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Air Quality and Air Treatment in Compressed Air Systems

a closer look at air treatment components and the benefits of each

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KEY TAKEAWAYS

- Compressed air quality is mission critical in manufacturing, but a great deal of compressed air is wasted.
- Effective compressed air systems help manufacturers achieve good air quality.
- Adhering to misconceptions about air quality can increase costs without providing benefits.
- In an effective compressed air system, air treatment components work together.
- Best-practice tips can help compressed air systems operate more effectively.

Compressed air quality is mission critical in manufacturing. When determining the right air treatment components for a compressed air system, there is a great deal to keep in mind. Careful planning can significantly reduce life cycle costs, improve uptime, and reduce product scrap. Don't be afraid to work with a compressed air expert to properly select the right air treatment solutions for your application.

When planning, designing, and installing a compressed air system it is important to not only focus on the compressors and air storage but also consider compressed air treatment components such as dryers, filters, drain traps, etc. The impact of air quality on your work flow and performance is huge. Compressed air contaminants—including water, oil, dirt, dust—can cause many problems including poor finish quality, product rejects/rework, and increased materials costs as well as increased equipment wear and maintenance costs.

In this paper, we discuss compressed air quality and how it impacts operating costs and production. We also outline information about designing a compressed air system for maximum effectiveness while minimizing costs. We will also discuss energy benefits where it applies.

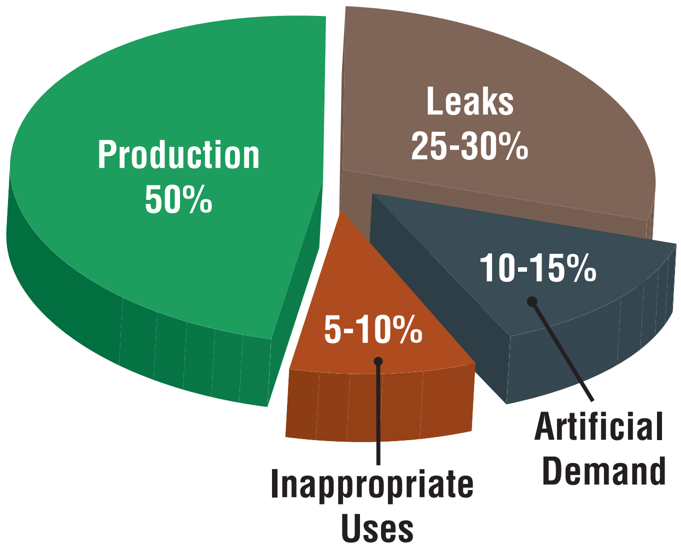
Compressed air quality is mission critical in manufacturing, but a great deal of compressed air is wasted.

In industrial production, plants aim to minimize downtime, scrap, rework, and energy. Compressed air quality and air treatment equipment can impact all of these areas. In many manufacturing plants, the compressed air system is the lifeblood of your production line, as it is used in more than 70% of all manufacturing activities.

Unfortunately, compressed air has a high energy cost and is expensive to create, and about 50% of it is wasted. Waste is often attributed to leaks, artificial demand, and inappropriate uses.

> *If compressed air is not delivered at the right air quality and quantity, production costs increase as both plant equipment function and product quality can be compromised.*
>
> *Michael Camber*

50% of Compressed Air Generated is Wasted Page



Effective compressed air systems help manufacturers achieve good air quality.

A common theme related to air quality is reducing contaminants to tolerable levels for a particular application.

Categories of contaminants are:	
Particulates	Solids, such as dirt and dust that can be picked up from ambient air and ingested into the compressor inlet. Particulate contamination can also come through piping, as rust and scale builds up in iron pipes and flakes off.
Moisture	When compressed air is heated and then cooled, moisture forms. Depending on the ambient humidity and temperature, this can be many gallons per hour.
Oils/Hydrocarbons	These contaminants can be in either liquid or vapor form. it is common for oils or hydrocarbons to be ingested from the ambient environment if solvents, spray lubricants or other volatile compounds are present.

There are several expressions to indicate the overall air quality needed. Common phrases include: plant air; clean, dry air (CDA); instrument air; process air; and breathing air. These terms are commonly understood but are not well defined. In the case of instrument air there is a standard (ISA S7.3) that describes the system design and specifications, but the standard is still rather broad. It doesn't prescribe specific levels of air quality or air treatment products. Even with standards, the air quality must meet the requirements of the user; the burden is on the user to understand and be aware of the requirements needed for their application.

Specifying the ISO class level for each contaminate can provide guidelines to help operators select compressed air dryers and filters. However, most operators don't have the ISO class specifications to use when designing their air systems. See figure 1 on the following page for an example.

The solution for operators can start with identifying whether a certain combination of dryers and filter models already works well for an application, and then approximating the ISO classes by looking at the specs of those products. By using this process to determine the ISO specification, an operator can use that spec when expanding, replacing, or replicating the air system in another plant.

Adhering to misconceptions about air quality can increase costs without providing benefits.

Misconceptions cause operators to err on the side of caution, but can dramatically increase costs without providing additional protection. These common misconceptions are over-designing, over-sizing, believing that more is better, believing an oil-free compressor is needed to have oil free air, and ignoring the compressed air pipe that is being used.

Misconception 1: Over-designing

A misconception is believing, "Air quality is extremely important. We should install any and every dryer and filter just to be safe."

Consider that for a typical industrial facility, 10% of the power used by motors in manufacturing were used by compressors; for some plants it is up to 30%. Over-designing—or having more components in the compressed air system than are necessary—can lead to unnecessarily high electricity costs, along with extra capital and maintenance costs. Also, each system component adds to the system pressure drop. (Every 2 psi increase of unnecessary pressure translates to approximately a 1% increase in compressor energy consumption.) Adding more elements to the design isn't necessarily better.

Misconception 2: Over-sizing

Conventional wisdom is that bigger dryers and filters are better. But larger dryers and filters won't remove more contaminants and won't provide a "cleaner" quality of air. Bigger requires spending more on the equipment, more on electricity, and more on maintenance. Bigger equipment also takes up more floor space, which could be used more productively. Instead of over-sizing, operators are encouraged to "right size" dryers and filters by using correction factors.

Correction factors are supplied by the manufacturer. Determining the appropriate correction factor requires knowing inlet pressure and temperature and ambient temperature, and planning for the worst-case scenario, which is typically in the summer.

Compressed Air Quality

according to ISO 8573-1 (2010)

for solids and dust, water, oil

SOLID PARTICLES / DUST

Class	Max. particle count per m³ of a particle size with d* (µm)		
	0.1 < d ≤ 0.5	0.5< d ≤ 1.0	1.0 < d ≤ 5.0
0	Better than Class 1. User defined.		
1	≤ 20,000	≤ 400	≤ 10
2	≤ 400,000	≤ 6,000	≤ 100
3	not specified	≤ 90,000	≤ 1,000
4	not specified	not specified	≤ 10,000
5	not specified	not specified	≤ 100,000
Class	Particle concentration* C_p (mg/m³)		
6	$0 < C_p \leq 5$		
7	$5 < C_p \leq 10$		
X	$C_p > 10$		

HUMIDITY AND LIQUID WATER

Class	Pressure dew point	
0	Better than Class 1. User defined.	
1	≤ -70°C	≤ -94°F
2	≤ -40°C	≤ -40°F
3	≤ -20°C	≤ -4°F
4	≤ 3°C	≤ 38°F
5	≤ 7°C	≤ 45°F
6	≤ 10°C	≤ 50°F
Class	Concentration of liquid water* C_w (g/m³)	
7	$C_w \leq 0.5$	
8	$0.5 < C_w \leq 5$	
9	$5 < C_w \leq 10$	
X	$C_w > 10$	

OIL

Class	Total oil concentration* (liquid, aerosol, and vapor)	
	(mg/m³)	(ppm w/w)
0	Better than Class 1. User defined.	
1	≤ 0.01	≤ 0.008
2	≤ 0.1	≤ 0.08
3	≤ 1.0	≤ 0.8
4	≤ 5.0	≤ 4
X	> 5.0	> 4

* At reference conditions: 68°F (20°C), 14.5 psia (1 bar), 0% relative humidity

Figure 1: An ISO Example. Specifying the ISO class level for each contaminate can provide guidelines to help operators select compressed air dryers and filters

Misconception 3: More is better

This misconception is that more protection is always better. This isn't always the case. Over-treating can result in higher capital costs and increased energy and maintenance costs. Over-treating doesn't necessarily improve product quality or reduce scrap.

The key is to right size your dryers and filters, and you can do this by using correction factors.

Neil Mehltretter

A common example of over-treating is using a desiccant dryer when only a refrigerated dryer is needed. A refrigerated dryer is adequate for 90-95% of applications, and is less expensive to buy and operate. Desiccant dryers are only necessary for moisture sensitive processes, such as electronics applications or when any part of the compressed air distribution is exposed to sub-freezing temperatures.

Misconception 4: Go oil free to be safe

A misconception is, "I need an oil-free compressor to have oil-free air." Actually, even an oil-free compressor doesn't mean there is no oil in the compressor; it means the oil doesn't come in contact with the air stream in normal operation. Keep in mind that whatever is in the ambient air will still be ingested into the compressor inlet and will flow through the compressor. Filtration and drying are still necessary with an oil-free compressor for clean, dry air in oil-free systems. In addition, oil-free compressors are usually less efficient, cost more up front, and have higher maintenance costs. They aren't necessarily a bad choice for applications but should be applied properly in proper applications such as pharmaceutical, electronics, and chemical.

Misconception 5: Just use the pipe that's there

You cannot forget about the piping. Plants spend time and energy selecting, purchasing, and installing a variety of compressed air treatment only to have the clean, dry, air pass into old dirty pipe. Piping materials can be a source of contaminants that can flake off and migrate to the production equipment.

The most common piping materials include black iron, galvanized, copper, and PVC. Aluminum compressed air piping is a relative newcomer but is on the rise. Figure 2 on the following page lists the advantages and disadvantages of each. PVC is included in the chart because it's commonly used since it is inexpensive, lightweight, and easy to find at local building supply stores. It is not a material that is recommended to use for compressed air because of the safety concerns associated with installing it, specifically OSHA has stated PVC should not be used in compressed air applications.

Piping selection directly affects three key elements in your compressed air system: flow, pressure, and air quality. Restrictions in airflow (rust, build-up, etc.) create air turbulence that results in reduced system pressure. The degree to which this occurs depends on the materials you've chosen and pipe size. To have clean, dry air, consider piping that is copper, aluminum, or stainless steel. They are not prone to build-up and will provide years of low pressure drop air delivery. Smooth clean pipe is good not only for air quality, but also good flow and stable system pressure. Figure 3 shows an example of each.

Material	Advantages	Disadvantages
Black Iron	• Moderate materials costs • Readily available in multiple sizes	• Labor intensive installation • May rust and leak • Rough inside promotes contaminant build-up and creates pressure drop
Galvanized Iron	• Moderate materials cost • Readily available in multiple sizes • Some rust protection	• Often exterior is coated • Labor intensive installation • Rough inside promotes contaminant build-up and creates pressure drop • May rust at joints and leak
PVC	• Lightweight • Inexpensive • Readily available in multiple sizes	• Low safety • Not compliant with OSHA • Subject to bursting • Adhesives not compatible with compressor oils • Carries static charge
Copper	• No rust, good air quality • Smooth interior—low pressure drop	• Requires quality brazing to prevent leaks • Susceptible to thermal cycling • Installation requires open flame
Aluminum	• Corrosion resistant • Lightweight • Easy to install • Lower cost of ownership • Smooth interior—low pressure drop	• Materials costs

Figure 2: Common compressed air piping materials with their advantages and disadvantages.

When selecting piping for your compressed air system, consider the following:

Air quality: Can your shop tolerate contamination from rust or other build-up flaking off from the pipe? (Black iron and galvanized iron are notorious for this).

Installation: Will you need to outsource? Also, do you anticipate growth or making changes to your piping? (Aluminum pipes can be disassembled easily and adding in drops to accommodate growth is fast. Copper is not as quick to install as aluminum, but it is still faster than threaded pipe).

Figure 3: Cut-away of corroded galvanized pipe with rust build-up compared to newer, smooth pipe.

Material cost: Will you need to purchase special tools to install or maintain the pipe?

Maintenance: Do you have the time and manpower to continually monitor and fix leaks that can occur with materials that are more susceptible to rusting at joints and leaking? (A concern for black iron and galvanized iron. Also, the brazing on copper should be inspected regularly).

Look at more than the cost of the material and installation. Think about how your shop is set up and the flow of the work. Piping should be sized and looped to reduce overall air velocity and pressure drop. Also, size piping with the future in mind.

Size your piping with the future in mind. Otherwise, when you expand and you add more compressed air to the system the increased pressure drop can add significantly to your scrap rates.

Neil Mehltretter

In an effective compressed air system, air treatment components work together.

Air treatment in a typical compressed air system is shown below in Figure 4.

Going from left to right, the key elements of this system are:

Compressors. Consider the operating temperature as well as the discharge temperature and noise levels of the compressors you are evaluating. The operating temperature is an important factor to remember because every 20° rise in temperature doubles air's ability to hold moisture in vapor state. Higher operating temperature makes it more difficult to cool and dry the compressed air effectively. Also, you should consider the location of the compressor. The hotter the room, the higher the compressor operating temperature.

Aftercooler. Aftercoolers can condense most of the moisture vapor the compressor ingests into droplets. Rotary compressors typically come standard with built-in, thermostatically controlled aftercoolers to cool the air to temperatures within 10 to 20°F of the ambient air before it leaves the machine. Shop piston compressors may have simple aftercoolers, but they don't have the same cooling effect. Supplemental aftercoolers may be advised, depending on the air quality needed and ambient conditions.

Moisture separator. Moisture separators remove liquid water condensed in the aftercooler (as well as tanks and refrigerated dryers). Some rotary compressors come with the moisture separator directly integrated into the package, but reciprocating compressors (piston style) typically do not. If you have a compressor without one, you will want to install the moisture separator shortly downstream of the aftercooler. On a rotary compressor this is the discharge of the package. With piston compressors, this may be after the tank or supplemental aftercooler.

Receiver tank. Air storage tanks (also referred to as receivers) are a critical air system component, so it's important to understand some of their functions and benefits other than just storing air. There are "wet" and "dry" receiver tanks. A wet tank is installed after the compressor and before the air treatment. Its main function is to remove the initial slug of water to help air treatment after the tank function more effectively. Air coming out of the compressor's aftercooler is usually fully saturated at 100% humidity, and some water has already been condensed to liquid. The tank provides a space for the liquid water to drop out and be drained away. Additionally, some moisture vapor will cool and condense (unless the tank is placed in a hot environment). A wet tank needs a functioning drain that is regularly checked. This type of tank should be sized at 1 to 3 gallons of storage per every cfm in your system.

A dry tank is installed after the air treatment. It creates storage to handle intermittent high-demand events. These tanks are typically sized at 3 to 5 gallons per cfm in your system.

Ideally systems would have both a wet and a dry tank, but this typically is not feasible. If that's the case, decide which is more of a priority—moisture control or storage.

Receiver tanks should not be placed directly in the air exhaust of the compressor, near any other heat source, or in direct sunlight

Figure 4: a typical compressed air system with air treatment components. *(Click to explore an interactive tool)*

Location, Location, Location

The type of compressor used affects where it's installed. Compressors are often installed where their noise, vibration and heat will be least bothersome to staff and customers rather than where they'll best perform and be easily serviced.

Here are some guidelines for where to install a compressor:

- Avoid extreme hot or cold temperatures.
- Ensure an adequate airflow for cooling as well as ventilation for heat exhaust generated from the equipment
- Avoid dirty/dusty areas.
- Allow enough space around the compressor for maintenance access.

because this will hinder proper cooling and moisture separation.

When selecting a tank, be sure the tank pressure rating exceeds the highest possible system pressure. You should make sure the tank has a safety relief valve, a pressure gauge, and a drain to remove liquids. The receiver tank should meet ASME or other required code for safety precautions.

Drains. Drains may be the least expensive component in a compressed air system but they are critical for air quality. Drains remove liquid contaminants from the system. If the filtered and separated contaminants (mostly water with some oils and particulate) aren't drained and removed from tanks, refrigerated dryers, and filters, they build up and find their way back into the air lines. Further, liquid accumulation in tanks will gradually eliminate the air storage capacity in the tank, causing periods of inadequate air flow/pressure and possibly causing the compressor to run more than necessary. As mentioned, drains should be installed on receiver tanks, filters, and dryers. Basic types of drains are:

1. Manual. These are hand-operated and inexpensive valves, but are not the best choice for consistent, reliable moisture protection since they rely on someone checking it manually.

2. Timed electric. These drains are set to discharge based on a timer, which makes them more reliable and consistent than manual drains, but they don't adapt to seasonal changes in how much condensate is created. However, they always open when the timer goes off, even when there is no moisture present, which can waste compressed air. For example, in Winter they will open when there is no moisture present and in Summer they may not open enough to remove accumulating water.

3. Demand. This is the most expensive, but best, drain option. A mechanical or electric device that activates when the liquid level reaches a certain point inside the drain. This drain only opens when moisture is present, so no compressed air is wasted. Also, some drains have additional contacts that can be connected to system master controls or to plant controls that would signal when there is an alarm. This is especially helpful for applications that cannot tolerate moisture.

Drains should be checked and periodically serviced. Lack of effective drains on moisture separators, tanks, dryers, and filters can reduce your air storage as well as increase the risk of contaminants, hurt compressor efficiency, increase the need for maintenance and repair, increase downtime, and add energy costs. More importantly, moisture at your point of use can significantly increase scrap and rework affecting your bottom line. Invest in quality drains to protect your investment in filters and dryers, and more importantly your business.

Drains may be the least expensive component in a compressed air system but they are critical for air quality.

Grayson Atkinson

Dryers. Dryers are key components in a compressed air system as they remove even more moisture vapor from the air stream. There are multiple types of dryers available, including refrigerated and desiccant dryers or sometimes dryers are integrated into rotary screw compressors and installed into an attached cabinet. They vary in the amount of moisture in the air that is sent downstream to the point of use. The type of dryer that is installed determines the filter(s) used.

Dryer performance is stated in terms of specific conditions (ambient temperature, compressed air inlet pressure and compressed air temperature). Without this set of conditions, suppliers could make performance claims based on installation conditions you never have. Quality industrial dryers are usually rated at 100°F ambient temperature, 100°F compressed air inlet temperature and 100 psig. And of course they are sized according to the air flow (cfm) you feed into them.

Dryers must be appropriately sized, and unless the plant conditions are constantly the same as the dryer's rated conditions, you need to look beyond the cfm rating. You have to consider the temperatures in the compressor room, keeping in mind that if the compressor room is not climate controlled, seasonal changes directly impact dryer performance. You should size your dryers for the worst case which is typically the summer months. Keep in mind that as your operating temperature goes up, the ability of the air to hold water goes up as well.

Your dryer vendor should be able to make some simple calculations to account for differences in flow, temperatures, and pressure. If they look at you funny when you ask, find another vendor.

Refrigerated dryers are the most common type of dryers. They employ a refrigeration system to lower the compressed air temperature below the ambient temperature. This condenses the moisture that's in vapor form at higher temperatures into liquid form that can be drained out of the system. This lowers the "pressure dew point" of the compressed air. As long as the compressed air isn't cooled below this new dew point, any remaining moisture will remain in vapor form. Most refrigerated dryers are designed to produce dew points near 40°F when properly sized.

Figure 5, shows you how ambient temperature impacts the actual capacity of a dryer. Just a ten degree difference can greatly reduce the amount of air a refrigerated dryer is able to properly dry.

In most cases, a properly sized refrigerated dryer of good quality will produce clean, dry air. However, there are cases when the ambient conditions or existing air system may need extra drying. If this is absolutely necessary, we recommend two options: desiccant dryers and membrane dryers.

Desiccant dryers operate differently from refrigerated dryers. They work by directing the compressed airflow across a bed of desiccant material that adsorbs moisture vapor out of the air. Desiccant dryers are often set for -40°F dew points and are recommended when air quality requirements are extremely high. Desiccant dryers cannot accept any oil or dirt which will clog the desiccant bed and reduce dryer performance. A good coalescing oil removal filter is a must upstream of the desiccant dryer.

Because these consume air and are expensive, they should only be applied where absolutely needed. It is a waste of money and energy to use a desiccant dryer for the whole plant.

Membrane dryers are another way to further dry air just for a single application in high moisture conditions. They use a water-permeable membrane which allows air to pass through, but pulls the moisture out and expels it. Unlike the desiccant style they provide dew point suppression—not a fixed dew point. So they are best used in conjunction with refrigerated dryers. They have a very simple operation with no moving parts and no desiccant to replace. Membrane dryers don't need electricity either. Like the desiccant, they must have a good coalescing oil removal filter in front of them. If they get oil in them they will be quickly ruined. Also like the desiccant dryer, they consume air. If you decide you need one, use it just where you need it.

Filters. There are different types of filters that remove different types of contaminants. As mentioned earlier, contaminants include oil, moisture, and particulates that can affect compressed air quality downstream, product quality, and production machinery. Installing particulate filters, coalescing oil removal filters, and/or vapor adsorbers will help protect your tools and machinery and increase product quality. Your dryer type and application demands will specify the correct filter type needed.

Filters are categorized based on the contaminants they're designed to capture (liquids, particles, and hydrocarbons/oils) and may be designed to capture more than one type. They often look similar on the outside, but they are not all the same.

- *Moisture separators* are designed to mechanically separate liquid water and oil from the air stream. One point to make clear: water vapor cannot be filtered out of air. Any water in a vapor state can only be removed by a dryer, but if it is liquid, it can be removed by a moisture separator that spins the water out. Some moisture separators include a filter element to remove particles, too. Many rotary screw compressors have an internal moisture separator to remove as much of the liquid water from the package prior to the air discharge, and is therefore highly recommended.

- *Particle filters* are designed to capture dirt, dust, etc., but may remove some water and oil mists. Particulate filters are typically placed upstream of dryers, especially with wet tanks or piping that are not corrosion resistant.

- *Coalescing oil filters* are finer filters designed to remove oil aerosols/mist and fine particles. These are usually placed after a refrigerated dryer. Coalescing filters are not only essential for all paint applications, but are critical to protecting membrane and desiccant dryers as they are installed just prior to the dryer inlet. There are additionally oil vapor filters that remove the taste and smell of oil, for specific applications.

Ambient/ Room Temperature	Air Pressure	Compressed Air Temp at Dryer Inlet	Correction Factor	Actual Capacity of 100 cfm Dryer
80°F	100 psig	95°F	1.22	122 cfm
90°F	100 psig	105°F	0.96	96 cfm
100°F	100 psig	115°F	0.69	69 cfm

Figure 5: Ambient temperature impacts the actual capacity of a dryer. Just a ten degree difference can greatly reduce the amount of air a refrigerated dryer is able to properly dry.

Filters should be installed in order—remove liquids, then particles, then oils. Staging the filters in a system provides more effective filtration, lower pressure drop at each filter, and longer filter life. Some have differential pressure gauges, liquid level indicators, and built-in drains. Keep in mind that filters removing liquids also need drains and that differential pressure gauges will indicate when the filter elements need replaced. Filters should be serviced regularly in order to maintain air quality and minimize pressure drop.

Condensate collection. A condensate collection system helps an operator ensure they are following environmental regulations. It is connected to drains on tanks, compressors, filters, and dryers and collects the condensate (water and oil). There are many types of condensate management systems, including skimming to separate, heating to separate, or using a filter to separator. Make sure you consult your local code for guidance on the disposal regulations.

Air main charge valve. This valve provides a controlled pressurization during start-up to prevent high-velocity air from overrunning air treatment components. It reduces wear and tear on air treatment and prevents contaminants from flooding past filters and dryers. It is useful for systems that are shut down and restarted regularly or systems that have a high air quality standard but run 24/7.

Best-practice tips can help compressed air systems operate more effectively.

Tips include:

1. Think of your compressed air system in terms of zones. If a specific section needs higher quality air, isolate the applications that require higher pressure and air quality as well as consider adding filtration near that application. It is much cheaper to treat an application instead of the entire system.

2. Think about controls when selecting dryers. Two common types of control are cycling and non-cycling. Cycling dryers match energy consumption to demand and is best applied when a system runs continuously and has varying demand loads. Some non-cycling dryers may be programmed for on/off times to meet specific shift requirements.

Careful planning can significantly reduce life cycle costs, improve uptime, and reduce product scrap. Don't be afraid to work with a compressed air expert to properly select the right air treatment solutions for your application.

Grayson Atkinson

3. Think about communications capabilities. With the industry moving towards IoT solutions, start planning now to be ready to integrate components and systems. Look for capabilities on dryers that enable communicating with air system master controls or plant control systems. Having this connection to a centralizing control system can enable alarm notification for when there is a dryer or drain alarm. When necessary, the master controller can be programmed to shut the system down to prevent contamination due to an air treatment malfunction. This can help protect products and reduce scrap.

Summary

Making sure you remove contaminants from your compressed air system is extremely important in manufacturing. Every component in your compressed air system plays a part in air quality and performance which both have an effect on your product quality.

The compressor selection influences the system performance, air quality, maintenance costs, and long term reliability of the air system. It can also affect the amount of moisture and oil that is carried over into the system. The receiver tank helps maintain proper system pressure and to remove bulk liquids before dryers and filters. Filters and dryers can be used to remove all types of contaminants and pipe size and material affect the pressure and flow.

When looking at your compressed air system, remember to carefully consider each system component and its impact on the application. Try to avoid the misconceptions about air quality and don't hesitate to ask an air system expert. No one wants to spend more money on compressed air equipment than what is necessary, but a little more initial investment can save you time, labor, and material costs later.

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