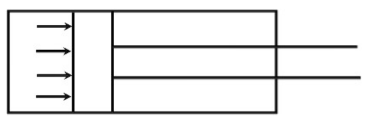
FLUID DRIVES

FLUID DRIVES

Pneumatics (medium – gas – mostly air)
Hydraulics (medium – liquids with admixtures)

- Advantages (strengths):
  - good realisation of straight movements
  - good force regulation, which is derived from the engine (piston, piston rod)

$$F = A \cdot p$$



(pressure control option)

where:
p – ***pressure*** *of the gas* [Pa]
A – ***area*** *of piston* [m^2]

  - low weight due to (considering) its power
  - they can be overloaded without any destruction

Fluid drives - ADVANTAGES

PNEUMATICS

- Higher speed (up to 3 ms^{-1}) ⇒ $$S \cdot v = Q$$

- Flexibility
- Medium is all around us
- Possibility of central compressed air production
- The compressor may not run continuously
- Possibility of long distance transport
- Simple line without return line (waste directly into the air)

Q … delivered amount of fluid $[m^3 s^{-1}]$

v … velocity of the flowing fluid $[m\ s^{-1}]$

S … cross-sectional area of the tube (hose) $[m^2]$

- When *Q* rises, *v* also rises
- The lowest possible fluid viscosity is required ⇒ The lower ↓ the viscosity, the more ↑ *Q* fluid passes through.

Fluid drives - ADVANTAGES

PNEUMATICS

- Cleanliness of operation
- Negligible influence of the environment (independent of T)
- Operational safety (non-flammability, non-explosive)
- Continuous setting of speeds and forces
- Assembly (simple construction of elements, convenient for assembly)
- Low weight due to power
- Robustness, easy to repair
- Overload tolerance
- High operational reliability

HYDRAULICS

- Possibility of high power transmission =
  = high forces $\Rightarrow$ up to 50 MPa
- Low speed
- High efficiency
- Smooth running at all speeds
- Good regulation in a wide control range
- Rigidity
- Accuracy
- Perfect lubrication of moving parts
- Simple overload protection and high overload capacity

Fluid drives - DISADVANTAGES

PNEUMATICS

- Poorly achieved small smooth speeds (2 – 3 ms^{-1})
- Difficult lubrication
- NO high forces (pressure – standard 0.6 MPa, max to 1.0 MPa) ⇒ it can't be compressed anymore, then it springs
- Noise (expansion of compressed air to the surroundings)
- Sensitivity to dirt ⇒ air treatment (all impurities must be removed to avoid excessive wear of the elements)
- Compressed air production is 6-8 times more expensive than electricity production and about 4 times more expensive than pressurized liquid production

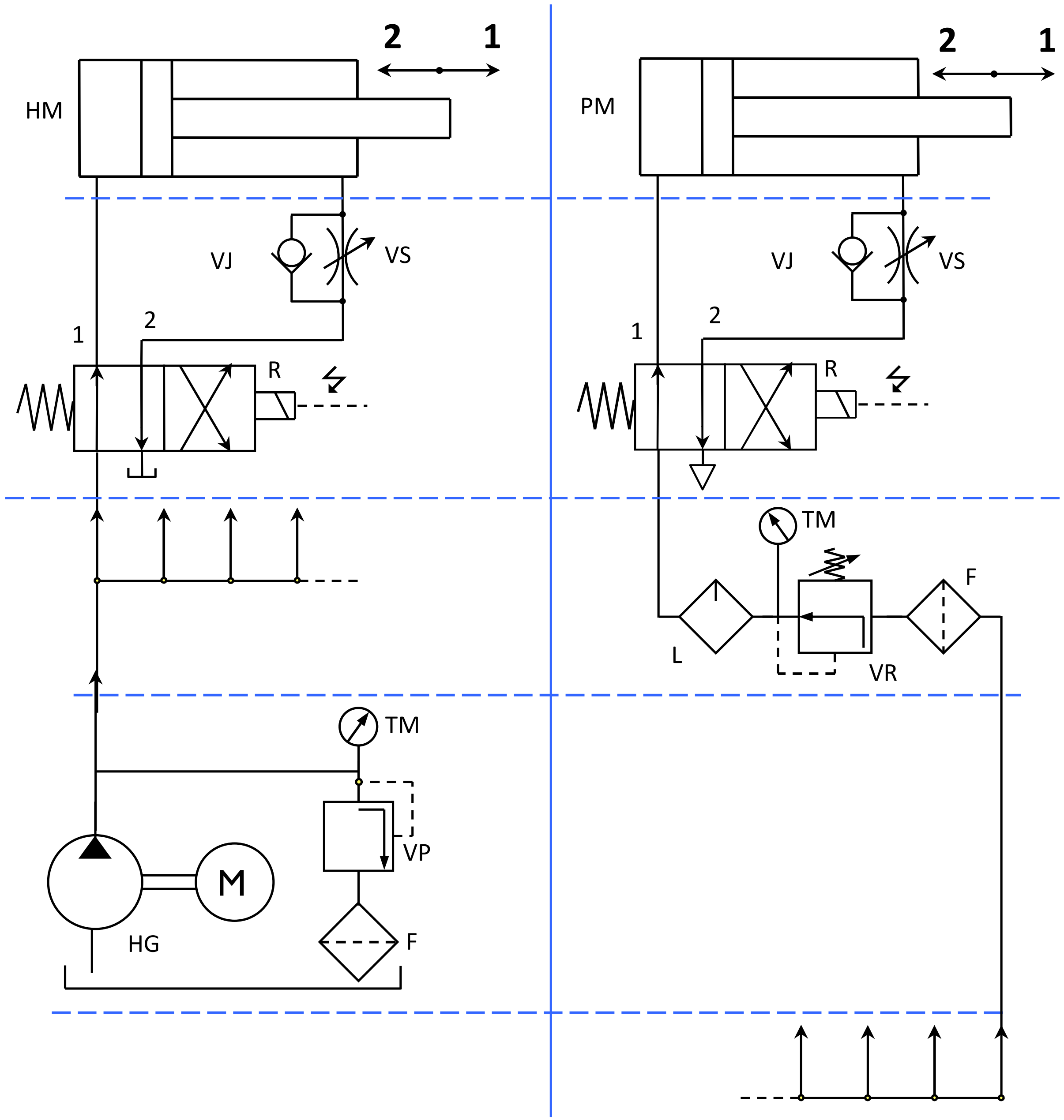
HYDRAULICS

- Flammability
- Dependence on T ⇒ dependence of mechanism properties on working liquid properties (thermal expansion, ageing)
- Significant losses in energy transmission ⇒ the unit (power pack) must be close to the engine
- Low speed
- Sensitivity to impurities in the liquid
- Ecological damage from the leakage of liquids into nature
- High parameters for geometric accuracy and maximum tightness of moving parts

PART 1

PART 2

HYDRAULIC CIRCUIT PNEUMATIC CIRCUIT



HM	Hydraulic cylinder
PM	Pneumatic cylinder
VJ	Non-return valve
VS	Flow control valve
R	Directional control valve
TM	Pressure gauge
L	Lubricator
F	Filter
VR	Pressure regulating valve
VP	Pressure relief valve
HG	Hydraulic pump
M	Motor

Control of fluid drives

Must be able to drive with fluid drives:

- Speed of movement
  - throttling – reducing the flow through the throttle valve
    - ⇒ throttling at the piston outlet eliminates vibration
    - ⇒ the pressure does not change; only the quantity
- Direction of movement
  - by rising pressure
  - by pressure drop
  - differential pressure effect
  - control by directional control valves – transfer of liquid or air to one or the other side of the piston
- Magnitude of force $F = p \cdot S$
  - fluid pressure regulation
    - – pneumatics – pressure relief valve
    - – hydraulics – pressure relief valve
  - change of cylinder size – change in the size of the surface on which the pressurised fluid acts

PNEUMATICS

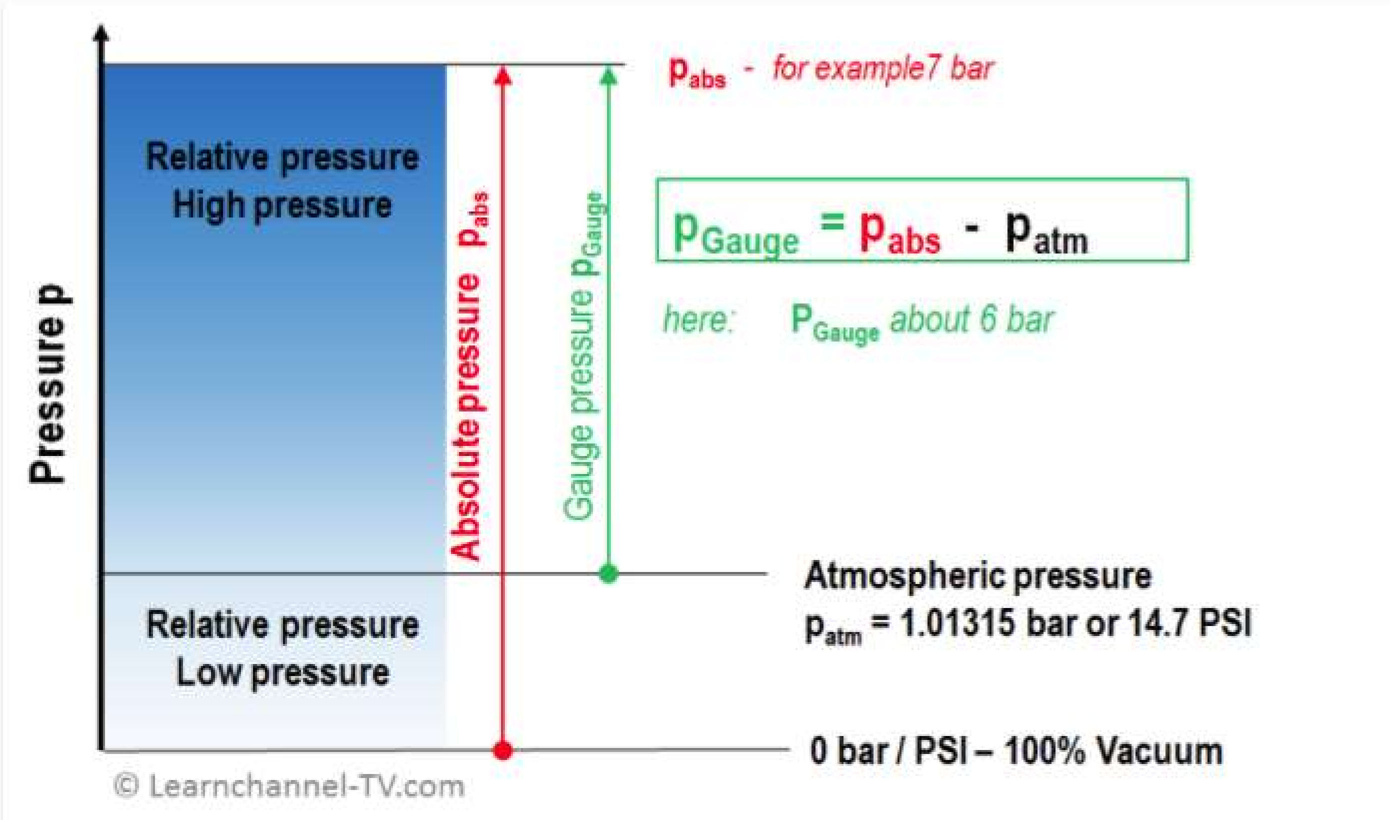
Pneumatic drives

Pneumatic mechanisms

Pneumatic mechanism

- equipment for energy transfer and transformation of input functions into output functions, where the energy carrier is a gas, usually atmospheric air
- Pneumatics (from the Greek πνευματικός *pneumatikos*, coming from the wind) is the use of pressurised gas to do work in science and technology.
- Pneumatic transfer systems are employed in many industries to move powders and devices.

[Heeresh Mistry, *Fundamentals of Pneumatic Engineering*, Create Space e-Publication, 2013, ISBN 1-49-372758-3.]

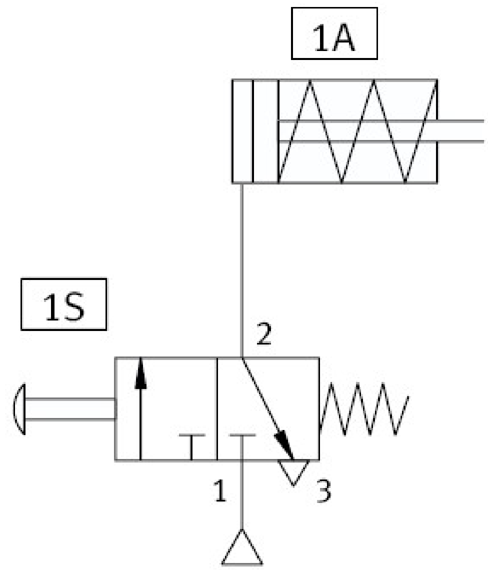


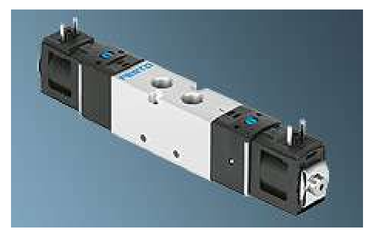
Pressure in Pneumatics - Definitions

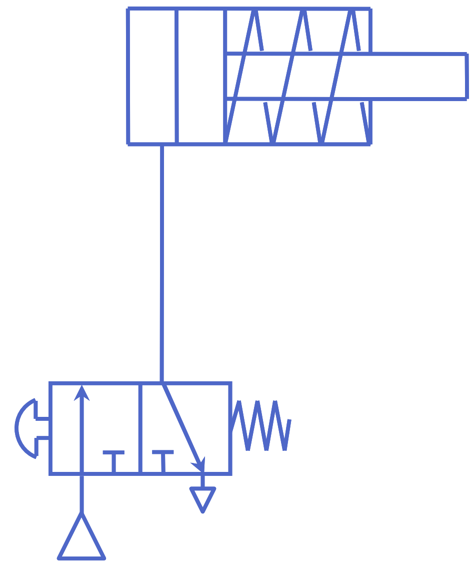
p_{atm}	atmospheric pressure, that means the pressure at sea level
p_{Gauge}	atmospheric differential pressure
p_{abs}	pressure in absolute numbers in relation to 0 bar or vacuum (abb. from pressure absolute)

[Learnchannel-TV.com, *The basic laws of pneumatics*, https://learnchannel-tv.com/pneumatics/basic-laws/]

Example of simple pneumatic drive

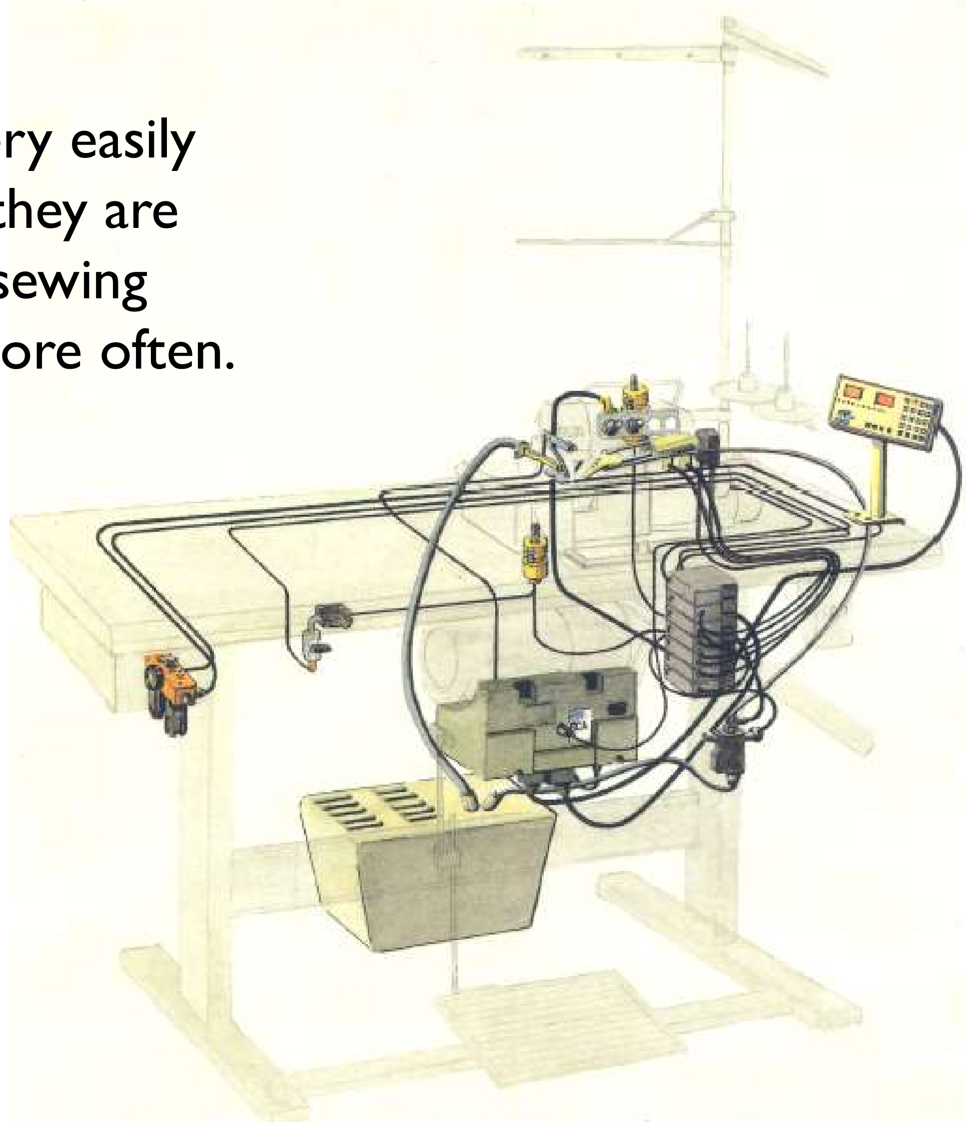






Pneumatic drive

- Pneumatic drives are very easily controllable, therefore they are used in the automated sewing operations more and more often.



Distribution of pneumatic mechanisms according to the used form of energy

Gas flow carries three main forms of energy:

- Potential
- Deformation
- Kinetic

a) pneumatic-static mechanisms

b) pneumatic-dynamic mechanisms

Division of pneumatic mechanisms, according to the functions they have in the machine

A. **mechanisms used mainly for energy transfer**
   1) sliding mechanisms – ensure relative movement between the two units
   2) servomechanisms – also used for information transmission and processing
   3) transmission mechanisms – transfer power to the output members of the machine

B. **mechanisms for transmitting information**

   Transmission delay (often greater than instrument delay) - only suitable where there are large time constants of the monitored system

⇒ Pneumatic mechanisms in **pressure zones** are used to transfer energy and information :
- **low pressure** (p = 0,1÷10 kPa),
- **medium pressure** (p = 20 ÷100 kPa), **and**
- **high pressure** (p = 200 ÷1000 kPa),

Advantages and disadvantages of pneumatic mechanisms

The advantages and disadvantages of pneumatic mechanisms result from two gas properties:

a) ***high gas compressibility***
b) ***low viscosity*** *and the resulting* ***low frictional resistances***

See pages 3 - 5 (Advantages and disadvantages of pneumatic and hydraulic circuits.

Air compressibility

Air - compressible (***compression***)

- expandable (***expansion***)

This phenomenon is described in ***Boyle – Mariotte law***

This applies to the ***isothermal process***

The following relationship applies:

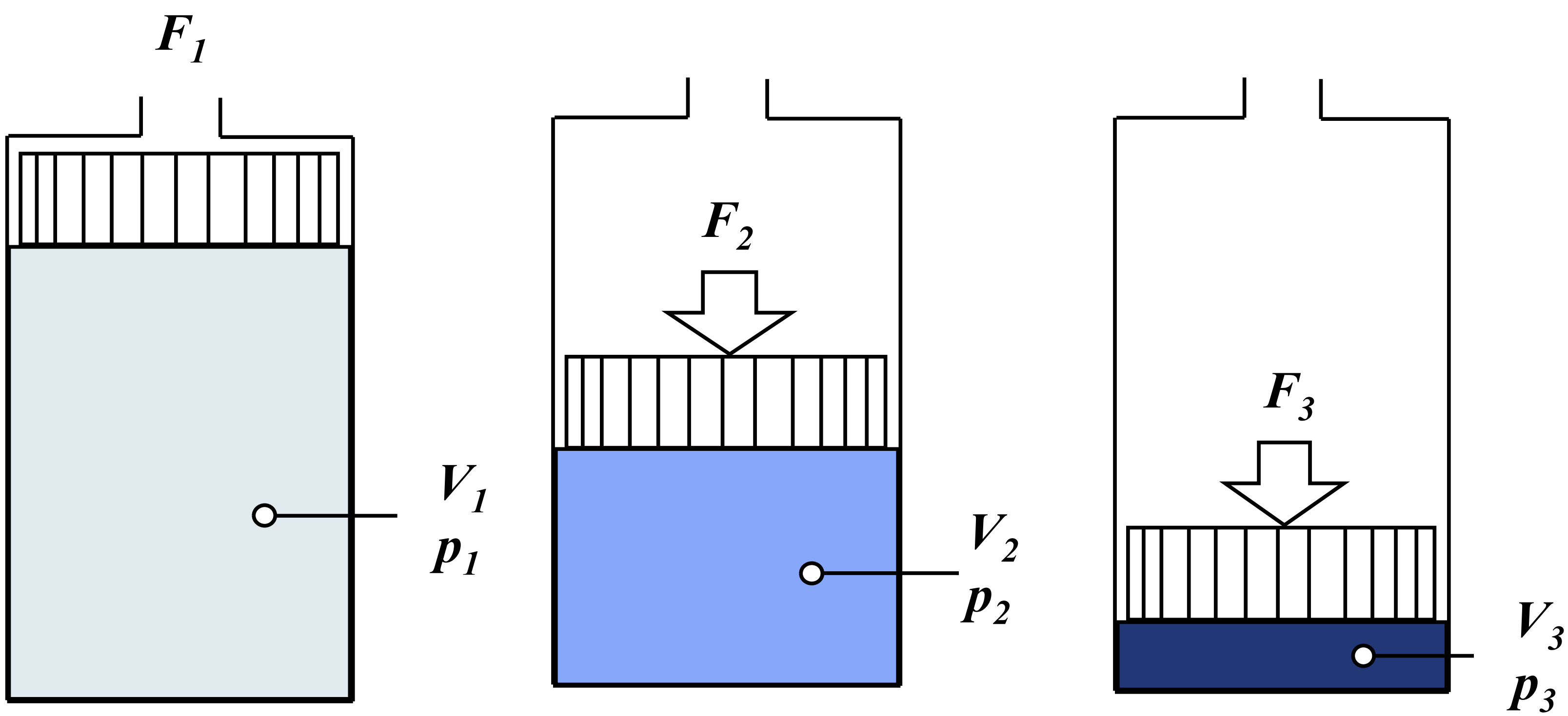
$$p_1.V_1 = p_2.V_2 = p_3.V_3 = constatnt$$

where:

- *p* – ***pressure*** *of the gas* [Pa]
- *V* – ***volume*** *of the gas* [m^3]

The product of the pressure *p* and the volume *V* of an ideal gas of a given mass is constant at constant thermodynamic temperatures *T*.

Air compressibility



Gay – Lussac´s law for isobaric process

The gas volume varies depending on the temperature

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = constant$$

In an isobaric process in an ideal gas of constant mass, the volume of the gas is directly proportional to its thermodynamic temperature T

The general relationship that applies to an **ideal gas**:

$$p \cdot V = n \cdot R \cdot T$$

Where:

- *p* – ***pressure*** *of the gas* [Pa]
- *V* – ***volume*** *of the gas* [m^3]
- *n* – ***amount of substance*** *of gas (number of moles)* [mol]
- *R* – *ideal or universal* ***gas constant*** [$J.mol^{-1}.K^{-1}$]
- *T* – *absolute* ***temperature*** *of gas* [K]

$$n = \frac{m[kg]}{M[kg \cdot mol^{-1}]}$$

Charles´ law for the isochoric process

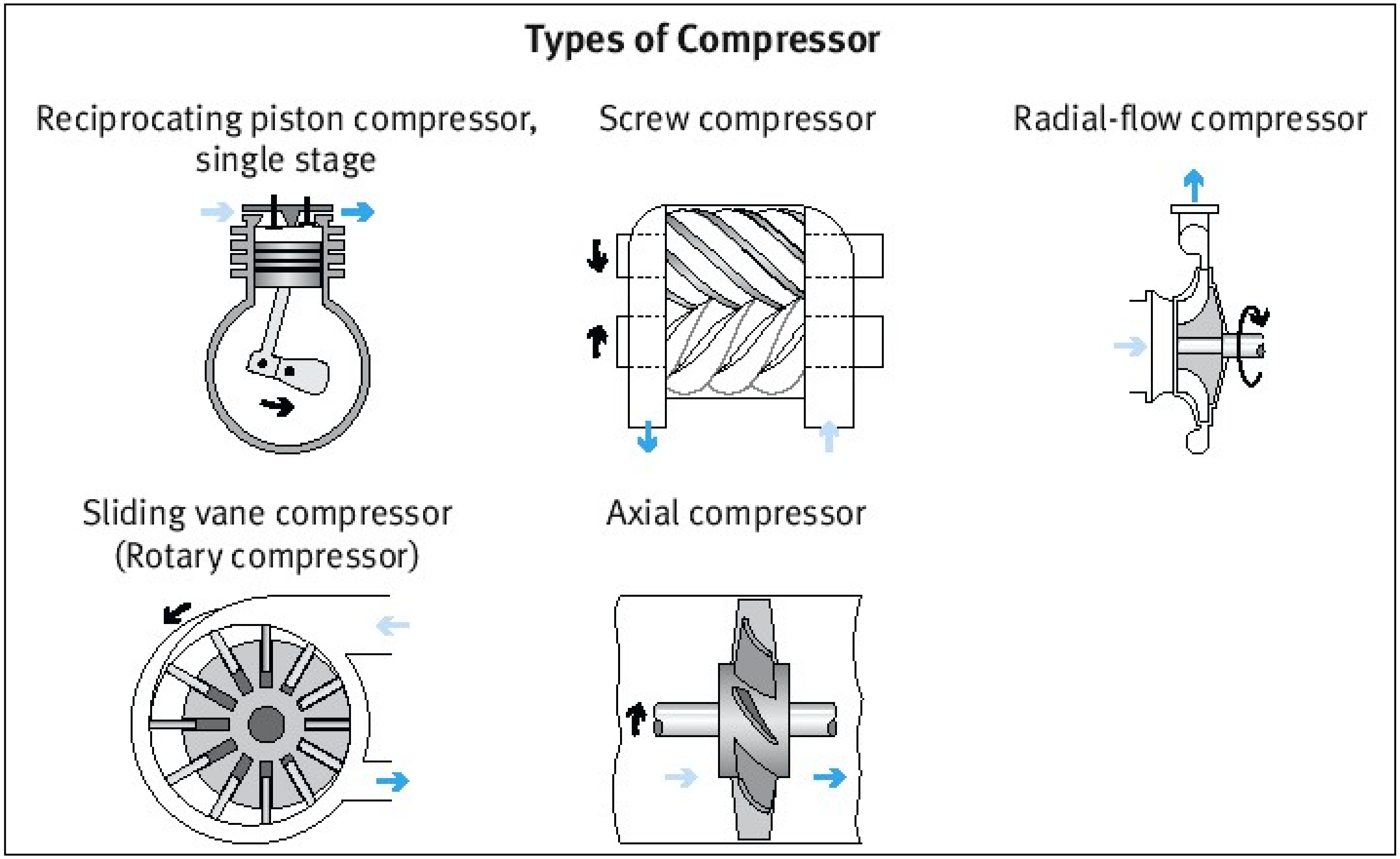
The temperature of a gas is directly proportional to its pressure.

The constant to the right of the equation is called the thermal expansion.

$$\frac{p_1}{T_1} = \frac{p_2}{T_2} = constant$$

In an isochoric process with an ideal gas at a constant mass, the gas pressure is directly proportional to its thermodynamic temperature

Air compressibility
TYPES OF COMPRESSORS



Compressed air production

A mechanically operated machine that raises the air pressure by reducing its volume is called **an air compressor**

- they compress the air from the ambient pressure to the required working pressure
- compress the gas to a positive pressure (overpressure) of more than 200 kPa

There are two basic designs:

Positive displacement compressors

reciprocating (piston, membrane) compressors

- reciprocating
- rotary

Dynamic compressors

Radial-flow compresor

Axial compresor

Centrufugal…

Air pressure

Pressure is defined as the force acting on a surface:

$$p = \frac{F}{A}$$

Where
p – pressure [Pa]
F – magnitude of normal force [N]
A – area of the surface on contact [m^2]

The SI unit for pressure is the **Pascal** [Pa]
(one newton per square metre)

$$Pa = \frac{N}{m^2}$$

Other units used:

a) **Atmosphere** – absolute pressure in the technical system

$$1\ at = \frac{1\ kp}{1\ cm^2} = 0.981\ bar$$

b) **bar**

$$1\ bar = \frac{10^5\ N}{1\ m^2} = 10^5\ Pa = 1.02\ at$$

c) **Torr**

$$1\ torr = 1\ mm\ Hg \approx 133.322\ Pa$$

$$1 Torr = \frac{1}{736} at$$

Hydrostatic pressure of a mercury column with height h = 1 mm, mercury density and normal gravitational acceleration

$$p = \rho h g = 13534 \cdot 10^{-3} \cdot 9.81 = 133.322$$ [Pa; kg·m^{-3}; m; m·s^{-2}]

$$1 Torr = \frac{1}{750} bar \qquad 1 Torr = \frac{1}{760} atm$$