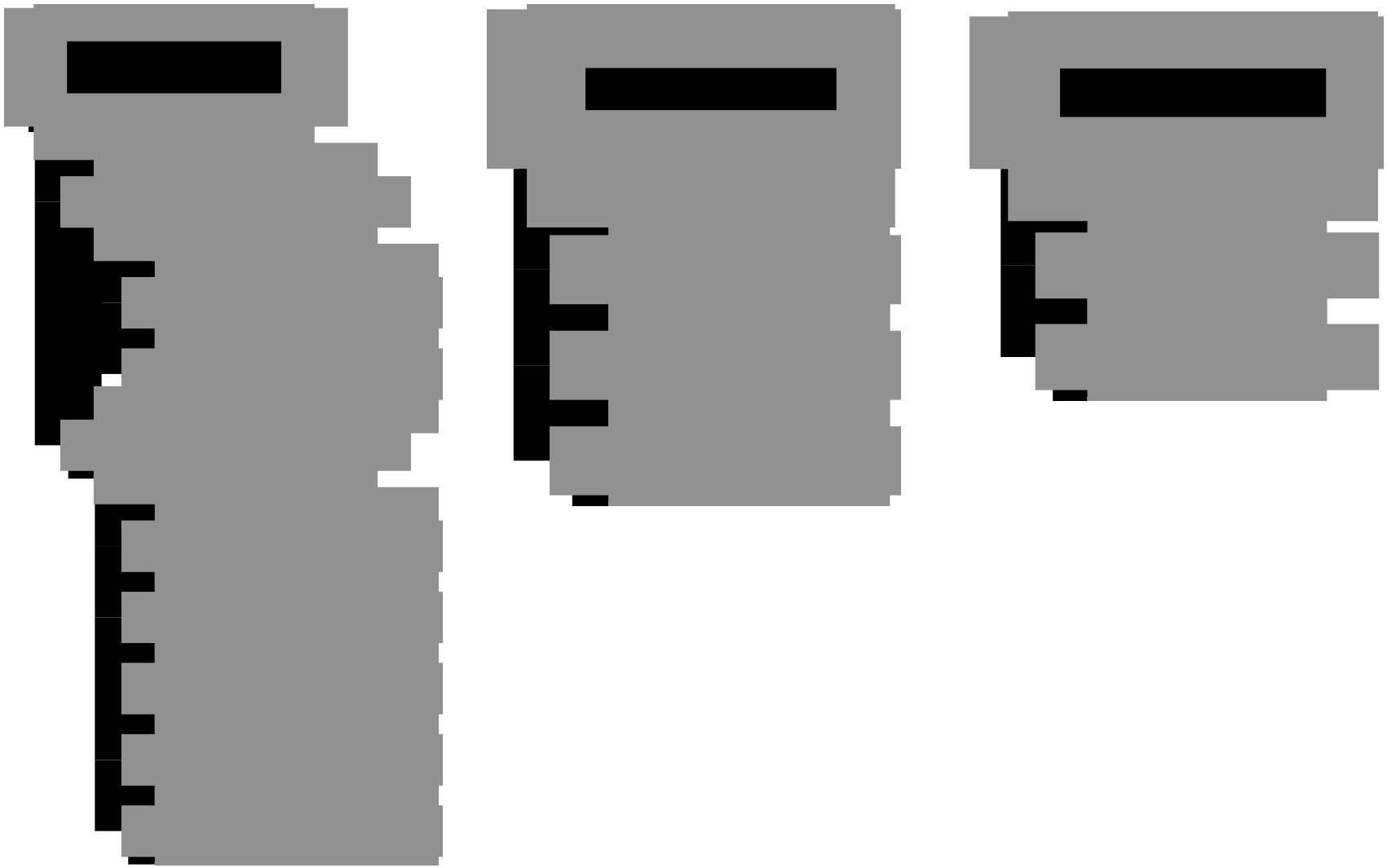
- Detect presence of object
- Determine type of material
- Recognize appearance of material
- Measure dimension of material
- Measurement of distance, force, pressure, temperature, speed and acceleration

Fields of application for Proximity Sensors

- Automotive industry
- Mechanical industry
- Packaging industry
- Woodworking industry
- Printing and paper industry
- Drinks industry
- Ceramics and bricks industries
- Plastics industry
- Electronics industry

Sensor Classifications

FESTO



Sensors

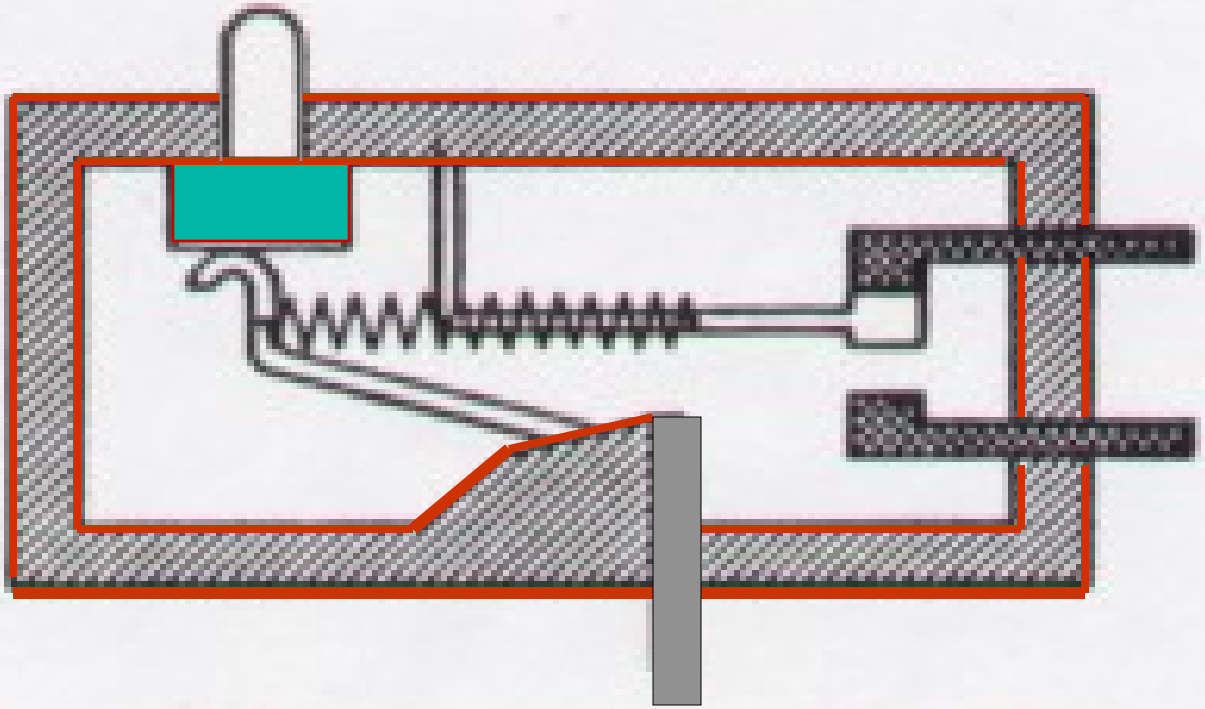
FESTO

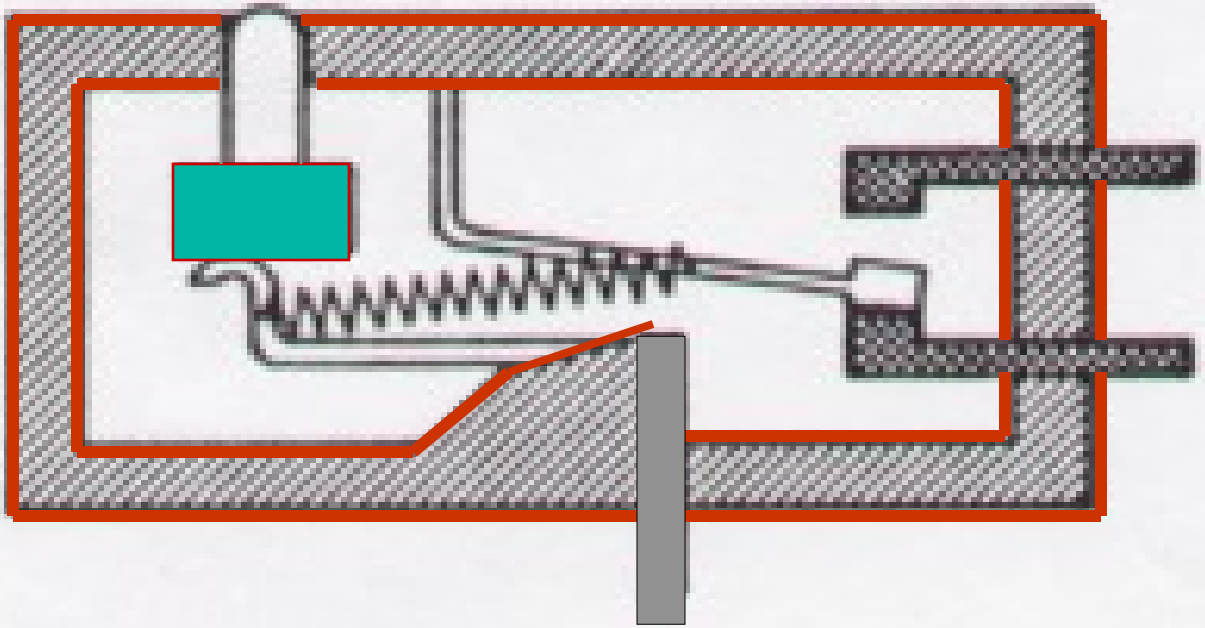
Devices which convert physical variables into form of electrical signals to gather data, monitor or control a process.

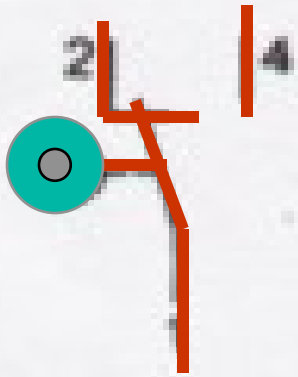
TYPES:

Contact Sensors – mechanical in nature, subject to mechanical wear and with predictable failure rate. Contact sensors include limit switches, roller switches, and pressure sensors.

Contactless Sensors – Proximity sensors (reed switch, inductive, capacitive, and optical sensors).

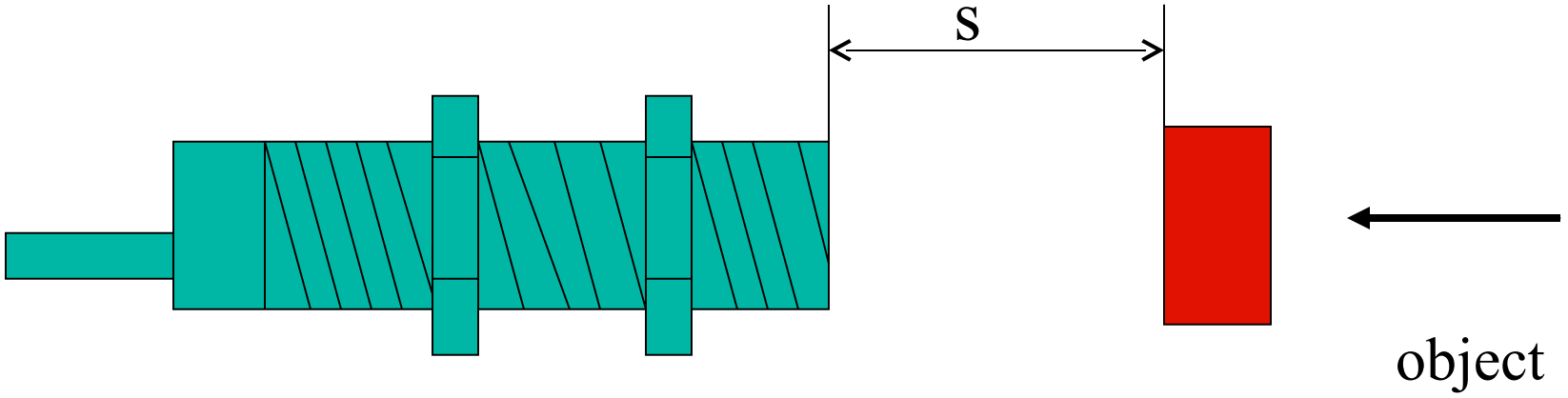





2
4

Switching Distance

- It is defined as the actuating distance between the object and the sensor. The switching distance is dependent upon the actuating object.

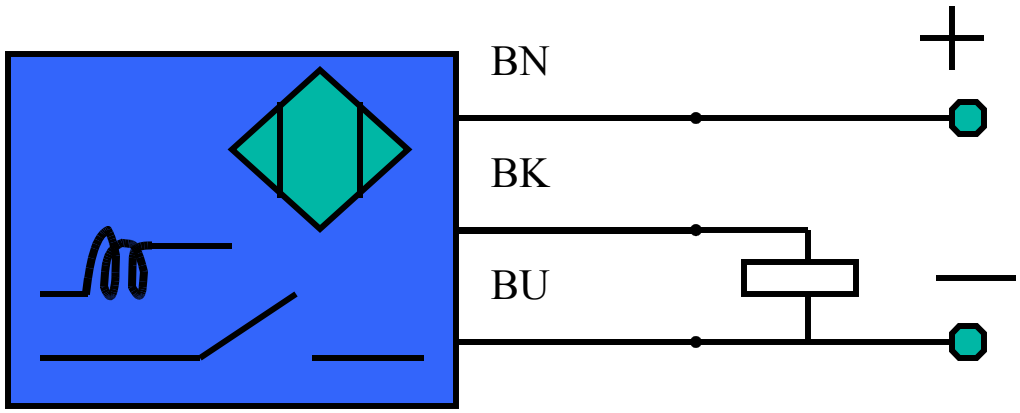


Inductive Proximity Sensor

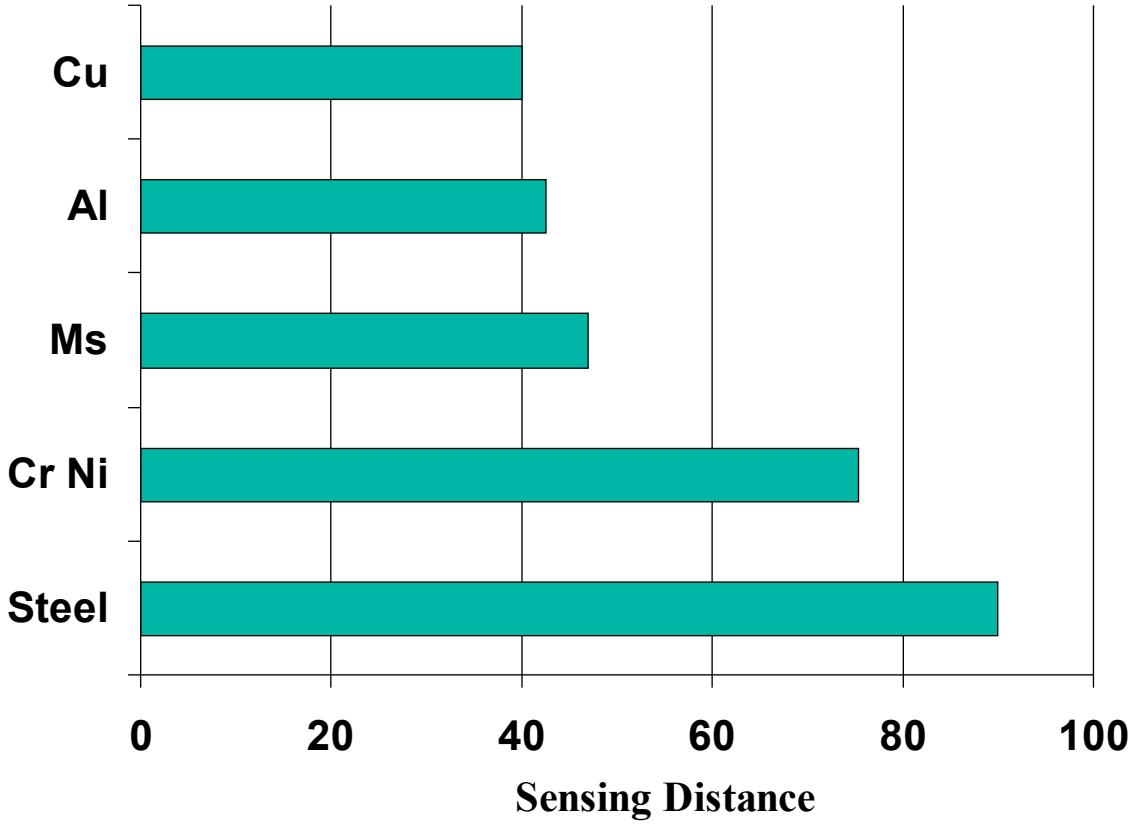
FESTO

Note:

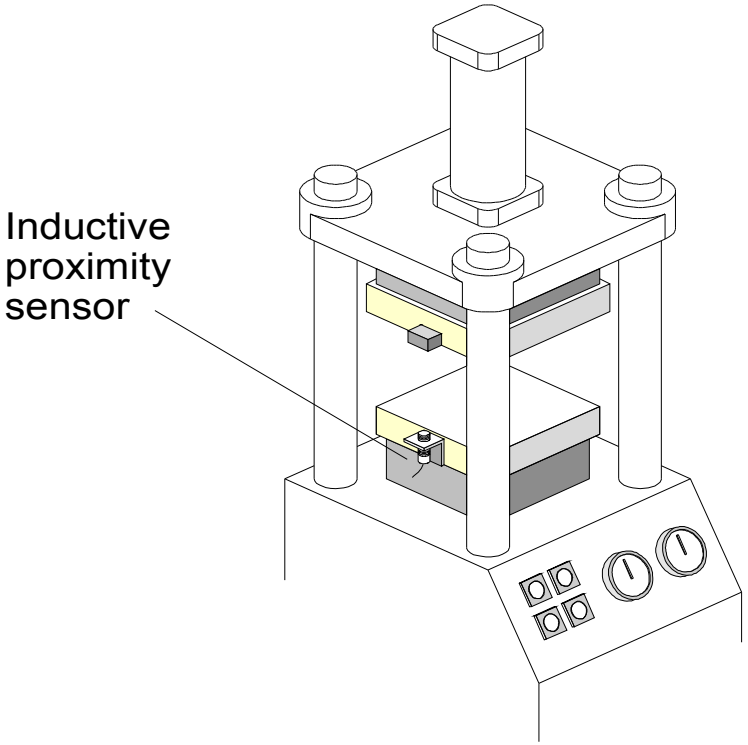
For metallic materials only



Sensing Distance of Inductive Sensors



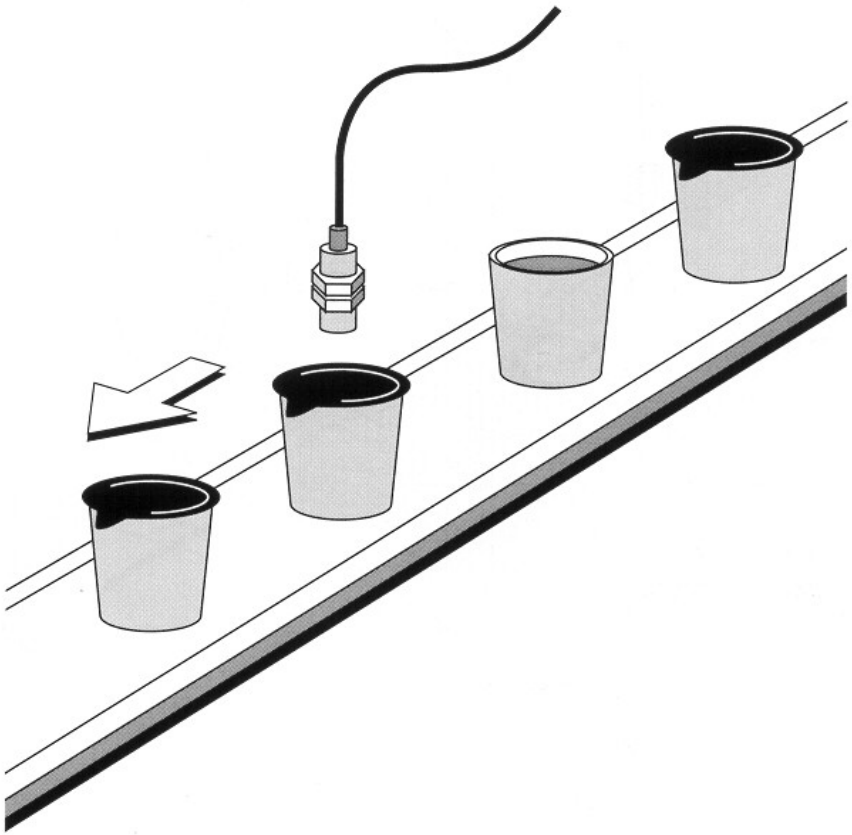
Applications



Detecting the End Position of a Press Ram

Detecting of aluminium caps

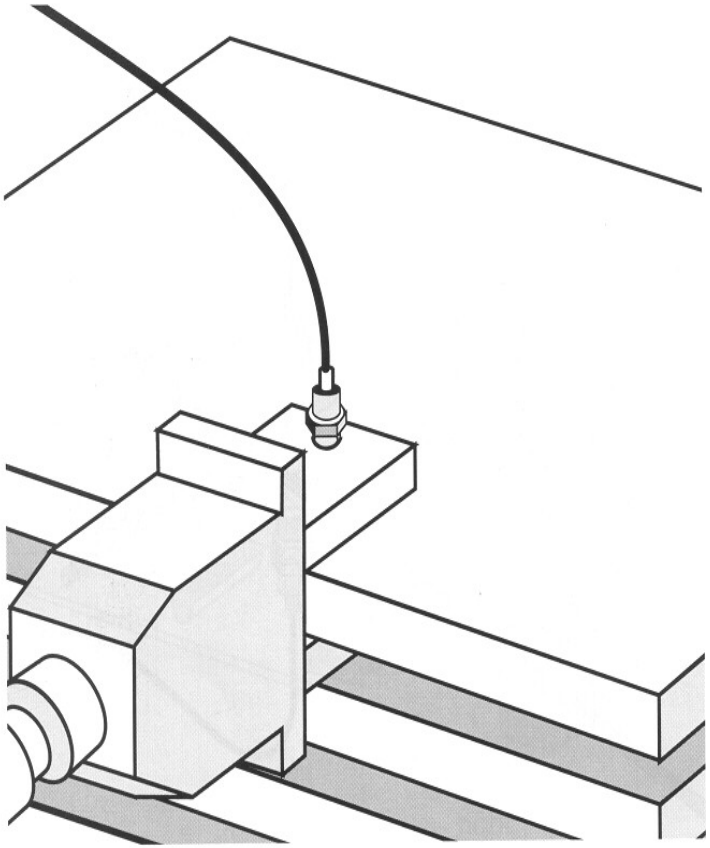
FESTO



- At the final control of yoghurt tubs, the presence of aluminium foils is to be detected.
- This is accomplished by means of a small, powerful proximity switch with a long switching distance.

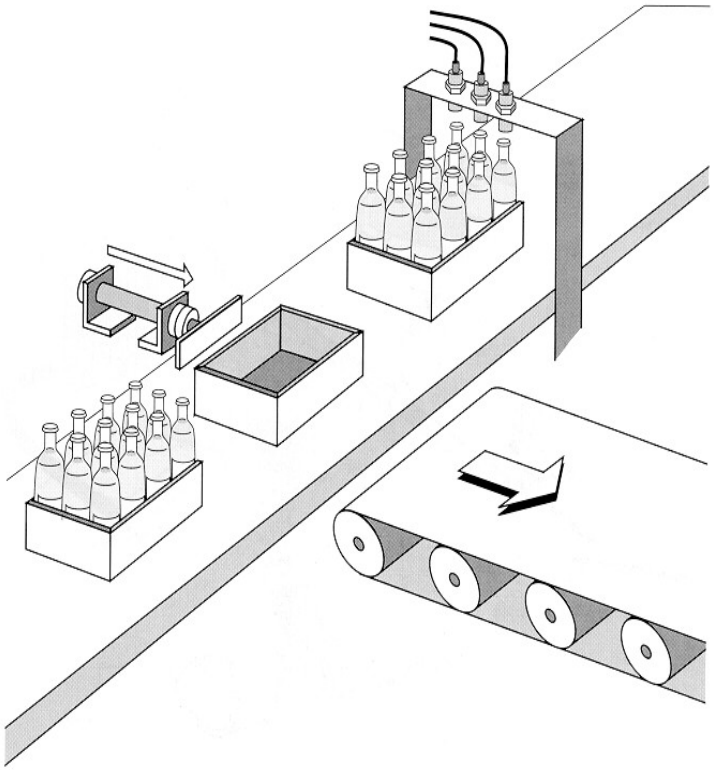
Check for gripped product

FESTO



- A particularly small inductive sensor with a diameter of just 4 mm is implemented in a gripper. From the picking up of the work piece to its depositing, the sensor controls whether the work piece is clamped in the gripper.

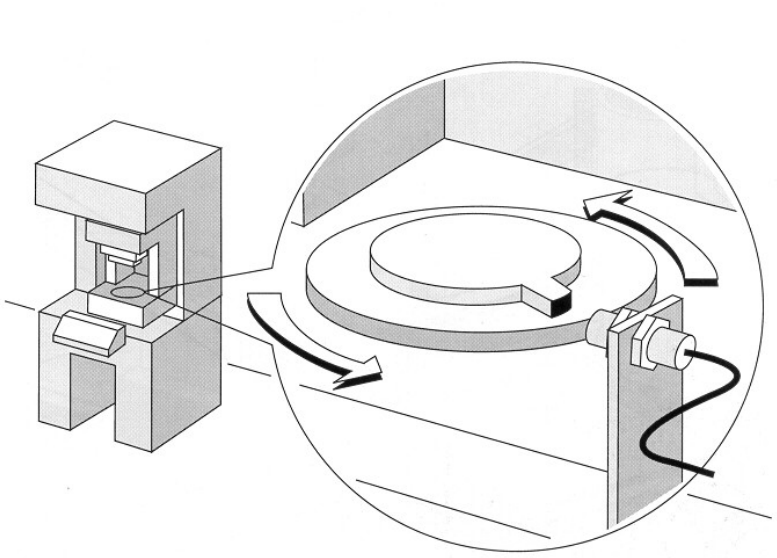
Sorting of pallets



- At a bottling plant for drink a synchronous belt is controlled as to the presence of empty pallets.
- Three inductive sensors detect each one row of bottles with aluminium caps. Empty pallets are sorted out by a pusher.

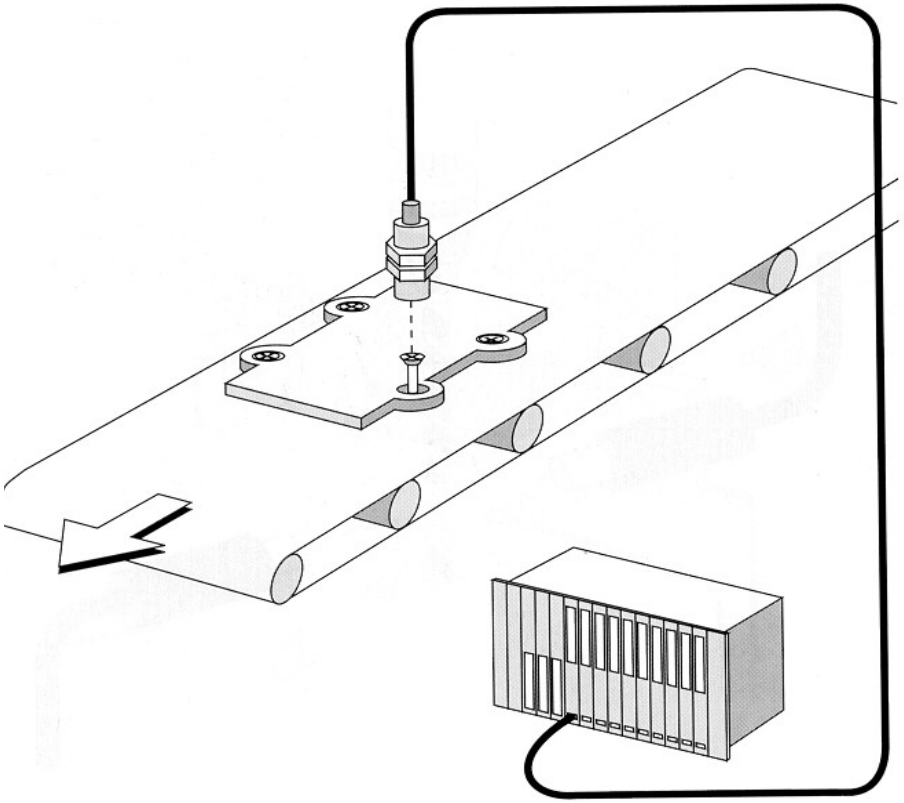
Positioning for punching

FESTO



- A round metal sheet with a hub is turned in the punching press until it reaches its exact punching position. Positioning is achieved by means of an inductive sensor of small design.

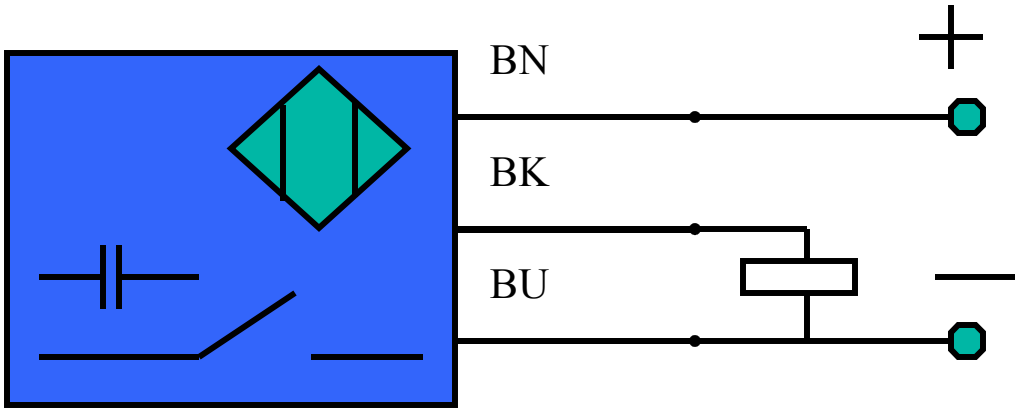
Detection of loose screws



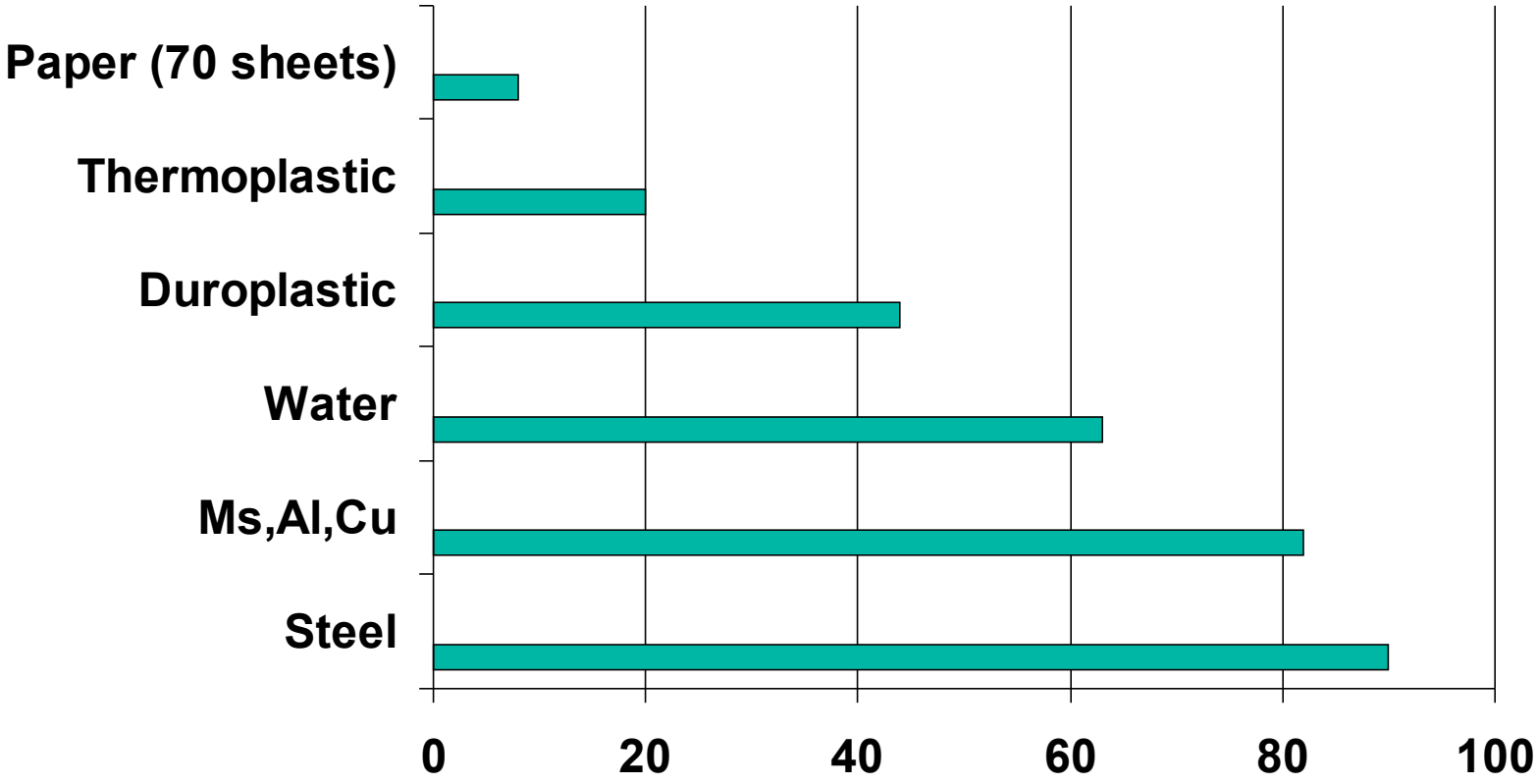
- An inductive sensor serves to detect loose screws.

Capacitive Proximity Sensor

FESTO

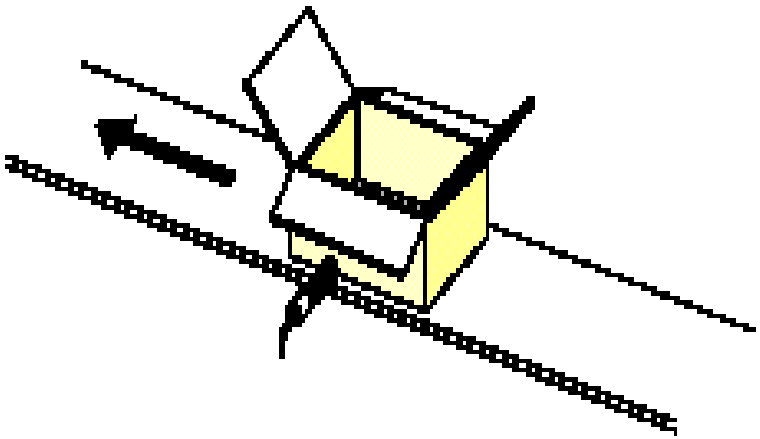


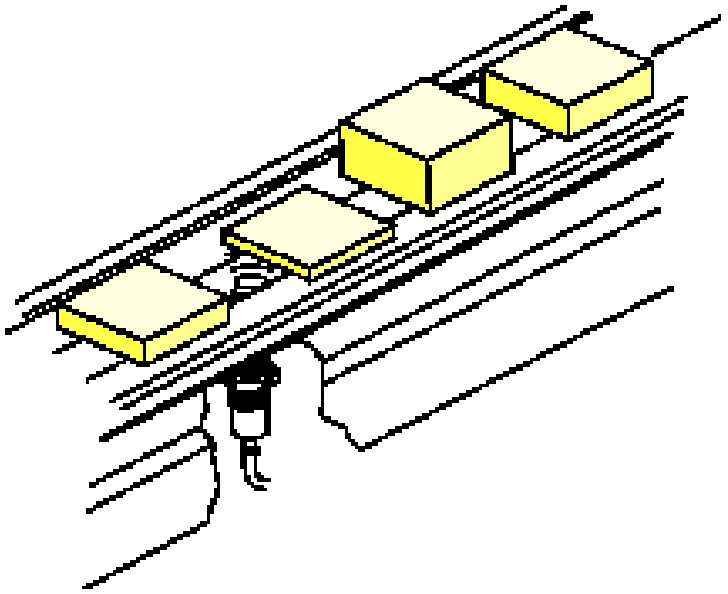
Sensing Distance of Capacitive Sensor



Detection of boxes

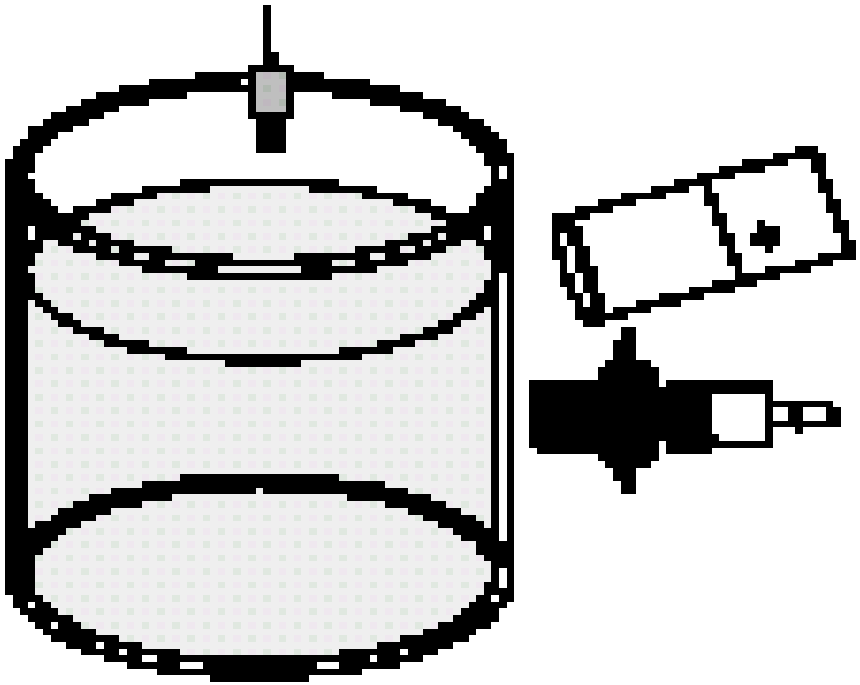
FESTO





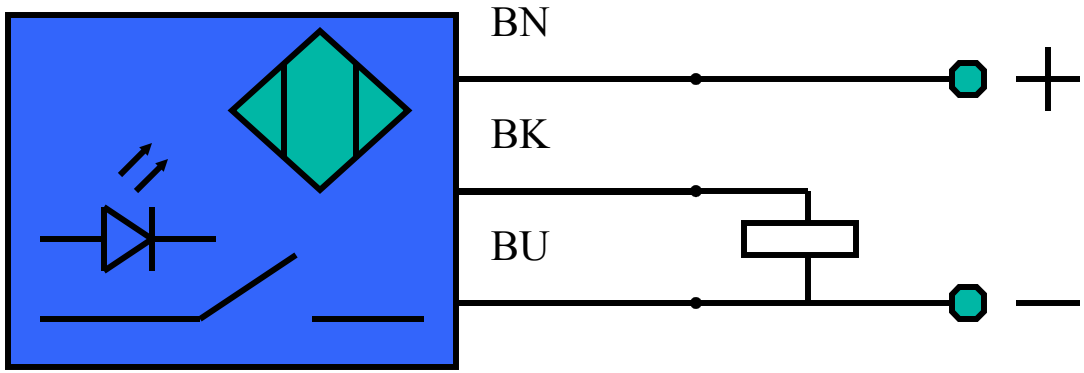
Detection of liquid level inside a plastic container

FESTO



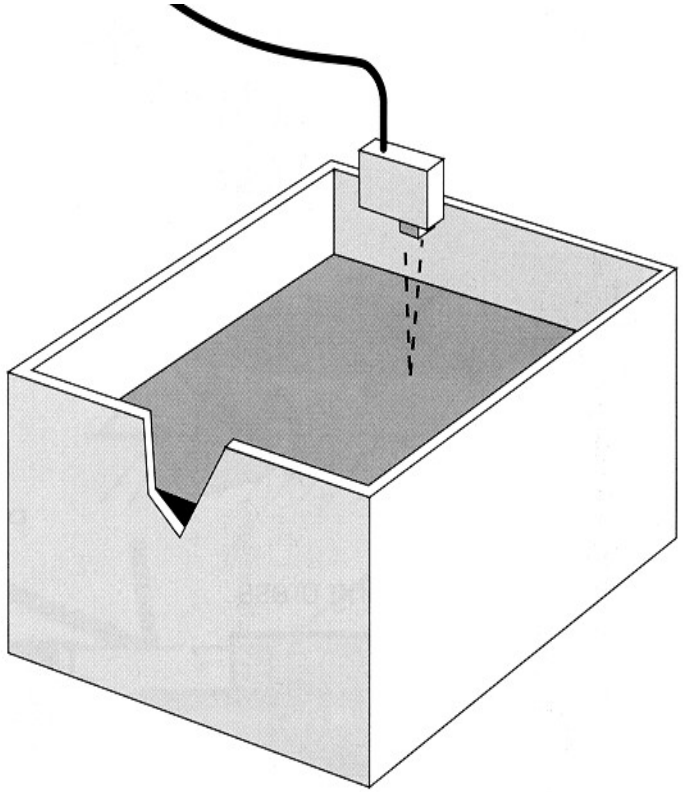
Optical Proximity Sensor

FESTO



Level control of powder

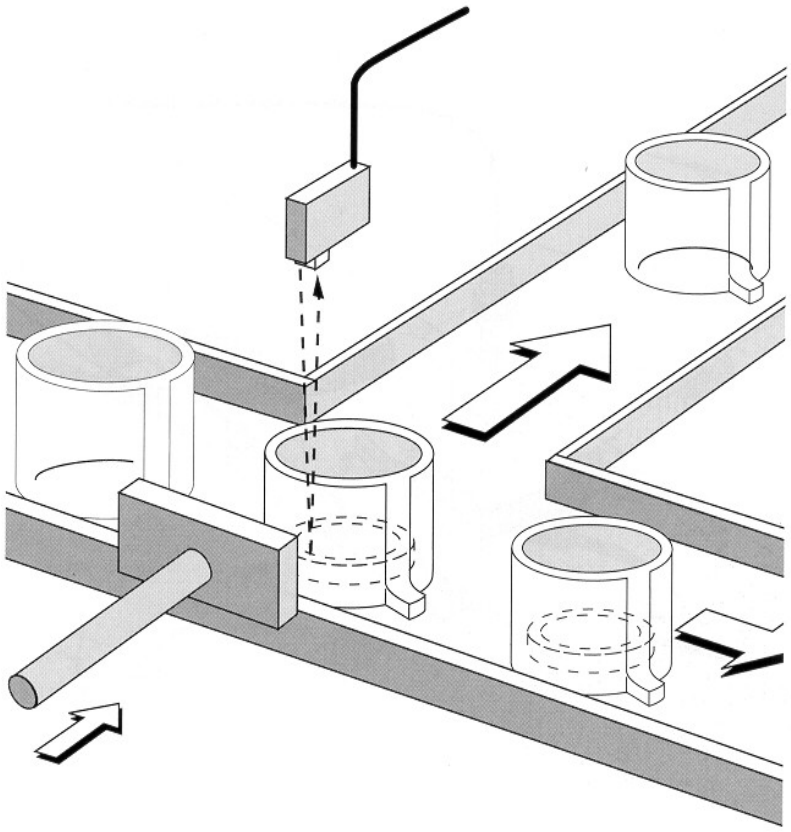
FESTO



- A diffuse sensor is fitted above a container filled with a light-coloured powder and is adjusted in such a way as to emit a signal if the container is filled and interrupt further feed

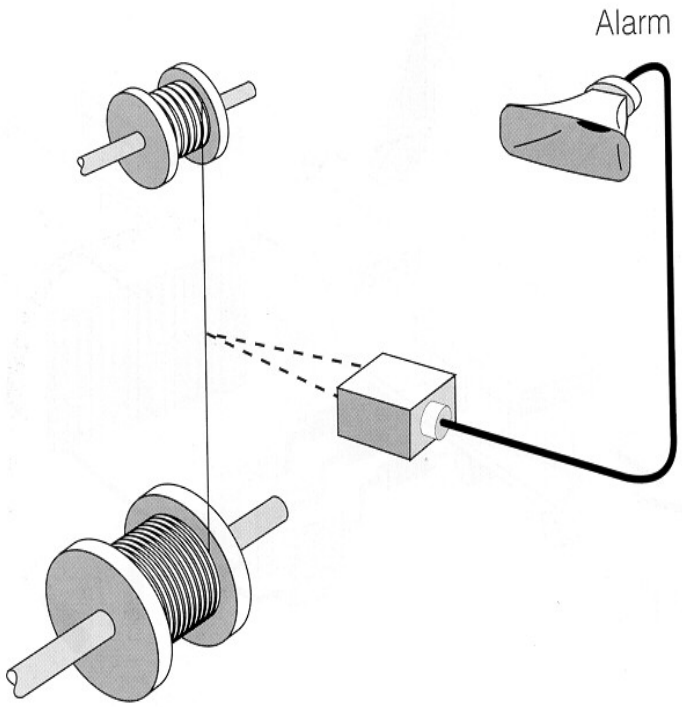
Sorting of cans

FESTO



- On a conveyor belt steel cans with an inserted ring only may be processed.
- A diffuse sensor is adjusted in such a manner that it emits an OK signal whenever a ring is present. Cans without rings are sorted out.

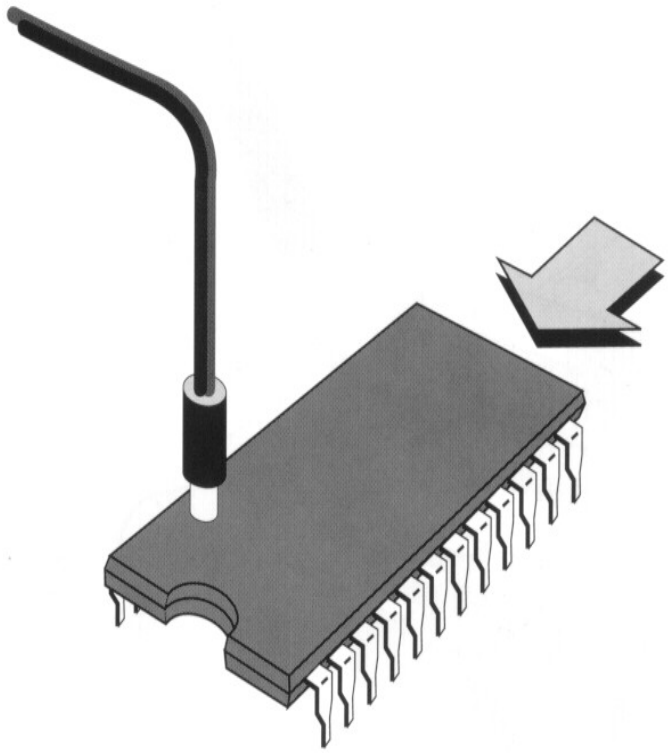
Wire break detection



- A wire to be winded is controlled for a break.
- A diffuse sensor or a through-beam sensor (depending on the thickness of the wire and the distance) is adjusted in such a manner that the sensor receives the emitter signal when wire is present. If no wire is to be detected, the sensor indicates wire break.
- The same applies to presence detection of a cotton, wool or vinyl string.

Detecting IC orientation

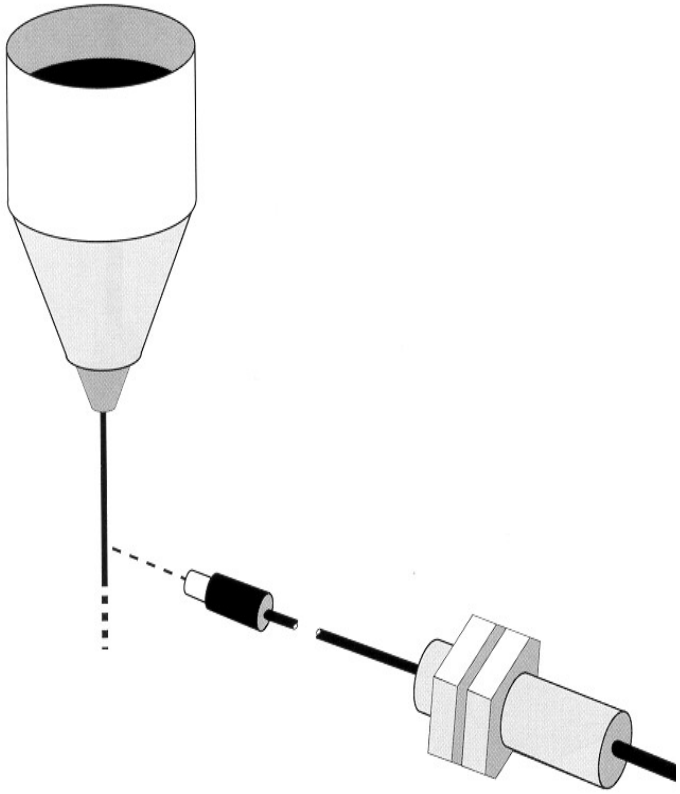
FESTO



- Before being packed, IC are checked for their correct position.
- A diffuse type sensor with fibre optic cable detects the hub of the housing of 2000 IC per minute.
- Wrongly positioned IC are pushed out.

Monitoring of injection nozzle

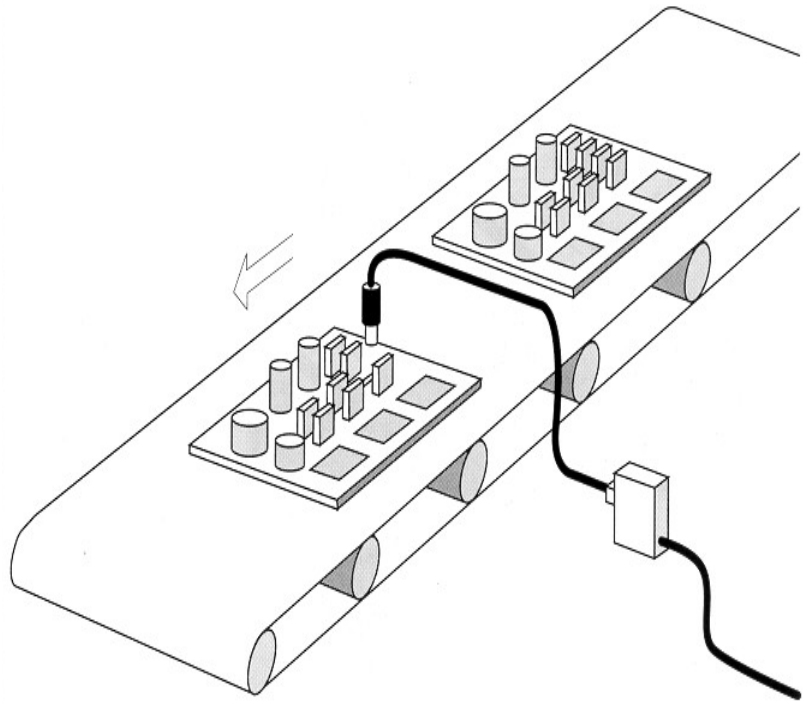
FESTO



- Monitoring of an injection nozzle using diffuse sensor.
- The continuous stream of adhesive material from a dosage nozzle reflects the light of the diffuse sensor. **If** the adhesive stream breaks away, there is no reflection and the sensor responds.
- The above arrangement also allows detection of single drops.

Presence of electronic component

FESTO

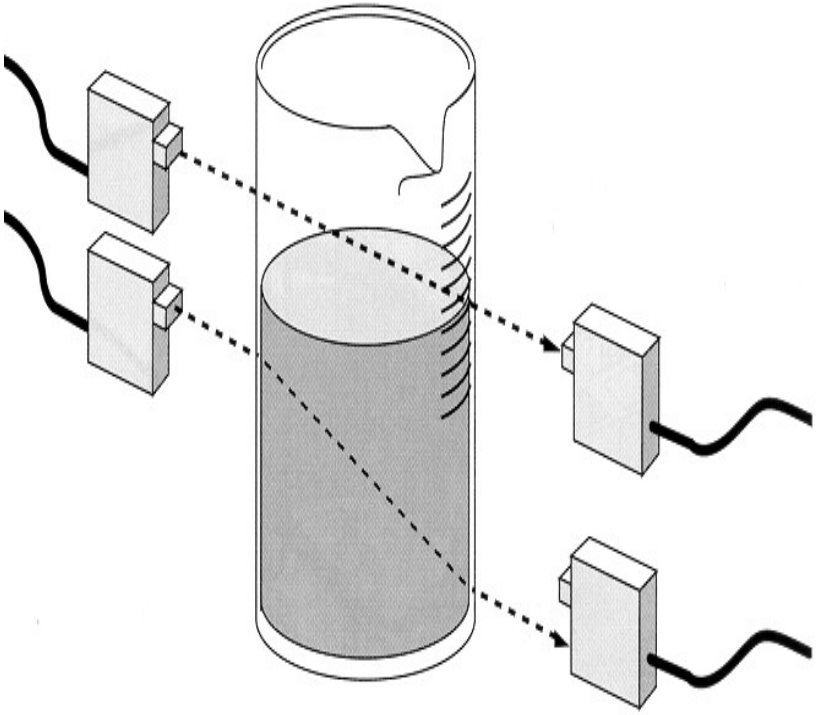


- A fibre optic cable and diffuse sensor connected are used to control the surface of circuit boards that are difficult to access for the presence of small components.

- The positions that are hard to access can only be attained by means of highly flexible polymeric fibre optic cables.

Monitoring of liquid level

FESTO

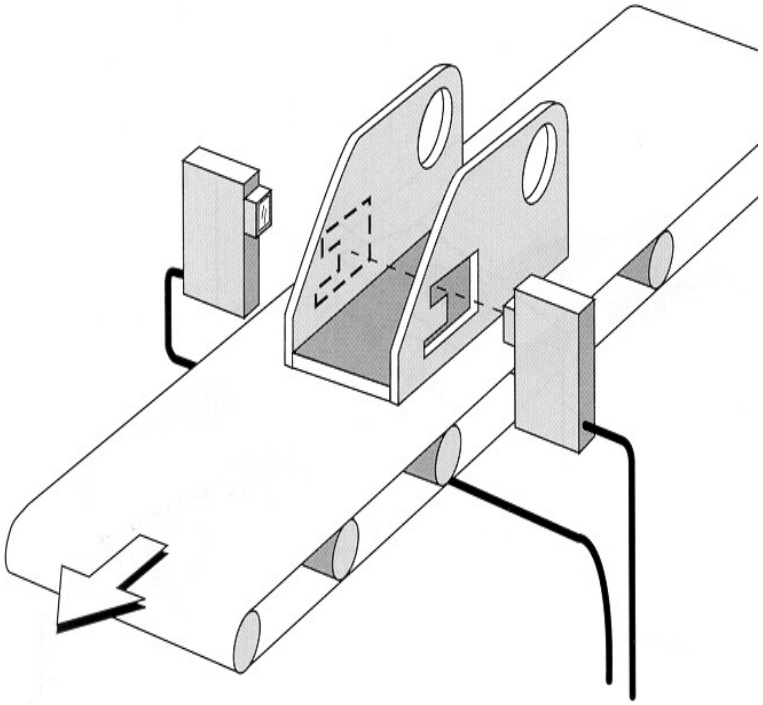


- Control of filling level through gauge glass, making use of the laws of refraction (simplified representation):

- The liquid, the optically denser medium, breaks the light beam Without liquid, the receiver is activated.

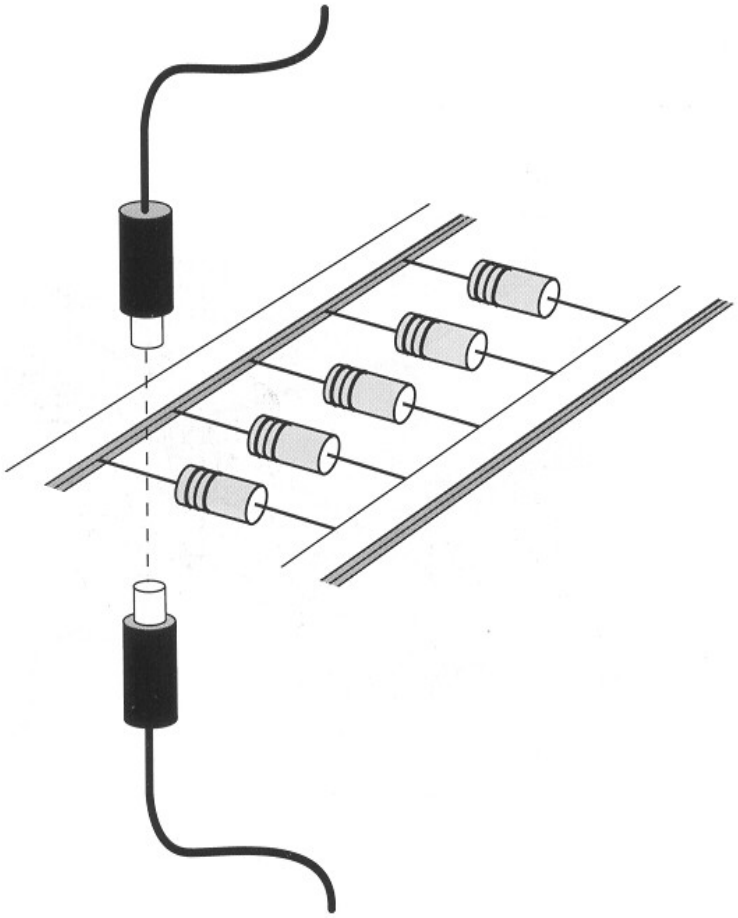
Checking of punched holes

FESTO



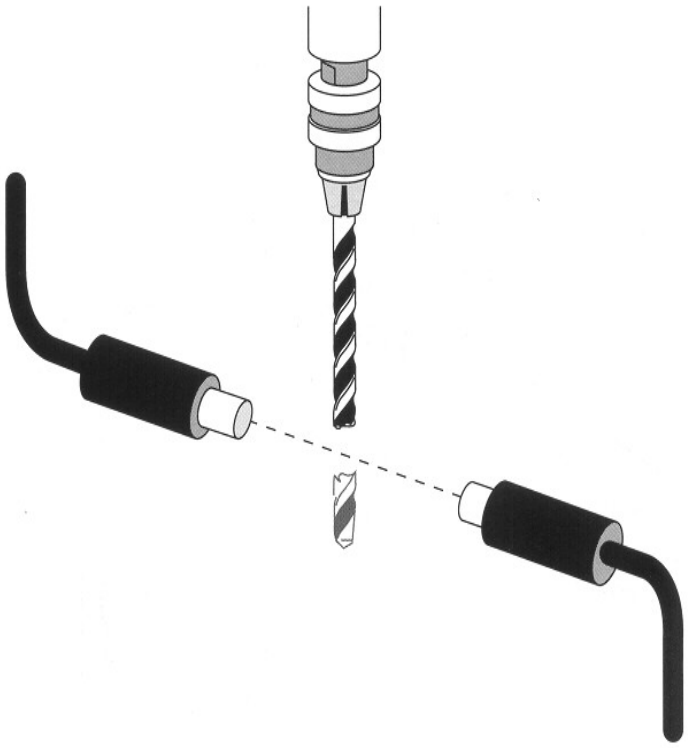
- Before a work piece is fitted after having punched, a through beam sensor checks whether the dipping have been removed.

Fast counting of resistors



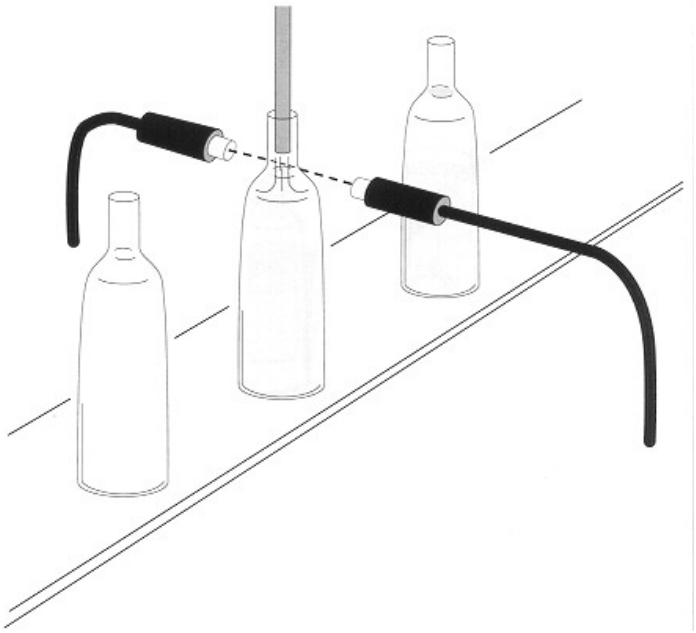
- On a production line for resistors 10,000 units per minute are produced.
- In order to achieve exact counting of the output of small components, a through-beam sensor connected with a fibre optic cable is aligned so as to point towards the resistors.

Checking of drill bit breakage



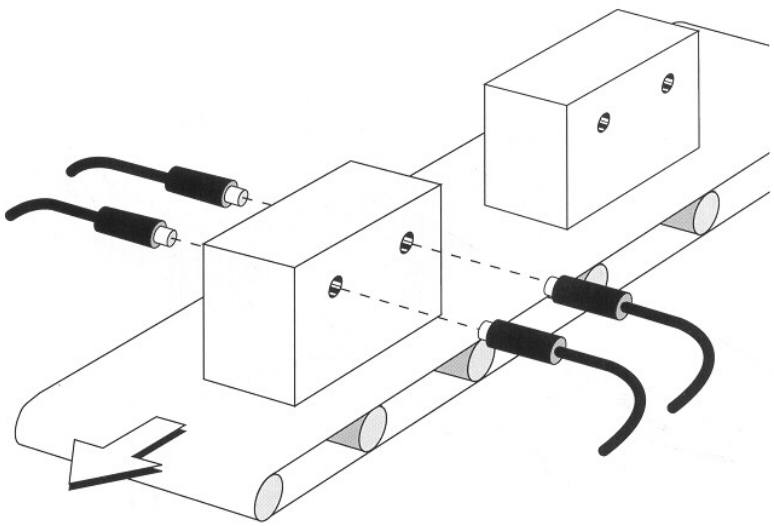
- A through-beam sensor in a machining centre controls a drill for breaks. Before every machining cycle, the drill is moved to a test position. If the drill point is present, it breaks the light beam and an OK signal is given to continue operation

Filling control



- At the bottling plant with a production rate of 16,000 bottles per hour a through-beam sensor is adjusted in such a manner that the light beam penetrates the bottle. If in any bottle the liquid attains the predetermined level, the light beam is broken and the sensor responds.

Checking of drill holes



- Two through-beam sensors connected with a fibre optic cable check the presence and the distance of 2 drill holes in a passing work piece. Only if both through-beam sensors simultaneously emit a signal, have the holes been drilled at the correct distance

Things to consider in Selecting a Sensor

FESTO

- Sensor Function
- Description of the object to be detected
- Installation conditions
- Environmental conditions
- Application area

Exercise 6

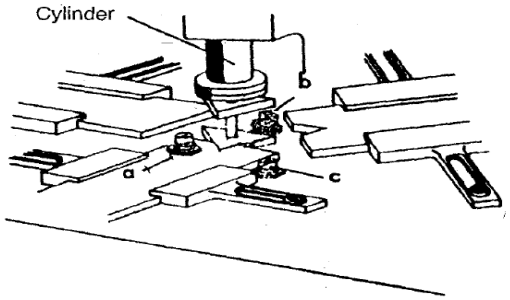
Punching device

Problem:

It must be possible to operate the punching device from three sides.

A notch is to punched in the workpiece by a pneumatic cylinder. The workpiece may be fed from any one of three work stations. The punching operation is to be triggered when 2 sensors emit a signal. The signaling elements a, b and c are installed for sensing. The cylinder returns to its retracted position when the part is pulled out of the device.

Positional sketch:



sensors			cylinder
a	b	c	z

FESTO

Flags

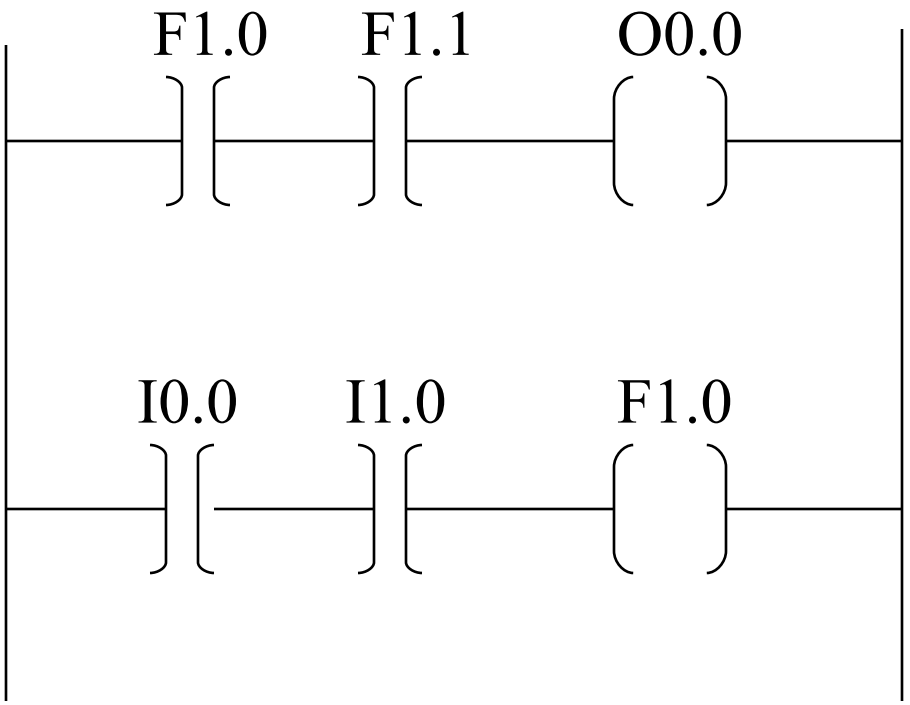
FLAGS

FESTO

- One bit memories
- May be set or reset and interrogated for logic 1 or 0.

a. Conditional Part

b. Executive Part



FESTO DIDACTIC

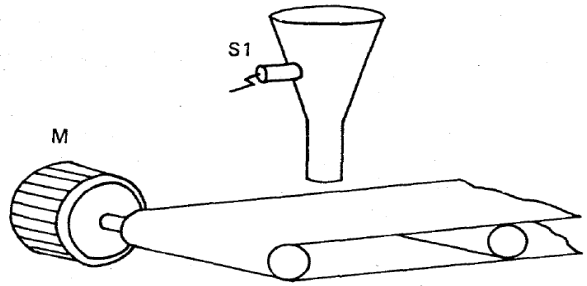
FESTO

Exercise 7

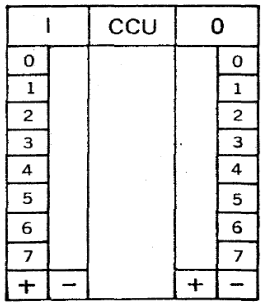
GRAVEL FILLING LEVEL CONTROL

The conveyor motor will run only if the gravel silo is sufficiently full, that is, sensor S1 = 1, and the START pushbutton (PB1) is pressed. If this condition is not met the motor should not run.

Positional Sketch



Circuit Diagram



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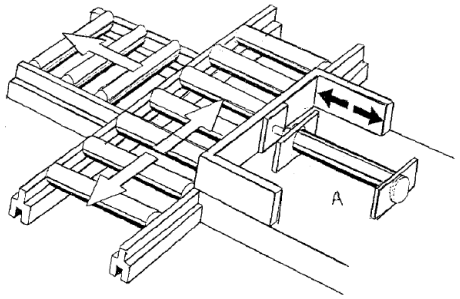
FESTO

Exercise 8

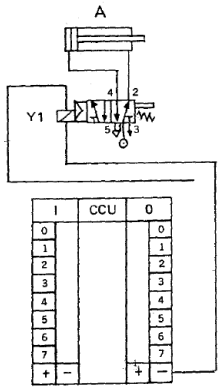
PUSHING DEVICE

Using a double-acting cylinder, a workpiece is pushed onto a conveyor belt. The operator actuates a pushbutton (PB) for the cylinder to extend. When it reaches the forward end position, the cylinder actuates a limit switch the cylinder to retract automatically.

Positional Sketch



Circuit Diagram



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Exercise 9

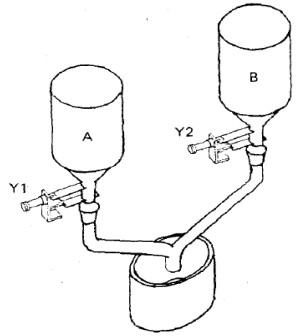
SILO CONTROL FOR TWO BULK MATERIALS

In a mixing unit, material selection is done by a latching pushbutton (SPST type), PB1.

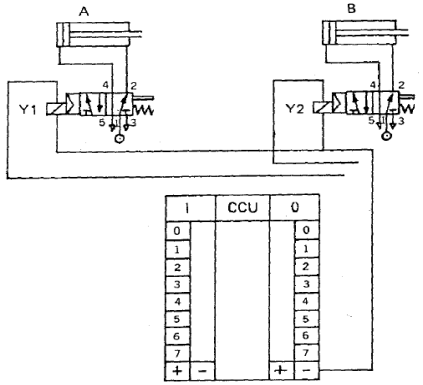
If (PB1) is OFF, material A is selected.
If (PB1) is ON, material B is selected.

When the START pushbutton (PB2) is pressed, the silo of the selected material is opened by a cylinder, and the material pours into a mixing container.

Positional Sketch



Circuit Diagram



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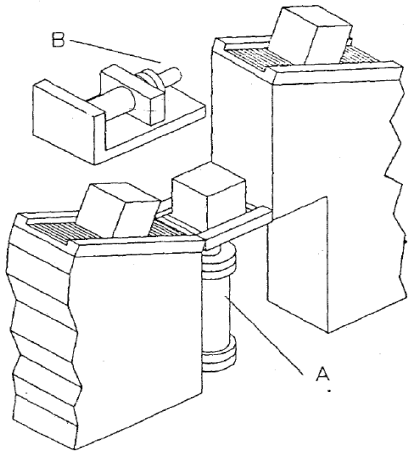
FESTO

Exercise 10

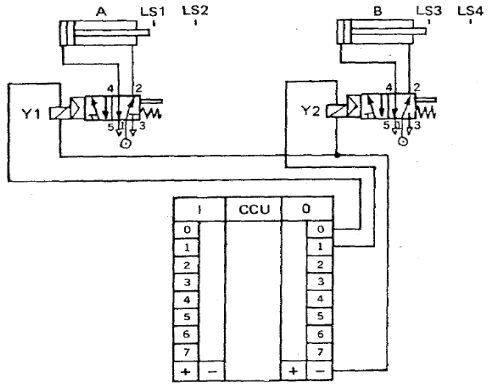
LIFTING DEVICE FOR PACKAGES

A box arrives at a lifting platform and actuates a proximity sensor S1. It is lifted up by cylinder A, and then pushed onto a second conveyor by cylinder B. Cylinder A retracts. Cylinder B retracts when cylinder A has reached its initial position.

Positional Sketch

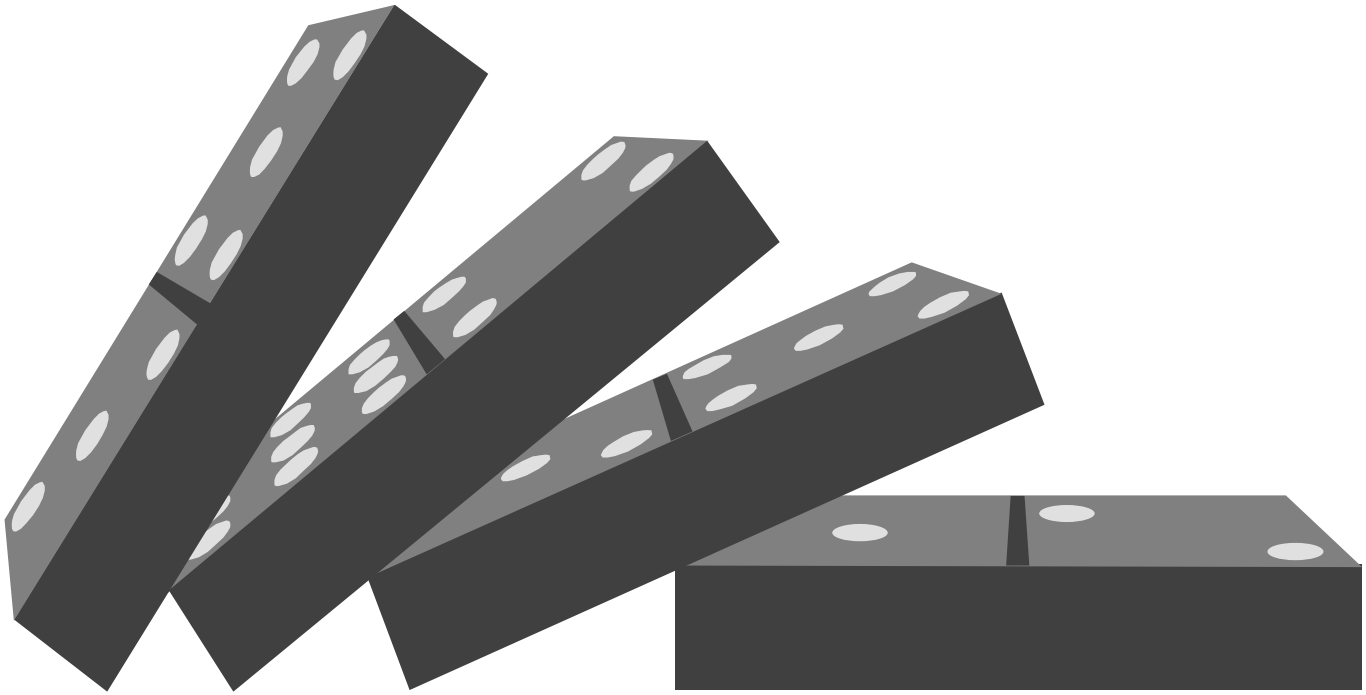


Circuit Diagram



FESTO

Motion Sequences



Sequence Control System

FESTO

This is a control system using a mandatory step by step sequence, in which the sequencing from one step to the next programmed step depends on certain conditions being satisfied.

Representations

FESTO

– Chronological Order

Cylinder 1.0 extends and lifts the box

Cylinder 2.0 extends and pushes the box

Cylinder 1.0 retracts, then

Cylinder 2.0 retracts

– Tabular Form

Work Step	Motion of Cylinder 1.0	Motion of Cylinder 2.0
1	out	-
2	-	out
3	in	-
4	-	in

Representations

FESTO

- Vector Diagram

Extension represented by

Retraction represented by

- Abbreviated Notation

Extension represented by : +

Retraction represented by : -

1.0 +

2.0 +

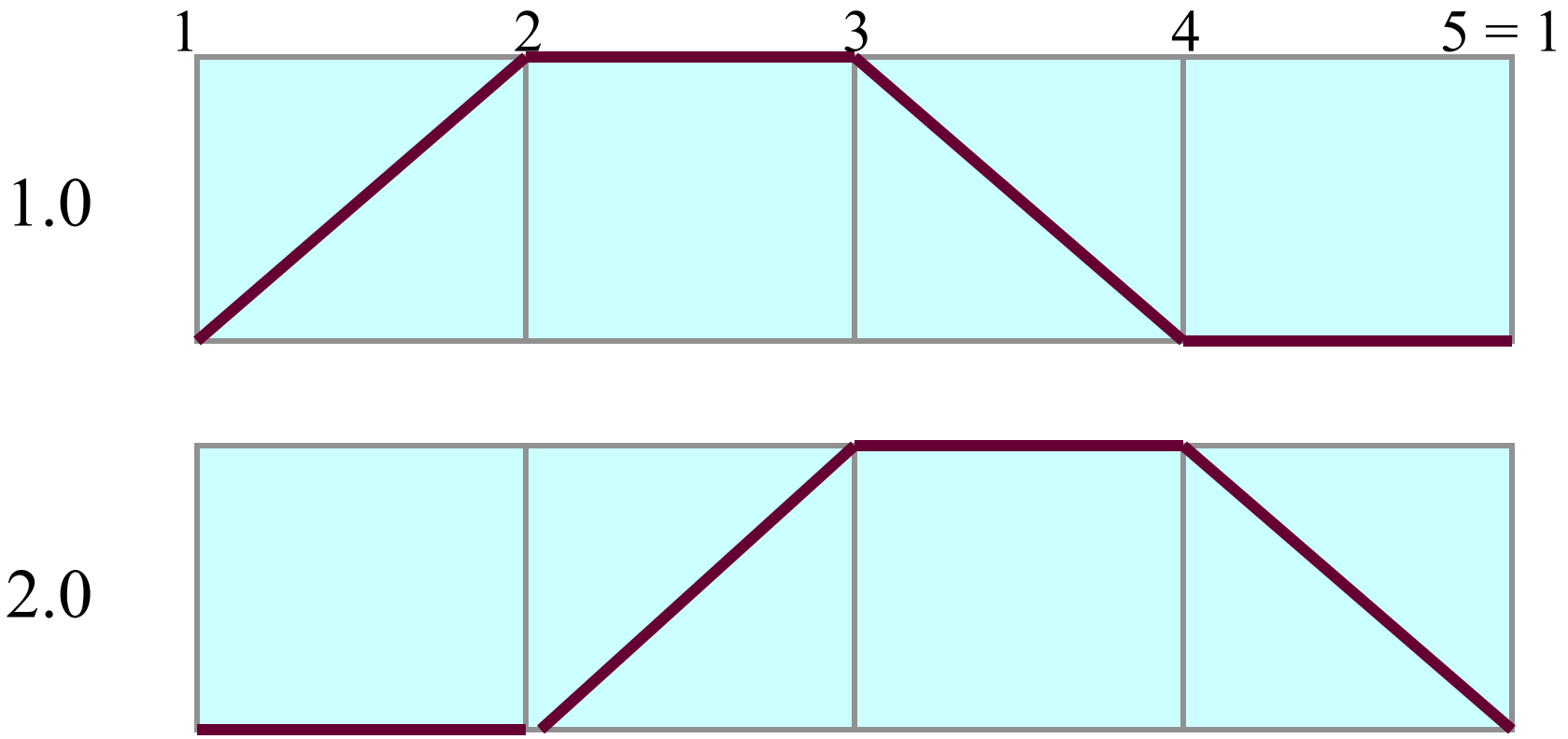
1.0 -

2.0 -

Representations

FESTO

- Motion Step Diagram



BASIC RULES IN DESIGNING THE LADDER DIAGRAM OF SEQUENCE CONTROLS

1. The CONTROL CIRCUIT is that part of the ladder diagram which processes input signals.
2. The POWER DIAGRAM is the part of the ladder diagram, which directly controls the outputs of the PLC.
3. In the control circuit, each step in the sequence has its own STEP FLAG. A flag is similar to a relay, which can be turned on or off and has multiple NO and NC contracts.
4. Each step flag, except the last step flag, employs a self-holding circuit.
5. A NO contact of the step flag N is in series with the step flag N + 1. This ensures that the step flags are activated in the correct sequence.
6. A NC contact of the last step flag is in series with the first step flag.
7. In the power circuit, if an output is activated at step N, a NO contact of the step flag N is connected in series with the said output.
8. If an output is de activated at step N, a NC contact of the step flag N is connected in series with the said output.

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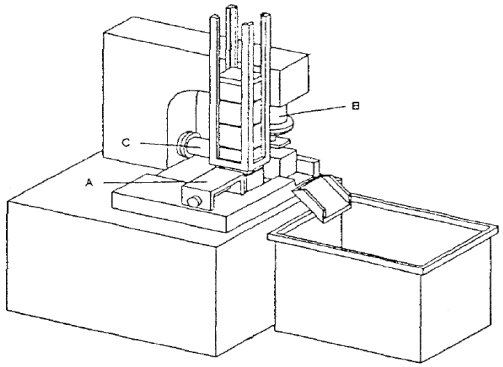
FESTO

Exercise 11

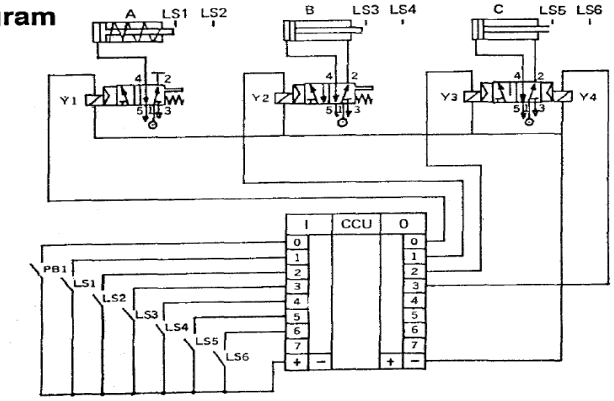
STAMPING DEVICE

Rectangular blocks are stamped in a machine. Once the START pushbutton PB1 is pressed, the workpiece is fed into the machine by cylinder A from a gravity-feed magazine and is clamped in place by the same cylinder. Next, it is stamped by cylinder B. After stamping, cylinder B retracts, followed by cylinder A. Once the workpiece is fully declamped, it is ejected by cylinder C.

Positional Sketch



Circuit Diagram



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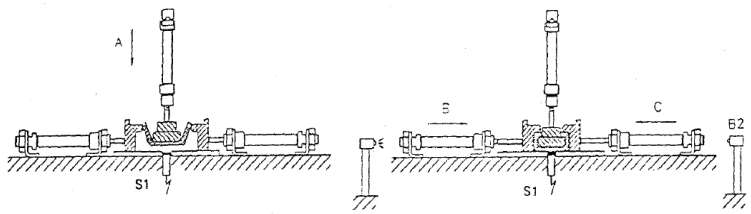
Exercise 12

FORMING STATION

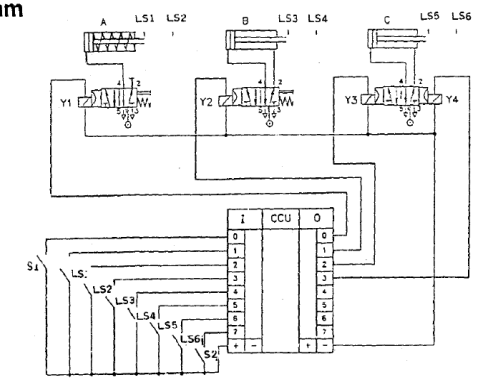
Sheet materials are formed in a workstation. A sheet is inserted manually into the machine. Sensor S1 is actuated once the sheet is in the corract position. In front of the machine, a light-barrier S2 monitors the operator's hand. If the operator has taken out his hand from the machine S2 will go off, and the machine starts automatically.

The sequence of operation is as follows. Once the machine starts, cylinder A extends. Then, cylinders B and C advance simultaneously from the sides. If cylinders B and C are fully extended, they retract immediately, followed by cylinder A. At this point, the operator can now take out the sheet and insert a new one.

Positional Sketch



Circuit Diagram



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Exercise 13

LIFTING AND SORTING

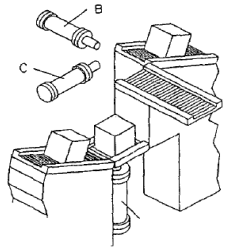
First, at a roller conveyor, a package passes through a length measuring device (LMD). If the package is short, the LMD emits a 0 signal, if the package is long, it emits a 1 signal. (The LMD is simulated by a latching SPST pushbutton PB1).

Second, the package arrives at a lifting table. If the START pushbutton PB2 is pressed, cylinder A lifts the package.

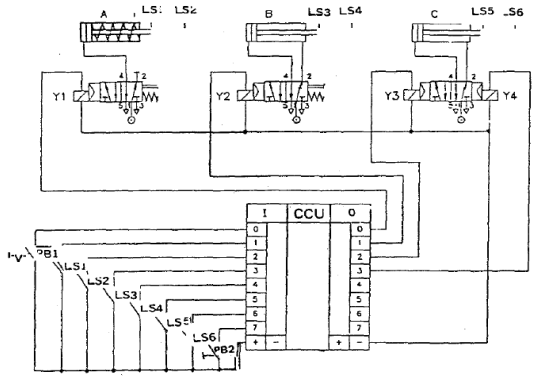
Third, sorting takes place. Short packages are pushed by cylinder B to a second conveyor, long packages are pushed by cylinder C to a third conveyor.

Fourth, once cylinders B and C are fully retracted, only then that cylinder A should retract.

Positional Sketch



Circuit Diagram



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Exercise 14

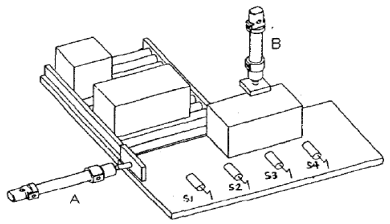
POSITIONING

First, short and long pieces of wood pass one at a time across sensors S1 and S2. Short pieces of wood actutes S1 only, while the long pieces actuates both sensors.

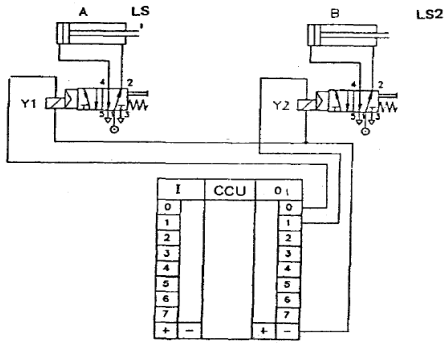
Second, cylinder A pushes the piece of wood in the correct position for stamping. If the piece is short, cylinder A retracts once sensor S3 is actuated; if the piece is long cylinder A will retract only if S3 and S4 are actuated.

Third, cylinder B, then, stamps the piece right at its center. After stamping, cylinder B retracts, and the piece is taken out from the workstation manually.

Positional Sketch



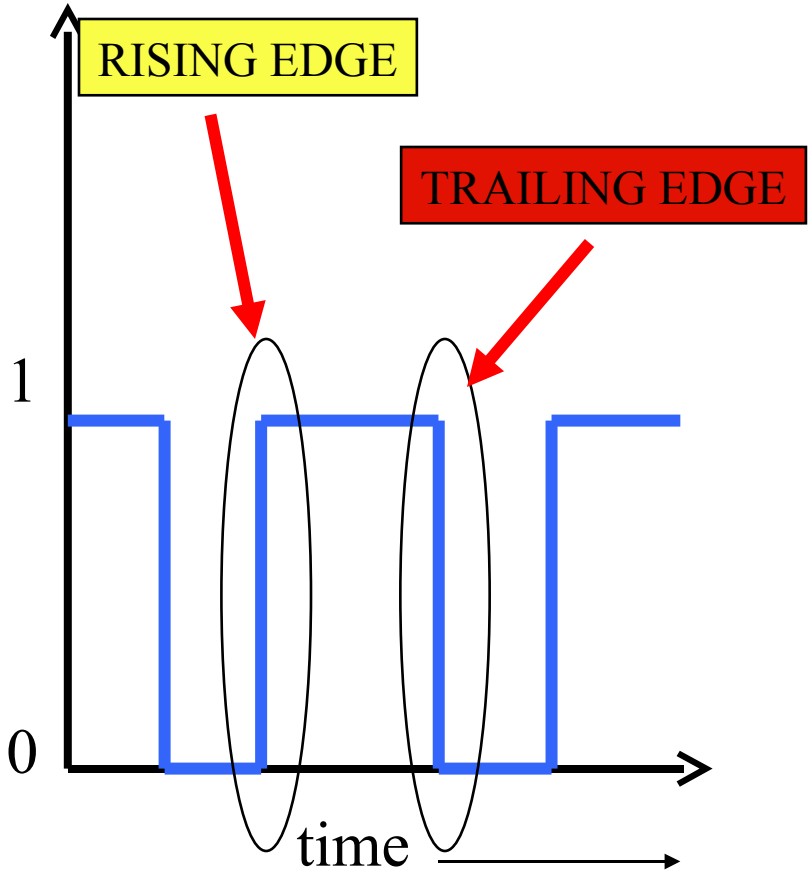
Circuit Diagram



FESTO

TIMERS

SIGNAL EDGES



- Every binary signal has a positive and negative edge
- POSITIVE EDGE (RISING EDGE) marks the moment at which a change from 0 to 1 takes place (or from OFF to ON.
- NEGATIVE EDGE (TRAILING EDGE) marks the moment at which a change from 1 to 0 takes place (or from ON to OFF)

Representations

FESTO

- Tnn for the timer status (active or inactive)

  - shows whether the timer is active or not. It is a one- bit operand than can be set, reset or interrogated. 1 = active, 0 = inactive

- TPnn for the timer preset (preset run-time)

  - defines the run-time of the timer given in hundredths of a second and can be in the range 0.00s to 655.35s. The operand for the timer preset is a permanent multi-bit operand and remains stored until a new preset is defined.

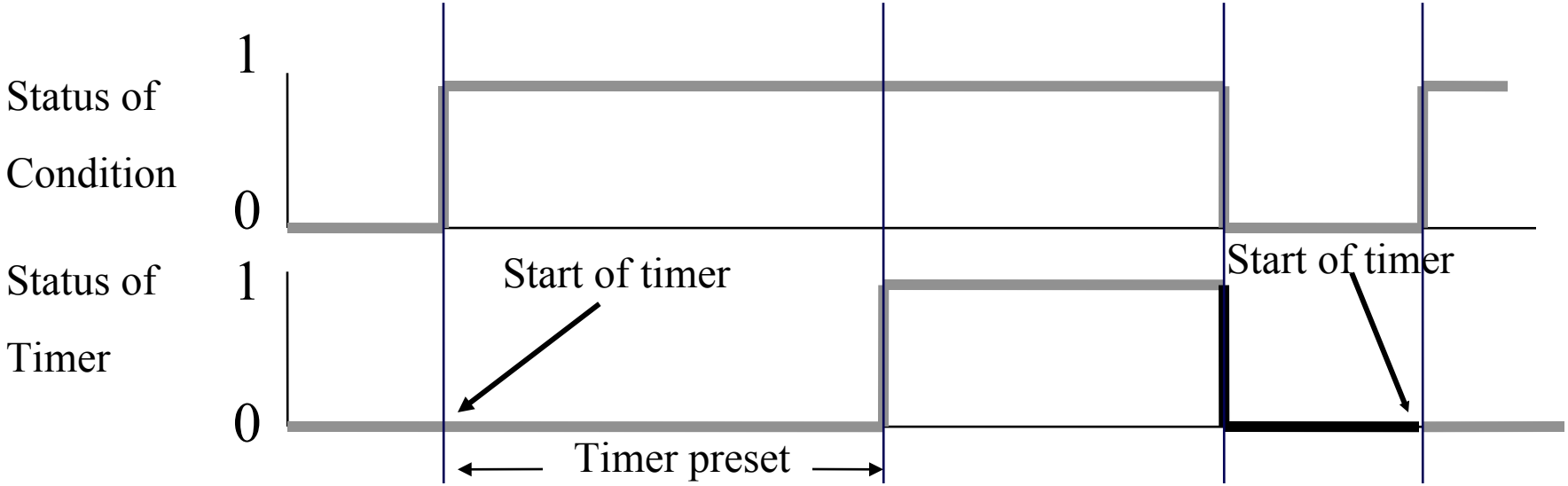
- TWnn for the timer word (current run-time)

  - is a multi-bit operand and represents the current run-time of the timer.

Switch-ON Delay Timer (TONnn)

FESTO

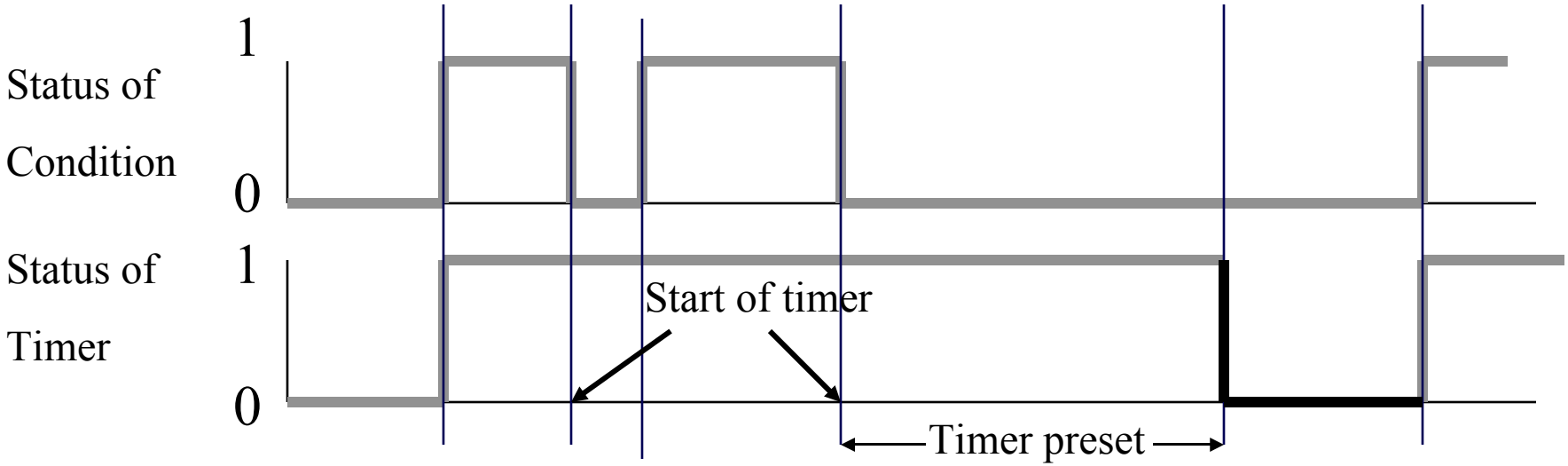
- allows outputs to be activated with a 1-signal after a delay time has expired. The timer preset represents the delay period. When the timer is started, the timer status TON does not become 1 until after the delay time has expired. A rising edge in the conditional part starts the timer. It starts running until the timer has expired or the condition changes to a 0-signal.



Switch-OFF Delay Timer (TOFFnn)

FESTO

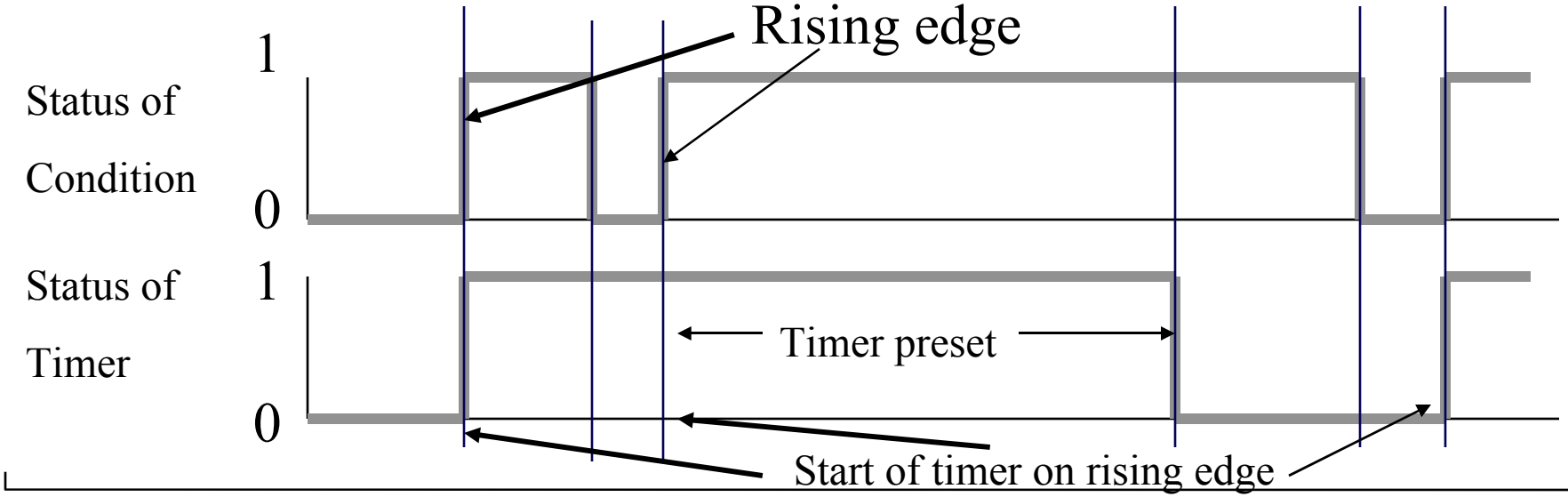
- allows outputs to be deactivated with a 0-signal after a delay time has expired. When a rising edge is recognized for the condition, the timer preset is loaded into the timer word. A trailing edge starts the timer, which runs until the timer has expired or the timer is reinitialized by a rising edge for the condition.



Pulse Timer (Tnn)

FESTO

- allows an output to be activated for a specified time when an input signal is present. It only reacts to the rising edge of the condition. This pulse starts the timer (Tnn=1). The timer preset is loaded into the timer and the timer starts to decrement until it reaches a value of zero, or a further edge (pulse) is detected at the conditional part, restarting the timer, or the timer is reset (Tnn=0).



FESTO DIDACTIC

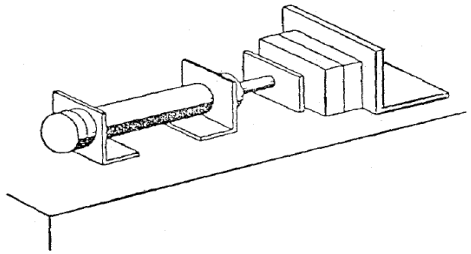
FESTO

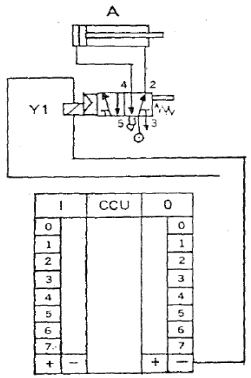
Exercise 15

CEMENTING PROCESS

A pushbutton is to control the forward stroke of a Cement press cylinder. After the piston rod has reached the forward end position, the components are to be pressed together for 20 seconds. Then the piston rod is to return automatically to the initial position.

Positional Sketch





FESTO

COUNTERS

Representations

FESTO

- Counter status - Cnn

  - indicates whether the counter is activated or deactivated. It is a one-bit operand that can be set, reset, or interrogated.

- Counter preset - CPnn

  - represents the end value for incremental counters and the start value for decremental counters. Ranges from 0 to 65535.

- Counter Word - CWnn

  - is a non-permanent multibit operand and indicates the current counter status.

Exercise 16

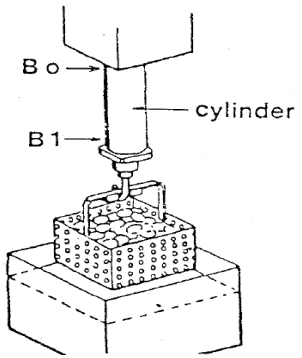
AUTOMATIC WASHING SYSTEM

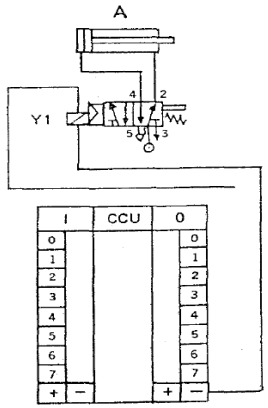
Metal components are to be cleaned in an acid bath. These components are placed in in a basket which is hung from a hook on a double-acting cylinder.

A single actuation of a push button causes the basket to be continuously lowered into and pulled out of the acid bath.

The sequence stops automatically after five cycles. Sensors Bo and B1 check the fully retracted and extended positions, respectively, of the cylinder.

Positional Sketch



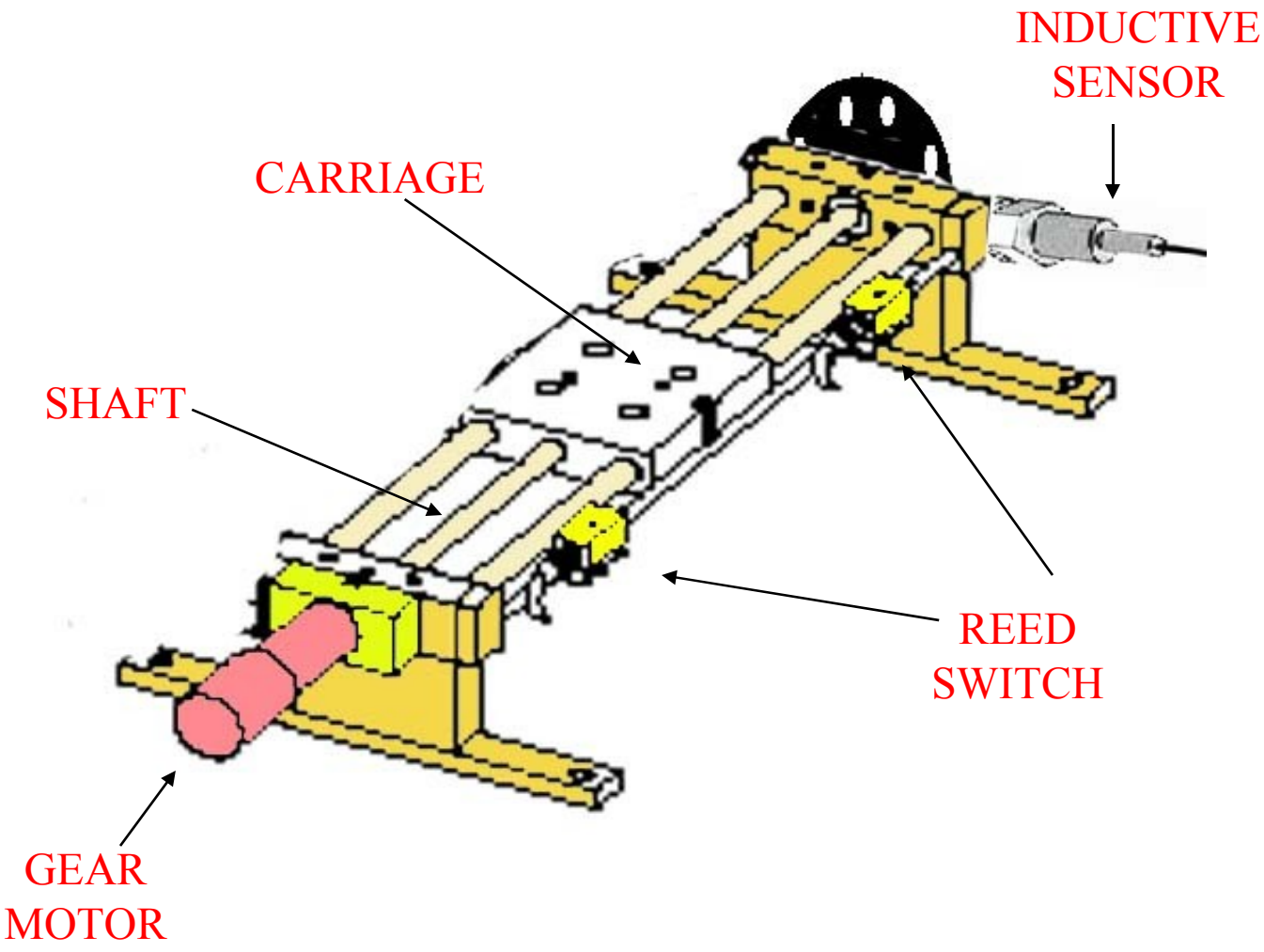


FESTO

Spindle Drive

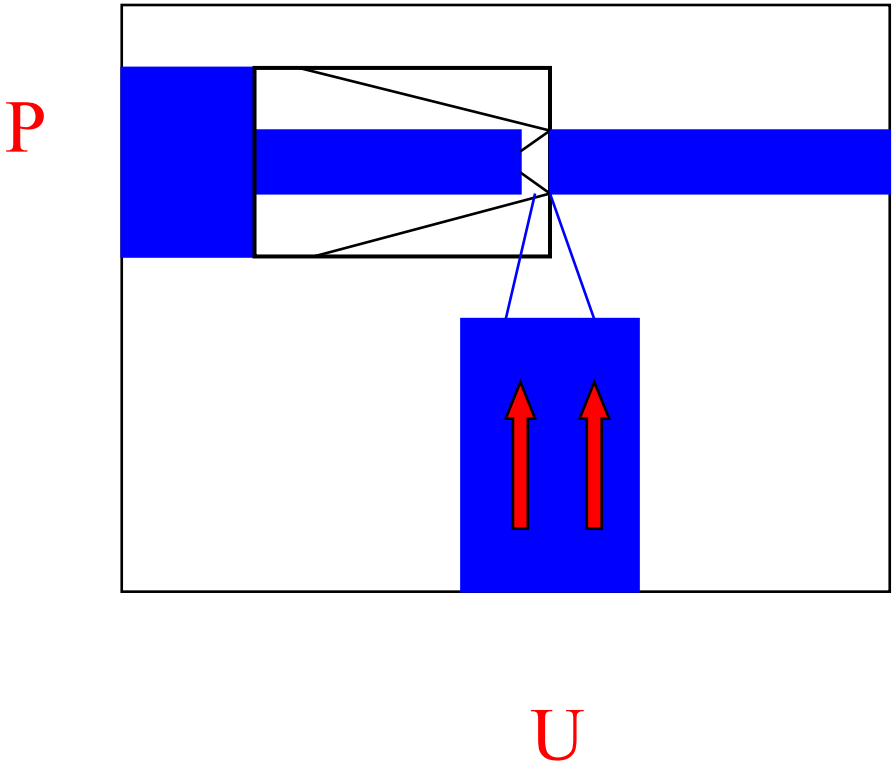
Spindle Drive

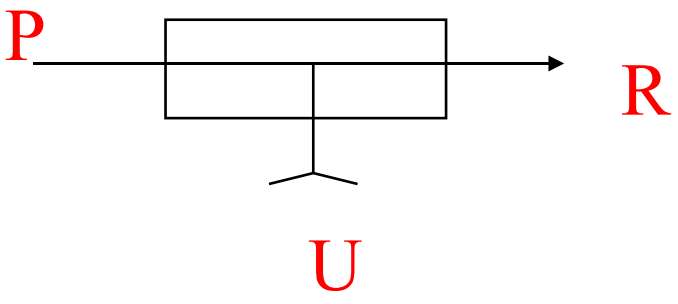
FESTO



Vacuum Generator

FESTO





- Workpieces with smooth and impervious surfaces can be picked up and held (for transporting and assembly) with this vacuum generator
- This produces vacuum in accordance with the venturi principle, using the compressed air from P to R.

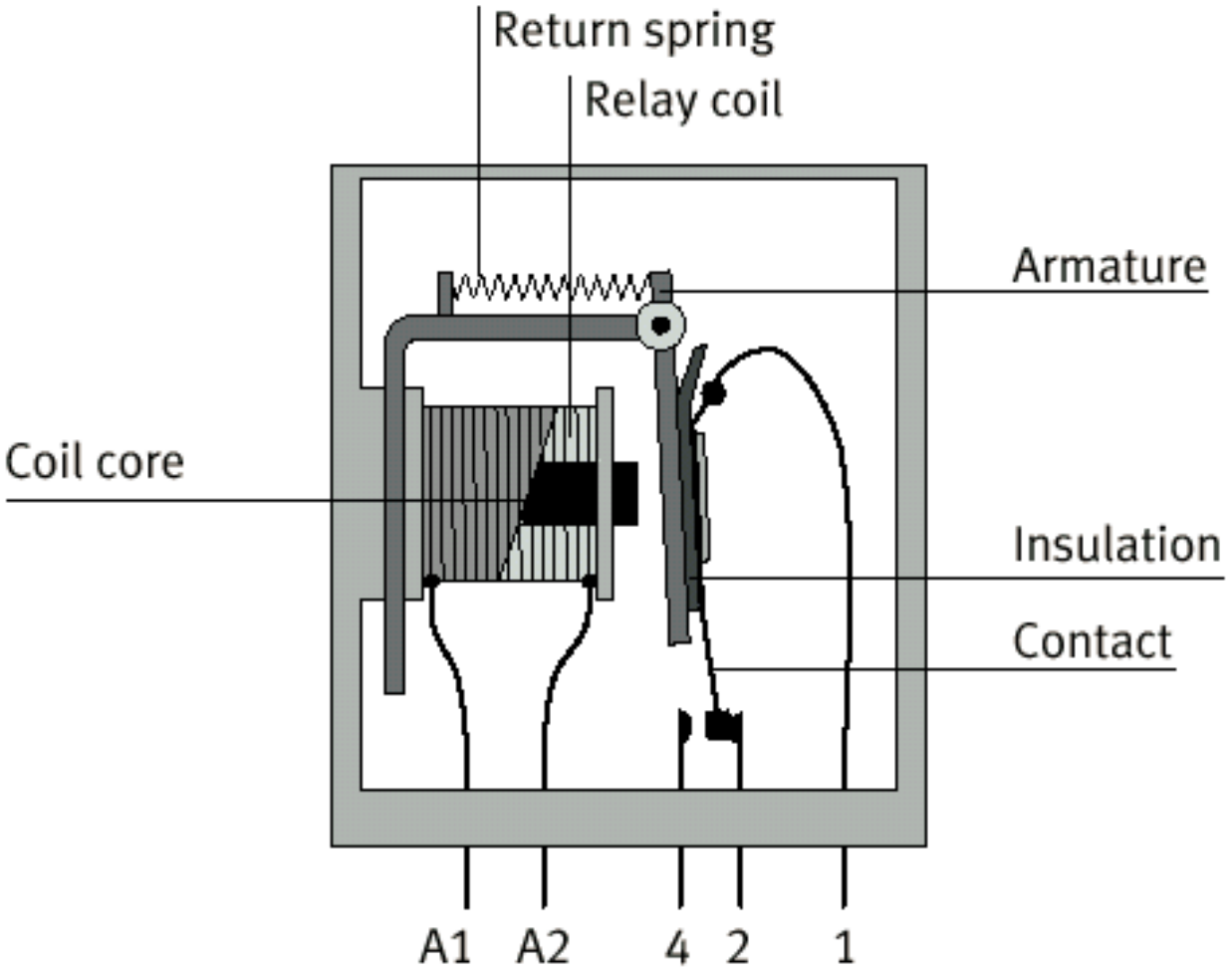
Relays

FESTO

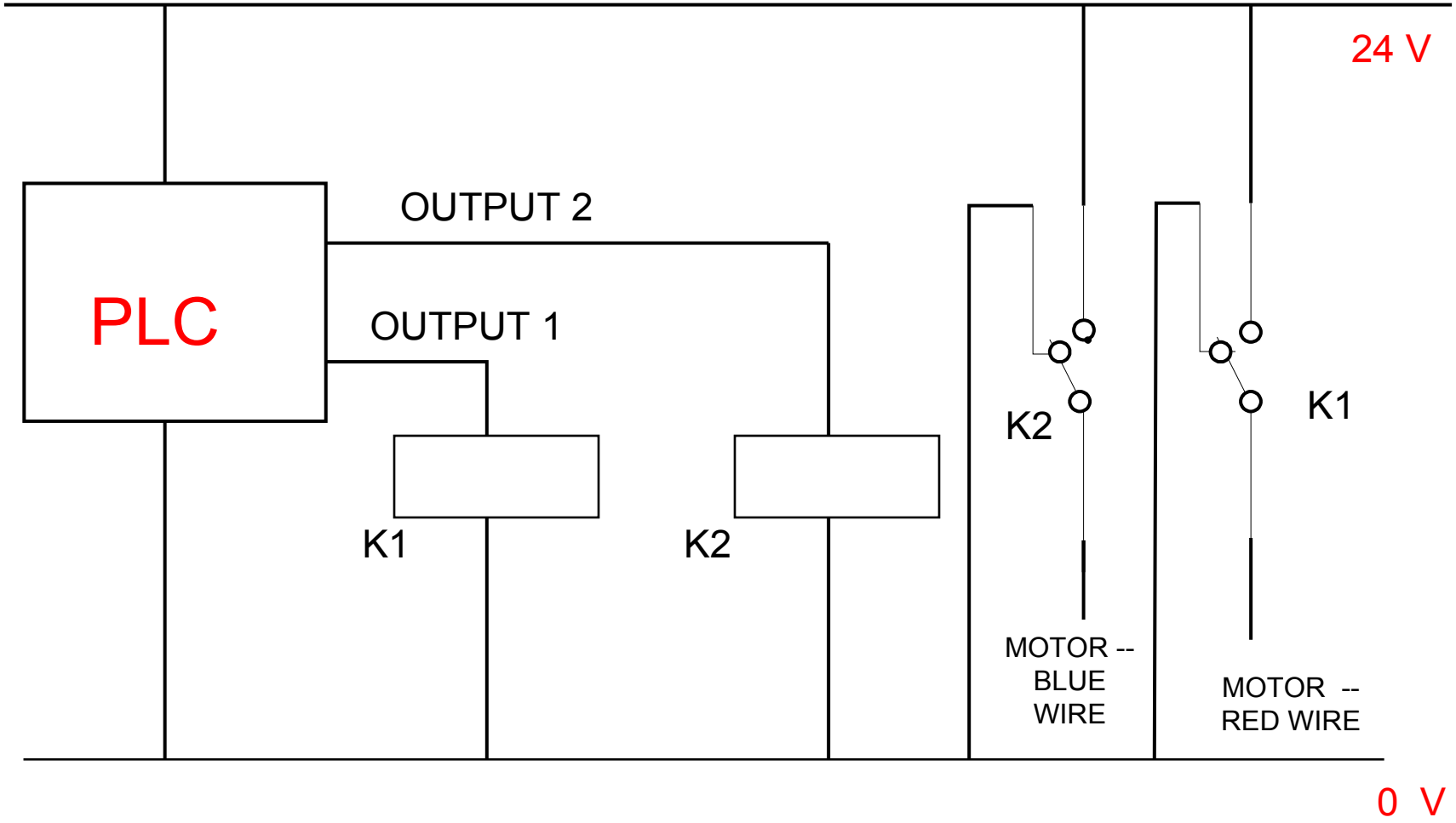
Relays are electro-magnetically actuated switches. They consist of a housing with electromagnet and movable contacts. An electromagnetic field is created when a voltage is applied to the coil of the electromagnet. This results in attraction of the movable armature to the coil core. The armature actuates the contact assembly.This contact assembly can open or close a specific number of contacts by mechanical means. If the flow of current through the coil is interrupted, a spring returns the armature to its original position.

Relays

FESTO



Controlling The Motor

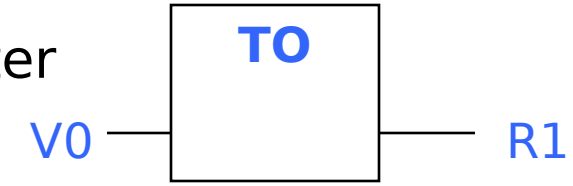


REGISTERS

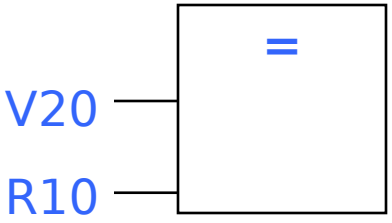
FESTO

- Used to store binary, octal or decimal values
- Can be used to perform mathematical functions
- Not addressable on a bit by bit basis
- Used to simplify controlling multiple sequential processes
- They are retentive. It stores its current value even with power loss

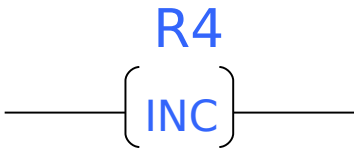
- Loading a value to a register
  (executive part)



- Interrogating a register
  (conditional part)



- Incrementing
  (executive part)



- Decrementing
  (executive part)

FESTO

MULTI TASKING

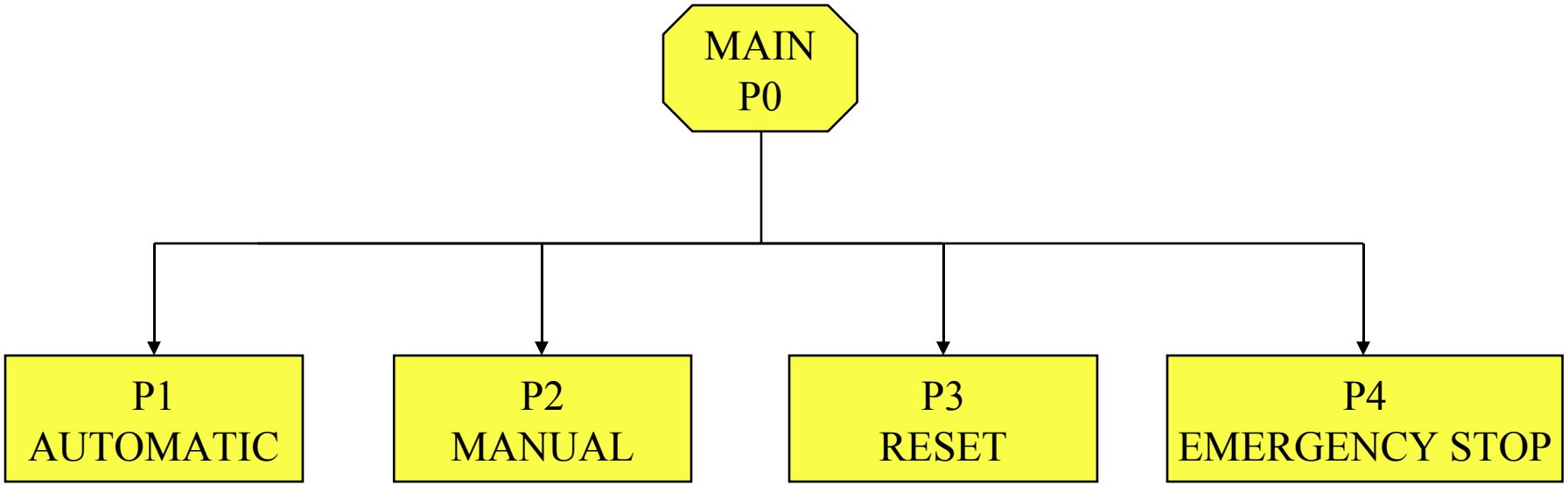
MULTI-TASKING

FESTO

- The FESTO PLC can execute the processing cycles of a number of programs one after the other (referred to as tasks).
- While in a task, one program is being processed, the other currently active programs are not processed.
- However, execution of the program segments and switching to the next program (task change) takes place so quickly that the programs appear to run in parallel. This is known as pseudo-parallel program execution.
- The idea is that a PLC can consist of several parts each of which is a program in its own right.

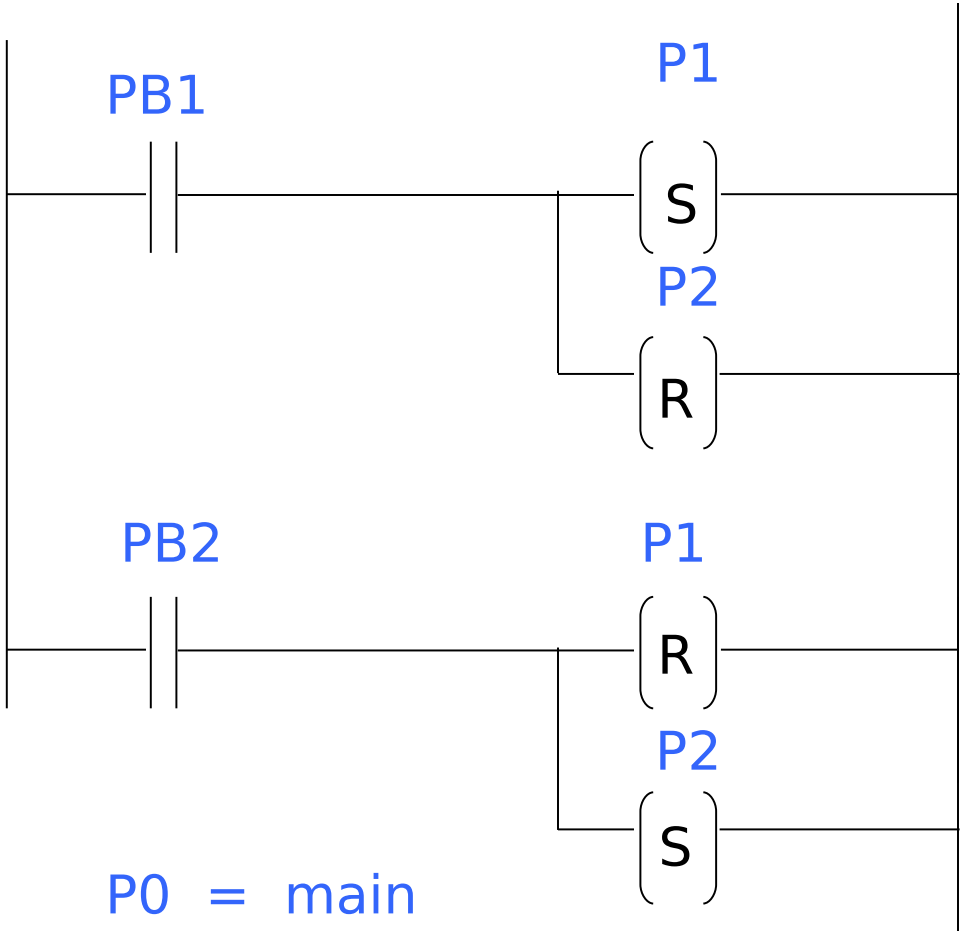
MULTI-TASKING

FESTO



MULTI-TASKING

FESTO



- A program can be activated (started) and deactivated (stopped) from within another program or module.
- The program is activated by setting the operand Pn, and deactivated by resetting it.
- Note: The LDR symbols --( )-- (assignment) and --(/)-- (negated assignment) cannot be used to activate deactivate a program. They are not permissible for the