Controlling Micro-organism Growth in Compressed Air

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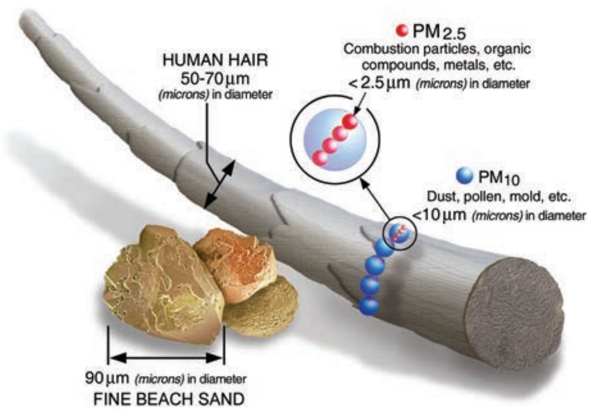
Micro-organisms in Compressed Air

Untreated, compressed air entering a wet air receiver and / or distribution piping system will contain many contaminants, including liquid water, water aerosols and it will also be 100% saturated with water vapor. Water is the most problematic of all compressed air contaminants as it not only causes damage through corrosion, more seriously; wet compressed air promotes the growth of micro-organisms.

It all starts with the ambient air

Solid (dirt) particles are all around us, present in the ambient air we breathe, however we can't always see them. In an urban environment, one cubic meter of ambient air typically contains between 140 and 150 million dirt particles, however 80% of these particles are less than 2 micron in size and not visible to the human eye. The smallest particle a human eye can see is in the order of 40 to 50 microns e.g. tip of a human hair.



The definition of Micron: "a unit of length equal to one millionth of a metre", Symbol: µ, mu.

The solid particles found in ambient air also include viable and non-viable particles.

- A viable particle is a particle that contains one or more living micro-organisms.
- A non-viable particle is a particle that does not contain a living micro-organism but acts as transportation for viable particles.

Of the 140 to 150 million particles per cubic meter of ambient air, anywhere up to 100 million of these could be micro-organisms.

The definition of micro-organism is as follows: "A living organism too small to be seen with naked eye but visible under a microscope". In simple terms, it is a particle of dirt that is alive.

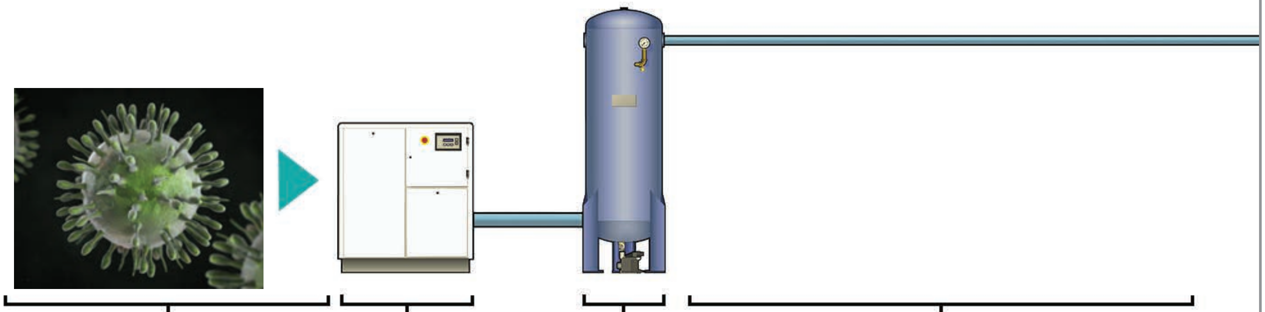
Examples of Micro-organisms found in ambient air & typical size in microns

Viruses
0.02µm - 0.2µm

Pathogenic Bacteria
0.3 µm - 5µm

Fungi (Moulds / Yeasts)
3µm - 10µm

How micro-organism enter the compressed air system



Ambient air can contain up to 100,000,000 micro-organisms per cubic metre

Micro-organisms are concentrated as ambient air is compressed

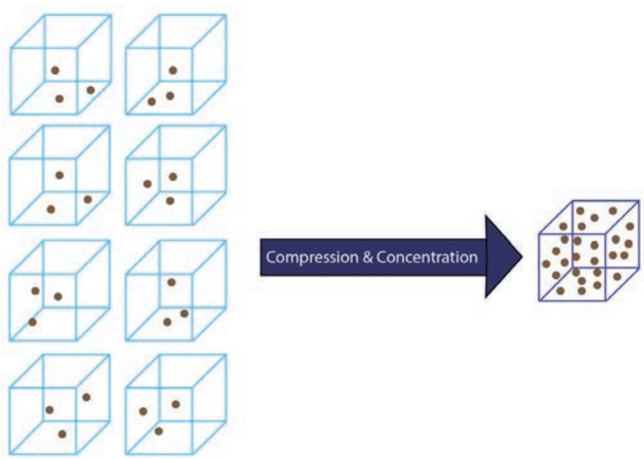
Fact: The heat of compression does not kill micro-organisms or sterilise compressed air

Micro-organisms continue to grow inside the wet compressed air system. They are present in both the compressed air and the liquid condensate.

Compressed air used in manufacturing processes with direct contact & indirect contact applications result in product contamination. Manufacturing area, production equipment, surrounding ambient air can also be contaminated with micro-organisms

How micro-organisms enter the compressed air system

As the air compressor is running, large volumes of ambient air are drawn into the compressor intake. Particles the size of micro-organisms are too small to be captured by the panel filters and intake filters used on modern air compressors, therefore, they travel unrestricted into the compressed air system.



Compression = Concentration

When the ambient air is compressed, it is "squeezed" down into a smaller volume. Unfortunately, this does not apply to the contaminants in the ambient air which instead are concentrated. The higher the pressure the air is compressed to, the higher the concentration of contamination.

Myth
During compression, the temperature of the air increases rapidly (typically in the range of 176°F to 248°F for oil lubricated compressors and 356°F to 392°F for oil free compressors). It was often thought that this temperature increase was enough to kill off micro-organisms and sterilize the compressed air.

Fact
While heat may kill some micro-organisms (typically viruses), time spent at temperature is also a factor for others. As soon as the ambient air is compressed, it is passed through an after-cooler to reduce its temperature to around 50°F above ambient. Micro-organisms are adaptive and the rapid heating and cooling can cause bacteria and fungi to change state to protect itself (forming a spore). Spores can lie dormant for long periods of time until the right conditions for growth present themselves. Cooling the compressed air has the effect of condensing water vapor into liquid water, generating aerosols of water and fully saturating the compressed air with water vapor. As the wet compressed air enters the storage and distribution system, it provides the ideal environment for further growth of micro-organisms.

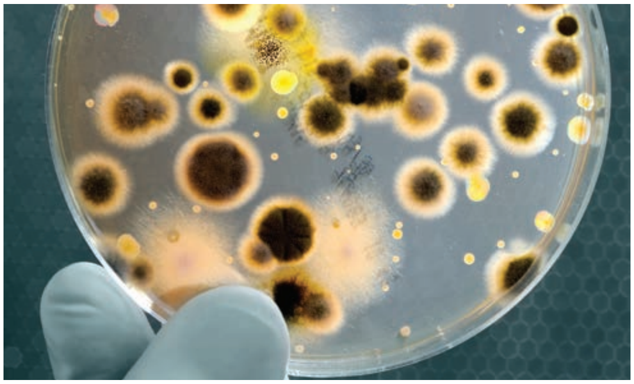
Microbial Growth in the Compressed Air System

The warm moist air found in and untreated or poorly treated compressed air system provides an ideal environment for the growth of micro-organisms. The air receiver and distribution piping store and distribute their ever expanding growth. Many critical applications require sterility or at least a degree of control of over the growth of micro-organisms.

If compressed air directly or indirectly contacts products, packaging materials, instrumentation or production machinery, then contamination is likely.

Microbial contamination from compressed air can:

- Potentially harm the consumer
- Diminish product quality, rendering a product unfit for use
- Lead to a product recall
- Cause legal action against a company
- Damage a manufacturers brand



Its not just critical applications at risk

Micro-organisms don't just cause issues for critical applications or sterile processes.

Compressed air is used widely in general industry and untreated compressed air exhausted from pneumatic tools, valves, cylinder or machinery will also contain micro-organisms. If this exhausted air is inhaled by employees working in the vicinity or using tools / machinery it can also lead to excessive work force illness.

Compressed Air Condensate

Personal Protective Equipment (PPE) should also be used when handling compressed air condensate as this also contains micro-organisms. Particular care should be taken as condensate discharges, especially when timed solenoid drains or manual drains are used as these can aerosolize the condensate (containing micro-organisms) and easily be inhaled.

Testing Compressed Air for Micro-organisms using ISO 8573-7

ISO8573-7 is the international standard used to test compressed air for micro-organisms. It is used in conjunction with ISO 8573-4 (solid particulate).

Air is first tested in accordance with ISO 8573-4 for solid particles. Next samples are taken using a slit sampler as a particle analyzer is unable to distinguish the difference between a particle and a micro-organism.

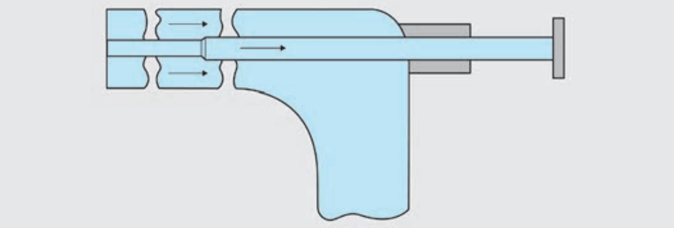
The slit sampler passes compressed air over an agar plate. The plate is then taken to a laboratory, incubated and checked for growth.

The purpose of the test is to determine if the air is sterile or non-sterile and if required to provide a count of colony forming units (CFU's).

Partial flow - Test Equipment Required:

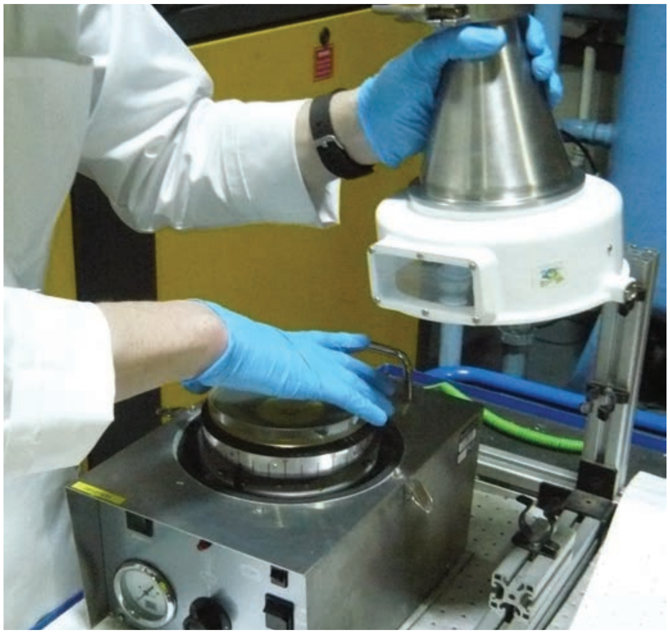
1. Sampling rig (including flow meter)
2. Iso-kinetic sample probes / piping
3. Sampling rig
4. Slit sampler & Agar Plates
5. Incubator (or access to a laboratory)

Sampling method shall be iso-kinetic using the method given in ISO 8573-4

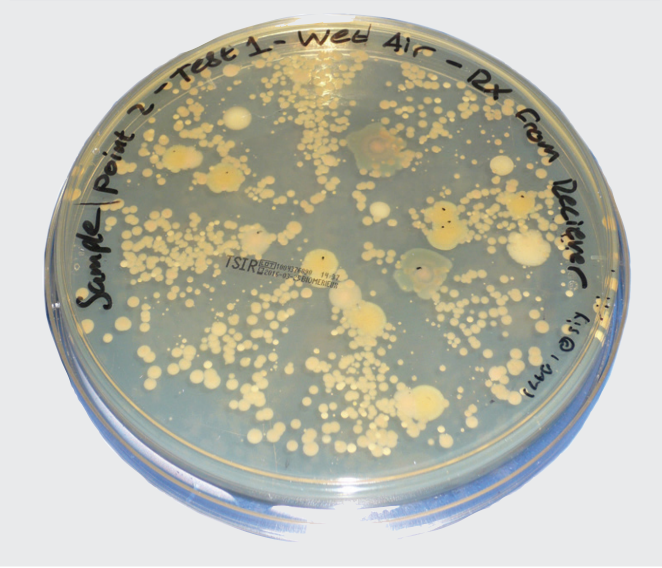


Slit Sampler

Flow, Pressure & Temperature Measuring Equipment

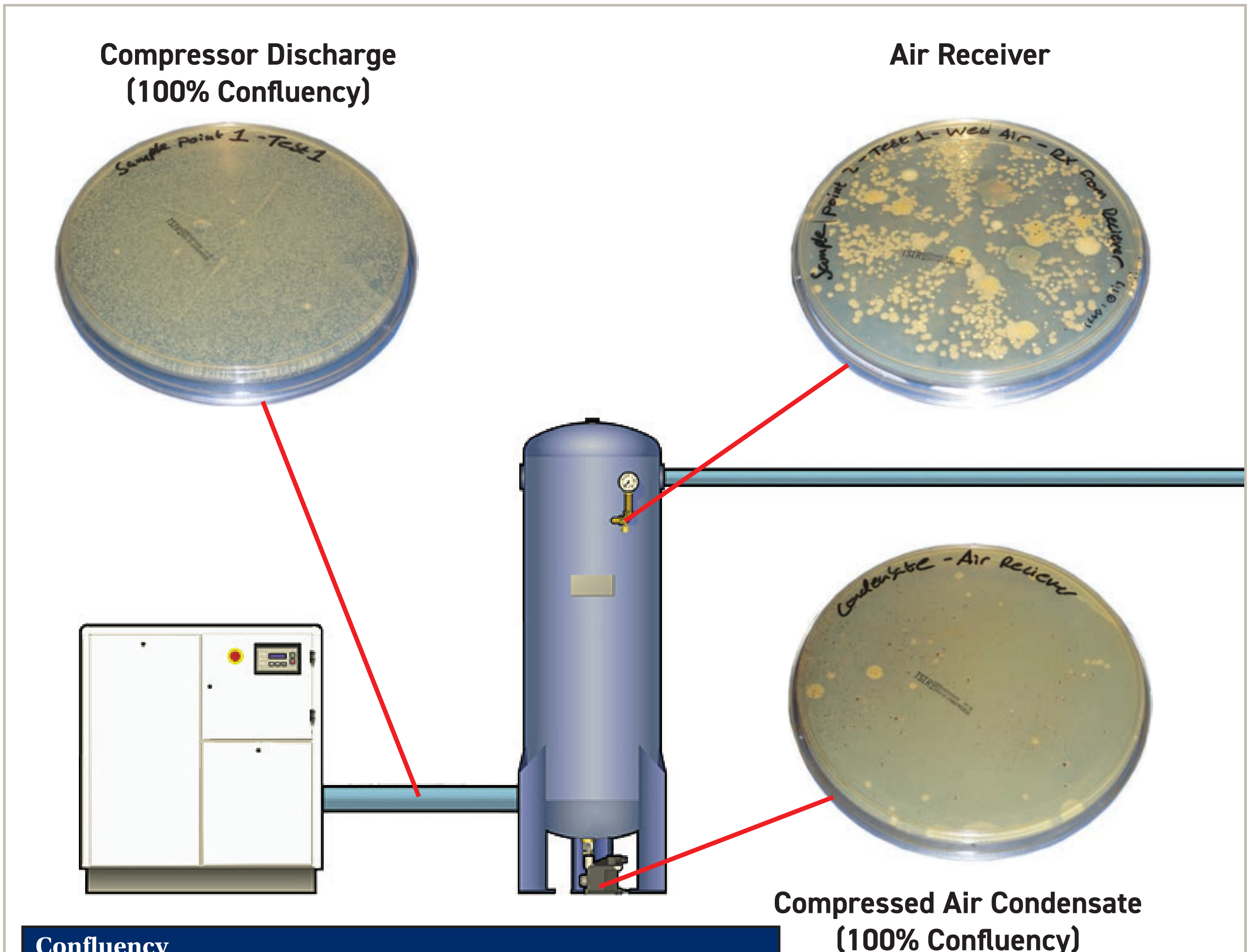


Agar plate with micro-biological growth from compressed air sample



Examples of Microbial Growth in a Compressed Air System

The following samples taken directly at the outlet of a typical industrial air compressor and at the air receiver pressure gauge port clearly show the presence of micro-organisms in untreated compressed air. Additionally, samples taken from the compressed air condensate also show the presence of micro-organisms in the liquid discharges from the compressed air system.



Confluency
In cell culture biology, confluence refers to the percentage of the surface of a culture dish that is covered by adherent cells. For example, 50 percent confluence means roughly half of the surface is covered, while 100 percent confluence means the surface is completely covered by the cells, and no more room is left for the cells to grow as a monolayer.

It's All About Control

The number of micro-organisms in the compressed air can be controlled, to the point where microbial levels are significantly lower than in the surrounding ambient air (ideal for food and beverage applications). And for critical applications, sterile compressed air can also be produced (ideal for products manufactured in sterile conditions, such as pharmaceutical products).

SEPARATE AND REMOVE ALL LIQUID WATER FROM COMPRESSED AIR

FILTER AIR TO REDUCE WATER AEROSOLS (<0.01 mg/m³)

REDUCE DEWPOINT TO A LEVEL THAT WILL INHIBIT THE GROWTH OF MICRO-ORGANISMS (≤-40°F PDP)

FILTER AIR TO REDUCE MICRO-ORGANISMS (<0.01 MICRON @ 99.9999% Efficiency)

FOR STERILE AIR FILTER AIR FURTHER TO CAPTURE ALL MICRO-ORGANISMS (<0.2 MICRON @ 100% Efficiency)

Microbial growth is controlled with a combination of very dry compressed air ***and*** the use of high efficiency filtration.

First all traces of liquid water and water aerosols must be eliminated from the compressed air.

Next, the dewpoint (dryness) of the compressed air must be reduced to a level known to inhibit (stop) the growth of micro-organisms.

Definition:

- Dewpoint refers to the temperature at which condensation will occur and is expressed as a temperature. Although expressed as a temperature, this figure is not the actual air temperature.
- Atmospheric dewpoint refers to a dewpoint measurement taken at atmospheric pressure, Pressure dewpoint refers to a dewpoint measurement taken at system operating pressure.

DEWPOINT HYGROMETER

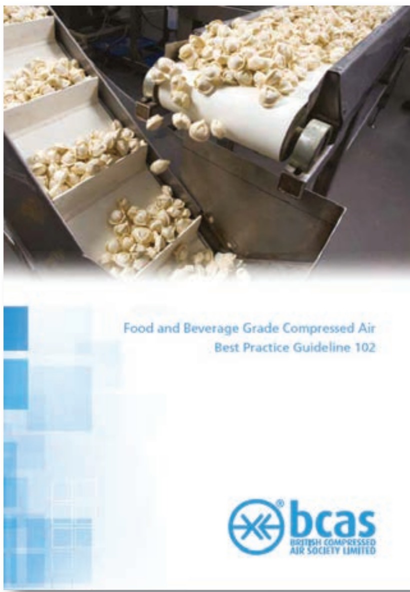
Having the right compressed air dewpoint will inhibit (stop) the growth of micro-organisms, however dewpoint alone is not enough. If the micro-organisms present are merely inhibited from further growth, they can still survive in a state whereby once reintroduced to the right environment (moisture), they can again begin to grow.

By combining the correct dewpoint with point of use high efficiency dry particulate filters (particle reduction down to 0.01 micron @ 99.9999% efficiency), microbial concentrations can be reduced significantly and brought down to acceptable levels which will be below the concentrations found in the ambient air.

Should 100% sterile compressed air be required, additional absolute rated, air steriliztation filters providing 100% removal of micro-organisms and particles can also be employed.

Which dewpoint specification should I select to control the growth of micro-organisms?

It has been found that a constant pressure dewpoint of <-15°F will inhibit (stop) the growth of micro-organisms. The lower the pressure dewpoint, the more effective the control.



For this reason, the British Compressed Air Society (BCAS) in their Food and Beverage Grade Compressed Air Best Practice Guideline 102 recommend ISO8573-1 Class 2 (Water Vapor) for direct contact applications, which equates to a constant pressure dewpoint of ≤-40°F.

Focus on hygiene in dental compressors

Scientist warns of risk of bacterial growth in compressed air receivers

Danish scientist, Finn Djurhus, was head of section at DTI Industri, Danish Technological Institute in Aarhus when he first used microbial testing to highlight the presence of micro-organisms in compressed air and compressed air condensate. Additionally he found that compressed air with a pressure dewpoint around -6°F to -15°F starts to inhibit microbial growth. Finn was also a technical advisor for the first edition of the BCAS food & beverage grade compressed air code of practice (now BCAS Best Practice Guideline 102 highlighted above).

Which Drying Technologies Deliver the Required Outlet Dewpoint to Inhibit Growth?

There are many different drying technologies available today, however, not all are able to deliver the outlet dewpoint required to inhibit the growth of micro-organisms.

The British Compressed Air Society Best Practice Guideline 104 - "The Filtration & Drying of Compressed Air" provides an excellent overview of the many drying technologies available.

- **Refrigeration Dryers** **(with 4 different cooling methods commonly used)**
- **Adsorption Dryers** **(with 6 different regeneration methods commonly used)**
- **Membrane Dryers** **(Dewpoint Suppression)**
- **HOC Adsorption Dryers** **(Dewpoint Suppression with 3 designs commonly used)**

Most global compressed air treatment manufacturers who produce these drying technologies, develop them to deliver an outlet dewpoint that corresponds to one of the six dewpoint classifications shown in ISO 8573-1:2010, the international standard for compressed air purity.

The dewpoint classifications can be seen in the table below, along with typical dryer technology used to achieve the required dewpoint.

ISO8573-1:2010 Classification	°F PDP	Dewpoint Band	Dryer Technology
Class 1	≤-94°F PDP	-176°F to -94°F	Adsorption / Hybrid*
Class 2	≤-40°F PDP	-93°F to -40°F	Adsorption / Hybrid*
Class 3	≤-4°F PDP	-39°F to -4°F	Adsorption / Hybrid*
Class 4	≤+37°F PDP	-3°F to +37°F	Adsorption / Hybrid* / Refrigeration**
Class 5	≤+45°F PDP	+38°F to +45°F	Refrigeration
Class 6	≤+50°F PDP	+46°F to +50°F	Refrigeration

Important Notes:

- * For classes 1 to 4, a hybrid dryer could be specified, however this technology incorporates an energy saving feature where by in summer, the adsorption dryer can be bypassed and shut off.
- This will result in a pressure dewpoint that will not inhibit the growth of micro-organisms.
- ** Some but not all refrigeration dryers are classified as Class 4 for dewpoint (however the limiting factor is freezing of condensed water below 32°F, therefore adsorption or hybrid dryers are typically used achieve dewpoints from 36°F down to -2°F.)
- Refrigeration dryers are typically classified as ISO 8573-1 Class 5 or Class 6 for water
- When control over the growth of micro-organisms is required, an adsorption dryer that can deliver an outlet dewpoint of ISO 8573-1 Class 2 (or Class 1) is typically recommended.

Choosing a Dryer Technology

When compressed air is used for critical applications, where water vapor reduction and control over the growth of micro-organisms are of extreme importance, a dryer capable of delivering a dewpoint capable of inhibiting the growth of micro-organisms ≤-40°F PDP) and a constant outlet dewpoint is always required.

Drying Technology	Dryer Type	Able to Deliver Dewpoint to Inhibit Microbial Growth	Constant Outlet Dewpoint	Dewpoint Suppression
Refrigeration	Direct Expansion	✕	✓	✕
	Thermal Mass (cycling)	✕	✕	✓
	Variable Speed	✕	✓	✕
	Regenerative	✕	✓	✕
Adsorption	Heatless	✓	✓	✕
	Vacuum Assisted Heatless	✓	✓	✕
	Internally Heated Purge	✓	✓	✕
	Externally Heated Purge	✓	✓	✕
	Externally Heated Blower	✓ *	✓ *	✕ *
	Externally Heated Vacuum	✓	✓	✕
Hybrid	Tandem Technology	✓ **	✓	✕
Heat of Compression (HOC)	HOC Twin Tower Full Flow	✕	✕	✓
	HOC Twin Tower Split Flow	✕	✕	✓
	HOC Drum	✕	✕	✓
Separation	Membrane	✕	✕	✓

* Not all variants deliver constant outlet dewpoint, some are dewpoint suppression dryers.
** Not suitable if the adsorption dryer can be shut down during summer months.

From the table, it is clear to see that not all dryers available today are suitable for critical applications that require control over the quantity and growth of micro-organisms.

The dewpoint delivered by a refrigeration dryer dewpoint is not low enough to inhibit (stop) the growth of micro-organisms.

Dewpoint suppression dryers (further detail later in this document) such as membrane and HOC dryers are either not capable of delivering a dewpoint low enough to inhibit the growth of micro-organisms or their dewpoint varies too much and a minimum dewpoint cannot be guaranteed (i.e. it is not constantly below the minimum dewpoint required to control growth).

Adsorption dryers are therefore recommended for applications that require control over the quantity and growth of micro-organisms.

Refrigeration Dryers and Micro-organisms

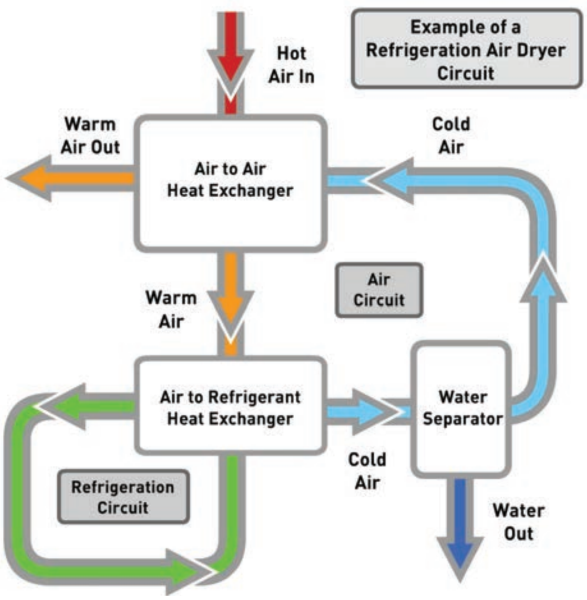
It is not uncommon to find refrigeration dryers installed in food, beverage or pharmaceutical applications where the control of micro-organisms is important. The choice to install this type of dryer is typically down to replacing an existing dryer with an equivalent type, price, or both. Often, the relationship between dewpoint and microbial growth has been overlooked.

Unfortunately, if the compressed air is being used directly or in-directly during the manufacture of food, beverage or pharmaceutical products and the presence of high concentrations of micro-organisms is undesirable, then the use of a refrigeration dryer is not recommended.

Refrigeration dryers are typically promoted as delivering ISO8573-1 classifications of Class 4, 5 or 6 for water vapor.

ISO8573-1:2010 states for water vapor:

ISO8573-1:2010 Classification	°F PDP	Dewpoint Band
Class 4	≤+37°F PDP	-3°F to +37°F
Class 5	≤+45°F PDP	+38°F to +45°F
Class 6	≤+50°F PDP	+46°F to +50°F



The most commonly used classification of the three is Class 4.

Care must be taken when selecting a dryer to achieve a Pressure Dewpoint of ISO8573-1:2010 Class 4 for water vapor. Refrigeration dryers are typically unable to guarantee a constant outlet dewpoint of ≤+37°F PDP.

During operation, they cool the compressed air down to a temperature of 37°F to induce condensation. They then employ a water separator for liquid reduction.

Unfortunately, water separators are unable to remove 100% of the condensed liquid (with some separator designs, liquid reduction efficiency can drop off significantly below 100% of rated flow). They are also unable to remove any aerosols generated in the dryer (common in cross flow & plate heat exchanger designs). Therefore, the remaining liquid and aerosols are vaporized as they leave the dryer, raising the outlet dewpoint.

Refrigeration dryer performance can also be affected by:

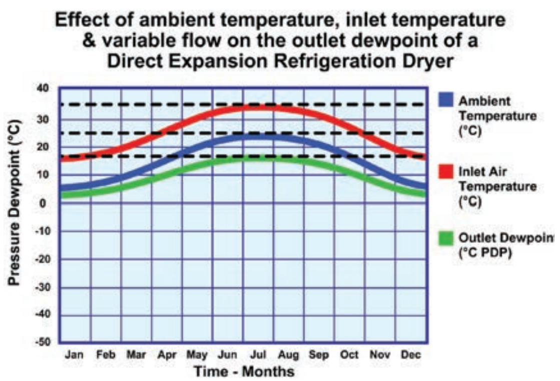
- High ambient temperatures & relative humidity
- High compressor room temperatures
- Poor ventilation
- Cleanliness of the condenser (air cooled, and water cooled)

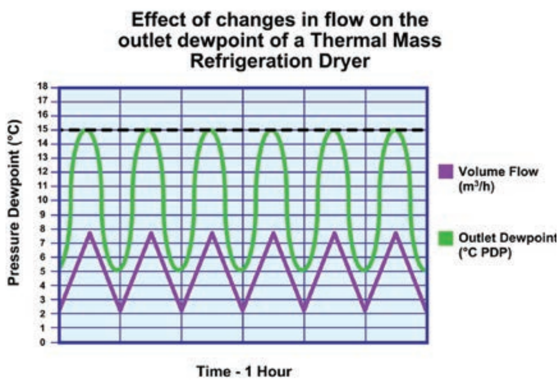
Refrigeration Dryer Type also Affects the Delivered Dewpoint

Refrigeration dryers are also available as 3 differing dryer technologies:

- Direct Expansion
- Thermal Mass
- Variable Speed

The operation of each of these technologies can also have an impact on the delivered dewpoint. For example, thermal mass dryers cool a mass then turn the refrigeration compressor on and off to save energy. This has a direct impact on the outlet dewpoint they deliver.





Refrigeration Dryer Dewpoint Indication

On a refrigeration dryer, the dewpoint indicator or digital display does not actually show the outlet dewpoint in the same was as a desiccant dryer.

Adsorption (desiccant) dryers use a hygrometer to measure outlet dewpoint. Refrigeration dryers however do not actually display dewpoint and do not incorporate a hygrometer sensor. They instead are only fitted with a temperature probe which typically indicates the temperature of the compressed air or sometimes the temperature of the refrigerant.

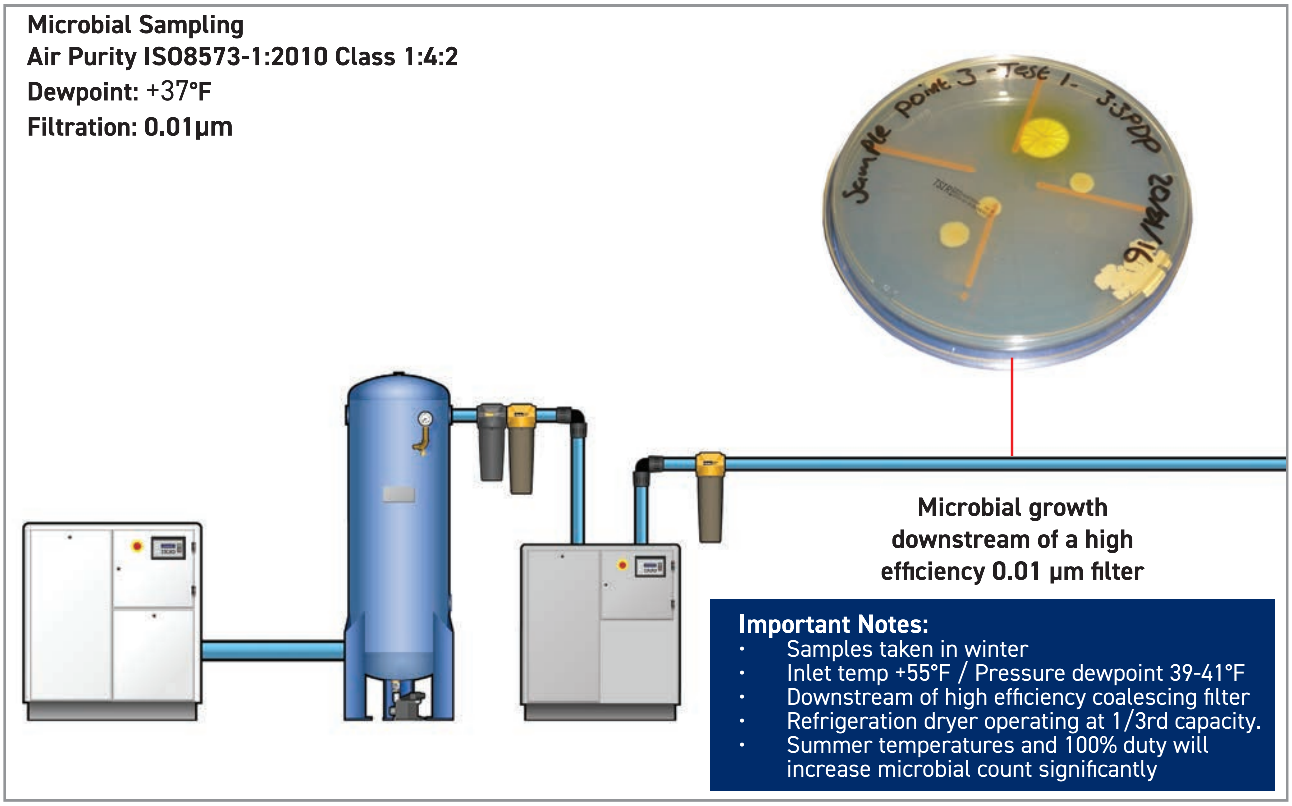
For a true reading of Pressure Dewpoint, a hygrometer must be used. This is in accordance with ISO8573-3 the international standard for compressed air dryer testing.

Important Notes:

- As previously mentioned, a pressure dewpoint lower than -15°F has been found to inhibit microbiological growth.
- As a refrigeration dryer dewpoint of does NOT inhibit the growth of micro-organisms, they can still grow freely in the compressed air system and left untreated, the high concentration of micro-organisms will not be effectively reduced by filtration.
- Microbial sampling of a compressed air system highlights why refrigeration dryers are not recommended.

Microbial Sampling Downstream of a Direct Expansion Refrigeration Dryer

The agar plate below is a sample taken downstream of a direct expansion refrigeration air dryer, delivering an outlet dewpoint around +37°F.



A typical refrigeration dryer installation comprises of a water separator for the treatment of liquids. Next, a general purpose coalescing filter is used to protect the dryer from liquids and particles. The refrigeration dryer reduces the water vapor (however, not as low as an adsorption dryer). At the outlet of the dryer a high efficiency coalescing filter is installed to capture liquids and aerosols carried over from the dryer.

Important Notes:

- As previously discussed, a pressure dewpoint lower than -15°F is required to control microbiological growth.
- A refrigeration dryer is unable to reach a dewpoint that will inhibit the growth of micro-organisms.
- Refrigeration dryers are typically unable to deliver a constant outlet dewpoint.
- Micro-organisms can therefore grow freely in the downstream piping system.
- The high concentration of micro-organisms will not be effectively reduced by point of use filtration (if installed).
- **Refrigeration dryers should therefore not be used to control the growth of micro-organisms.**

Adsorption Dryers and Outlet Dewpoint

While many manufacturers may claim that their adsorption (desiccant) air dryer will be able to deliver a dewpoint that will inhibit the growth of micro-organisms, adsorption dryers actually differ in the consistency of the outlet dewpoint they deliver. They will be designed to either deliver a constant outlet dewpoint (which has little variation) or provide dewpoint suppression (with large dewpoint variations).

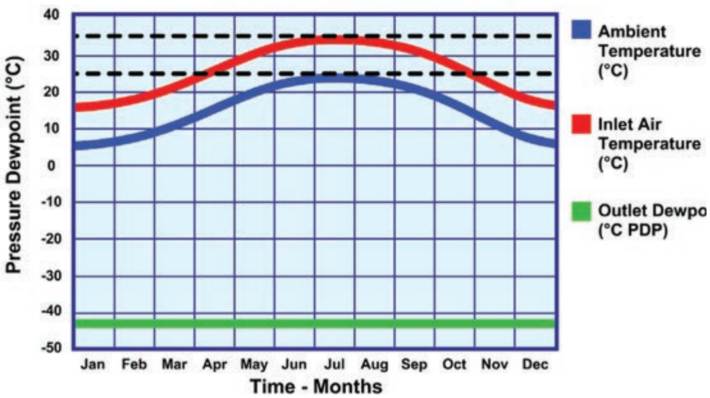
Constant Outlet Dewpoint

A constant outlet dewpoint dryer is first 'sized' to match worst case inlet and ambient conditions of the user's site. This ensures the dryer has enough drying capacity (usually adsorbent material) to handle the maximum water vapor loading of the system, while being able to deliver a consistent outlet dewpoint.

A dryer delivering a constant outlet dewpoint will see small fluctuations, but always deliver the minimum pressure dewpoint it was sized for.

For example, if an adsorption dryer is sized to deliver a ≤-40°F PDP, then -40°F PDP will be the worst dewpoint delivered. Typically, the outlet dewpoint will fluctuate between say -58°F & -40°F due to the way the adsorption dryer operates.

Effect of ambient temperature, inlet temperature & variable flow on the outlet dewpoint of a -40°C PDP adsorption dryer

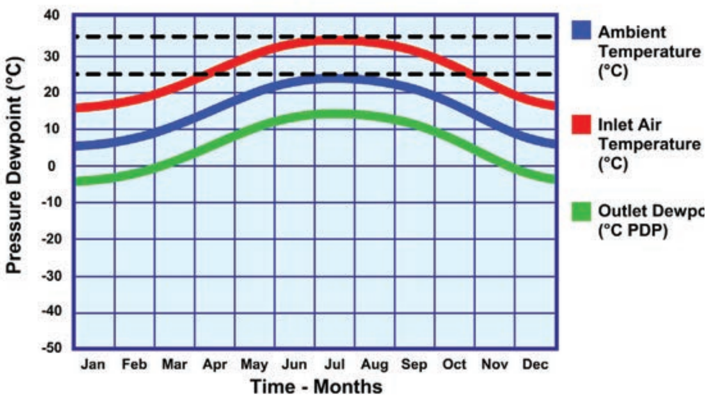


Dewpoint Suppression

Dryers designed to provide dewpoint suppression are not sized to match ambient conditions resulting in a smaller amount of adsorption material available for drying. The disadvantage is that the outlet dewpoint delivered by a suppression dryer can vary significantly.

Dewpoint suppression dryers are affected by changes in ambient air temperature and inlet temperature. If a dryer is designed to provide a dewpoint suppression of -4°F, then it will reduce the dewpoint to 20 degrees below the compressed air temperature (this figure of -4°F should not be confused as a constant outlet dewpoint as it often is).

Effect of ambient and inlet temperature on the outlet dewpoint of a 20°C dewpoint suppression dryer



Dewpoint Suppression - Heat of Compression (HOC) Adsorption Dryers

One variant of dewpoint suppression dryer, the Heat of Compression (HOC) dryer is an adsorption dryer designed to utilize the high compression temperatures generated by an oil free screw compressor (the heat is used to regenerate the adsorbent material).

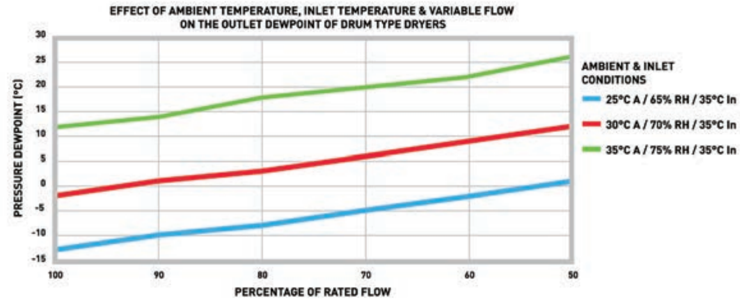
HOC dryers are not sized to match ambient conditions, therefore their adsorbent beds are significantly smaller than a constant dewpoint dryer (typically only 5% - 10% of a constant outlet dewpoint dryer).

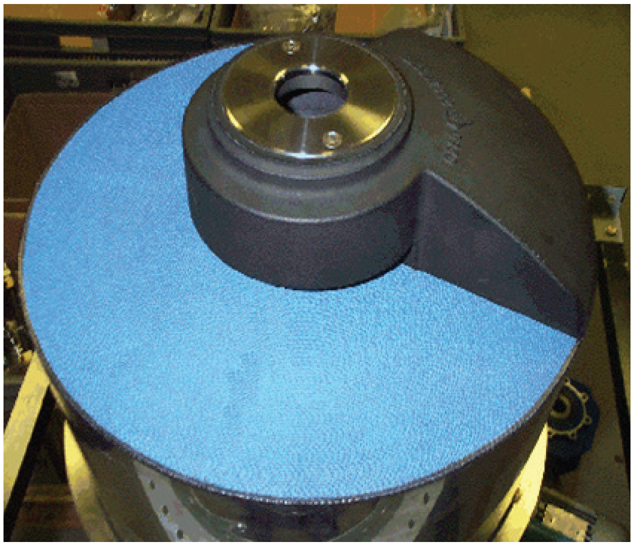
A small adsorption bed has a direct impact on outlet dewpoint (and adsorbent lifetime), especially as water vapor loading increases in summer.

HOC dryers are sold as low energy air dyers and have great appeal; however, they also require the compressor to be operating at maximum for optimal regeneration.

Compressor loading varies constantly (especially with variable speed compressors), therefore without full heat for regeneration, the adsorption material is not fully dried during regeneration. If the adsorbent material is not completely regenerated, the outlet dewpoint will naturally suffer.

Changes in ambient temperature also affect the ability to cool the adsorbent material. Hot adsorbent will not dry the compressed air efficiently, again varying the outlet dewpoint.





Important Note:

- The combination of small adsorbent bed, constantly changing compressor duty and inefficient cooling means the outlet dewpoint from an HOC dryer is constantly changing, delivering only dewpoint suppression, not a constant outlet dewpoint.

How to Identify if an Adsorption Dryer Provides Constant Dewpoint or Dewpoint Suppression

Equipment manufacturers do not always state if their compressed air dryer delivers a constant outlet dewpoint or a suppression dewpoint. It is often assumed that if a manufacturer states a dewpoint, it is delivered all the time the dryer is operating, but unfortunately this is not always the case. One way to determine if the dryer delivers a constant dewpoint is to see if the manufacturer states a dewpoint classification in accordance with ISO8573-1 for water.

ISO8573-1:2010 is the International Standard relating to compressed air purity and includes 6 dewpoint classifications in bands from -94°F to +50°F.

To comply with an ISO8573-1:2010 classification, a dryer must always deliver the outlet dewpoint within the band of one classification.

ISO8573-1:2010 Classification	°F PDP	Dewpoint Band
Class 1	≤-94°F PDP	-176°F to -94°F
Class 2	≤-40°F PDP	-93°F to -40°F
Class 3	≤-4°F PDP	-39°F to -4°F
Class 4	≤+37°F PDP	-3°F to +37°F
Class 5	≤+45°F PDP	+38°F to +45°F
Class 6	≤+50°F PDP	+46°F to +50°F

A constant outlet dewpoint dryer will typically state an ISO8573-1:2010 classification as the dewpoint can clearly fall within a defined band. A dewpoint suppression dryer such as an HOC adsorption dryer or membrane dryer does not typically state an ISO8573-1:2010 classification as the outlet dewpoint varies too greatly and falls into 2 or more bands.

Additionally, installing a dryer fitted with a dewpoint hygrometer or using a separate dewpoint hygrometer downstream of the dryer will allow the user to easily verify that the dryer is delivering the agreed outlet dewpoint.

Recommended Dryer Technologies

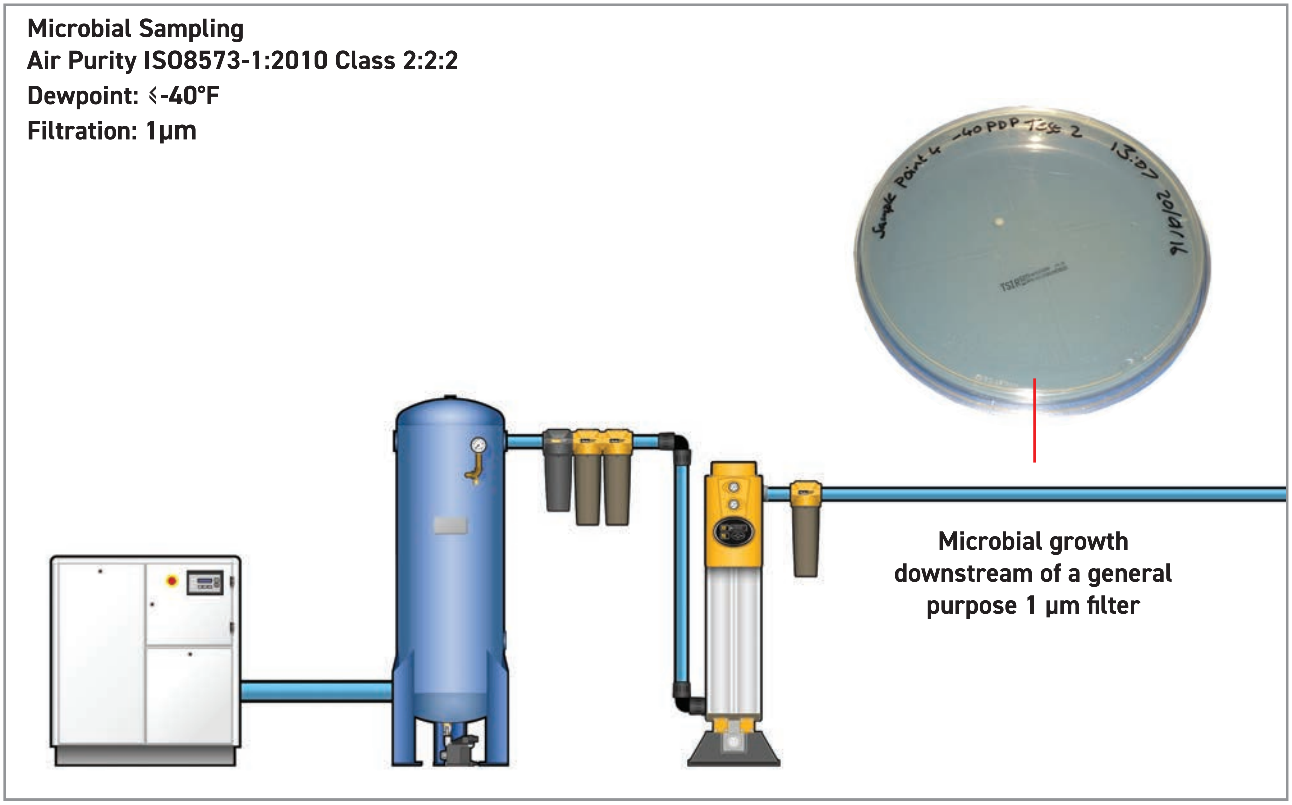
While constant dewpoint adsorption dryers are able to deliver a dewpoint that inhibits the growth of micro-organisms, some technologies may not be the preferred solution for an application. Two of the externally heated dryers listed in the table below use untreated ambient air for regeneration of the desiccant material. It is therefore recommended that a user who is considering the use of these drying technologies to control the growth of micro-organisms performs a Hazard Analysis on the dryer technology to determine any potential risk to their manufacturing process before selecting this type of dryer technology.

Drying Technology	Dryer Type	Able to Deliver Dewpoint to Inhibit Microbial Growth	Constant Outlet Dewpoint	Uses Untreated Ambient Air for Regeneration
Adsorption	Heatless	✓	✓	✗
	Vacuum Assisted Heatless	✓	✓	✗
	Internally Heated Purge	✓	✓	✗
	Externally Heated Purge	✓	✓	✗
	Externally Heated Blower	✓ *	✓ *	✓
	Externally Heated Vacuum	✓	✓	✓
Hybrid	Tandem Technology	✓ **	✓	✗

* Not all variants deliver constant outlet dewpoint, some are dewpoint suppression dryers.
** Not suitable if the adsorption dryer can be shut down during summer months.

Microbial Sampling Downstream of a Constant Outlet Dewpoint Adsorption Dryer

The agar plate below is a sample taken downstream of an adsorption (desiccant) air dryer, delivering a constant outlet dewpoint ≤-40°F.



A typical adsorption (desiccant) air dryer installation comprises of a water separator for the treatment of liquids. Next, a pair of coalescing filters are installed for the reduction of water aerosols (plus atmospheric particulate, rust, pipescale, micro-organisms and oil aerosols). Coalescing filters are installed in pairs, the first a general purpose grade which is designed to protect the finer, high efficiency filter. The adsorption (desiccant) air dryer reduces the water vapor, its performance is measured as outlet dewpoint. As the adsorbent desiccant material used in this type of air dryer can produce particulate, a general purpose dry particulate filter is typically installed in the compressor room.

Important Notes:

- The coalescing filters before the dryer will start to reduce the quantity of micro-organisms, however as the air is still saturated with water vapor at this point, growth downstream of the filter will still occur.
- The 1 micron filter on the outlet of the dryer is typical for a compressor room installation, however this filtration grade is not fine enough to trap particles the size of micro-organisms.
- High efficiency grade (0.01 micron @ 99.9999% efficiency) filters are recommended at each point of use.
- **This is the recommended setup to control the growth and quantity of micro-organisms in a compressed air system**

Compressed Air Standards / Breathing Air & Medical Air Standards / Best Practice Guides

There are a number of documents used globally to specify compressed air quality. Some allow a user to specify air quality they require, while others provide a minimum specification required for a specific application (sometimes enforceable in law). The following is a review of such documents and how they relate to micro-organisms and / or the control of micro-organism growth.

International Compressed Air Standards

Whilst the part 1 of the ISO8573 series of standards provides air purity classes for common contaminants (Solid Particulate / Water / Total Oil), it does include a specific classification for micro-organisms or CFU (Colony Forming Unit) count. It does however identify that micro-organisms can be detected in compressed air as a solid particle (using methods & equipment in ISO 8573-4) and also includes a specific standard (ISO 8573-7) for the detection of and counting of micro-organisms in compressed air.

Industrial Breathing air Air Standards

Global industrial breathing air standards relating to compressed air such as EN12021, OSHA 29 CFR 1910.134 Grade D and CSA Z180.1 are focused mainly on the reduction of dangerous gaseous contaminants and do not specifically mention the presence of, or the control of micro-organisms, nor do they include a specification level for CFU's (Colony Forming Units).

EN12021 and CSA Z180.1 do include levels for water, however these will not be sufficient to inhibit the growth of micro-organisms. OSHA 29 CFR 1910.134 Grade D specification does not include any minimum levels for water.

Medical Air Standards

The European Pharmacopoeia standard used in hospitals across the European Union states a water vapor level of 67ppm which equates to an atmospheric dewpoint of -49°F. At 100 psi g (typical operating pressure) this equates to a pressure dewpoint of around -15°F and this should be seen as a minimum dewpoint to be achieved (≤-40°F PDP recommended).

Food & Beverage Standards

There is no legislation globally relating to the use of compressed air in the food, beverage or pharmaceutical industries. These industries however are required to comply with local hygiene legislation, for example in Europe, manufacturers must comply with EN852/2004 and this is enforceable in law. Hygiene legislation does not provide a standard nor does it specifically relate to compressed air, however globally, they typically require a manufacturer to follow the principles of HACCP (Hazard Analysis Critical Control Point) when compiling their FSMS (Food Safety Management System).

Compressed air is a known source of contamination (including micro-organisms) and can directly or indirectly contact ingredients, manufacturing equipment, preparation surfaces, foodstuffs and packaging materials. If the compressed air contains micro-organisms, all of these can be contaminated. The compressed air system should therefore be included as part of the HACCP hazard analysis (for further information, refer to Parker White Paper "High Quality Compressed Air for the Food and Beverage Industries".)

Many manufacturers choose to follow a recognized food safety scheme and are also audited to the selected scheme to show compliance to hygiene legislation.

A review of the commonly used global food safety schemes has shown that while most do mention compressed air, they are very generic and do not provide a usable compressed air specification, for example: FDA Code of Federal Regulations Title 21CFR

"Compressed air or other gases mechanically introduced into food or used to clean food contact surfaces or equipment shall be treated in such a way that food is not contaminated with unlawful indirect food additives"

Best Practice Guidelines

The British Compressed Air Society (BCAS) "Food and Beverage Grade Compressed Air - Best Practice Guideline 102" referred to earlier in this document does make specific references to micro-organisms, HACCP hazard analysis and provides a specification to inhibit and control the growth of micro-organisms.

Recommended Specification to Control the Growth of Micro-organisms

As previously discussed, the recommended pressure dewpoint to control the growth of micro-organisms is ≤-40°F PDP, equivalent to ISO8573-1:2010 Class 2 for water. This dewpoint will inhibit (stop) the growth of micro-organisms in the compressed air distribution piping system and prevent high efficiency dry particulate filtration from being overwhelmed. The recommended specification for point of use dry particulate filtration is a high efficiency grade providing particle reduction down to 0.01 micron with a removal efficiency of 99.9999% and equivalent to an ISO 8573-1:2010 Classification of Class 1 for solid particulate. Compressed air specifications using ISO 8573 typically include a recommendation for total oil. The minimum recommendation for total oil for any industrial application would be Class 2, however as control over microbial growth is paramount for critical applications in the food, beverage, pharmaceutical and cosmetics industries (and for breathing air & medical air), these applications typically require "Technically Oil Free" air. Therefore a classification of ISO 8573-1:2010 Class 1 or Class 0 for total oil is recommended for such applications. This results in a recommended specification of ISO 8573-1:2010 Class 1:2:1 or ISO 8573-1:2010 Class 1:2:0

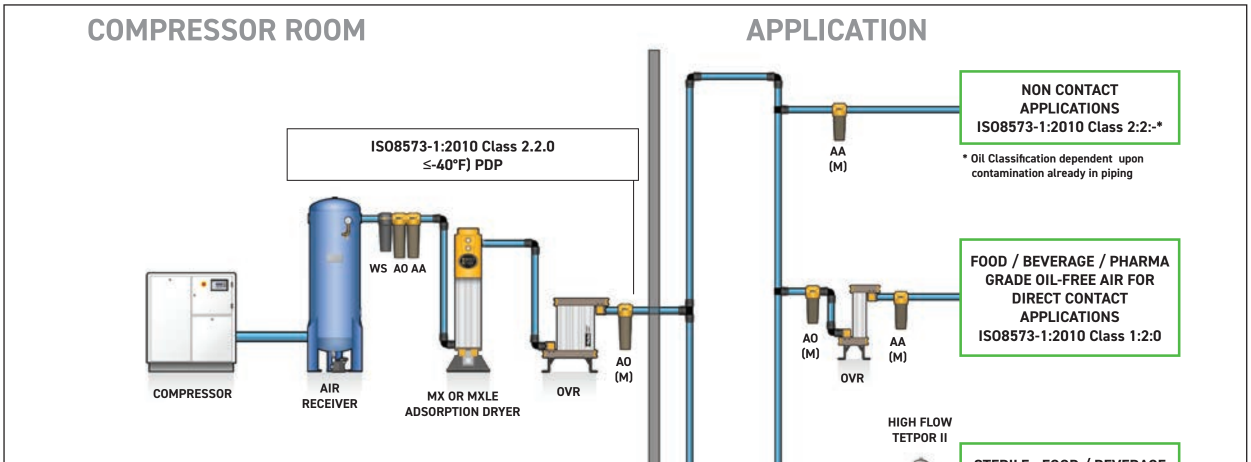
Recommended Air Quality	**Parker Compressed Air Treatment products for the treatment of**		
	Solid Particulate	**Water (Vapor)**	**Total Oil (Aerosol + Vapor)**
ISO 8573-1:2010 Class 1:2:1 **ISO 8573-1:2010 Class 1:2:0**	**Compressor Room** OIL-X Coalescing Filters Grade AO + AA	Adsorption Dryer ≤-40°F PDP	OIL-X Coalescing & Oil Vapor Reduction Filters Grades AO + AA + OVR or OFAS / FBP Oil Free Air Systems
	Point of Use OIL-X Dry Particulate Filters Grade AO (M) + AA (M)		

Cost Effective system Design

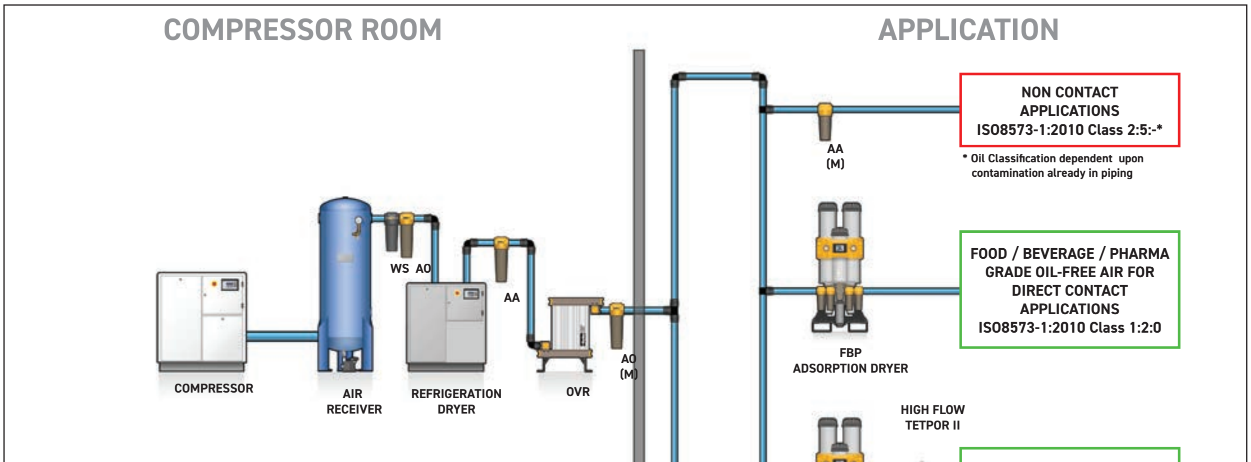
To achieve the stringent air quality levels required for today's modern production facilities, a careful approach to system design, commissioning and operation must be employed.

Treatment at one point alone is not enough and it is highly recommended that the compressed air is treated in the compressor room to a level that will provide general purpose air to the site and also protect the distribution piping. Point of use purification should also be employed, not only to remove any contamination remaining in the distribution system, but also with specific attention on the quality of air required by each application. This approach to system design ensures that air is not 'over treated' and provides the most cost effective solution to high quality compressed air.

FOOD / BEVERAGE / PHARMACEUTICAL - DIRECT CONTACT APPLICATIONS



IMPORTANT NOTES:
The purification equipment requirements are identical for both oil-free and oil lubricated compressors.
Green Box at point of use = Control Over growth of Micro-organisms.
Red Box at point of use = No Control over growth of micro-organisms

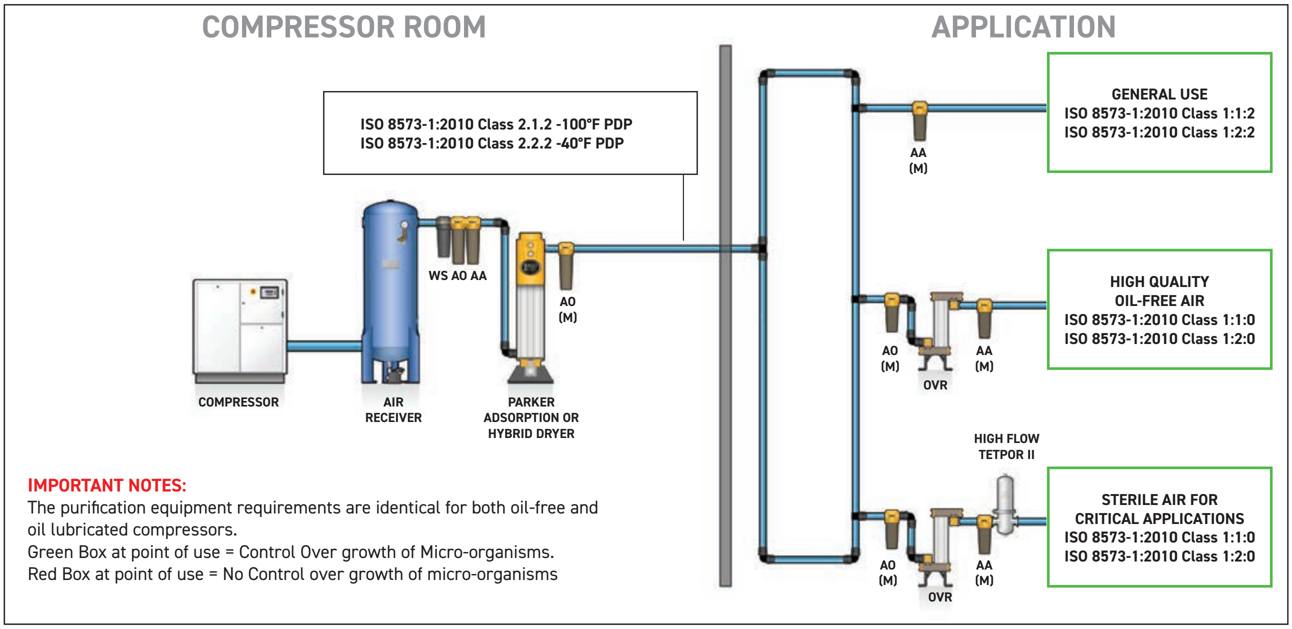


IMPORTANT NOTES:
The purification equipment requirements are identical for both oil-free and oil lubricated compressors.
Green Box at point of use = Control Over growth of Micro-organisms.
Red Box at point of use = No Control over growth of micro-organisms

Typical Applications

Direct contact / in-direct contact applications in food manufacturing / beverage bottling / pharmaceutical manufacturing / dairies / breweries / wineries / distilleries (In accordance with BCAS Best Practice Guideline 102 Food & Beverage Grade Compressed Air).

HIGH QUALITY TECHNICALLY OIL-FREE AIR



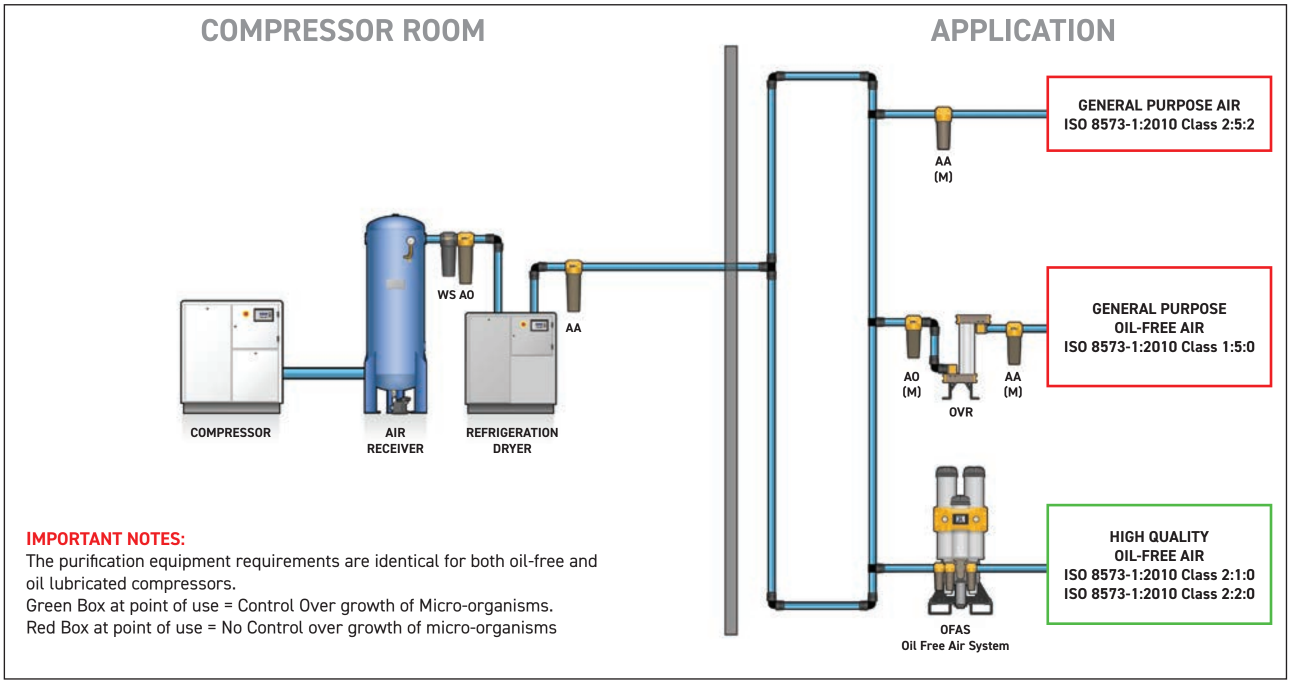
Typical Oil-Free Air Applications

Blow molding of plastics e.g. P.E.T. bottles
Electronics manufacturing
CDA systems for electronics manufacturing
Film processing
Critical instrumentation
Advanced pneumatics
Air blast circuit breakers

Decompression chambers
Cosmetic production
Medical air
Dental air
Lasers and optics
Robotics
Spray painting

Air bearings
Pipeline purging
Measuring equipment
Blanketing
Modified atmosphere packaging
Pre-treatment for on-site gas generation

GENERAL PURPOSE AIR WITH OIL-FREE AIR FOR CRITICAL APPLICATIONS



Typical General Purpose Applications

General ring main protection
Pre-filtration to point of use adsorption air dryers
Plant automation
Air logistics
Pneumatic tools
General instrumentation
Metal stamping

Forging
General industrial assembly (no external piping)
Air conveying (Non Food)
Air motors
Workshop (Tools)

Garage (Tire filling)
Temperature control systems
Blow guns
Gauging equipment
Raw material mixing
Sand / bead blasting

High Quality Compressed Air Guaranteed

To guarantee maximum performance and reliability, Parker compressed air treatment products protect the entire compressed air network, providing the perfect grade of high quality compressed air, exactly where it is needed.

Recommended Filtration Products

OIL-X Water Separators
Coalescing Filters & Dry Particulate Filters

OIL-X OVR Oil Vapor Reduction Filters

Recommended Drying Products

CDAS
Clean Dry Air System

OFAS
Oil Free Air System

FBP
Food / Beverage / Pharmaceutical
Oil Free Air System

Parker OIL-X filter range and Parker modular dryer ranges have been designed to provide compressed air quality that meets or exceeds the levels shown in all editions of ISO8573-1, the international standard for compressed air quality and the BCAS Food and Beverage Grade Compressed Air Best Practice Guideline 102.

Filtration & dryer performance has also been independently verified by Lloyds Register.

OIL-X Water Separators
Water separator performance has been tested in accordance with ISO12500-4 and ISO8573-9.

OIL-X Coalescing Filters
Coalescing filter performance has been tested in accordance with ISO12500-1, ISO8573-2 and ISO8573-4.

OIL-X Dry particulate Filters
Dry particulate filter performance has been tested in accordance with ISO8573-4.

OIL-X Oil Vapor Removal Filters
Oil vapor removal filter performance has been tested in accordance with ISO8573-5.

Adsorption Dryer Ranges
CDAS, OFAS, FBP, CDAS ATEX, MX, MX ATEX & MXLE dryer performance has been tested in accordance with of ISO7183.

In addition to performance validation, the materials used in the construction of the ranges recommended below for use in food and beverage manufacturing are FDA Title 21 Compliant and EC1935-2004 exempt. Certificates available on request.

MX
Heatless Adsorption Dryer

MXLE
Heatless Low Energy Adsorption Dryer

Worldwide Filtration Manufacturing Locations

North America

Compressed Air Treatment

Industrial Gas Filtration and Generation Division
Lancaster, NY
716 686 6400
www.parker.com/igfg

Haverhill, MA
978 858 0505
www.parker.com/igfg

Engine Filtration

Racor
Modesto, CA
209 521 7860
www.parker.com/racor

Holly Springs, MS
662 252 2656
www.parker.com/racor

Hydraulic Filtration

Hydraulic & Fuel Filtration
Metamora, OH
419 644 4311
www.parker.com/hydraulicfilter

Laval, QC Canada
450 629 9594
www.parkerfarr.com

Velcon
Colorado Springs, CO
719 531 5855
www.velcon.com

Process Filtration

domnick hunter Process Filtration SciLog
Oxnard, CA
805 604 3400
www.parker.com/processfiltration

Water Purification

Village Marine, Sea Recovery, Horizon Reverse Osmosis
Carson, CA
310 637 3400
www.parker.com/watermakers

Europe

Compressed Air Treatment

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Gateshead, England
+44 (0) 191 402 9000
www.parker.com/dhfns

Parker Gas Separations
Etten-Leur, Netherlands
+31 76 508 5300
www.parker.com/dhfns

Hiross Zander
Essen, Germany
+49 2054 9340
www.parker.com/hzfd

Padova, Italy
+39 049 9712 111
www.parker.com/hzfd

Engine Filtration & Water Purification

Racor
Dewsbury, England
+44 (0) 1924 487 000
www.parker.com/rfde

Racor Research & Development
Stuttgart, Germany
+49 (0)711 7071 290-10

Hydraulic Filtration

Hydraulic Filter
Arnhem, Holland
+31 26 3760376
www.parker.com/hfde

Urjala, Finland
+358 20 753 2500

Condition Monitoring Parker Kittiwake
West Sussex, England
+44 (0) 1903 731 470
www.kittiwake.com

Process Filtration

domnick hunter Process Filtration Parker Twin Filter BV
Birtley, England
+44 (0) 191 410 5121
www.parker.com/processfiltration

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Castle Hill, Australia
+61 2 9634 7777
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www.parker.com/br

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Miami, FL
305 470 8800
www.parker.com/panam

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www.parker.com/africa

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