compressed air, drying, filtering, dew point

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COMPRESSED AIR MECHANICAL DRYING FOR RAILWAY BRANCH OF EUROPE

Summary. The up-to-date compressed air drying methods for necessities of different industrial branches are covered. In particular, the approved, reliable method of compressed air drying is suggested. It has proved its solvency at the enterprises of open joint-stock company "RZD".

МЕХАНИЧЕСКАЯ ОСУШКА СЖАТОГО ВОЗДУХА ДЛЯ ЖЕЛЕЗНОДОРОЖНОЙ ОТРАСЛИ ЕВРОПЫ

Аннотация. В статье рассматриваются современные методы осушки сжатого воздуха для нужд различных отраслей промышленности. В частности, предлагается апробированный, надёжный метод осушки сжатого воздуха, доказавший свою состоятельность на предприятиях ОАО «РЖД» в России.

Compressed air is one of the most widely spread sources of energy. Being comparatively cheap it has its lacks: it is permanently wet, oily and contains different by-products. Naturally it leads to technological process breach, running out pneumoautomatic elements. All these leads to economical losses.

The railway branch widely uses compressed air in different depot, plant technological processes and the train brakes management as well.

What are the main contents of the compressed air flow in mains? As the atmospheric air compresses, big quantity of moisture appears at pneumatic system. Cooling at the storage volumes and distributive mains the water vapor condenses, and the moisture becomes the main formation. The not removed wet rises corrosion risk of the distributive mains, valve, mechanism freezing, and, consequently, technological process breach. In case of wet freezing in train pneumatic main the braking system will run out, what leads to accident. A big quantity of moisture remove out of compressed air necessity is more than clear.

There are several compressed air drying methods: physical, chemical and mechanical. Different requirements for technological processes and economical possibilities define the projectors and exploitants choice for one or another system. Western specialists, as a rule, cease their choice on the compressed air drying and purification elements combination and divide into 3 main steps:
- drying;
- filtration;
- condensate management.

Based upon the class of air desired for your application, you will need various combinations of drying and filtration products to produce the compressed air effluent quality (table 1). Condensate (run-off) formed by the system may contain oil and other by-products – needed to be disposed properly to avoid contamination of the environment.

Table 1

Compressed air uses and quality standards (ISO/DIS8573-2)

Class	Oil, ppm	Water (dew point), ^0C	Dirt, μ	Typical application
1	0,01	-73	0,1	Highly sensitive equipment, critical applications
2	0,1	-58	1	Instrument quality air – instrumentation, automation, process air, paint systems
3	1	-20	5	Pneumatic machinery, air tools
4	5	2	15	General purpose – shop air
5	25	27	40	
6	–	32	–	

The basic set of elements (fig. 1) contains prefilter (1), dryer (adsorber) (2), microfilter (3), activated carbon filter (4), sterile filter (5) and steam filter (6) (for cleaning sterile filter) allows to reach compressed air of the highest quality (table 2).

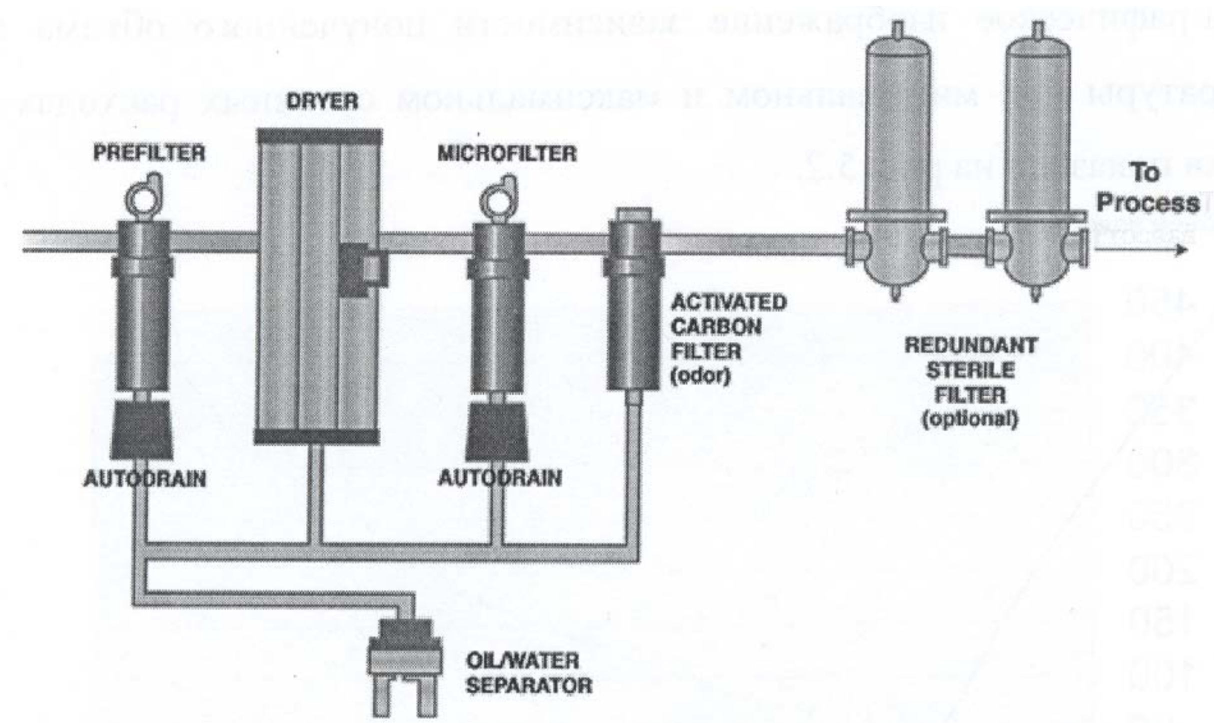

Fig. 1. Typical scheme of compressed air filtrating and drying elements
Рис. 1. Типовая схема элементов фильтрации и охлаждения сжатого воздуха

Most companies are aimed at modernization and simplifying such a set for compressed air drying. For example, Donaldson engineers use water filter-separator with cyclone system and filter element available in different pore sizes, membrane dryer, pressure regulating valve. Such a modular system is much more reliable comparing to the mentioned above, as the adsorber and all the operational inconveniences (regeneration, constant adsorbent heating etc.) are absent. Instead of it the membrane dryer is offered, allowing the -70 ^0C dew point to reach (fig. 2).

Table 2

Select guide for better air filtration system

Type of air	Examples	Recommended filter stages
Clean	General use, blow guns, simple robotics, air gauging, fine pneumatic tools	Prefilter (1) and microfilter (3)
Clean and odor free	Blow moulding, simple breathing air, instrumention	Prefilter (1), microfilter (3), activated carbon filter (4) cosmetics, food packaging, dairy production
Clean with reduced dew point	Good factory air, air gauging, conveying, shot blasting, fluidies	Prefilter (1), dryer (2), microfilter (3)
Clean and dry	Air bearings, fluidic sensors, paint spraying, critical control air	Prefilter (1), dryer (2), microfilter (3), sterile filter (5), cold atmosphere conditions
Sterile air	Process contact air, pharmaceutical, food/beverage, dairy, hospitals	Prefilter (1), dryer (2), microfilter (3), activated carbon filter (4), sterile filter (5), and steam filter (6) [for cleaning sterile filter]

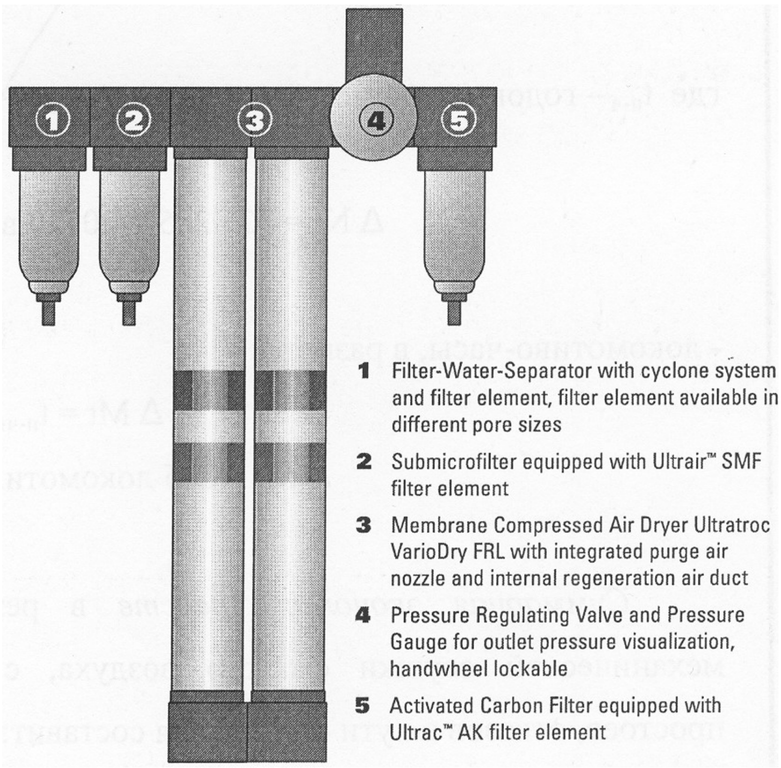

Fig. 2. Modular compressed air purification
Рис. 2. Модульная очистка сжатого воздуха

However, all the given dignities of such compressed air drying systems are very expensive and have a long recoupment period.

The fundamental investigations of compressed air drying problems for the railway transport have been working over by the group of scientists for the last 30 years at the automatic braking laboratory of the Rostov State University of Transport Communications – The Russian Federation. As the result became the device for wet removing out of compressed air, worked out by d.sc., prof. Tatiana Ripol-Saragosi [1]. The device has successfully passed the tests at the tractive aggregate of mining and processing enterprises of Russia, the Ukraine, Kazakhstan and main electric locomotives of Russia (the VL series) and the Ukraine (DE1 and DS3 with Siemens).

The construction simplicity, ecology, economy of the device, the human factor and the necessity in serving the device absence rightly make it competitive.

Setting the device at the locomotive main reservoirs it is necessary and enough to equip 4 volumes with the jalousie separators. Even for the hardest compressor work mode under Switching on/off 50% the moisture getting into the braking main is totally excluded [2].

Stationary depot and plants compressors are far from perfectness. The big quality of moisture and oil form emulsion, which appears in the main and clogs valves of distributors and then goes to the rolling stock. Depot pneumatic system as a rule consists of the following elements: compressor, compressed air storage volume(s), air cooling system. The exist elements are not enough to cool the compressed air up to environmental temperature. Hence, the moisture will condensate along the main length and go with the compressed air to the rolling stock. The condensation process will go on there as the braking mains, air distributors; supply reservoirs temperature will be considerably lower the compressed air temperature out of pressure main [3].

The idea to equip pneumatic system with the manageable throttle and the set of jalousie separators was suggested by the scientists of the RSUTC. The compressed air 0,2 MPa throttling with the following moisture precipitation allows to get the dew point reserve up to 5 degrees not depending on compressed air expense. Mathematic model with the going out to engineer formula allows to determine the compressed air moisture consistence has acknowledged the rightness of the suggested hypothesis. Taking the outcome parameters of a calculated element as the income for the following element and have united all the elements to the single whole the compressed air moisture consistence at the pneumatic system exit point equation was received:

$$x = A^{*}\left(\sqrt[40]{\left(\frac{P_1 x_1}{T_1}\cdot\frac{L_{in}}{S_{in}}\right)^{7}}\right)^{3,062}\left(\frac{(V_1+V_2)\cdot n}{(t_{in2}-t_{in1})}\frac{P_2}{T_{12}}\right)^{2,020}\cdot\left(V_{rec}\sqrt[5]{\left(\frac{P_1 X_1}{T_1}\right)^{4}}\right)^{1,396} *$$

$$*\left(0,2647\frac{(L_{tube}\cdot S_{tube}+L_{c.tube.}S_{c.tube})}{T_{12}-T_1}\right)^{4,890} *\left(0,3975\left(\frac{P_3(\rho_1\cdot W)^{0,94}S_{thr}\,F_{sep}^{\;0,37}}{2\pi\,T_{17}\,\rho_2\,W}\right)\right)^{6,890};$$

where: x – compressed air moisture consistence at the pneumatic system exit; A^* – determines environmental influence factors on air moisture consistence at the compressor entrance and cooling water influence factors between I and II stages of compressor on compressed air moisture consistence at the given point; x_1 – compressed air moisture consistence at the atmosphere air; P_1 – pressure at the entrance to compressor; T_1 – atmosphere air temperature; L_{in} – entrance branch pipe length to compressor; S_{in} – entrance branch pipe section square to compressor; V_1 and V_2 – first and second compressor stages piston volumes; n – piston turns number; P_2 – pressure at the exit of compressor; $t_{в1}$ and $t_{в2}$ – cooling water temperature at the entrance and exit of compressor; T_{12} – compressed air temperature at entrance to receiver; V – receiver volume; L_{tube} – total main length; S_{tube} – main tube section square; $L_{c.tube.}$ – cooler tube total length; $S_{c.tube.}$ – cooler tube section square; P_3 – exit pressure of the jalousie separators set; W – compressed air expense; S_{thr} – throttle through-passage hole section square; F_{sep} – jalousie separators precipitation surface square; T_{17} – compressed air temperature at the jalousie separators system exit; ρ_1 and ρ_2 – wet air density at the entrance and exit of manageable.

Power coefficients of the each equation factors determine "the weight of responsibility" for each pneumatic system element moisture precipitation ability. The calculation trustworthiness is acknowledged by 24168 experimental results treatment of Bataisk wagon depot. It goes out of the equation that the weightiest are the jalousie separator system and the throttle.

The mathematical model figure investigating co-ordination analysis with the experimental data is held by superpositioning the theoretical curves on the experimentally received values fields. The figure 3 gives the diagrams characterizing compressed air temperature and humid state at a pneumatic system of Breaks Charge and Test Device (BCTD) during the cold period of year.

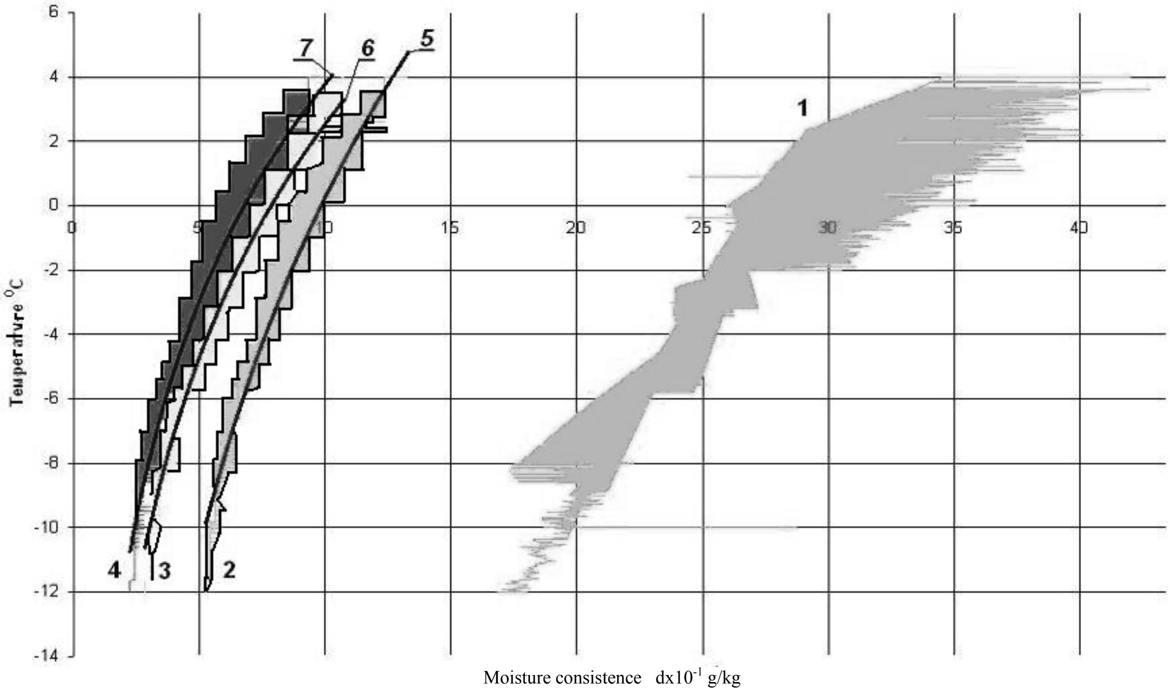

Fig. 3. T-X diagram for wet compressed air state at the pneumatic system of Bataisk wagon depot at the cold period of year

Рис. 3. T-X диаграмма состояния влажного сжатого воздуха пневматической системы Батайского вагонного депо в холодное время года

The field 1 of the fig. 3 is moisture consistence changing at the atmospheric and compressed air dependence on environmental temperature and barometric pressure as well. The field 2 shows the same parameters changing for compressed air pressure at the pneumatic system exit under P=0,8 MPa, the field 3 - the same under P=0,7 MPa and the field 4 – the same under P=0,6 MPa. The 5,6,7 are the calculated curves of compressed air moisture consistence changing dependence on environmental temperature under the different throttling pressures: «5» (P_{in}=0,8 MPa, P_{out}=0,8 MPa), «6» (P_{in}=0,8 MPa, P_{out} = 0,7 MPa) and «7» (P_{in}=0,8 MPa, P_{out}=0,6 MPa).

In conclusion, the constructive realization of the compressed air drying mechanical method both for locomotives and wagon depots (in combining with the throttle) is reliable pneumatic protection remedy from moisture, oil, by-products. It totally excludes a possibility of freezing both pneumatic main and its separate units [4].

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