Compressor Theory

Technical Training

al Information - Compressors

High pressure compressor units are complete units for filling air tanks in the high pressure ranges PN 200 and PN 300 bar. The compressors are mainly used to compress air for breathing as required in diving and fire fighting applications, for instance.

The heart of this unit is formed by a three- or four stage, air-cooled **high pressure compressor block**.

The **Purus, Utilus 10** and **Junior** range compressor units are splash-lubricated.

From the **Utilus, Capitano** and **Mariner** range compressor units onwards, the last stages are lubricated by means of the forced-feed lubrication system, the other cylinders are splash-lubricated.

All units are equipped with a breathing air - processing system (P-filter system), that surpasses the quality requirements

The compressor unit comprises the following major assemblies:

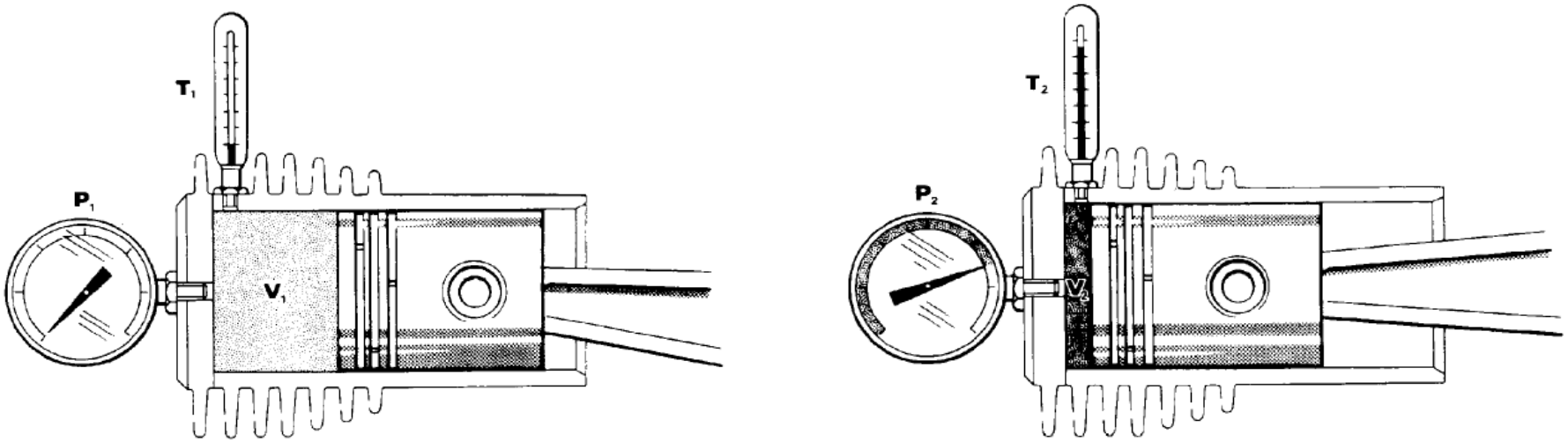
- compressor block
- drive motor
- filter set
- base and frame assembly with instrument/filling panel
- electric control system[a)]
- electronic monitoring system[a)]
- automatic condensate drain[a)]

It is impossible to compress air to more than 10 bar in one go for three reasons :

- Heat
- Mechanical limitations
- Water (moisture)

This represents a maximum compression ration of 10:1

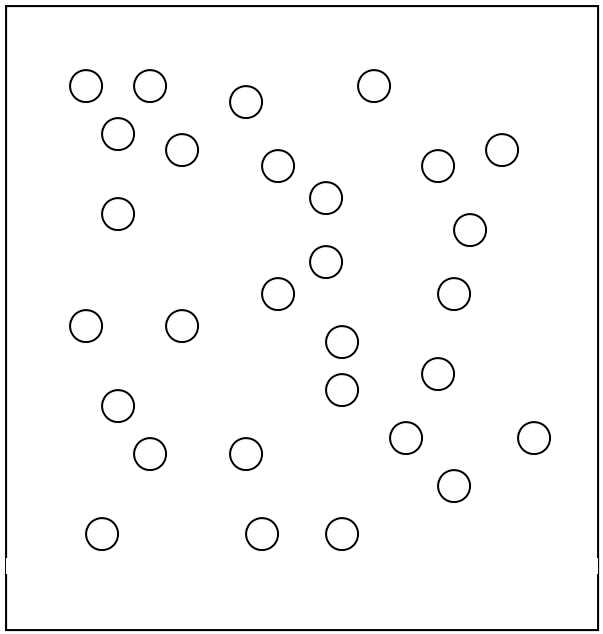
I Information – Temperature Rise



When the piston moves into the cylinder, the pressure rises in the cylinder. At the same time however, the temperature of the enclosed gas also rises. This is a basic physical law (Gay-Lussac).

Since with increasing pressure, the occuring temperatures would soon reach inadmissibly high values, the compression has to be divided into various stages. After every stage the gas is cooled back to approx. 10 – 15 °C above ambient temperature. This is the main reason for designing compressors with 3 or 4 stages.

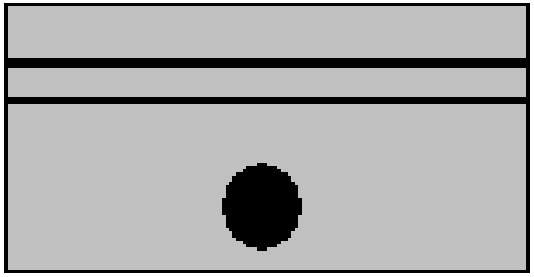
How is compression accomplished and what effects occur during the compression process:



(P)ressure Increases

(T)emperature Increases

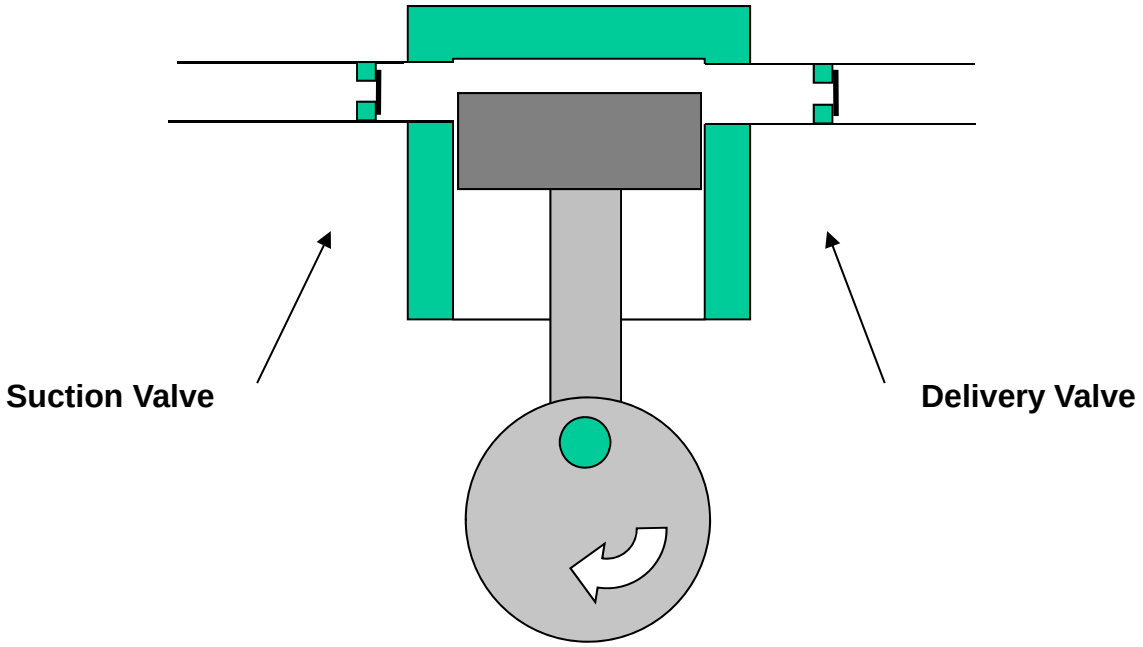
(V)olume Decreases



Reciprocating Compressors

What is a reciprocating compressor

- A reciprocating compressor uses a piston or group of pistons to compress air.



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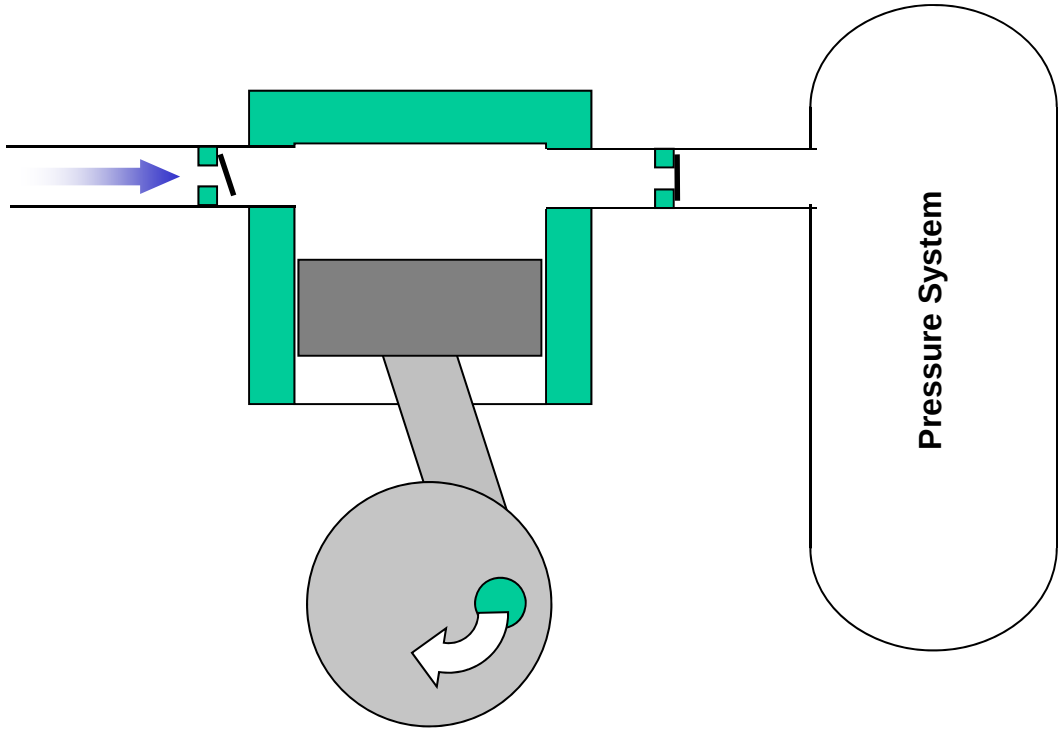

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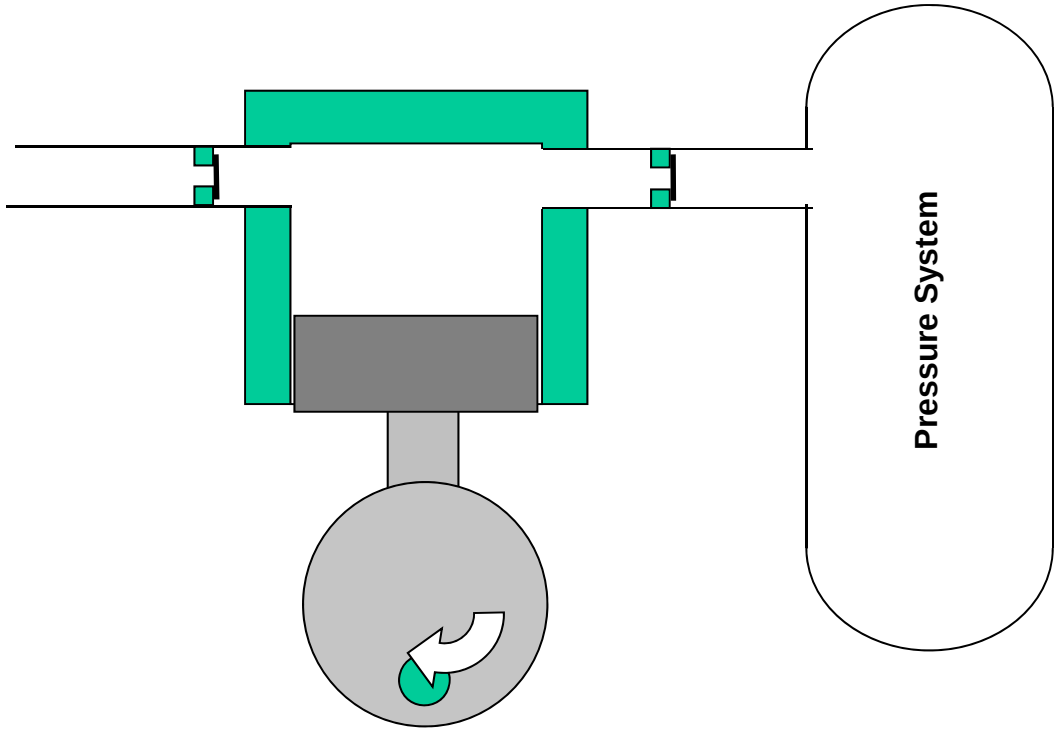

Reciprocating Compressors

What is a reciprocating compressor

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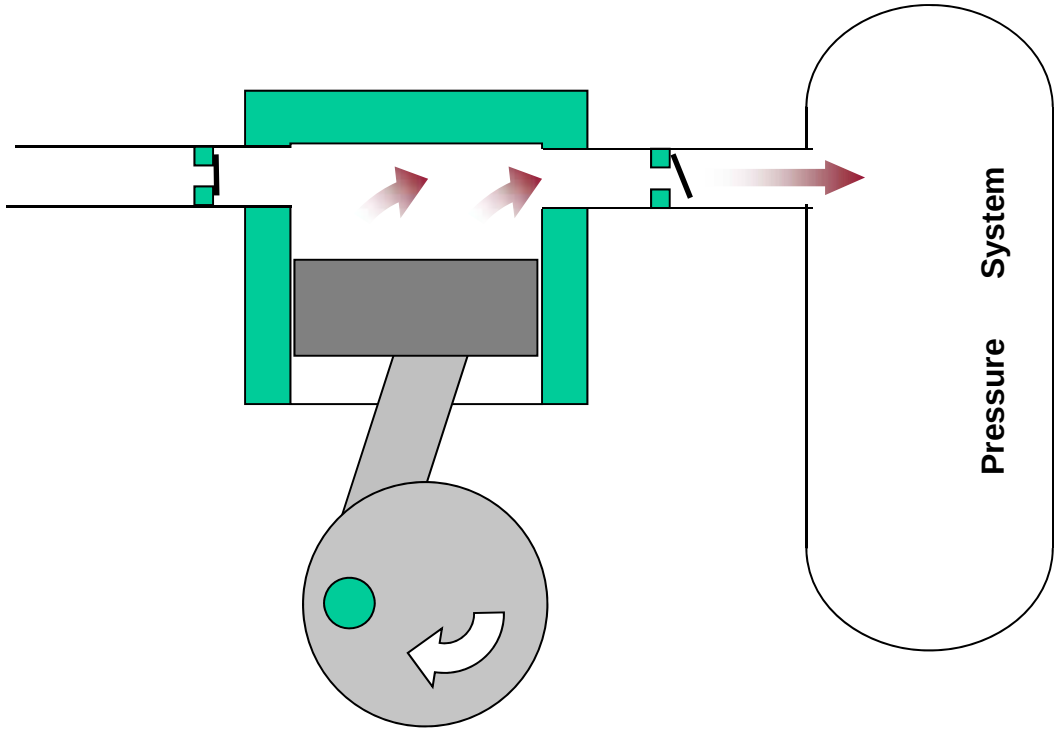
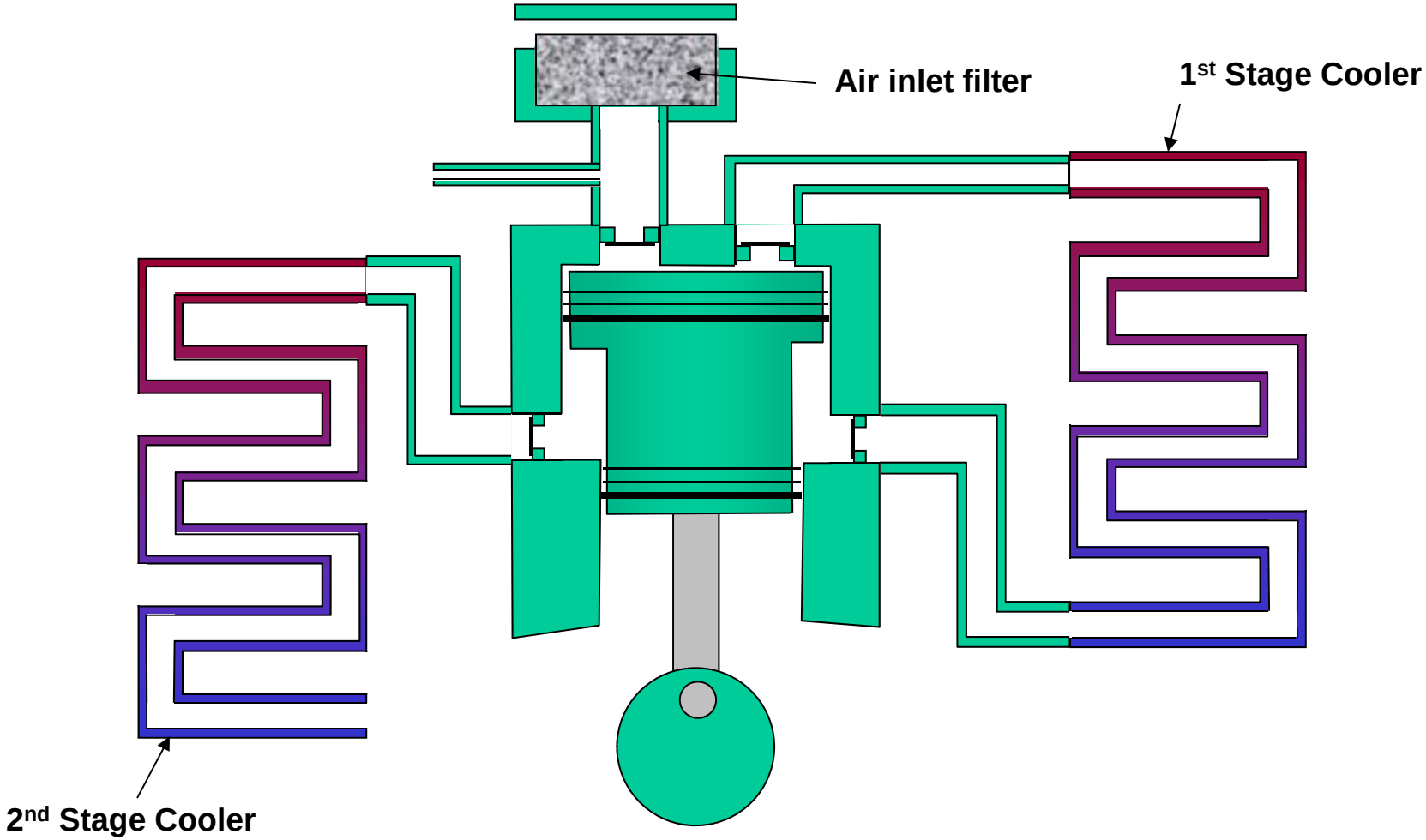
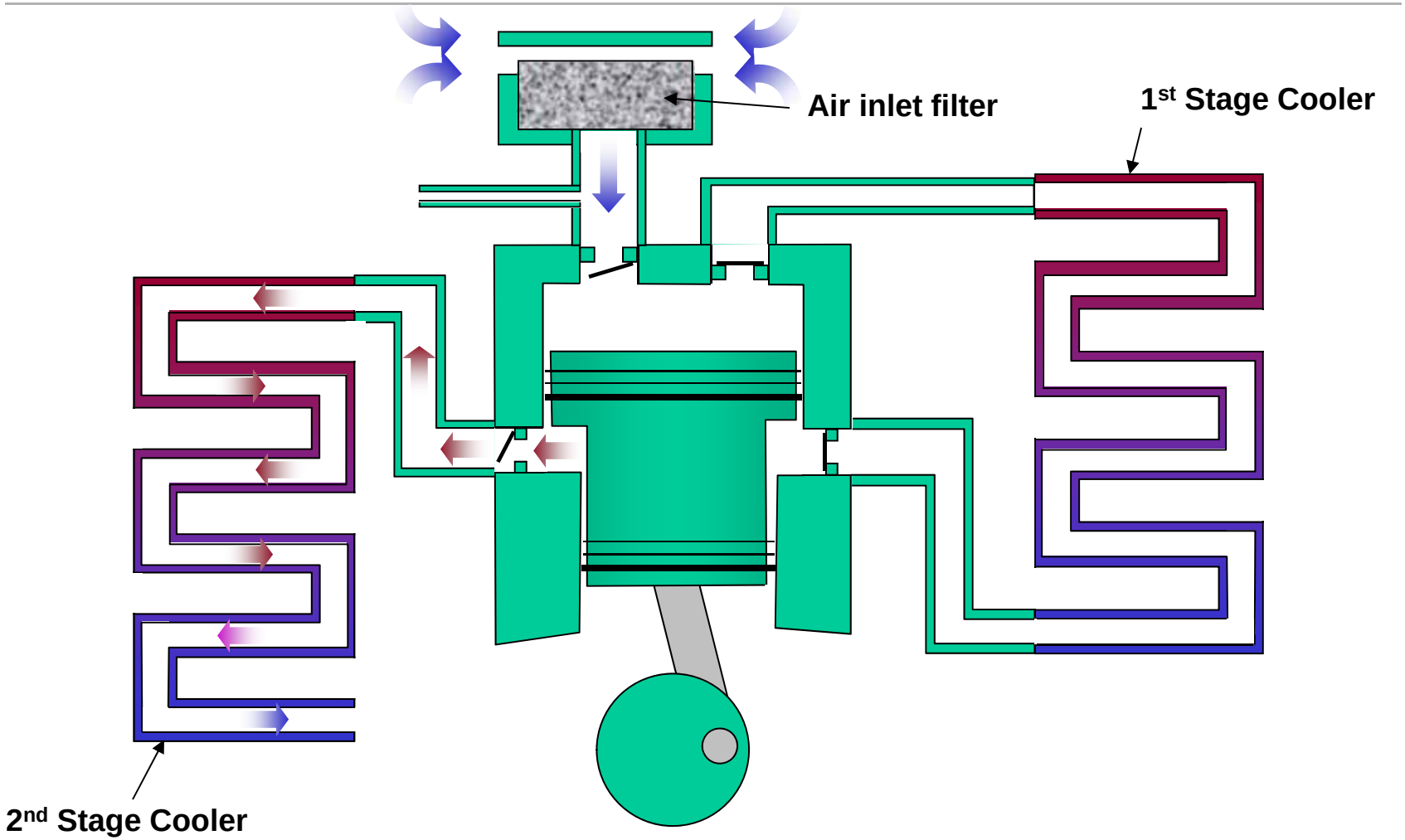


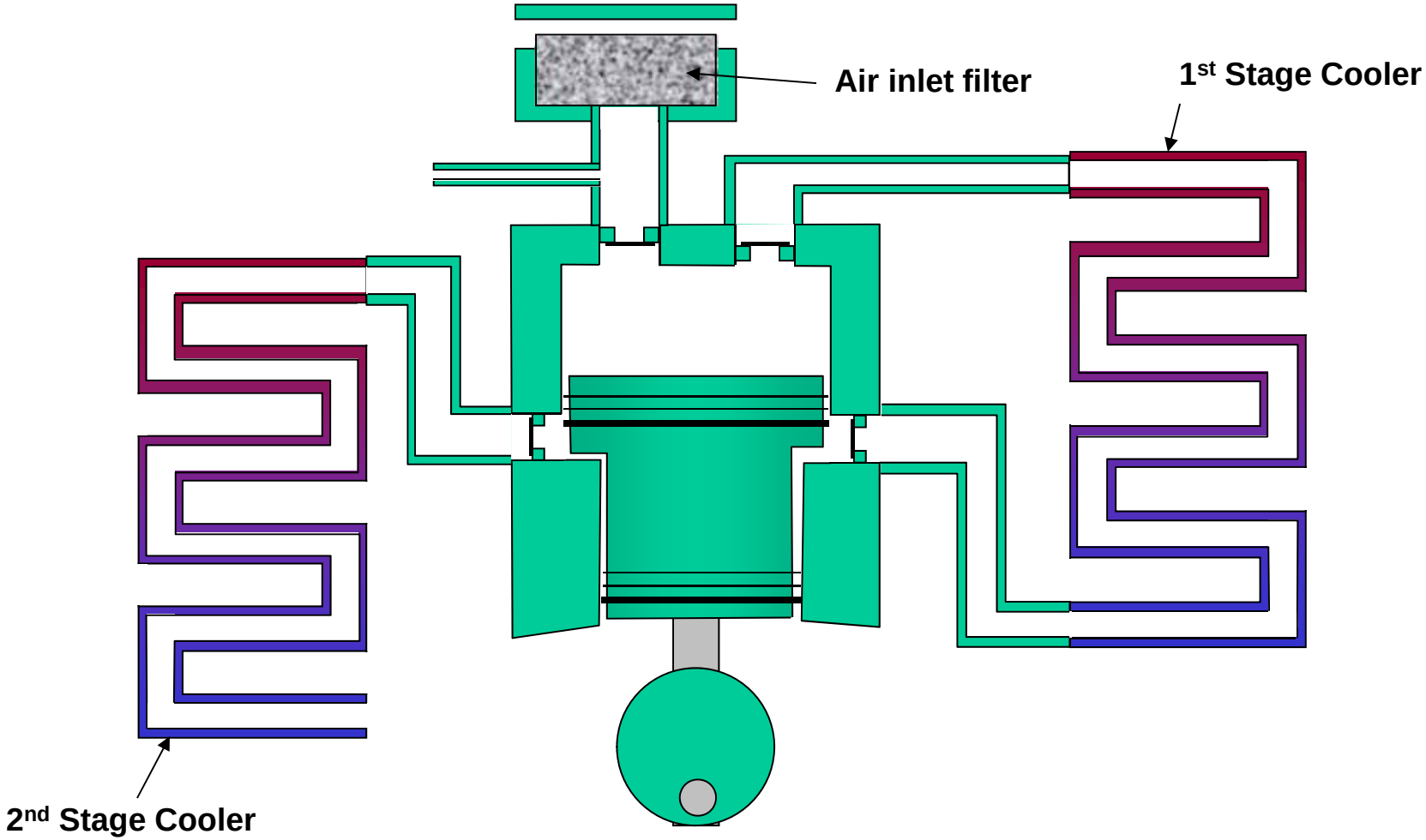
1st and 2nd stage



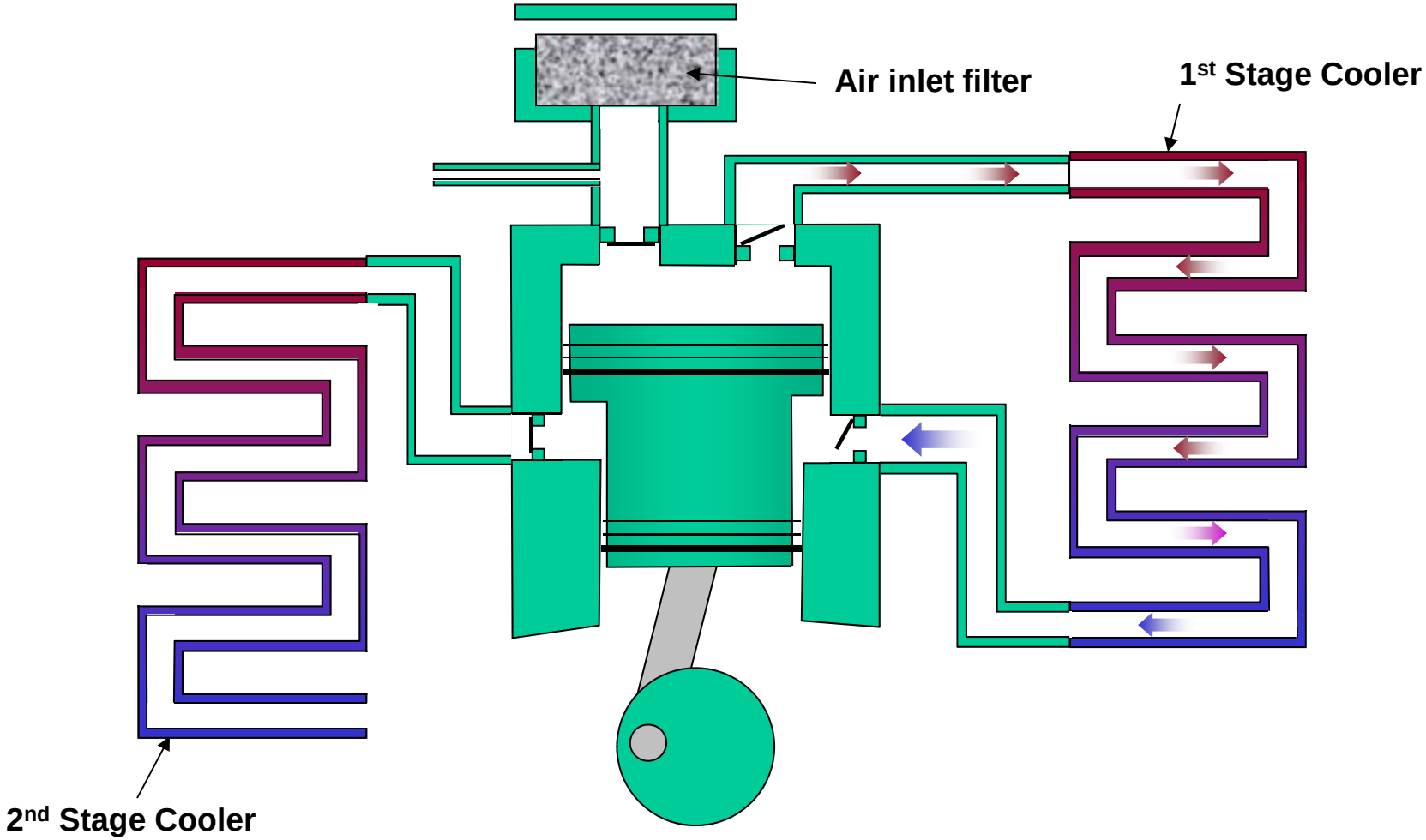
1st and 2nd stage



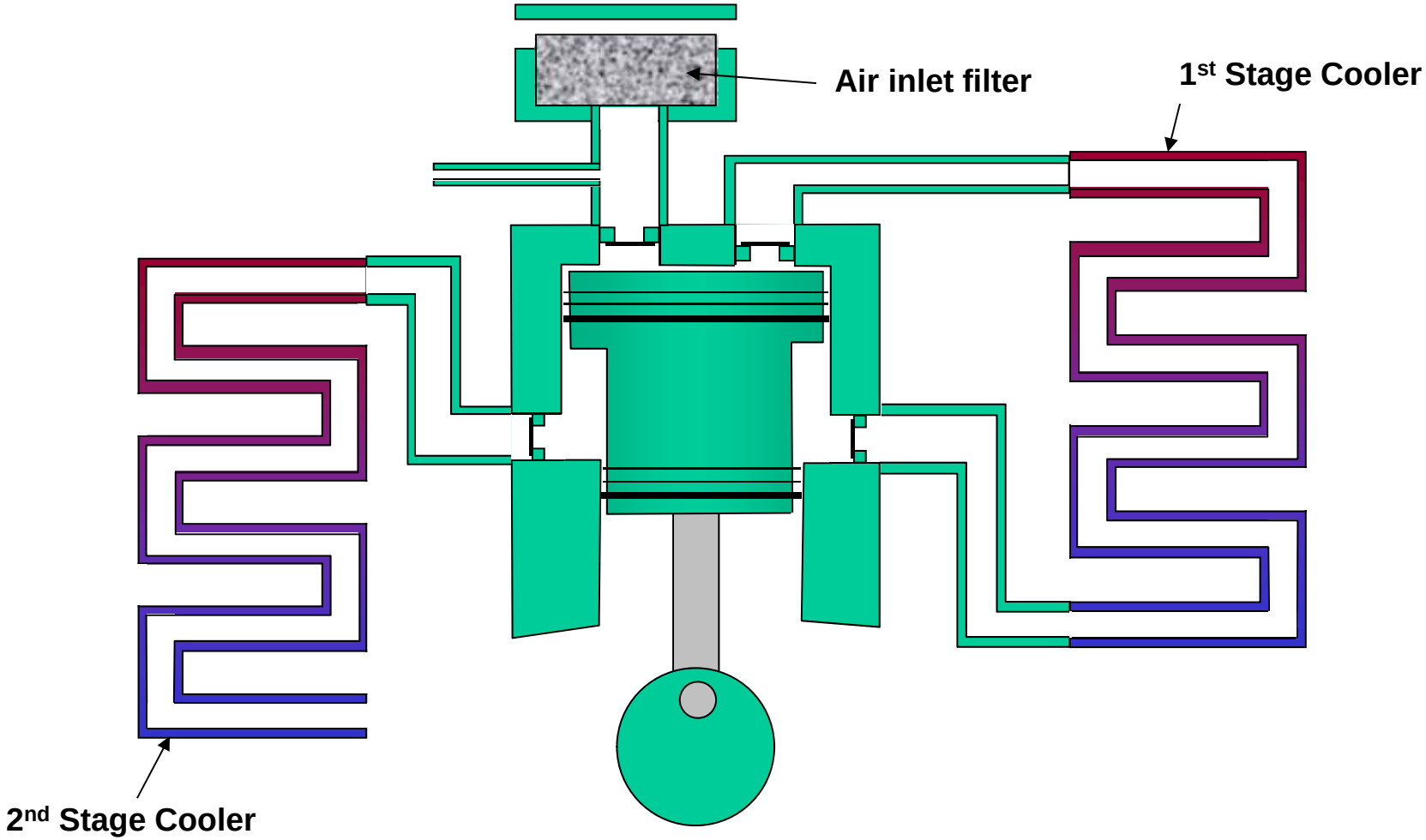
1st and 2nd stage



1st and 2nd Stage

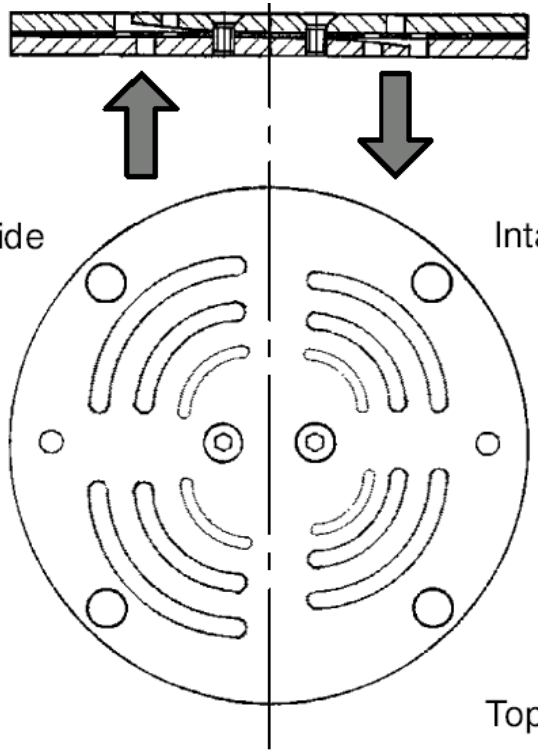


1st and 2nd stage



Function of reed valves

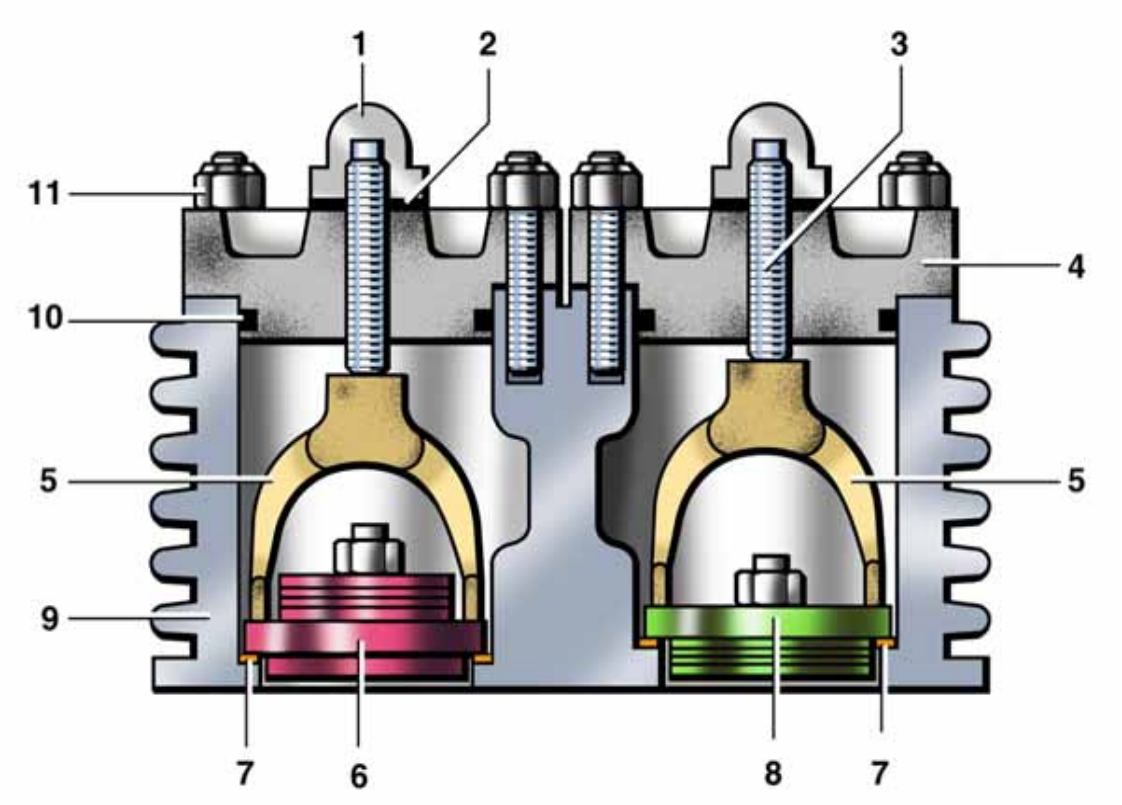
Note that the valves are operated by the flow of the medium. On the suction stroke, the intake valves open and the medium flows into the cylinders. At the start of the compression stroke the intake valve closes and the medium opens the pressure valve,



Reed valve i.e.
K14, IK 12.14

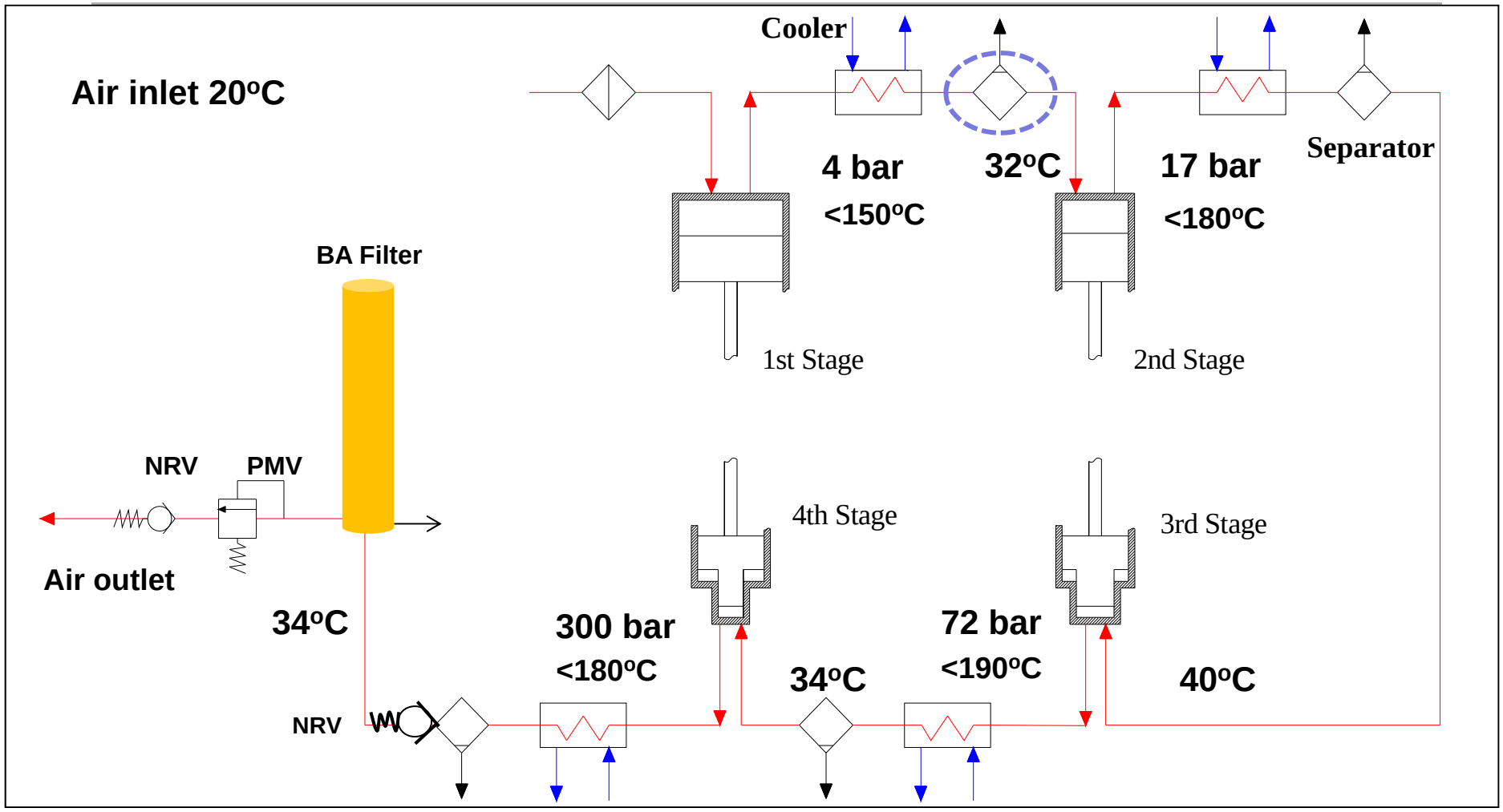
IK 18.1

Individual Suction & Delivery Valves



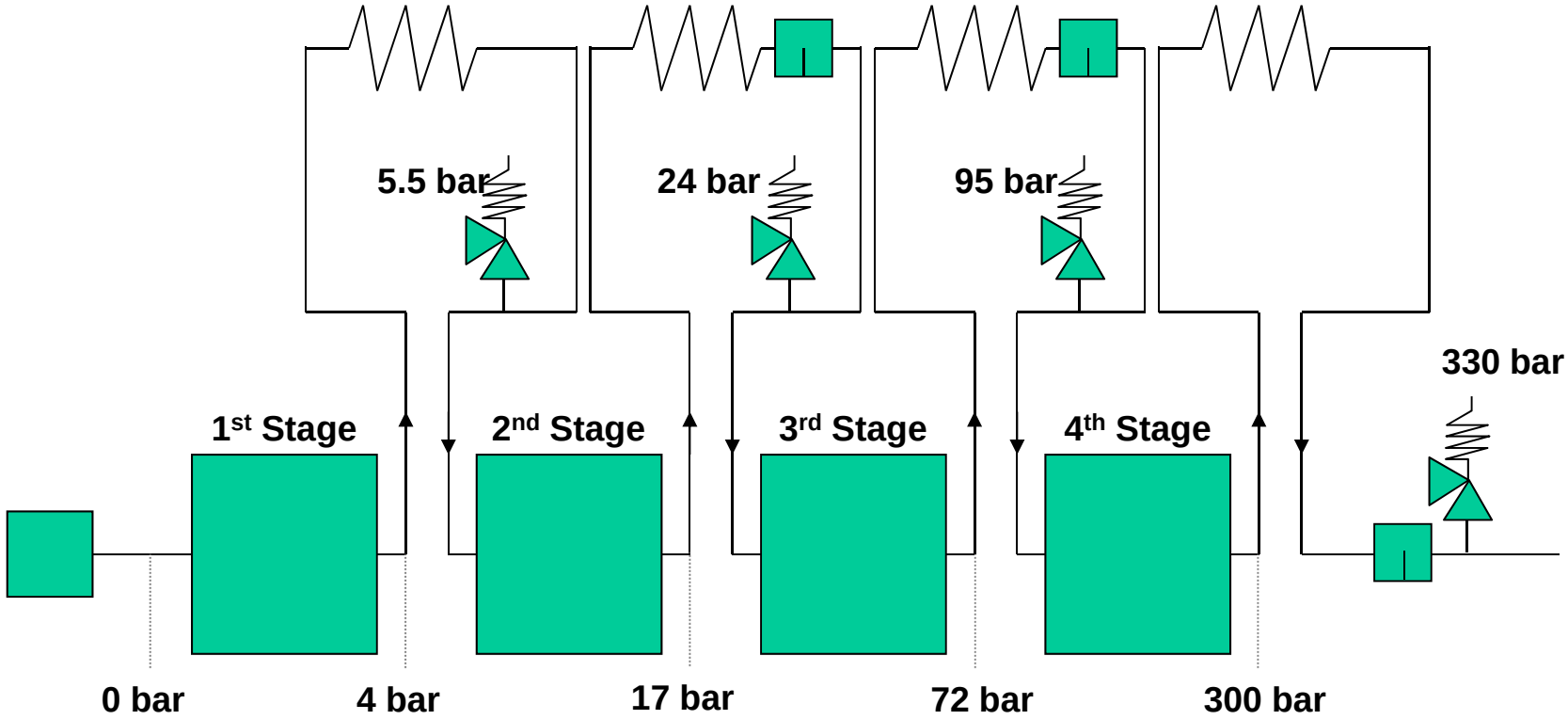
01 Cup nut
02 Copper gasket
03 Stud
04 Valve cover
05 Retainer
06 Discharge valve
07 Copper gasket
08 Intake valve
09 Valve head
10 O-ring
11 Lock nut

Compressor Circuit-Typical Values

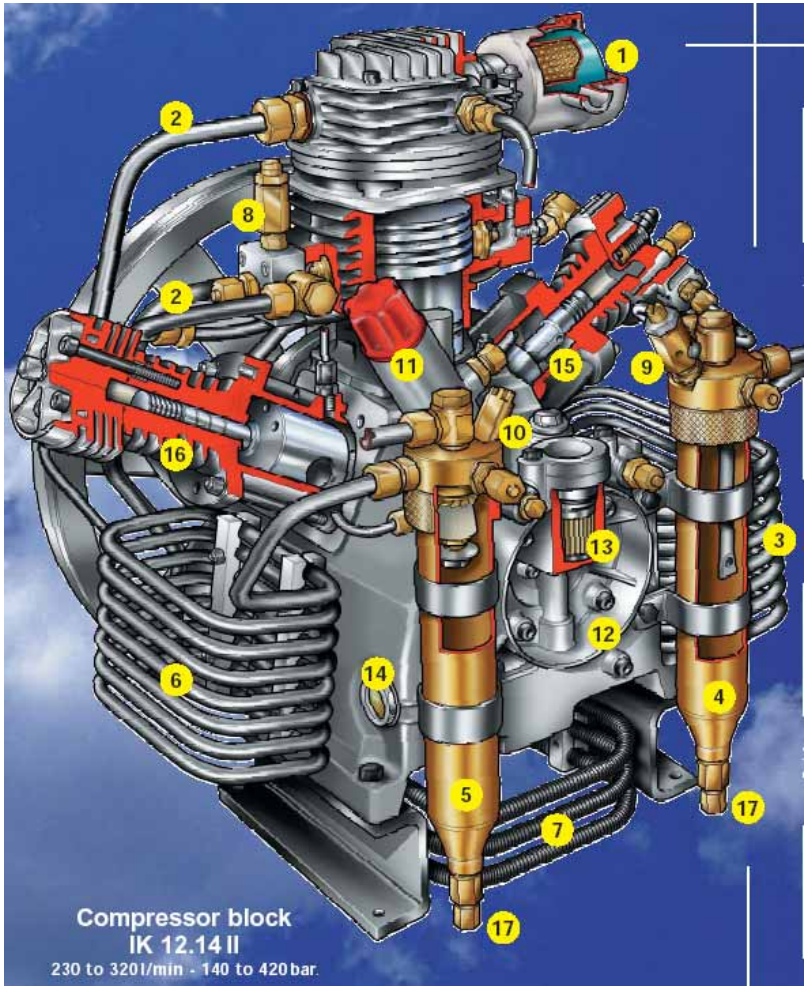


Compressor Safety Valves-Typical values

The compressor is protected against over pressure by safety valves

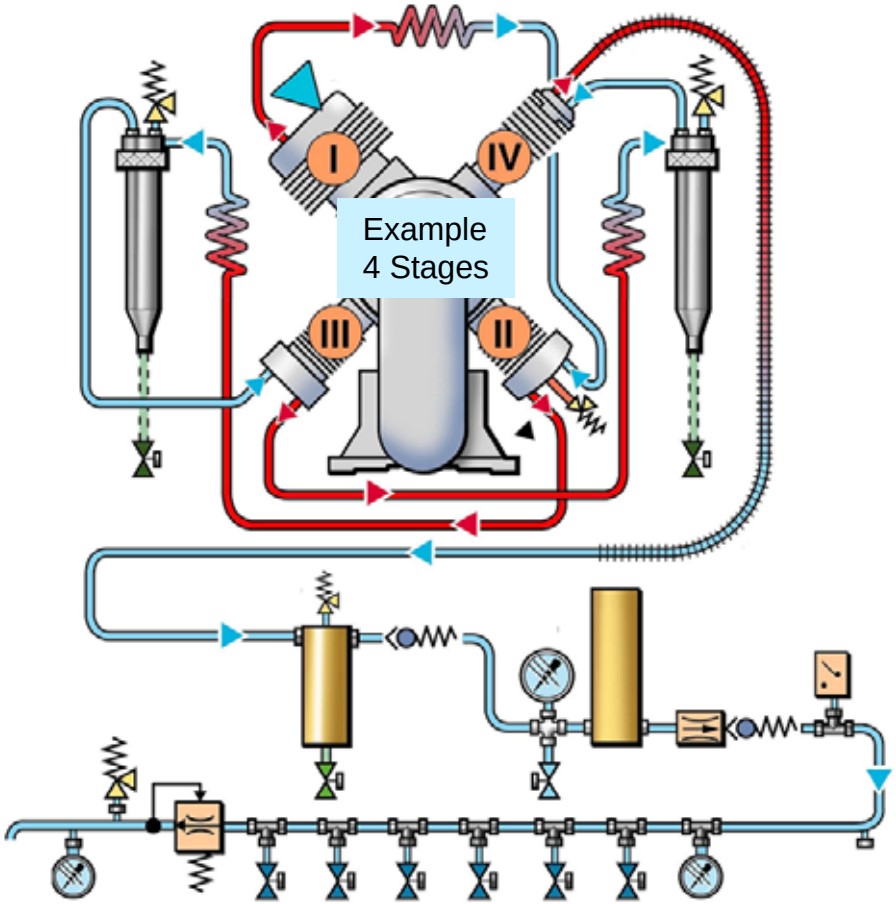


General Configuration - 4 Stage Block

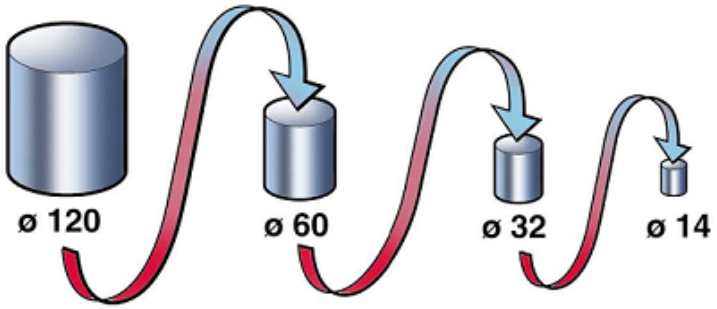


1. Intake Filter
2. Inter-cooler 1st 2nd Stage
3. Inter-cooler 2nd 3rd Stage
4. Intermediate Separator 2nd Stage
5. Intermediate Separator 3rd Stage
6. Inter-cooler 3rd 4th Stage
7. After-cooler
8. Safety Valve 1st Stage
9. Safety Valve 2nd Stage
10. Safety Valve 3rd Stage
11. Oil Filler neck
12. Oil Pump
13. Oil Micro Filter
14. Oil Sight Glass
15. Cylinder with Piston 3rd Stage
16. Cylinder with Free Floating Piston 4th Stage
17. Condensate Outlet

Compressor block - theory



Example: BAUER IK150 - Block:



Stroke: 50mm

$$pressure\_ratio = \sqrt[stages]{pressure}$$

$$pressure\_ratio = \sqrt[4]{300bar} = 4{,}16$$

Interstage pressures (theoretical):
1. Stage: 4bar
2. Stage: 17bar
3. Stage: 72bar
final stage: 300bar

Compressor block - theory

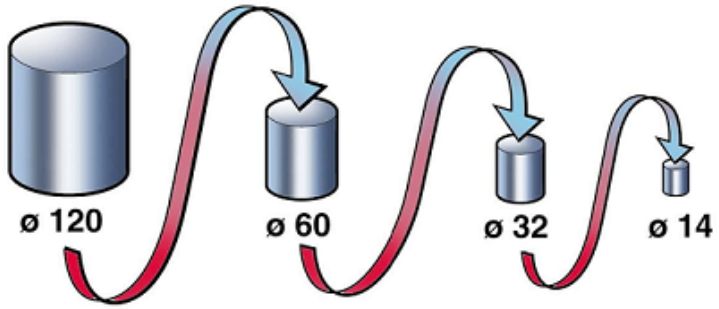
Example: BAUER IK150 - Block:
Capacity of compressor block:

$$FAD[l/\min] = P_{st} \times Stroke \times \frac{\pi}{4} Diameter_{Piston}{}^{2} \times Speed \times efficiency_{volumetric}$$

$$FAD[l/\min] = 1 \times 0{,}50dm \times \frac{\pi}{4}(1{,}20dm)^2 \times 1200\frac{1}{\min} \times \eta_{volumetric}$$

$$FAD[l/\min] = 500$$

$$\eta_{volumetric} \approx 0{,}5 - 0{,}85$$



I150-15-5:

Stroke: 50mm
Piston Diameter: 120mm
Speed: 1230 1/min
Capacity: 500 l/min

IK100 & IK120

Description

The compressor blocks IK100 and IK120 are used to compress air up to 350 bar.

Compressor block IK100-420 has a maximum operating pressure of 420 bar. Both compressor blocks are of a three stage, three cylinder design.

The cylinders are arranged in a W form, 1st stage in the center, 2nd stage on the right, and 3rd stage on the left side looking from the filter side.

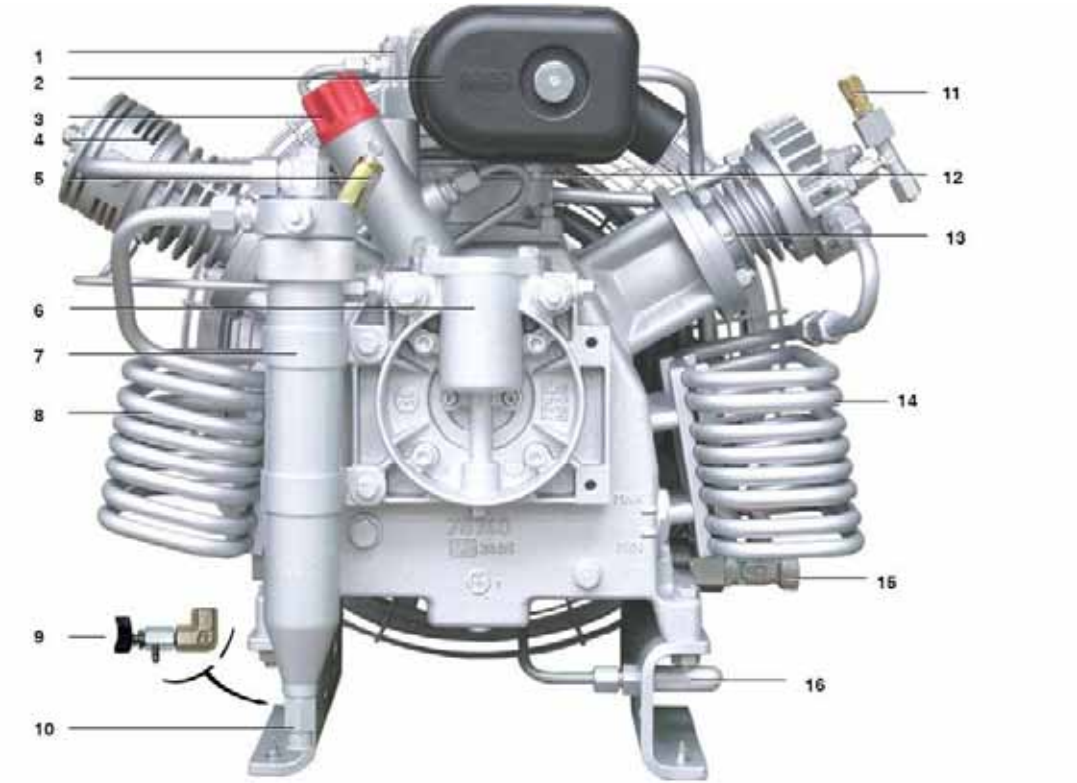
These compressor blocks are particularly suitable for continuous operation because of their rugged design and the corrosion resistant intermediate filter and cooler assemblies.

Smooth running is a particular feature of this BAUER design. The moving parts of the driving gear are all equally balanced. This results in a vibration-free running.

The driving gear is fitted with energy saving cylinder roller bearings.

The upper and lower connecting rod bearings are also roller bearings. This allows for an even longer life which lasts at least 30,000 operating hours.

Compressor block IK100 / IK120



1 Cylinder 1st stage
2 Intake filter
3 Oil filler neck
4 Cylinder, 3rd stage
5 Safety valve, 2nd stage
6 Oil filter housing
7 Intermediate separator, 2nd stage
8 Inter-cooler 2nd stage
9 Condensate drain tap
10 Condensate drain connector
11 Safety valve, 1st stage
12 After-cooler
13 Cylinder, 2nd stage
14 Inter-cooler 1st stage
15 Oil drain tap
16 Air outlet connector

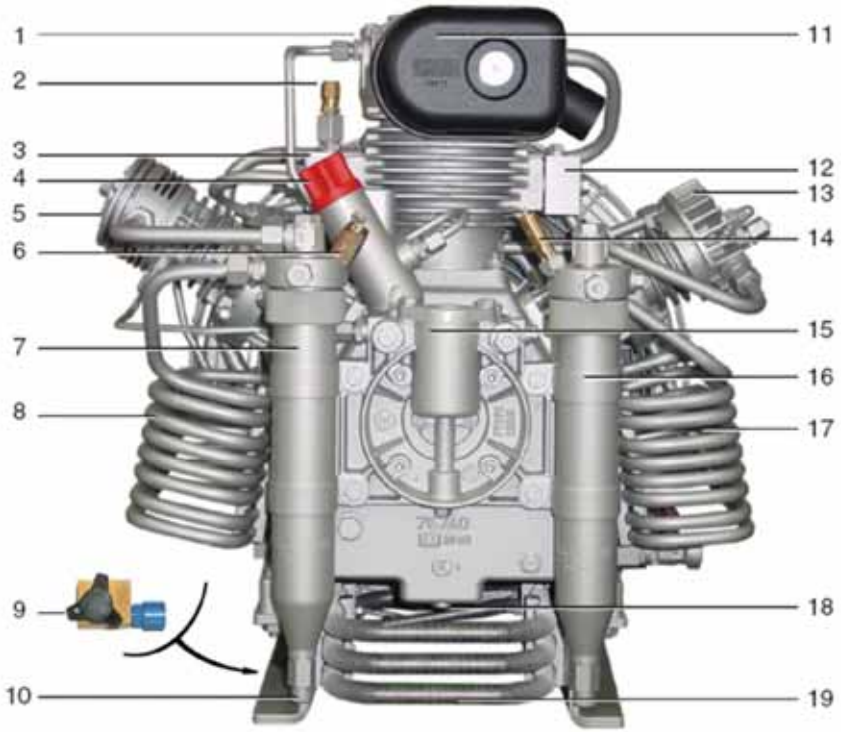
IK 12.14 II COMPRESSOR BLOCK

Description

The IK12.14 II compressor block is used to compress air up to 6,000 psi.

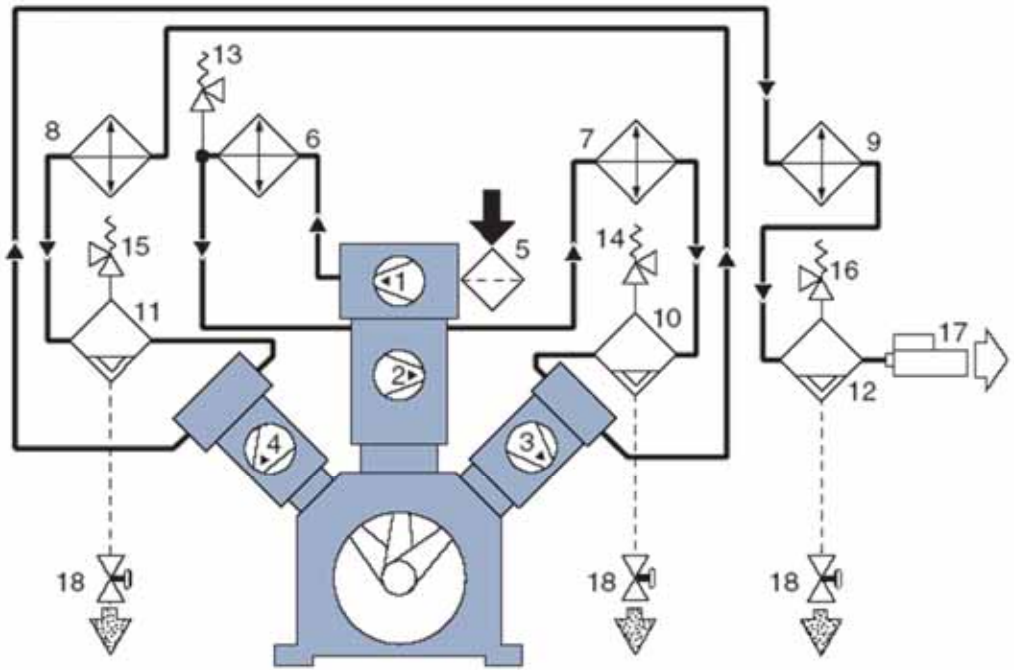
- **This compressor is a four stage, three cylinder air cooled, oil lubricated reciprocating compressor.**
- **The cylinders are arranged in a “W” configuration, the 1st/2nd stage vertical stepped cylinder is in the center, 3rd stage on the right and 4th stage on the left looking from the intake filter side.**
- **This compressor block is particularly suitable for continuous operation because of their rugged design and corrosion resistant intermediate filter and cooler assemblies.**

IK12.14 II Compressor Block, Front View



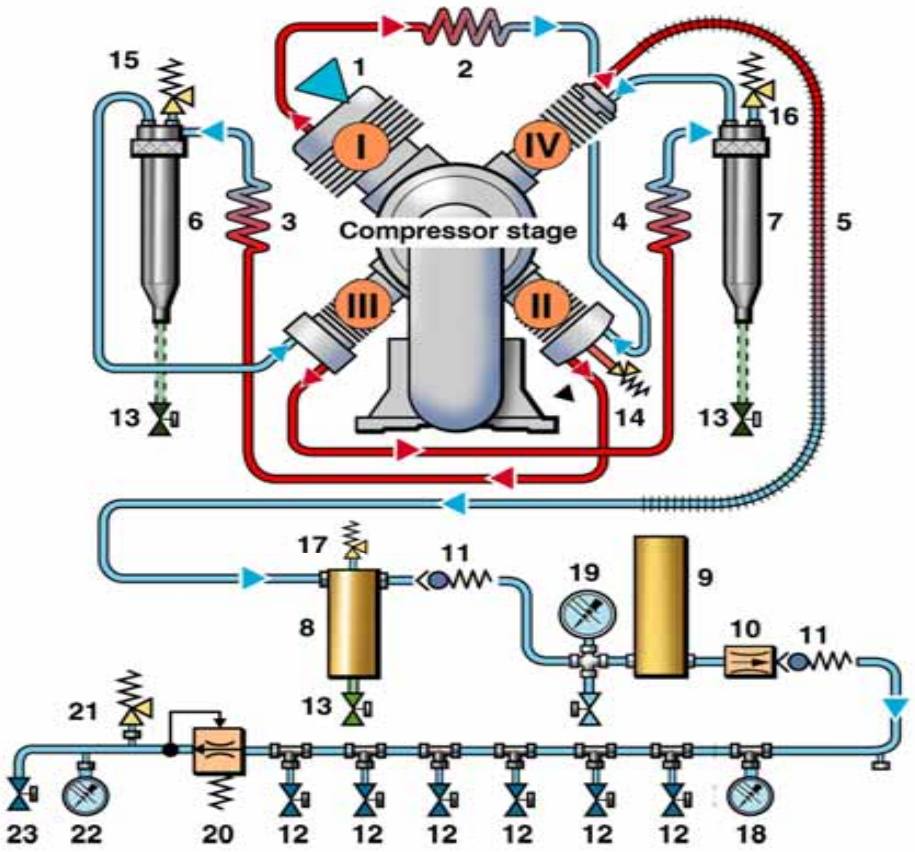
1. Intake Filter
2. 1st Stage Safety Valve
3. 2nd Stage Intake Manifold
4. Oil Filler Neck
5. 4th Stage Cylinder
6. 3rd Stage Safety Valve
7. 3rd Stage Separator
8. 3rd Stage Intercooler
9. Oil Drain Plug
10. Condensate Drain Connector
11. 1st Stage Valve Head
12. 2nd Stage Pressure Manifold
13. 3rd Stage Cylinder
14. 2nd Stage Safety Valve
15. Oil Filter Housing
16. 2nd Stage Separator
17. 2nd Stage Intercooler
18. Compressed Air Outlet
19. 4th Stage Aftercooler

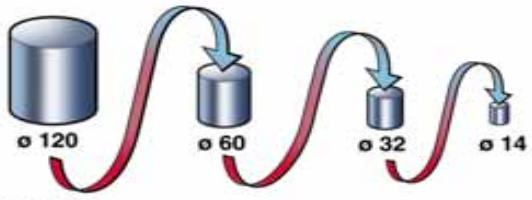
Air Flow Diagram



1. 1st Stage Cylinder
2. 2nd Stage Cylinder
3. 3rd Stage Cylinder
4. 4th Stage Cylinder
5. Air Filter
6. 1st Stage Intercooler
7. 2nd Stage Intercooler
8. 3rd Stage Intercooler
9. 4th Stage Aftercooler
10. Intermediate Separator after 2nd Stage
11. Intermediate Separator after 3rd Stage
12. Oil and Water Separator
13. 1st Stage Safety Valve
14. 2nd Stage Safety Valve
15. 3rd Stage Safety Valve
16. 4th Stage Safety Valve (Final Pressure)
17. Pressure Maintaining Valve
18. Manual Condensate Drain Valves

gh pressure unit i.e. IK 150





BREATHING AIR COMPRESSOR

Piston Ø 1st/2nd/3rd/4th stage

I 1stage
II 2nd stage
III 3rd stage
IV 4th stage

01 intake filter
02 intercooler 1st - 2nd stage
03 intercooler 2nd - 3rd stage
04 intercooler 3rd - 4th stage
05 after cooler
06 intersepartaor 2nd stage
07 interseparator 3rd stage
08 final separator
09 purifier
10 pressure maintaining valve
11 check valve
12 filling valve - working pressure i.e. 300 bar
13 drain taps
14 interstage safety valve 1st stage
15 interstage safety valve 2nd stage
16 interstage safety valve 3rd stage
17 final safety valve 330 bar
18/19/22 pressure gauges
20 pressure reducer
21 safety valve 225 bar
23 filling valve - working pressure i.e. 200 bar

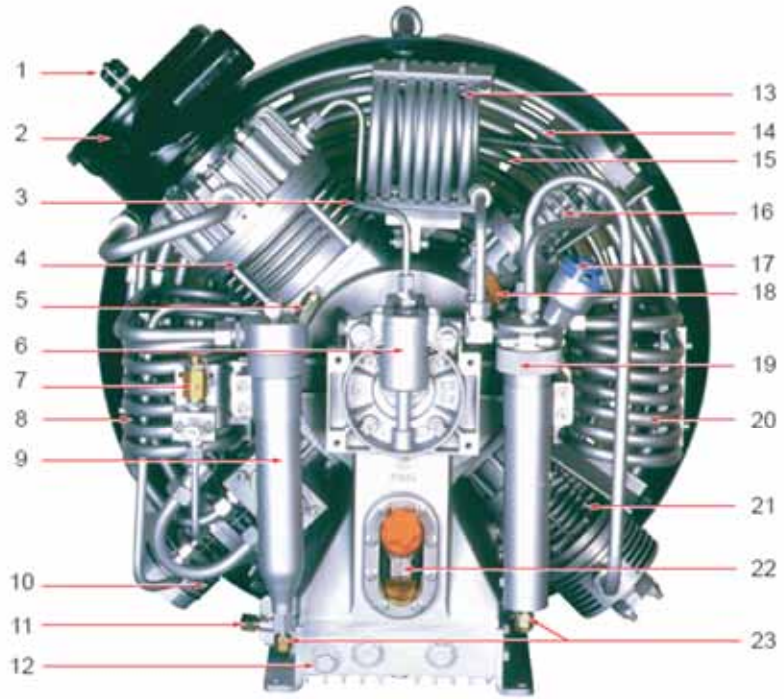
IK18.1 II Compressor Block

Description

The IK18.1 II compressor is used to compress air up to 5000 psi.

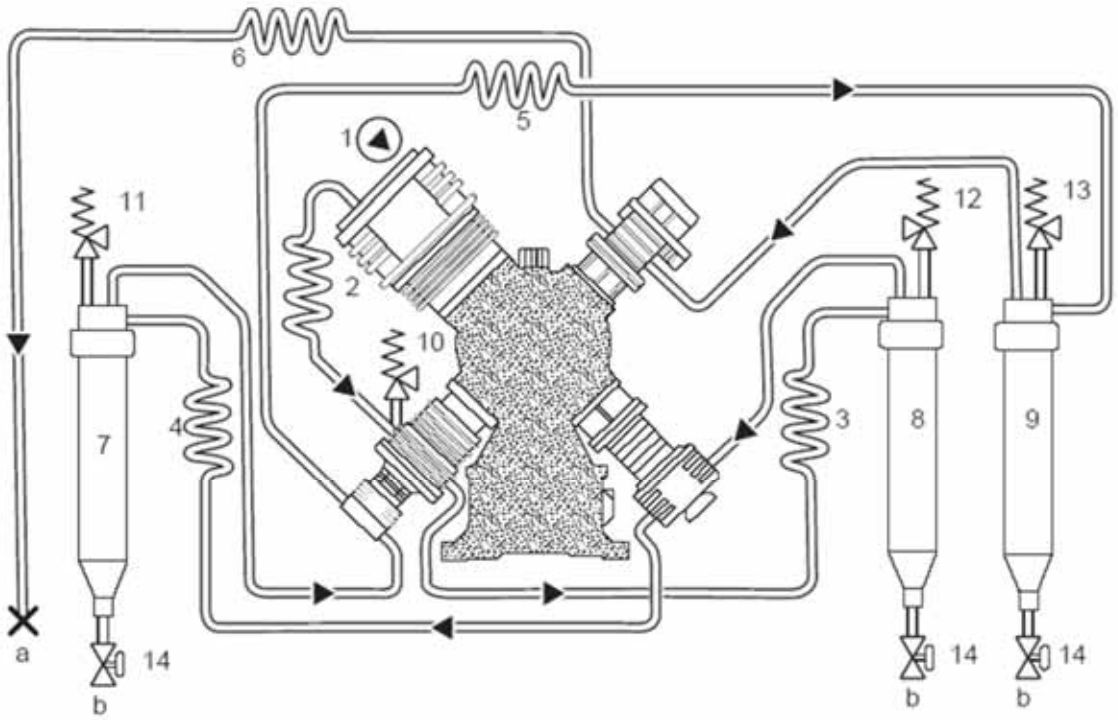
- **This compressor is a four cylinder, five stage air cooled, oil lubricated reciprocating compressors.**
- **The 5th stage cylinder is lubricated by means of the forced feed lubrication system, while the other cylinders are splash lubricated.**
- **The cylinders are arranged 90° apart, with the 1st ,2nd stage and 4th and the 3rd and 5th stage opposite each other.**
- **These compressor blocks are particularly suitable for continuous operation because of their rugged design and corrosion resistant intermediate filter and cooler assemblies.**

Compressor Block (Front View)



1. Service Indicator
2. Intake Filter
3. Crankcase Oil Feedback Vent Line
4. 1st Stage Cylinder
5. 3rd Stage Safety Valve
6. Oil Pump Housing
7. 1st Stage Safety Valve
8. 3rd Stage Intercooler
9. 3rd Stage Separator
10. 3rd Stage Cylinder
11. Air Outlet Connection
12. Oil Drain Plug
13. 4th Stage Intercooler
14. 1st Stage Intercooler
15. 5th Stage Aftercooler
16. 5th Stage Cylinder
17. 4th Stage Safety Valve
18. 3rd Stage Safety Valve
19. 4th Stage Separator
20. 2nd Stage Intercooler
21. 3rd Stage Cylinder
22. Oil Filler with Sight Glass
23. Condensate Drain Connections

FIve Stage Compressor Air Flow



1. Intake filter
2. Intercooler 1st stage
3. Intercooler 2nd stage
4. Intercooler 3rd stage
5. Intercooler 4th stage
6. Aftercooler
7. Inter-filter 2nd/3rd stage
   a. Air outlet
8. Inter-filter 3rd/4th stage
9. Inter-filter 4th/5th stage
10. Interm. pressure safety valve, 1st stage
11. Interm. pressure safety valve, 2nd stage
12. Interm. pressure safety valve, 3rd stage
13. Interm. pressure safety valve, 4th stage
14. Manual condensate drain valves
    b. Condensate drain outlet

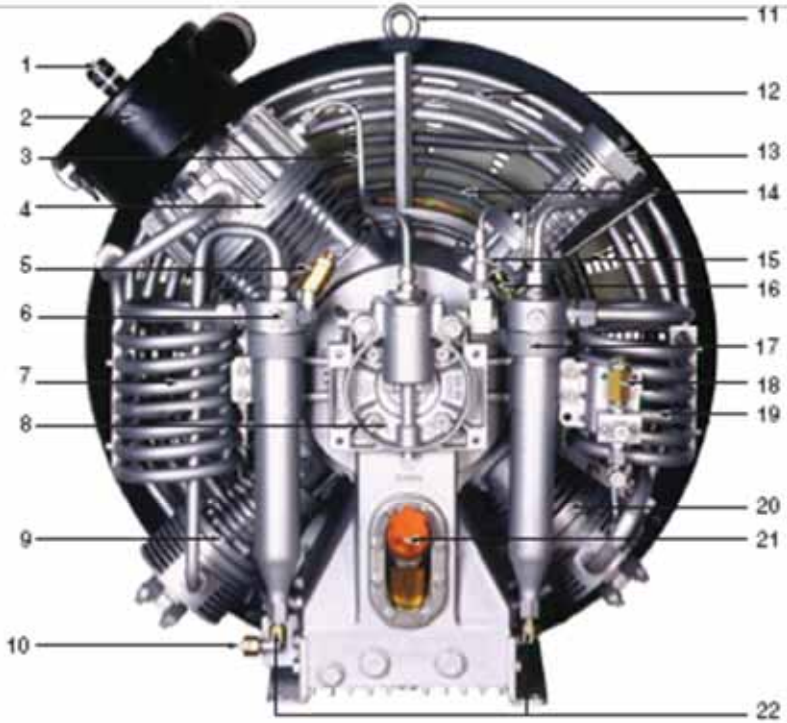
IK150 II COMPRESSOR BLOCK

Description

The IK150 II compressor is used to compress air up to 5000 psi.

- **The IK150 II compressor is a four cylinder, four stage air cooled, oil lubricated reciprocating compressor.**
- **The 4th stage cylinder is lubricated by means of the forced feed lubrication system, while the other cylinders are splash lubricated.**
- **The cylinders are arranged 90° apart, with the 1st and 2nd stage, and the 3rd and 4th stage opposite each other.**
- **This compressor block is particularly suitable for continuous operation because of their rugged design and corrosion resistant intermediate filter and cooler assemblies.**

IK150 II Compressor Block (Front View)



1. Service Indicator
2. Intake Filter
3. Crankcase Vent Feedback Line
4. 1st Stage Cylinder
5. 2nd/3rd Inter Stage Pressure Valve
6. 2nd Stage Separator
7. 2nd Stage Cooler
8. Oil Pump Housing
9. 3rd Stage Cylinder
10. Compressed Air Outlet
11. Lifting Eyebolt
12. 1st Stage Inter Cooler
13. 4th Stage Cylinder
14. 4th Stage After Cooler
15. Oil Pressure Regulating Valve
16. 3rd/4th Inter Stage Pressure Valve
17. 3rd Stage Separator
18. 1st/2nd Inter Stage Pressure Valve
19. 3rd Stage Cooler
20. 2nd Stage Cylinder
21. Oil Filler with Sight Glass
22. Condensate Outlet

IK180 II Compressor Block

Description

The IK180 II compressor is used to compress air up to 5000 psi.

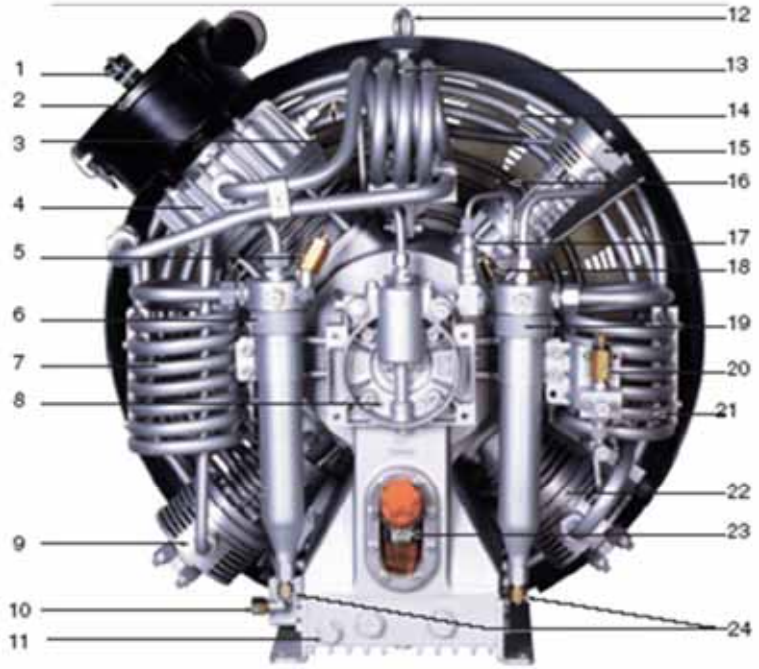
Compressor is four cylinder, four stage air cooled, oil lubricated reciprocating compressors.

The 4th stage cylinder is lubricated by means of the forced feed lubrication system, while the other cylinders are splash lubricated.

The cylinders are arranged 90° apart, with the 1st and 2nd stage, and the 3rd and 4th stage opposite each other.

These compressor blocks are particularly suitable for continuous operation because of their rugged design and corrosion resistant intermediate filter and cooler assemblies.

IK180 II Compressor Block (Front View)



1. Service Indicator
2. Intake Filter
3. Crankcase Vent Feedback Line
4. 1st Stage Cylinder
5. 2nd/3rd Inter Stage Pressure Valve
6. 2nd Stage Separator
7. 2nd Stage Cooler
8. Oil Pump Housing
9. 3rd Stage Cylinder
10. Compressed Air Outlet
11. Oil Drain Plug
12. Lifting Eyebolt
13. 1st Stage Auxiliary Cooler
14. 1st Stage Inter Cooler
15. 4th Stage Cylinder
16. 4th Stage After Cooler
17. Oil Pressure Regulating Valve
18. 3rd/4th Inter Stage Pressure Valve
19. 3rd Stage Separator
20. 1st/2nd Inter Stage Pressure Valve
21. 3rd Stage Cooler
22. 2nd Stage Cylinder
23. Oil Filler with Sight Glass
24. Condensate Outlet

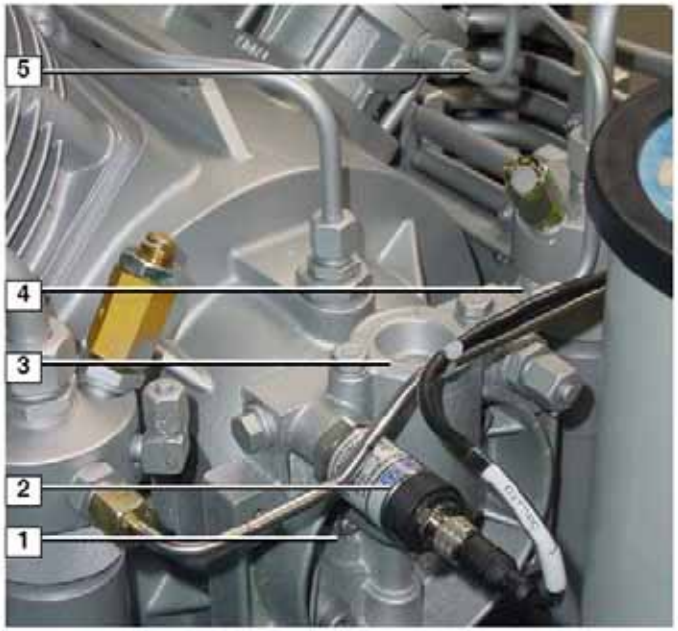
Oil Lubrication

BAUER compressors are equipped with an industrial grade oil pump and filter.
Effective lubrication of pistons, cylinders and the drive gear guarantees minimum wear and maximum compressor life.
BAUER compressors are designed and manufactured for continuous running.
BAUER compressors are designed to inject a precise amount of oil into the final stage's guiding piston at constant pressure.
The oil drips down onto the spinning driving gear. This produces a fine oil mist, which lubricates the bearings and cylinder walls.
Three main reasons for lubricating compressors is to:

- Minimizing friction
- Minimizing wear, especially in the cylinders and bearings
- Cool the unit

Careful selection of adequate lubricants is of prime importance.
Since these are in contact with breathing air, they have to be physiologically and toxicologically safe.
Brands have to be certified for the use in BAUER breathing air compressors.
The choice of oil also has fundamental influence on the compressor's lifetime.
Lubricants are either synthetic or mineral oils.
Synthetic oils are designed for heavy-duty use and continuous running over a wide temperature range (+5°C to +45°C).
Synthetic oil ought to be changed after 2000 operating hours or after two years, whichever occurs first.
The specific servicing interval is indicated in every model's operating manual.
Mineral oils are designed for light duty compressor use and for a narrower temperature range (+5°C to +35°C).
Mineral oil ought to be changed after 1000 operating hours or after 12 months, whichever occurs first.

Lubrication



1 Oil pump housing
2 Oil pressure sensor
3 Oil filter housing
4 Oil pressure regulating valve
5 Injection line to cylinder last stage

Fig. 16 Lube oil system IK150 to IK18.1

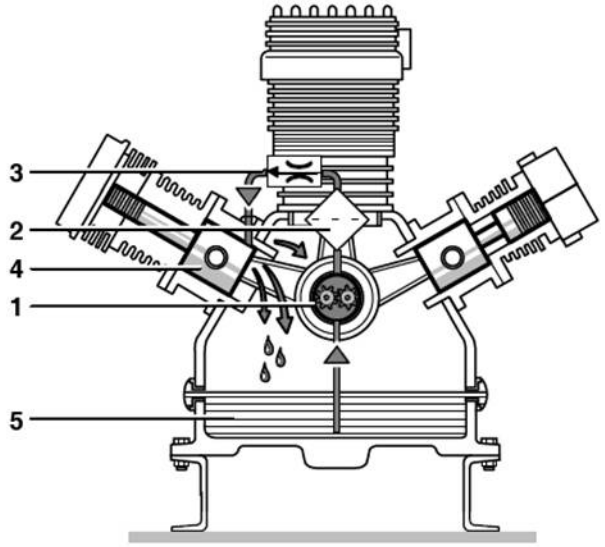
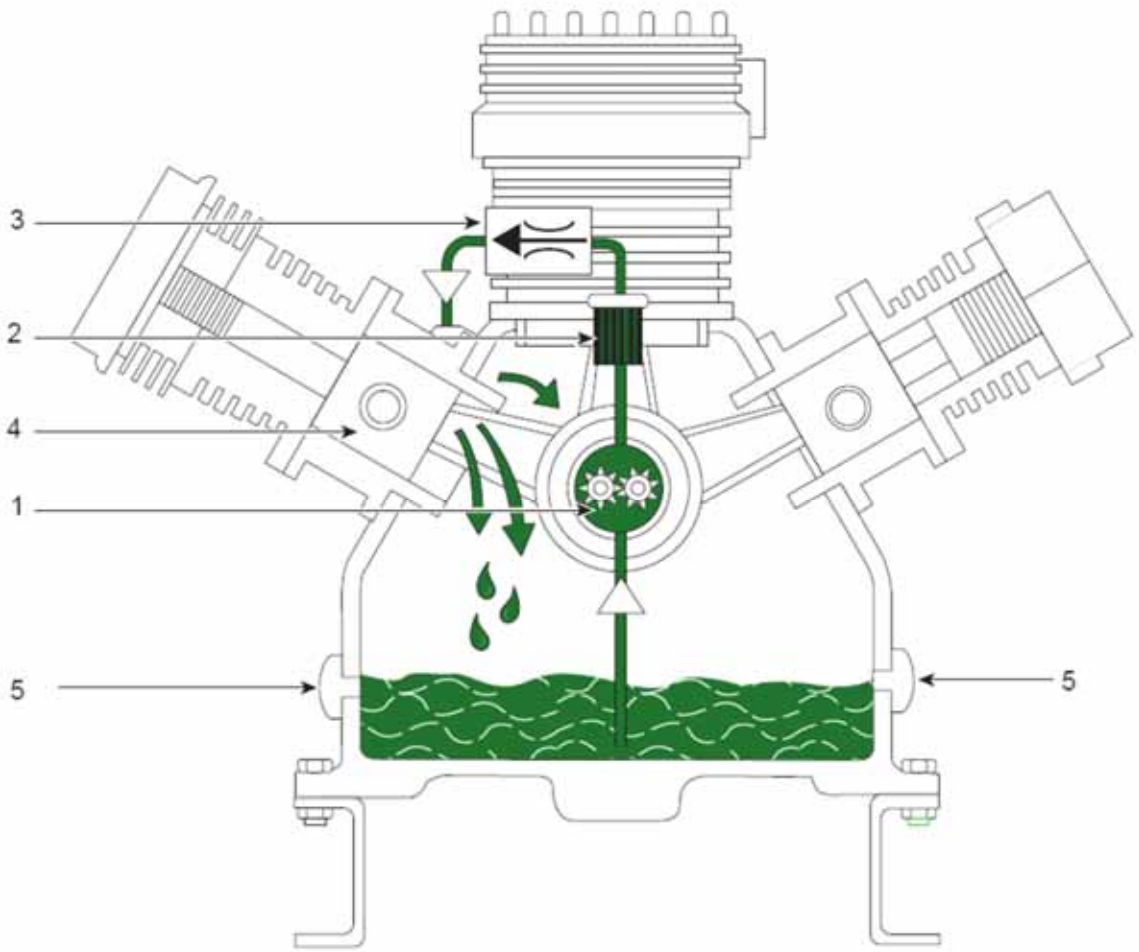


Fig. 15 Lube oil circuit, IK100, IK120, IK12.14, BK 12.3, BK 12.2

Lubrication Oil Circuit



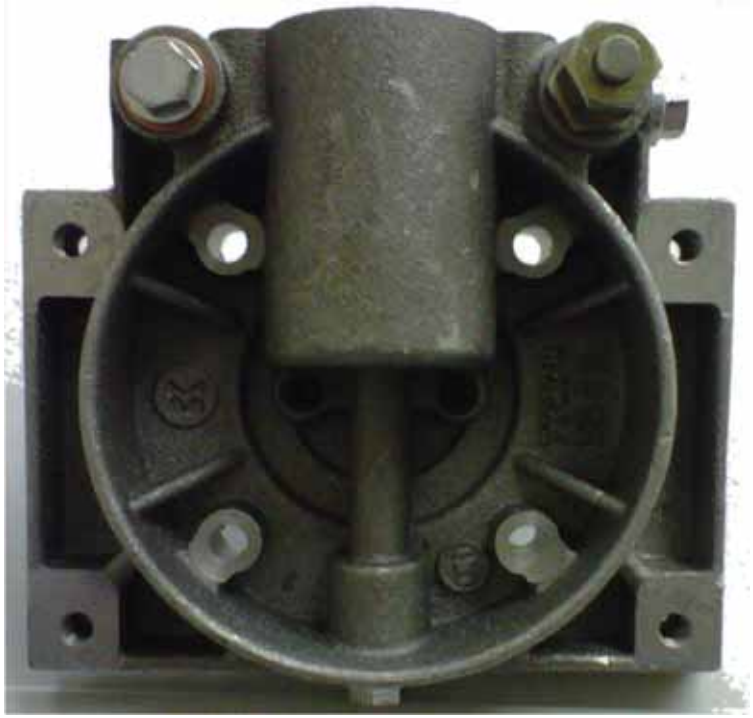
1. Oil Pump
2. Oil Filter
3. Minimum Pressure Valve
4. Guide Piston
5. Oil Sight Glass

Compressor Lubrication

- **The compressor is provided with forced-feed lubrication.**
- **The oil pressure is produced by a low speed gear pump (1).**
- **The oil pressure is approximately 73 psi (5 bar).**
- **The oil pump (1) is coupled to and driven by the crankshaft. It pumps oil through the oil line filter (2) and a minimum pressure valve (3) to the 3rd stage cylinder. The oil is then distributed by the guide piston (4) of the 3rd stage and lubricates all the moving parts of the compressor block.**
- **The minimum pressure valve (3) allows for oil pressure indication at a pressure gauge and/or electronic oil pressure monitoring.**

Oil Regulators

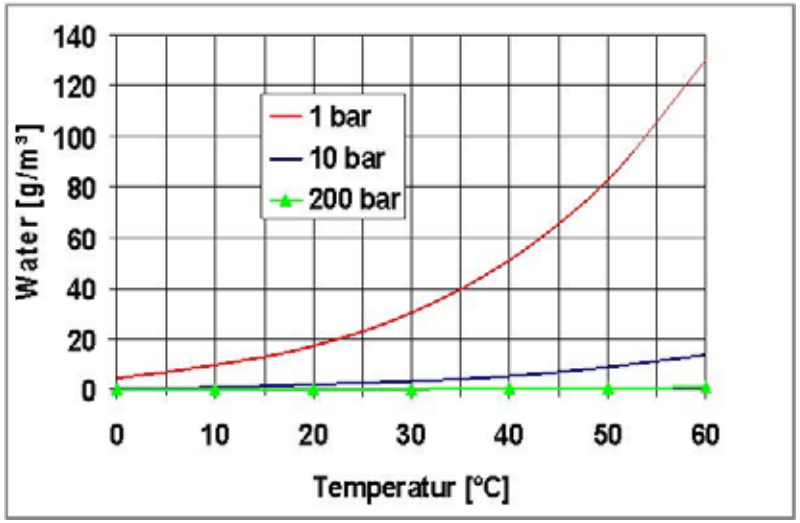
Oil pump drive



Oil pump drive

Condensate

- Condensate is a white, translucent emulsion consisting of water and tiny, suspended oil droplets. and is highly stable and difficult to separate. The oil originates from the "blow by" used to lubricate the compression chamber, the water is humidity from the intake air.
- At atmospheric pressure, water content depends largely on air temperature; warm air absorbs more water than cold air:



Condensate

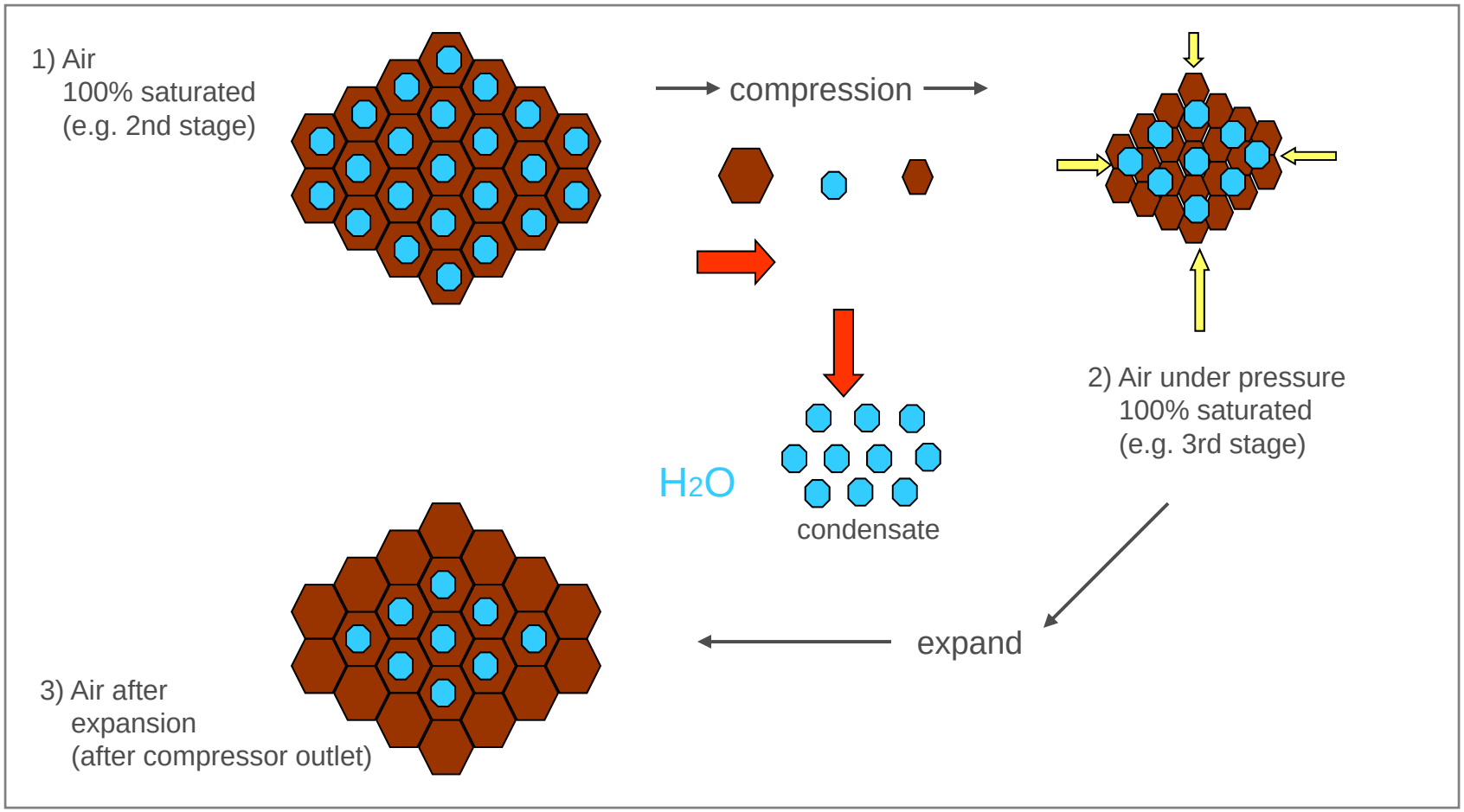
- During compression the volume of air decreases drastically. The amount of water vapour contained in the intake air stays the same. Hence, the level of humidity rises sharply, even though the temperature of the compressed air rises concurrently. Once 100% humidity is reached, water vapour condenses because the compressed air is entirely saturated.

- The separators, which are located between the individual compressor stages and after the final stage, collect the liquid condensate.

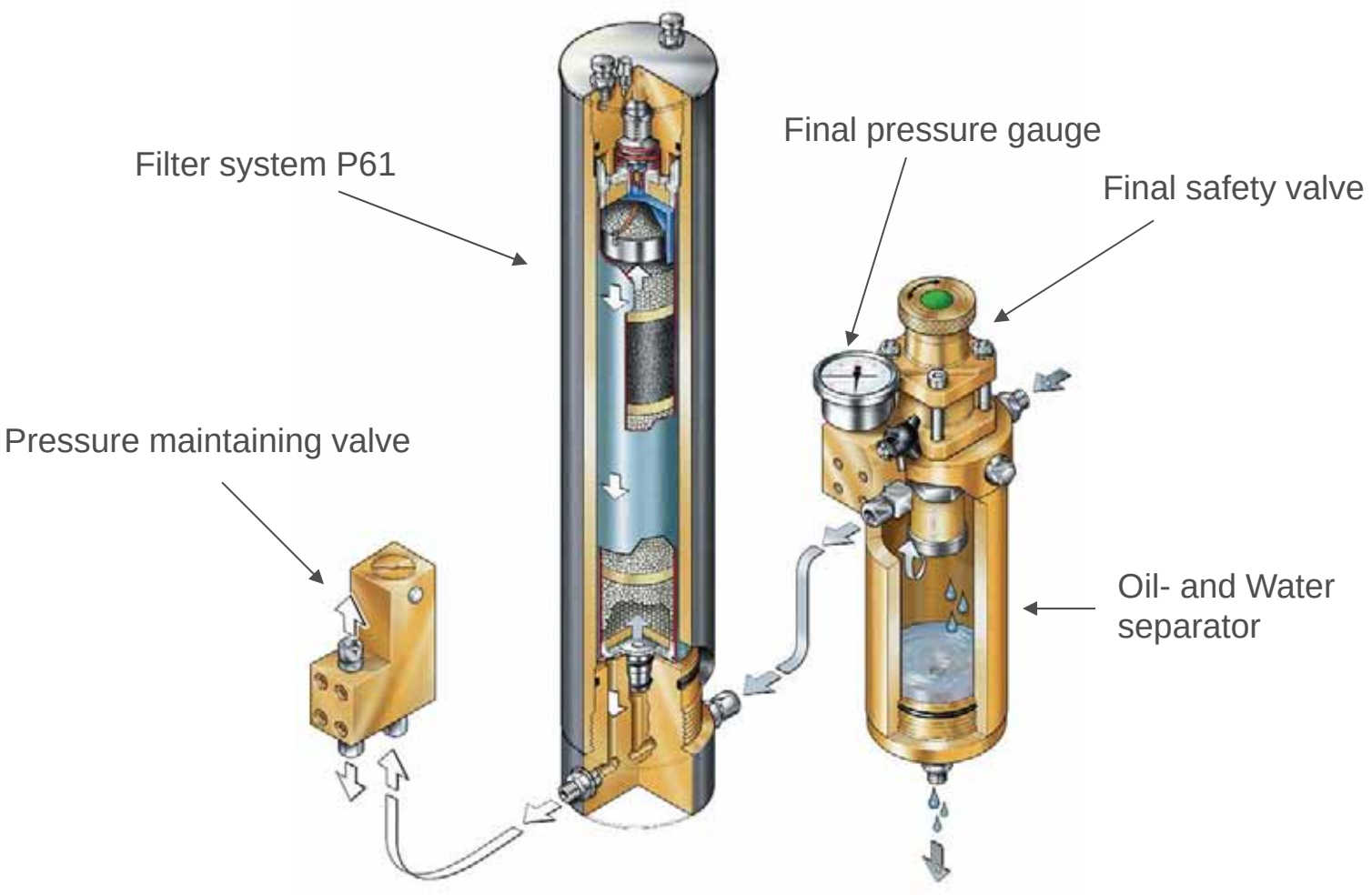
Several methods can be used to separate condensate from air:

- The unfiltered air can be passed through a sinter metal, which causes oil and water vapours to condense.
- A cyclonic separator deflects a jet of unfiltered air so that the heavy oil and water vapours are forced against the housing of the filter tower, condense and trickle down.
- As temperature of the compressed air drops in the inter- and after coolers, the relative humidity goes up and an oil-water emulsion condenses.

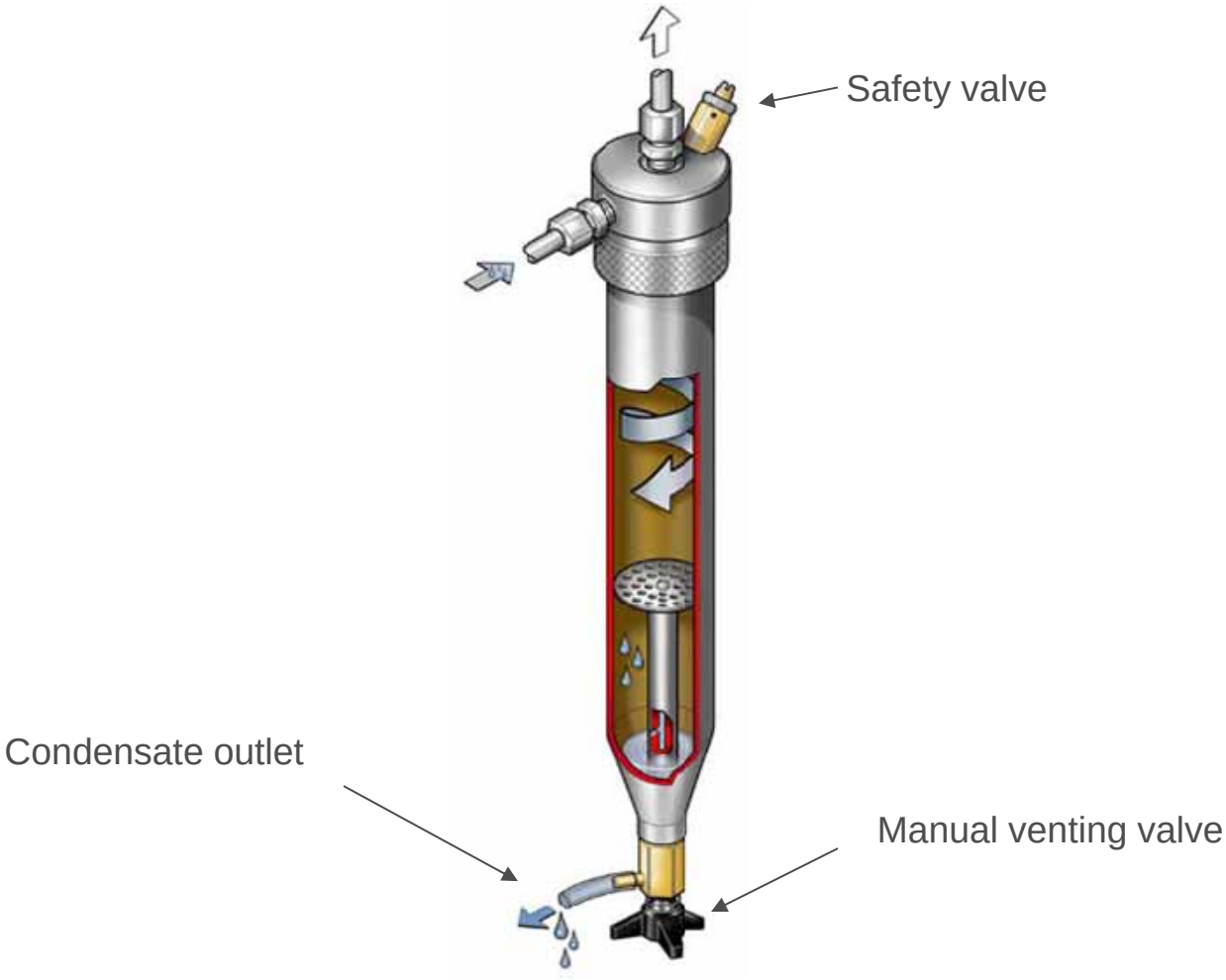
Condensate


1) Air
100% saturated
(e.g. 2nd stage)
compression
2) Air under pressure
100% saturated
(e.g. 3rd stage)
H2O
condensate
expand
3) Air after
expansion
(after compressor outlet)

Condensate


Filter system P61
Final pressure gauge
Final safety valve
Pressure maintaining valve
Oil- and Water separator

Condensate – Interstage separator



Automatic Condensate Drain System

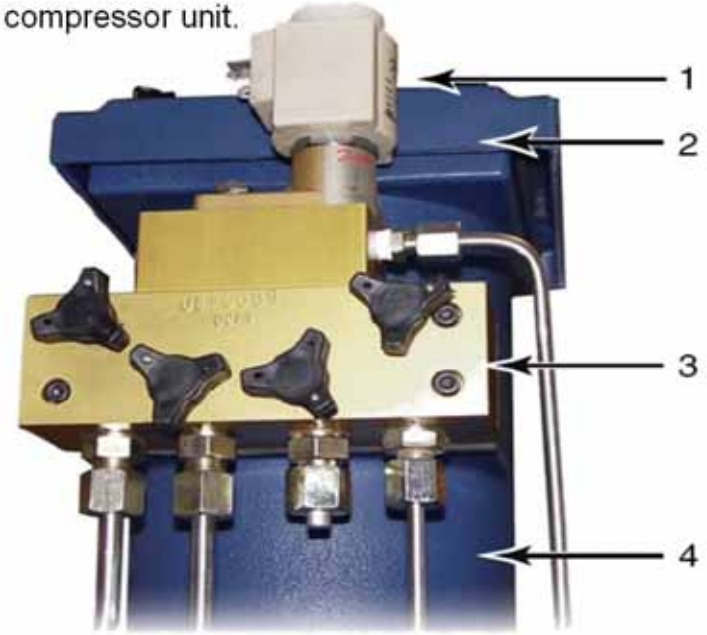
The automatic condensate drain system operates electro pneumatically and is comprised of the following:

- A condensate manifold
- A pneumatic condensate drain valve
- An electrically controlled solenoid valve
- A condensate separator
- A condensate collector tank

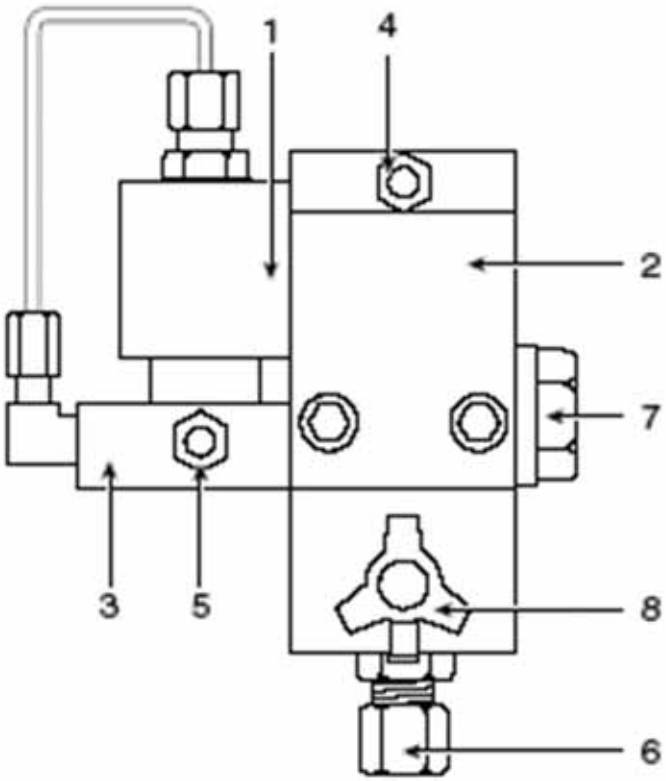
The automatic condensate drain system drains the intermediate and final separators every 15 minutes during operation.

Additionally the automatic condensate drain system unloads the compressor during the starting phase and drains these separators at shutdown of the compressor unit.

1. Solenoid Valve
2. Condensate Separator Cap
3. Condensate Drain Manifold
4. Condensate collection Tank

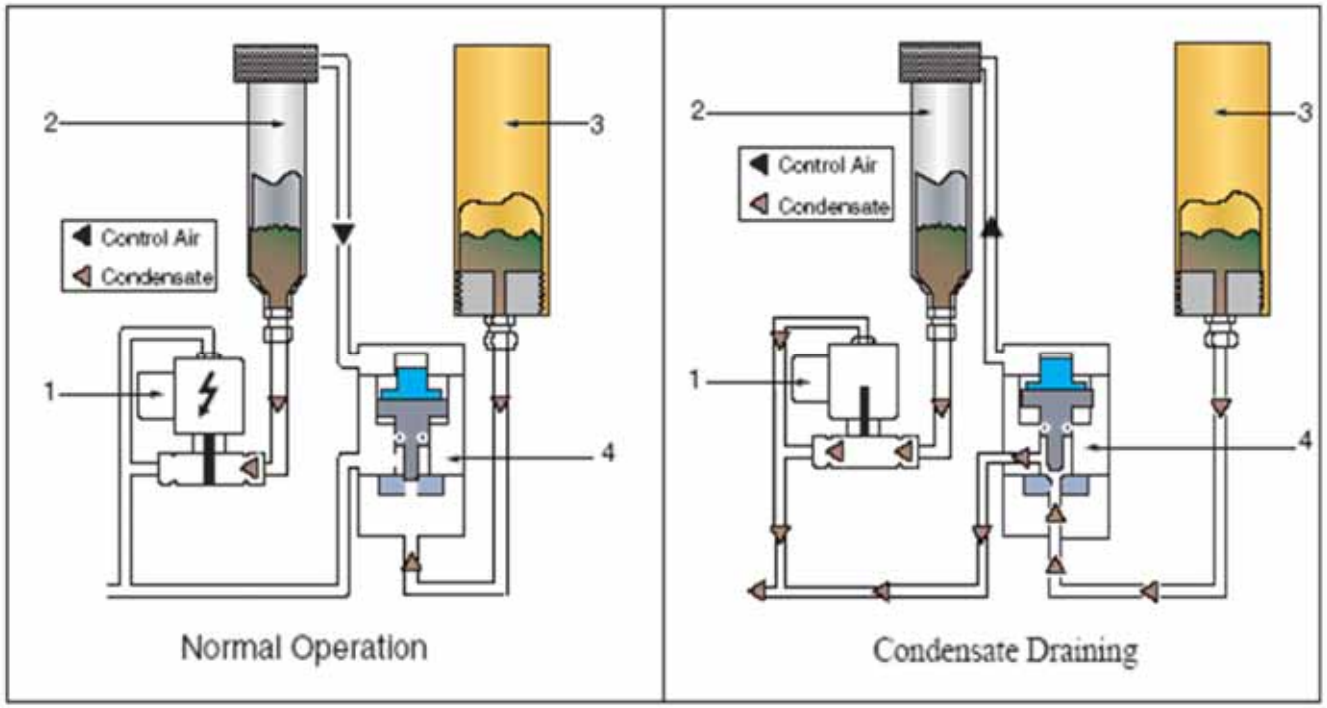


3-Stage Condensate Drain System



1. Solenoid valve
2. Condensate drain valve
3. Condensate drain manifold
4. Control air connection
5. Intermediate separator condensate connection
6. Oil and water separator condensate connection
7. Condensate collector bottle connection
8. Manual condensate drain valve

3-Stage Condensate Drain System



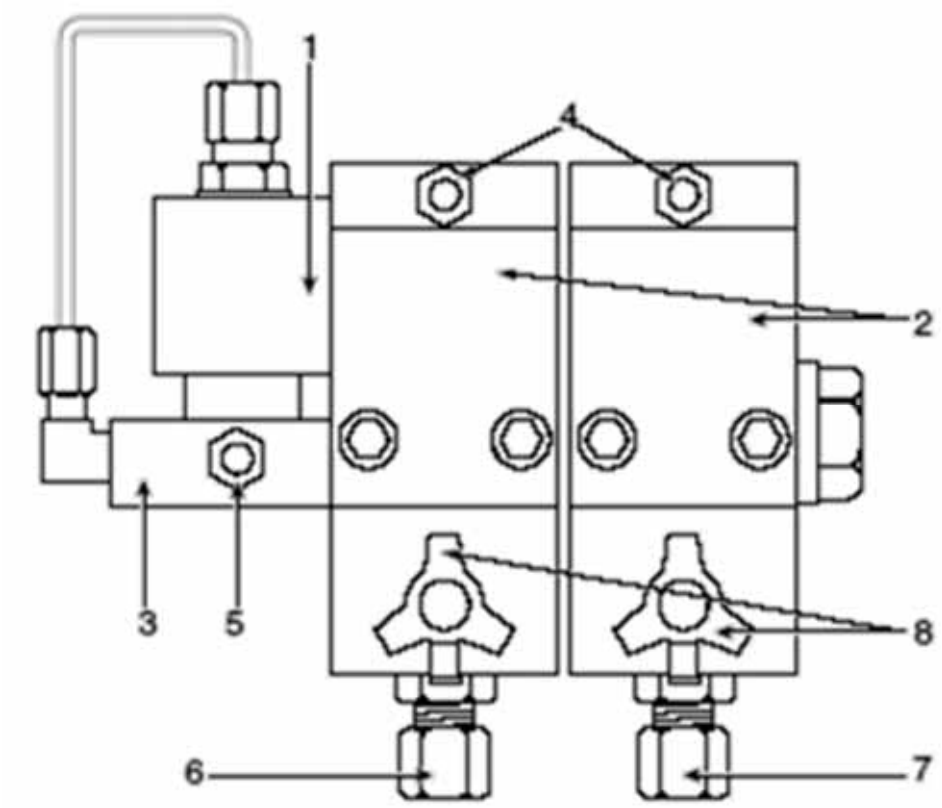
1 – Solenoid valve

2 – Intermediate separator

3 – Oil and water separator

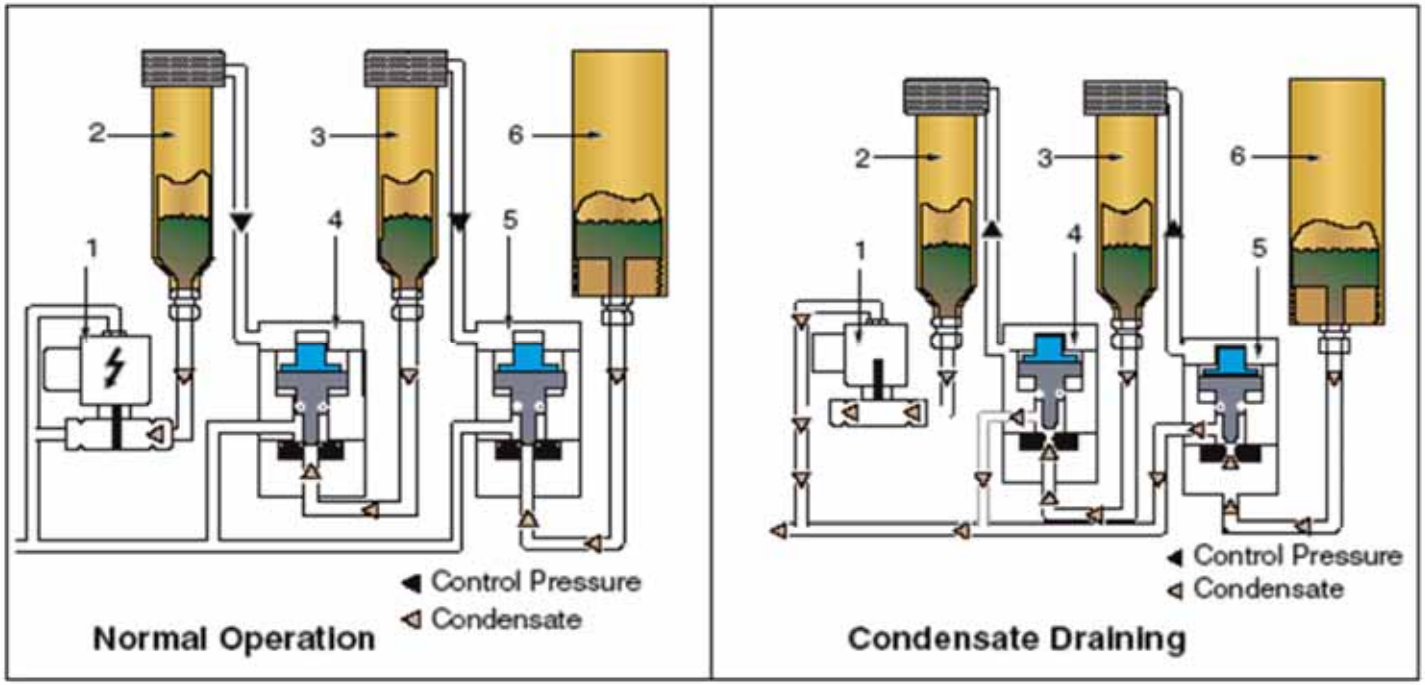
4 – Condensate drain valve

4-Stage Condensate Drain System



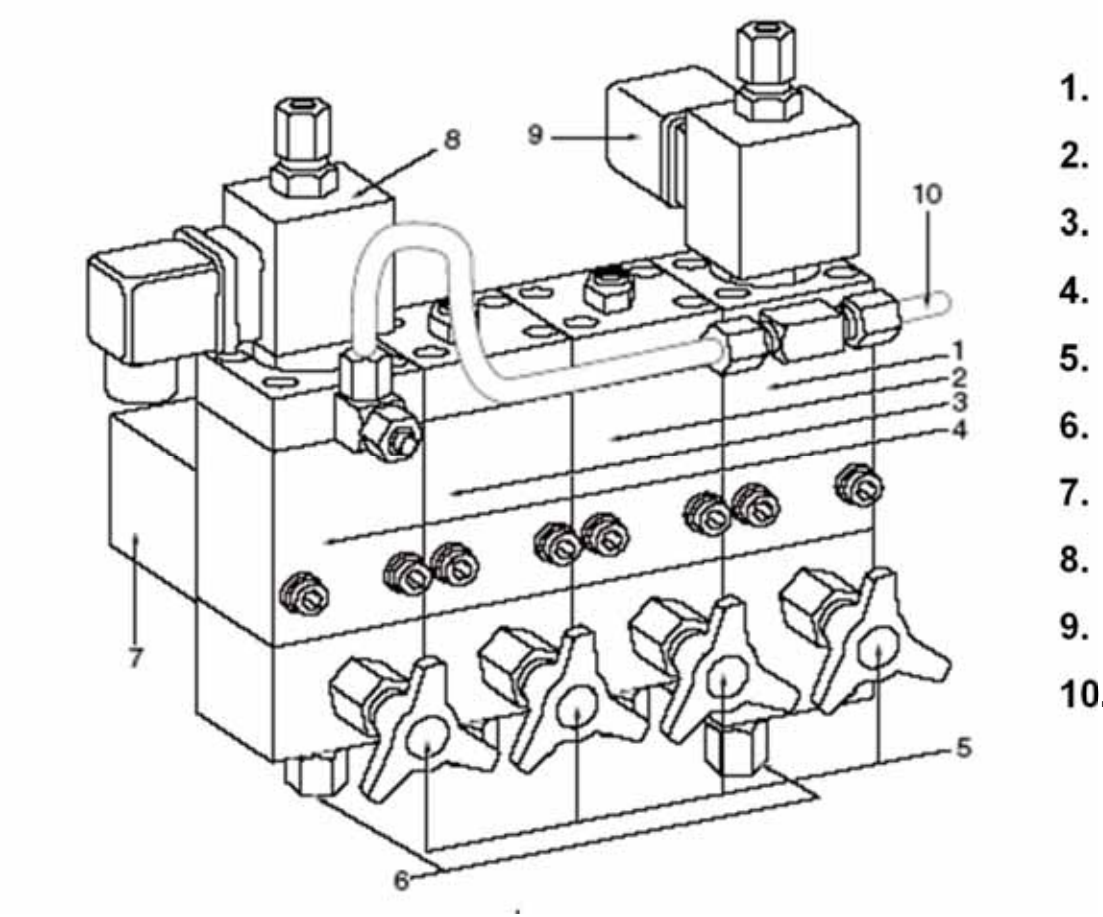
1. Solenoid valve
2. Condensate drain valve
3. Condensate drain manifold
4. Control air connection
5. 2nd stage intermediate separator condensate
6. 3rd stage intermediate separator condensate
7. Oil and water separator condensate connection
8. Condensate collector bottle connection
9. Manual condensate drain valve

4-Stage Compressor Condensate Drain



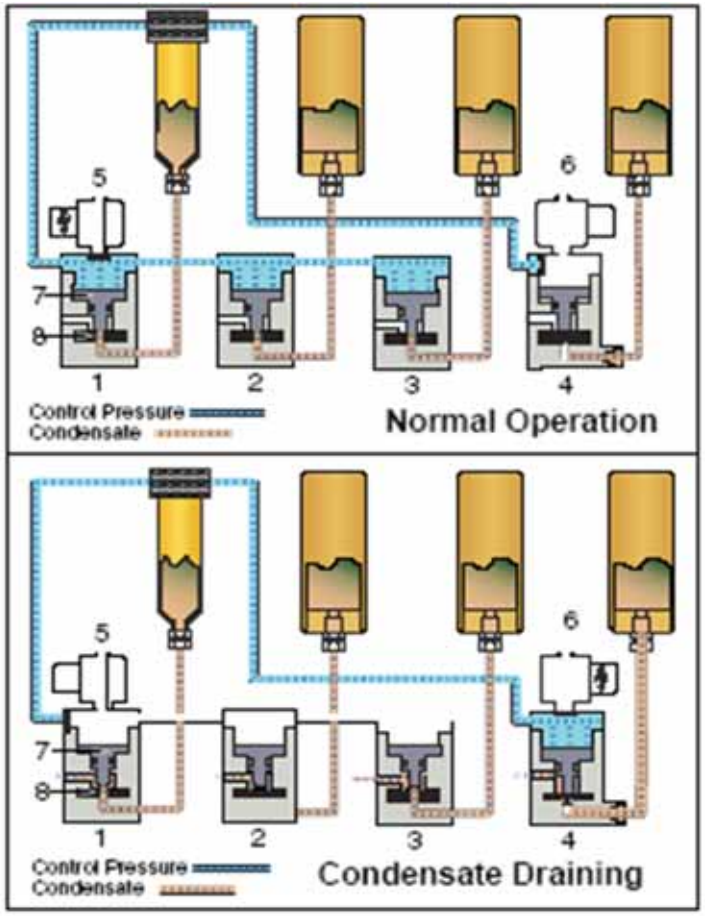
1. Solenoid valve
2. 2nd stage intermediate separator
3. 3rd stage intermediate separator
4. 3rd stage condensate drain valve
5. Oil and water separator condensate drain valve
6. Oil and water separator

5-Stage Condensate Drain System



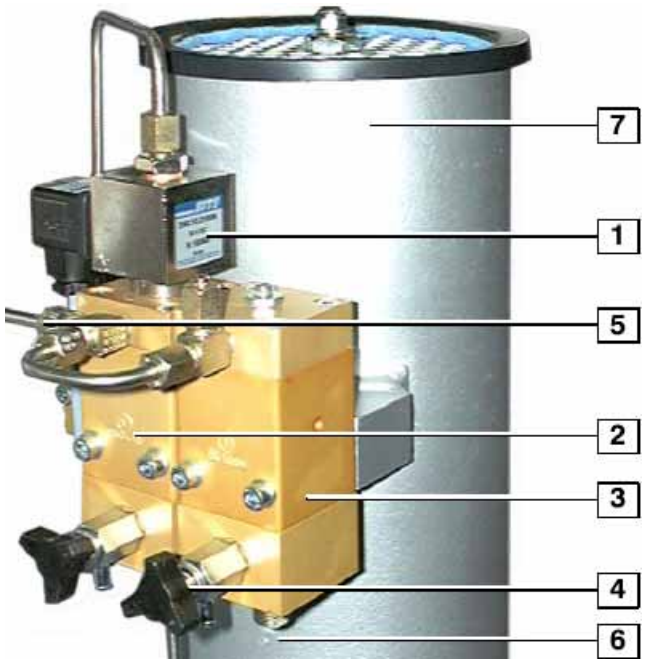
1. 5th stage ACD valve
2. 4th stage ACD valve
3. 3rd stage ACD valve
4. 2nd stage ACD valve
5. Manual condensate drain
6. Condensate inlets
7. ACD manifold
8. Electric solenoid
9. DIN connector
10. Control medium connection

5-Stage Compressor Condensate Drain



1. 2nd stage ACD valve
2. 3rd stage ACD valve
3. 4th stage ACD valve
4. 5th stage ACD valve
5. 2nd, 3rd and 4th stage electrical solenoid
6. 5th stage electrical solenoid
7. Valve piston
8. Valve seat

ACD - Automatic Condensate Drain System



1 3/2way solenoid valve
2 Condensate drain valve 2nd stage
3 Condensate drain valve 3rd stage
4 Manual drain tap
5 Control pressure line
6 Condensate inlet
7 Condensate collector

Any Questions?