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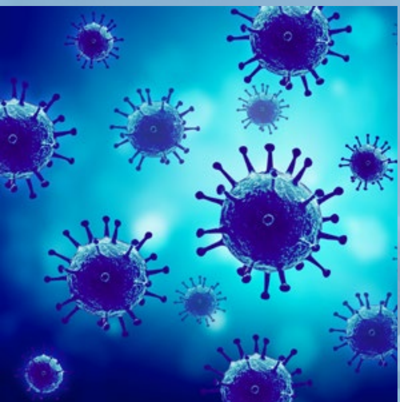
Compressed Air & Gas Institute

COMPRESSED AIR PURITY GUIDE

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INTRODUCTION

This Compressed Air Purity Guide addresses the critical importance of clean-dry compressed air in the multitude of industries that rely upon compressed air as a utility. This guide focuses on compressed air used in industrial applications and does not address compressed air for use as breathing air or sterile air applications.

The atmosphere is comprised of a gaseous mixture that we call “air.” Air is 78% nitrogen, 21% life-giving oxygen, with the remaining 1% comprised of naturally occurring inert gases as well as trace amounts of carbon dioxide, water vapor, methane, and hydrogen. Air is a gas that blankets the planet, and it contacts everything that mankind or Mother Nature can produce.

When manmade or naturally occurring substances become airborne, these chemicals, compounds, and matter contaminate the air and affect the reliability and efficiency of any compressed air system. Contaminants can cause catastrophic damage to equipment and costly losses if they contact a sensitive product, such as food or pharmaceuticals. For this reason, compressed air, as used in industrial processes, must be treated to achieve a desired level of purity.

The International Standards Organization (ISO) has developed an air purity standard that can be used to describe any compressed air purity level regarding the three fundamental air contaminants: particles, water, and oil. The latest edition of ISO 8573-1, Compressed Air: Part 1: Contaminants and Purity Classes is a quantitative description of the presence of these three contaminants within compressed air. It is the standard for classifying air purity levels throughout industry and the world.

The objective of this Compressed Air Purity Guide is to explain the ISO 8573-1 specification and to guide users of compressed air how to use this specification, along with proper equipment selection, to achieve and maintain the required level of compressed air purity for the three generally accepted application categories of compressed air: plant air, instrument air, and process air.

This guide references detailed information that is in the online version of the Compressed Air and Gas Handbook. Chapter 3, “Compressed Air Treatment,” thoroughly describes the equipment available to meet the specific ISO 8573-1 classes, including various types of dryers, filters, moisture separators, and drains. Chapter 4, “Compressed Air System Design,” provides examples of proper equipment selection for achieving a desired compressed air purity quality. Content for this Compressed Air Purity Guide has been provided by members of the Air Drying & Filtration Section.

NEED FOR CLEAN-DRY-AIR

Compressed air is a widely used utility worldwide, powering pneumatic systems and the equipment used for a range of critical applications including manufacturing, automation, instrumentation, pharmaceutical, food and beverage, and more. While optimizing the compressed air system for maximum efficiency and productivity is a key focus of management, compressed air purity often gets overlooked despite its profound impact on processes, productivity, efficiency, product integrity, and profit.

Contamination within atmospheric air is omnipresent and unavoidable. Dust, pollen, spores, smoke, chemicals, water, and hydrocarbons are a few of the unwanted contaminants that are present in varying quantities within atmospheric air. When these contaminants are ingested into an air compressor, they become part of the compressed air stream. The compressor itself can introduce additional contaminants to the air stream, as can the downstream air distribution network as a result of corrosion. By the time the compressed air reaches its intended end user, it can be highly contaminated and unfit for use. Equipment reliability can be greatly affected as contaminants can accumulate in pneumatic equipment, causing blockages, valve malfunctions, and increased wear and tear. Contaminated compressed air can compromise the purity and consistency of end products, leading to rejections, recalls, and customer dissatisfaction. Contaminated air can quickly blind inline filters and cause energy-robbing pressure drops that reduce the efficiency and productivity of any compressed air system.

How much compressed air contamination is too much? This measure varies amongst the many varieties of compressed air applications, but the initial step in answering this question is to establish a reliable and consistent quantitative measurement of the purity level of a compressed air stream. This standard is ISO 8573-1, Compressed Air: Part 1: Contaminants and Purity Classes and it can be used to identify the specific air purity required for any compressed air application. Once the required air purity for an application or entire system has been determined, the task becomes one of installing the proper air compressors and air treatment equipment to achieve the required level of air purity and then maintaining that equipment in a manner that ensures the continuance of the desired air purity.

COMPOSITION OF ATMOSPHERIC AIR

Atmospheric air is a mixture of chemically different gases and suspended particles that surround the earth. The blend of gases provides the air we breathe, protects us from ultraviolet radiation from the sun, and maintains temperatures habitable for life on Earth. Standard dry air is composed of three primary gases, Nitrogen (N_2) making up 78% of atmospheric air, oxygen (O_2) constituting 21%, and Argon (Ar), representing 0.93% by volume. The remaining portion of gases, .07% by volume, is comprised of rare gases such as helium (He) and neon (Ne) as well as greenhouse gases, notably water vapor (H_2O) and carbon dioxide (CO_2).

CONTAMINANTS IN ATMOSPHERIC AIR

Atmospheric air also contains contaminants in the form of minute particulates, microorganisms, water, and hydrocarbon vapor. The contaminants and their concentration in the atmospheric air must be considered when selecting the optimal location for the air compressor intake. The adage, “garbage in, garbage out,” is no truer than when considering the air that the compressor ingests prior to compression. Accordingly, to ensure that the cleanest intake air is being fed to the compressor, it is critical to locate the compressor intake as far away from the source of the potential contaminants as is possible. Locate the compressor in a cool, clean, and dry uncontaminated area. Avoid locations nearby to painting, chemical cleaning, engine exhaust, or environments where corrosive fumes such as chlorine, sulfur, and ammonia are detected. The compressor room, which is often also the junk storage room in the facility, should be cleaned on a regular basis to reduce the amount of ambient dirt and dust in the air. The quality of the compressor intake air affects the selection of the air treatment equipment that is required to condition the air effectively and efficiently to achieve and maintain a desired ISO 8573-1 air purity. As illustrated in Table 1 below, ISO 8573-1 identifies three basic atmospheric contaminants: particulate matter (including microorganisms), water, and oil. An ISO 8573 class description is a three number classification. The first number represents the solid content, the second number represents the water content, and the third number represents the oil content within an air stream. For example, in ISO 8573 classification 3:4:2 indicates Class 3 Solid Content, Class 4 Water Content and Class 2 Oil Content. Similarly [-:4:-] represents Class 4 Water Content.

Table 1

ISO 8573-1:2010, *Compressed Air: Part 1 Contaminants and Purity Classes*

Class	Particles				Water			Oil
	By Particle Size (maximum number of particles per m³)			By Mass	Vapor Pressure Dew point		Liquid	Liquid, Aersosol, & Vapor
	0.10 – 0.5 microns	0.5 – 1.0 microns	1.0 -5.0 microns	mg/m³	°C	°F	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	≤ -94	-	<0.01
2	400,000	6,000	100	-	≤ -40	≤ -40	-	<0.1
3	-	90,000	1,000	-	≤ -20	≤ -4	-	<1
4	-	-	10,000	-	≤ +3	≤ +37	-	<5
5	-	-	100,000	-	≤ +7	≤ +45	-	-
6	-	-	-	0-5	≤ +10	≤ +50	-	-
7	-	-	-	5-10	-	-	0.5	-
8	-	-	-	-	-	-	5	-
9	-	-	-	-	-	-	10	-
X	-	-	-	>10	-	-	>10	>5

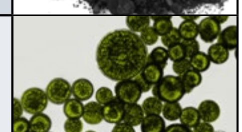
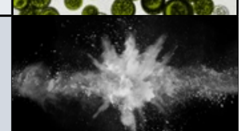
Particulate Matter

On average, about 20 teragrams (20 trillion grams) of dust are suspended in the atmosphere at any given time.[1] Twenty (20) teragrams equals 44 billion pounds. Even in clean rural areas, a cubic foot of air is contaminated with 2.8 million particles, many of which will be microorganisms.[2] In general industrial areas, there are approximately 4,000,000 airborne particles per cubic foot of free air[3]. Finely divided solid particles such as dirt, dust, and pollen originate from natural sources including deserts,

[1] National Environmental Satellite, Data, and Information Service.
[2] The Direct on Atmospheric Dust.
[3] Controlling Micro-organism Growth in Compressed Air, A White paper by Mark White, Compressed Air Treatment Applications Manager, Parker Hannifin.

agricultural operations and construction activities. Sources for manmade, aerosol-based particles, formed by complex chemical reactions in the air, include emissions from industrial processes and the burning of fossil fuels.

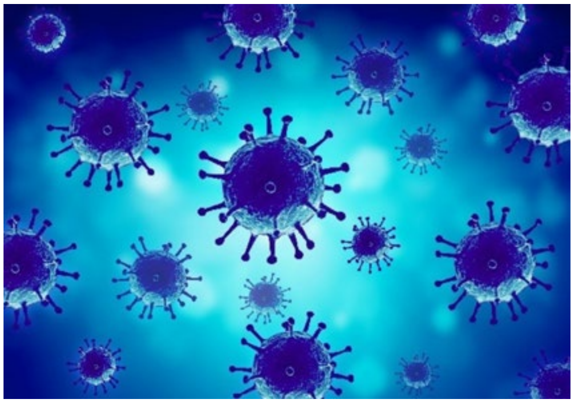
Particles can come from many sources such as agriculture operations.

CONTAMINANT	SMALLEST (µM)	LARGEST (µM)	IMAGE
Smoke	0.01	1	
Carbon Black	0.01	0.3	
Bacteria	0.25	30	
Ground Talc	0.4	50	
Coal Dust	1	200	
Human Hair	30	200	
Beach Sand	100	1000	

ISO 8573-1 uses the micron (µm) to measure the size of particles. A micron is a unit of measure in the metric system to quantify length. One micron is equivalent to one-millionth of a meter or 1/25,000th of an inch.

The size of particulate matter in atmospheric air varies, from fine, invisible particles with diameters down to 0.002 micron to larger particles measuring 100 µm, that are barely visible to the naked eye. Approximately 85% of airborne particles measure 2.0 µm or less.

Atmospheric air contains microbiological contamination. Viable, metabolically active microorganisms are derived from the oceans, soil, and plant life. Species include bacteria, algae, viruses, and fungi that grow at a rapid rate in moist, nutrient rich environments. For bacteria and fungi alone, atmospheric cell concentration can be up to 100,000 cells per cubic meter of air. Non-viable, non-living particles, such as dirt, sand, and dust, serve as transporters for viable particles. Microorganisms possess various dimensions and sizes, from round to string-shaped, ranging 0.3 µm to 60.0 µm in size. Due to their extremely small density, microorganisms may remain suspended in the atmosphere for prolonged periods of time and aided by wind gusts, may travel long distances before settling back to ground or water.



Bacteria is the most abundant microorganism in atmospheric air.

Water

Water cycles continuously throughout the atmosphere in the form of a solid, liquid, or gas (vapor). Water on the surface of the earth evaporates into a vapor, rises on warm updrafts into the atmosphere, then releases back to the Earth as precipitation in the form of rain or snow. Water vapor constitutes 0.25% of total atmospheric gases by mass under average conditions and up to 2.0% under warm, humid conditions.

99% of atmospheric water is in a vapor state that condenses forming clouds.

One cubic foot of compressed air at 100 psig begins as 7.8 cubic feet of free air at atmospheric pressure. Accordingly, the entire concentrations of water vapor and the multitude of contaminants occurring within the 7.8 ft^3 of free air are concentrated within the 1 ft^3 of 100 psig compressed air. In total volume, water represents 99.9% of the liquid contamination in a compressed air system. The amount of water vapor introduced into a compressed air system is dependent on ambient air dew point (°F) and flow rate (scfm). As illustrated in Table 2 below, an air compressor delivering 100 scfm and ingesting 60°F dew point ambient air will introduce approximately 14 gallons of water into the air system over a 24-hour period.

Table 2

Gallons of Water Entering a System Per 24 Hours

Flow (scfm)	Ambient Dew Point (°F)				
	40	50	60	70	80
100	6.7	9.9	14.3	20.4	28.8
250	16.8	24.7	35.7	51.0	72.0
500	33.6	49.4	71.5	102.1	144.0
750	50.4	74.1	107.2	153.1	216.0
1000	67.3	98.8	143.0	204.1	287.9
1500	100.9	148.3	214.5	306.2	431.9
2000	134.5	197.7	286.0	408.2	575.9
2500	168.2	247.1	357.5	510.3	719.9
3000	201.8	296.5	428.9	612.3	863.8

Air exiting the compressor is saturated with water in a gas phase. As the air cools within the piping system, the water vapor condenses into liquid form.

Moisture and liquid water in compressed air systems are catalysts for rust and corrosion throughout the distribution network and moisture supports the growth of microorganisms. Liquid water fouls filters, creating energy-robbing pressure drops, and water can severely affect product quality and pneumatic device reliability and longevity.

Oil Vapor and Other Gaseous Contaminants

Atmospheric air may include condensable hydrocarbons. These compounds are the primary byproduct of fossil fuel combustion, including automobile exhaust, industrial emissions, and petrochemical processes. Oil vapor concentrations in ambient air range from 0.05 mg/m^3 in light industrial settings up to 0.50 mg/m^3 in heavy industrial areas, with submicronic aerosols ranging from 0.80 μm to 0.01 μm. Since these hydrocarbons are in a vapor phase, they are not captured by the compressor intake air filter, and they become part of the compressed air stream. When concentrated as a result of the compression process, these oil vapors readily condense into liquid oil once the warm, saturated compressed air exits the compressor and enters cooler temperatures within the piping system. On a continuously operating compressed air system, oil vapor condensation can add as much as 0.50 ounces per scfm/ per month of oil into the air system.

Hydrocarbons are molecules of carbon and hydrogen in various combinations.

CONTAMINANTS IN COMPRESSED AIR

Compressed air is contaminated from three primary sources: atmospheric contamination, contamination generated by the air compressor, and contamination introduced from the compressed air distribution system. The role that airborne atmospheric contamination plays in contaminating compressed air has already been addressed. Below is a discussion of the other two sources of compressed air contamination. Early detection of contamination and accurate identification of the contamination sources are essential to achieving and maintaining the specified compressed air purity.

Contamination Generated During the Compression Process

In addition to ingested air contamination, the second largest concentration of solid and liquid contaminants present in a compressed air system originates from the air compressor itself.

Compressor Lubricant

End users have the option of selecting from several air compressor technologies, some of which require oil in the compression chamber for lubrication, cooling, and sealing purposes, and others that operate without oil in the compression chamber. The end user determines which compressor design best meets the specified requirements for the application. Those compressors that utilize oil in the compression chamber introduce oil into the compressed air stream in varying quantities depending upon the type and mechanical condition of the compressor.

In compressed air systems the amount of oil within the compressed air is expressed as ppm/w. For example, a 25-horsepower air compressor, rated at 100 scfm that operates for 2000 hours (40 hours a week for 50 weeks per year) compresses 12,000,000 cubic feet of ambient air per year. With ambient air weighing 0.075 pounds per cubic foot, the amount of air compressed totals approximately 900,000 pounds. If the compressor operates with a 2.0 ppm/w of oil carryover that equates to two pounds of oil being introduced with every 1,000,000 pounds of air compressed. Since the 25-horsepower compressor produces 900,000 pounds of air, the amount of oil carryover is 90% of 2 pounds, or 1.8 pounds of oil. With oil weighing an average of 7.5 pounds per gallon, 1.8 pounds of oil equals 0.24 gallons or approximately one quart. Excessive compressor lubricant carryover can lead to downstream contamination that compromises the integrity of products, fouls filters, increases energy-robbing pressure drops, and poses serious reliability issues with all pneumatic devices. Although most pneumatic tools require lubrication, compressor lubricant carryover is not designed for tool lubrication and can damage the tool. For proper tool lubrication, FRLs (filter-regulator-lubricator) are installed prior to the tool.

Dependent on the age of the compressor and the extent of preventative maintenance performed, a lubricated rotary screw air compressor will introduce 2.0 to 10.0 ppm/w of oil into the air system as oil carryover. As illustrated in Table 3 below, a well maintained 50 horsepower (250 scfm) lubricated air compressor, with a conservative 4.0 parts per million lubricant carryover will pass up to 4.8 gallons of oil into the air system when operating 8000 hours, or approximately every year.

Table 3

Oil Carryover in Gallons from a Lubricated Rotary Screw Compressor

Concentration (ppm/w)	Time (Hours)	25 HP (100 scfm)	50 HP (250 scfm)	100 HP (500 scfm)	200 HP (1000 scfm)
2.0	2000	0.2	0.5	1.2	2.4
	4000	0.5	1.0	2.4	4.8
	8000	1.0	1.9	4.8	9.6
4.0	2000	0.5	1.2	2.4	4.8
	4000	1.0	2.4	4.8	9.6
	8000	1.9	4.8	9.6	19.2
6.0	2000	0.7	1.8	3.6	7.2
	4000	1.4	3.6	7.2	14.4
	8000	2.9	7.2	14.4	28.8
8.0	2000	1.0	2.4	4.8	9.6
	4000	1.9	4.8	9.6	19.2
	8000	3.8	19.2	19.2	38.4
10.0	2000	1.2	2.9	6.0	12.0
	4000	2.4	5.8	12.0	24.0
	8000	4.8	11.6	24.0	48.0
Gallons of lubricant entering a compressed air system based on operating hours, concentration of oil carryover, and scfm.					

Depending on the type of compressor, compression temperatures may reach 200°F to 400°F. At these high temperatures, most compressor lubricants degrade and create carbon deposits. When these deposits mix with water, they create acidic varnish that may contaminate and corrode compressor rotors, metal pipework, storage tanks, and pneumatic components.

Properly maintained and unvarnished rotary screw rotors.

Heavily varnished rotary screw rotors due to excessive temperature operation.

Photo courtesy of Hitachi Global Air Power US, LLC.

To eliminate the intentional introduction of oil into the compression process, and the issues that oil carryover creates, end users may specify an oil-free compressor. With such a compressor, lubricant is only required for the bearings and timing gears, which are segregated from the compression chamber. This technology, however, will not eliminate the possibility of oil contamination and is subject to the inherent challenges presented by the quality of the intake air. An oil-free compressor will deliver compressed air that has an oil content no greater than what is ingested by the compressor at its intake.

Contaminants From Compressor Wear Particles

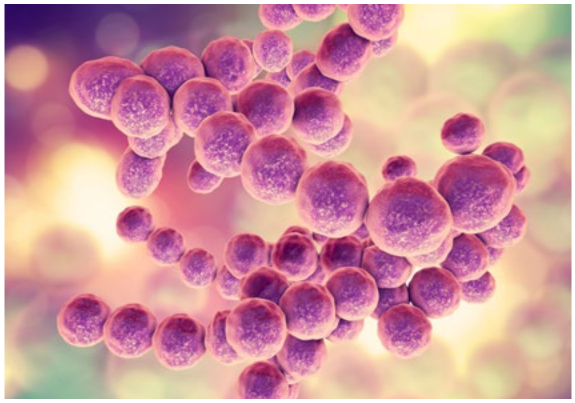
The air compressor is also a source for solid contaminants being introduced into the air system. Depending on the type of compressor, its age, and its maintenance schedule, the mechanical action of the compressor will generate wear particles in the form of metal fines, rotor coatings, varnish, and carbon that will be added as contaminants to the air.

Contaminants From the Compressed Air System

The role of the compressed air distribution and storage network is to deliver a stable supply of compressed air from the compressor discharge to the points of use. During the compression process, solids, water vapor, and oil become highly concentrated within the compressed air stream. If these contaminants are left in the compressed air and allowed to pass downstream, they will condense and form sludgy, scaly deposits on the interior surfaces of the piping and air receivers. These contaminated surfaces become breeding grounds for rust formation and corrosion. Over time, the rust and pipe scale break free and travel long distances throughout the piping network. Solid particles range from 1.0 μm to 40 μm, with 80% approximately 10 μm in size. Due to the small size of the particle matter, they can remain suspended in the compressed air for hours and travel the entire length of the piping. This contamination will negatively impact air quality, foul filters, and plug orifices on sensitive pneumatic devices.

Water residing in piping distribution systems forms rust and pipe scale.

Viable microorganisms, such as bacteria, mold, and fungi, flourish in warm, moist environments. Microorganisms feed off nutrient sources such as water and may even consume oil and rust. Microbes adapt to their environment and can remain dormant for prolonged periods of time, and under the right conditions, begin to grow and colonize. Wet receiver tanks, drip legs, and drain traps are ideal locations within the piping system to foster microorganism growth.



Microorganism growth with presence of water.

DETERMINE THE APPROPRIATE AIR PURITY FOR ANY APPLICATION

Typical purity classes of compressed air applications

Determining what purity of air is required for a specific application is both an art and a science. Wherever possible, adhere to the purity level recommended by the original equipment manufacturer (OEM) of the equipment in question. The OEM, through testing and experience, knows what purity level of air is required for its equipment to function reliably, efficiently, and productively. When no OEM direction is available, users must rely upon the "art" of past experience, common sense, or refer to one of the many air-purity-by-application charts that are available. Several industrial associations have established air purity guidelines for applications within specific industries based upon their experience. Two such associations are the German Mechanical Engineering Industry Association (VDMA) and the British Compressed Air Society (BCAS). These associations recommend air purities both for specific applications and for general service conditions, such as air purity for direct food contact applications. These recommendations are typically referenced by the air quality classes in the ISO 8573-1:2010 specification.

METHODS FOR ATTAINING THE REQUIRED AIR PURITY LEVEL

Once the user has determined the level of compressed air purity that is required for the application, the task becomes one of selecting and installing the air treatment equipment that will reliably deliver the required air purity. Solid particles are removed from the air stream by filters. Particle filters are of the surface type and are used to remove solid particles. Coalescence filters are of the depth type and are used to remove liquids as well as solids from the air. Filter manufacturers assign two ratings to a filter: a micron rating in (µm) and a capture efficiency in (%). For example, a filter rated for 1.0 µm and 95% efficiency will capture and remove 95% of particles sized 1.0 µm and larger from the airstream that is passing through the filter media.

Bulk liquids, both water, and oil are removed from the compressed air stream by moisture separators. Water vapor is removed from the compressed air stream by passing the airstream through one of several types of compressed air dryers: refrigerated, adsorption, and membrane.

Oil vapors and odors are removed from compressed air by activated carbon filters or activated carbon adsorbers. Catalyst systems are also used to remove oil vapors and odor from compressed air. Table 4 below shows the type of contaminants that can be removed from an airstream by various common types of air treatment equipment.

Table 4 Contaminant Removal by Air Treatment Component [4]

Treatment Component	Typical Contaminants					
	Water Stream – Droplets	Water aerosols	Water vapor	Solid particles and *microorganisms	Oil Droplets – Aerosol	Oil vapor
Water Separator	√ – √				√ – X	
Refrigeration Dryer			√			
Membrane Dryer			√			
Adsorption Dryer			√			
Coalescing Filter		√		√	√ - √	
Particle Filter				√		
Activated Carbon Filter/ Adsorber						√
Catalyst						√

Possibilities of treatment components for typical contaminants in compressed air

√ = Effective for contaminant removal

X = Not effective for containment removal

*Microorganisms may require sterile filters that are not discussed in this document.

Tables 5a, 5b, and 5c are more detailed tables showing the type of equipment required to achieve specific air purity. Each table is dedicated to one of the specific contaminants as outlined in ISO 8573-1: particles, water, and oil. These tables list general recommendations for the type of treatment devices and technologies that are used to achieve the respective purity class.

The ISO 8573-1 air quality specification provides precise filtration guidelines and filters should be selected to provide the required level of air quality with the least amount of pressure drop. Filters are designed to plug up and as they do so, energy-robbing pressure drop increases. For this reason, all filters should be serviced regularly and replaced at the manufacturer's recommendation. Even though compressed air from an oil-free compressor has no oil added to the air from the compression process, oil-free air still contains oil from the ambient air and particulates from the compressor which require filtration.

[4]This table was sourced from VDMA 15390-1:2014-12, Compressed Air Purity – Part 1: Typical application specific purity classes according to ISO 8753-1:2010 and Guidance for Achieving and Monitoring of a Respective Compressed Air Purity for Industrial Applications with modifications.

Table 5a

Typical Treatment Products for Particulate Reduction

Target Purity Class	Equivalent Particle Content	Typical Removal Device	Comment
[7: –: –]	< 10 mg/m^3	Coarse filter (ref. "40 µm" filter)	In combination with an upstream liquid separator also suitable for separation of liquid oil or water.
[6:–:–]	< 5 mg/ m^3	General purpose filter (ref. "5 µm" to "3 µm" filter)	In combination with an upstream liquid separator also suitable for separation of liquid oil or water.
[5:–:–] - [2:–:–]	See Table 1	High efficiency filter (ref. "1 µm" to "0.01 µm" filter)	Also suitable for oil aerosol separation in coalescing design. **Prerequisites:** compressed air free from water
[1:–:–]	See Table 1	Superfine filter (ref. "0.01 µm" filter)	Also suitable for oil aerosol separation in coalescing design. **Prerequisites:** compressed air free from water.

Table 5b

Typical Treatment Products for Water or Humidity Reduction

Target Purity Class	Equivalent Water Content	Typical Removal Device	Comment
[–:9:–] - [–:7:–]	< 10 g/m^3… 0.5 g/m^3	Coarse filter (ref. "40 µm" to "5 µm" filter) preceded by spin/cyclone separator, water separator	Also suitable for oil droplet separation.
[–:6:–] - [–:4:–]	pressure dew point <+50°F … +37.4°F	Refrigeration dryer	It may require upstream liquid separation according to manufacturer.
[–:5:–] - [–:2:–]	pressure dew point suppression of 36°F to over 100°F	Membrane dryer	Outlet pressure dew point depends on intake conditions. **Prerequisites:** compressed air free from liquid oil, water and particles.
[–:3:–] - [–:1:–]	pressure dew point ≤ -4°F … ≤-94°F	Adsorption (i.e. desiccant) dryer	**Prerequisites:** compressed air free from liquid oil, water and particles.

Table 5c

Typical Treatment Products for Oil Removal

Target Purity Class	Equivalent Total Oil Content	Typical Removal Device	Comment
[–:–:4] - [–:–:3]	< 5 mg/m^3 - < 1 mg/m^3	Coarse or general-purpose coalescing filter (ref. “3 µm” or “1 µm” filter)	Also suitable for particle separation.
[–:–:2]	< 0.1 mg/m^3	Superfine coalescing filter (ref. “0.01 µm” filter)	Also suitable for particle separation. **Prerequisites:** compressed air free from water.
[–:–:1]	< 0.01 mg/m^3	Superfine coalescing filter (ref. 0.01 µm” filter, respectively) followed by activated carbon filter or catalyst oil removal device.	**Prerequisites:** compressed air free from liquid oil, water and particles.

Note: Identifying filters by nominal rating (e.g., “coarse,” “general purpose,” “high efficiency,” “fine,” “superfine”) refers to industry accepted levels of filtration media and is not intended to imply a guaranteed level of filtration efficiency. These tables are sourced from VDMA 15390-1-2014 with modifications.

As illustrated in Table 6 below, some treatment components, because of the nature of their design and function, require pretreated compressed air at the inlet to ensure reliable operation and to achieve the desired compressed air purity. Always consult the manufacturer’s recommendation for the air treatment component to be aware of the required air purity at the inlet of the component.

Table 6

Typical Pre-Treatment Requirements for Air Treatment Devices

	Purity classes according to ISO 8573-1:2010		
	Particles	Water content (vapor)	Oil content
Adsorption dryer	2	7	1*
Membrane dryer	1	6	1*
Refrigerated dryer	4	7	3*
Activated carbon filter/adsorber	2	4	1*

*Relates exclusively to liquid oil
This table is sourced from VDMA 15390-1-2014 with modifications.

CLASSIFICATIONS OF INDUSTRIAL COMPRESSED AIR

The compressed air industry identifies three general levels of air quality under which most applications can be categorized: plant air, instrument air, and process air. The following discussion will describe each classification and provide an ISO 8573-1 air quality standard for each category.

Plant Air

Plant air, or shop air to which it is frequently referred, is the term given to the "clean-dry" compressed air that is used to power the numerous varieties of pneumatic tools and devices that are used throughout industry. Pneumatic tools consume a significant portion of what is classified as Plant Air. A typical industrial pneumatic tool is the nutrunner, an essential hand-held tool used extensively in automotive assembly plants. The primary cause for degraded air tool performance is liquid water within the compressed air stream. Pneumatic tools require constant lubrication to perform reliably and at their peak performance. Such lubrication is supplied manually by the operator or more often automatically by a Filter-Regulator-Lubricator (FRL) that is attached to the air line directly prior to the tool. Liquid water washes the lubrication out of the tool, greatly increasing the friction and wear within the tool air motor. Since much of Plant Air serves air tools, the elimination of water from the compressed air stream is the key air purity variable for the Plant Air classification. An ISO 8573-1 air purity specification of [-:4-5:-] with a minimum point of 45°F satisfies the Plant Air classification. Since most pneumatic tools and devices incorporate an FRL, the variable particulate and oil contaminants in Plant Air are controlled by the FRL.

Plant Air implies a centralized compressed air supply with all of the compressed air being treated within the compressor room to a baseline level of purification with regard to particulate, water, and oil content. Plant Air requires the minimal amount of air treatment. Compressors frequently have integrated aftercoolers that will effectively remove a significant amount (~70%) of the bulk water present in the compressed air stream. Water separators are recommended at the outlet of aftercoolers as these will effectively separate the liquid portion of water content from the compressed air. However, whether compressor aftercoolers are present or not, dedicated water separators are useful in all systems because they offer relatively low pressure drop and significantly reduce the water load on downstream coalescing filters and air dryers, therefore extending their service life. Water separators will not remove water vapor/aerosols or reduce the pressure dew point, so further treatment is needed for this purpose.

Once the bulk/liquid water has been removed, the saturated compressed air should pass through a coalescing filter to remove solids and liquid aerosols of both water and oil. The air is now ready for drying; reducing its pressure dew point to prevent the possibility of downstream water condensation. This normally can be achieved with a refrigerated air dryer to reach an ISO 8573-1 class 4 or 5 moisture purity. If the Plant Air is going to experience temperatures below the pressure dew point of the refrigerated dryer, then an adsorption (desiccant) dryer should be considered. In some cases, the pressure dew point requirement for Plant Air may fluctuate seasonally, in which case a combination of dryer types (or hybrid dryer) may be needed to cover all environmental conditions. In such situations a refrigerated dryer would be sufficient in the warmer months and an adsorption dryer would be required in the colder months. Even though the adsorption dryer would handle the drying over the entire temperature variation, it is more costly to operate than a refrigerated dryer and a significant savings can be realized by splitting the drying tasks between the two technologies. When using adsorption type dryers, note that coalescing pre-filters are required to meet the dryer's minimum inlet pre-treatment requirements (see Table 6), as oil aerosol contamination would foul the desiccant.

Plant Air downstream from the dryer(s) will be void of water and acceptable for air tool and other general compressed air requirements, e.g., blow off, cooling, drying. Other applications might require additional filtration to achieve a specific ISO 8573-1 classification regarding particulates and oil. For such applications a combination of filters may be used based on the nature of the contaminants and other factors. For example, where lower ISO 8573-1 particulate class air is required, the use of multistage or series filtration is recommended, with more coarse filters located before fine grade filters. Note that particulate filters are always required after adsorption dryers to capture any abraded desiccant particles entrained in the compressed air. Coalescing or "wet" filters will effectively remove particulates as well as the finest water and oil mist/aerosols that might remain in Plant Air. When a majority of the downstream applications in a facility require higher purity than Plant Air, it is recommended to treat the entire compressed air supply directly from the compressor room to a higher purity, such as Instrument or Process quality air as described below.

Instrument Air

Instrument air is a compressed air purity category typically specified for use with various sensitive equipment such as pneumatic control devices, sensors, and instruments requiring clean dry air of a higher purity than Plant Air. The Instrument Society of America's Quality Standard for Instrument Air can be interpreted as Class [2:<4:3] per ISO 8573-1 and it is a globally recognized specification for instrument-quality air. The requirements of this standard provide some flexibility in allowable water content to allow for variations in the minimum ambient temperature. A refrigerated dryer is required as a minimum, although dryers having lower outlet pressure dew points (e.g., adsorption or membrane) may be required based on minimum ambient temperature.

Throughout industry, instrument quality air is required to power pneumatic actuators that are used to open and close valves in fluid handling applications. Pneumatic actuators are used extensively in the power generation industry to remotely operate steam valves within the power plant. A higher purity of compressed air beyond Plant Air is necessary to ensure the reliability and longevity of the pneumatic actuator. Instrument air particle purity class 2 can be achieved with fine or super-fine particulate filtration, moisture purity class 2 can be achieved with an adsorption or a membrane air dryer, and the oil purity class 3 can be achieved with general purpose oil filtration.

Process Air

Process air implies that the compressed air directly contacts the product somewhere within the production process. Accordingly, process air typically requires a lower moisture level and oftentimes the further removal of other contaminants beyond Plant Air and Instrument Air. Unlike Instrument Air, a unified standard for specifying process air does not exist. However, as CAGI's Compressed Air & Gas Handbook describes, Process Air applications typically require extremely low moisture levels in order to prevent undesirable scenarios such as: adverse chemical reactions, damage to product being produced, freezing of air lines because of low operating temperatures, etc. For these reasons process air applications typically have pressure dew point requirements from -40 to -100 °F (ISO class [–:2:–] to [–:1:–], respectively) where adsorption dryers are used.

Air knives that direct a stream of high-pressure air onto a product are used extensively within the food processing industry. They are used to cool products and to blow off excess moisture or ingredients.

A typical air knife application on a chicken nugget production line is used to blow off excess bread-crumbs from the nuggets as they move along a conveyor belt. This process air makes direct contact with the nugget and requires an ISO 8573-1 air purity specification of 2-2-1. Particle purity class 2 can be achieved with fine particulate filtration and moisture purity class 2 can be achieved with an adsorption (desiccant) or membrane air dryer. Oil purity class 1 can be achieved with either a lubricated compressor with fine to super fine coalescing filtration followed by activated carbon filtration or a catalyst oil removal device or by using an oil free compressor subject to the oil content of the ambient air, which may require additional downstream filtration to achieve class 1 oil purity.

Air treatment costs include initial capital investment, as well as energy and maintenance costs. These costs will increase proportionately as the level of air treatment purity increases. For this reason, only treat the compressed air to the purity level that satisfies the majority of the applications within the facility. If specific applications require additional treatment to attain a higher purity, these applications can be addressed individually.

One solution for supplying compressed air of higher purity than Plant or Instrument quality air is to use a dedicated compressed air system for the higher purity application. This can be costly and can consume additional space. A more common solution is to install additional air treatment at the point of use to meet the minimum requirements for the higher purity application. With such a decentralized, point-of-use approach, it is important to consider the effect that the upstream air distribution system has on the purity of the air that enters the point-of-use filtration. For example, although centralized Plant Air may have been treated in the compressor room to a nominal ISO 8573-1 class [4:4:5] the plant air actually entering the higher purity application may have picked up contaminants from the plant air network. Accordingly, additional pre-treatment of the Plant Air may be required to bring it back to the purity level it had when exiting the compressor room.

Summary

Compressed air is considered the fourth utility. As such it is required to be clean, dry, and at a stable pressure. The three main compressed air contaminants are particles, water, and oil. The concentration of these contaminants within a compressed air stream is determined by factors such as the purity of the ambient atmospheric air, the type of compressor, the type of air treatment equipment, and the distribution network that delivers the compressed air from the compressor room to the individual points of use.

The International Standards Organization (ISO) has developed air purity standard ISO 8573-1, Compressed Air: Part 1: Contaminants and Purity Classes as a quantitative description of the presence of these three contaminants within compressed air. It is the standard for classifying air purity levels throughout industry and the world. Original Equipment Manufacturers utilize ISO 8573-1 to specify the air purity that is required for the reliable, efficient, and productive operation of their pneumatic equipment. Users of compressed air equipment should rely upon the air purity requirements recommended by OEMs when selecting, installing, and maintaining their compressed air systems to ensure that the air that reaches the pneumatic equipment is of the purity required. If OEM air purity requirements are unavailable, then users should consult tables that state the recommended air purity levels for specific applications within various industries. VDMA and BCAS are two professional associations that offer such air purity advice.

The compressed air industry, as well as CAGI, recognize three, general compressed air purity classifications for industrial applications: Plant Air, Instrument Air, and Process Air. As air purity increases from Plant Air to Process Air, so too does the cost to produce the higher purity air. Compressor type, air treatment equipment, and air distribution network all affect the purity of the compressed air stream as it reaches its point of use. Careful system design is important to ensure that the proper air purity is achieved with the most cost-effective compressed air solution. Chapter 3, “Compressed Air Treatment,” of the online version of the Compressed Air and Gas Handbook thoroughly describes the equipment available to meet the specific ISO 8573-1 classes, including various types of dryers, filters, moisture separators, and drains. Chapter 4, “Compressed Air System Design,” provides examples of proper equipment selection for achieving a desired compressed air purity quality. Content for this Compressed Air Purity Guide has been provided by members of the Air Drying & Filtration Section of CAGI.

GLOSSARY OF TERMS

Aerosol - solid, liquid, or particles, liquid particles, or solid and liquid particles suspended in a gaseous medium having negligible fall-velocity/settling-velocity.

Catalyst Oil Removal System – a device for removing hydrocarbon vapors from compressed air that utilizes an externally heated reactor, filled with a catalyst, that converts hydrocarbon vapor into carbon dioxide and water.

Coalescing Filter - filtration system consisting of filtration media that use the principle of agglomeration to concentrate smaller particles/droplets into a larger mass that can be separated from the compressed air stream.

Compressed Air Distribution System – pipes, fittings, and air storage receivers designed to deliver an uninterrupted supply of compressed air from the source to the point-of-use in optimal conditions.

Condensation/Condense – the phase change of a vapor or gas to liquid.

Contaminants

- **Viable** - a particle that contains one or more living microorganisms.
- **Non-Viable** - a particle that does not contain a living microorganism but acts as transportation for viable particles.

Dew Point Temperature – temperature at which water vapor begins to condense.

Filter-Regulator-Lubricator (FRL) - combines a filter, regulator, and lubricator into one component to keep air tools in optimal working condition.

Hydrocarbons - organic compound consisting mainly of hydrogen and carbon.

Micron – a unit of length equal to one millionth of a meter.

Microorganisms – a microscopic viable or non-viable organism.

mg/m^3 – milligrams per cubic meter.

Nominal rating – classification of a filter based on an industry accepted level of filtration, but not supported with valid efficiency ratings for any specific size of particle with no bearing to the filter's actual efficiency at the stated micron size.

Oil-free compressor – air compressors that operate without oil in the compression chamber.

Oil Vapor - sum of all gaseous hydrocarbons or organic compounds starting from n-hexane.

Particulates (particle) – microscopic solid or liquid matter suspended in the air.

Particle Filter – filtration system consisting of a media that removes dry particles.

Particle Matter (particulate) - a complex mixture of extremely small matter and liquid droplets suspended in the air. These particles include contaminants such as dust, pollen, soot, smoke, and liquid droplets.

PPM/w – Parts per million by weight.

SCFM – standard cubic feet per minute.

Water Vapor – gaseous phase of water and can be produced through evaporation or boiling of liquid water, as well as the sublimation of ice.