The application of sorption rotors in the air drying technology

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All types of buildings are for dehumidification systems largely driven by concerns over energy usage, indoor air quality and the operational effectiveness of program types that handle hygroscopic materials. Therefore, the ability to maintain strict humidity levels within a desired range by removing moisture from supply air is a critical aspect of air conditioning system design.

Keywords: air dehumidification; the application of sorption rotors; LCC analysis; condensation method of drying

Typical buildings that need air dehumidification

The main problems that occur in the case of increased humidity above certain level in buildings of various purposes are the next:

- development of mold and bacteria
- condensation on all structures
- corrosion
- feeling of stuffy and uncomfortable air
- forming of frost or ice on heat exchangers.

Just because of that, different buildings and facilities presented in **Table 1**, require air drying treatment in order to avoid the indicated consequences :

Table 1. *Building types and humidity problems.*

#	Buildings that require moisture removal	Consequences
1	Pharmacy - production of hygroscopic medicaments	a) Medicaments cannot be used
2	Ice halls and hockey arenas	a) Deterioration of ice quality b) Increasing of the ice thickness c) Condensation of water vapor
3	Facilities with swimming pools	a) Destruction of the building structure and external walls, corrosion on metal surfaces b) Bad climatic conditions for living and strong smell of chlorine
4	Food industry, raw material warehouses	a) Formation of places with intensive growth of fungi and bacteria, issues of the microbiological situation b) Corrosion
5	Beer production	a) Growth of bacteria and microorganisms b) Low quality products

Different methods of air drying

Condensation method. The essence of the method is based on the principle of water vapor condensation, contained in the air, when it is cooled below the dew point.

The executive mechanism of the process is a heat pump with a freon contour, whose elements, the evaporator and the condenser, are located one after the other (**Figure 1**).

Moisture adsorption. Adsorption is the separation of a substance from a gaseous medium or solution by means of a surface layer of a liquid or solid. (**Figure 2**).

Thanks to the porous capillary structure of the adsorbent, it very efficiently draws water vapor out of the air, but if it is saturated with moisture, the efficiency drops drastically.

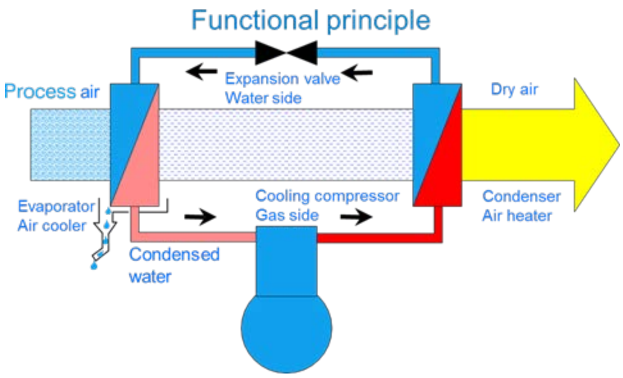

Figure 1. Functional diagram of the condensation method.

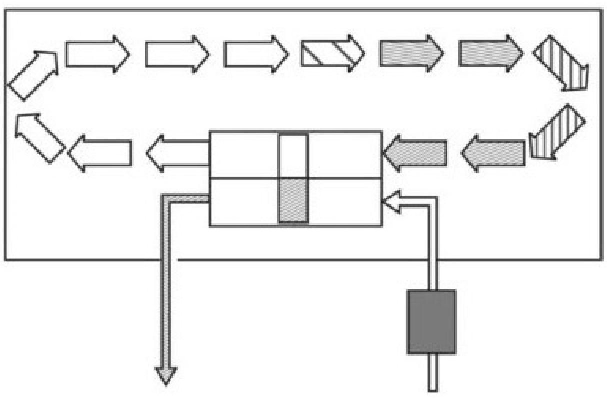

Figure 2. Scheme of sorption method of air drying.

In order to achieve a continuous process, the adsorbent must be periodically regenerated, i.e. it is necessary to eliminate the accumulated moisture by blowing hot air. In accordance with the above, the change and decrease in relative humidity can be illustrated by means of H-x diagrams (**Figure 3**):

- air heating
- cooling and then heating the air
- sorption air dehumidification

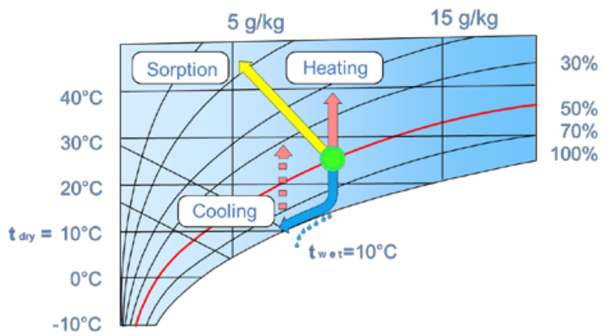

Figure 3. Changes in the condition of the air in the H-x diagram leading to a decrease of relative humidity.

Comparative analysis of different air drying methods

Sorption method against condensation. If we generally compare two conceptually different, and, in any case, realistic methods, dehumidification by cooling is functional in the case of small changes in moisture content in the air, because the difficulties in operation are necessarily manifested by freezing frost and ice on the heat exchanger – cooler with temperatures below 0°C, as soon as the task of removing a larger amount of moisture occurs.

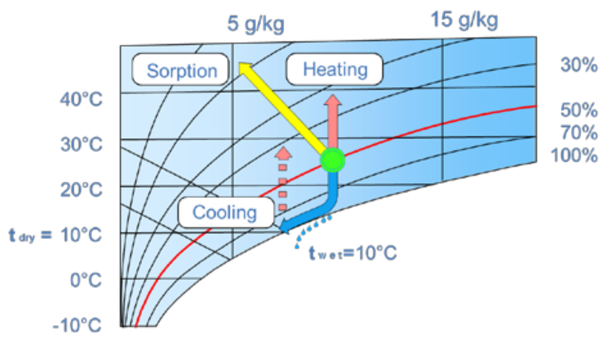

Figure 4. Comparison of different air drying methods in the H-x diagram,

On the other hand, sorption dehumidifiers function normally in the case of the elimination a large amount of moisture from the air, and they require a smaller amount of air than the condensation method to remove the same amount of moisture.

Real application of different methods in practice. The dehumidifier with integral freon contour works better in high humidity conditions, where there is no risk of ice freezing on the freon evaporator, especially for swimming pools.

Sorption humidifier works well in both dry and humid environments, but is more expensive to invest in and operate than condensation-type air drying in humid environments.

Different variants of the air drying sorption method. The RECUSORB principle (**Figure 6**) implies integrated heat recovery in the part of the sorption rotor, as a result of which the energy costs of rotor regeneration are reduced, and the dried air is drier and cooler compared to other sorption drying methods. It is characteristic for climates with moderately humid climate.

The CONSORB principle (**Figure 7**) is primarily used in very humid climates, where it shows more significant efficiency compared to RECUSORB.

Life cycle costs LCC of different air drying methods

Sorption method compared to condensation. The LCC calculation performed in this paper is based on the recommendations of the Eurovent certification system and the provisions of important standards in this area VDI 2067-1 and DIN V 18599-3.

In the HVAC technique, there are rough estimates of the operating costs of air conditioning units (**Figure 8**), but for accurate conclusions about expected costs it is necessary to calculate the LCC life cycle costs.

As a rule, the calculation takes place in accordance with the climatic conditions of the facility on which the equipment is planned to be installed and the period of its operation.

The behaviour of the building in the climatic sense is simulated by different scenarios which primarily depend on the parameters of the outside air. The following influential variables, such as energy prices, investment and maintenance costs, complete the base for the calculation.

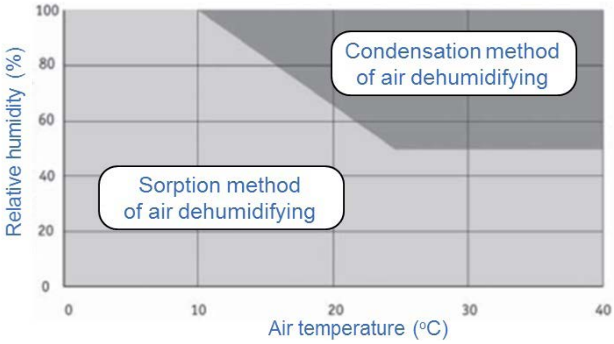

Figure 5. Areas of two methods application depending on the drying air parameters.

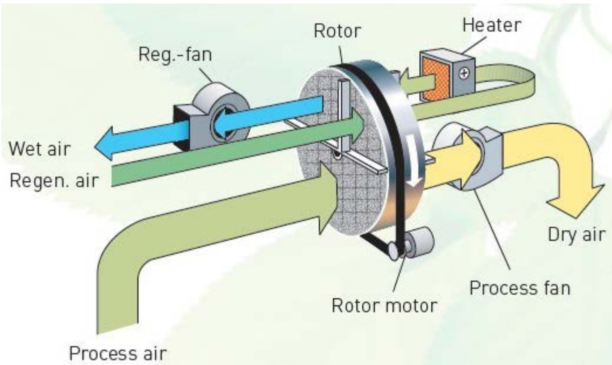

Figure 6. Schematic overview of the sorption drying method RECUSORB.

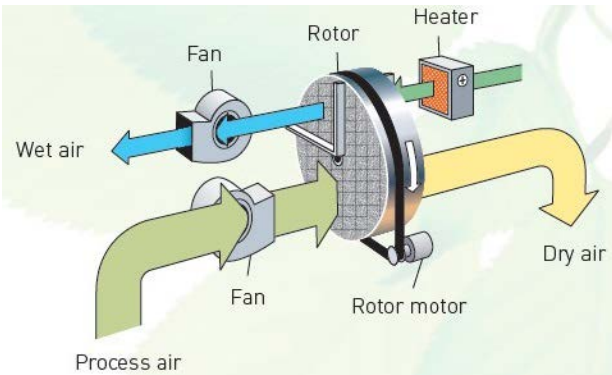

Figure 7. Schematic overview of the sorption drying method CONSORB.

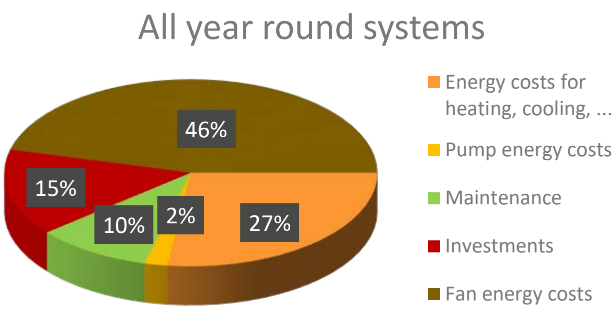

Figure 8. The share of various factors in the total cost of the equipment operating.

Concept of sorption method for air drying. The AHU for process air in hygienic design (**Figure 9**) is equipped with a mixing section with the aim of recirculating 50% of air from the room, filter section, sorption rotor, water heater, freon evaporator, compressor, fan, silencer and second stage filter. Part of the unit are sections for rotor regeneration using room air, filter, with electric heater and fan.

A ventilation unit for air extraction and recirculation has been designed separately. An obligatory element in this concept is the remote freon condenser, and the correctly chosen rotor is most responsible for the functionality and dehumidification of the air (**Figure 10**).

Tandem compressors ZR94 + ZRD94 (**Figure 11**), one of which is digital, due to precise automatic regulation, together with the evaporator and remote condenser, cool the heated air after the rotor with a slight deviation from the desired parameters of the incoming air.

Concept of condensation method for air drying. It was designed the two-stage AHU with mixing section, air heater, glycol cooler with the specific temperature regime of propylene glycol –3 / –8°C, electric heater, fan, silencer and a second-stage filter (**Figure 12**).

The specificity of this unit is the need for cooling and drying the air to a temperature of 0°C, as a result of which there is the formation of frost and ice on the exchanger, which must be eliminated due to functionality by means of electric heaters built into the fins. This need also requires the use of a non-standard chiller which has the ability to cool a mixture of water and glycol to a regime of –3 / –8°C.

General conditions for the equipment selection of both systems

A detailed overview of costs for 15 years operation time period is presented in the Annex of online version of this article.

Conclusion

The presented LCC analysis compares, from the technical-economic aspect, two realistic methods for dehumidification of air in space, sorption and condensation.

The method for dehumidification with by means of a sorption rotor is characterized by significantly higher investment costs, but during operation it has a distinct advantage in reduced consumption of electricity and

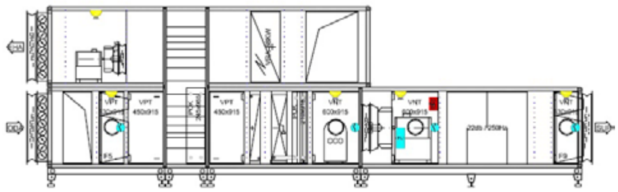

Figure 9. The drawing of Air Handling Unit for process air treatment.

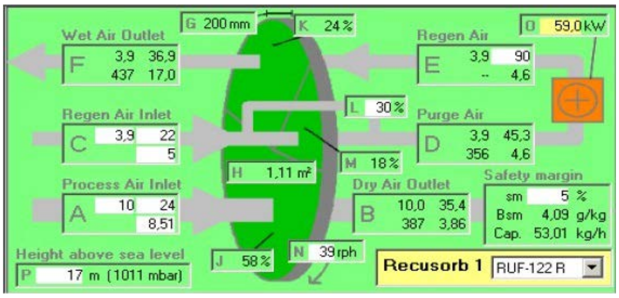

Figure 10. Technical characteristics of the sorption rotor.

Figure 11. Cooling circuit with tandem compressors in the AHU.

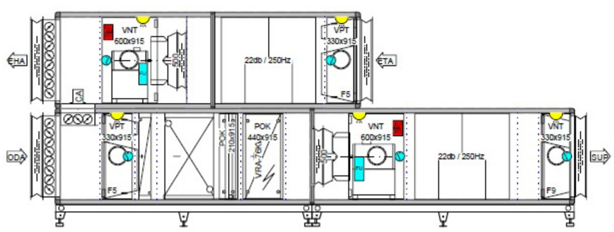

Figure 12. Drawing of AHU for air drying by condensation method.

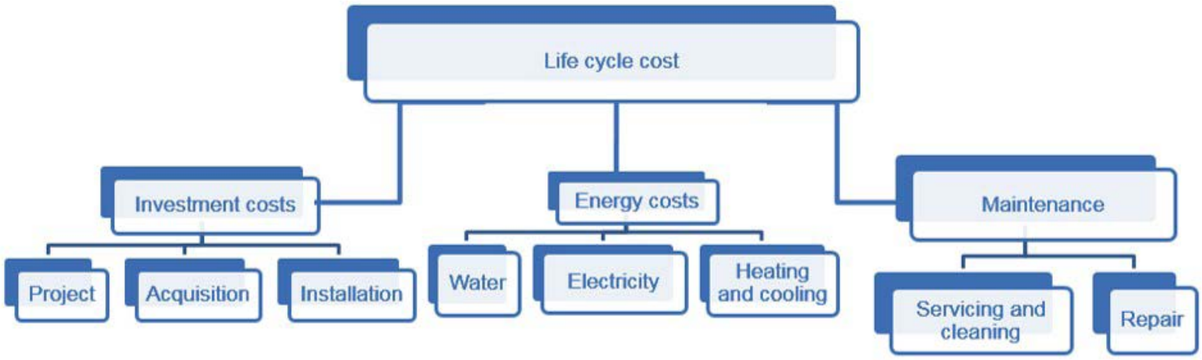

Figure 13. Components considered in the LCC calculation.

cooling energy, to the extent that the investment pays off after 8 months from the start of operation.

The LCC analysis calculation has been done for a pharmaceutical plant in close environment of Moscow, Russia, the main input data were presented in **Table 2** and comparative chart for both system on **Figure 14.** ■

Results of LCC analysis

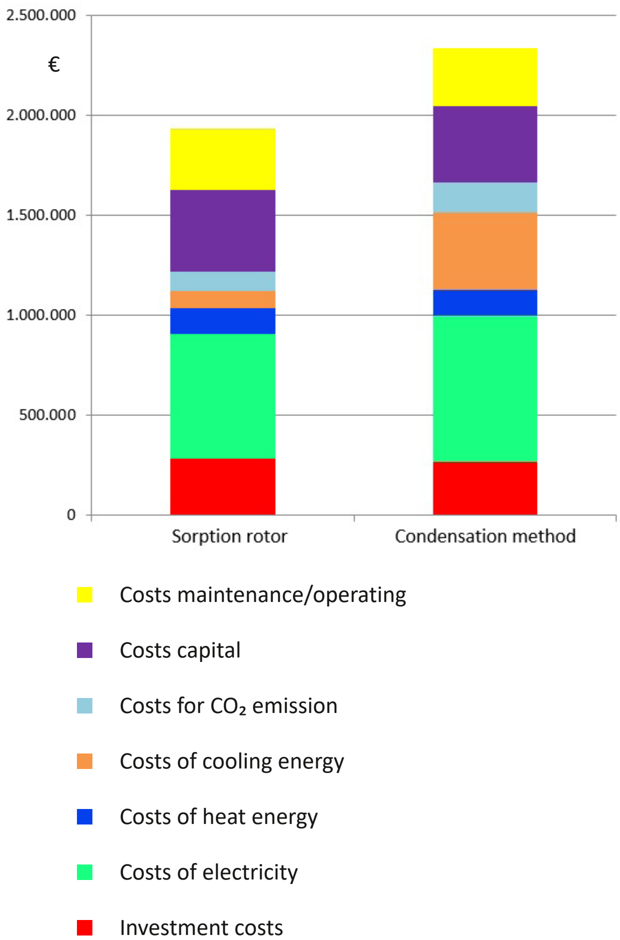

Figure 14. Comparative chart of LCC costs.

Table 2. *Input data for LCC analysis (Location: Moscow, Russian Federation).*

Review period	15 years
Period of operation time	15 years
Annual interest rate	5%
Annual service and maintenance costs	6%
Annual system operation time	8760 hours, without stopping
Supply airflow	10.000 m^3/h
Exhaust airflow	10.000 m^3/h
Room temperature	22°C
Relative humidity all year round no more than	30%
Outdoor air parameters in Moscow	
Winter	$T = -25°C$, $\varphi = 83\%$
Summer	$T = 26°C$, $\varphi = 55{,}9\%$
Energy costs in Moscow	
Electricity	0,11 €/kWh
Heating	0,03 €/kWh
Cooling	0,05 €/kWh
Emission CO_2	0,017 €/kg
Price change factors	
Investment/service/operation	3%
Energy consumption	4%

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