



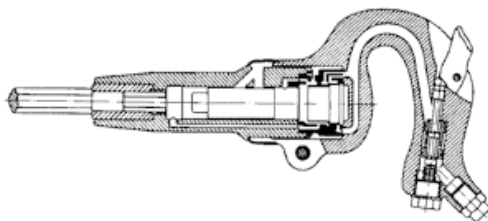
Introduction:

Compressed air is used increasingly preferentially because it possesses a range of outstanding characteristics:

- Can be easily transported
- After use no return is necessary
- Easy to store
- Clean and dry
- Light
- Simple and robust equipment
- Safe from overloading
- A fast working medium
- Easy to regulate

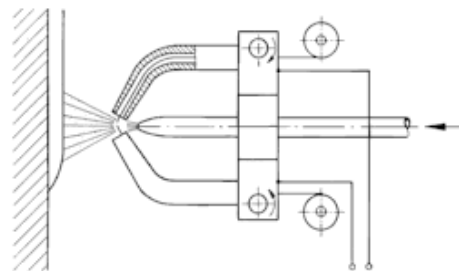
The disadvantage is that only 10% of the input energy is transformed into compressed energy. 5% is transformed into the exergy component and is therefore irreversible (non-returnable). 85% of the input energy is lost as heat. Because of this, compressed air is a very expensive energy application. As a result, compressed air should be generated, treated and used very efficiently in order to avoid high electricity costs.

Use Areas for Compressed Air:



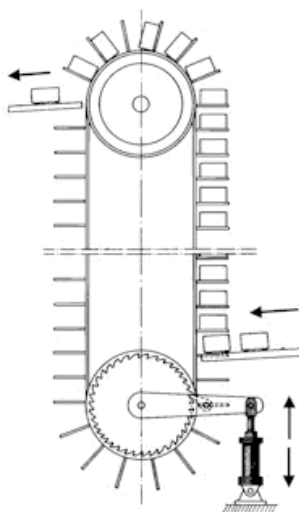
Pneumatic Drives

Example: Hammering compressed air tool
Picture: Valveless pneumatic jackhammer



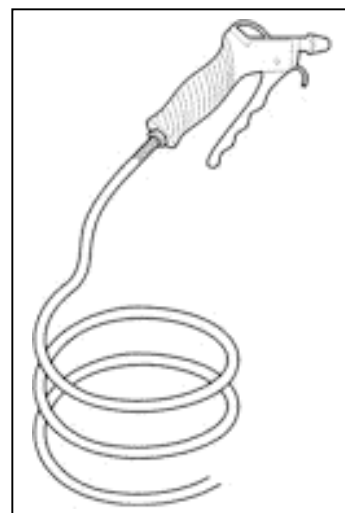
Spraying

Example: Sandblasting, spray painting
Picture: Metal spraying arc unit



Transporting

Example: Conveyor units
Picture: Height bridging with a Pneumatically driven elevator

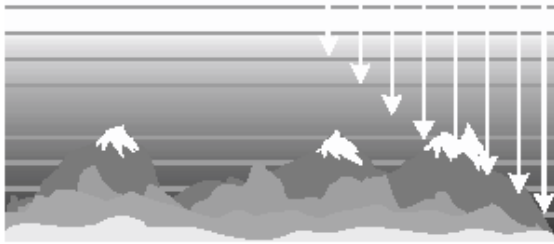


Blowing

Example: Blowing out, cleaning
Picture: Blow gun with spiral hose

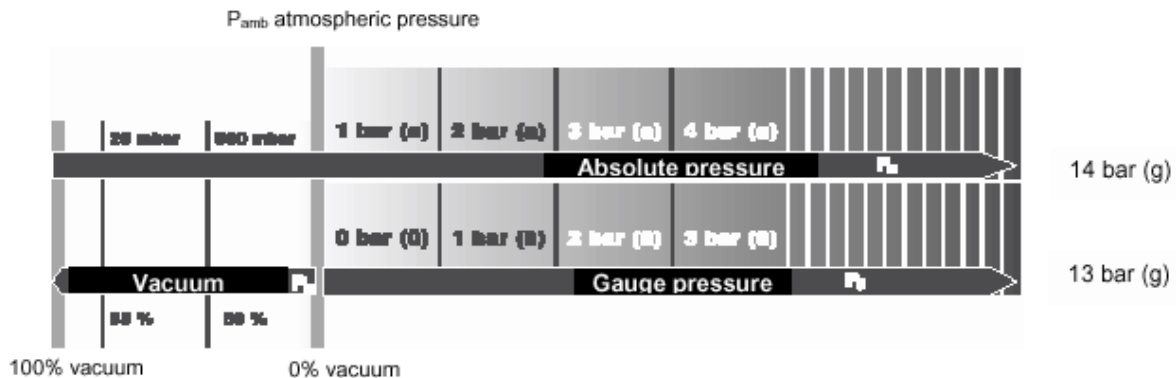


Theoretical Principles:



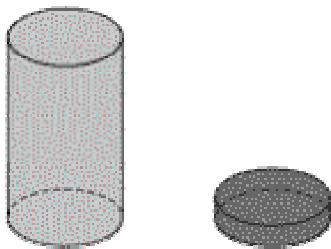
Atmospheric pressure is produced as a result of the weight of the atmosphere around the earth. It is dependent upon the density and height of the atmosphere. At sea level the following is valid:
 1.013 bar = 760 mm/Hg (Torr)

Absolute pressure and gauge pressure:



In compressed air technology all pressure information refers to gauge pressure. A level of 6 bar in the compressed air network means an absolute pressure of 7 bar.

Operating volume = compressed air in the compressed state



In the operational state, the volume is relative to the actual state. Temperature, air pressure and humidity must be taken into account as parameters. When discussing operating volume, the pressure is always mentioned e.g. 1m^3 at 7 bar positive pressure means that 1m^3 of air is compressed at 7 bar positive pressure (= 8 bar absolute) and only takes up 1/8 of the original volume.

0 bar absolute 8 bar absolute

Pressure ranges:

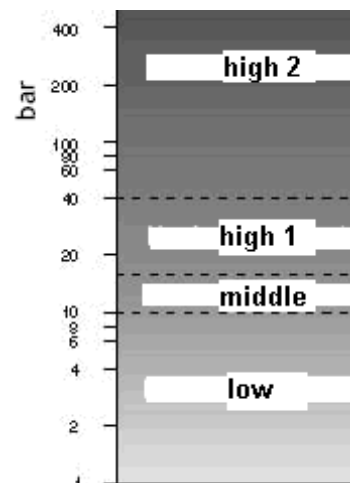
Low pressure: Most applications in industry and trade lie within this pressure range. Compressor:

1-2 stage piston and screw compressors

Med. pressure: Heavy vehicle tyres, special machinery

High pressure 1: Pipe pressure testing, blow moulding of plastic containers. Compressor: 3-stage piston and screw compressors

High pressure 2: Leak testing, power stations and rolling plants, oxygen compression. Compressors: 3-4 stage piston compressors

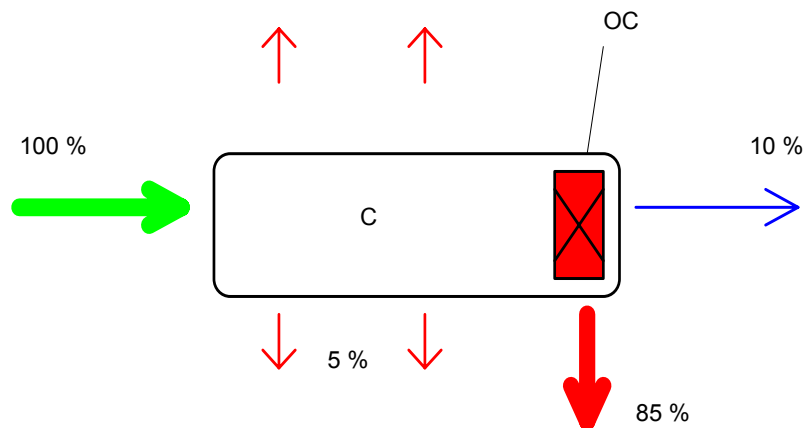




The principle of air compression:

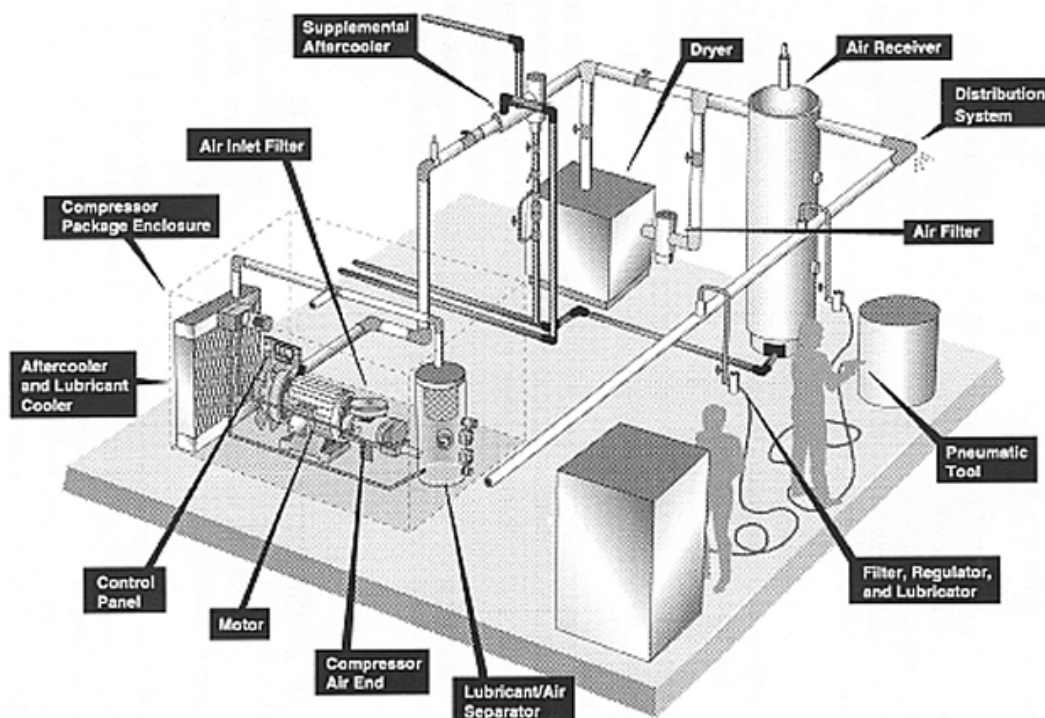
In air compression, a polytropic compression takes place i.e. the work applied to achieve volume adjustment is mostly transformed into heat (the air heats up due to compression). Part of the heat is transferred through the cylinder wall (piston compressor). Part of the work applied to volume adjustment is incorporated into the compressed air in the form of compressed energy.

The Energy balance (c = compressor):



Out of 100 % of the electrical energy inputted, ca. 10% is transformed into the form of compressed air energy and 90% into heat of which 85% can be reused by means of a heat exchanger (OC = oil cooler). 5% is lost into the surroundings as radiated heat.

Components of a Compressed Air Unit:





Preparation material Compressed air

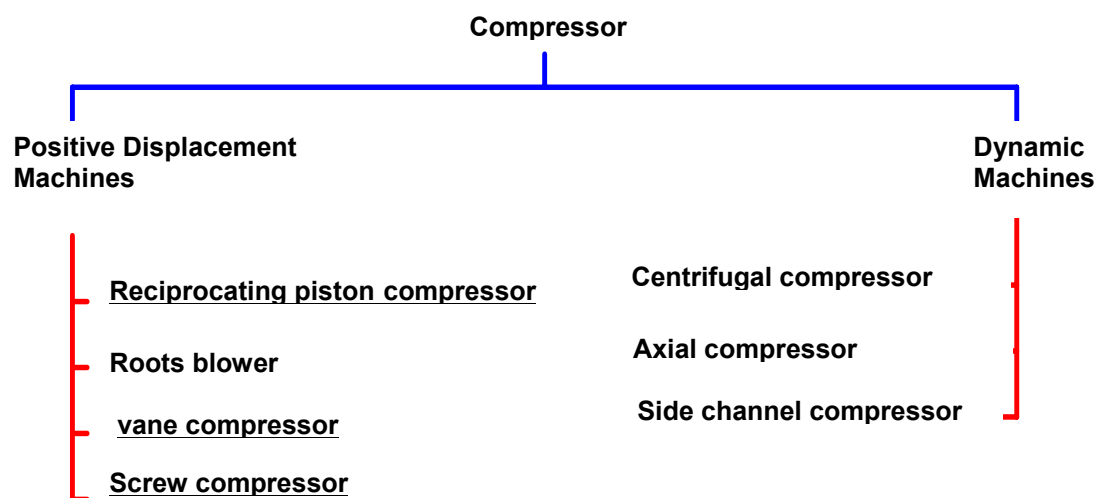


These components can be broken down into four main modules:

1. Compressor (inlet filter, compression elements, coolers, control system)
2. Filter systems (the removal of solids and oil particles from the compressed air according to the quality requirements)
3. Drying (dehumidification of the compressed air in driers)
4. Compressed air receiver and compressed air network (storage and distribution of the compressed air)

Compressors:

The compressors are classified into different types. These are used depending on end purpose and size of machine.



The underlined compressor variants are the types of machines used most often. The focus of our considerations is directed at these types of structural units.

Air-cooled variants of the reciprocating piston compressor are commonly used for small sizes (up to 4 kW), although they can go up to 90 kW. Water cooled variants of this compressor are also used for larger capacities and have efficiency advantages through having double action pistons over the screw and vane compressors. However, the purchase cost is also much higher and very few new machine are sold for air generation.

Manufacturers are increasingly concentrating on manufacturing large numbers of screw elements. As a result, there are few manufacturers of screw elements today but many types of screw compressors. This means that the same type of screw elements may be found within a range of different housings. For the same reasons, the market share for vane compressors (ca. 5%) is continuously declining. In the medium term, vane compressors are likely to be driven off the market apart from at they very small end. Therefore, it is sensible for users to concentrate on the screw-based technology.



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Compressed air treatment (compressed air quality)

A further important aspect to consider is the compressed air quality required, i.e. “compressed air treatment“. Under the term compressed air treatment the required treatment and finishing of compressed air, according to the compressor type, in order to offer best possible solution to the end user is considered. The following possibilities are available:

- **Filtration**, in order to prevent contamination and to guarantee the desired purity of the compressed air. Various filter systems are available for filtration (separation is related to the size of particulate matter in the flow):
 - I. Simple filter (separation 5 mg/m³)
 - II. Micro- or fine filter (separation 0,01 mg/m³)
 - III. Activated carbon filter (0,003 mg/m³)
 - IV. Sterile filter (for 100% germ free compressed air)

The separation capability of these filters is based upon an operating temperature of 20°C. Higher temperatures impair the effectiveness of the filter. The filters complement each other, i.e. first stage I, then II etc. Example: Quality required: 0,003 mg/m³ - thus filters I, II und III are connected in series. In this regard be aware that each installed filter creates a pressure loss and associated cost. It is therefore essential to think carefully about the level of air quality that is required.

- **Drying** of the compressed air or removal of condensation. For drying, the following systems available are:
 - I. Aftercooling (included on compressor, no external treatment)
 - II. Refrigerant drying (typical pressure dewpoint +3°C)
 - III. Adsorption drying (Dessicant or sorption dryers) (typical pressure dewpoints -20, -40, -70°C)

The above named systems are not mutually exclusive in this regard and thus, in principle, can be complementary. A tabulated overview of the quality classes and requirements for various use areas is found in Appendix 1.

Compressed air network and compressed air receiver:

The compressed air network must fulfill various conditions:

- Sufficient flow volume and working pressure for each user
- Supply the user with compressed air at the required level of quality
- Low pressure drop and a high degree of reliability

The compressed air receiver has to fulfill the following duties:

- **Storage:** Short term peak flows can be covered from the volumes stored in the compressed air receiver. The compressor cycles less frequently and can therefore work more continuously.
- **Pulsation damping:** Pulsation of the flow volume caused by piston compressors is damped by the compressed air receiver.
- **Condensation separation:** The moisture contained in the air condenses in the compressed air receiver and collects in the base from where it can be drained away.



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Appendix 1: Compressed Air Quality; Quality Classes According to the ISO 8573-1:2002 Standard:

Humidity and oil

Class	Pressure dewpoint, °C	Oil carry over, mg/m ³
0	As specified by the equipment user or supplier and more stringent than class 1	
1	<= -70	<=0.01
2	<= -40	<=0.1
3	<= -20	<=1
4	<= +3	<=5
5	<= +7	
6	<= +10	

Particulate

Class	Maximum number of particles per m ³				Particle size	Concentration
	Particle size					
	≤0.1	0.1<d≤0.5μm	0.5<d≤1.0μm	1.0<d≤5.0μm	μm	Mg/m ³
0	As specified by the equipment user or supplier and more stringent than class 1				Not applicable	Not applicable
1	Not specified	100	1	0		
2	Not specified	100,000	1,000	10		
3	Not specified	Not specified	10,000	500		
4	Not specified	Not specified	Not specified	1,000		
5	Not specified	Not specified	Not specified	20,000		
6	Not applicable				<=5	<=5
7	Not applicable				<=40	<=10

In all cases the reference conditions for the volume measurements are 1 bar absolute, 20°C, 0%RH.



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Recommended Quality Classes According to Purpose of Use (In Accordance With the Association of German Compressed-Air Specialists):

Application	Solids	Water	Oil
Storage air	3	5	3
Instrument air	2	3	3
Air motors	4	4-1	5
Small air motors	3	3-1	3
Air turbines	2	2	3
Machinery for shoes, stone or glass	4	4	5
Cleaning of machinery parts	4	4	4
Construction areas	6	6	6
Delivery of grits	3	4	3
Delivery of powders	2	3	2
Foundry machinery	4	4	5
Delivery of foods and drinks	2	3	1
Hand tool industry	4	5-4	5-4
Tooling machines	4	3	5
Mining	6	6	6
Packaging and textile machinery	4	3	3
Photographic film finishing	1	1	1
Compressed air cylinders	3	3	4
High sensitivity pressure regulation	3	2	3
Process control equipment	2	2	3
Hammer drills	6	6	6
Stationery sandblasting units	-	3	3
Mobile sandblasting units	6	6	6
Spray guns	3	3-2	3
Welding machines	4	4	4
General plant air	4	4	4