Methods of Selecting a Compressor Station and Compressed Air Purification Systems

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Abstract

The article offers a detailed breakdown of the process of selecting a compressed air station according to the needs of production, specifics of the environment, as well as the level of air purity and dryness requirements. Formulas for calculating the compressor power required by the consumer are given. The importance of taking into account pressure losses in the pneumatic network and the correct choice of the type of dryer and compressed air receiver is indicated, as it lowers the stress upon the compressor station and reduces the energy usage by up to 25%. Correspondence tables for the degree of air purification from contaminants in accordance with (ISO 8573-1:2010) directive are shown in this article. Recommendations on choosing the length and diameter of pneumatic lines in order to reduce pressure loss in the compressed-air network are given.diameter of pneumatic lines in order to reduce pressure loss in the compressed-air network are given.

Keywords: *compressed air, compressor, compressor station, energy saving, pressure, production, compressed air purification, receiver, dryer.*

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Kompressor stansiyasının və sıxılmış havanın təmizlənməsi sistemlərinin seçilməsi üsulları

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Xülasə

Məqalədə, istehsalın ehtiyaclarından, ətraf mühitin xüsusiyyətlərindən, habelə havanın qurudulması və təmizlənməsi dərəcəsinə olan tələblərdən asılı olaraq, kompressor stansiyasının seçilməsi prosesinin ətraflı təhlili verilmişdir. İstehlakçıya lazım olan kompressor gücünün hesablanması düsturları verilmişdir. Pnevmosetdə təzyiq itkilərinin nəzərə alınmasının və sıxılmış havanın quruducu və resiver tipinin düzgün seçilməsinin vacibliyi göstərilir ki, bu da kompressor stansiyasının yükünü azaltmağa və enerji xərclərini 25% -ə endirməyə imkan verir. ISO 8573-1: 2010 direktivinə əsasən, havanın qarışıqlardan təmizlənmə dərəcəsinin uyğunluq cədvəlləri verilmişdir. Sıxılmış hava şəbəkəsində təzyiq itkisini azaltmaq məqsədilə pnevmolinlərin diametri və uzunluğunun seçilməsi ilə bağlı tövsiyələr verilmişdir.

Açar sözlər: *çarpaz külək, krab üsulu, aşağı qanad üsulu, proqram təminatı, yan yüklər, təyyarə.*

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Методы подбора компрессорной станции и систем сжатого воздуха

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Аннотация

В статье приводится подробный разбор процесса подбора компрессорной станции в зависимости от потребностей производства, особенностей окружающей среды, а также требований к степени осушения и очистки воздуха. Даны формулы расчета необходимой потребителю мощности компрессора. Обозначается важность учета потерь давления в пневмосети и правильного выбора типа осушителя и ресивера сжатого воздуха, что позволяет снизить нагрузку на компрессорную станцию и уменьшить энергозатраты до 25%. Приведены таблицы соответствия степени очистки воздуха от примесей в соответствии с директивой ISO 8573-1:2010. Даны рекомендации по выбору диаметра и протяженности пневмолиний с целью снижения потери давления в сети сжатого воздуха.

Ключевые слова: *сжатый воздух, компрессор, компрессорная станция, энергосбережение, давление, производство, очистка сжатого воздуха, ресивер, осушитель.*

Introduction

Well-known global manufacturers of compressor equipment today offer a number of oil-free and oil-free piston compressors, industrial high-pressure compressors, modern screw compressors on the Azerbaijani market (Fig. 1, 2).

Air compressors are used in workshops and in construction, in medicine, on offshore platforms, in the light and food industries, as well as in leading enterprises of the defense complex and in the space industry of the country.

The compressor allows you to convert electrical energy into pneumatic energy. Power replacement is a factor in improving safety and cost-effectiveness of use: "Losses of electricity in the electrical networks of the Azerbaijan Energy System in 3 times higher than in industrialized countries. Reserves for reducing electricity losses are estimated at the level of 1.5 billion kWh per year.

A systematic approach to the problem of energy efficiency is required" [1].

In harsh conditions, clean-room areas or on the high seas – compressed air systems ensure maximum efficiency all over the world and in any environment. Compressor systems are known for being extremely reliable, with low maintenance and energy consumption levels.

The complexity of supplying an industrial plant with compressed air isn't limited to a choice of a compressor. For the adequate operation of pneumatic devices, equipment and tools, it is necessary to use compressed air without contaminants. To address this matter, air preparation systems are used.

Figure 1 – Screw Compressor BOGE S 110-4 L (Germany)

In this article, we will go over the questions of putting together compressed air stations and offer recommendations on the capacity of the compressor, the needed volume of the receiver, as well as filters and dryers.

Problem statement

A compressed air station is a "chain" of equipment for the production, storage and preparation (purification and drying) of compressed air in accordance with the requirements of the technological process.

Figure 2 – Screw Compressor ALMIG COMBI 18 (Germany)

The main criteria determining the completeness of the compressed air station are the maximum operating pressure, the purity (quality) of compressed air, and the volumetric air output [2, 3].

In addition, you should pay attention to the temperature inside the room of the compressed air station and how dusty it is (compressors, without special preparation, operate at ambient air temperatures from +5°C to +40 ... +45°C). Check the state of the pneumatic systems of the facility (clogged pipelines, leakage) and the intended mode of operation of the equipment (single/double shift, around-the-clock, etc.) [4].

Choosing the Compressor

The required output of the compressor should be calculated by summing up the total consumption of the equipment, the possible amount of leakage (5-30%), and also the supposed increase in compressed air usage, accounting for the future expansion of your production. Calculated output should not exceed 90% capacity of the compressor station.

Maximum operating pressure: compressor equipment for 7, 8, 10, and 13 bar is available on the screw compressor market. For most industrial plants, a compressor with a maximum pressure of 8 bar would suffice, since a significant part of equipment operates at a pressure of 6 bar [5]. But experts, in most cases, suggest picking the 10 bar option. The main reason is that there is a pressure drop along the pass of compressed air from the compressor to the equipment. The longer the pipe line and the more local obstructions along its way (stop valves, angles, tees, fittings, etc.), the greater the pressure drop.

The formula for calculating the pressure loss in the pneumatic network:

$$\Delta_p = \frac{1.6 \cdot \left(\frac{V}{60}\right)^{1.85} \cdot L \cdot 10^6}{d^5 \cdot p_e}$$

where V - total volumetric flow; L - pipe length to accommodate flow rate; d - internal diameter of the pipe; P_e - compressor switch-off pressure.

If we compare two sections of pipe of the same length but with different diameters, for example, 1/2" and 3/4", then a "half-inch" pipe will have a bigger pressure drop [6, 7]. The pressure drop also occurs in equipment for drying/purification of compressed air: when passing through the 0.2 bar dryer and when passing through each of the 0.1 - 0.15 bar filters and, as the filter element becomes dirty, this value will increase.

Below is the calculation formula for minimum nominal pipe width:

$$d_i = \sqrt[5]{\frac{1.6 \cdot V^{1.85} \cdot L}{107 \cdot \Delta_p \cdot p_{max}}}$$

where V - total volumetric flow rate; L - pipe length to accommodate flow rate; Δp - intended pressure drop; P_{MAX} - swich-off pressure of compressor [8].

Preparation of compressed air

To produce one cubic meter of compressed air with an overpressure of 10 bar, a compressor has to suck in eleven cubic meters of ambient air. Together with this air, it also sucks in all the impurities it contains, just like a large vacuum cleaner: dust, fumes, oil vapor, chemicals, etc. Added to this is the natural air humidity. Despite high-quality intake filters, all these components of the intake air are found in the compressed air. The substances that were distributed over eleven cubic meters of ambient air before compression are now concentrated in a single cubic meter of compressed air.

To ensure trouble free operation, dirt, water and oil must therefore be separated from the compressed air.

Humidity

Compressed air contains moisture depending on the ambient conditions. Depending on the application, this moisture must be extracted from the compressed air. There are the following possibilities: Cyclone separator: removes free water droplets from the compressed air, Refrigeration dryer: possible dew point up to max. +3 °C, Adsorption dryer: possible dew point down to -70 °C.

Which drying is required in individual cases depends on the consumers operated. Symptoms of incorrectly designed drying are moisture in the compressed air network, icing in winter or increased component wear due to corrosion. To drain moisture from the compressed air system and dispose of it properly, it is recommended to use: Condensate drain, Oil-Water separators.

Solid impurities/oil

In addition to moisture, the compressed air is also contaminated with particles and oil. To remove these components, it is recommended to use filters such as: Coarse filter, Microfilter, Submicrofilter, Activated carbon filter, Activated carbon adsorber.

By combining different preparation methods, the purity classes prescribed or recommended for the respective applications can be achieved (Table 1).

Choosing the Air Dryer

Refrigerated compressed air dryers use a small refrigerator to cool down the compressed air to about 3 degrees Celsius (Figures 3, 4, 5).

At this low temperature, condensate will form which is removed by a condensate trap. When all the water is removed, the air is reheated to room-temperature. Your air is now dry and will not form any water as long as it stays above 3 degrees Celsius (Table 2).

Table 1 – Compressed air quality classes according to ISO 8573-1:2010

ISO 8573-1:2010	Solid impurities			Humidity (vaporous)		Total oil content (liquid & gaseous)
Class	$0.1\mu < d \le 0.5\mu$	$0.5\mu < d \le 1.0\mu$	$1.0\mu < d \le 5.0\mu$	Pressure dew point		
0	better than Class 1 and to be agreed separately					
1	≤ 20.000	≤ 400	≤ 10	≤ -70°C		≤ 0,01 mg/m³
2	≤ 400.000	≤ 6.000	≤ 100	≤ -40°C		≤ 0,1 mg/m³
3	—	≤ 90.000	≤ 1.000	≤ -20°C		≤ 1 mg/m³
4	—	—	≤ 10.000	≤ +3°C		≤ 5 mg/m³
5	—	—	≤ 1000.000	≤ +7°C		—
6	Mass concentration C_p (mg/m³)		$0 < C_p \le 5$	≤ +10°C		—
7			$5 < C_p \le 10$	Residual humidity *cw* g/m³	$cw \le 0,5$	—
8			$C_p < 10$		$0,5 < cw \le 5$	—
9	—	—	—		$5 < cw \le 10$	—
X	—	—	—		$cw \le 10$	> 5 mg/m³
	Maximum number of particles per m³ of the given size in µm measured according to ISO 8573-4 Reference conditions: 1 bar absolute, 20°C, 0% r. h.			Maximum pressure dew point measured according to ISO 8573-3 at operating pressure. Reference conditions for residual humidity: 1 bar absolute, 20°C, 0% r. h.		Maximum total oil content measured according to ISO 8573-2 and ISO 8573-5. Reference conditions: 1 bar absolute, 20°C, 0% r. h.

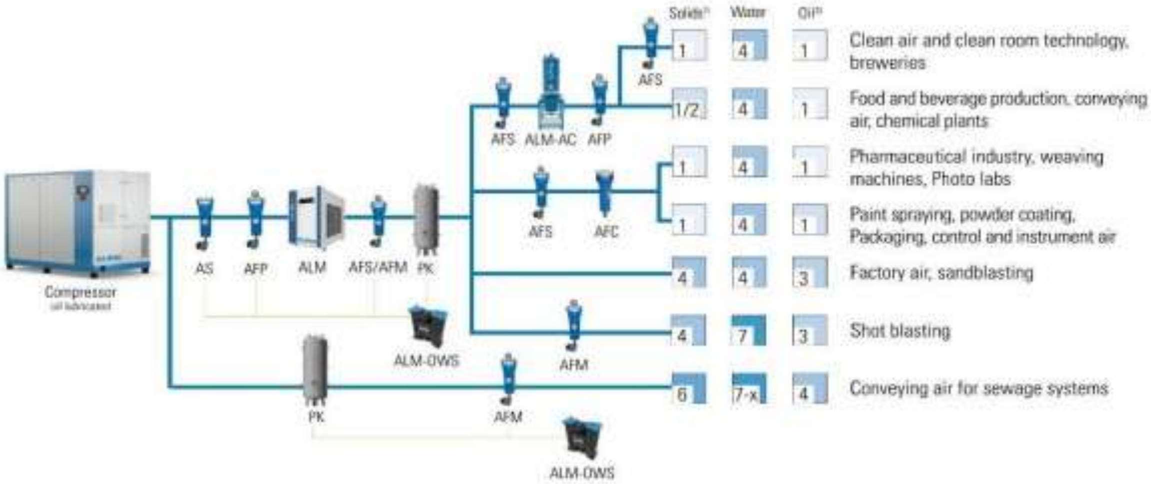


Figure 3 – Compressed air treatment with refrigeration dryer

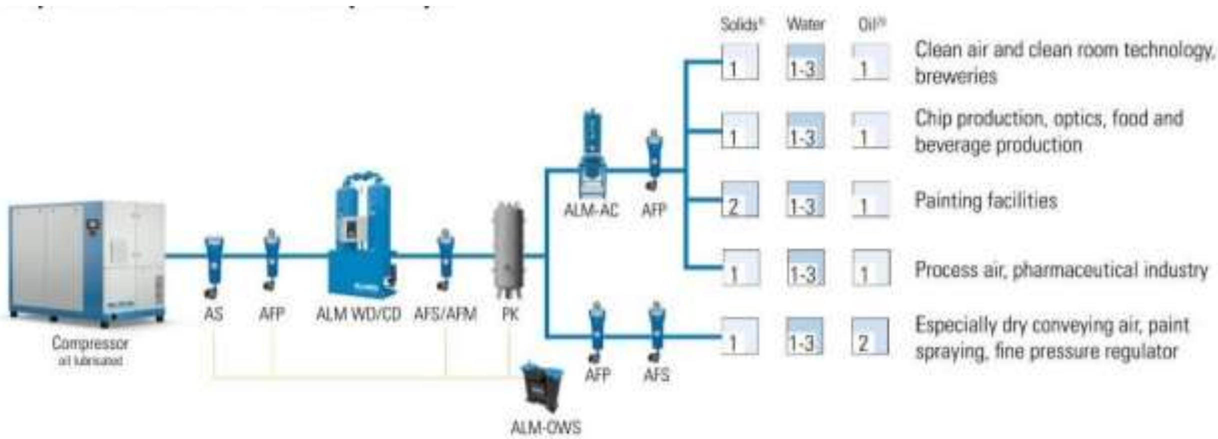
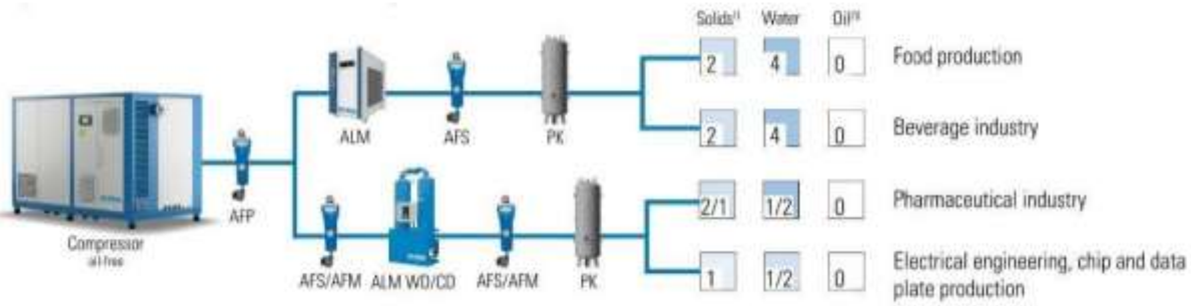


Figure 4 – Compressed air treatment with adsorption dryer



Explanations

AS	Cyclone separator	AFM	Micro filter	ALM-AC	Activated carbon adsorber	ALM	Refrigeration dryer
PK	Compressed air receiver	AFS	Submicro filter	ALM-WD/ ALM-CD	Adsorption dryer	ALM-OWS	Oil-water separators
AFP	Prefilter/coarse filter	AFC	Activated carbon filter				

Figure 5 – Compressed air treatment with oil-free dryer

Table 2 – Correction factors for ALM-RD dryers

Inlet Temp. (°C)	30	35	40	45	50	60	-	-
F1	1.29	1	0.92	0.78	0.65	0.45	-	-
Ambient Temp. (°C)	20	25	30	35	40	50	-	-
F2	1.05	1	0.98	0.93	0.84	0.7	-	-
Pressure (bar)	4	6	7	8	10	12	14	16
F3	0.80	0.94	1	1.04	1.11	1.16	1.22	1.25

Example for choosing the correct dryer:

If a compressor delivers 200 m³/hr at 8 bars, the dryer inlet temperature is 45°C and ambient temperature is 35°C, then please choose your dryer as follows:

200 m³/hr / 0.93 / 0.78 / 1.04 = 265 m³/hr

Desiccant compressed air dryers:

Desiccant air dryers use desiccant to remove the water from the compressed air. Basically, the water will 'stick' to the surface of the desiccant, resulting in dryer air. Every once in a while, the desiccant is regenerated. This is done automatically by the dryer. It blows dry, hot air through the desiccant to remove the water. The desiccant is now ready to do its job again. Desiccant compressed air dryers can reach much lower dew-points, up to -70 degrees Celsius. A properly selected dryer prevents water from entering the compressed air line, otherwise it may lead to costly repairs of pneumatic equipment.

Choosing the compressed air receiver

Air receivers are vessels, which are used to store compressed air, eliminate pressure pulsations and accumulate condensate (due to the cooling of compressed air and the process of the flow hitting against the walls of the receiver). The main purpose of the air receiver is to store compressed air. In order to meet the needs of a particular compressor system, the volume of the receiver must be properly calculated. Accurate selection of the receiver will not only reduce the frequency of load/unload cycles of the compressor, which lowers compressor's maintenance costs, but will also save energy costs by decreasing unload setpoint [9].

Below is a formula for calculating the volume of a compressed air receiver:

$$V_B = \frac{V_{eff} \cdot P_R}{4 \cdot \Delta p \cdot z_s}$$

where V_{eff} - volumetric flow rate of the biggest compressor; Pr - pressure in situ; Z_s - operating cycle frequency of the compressor per hour (load / no-load); Δp - switching pressure differential [10].

Conclusion

A systematic approach to the design of a compressed air station and the accurate selection of a compressed air preparation system, make it possible to ensure the stable operation of the enterprise, protect high-tech equipment from breakdowns and meet high production standards. Timely maintenance, correct settings of the compressed air station and regular checking of pipelines for leaks, can reduce energy costs by up to 30%, which undoubtedly has a positive effect on the environment.

Conflict of Interests

The authors declare there is no conflict of interests related to the publication of this article.

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