Basics of safety and organization of the workplace during the operation and repair of compressors at the enterprises of ATP

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Abstract. For many decades, any organization involved in the operation and maintenance of vehicles cannot imagine its activities without compressor units. Compressors are used in all sectors of the national economy, and are valued for their reliability, high efficiency, long service life. The scope of the equipment is very wide, without it the work of any large industrial enterprise is indispensable. Compressors are used in mechanical engineering, metallurgy, oil and gas industry, car services, construction and other industries. Each compressor unit is equipped with an emergency protection system that provides: automatic shutdown of the compressor; sound and light alarm. According to the requirements of the Rules, all compressor units are equipped with instrumentation: pressure gauges for measuring pressure, thermometers or other sensors for measuring temperature. The compressor is placed in a separate room, which should not be connected with the premises where explosive and chemically hazardous industries are located. In the premises of compressor units, it is not allowed to place equipment and equipment that are technologically and structurally not related to compressors.

1 Introduction

Compressors are used in all sectors of the national economy, and are valued for their reliability, high efficiency, long service life. The scope of the equipment is very wide, without it the work of any large industrial enterprise is indispensable. Compressors are used in mechanical engineering, metallurgy, oil and gas industry, car services, construction and other industries [1].

A compressor is a power machine or device for increasing pressure and moving goods or their mixtures. The compressor together with the drive (electric motor, internal combustion engine) forms a compressor unit. A compressor unit with additional equipment is called a compressor unit [2, 3].

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2 Materials and methods

The main regulatory document for compressor units is the Order of the Federal Environmental, Industrial and Nuclear Supervision Service of December 15, 2020 No. 536 "On Approval of Federal Norms and Rules in the Field of Industrial Safety" Industrial Safety Rules for the Use of Equipment Operating under Excessive Pressure "". The rules apply to stationary reciprocating, rotary and screw oil-filled and dry compressor units, as well as to operating compressor units with a capacity of 14 kW or more, air ducts and gas pipelines operating on air and inert gases with a pressure of 0.2 to 40 MPa (from 2 up to 400 kgf/cm^2).

According to GOST 28567-90, compressors are divided into volumetric compressors and dynamic compressors [4].

In volumetric compressors, the working process is carried out as a result of cyclic measurement of the volumes of working chambers. These compressors include reciprocating and rotary compressors. In rotary compressors, the change in the volume of the working chambers occurs as a result of the rotation of the rotor. With the pressure of the volume of the chambers, the gas enters the chambers, and with a decrease in the volume of the chambers, the gas is compressed in them.

Positive displacement compressors include reciprocating, rotary and screw compressors.

By pressure, compressors are divided [2]:

- Low pressure (final pressure below 1.5 MPa (15 kgf/cm^2)).
- Medium pressure (final pressure from 1.5 to 10 MPa (from 15 to 105 kgf/cm^2)).
- High pressure (final pressure from 10 to 100 MPa (from 102 to 1020 kgf/cm^2)).
- Ultra-high pressure (final pressure from 100 MPa (from 1020 kgf/cm^2 and above).

Compressors are divided into:

- Low productivity (up to 10 m^3/min, 0.17 m^3/s).
- Average productivity (above 10 to 100 m^3/min, above 0.17 to 1.7 m^3/s).
- High productivity (more than 100 m^3/min, 1.7 m^3/s).

Piston compressors are widely used at ATP. The classification of reciprocating compressors is shown in Figure 1.

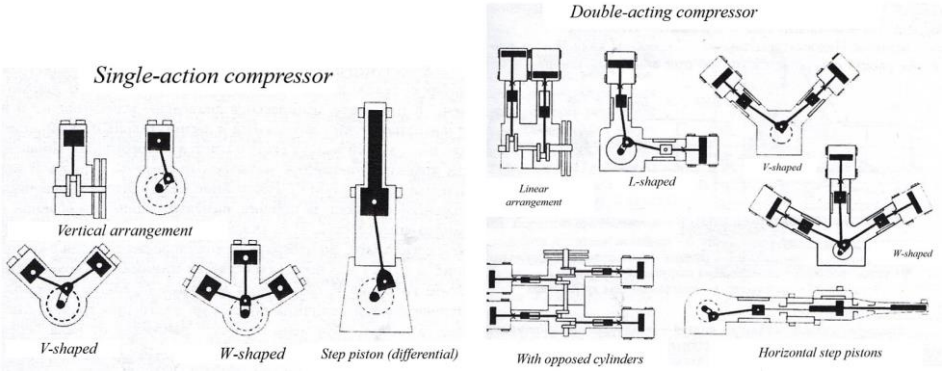
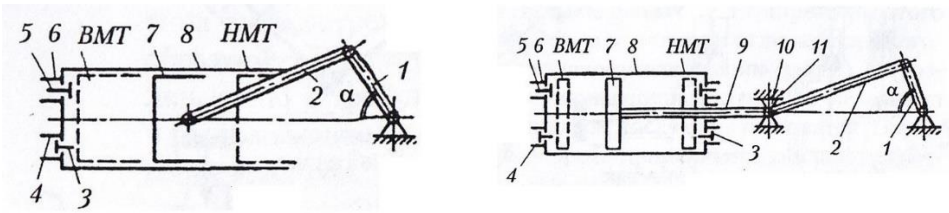


Fig. 1. Classification of reciprocating compressors.

Consider a single-stage reciprocating and double-acting compressor (Figure 2).



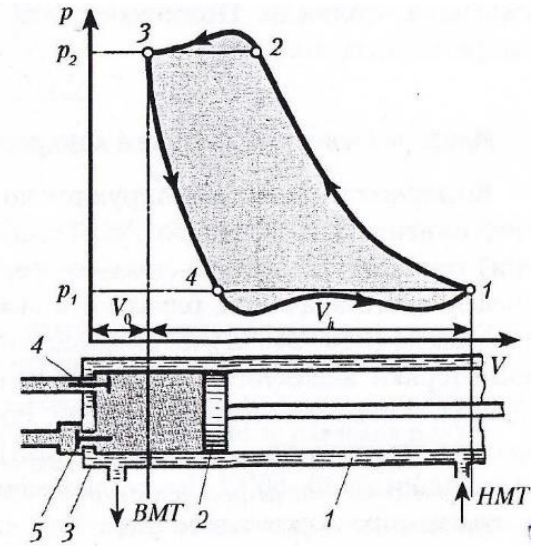
1 – crankshaft; 2 – connecting rod; 3, 5 – discharge and suction valves; 4, 6 – discharge and suction pipes; 7 – piston; 8 – cylinder; 9 – stock; 10 – crosshead; 11 – crosshead guides; TDC – top dead center; BDC – bottom dead center;

a) b)

Fig. 2. Structural diagrams of compressors: a) crossheadless; b) crosshead.

A single-stage compressor (Figure 2a) is a cylinder with a cooling jacket inside which a piston moves. Suction and discharge branch pipes with exhaust and discharge valves are connected to the compressor cylinder, through which air (gas) is supplied to the consumer. The piston has two extreme positions, called top and bottom dead centers (TDC and BDC). In single-stage reciprocating and compressors, the air (gas) sucked in and compressed is in contact with one up-per surface of the piston. It takes one stroke of the piston to suck in the gas and compress it. The disadvantage of such a compressor is that useful work is done only when the piston moves in one direction. More productive and economical is the design of a double-acting compressor (Figure 2b). In these compressors, in one cylinder, gas is simultaneously compressed (in the volume above the piston) and gas is sucked in (in the volume below the piston). In a double-acting compressor, both sides of the piston are active.

When the piston moves from BDC to the left, the suction valve closes and the air in the cylinder is compressed (Figure 3).



1 – cylinder; 2 – piston; 3 – cooling jacket; 4 – suction valve; 5 – discharge valve

Fig. 3. Indicator diagram and diagram of a single-stage reciprocating compressor.

At point 2, the pressure in the compressor cylinder is equal to the air pressure in the discharge pipe. However, then the pressure in the cylinder increases further, which ensures that the valve opens and air is forced out into the discharge pipe (into the air receiver with

pressure p_2). As the piston approaches the extreme left position, its speed decreases, the pressure drop between the cylinder and the receiver (air collector) located by the compressor also decreases, and when the piston reaches TDC (point 3), the pressure in the cylinder and receiver are compared. When the piston moves in the opposite direction, the pressure in the cylinder drops, the valve closes and the air compressed in the volume V_0 of the harmful space expands (process 3-4). At point 4, the pressure in the cylinder is equal to the ambient pressure p_1, after which a certain vacuum is formed in the cylinder, which ensures the opening of the suction valve and the suction of air in the cylinder from the environment. At point 1, the suction valve closes, and when the piston moves back, a new portion of air is compressed.

Measurement of gas pressure in the cylinder during piston movement is shown by the indicator diagram of the compressor (Figure 3). It reflects the course of the following processes [5]:

- 1-2 - gas compression by the piston in the cylinder when the piston moves from BDC to TDC.
- 2-3 - injection of gas compressed to pressure p_2 from the cylinder into the discharge pipe.
- 3-4 - expansion of the compressed gas remaining in the dead volume V_0 to the pressure at the inlet to the cylinder p1 and further to the pressure at which the suction valve opens.
- 4-1 - suction of gas into the cylinder when the piston moves from TDC to BDC.

When a gas (air) is compressed, its temperature rises. Compressing the combustible gas requires a lot of energy and is associated with the risk of deterioration of the lubrication of the cylinders. Therefore, the cylinders are cooled by wa-ter, which is pumped through a water jacket (cavity) surrounding the cylinder. Air-cooled compressor cylinders are also used.

Such reciprocating compressors include: KronVuz, Abac, ASO, Remeza, cat, fiac, Fubag, Dari, Fini, Aurora, Comprag [3].

The units that ensure the safety of compressor operation include pipelines and fittings [6]. Air pipelines, gas pipe-lines and oil pipelines of compressor units with pressure from 0.2 to 40 MPa (from 2 to 400 kg / cm^2) may be subject to the Rules for the Design and Safe Operation of Process Pipelines (PB 03-585-03), which apply to designed, newly man-ufactured and modernized steel technological pipelines intended for transportation of gaseous, vaporous and liquid media in the range from residual pressure (vacuum) 0.001 MPa (0.01 kgf/cm^2) to nominal pressure 320 MPa (3200 kgf/cm^2) and working temperatures from -196 to +700°C.

The pipelines of compressor units include pipes, fittings, fittings, compressors, supports, hangers and fittings.

In accordance with the terminology established by GOST R 52720-2007 “Pipeline fittings. Terms and definitions”, industrial pipeline fittings is a device (a set of devices) installed on a pipeline and a tank and providing control of the flow of the working medium by changing the flow area [5].

By operational purpose, valves are distinguished as shut-off, control, return and safety valves. The main function of valves is to ensure the control of the flow of working media and the safety of operation of pipelines and compressor units.

The main types of valves are shown in Figure 4.

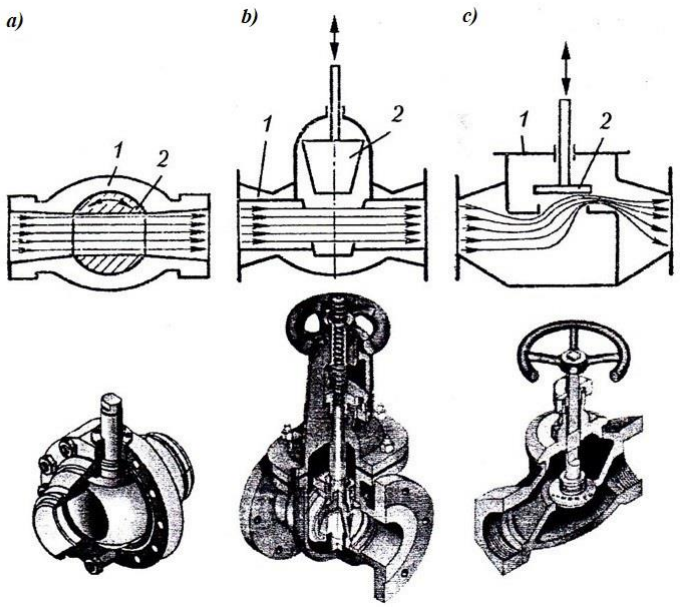


Fig. 4. Schematic diagrams of the operation of locking devices: a) crane; b) valve; c) shut-off valve (valve).

Depending on the conditions of the working process, one or another type of steam valve is used. Each of the three main types of valves has both positive and negative qualities.

The fittings must be completed with operational equipment, including a passport, technical description and operation manual [6].

The fittings must be clearly marked on the body, to which are indicated:

- Name or trademark of the manufacturer.
- Conditional pass.
- Conditional pressure or working pressure and temperature of the medium.
- Direction of the medium flow.
- Brand of body material.

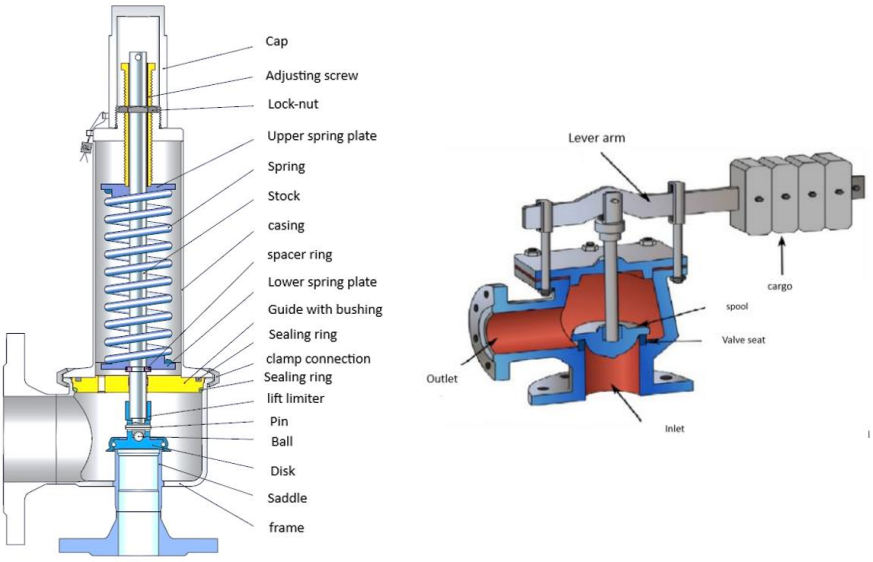
Valve handwheels must be marked with the direction of rotation when opening and closing the valve.

The seal tightness classes should be selected depending on the purpose of the valve:

- Class A - for substances of group A, B (a), B (b).
- Class B - for substances of group B (c) and C with Ru more than 4 MPa (40 kgf / cm^2).
- Class C - for group B substances with Ru less than 4 MPa (40 kgf/cm^2).

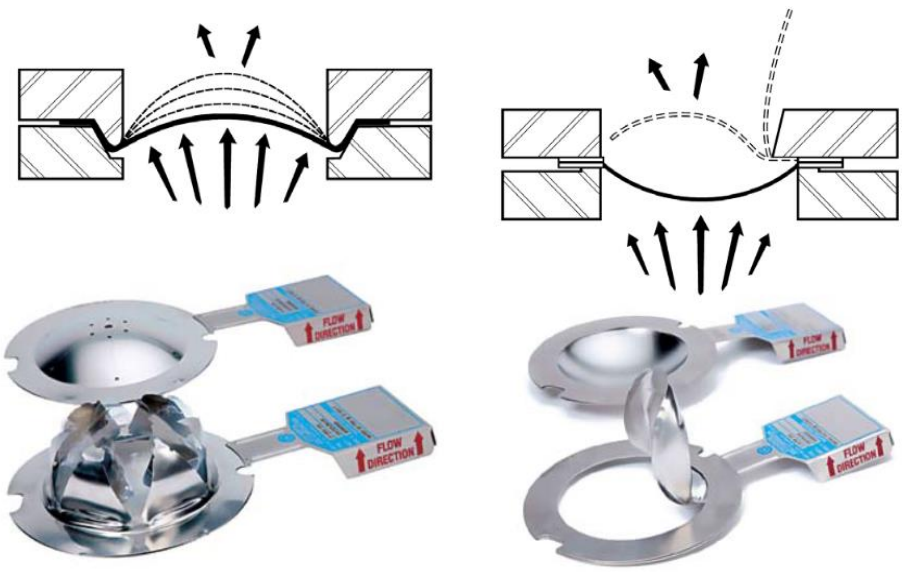
Safety valves (Figure 5) must be installed after each compression stage of the compressor in the chilled air section. If one air receiver is provided for each compressor and there are no shut-off valves on the discharge pipeline, the safety valve after the compressor can only be installed on the air receiver.

Diaphragm safety devices (Figure 6) are installed on vessels instead of other valves when they have unacceptable inertia or when the medium adversely affects lever and spring valves, as well as in parallel with other safety devices to increase their throughput.



a) b)

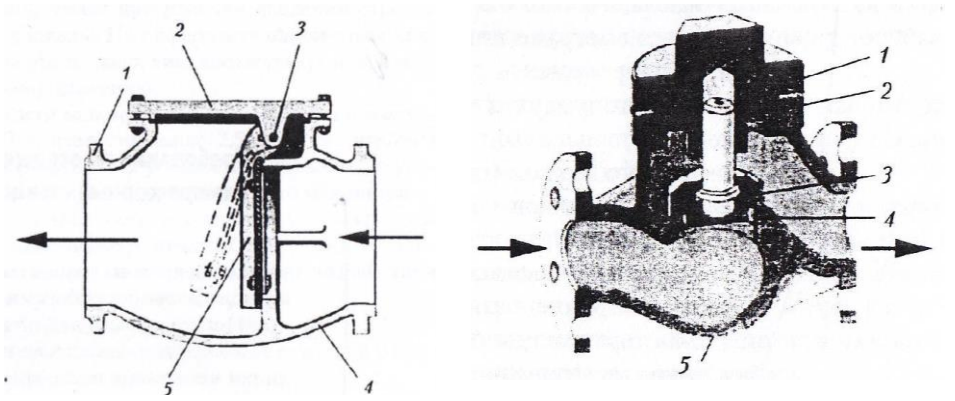
Fig. 5. Safety valves: a) spring loaded safety valve; b) lever safety valve.



a) b)

Fig. 6. Safety membranes: a) bursting type membrane (direct action); b) flapping type membrane (reverse action).

Check valves and gates are self-acting safety devices that prevent the reverse movement of the working medium (Figure 7).



1 – flange; 2 – cover; 3 – axis; 4 – body; 5 – locking plate

a)

1 – cover; 2 – spindle; 3 – plate; 4 – saddle; 5 – shutter disc

b)

Fig. 7. Check valves and gates: a) check valve; b) check valve.

Check valves must be installed on the discharge pipeline to the air or gas collector.

According to the requirements of the Rules, all compressor units must be equipped with the following control and measuring instruments (CMI) [7, 8]:

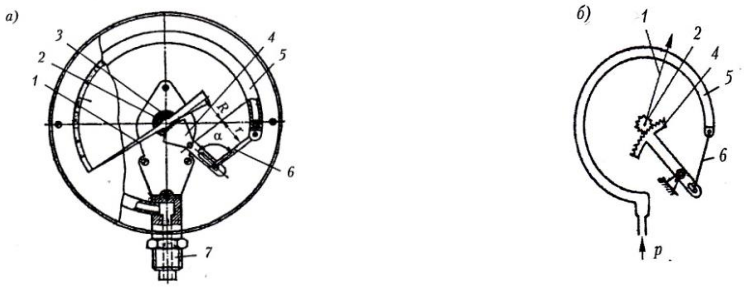
1. Gauges for measuring pressure:

- Air (gas) after each compression stage and on the discharge line after the compressor.
- Air (gas) after the air collector.
- Oils.

2. Thermometers or other sensors to measure temperature:

- Compressed air (gas) after each compressor stage.
- Compressed air (gas) after intermediate and end coolers.
- Discharge water from compressors and refrigerators.
- Oils behind the refrigerator and on the drain line.

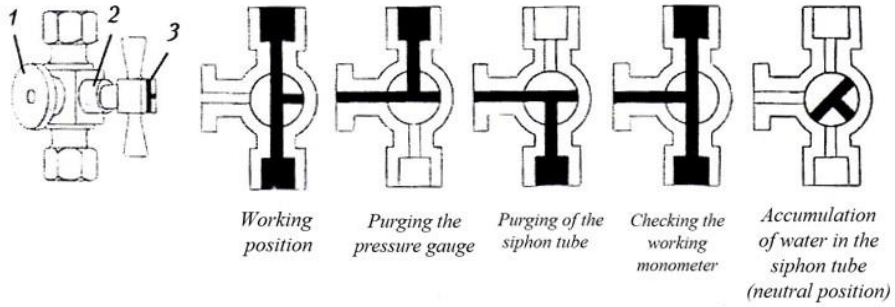
For periodic pressure measurement, stationary indicating spring pressure gauges are used (Figure 8).



1 – arrow; 2 – gear; 3 – spring; 4 – gear sector; 5 – tubular spring; 6 – leash; 7 – fitting

Fig. 8. Device (a) and kinematic diagram (b) of a spring pressure gauge.

The pressure gauge scale should be such that at operating pressure the pointer is in the middle third of the scale. To check the serviceability, the pressure gauge must be equipped with a three-way valve (Figure 9).



1 – flange for connecting a control pressure gauge; 2 – stopper of the crane; 3 – risks

Fig. 9. Three-way valve and its position during operation and purge of the pressure gauge.

Gauges are not allowed to be used if:

- There is no seal or stamp on the pressure gauge with a mark on the test.
- The arrow of the pressure gauge, when it is turned off, does not return to the zero mark of the scale by an amount exceeding half of the permissible error for this pressure gauge.
- The glass is broken or there is other damage to the pressure gauge, which may affect the correctness of its readings.

The causes of accidents of compressor units can be [7, 9]:

- Increasing the temperature of compressed air in the compressor cylinder in excess of the calculated one.
- Formation of explosive mixtures in compressed air.
- Increasing the pressure of compressed air in the compressor cylinder or receiver in excess of the normally allowable.
- Sparking in an explosive mixture environment.
- Poor quality lubricant.
- Water hammer.
- Poor installation quality.
- Malfunction of instrumentation, safety devices.
- Poor maintenance and unsatisfactory maintenance of the installation.

Each compressor unit is equipped with an emergency protection system that provides [8]:

1. Automatic stop of the compressor.
2. Sound and light alarm in cases:

- increasing the oil pressure to lubricate the pressure mechanism below the permissible value.
- increasing the temperature of the compressed air above the permissible level.
- interruption of the supply of cooling water.

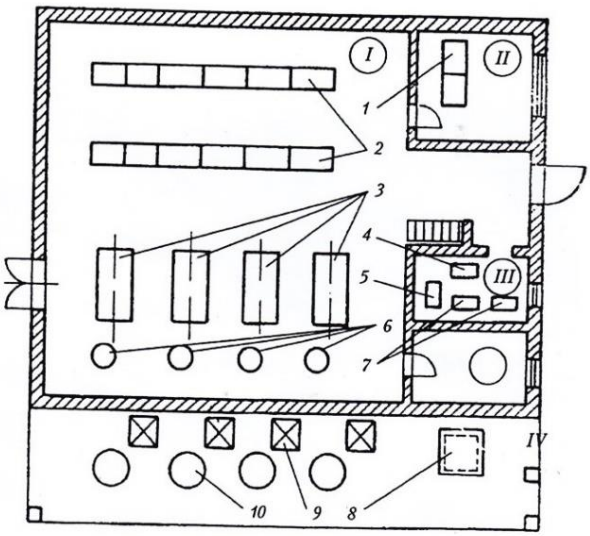
The compressor must be stopped immediately in the following cases:

- Discharge pressure at any stage has risen above the allowable level.
- The manometer of the lubrication system of the movement mechanism shows low pressure.
- Water supply for cooling stopped.
- Knocks, blows, etc. are heard.
- The temperature of the compressed air has become higher than the permissible value.
- There was a smell of burning, smoke.
- With noticeable vibration of the compressor, electric motor and other components.

The compressor is placed in a separate room, which should not be connected with the premises where explosive and chemically hazardous industries are located.

Passages in the engine room should be at least 1.5 m wide, and the distance between the equipment and the walls of buildings should be at least 1 m. To reduce vibration, the platforms between adjacent foundations of compressors are made inset, freely resting on the foundations. Pipelines connected to the compressor and building structures are connected to them through compensating devices. Pipelines that connect the compressor cylinders with intermediate coolers and buffer tanks must also have self-compensation. The case of compressors, refrigerators and moisture-oil separations are grounded.

An example of a low pressure compressor station poster is shown in Figure 10.



I – engine room; II – operator's room; III – room for charging filters; IV-household premises; 1, 2 – automatic control panels; 3 – compressors; 4 – bath for filter settling; 5 – bath for oiling filters; 6 – end coolers; 7 – bath for washing filters; 8 – purge tank; 9 – filter chamber; 10 – air collector

Fig. 10. Plan of the low pressure compressor station.

3 Results

Responsible for safe operation is a specialist who reports to the personnel servicing compressor units or the head of the area where compressor units are present.

The person responsible for safe operation must ensure:

- Admission to maintenance of compressor units only by trained and certified personnel.
- Periodic checking of knowledge by the personnel of instructions on the mode of operation and safe operation of compressor units.
- Availability of production safety instructions for the personnel.
- Personnel undergoing periodic medical examinations.
- Maintenance and storage of technical documentation for the operation of compressors.
- Timely stop of compressors, and their preparation for technical examination.

During operation of the compressor unit, it is necessary:

- Control and record the oil consumption for each lubrication point each shift and compare it with the consumption in the factory manual.

- Daily check by forcibly opening under pressure safety valves operating at a pressure of 1.2 MPa (12 kgf/cm^2).
- In the absence of an aftercooler and a moisture-oil separator, blow the air collector (gas collectors) at least twice per shift.
- I there is an aftercooler and a moisture-oil separator, blow the air collector (gas collectors) at least once per shift.
- Control the pressure and temperature of the compressed gas after each compression stage and after the coolers.
- Control the flow of cooling water into compressors and refrigerators.
- Control the temperature of the cooling water at the inlet and outlet of the cooling system point by point.
- Control the pressure and temperature of the oil in the lubrication system.
- Check the air filters and the periods specified in the compressor operating instructions.
- Perform regular external inspection, wiping and cleaning of the external surfaces of the equipment of the compressor unit from dust and dirt.

Instrument readings are recorded in the compressor log at least every 2 hours, unless instructions specify other time intervals [11].

According to the instructions, during the operation of the compressor unit, it is prohibited [11, 12]:

- To clean and repair equipment under pressure.
- Leave a running compressor unattended.
- Store flammable materials in the compressor room.
- Make an open fire in the compressor room.
- Clean, lubricate, wipe the rotating parts of the mechanisms, climb over the fences or put your hands behind them for lubrication and cleaning.
- Stop manually rotating mechanisms.
- Open fittings without protective gloves.
- Step on manhole covers, wells, channels.

4 Discussion

Inspection and cleaning of equipment. Air viscin filters after 1000 hours of operation, but at least once every two months, should be thoroughly cleaned of dust and, after drying, lubricated with viscin or other similar oils.

Cleaning of air collectors, moisture-oil separators, intermediate and end coolers and pressure air ducts from oil deposits must be carried out after 5000 hours of operation in a manner that does not cause metal corrosion.

Each compressor unit is equipped with the following technical documentation:

- Passport (form) for the compressor unit.
- A diagram of pipelines (compressed air or gas, water, oil) indicating the installation locations of valves, valves, moisture-oil separators, intermediate and end coolers, air collectors, instrumentation, as well as electrical cables, automation, etc.. schemes are posted in a conspicuous place.
- Instruction (manual) for safe maintenance of the compressor unit.
- Compressor operation register.
- A journal (form) for accounting for the repair of a compressor unit.
- Passports-certificates of compressor oil.
- Passports of all pressure vessels.
- Plant repair schedule.

During the technical examination of the compressor installation, the test pressure is maintained for 5 minutes, after which it is reduced to the working one [10].

At operating pressure, the pipeline and welds are inspected. The test is considered satisfactory if during the test there was no pressure drop on the pressure gauge, and welds, pipes, housings, fittings, etc. no signs of rupture, leakage or fogging were found. The results of the test are recorded in the journal (form) of accounting for the repair of the compressor unit.

5 Conclusion

It should be noted that ensuring safety during operation requires personnel to strictly comply with the requirements of all norms and rules, since otherwise an explosion of the compressor unit is possible.

Ensuring safety during operation includes the organization of a workplace with ventilation and lighting equipment, compliance with the rules and regulations when performing plumbing and machine work, as well as knowledge of the functioning of equipment and equipment.

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