Auxiliary Equipment

1. Compressor Coolers

Approximately 80% of the electrical energy used by the compressor is converted to heat during the air compression process. Removal of the heat thus released from the compressor is important in terms of compressor's sound operation. Compressor cooling is usually achieved with air and/or water.

Air intake coolers are used to cool the air taken into the compressor as much as possible especially in applications with high ambient temperature. In this way cold air that is denser than hot air can be compressed to a larger degree in each compression cycle. Furthermore coldness of the air taken into the compressor lowers the effort that will be probably expended in intercoolers and aftercoolers in subsequent stages.

Intercoolers are usually used to maintain system efficiency by cooling the air that has heated in the compressors that perform compression in two or more stages between the stages.

Aftercoolers are used to cool the air that has been heated after the compression process or to cool the oil in oil injected systems. In these systems, cooling can be achieved with air or water. Since the moisture holding capacity of cooled compressed air will be less than hot air as shown in Figure 12, overloading of the air dryer equipment used to dehumidify the air can be minimized with aftercoolers.

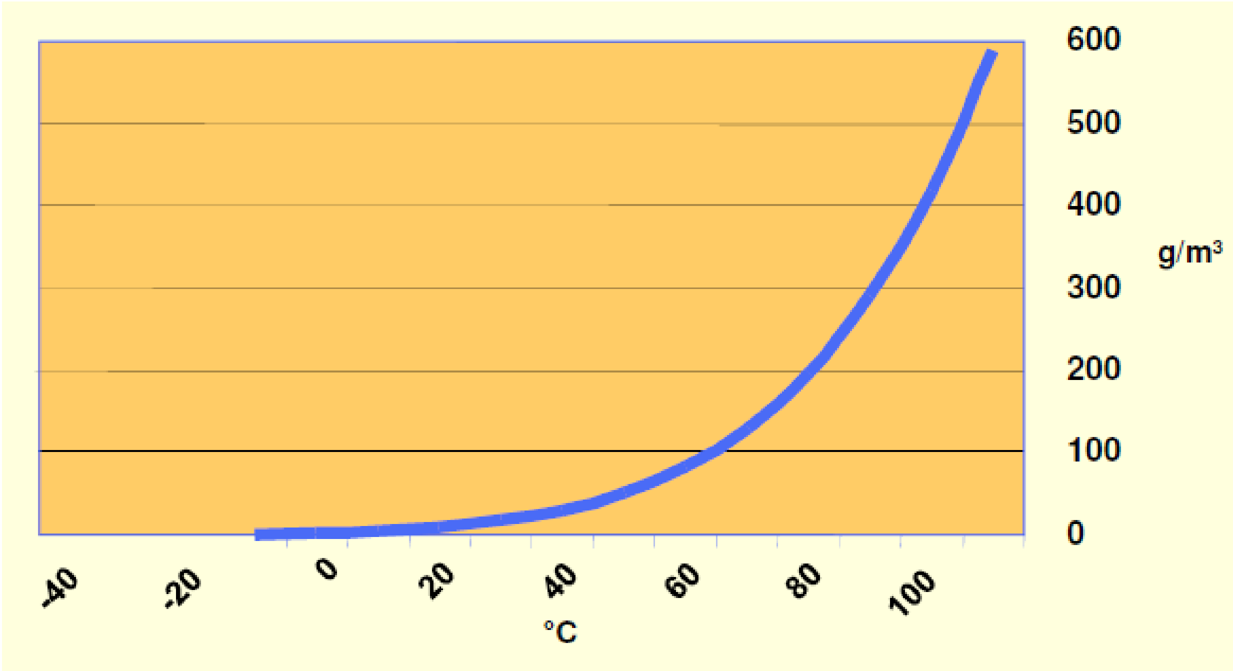


Figure 12. Moisture Holding Capacity of Air According to Temperature

2. Air Dryers

The temperature of air that issues from aftercoolers and water separators is usually higher than ambient temperature and the air is fully saturated with moisture. Compressed air cools as it moves along the air distribution line and its moisture content condenses. This results in rusting of pipes in air distribution pipes as seen in the examples in Figure 13, and contamination of air in end use points.

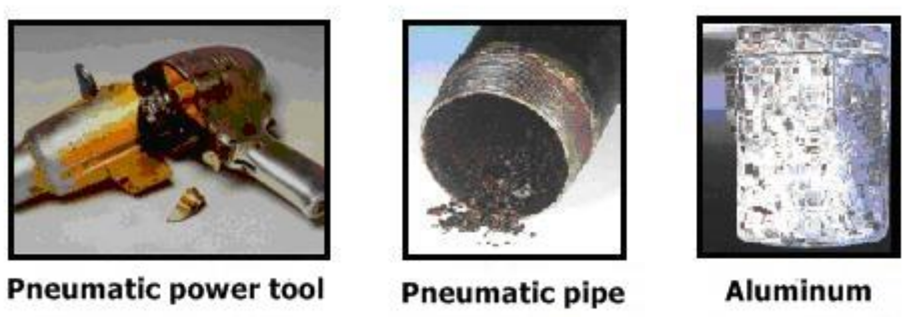


Figure 13. Consequences of Using Humid Air

Dryers with different operating characteristics and dew points (the temperature at which the moisture in the air begins to condense) can be needed in different compressed air applications. Particularly in applications where ambient temperature is very low in winter conditions, dryers with excessively low dew point is required to prevent frosting in pipes.

Refrigerant dryers, adsorption dryers, and membrane dryers are types of dryers commonly used in the compressed air industry. Dew point classes of the above mentioned dryer types according to energy requirements has been shown in Figure 14.

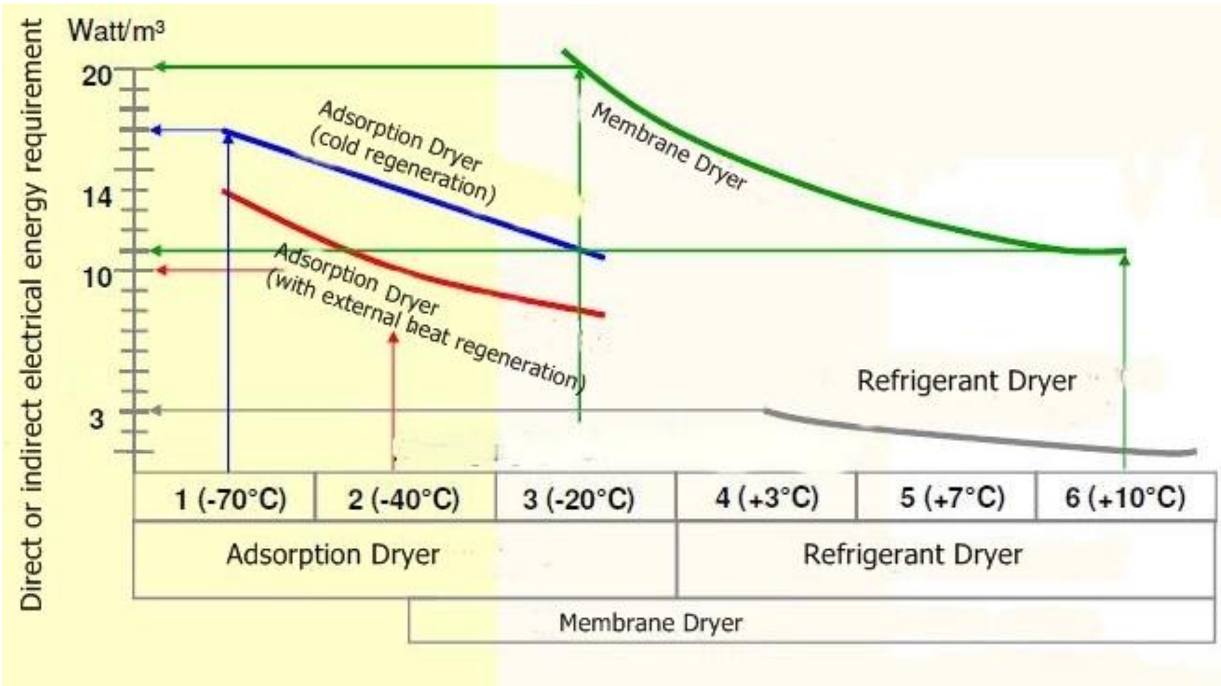


Figure 14. Pressurized Dew Point Classes of Dryers

2.1. **Refrigerant dryers:** In this system, compressed air is cooled via a refrigerant gas in the heat exchanger. The moisture in the compressed air condenses and is removed from the system. The difference between the intake air temperature and dew point temperature determines the amount of condensed moisture. The higher the difference the higher the condensation and the lower the amount of moisture remaining in the air. The structure of a refrigerant gas dryer is presented in Figure 15.

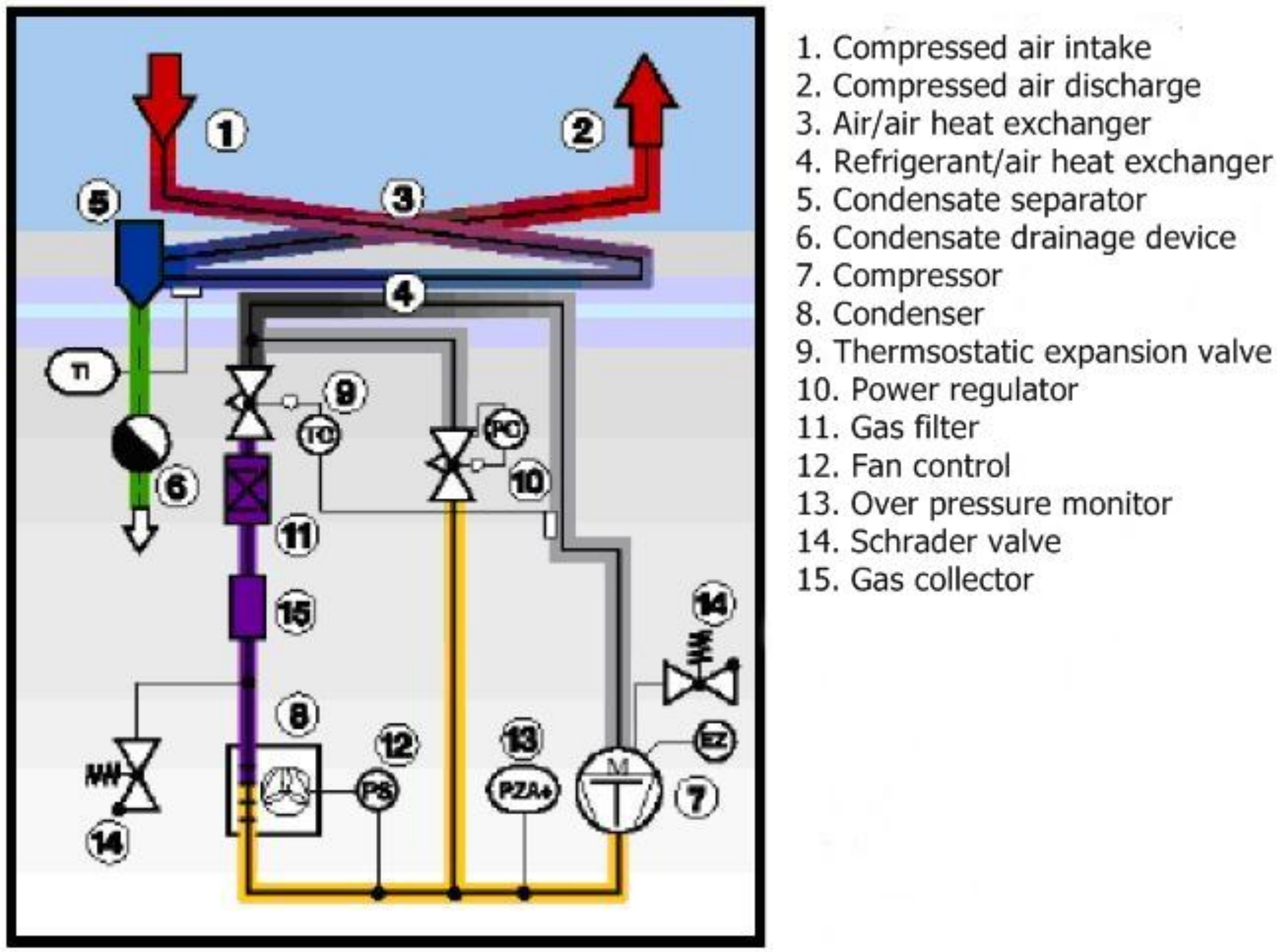


Figure 15. The Structure of a Refrigerant Dryer

The drying step comprises two steps. In the first step, the hot, compressed air is subjected to pre-cooling in a counter flow air/air heat exchanger with the excessively cold air issuing from the refrigerant gas exchanger. This stage which does not consume energy lowers the load of the cooling compressor, lowering energy expenditure also warms the discharged air, helping prevent condensation within pipes in the air distribution line, and the consequent corrosion. Approximately 60% of condensation occurs in this stage. In the second step, compressed air that passes through the exchanger set up where cooling occurs with the refrigerant is cooled down to the dew point, after which the moisture remaining in the compressed air is condensed and automatically removed from the system.

2.2. **Adsorption dryers:** Dryers of this type dry the humid air using the porous dry material they include. This dry material that has been saturated with the moisture from the air has to be de-humidified before it can be used again. Air below the 0°C pressurized dew point can be obtained with adsorption dryers. However the regeneration air needed to render the moisture saturated dry material usable means that these systems using this type of dryer consume extra energy. Figure 16 shows the structure of adsorption dryers.

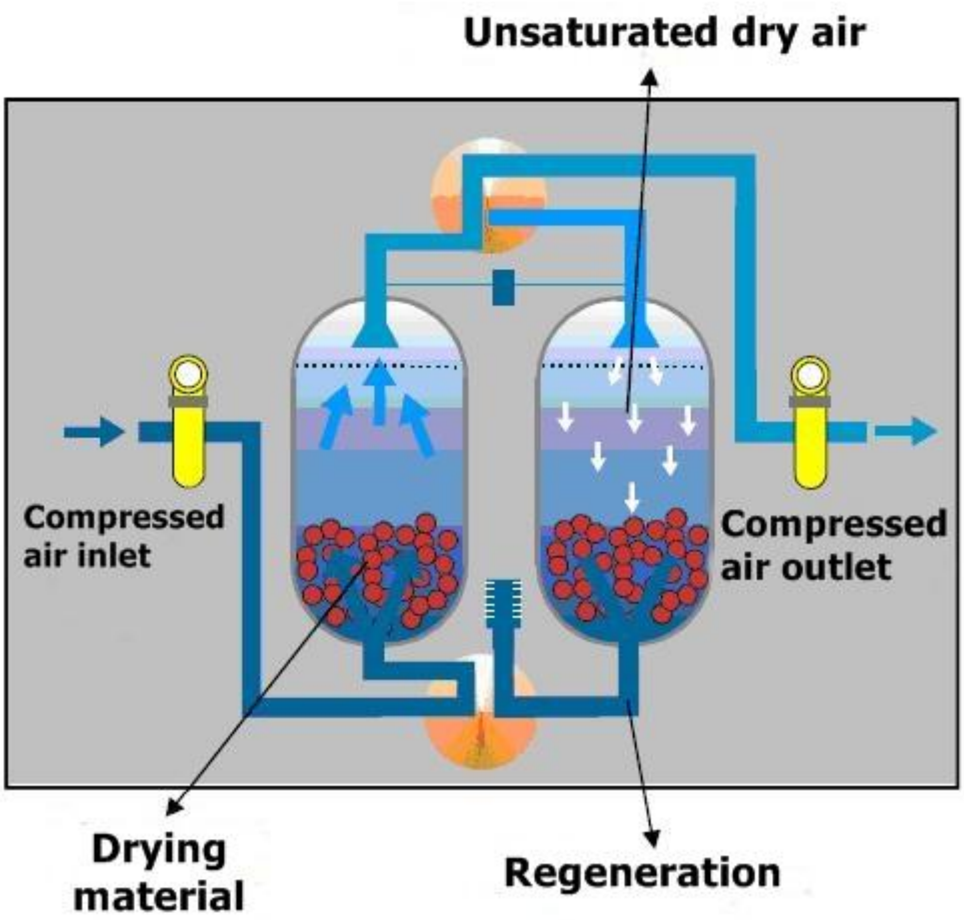


Figure 16. Structure of Adsorption Dryer

Adsorption dryers that allow cooling below the pressurized dew point of -70°C and are also known as regenerative dryers, are classified according to their methods of regeneration.

Heatless regenerative dryers operate on the principle of using part of the dried air as regeneration air. This regeneration air first expands and becomes ready to hold moisture. As it passes over the moisture saturated dryer it removes the moisture on the material and is released to the atmosphere from a discharge. In this way, the air that is saturated in moisture is discharged to the atmosphere and can not be recovered. Heatless regenerative dryers spend approximately 15-20% of their capacity to provide the regeneration air, which translates to roughly 3-4 kW of energy being lost for every 170 m^3/h of flow.

Thermal regenerative dryers without a fan take a small portion (approximately 7%) of the dried air and heat it by passing it through an integral our external electrical dryer. The heated dry air efficiently removes the moisture held by the dryer material. Dryers of this type use approximately 2.25 kW of electrical energy per 170 m^3/h of flow.

Thermal fan regenerative dryers pass the heated ambient air over the moisture saturated dryer material using a fan. Since compressed air obtained from the compressor is not used, no losses occur during the process. After this heating cycle a quantity of compressed air is usually used to reduce the dryer material to operational temperature. The air used for this cooling process consumes approximately 2.5 kW of electrical energy per 170 m^3/h of flow. If an additional unit is used to cool the compressed air, this leads to an additional energy consumption of 0.6 kW.

2.3. Membrane dryers: In this type of dryer, drying is achieved as moisture is separated from the air by passing through a semi permeable membrane element of a micro fiber structure that allows the passage of only water vapor molecules. These units use approximately 20% of their rated power to sweep the moisture held on the membrane with compressed air. Since the compressed air used for sweeping moisture is released into the atmosphere air losses are unavoidable with membrane type dryers. Figure 17 shows the structure of membrane dryers.

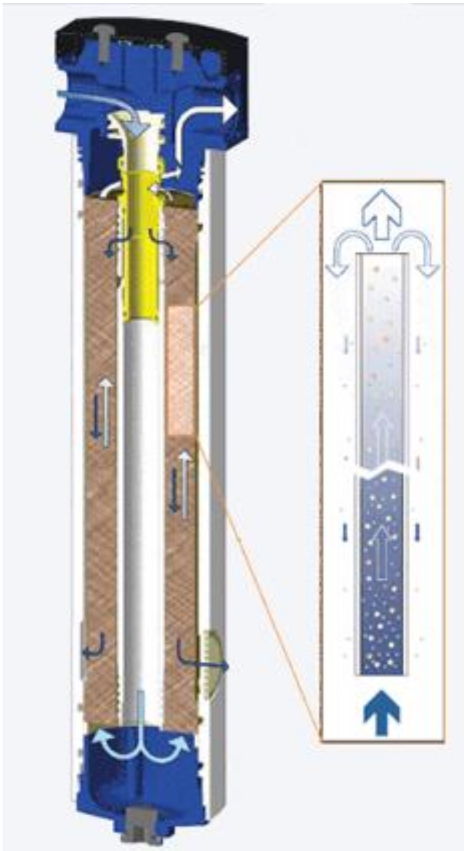


Figure 17. Structure of Membrane Dryer

The dryer module consists of thousands of specially selected porous membrane packages and a pipe open at both ends in which these are contained. A quantity of dried compressed air (regeneration air) from the module outlet is passed from a restricting valve via the bypass system and flows in the counter direction around the membranes. Water vapor molecules seeping from the membranes are discharged into the atmosphere via this air. Membrane dryers can be adapted to various intake temperature conditions and pressurized dew point temperatures of almost -30°C can be achieved.

3. Compressed Air Filters

Particles contained by within the compressed air are filtered in various methods according to their dimensions as can be seen in Figure 18. If the size of a particle is larger than the opening of the filter material, the filtration occurs mechanically. This process usually applies to particles larger than 0.5 micron and surface filters are used for this purpose. Deep bed filters are used for particles smaller than 0.5 microns.

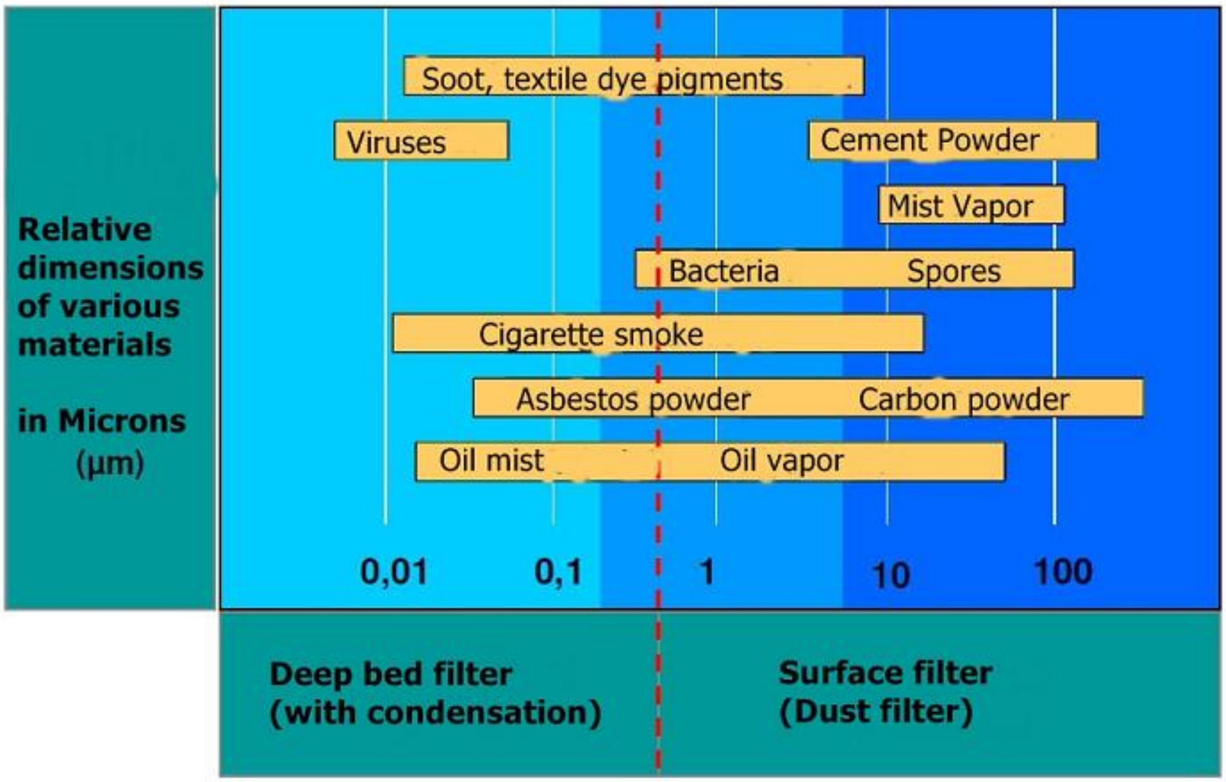


Figure 18. The Filtration Spectrum

In surface filters, particles are separated on surfaces placed transverse to the direction of flow. As seen in Figure 19, particles larger than filter pores are held up on the surface, achieving filtration. If maintenance periods are not applied, particle build up on the filter surface leads to substantial pressure losses. Air flow is always from the outside in. Surface filters are usually used as pre filters.

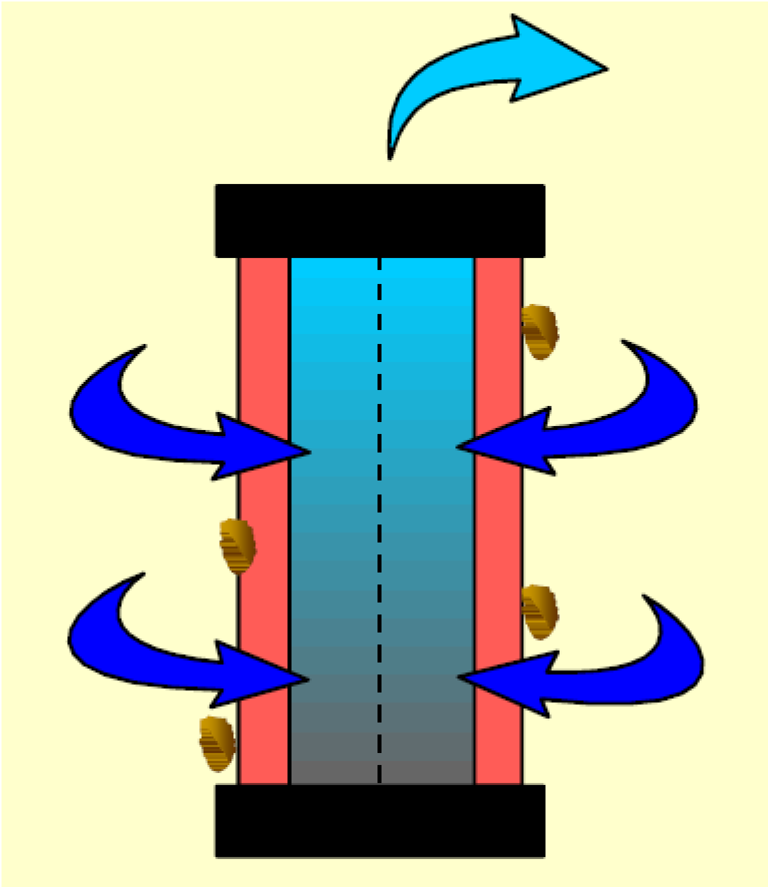


Figure 19. Structure of a Surface Filter

Deep bed filters are also known as micro filters. Air flow is from the outside to the inside as indicated in Figure 20. They are used for filtering particles smaller than 0.5 microns. Filtration occurs through direct contact, permeation or diffusion depending on particle size.

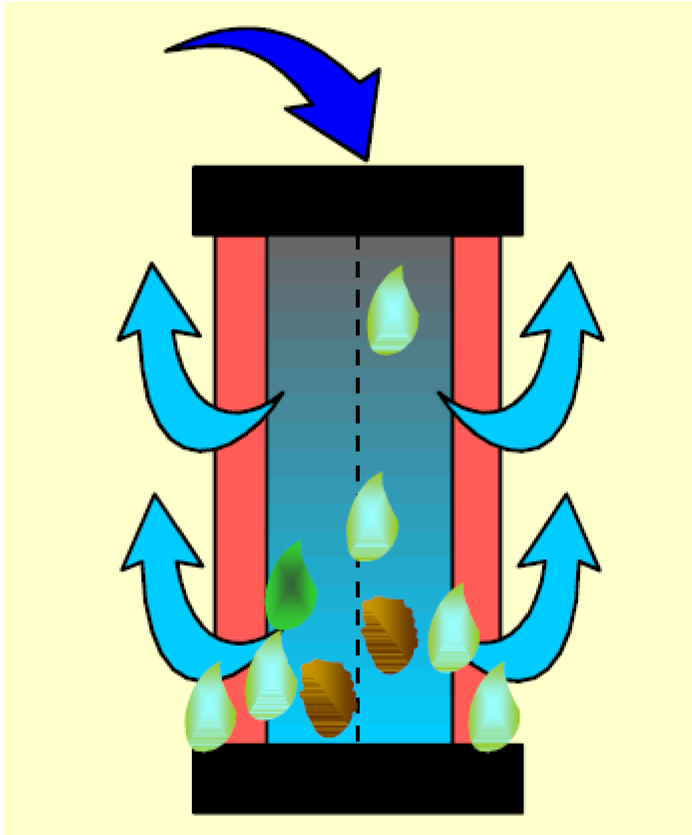


Figure 20. Structure of a Deep Bed Filter

While surface and deep bed filters can be used for the filtration of gaseous oil contained in compressed air, the filtration of liquid oil occurs by a different method. For the filter to be able to hold liquid oil, it should contain materials capable of adsorption and generally active carbon filters or active carbon separators are used for this process as in Figure 21. While active carbon filters have a short service life and require pre-filtration, active carbon separators have longer service lives as compared to active filters but also require post- as well as pre-filtration.

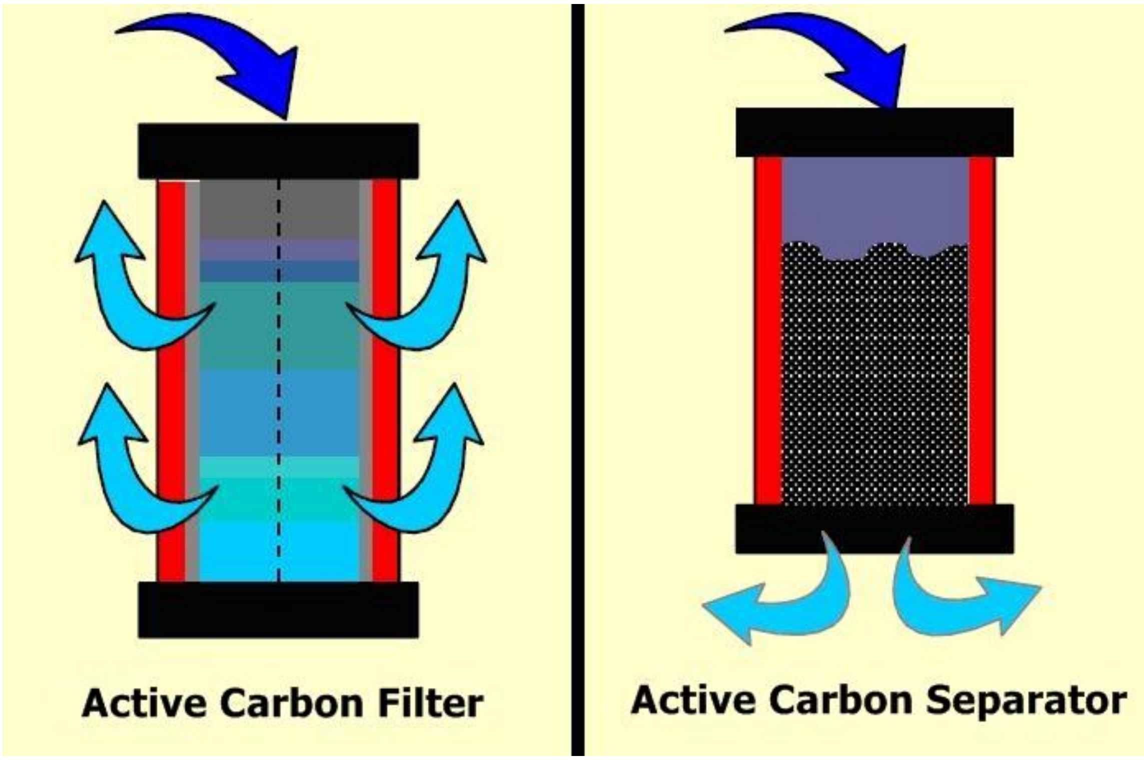


Figure 21. Oil Filtration Equipment

The quality of the compressed air is classified by its particle quantity, and water and oil density. Standardized compressed air quality is defined in ISO 8573-1 as provided in Table 1.

Table 1. Compressed Air Quality Classes in ISO 8573-1

ISO 8573-1 Class	SOLID PARTICLES		MOISTURE AND WATER		OIL
	Max. particle size [micron]	Max. concentration [mg/m³]	Pressure dew point [°C]	Liquid water content (x) [g/m³]	Total oil content [mg/m³]
0	Please contact DALGAKIRAN for clean room and pure air technologies.				
1	0.1	0.1	≤ - 70	-	≤ 0.01
2	1	1	≤ - 40	-	≤ 0.1
3	5	5	≤ - 20	-	≤ 1
4	15	8	≤ + 3	-	≤ 5
5	40	10	≤ + 7	-	-
6	-	-	≤ + 10	-	-
7	-	-	-	x≤ 0.5	-
8	-	-	-	0.5<x≤ 5	-
9	-	-	-	5<x≤ 10	-

The table for refrigerant dryers and adsorption dryer with different filter variations in light of the ISO 8573-1 compressed air quality classes is provided respectively in Figures 22 and 23.

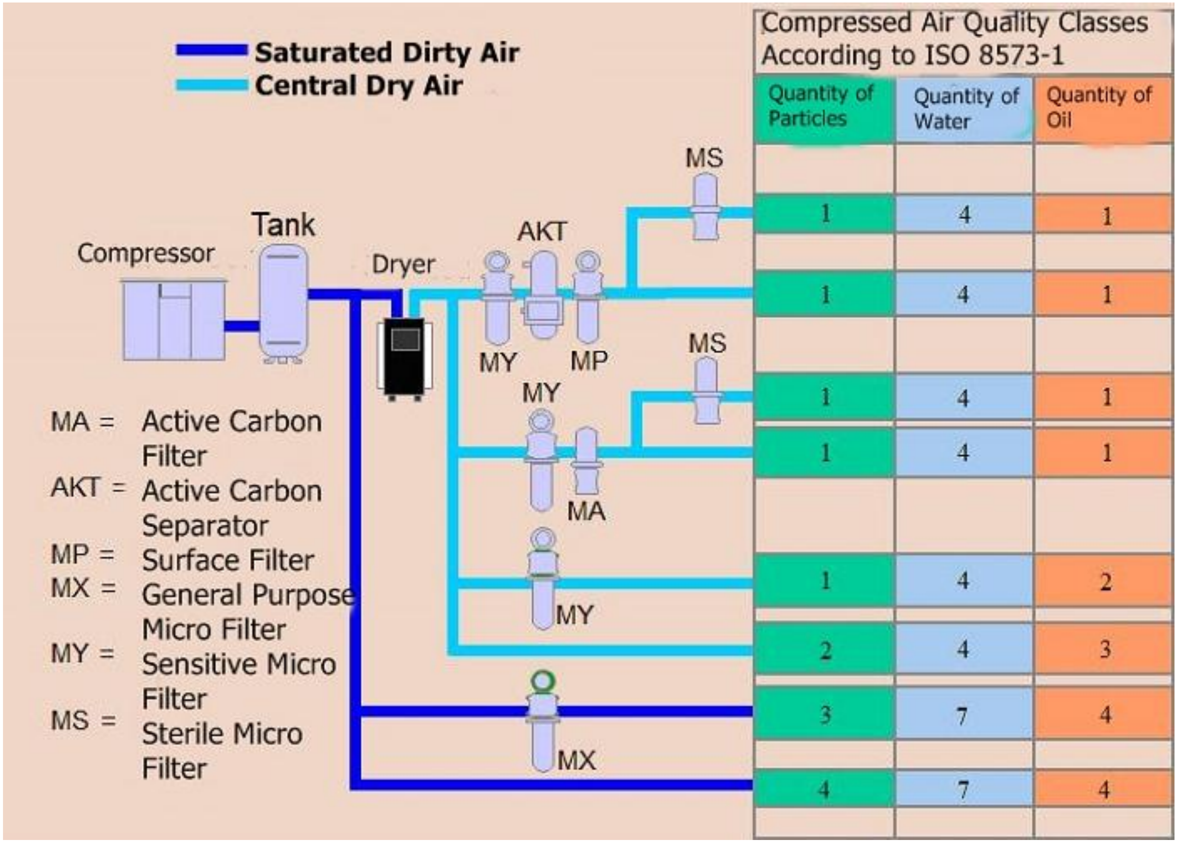


Figure 22. **Air Quality Classes by Refrigerant Dryers**

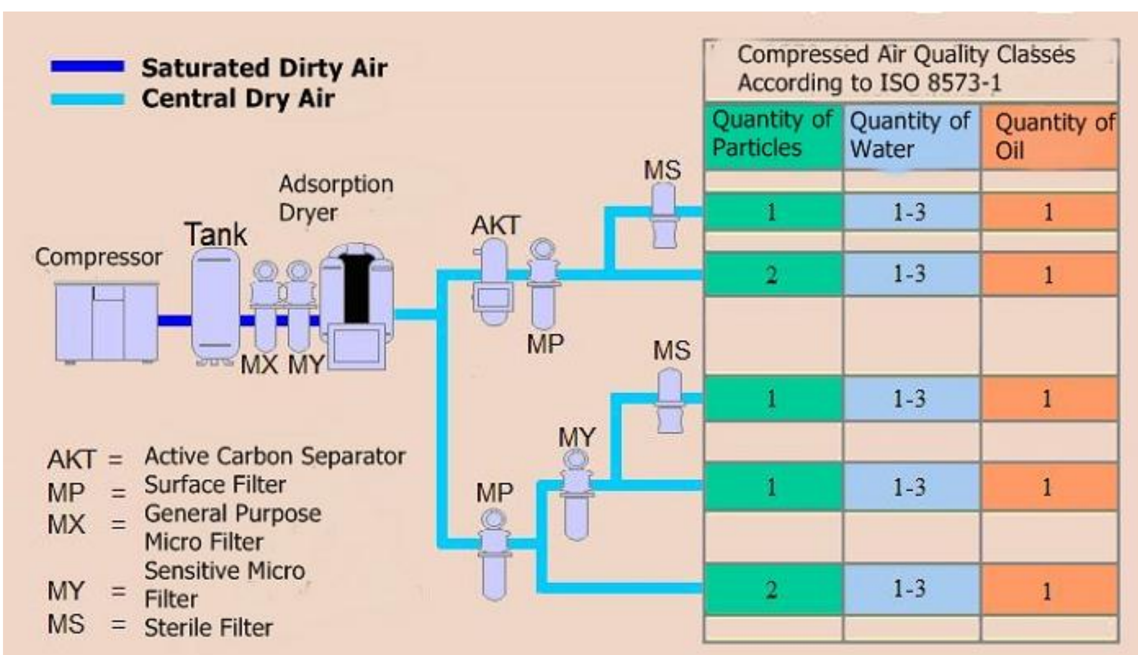


Figure 23. **Air Quality Classes by Adsorption Dryers**

4. Compressed Air Tanks

Using pressure vessels with sufficient capacity in compressed air systems is of utmost importance in maintaining air quality and the efficiency of the air system. They can be manufactured in horizontal, or vertical form as shown in Figure 24, according to the area of use. Tanks are equipped with manometer, safety valve, inlet-outlet fitting and condensate relief valve as standard. Tanks are typically examined in two groups, namely primary and secondary air tanks.

Figure 24. A Vertically Placed Air Tank

Primary air tanks generally serve as a tank for general system, and are placed near the compressor. Among the significant benefits of primary air tanks in compressed air systems are preventing the fluctuations caused by reciprocating compressors, creating an environment to remove the oil and water from the air, supplying the required amount of air when the demand of compressed air peaks without an extra compressor, lowering the frequency of start-stop and loaded-unloaded operations of screw compressors, and obtaining better compressor control and stable system pressures by minimizing the system pressure differentials. The location of primary air tanks in relation to the dryers also has a strong effect on pressure stability. The primary air tank placed after the dryer can use the dried air it stored when a sudden increase in compressed air demand occurs, whereas a primary air tank placed before the dryer can put a strain on dryer capacity since it has to feed the compressed air to the dryer first, thus meaning an inefficient drying process and higher energy consumption.

Secondary air tanks, on the other hand, are typically placed near the end use points of air distribution systems. Secondary air tanks have such duties as protecting sensitive equipment against temporary pressure drops and protecting many users in the system for compressed air applications in a broad range, and maintaining the stability of system pressure equipped with air distribution lines that are designed narrower than then they need to be.

5. Separators and Condensate Drains

Separators remove the liquid molecules that are collected with the air stream in the compressor inlet from the compressed air. They are typically placed after the aftercooler and remove the condensate.

Condensate drains assume the duty of ejecting condensed liquid molecules in all separators, filters, dryers and air tanks in the compressed air system. There are four options for condensate drains, namely manual, floating, time controlled solenoid valve, and electronical level controlled drain.

Manual drains are generally placed where the condensate is accumulated and this condensate is drained manually from the system. It allows the compressed air to be ejected from the system along with the condensate since the draining process is manual.

Floating drains do not allow air leaks when operating properly. However, due to the fact that it is difficult to determine whether it is operating, its maintenance is difficult, and it is prone to clogging due to deposit accumulation, it can not be said to be a very efficient drainage mechanism.

In time controlled solenoid valves, since the time setting is usually adjusted to the worst condensate density scenario, excessive air leakage is unavoidable in case of low condensate accumulation. In some cases when a shorter time setting is made than required for the completion of the condensate drainage, the condensate accumulated in the system leads to corrosion, reduced air quality, and resultant energy loss.

When drains with electrical level control are used, since the accumulated condensate is electronically regulated drainage valves are only opened to the extent required and air leakages are not observed in the system. Such condensate drains are not affected by dirty environments, and are easy to maintain. This is the most current and efficient drainage method.

6. Flow Regulators

Flow regulators are usually used on outlet points of compressor chambers to compensate more precise system pressure as compared to compressor controllers. These units can be controlled pneumatically as in Figure 25, as well as electronically by precise PID control. More efficient air pressure and higher system pressure stability can be obtained thorough these valves.

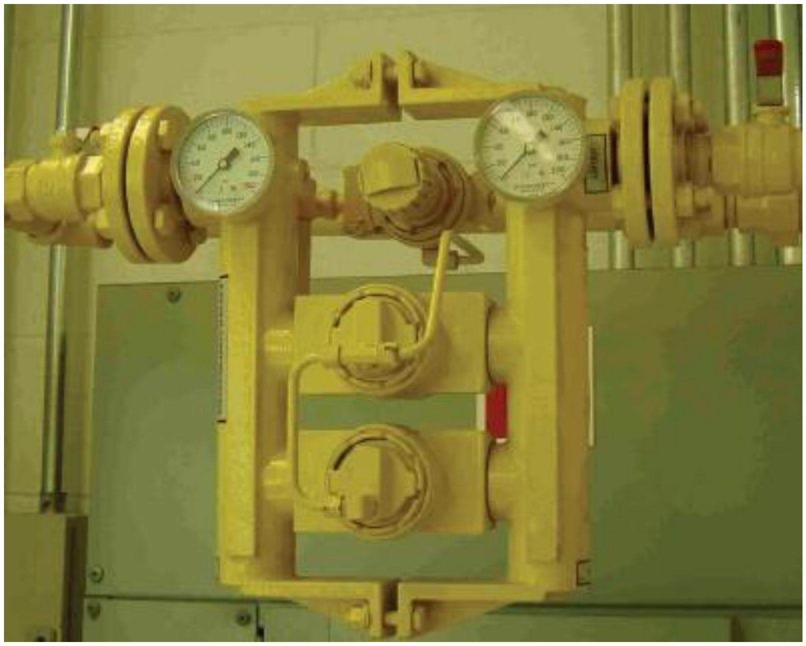
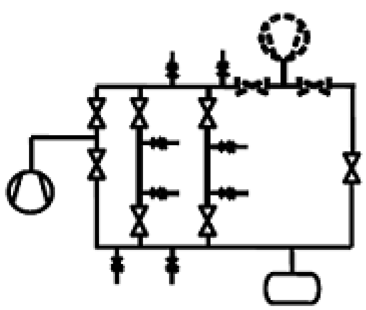


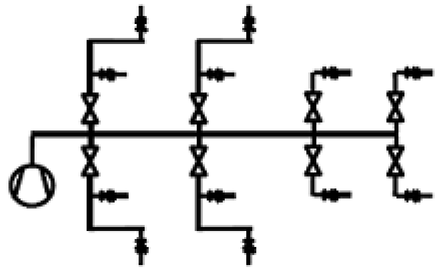
Figure 25. **Pneumatic Flow Controller**

7. Air Distribution Systems

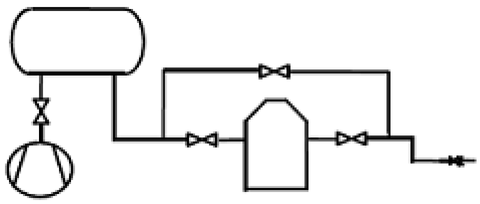
In cases where a centralized compressed air system is employed, pipelines to feed all points that require compressed air should be installed. Pipelines have the duty of providing sufficient amount of economic compressed air in desired pressure level and quality, and with the minimum pressure drop possible. Flow rate, operating pressure, length of the line and pressure drop are the criteria to be considered when determining the size of the pipe line. Compressed air systems are usually applied in the form of ring lines, linear lines with side branches, and independent local compressed air stations.



Since air flow can come from all directions, it is possible to reduce the cross section of pipes by half in **ring lines**. The point that requires attention is ensuring the insulation by placing a secondary tank near these points in order to prevent pressure fluctuations that might occur due to the independent points that consume excessive air.



Linear lines with side branchescomprise a main line coming out of the compressed air station and branches that distribute the air to the consumption points through this line. Cross sections of the branch lines are smaller than of the main line.



Local independent compressed air stations can be preferred in places such as iron and steel facilities that have very long compressed air cycles and heavy energy consumptions independent from each other. In this way, the necessity for overly large pipe diameters is averted.