Compressed Air System Filters

This white paper explains the different Compressed air treatment filters available to eliminate the unwanted substances in compressed air and the advantages of using the correct purification system.

Compressed Air

Before talking about filtration, we need to assess the composition of air and the reasons for compressed air treatment.

Compressed air is an integral part of every manufacturing industry from small machine shops to large scale plants. It is widely regarded as the fourth utility.

Compressed air is the ambient air that has been pressurized to perform a particular task. It is preferred over utilities like electricity and steam because of its flexibility, safety and adaptability along with its ease of storage and transmission.

Compressed air system consists of supply and demand side. The supply includes the compressor, treatment equipment and air receiver while demand is the point of use application.

Compressed Air Contaminants

Ambient air is a mixture of gases and other constituents in varying amounts. 1% of the ambient air composition includes water vapour and pollutants such as dust, oil vapour, pollen, micro-organisms and Volatile Organic Compounds (VOC) etc. The amount of moisture in the atmosphere can depend on the temperature. The composition of these substances in the ambient air can be considered negligible.

The compressor sucks in large volume of the ambient air and pressurizes it to smaller compressed volume. While the volume of the air decreases, the incompressible contaminants and moisture increase in concentration. The oil vapour and VOC's coalesce to form bigger droplets. The compressor itself will contribute to the contamination in the form of rust and compressor oil-carry over (in oil-flooded compressors). These contaminants can have harmful effects on the compressed air system and the point of use machines as well as products. Most air compressor has an intake particulate filter which can remove dust and dirt particles up to a particulate size of 25µm, but they are designed to protect the compressor rather than the downstream equipment.

Compressed Air Treatment

The treatment of the contaminants is dictated by the quality of air required by the application.

Compressed air usage in a plant can be broadly categorized into the following along with the problems they face.

- **Plant air**: - Dust, water and oil will get deposited in the inner surface of the pipes and machines. This results in pressure drop and reduction in machine efficiency, driving up the cost of production. The contaminants also form a sludge and plug the pipes, fittings and machines, causing total shutdown.

- **Valves & Cylinders**: - The sludge can create resistance to the motion of the pneumatic cylinders. The dust renders the lubricants ineffective and causes wear on the seals and bearings. The rubber diaphragm can stiffen and rupture after absorbing moisture.
  The pneumatics loses its versatility and precision leading to defective products.

- **Air Tools**: - Pneumatic tools are designed to work with clean, dry air at a designed pressure. The air motor powering most air tools have close tolerance between the rotor and the cylinder. In the presence of the contaminants, the motor gets choked, resulting in frequent expensive maintenance. The lubricant quality also degrades, resulting in excessive wear.

- **Instrument air**: - Control air supplied to transmitters, sensors, indicators, gauges and other critical equipments have orifices that can be easily clogged by dirt. The malfunction of these vital equipments can be hazardous and corrupt data.

- **Process Air**: - The air comes in direct contact with the product in many industries. In industries like textile and print, oil can degrade the quality and render the product unusable. In pharmaceutical and food industry, these contaminants can be life threatening and can damage the reputation of the brand.

  There are multiple health and safety standards, imposing strict regulations on the compressed air used for direct product contact.

- **Test Chambers**: - Various testing facilities depend on the accuracy of their machines. Machines like CMM use air-bearings which can be choked by dust and oil.

- **Breathing air**: - Healthcare facilities depend on the quality of the compressed air for breathing as well as for generation of various gases. Contaminants can cause microbial growth in pipelines, infecting the consumer.
  The ingestion of contaminants like VOC’s can be lethal to humans and have stringent regulations for its control. Respirators are also used in industries with hazardous environment.

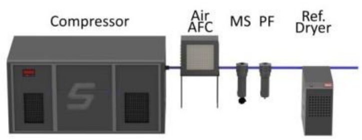
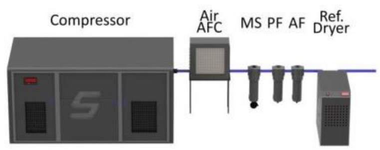
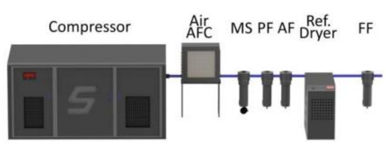
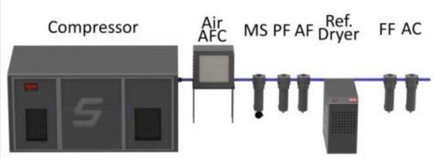
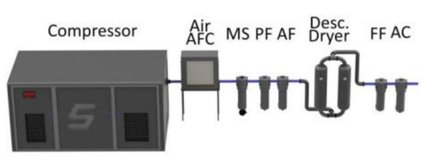
Application	Circuit Layout	ISO Rating		Application
		Without Dryer	With Dryer	
Simple Dust Filtration		3.-.-	3.4.-	Dust filter for dessicant dryers. bulk dust removal, pre filter to AF & FF grade filters
General Purpose		3.-.-	3.4.-	General engineering, bulk particle removal, heavy pneumatic tools, air blowers, pre filter to vaccum pump
Oil Removal		2.-.2	2.4.2	bulk liquid removal, pneumatic tools/controls. compressed air motors/conveyors. sand blasting. shipyards and off shore. pre filters to dessicant dryers. pre filter to FF & CF grade filters
Oil aerosol Removal- oil free		1.-.1	1.4.1	spray painting, air bearings, analytical instrumentation, air gauging, precision pneumatic tools/ regulators cnc machines, packaging. pre- filter to dessicant dryers- oil free air. pre- filter to cf grade filters
Totally oil free		1.-.1	1.4.1	process air pharmaceuticals, food & beverages, medical, hospitals, photographic labs, critical instrumentation, diaries, galvanizing smell & taste removal, breathing, aviation, cosmetics, electronics etc
Bone dry air		N.A.	1.3.1 (-20Deg.C) 1.2.1 (-40 Deg.C) 1.1.1 (-70Deg. C)	all the above application, but with very low dew point, in industries like hospitals, dairies, refineries, aviation plastics etc.,

Figure 1: Layout configuration based on application conforming to ISO 8573.1

ISO 8573.1

International Organization for Standardization (ISO) has defined a quality standard for the production and testing of compressed air, termed ISO 8573 Series. ISO 8573.1 is used to classify the purity while ISO 8573.2-9 specify the test to check for one or more contaminants in the compressed air. ISO 8573.1 was published in 2010 and last reviewed in 2017.

ISO 8573-1:2010 specifies purity classes of compressed air with respect to particles, water and oil independent of the location in the compressed air system at which the air is specified or measured.

ISO 8573-1:2010 provides general information about contaminants in compressed-air systems as well as links to the other parts of ISO 8573, either for the measurement of compressed air purity or the specification of compressed-air purity requirements.

In addition to the above-mentioned contaminants of particles, water and oil, ISO 8573-1:2010 also identifies gaseous and microbiological contaminants. The standard is further divided into Classes. The standard defines the maximum level of contaminants in compressed air for each of these classes. The higher the class, the lower the required degree of purity. The required class of air is usually defined by the manufacturer of the point of use machines and the application.

ISO 8573.1-2010	Solid Particles				Water		Oil
	Max. number of particles per m^3			Mass concentration	Vapour pressure dew point	Liquid	Total oil content (liquid, aerosol and vapour)
Class	0.1 – 0.5 µm	0.5 – 1 µm	1 – 5 µm	mg/m3	°C	g/m3	mg/m3
0	As specified by the equipment user or supplier and more stringent than Class 1						
1	≤ 20,000	≤ 400	≤ 10	–	≤– 70	–	0.01
2	≤ 400,000	≤ 6,000	≤ 100	–	≤ –40	–	0.1
3	–	≤ 90,000	≤ 1,000	–	≤ –20	–	1
4	–	–	≤ 10,000	–	≤ +3	–	5
5	–	–	≤ 100,000	–	≤ +7	–	–
6	–	–	–	5	≤ +10	–	–
7	–	–	–	5 – 10	–	≤ 0.5	–
8	–	–	–	–	–	0.5 – 5	–
9	–	–	–	–	–	5 – 10	–
X	–	–	–	> 10	–	> 10	> 10

Table 1: Overview of purity classes in compressed air for particles, water and oil as per ISO 8573-1:2010 at 20°C and 1 bar abs pressure.

Here Class 0 air is the highest purity of compressed air achievable. The essential air quality will be defined by the supplier or the consumer and will be adhering to stricter quality than Class 1. Class 0 air is mainly used in industries like pharmaceuticals, food, textile and electronics etc., where the air comes in direct contact with the product and contaminants can hamper the quality of the product. It is achieved through a combination of oil-free compressor and compressed air treatment equipments.

Compressed air system layout

A typical compressed air layout is shown in Fig. 2. The compressor is connected to a series of treatment equipments to remove the contaminants and moisture from the compressed air. The supply side equipments also have the function of reducing the temperature of the air as high temperature can damage the end-use machine parts like rubber seals and diaphragm. The selection of the equipments depends on the application and the quality standards.

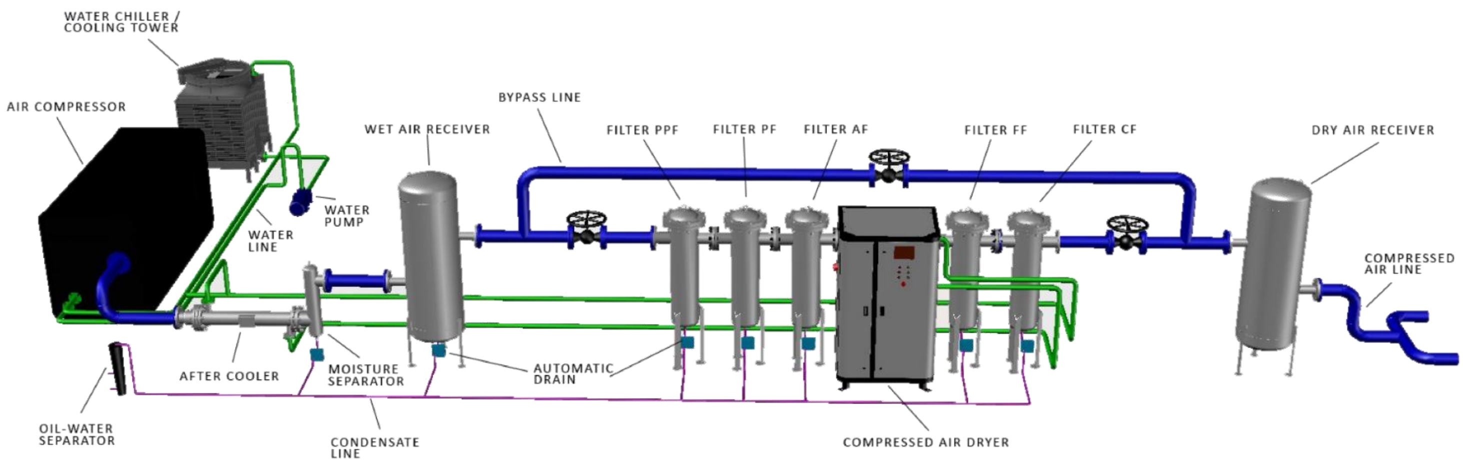


Figure 2: Compressed Air system Layout

Common treatment equipments are Aftercoolers, Moisture Separators, Dust and Oil removal coalescing Filters and Air Dryers along with Condensate management Automatic Drains.

The Wet Air receivers also help in collecting the condensed water and oil that has been carried over from the compressor because of the drop in the temperature of air.

This white paper will focus on the importance of filters and the different types of filters effective for different contaminants.

Filters

Filters remove a wide variety of unwanted particles from the compressed air like dust particles, oil mist, oil aerosols, oil vapour, rust, unwanted gases and even bacteria. Filters vary based on the contaminant to be eliminated the class of air required.

An Air Filter generally has three main parts: - Filter body, Filter element and a Drain for removing the condensate. The body provides structural integrity and withstands the pressure. The filter element is housed in the body and the Drain attached at the bottom of the housing.

Filter sizing is based on flowrate of the air and air pressure. Under sizing the filters can choke the filter and cause a back pressure while over sizing results in unnecessary expenses in the form of filter cost and replacement needs.

Lower the flowrate for a Filter; higher is the Filter element life and Higher the flowrate; lower is the life of the filter element.

Compressed air filters performance is verified by ISO 12500 series. It acts as a complement to ISO 8573 series and consists of test methods for oil mist, aerosols, oil vapour, particles and water. The efficiency of compressed air filter is measured by Beta ratio. It is obtained by measuring the number of particles in the fluid on either side of the filter at test conditions.

$$\beta_x = \frac{Number\ of\ particles\ greater\ than\ x\ microns\ upstream}{Number\ of\ particles\ greater\ than\ x\ microns\ downstream}$$

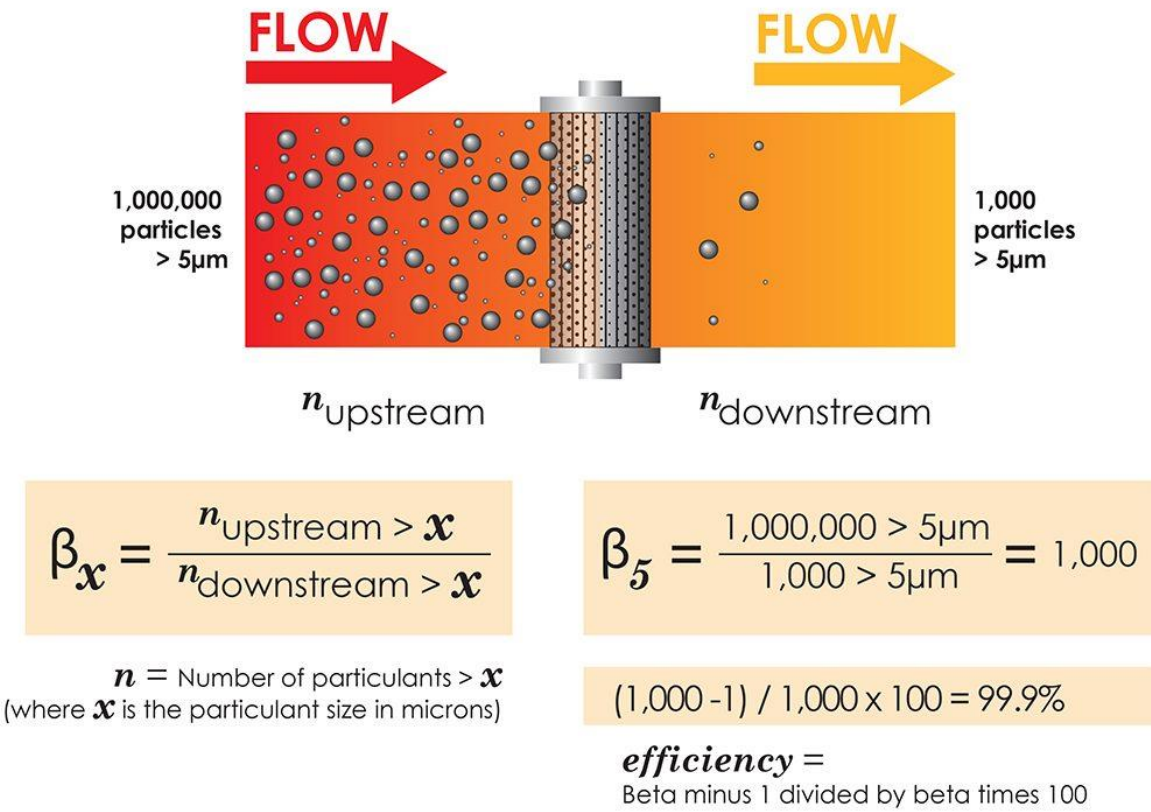


Figure 3: Beta ratio

Filters are classified into three main categories based on working principle. They are Particulate filters, Coalescing filters (Depth Filters) and Adsorption filters. Filters can be further divided based on the level of filtration and the material used. They are: -

- **Primary Pre-Filter (PPF): -**
  It is the primary line of defense against dust particles apart from the compressor filters. It is a surface filter, meaning it uses sieves of different porosity to filter the dust particles, mainly on the surface. It is also a dry particulate filter. It works by trapping bulk liquids and particles of dirt and rust between the mesh (as given in Fig. 4).

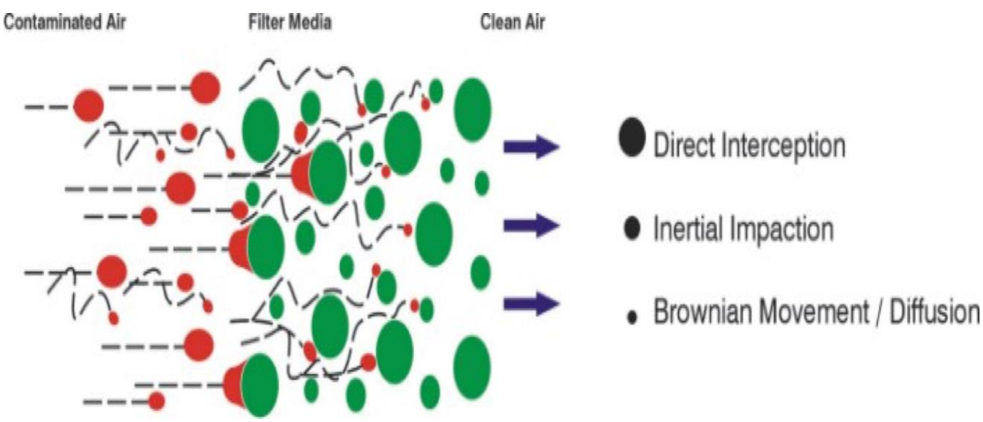


Figure 4: Particulate Filtration

It can filter particles up to a minimum size of 20 micron. It is made of pleated stainless-steel mesh.

When the filter becomes filled with particles, it creates an obstruction to the flow of air and increases the pressure drop. Increased pressure drop is a sign of filter maintenance requirement. Stainless-steel mesh element is washable for up to five times, after which it needs replacement.

- **Pre-Filter (PF): -**

  It is designed for bulk liquid and particle removal down to 3 microns. It is a surface filter and a particulate filter. It is made of pleated cellulose acetate. The particulate filtered includes dust, rust, dirt or pollen. It is connected before the dryer to limit particulates from entering the dryer

  A PPF and PF do not need an upstream filter to protect them. Water in the form of condensate is also trapped in particulate filters like PF and PPF and is drained through condensate management equipment at the bottom of the filter casing. These filter elements are not reusable after it reaches its service life and needs replacement.

- **After filter (AF) & Final Filter (FF): -**

  These are depth filters, meaning they trap the substances between the matrixes of filter media - Borosilicate glass fiber. They are also called Coalescing Filters or Depth Filters because droplets of oil mist and aerosols and water between the elements, causing it to coalesce into larger droplets and exit through the drain. It can also trap particulates of required filtration size. Coalescing filters work on the principles of Direct Interception, Inertial Impaction and The Brownian motion.

  After filters are placed before the compressed air dryer and can reduce particle size to 0.1 micron and residual oil content to 0.5 mg/m^3. It is made of pleated borosilicate glass fiber. After filter has a fiber spacing of 0.7 micron to allow air flow.

Final filter is also made of pleated borosilicate glass fiber and has a fiber spacing of 0.5 micron. It is placed after the dryer and can reduce particle size to 0.01 micron and residual oil content to 0.01 mg/m^3.

A final filter must always be connected after a Pre-filter (PF). This is to prolong the life of the FF filter element.

- **Carbon Filter (CF): -**

  Carbon filter is made of activated carbon bed to filter the oil vapour and make compressed air odor free. It is an adsorption filter, i.e., it adsorbs oil vapours on its surface as the final mode of removing lubricant and oil from the compressed air for most applications.

  It can remove residual oil content of 0.003 mg/m^3. CF requires the connection of an FF, which in turn needs a PF. So, the supply of CF must always be complemented by a PF and FF to prolong the filter element life.

Figure 5: Filter Cross-section

There are applications that require further filtration of compressed air to prevent gases like CO & NO_x and need steam venting to sterilize air and kill microbes. For example, PTFE (Polytetrafluoroethylene) membrane filters are used downstream in dairy churning and testing because of its properties of hydrophobia and chemical resistance.

Filter Grade				
ISO 8573.1 Class	**Max. Particle size**	**Max. Oil concentration***	**Initial pressure drop**	**Filtration Principle**
	micron (µm)	**mg/m^3**	**bar**	
PPF	25	-	0.02	Particulate filter
PF	3	-	0.02	Particulate filter
AF	0.1	0.5	0.05	Coalescing filter
FF	0.01	0.01	0.08	Coalescing filter
CF	-	0.003	0.06	Adsorption filter

Table: 2: Choosing the filter grade

*** Referred at 20^0C and 1 bar abs**

Filter Selection and Maintenance

Filters should be connected at the point of use in addition to the central compressed air system. This is to prevent the contaminants such as rust and dirt formed inline. The filters must be selected based on the flowrate and operating pressure. Filtration is a step by step process. Filters like CF need an FF and PF to prolong its life, while an FF needs a PF.

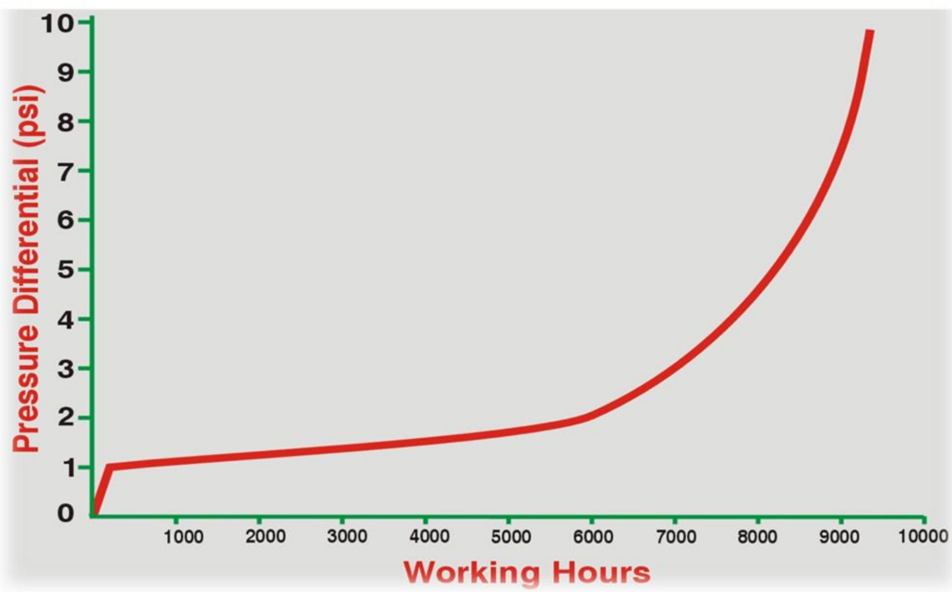


Figure 6: Filter element working hour's vs Pressure differential

Filter element must be periodically replaced for efficient operation of the system. This depends on the quality of supply air and working hours. For example, the filter element in a cement plant can be choked in one month while it may last a year in an automotive plant. Average working hour of the filter element is 8000 hours at a pressure drop of 0.5 bar (as given in Fig. 6). This can be roughly estimated as 1 year.

A reliable method of checking the life of a filter element is using a differential pressure gauge or indicator. It measures the filter's pressure between inlet and output.

Without regular replacement, pressure drop rises as well as the machines are starved, leading to increasing strain on the compressor. It also elevates the energy consumption and cost of operations.

Conclusion

Filters are an integral part of compressed air treatment system. Every compressed air system needs a combination of central and point of use filters, actively working to safeguard the quality of air.

Compressed air as a utility needs stringent quality standards adhering to ISO 8573.1 to ensure the efficiency of the manufacturing process and safety of the products.