ABSTRACT

COMPRESSED AIR: THE DRIVING FORCE IN POWDER COATING

This paper will address how compressed air is used in a powder coating system. The purpose of the compressed air system will be presented to show that not only high pressure air but also filtered and conditioned air is required to operate a powder coating system. The compressed air system components and their functions will be discussed as well as how one component’s performance can affect another component. The paper will end with some guidelines for compressed air system selection and maintenance.
COMPRESSED AIR: THE DRIVING FORCE IN POWDER COATING

1.0 INTRODUCTION

Compressed air is the main power source in powder coating systems. It is used for almost every function including fluidizing, transporting, and conditioning powder; controlling the gun fan pattern; cleaning the filter cartridges; cleaning the flame detection heads; inflating a seal; and keeping the rotary sieve clean and spinning freely. The energy provided by compressed air comes from the release of pressure, allowing the compressed air to expand to atmospheric conditions in a controlled manner. In powder coating, the energy released by expanding compressed air is used to lift and fluidize powder and to pull powder out of a hopper and push it through the hose to a spray gun. The release of pressure can be controlled to provide the proper powder flow rate or gun fan pattern needed to coat a part.

As the complexity of application equipment, sensors, and specialty powder coatings increases, the importance of a continuous supply of clean, dry, and oil free compressed air also increases. Rejected parts from compressed air contaminants, as well as powder paint line down-time due to compressed air supply problems, can be avoided in most cases with a good plant compressed air system design and regular maintenance. This paper will describe the purpose, components, selection, and maintenance for an effective compressed air system.

2.0 PURPOSE FOR COMPRESSED AIR SYSTEMS

The purpose for compressed air systems is to deliver a steady supply of high pressure, contaminant free air to the powder coating system. Because a powder system uses compressed
air to condition and transport powder, to operate controls, and to perform other mechanical operations in the coating process; it requires a steady supply of clean, dry, and oil free compressed air. Any malfunctions in the compressed air can cause production down time or a poor coating finish. Therefore, the compressed air system’s reliability and ability to remove contaminants are critical in the powder coating process.

2.1 THE COMPRESSION PROCESS

The energy provided by compressed air comes from the controlled release of pressure. Energy is stored in compressed air by taking a volume of low pressure air and compressing it into a smaller volume, increasing the pressure of the air. The air source for a compressed air system is the atmosphere. A volume of atmospheric air is pulled into an air compressor, compressed into a smaller volume, and piped into the compressed air system. The smaller the volume the air is squeezed into, the higher the pressure. For example, if 100 standard cubic feet of air (air at standard atmospheric conditions; 14.7 psia, 68° F, and 36% relative humidity) is compressed to 50 psig, then its volume will be about 25.64 actual cubic feet, or about one quarter of its initial volume. If it is further compressed to 100 psig, then its volume will be reduced to about 12.82 actual cubic feet, or about one-eighth of its initial volume. A simple rule of thumb is that 7.8 cubic feet of air at atmospheric conditions is needed to generate 1 cubic foot of air at 100 psig.

The actual cubic feet per minute (acfm) of a system is the actual volume of air flowing through the compressed air lines. The actual volume of air flowing through a compressed air systems varies based on the pressure of the compressed air, and each device using compressed air usually varies in its pressure requirements. Therefore, a measurement of the acfm of each device is usually not a useful number for determining the total amount of air consumed by the
entire compressed air system. To standardize the industry, all compressed air capacities and usage requirements are stated in standard cubic feet per minute (scfm). The scfm of a system is the amount of atmospheric air pulled into a compressor to supply the compressed air requirements of the system. This allows the air consumption of each device to be easily added together to determine the total compressed air usage for a system without having to correct for the differing pressure requirements of each device. For example, two devices use compressed air. One device operates at 50 psig while the other operates at 100 psig. The 50 psig device requires 25.64 acfm while the 100 psig device requires 12.82 acfm. Correcting the air consumption to standard conditions shows that these two devices each consume 100 scfm of air. Stating the air consumption requirements based on standard conditions eliminates the need to correct for the unique pressure requirement of each device and allows the air consumption of each device to be easily added to determine the compressor capacity required.

2.2 CONTAMINANTS IN COMPRESSED AIR

Part of the purpose for a compressed air system is to remove contaminants that will impede the powder coating system performance. The contaminants in a compressed air system are either pulled into the compressor and concentrated during the compression process, generated by the compressor itself, or generated inside the compressed air piping system. Contaminants in a compressed air system can be either vapor, liquid, or solid. The temperature of the compressed air can also be considered a contaminant if the air is too hot or too cool for use. Most of these contaminants must be eliminated before the compressed air can be used, and each contaminant has its own removal process.
2.2.1 WATER VAPOR

Water vapor is always present in the atmosphere and will always be present in a compressed air system since atmospheric air is the compressor’s source for compressed air. Two terms are used to define the moisture content of air. The “atmospheric dew point” of air is the temperature at which water vapor will condense into liquid in a volume of air at atmospheric pressure. Likewise, the “pressure dew point” of air is the temperature at which water vapor will condense into liquid in a volume of air at a specified pressure. The pressure dew point is always higher than the atmospheric dew point for a specific volume of air.

Moisture content in air is measured by the weight or “grains” of moisture per cubic foot of air. When air is pulled into the compressor, the compression process greatly reduces the volume of the air and greatly increases the pressure of the air. However, the grains of moisture remains the same. Compressing 7.8 cubic feet of air at atmospheric pressure (14.7 psia) to a pressure of 100 psig reduces its volume to 1 cubic foot. The 1 cubic foot of compressed air contains the same number of grains of water as the 7.8 cubic feet of air at atmospheric pressure. For example, air at atmospheric pressure has an atmospheric dew point of 73° F. Each cubic foot of atmospheric air contains 8.848 grains of water vapor. If 7.8 cubic feet of atmospheric air are used to generate 1 cubic foot of compressed air at 100 psig, then each cubic foot of compressed air will contain 69.014 grains of water vapor (7.8x8.848=69.014). This gives the compressed air a pressure dew point of 147° F. The compression process does not add water vapor to the compressed air; it simply concentrates the water vapor already present in the atmosphere.

Increasing pressure decreases air’s ability to hold water vapor, while increasing the temperature of air increases its ability to hold water vapor. As a general rule, for every 20° F
increase in temperature, the amount of water vapor a volume of air can hold approximately doubles.

Water vapor in a compressed air system is not necessarily a problem as long as the water remains in a vapor state. It is usually very expensive and impractical to remove all of the water vapor from a compressed air system, and most powder coatings systems do not require compressed air that is free of water vapor. The key is to reduce the water vapor content to a level that prevents condensation of liquid water, since liquid water creates many problems in a compressed air system. Water vapor must always be removed using an air dryer. Separators, filters, and extractors are not designed to remove water vapor.

2.2.2 LIQUID WATER

Liquid water is usually the most apparent contaminant in a compressed air system. As compressed air cools, its ability to hold water vapor is reduced. As soon as the compressed air reaches its pressure dew point, excess water vapor begins to condense into liquid water. The more the compressed air cools, the more liquid water that will form from the condensing water vapor. Liquid water will always appear in a compressed air system because of the nature of how compression affects the dew point of air and cooling of air as it travels through compressed air lines. Liquid water can be in the form of aerosols or droplets. Aerosols are really tiny liquid droplets that are entrained in the compressed air stream like a fine mist. These aerosols coalesce to form droplets and puddles. Liquid water in a compressed air system can corrode pipes (generating leaks and solid contaminants), wash away lubricants, and damage equipment. In cold weather, liquid water can freeze in outdoor compressed air lines, causing blockage and burst pipes. Liquid water will quickly contaminate a powder coating system, requiring extensive down-time to remove contaminated powder, clean contaminated equipment,
and replace contaminated fluidizing plates and filters. Liquid water must be drained from the compressed air system before it can reach any equipment.

Using the example from the previous section shows how liquid water is formed in a compressed air system. Atmospheric air with an atmospheric dew point of 73° F is pulled into an air compressor and compressed to 100 psig. As shown in the previous section, each cubic foot of air at 100 psig contains 69.014 grains of water vapor, and the compressed air has a pressure dew point of 147° F. When compressed air exits a compressor, it is usually between 150° F and 325° F (from compression and frictional heat), far above the pressure dew point of the compressed air. This is why condensation is not seen in compressed air lines immediately down stream of a compressor. While compressed air travels through the compressed air piping system, it cools down to the room temperature inside of the plant. As soon as the compressed air temperature cools below 147° F, water vapor begins to condense into liquid water. The amount of liquid water generated depends on the temperature the compressed air reaches and the amount of compressed air flowing through the pipes. If the compressed air in this example cools to 100° F, then 49.046 grains of water will condense out of each cubic foot of compressed air. For a powder coating system that uses 200 scfm, this means that 0.022 gallons of water will be generated per minute or 10.34 gallons during an 8 hour shift.

When pressure is released to operate a tool or spray powder, the compressed air cools as it expands. This cooling can be significant, as much as 30° F. Condensation can occur in the compressed air if the pressure dew point of the compressed air is too high. If the compressed air is being used to spray powder, then this condensation can cause agglomeration of the powder, poor fan patterns, and poor part coverage. Since rapid air expansion also cools the gun nozzles, condensation from atmospheric air can also occur if the atmospheric dew point in the
powder coating room is too high. This will cause water droplets to form on the gun nozzles which will also cause agglomeration of the powder, poor fan patterns, and poor part coverage. For this reason powder paint systems should be used in climate controlled rooms that can maintain consistent temperature and atmospheric dew point, which will not allow condensation at any of the gun nozzles or other compressed air equipment.

Liquid water can be a major cause of compressed air related problems in a powder coating system. The best solution is to remove the excess water vapor in the compressed air before it can condense into liquid. If liquid water is apparent in a compressed air system, then it must be removed using a coalescing filter and a drain.

2.2.3 OIL VAPOR AND LIQUID OIL

All lubricated compressors will discharge some oil in the form of an aerosol mist as well as oil vapor. A typical reciprocating compressor in good working order can put up to 45 ppm (parts per million) of oil by weight into the compressed air system. Most rotary screw compressors flood the compression chamber with oil or a synthetic lubricant. Most but not all of this oil separates from the compressed air before it leaves the compressor. A typical screw compressor in good working order may put up to 80 ppm of oil by weight into the compressed air system. Most of this oil is in aerosol form and some of it is in vapor form.

The term “oil” used in this paper refers to either natural oil, distilled from petroleum, or synthetic lubricants. Both types of oil contain hydrocarbons, but synthetic oils usually contain additional materials to aid lubrication of the compressor, extend the life of equipment, and reduce maintenance down-time. Synthetic oil can be corrosive to some filter seal materials. Filter seals which are not affected by synthetic oils should be specified for all compressed air systems which use synthetic oil in their compressors.
Oil vapor is generated by the high temperatures inside a compressor which cause some of the oil in the compressor to evaporate. Oil vapor in a compressed air system is what causes the objectionable odor and taste present in most compressed air.

Oil vapor itself is not usually a problem for powder coating systems, as long as it remains in a vapor state. It is very expensive to remove all of the oil vapor in a compressed air system, and most powder coating systems do not require compressed air that is completely free of oil vapor. The key is to reduce the oil vapor concentration to a level which will prevent condensation of the oil vapor into liquid oil. Just like water vapor, the temperature of the compressed air determines how much oil vapor it can hold. As the compressed air cools, excess oil vapor condenses into liquid oil which is the cause of oil problems in a powder coating system. Oil vapors cannot be removed using traditional particulate or coalescing filters. Oil vapors can be removed by cooling the compressed air, condensing the vapor into liquid oil which can then be filtered. If oil vapors are a problem, special (and expensive) oil vapor filters are also available which adsorb oil vapor directly from the compressed air.

Liquid oil and oil aerosols can be injected into the compressed air by the compressor or can accumulate from condensed oil vapor. Liquid oil can cause serious contamination of a powder coating system because oil will not simply evaporate like liquid water contamination. Every device which is contaminated by liquid oil will require extensive down-time to clean or replace. Since compressed air is used to condition and spray powder, liquid oil can cause contamination of powder and fouling of the powder hoses. Liquid oil can also cause blemishes on powder coated surfaces. Liquid oil can be easily removed from a compressed air system using a coalescing filter and an automatic drain.
2.2.4 SOLIDS

Solid or particulate contaminants in compressed air systems include rust, pipe scale, dirt, pollen, dust, and desiccant dust. Pipe scale and rust are usually generated in the compressed air pipes and are caused by liquid water corroding the pipes. Over time the rust and scale deposits building up in the pipes break loose and are carried with the compressed air. Dirt, dust, and pollen are pulled in along with atmospheric air by the compressor. A compressor has a filter on its intake to prevent contaminants from being ingested, but sometimes these filters are inadequate or have been removed. Desiccant dust is generated from the desiccant particles in a regenerative air dryer abrading each other into a fine powder. All of these particulate contaminants can block tiny orifices, airlines, equipment, and valves and can also contaminate powder coated parts. Solid contaminants are not often visible on an uncured powder coated part but become obvious after curing. Depending on the type of finish required, particulate contaminants in compressed air can cause a considerable number of rejects and rework. Particulate contaminants must be filtered from the compressed air using a particulate filter.

2.2.5 HEAT

Most heat in a compressed air system is generated in the compressor. When air is compressed, a significant amount of the energy used for compression is converted into heat, referred to as the “heat of compression.” In addition to the heat of compression, heat is added to compressed air through friction in the compressor. Reciprocating compressors commonly generate temperatures around 325° F while rotary compressors commonly generate temperatures around 150° F. Compressed air at these temperatures is unusable for most functions in powder coating. Most air dryers are sized based on a compressed air inlet
temperature of 100° F. A higher temperature at the inlet to the air dryer will cause the dryer to not function properly or it will require a larger dryer to be purchased. The compressed air must be cooled to at least 100° F before being delivered to air drying equipment or the powder coating system. An aftercooler is usually the best way to cool the compressed air to a useable temperature.

3.0 COMPONENTS OF A COMPRESSED AIR SYSTEM

In order for a compressed air system to supply clean, dry, oil free compressed air it has to be properly designed and sized, and the components have to be placed properly in the system. In most plants, a single compressed air system is the most cost effective means to provide compressed air to all of the equipment requiring compressed air. Some components, such as an air dryer, may only be needed for certain equipment or specific areas of the plant. For these instances, it is better to buy a small air dryer and use it just for the equipment (i.e. powder systems) that require clean, dry air rather than buying a larger air dryer for the entire plant. Because contaminants can be generated inside of compressed air pipes, it is better to locate filtration as close to the powder system as possible to prevent contamination.

3.1 COMPRESSOR

The first component of any compressed air system is the air compressor. An air compressor pulls in a volume of air at atmospheric pressure and squeezes it to a smaller volume at a higher pressure. All compressors are sized by the scfm, or the volume of atmospheric air they pull in per minute to supply the compressed air system at the required pressure. The two basic types of compressors are reciprocating (piston) and rotary (screw).
Reciprocating compressors use a piston to compress a volume of air at atmospheric conditions into a smaller volume at higher pressure. These compressors are designed to run until the pressure in the compressed air system reaches a set upper limit, then the compressor cycles off. As compressed air is used, pressure drops in the compressed air system. Once the pressure reaches a set lower limit, the compressor cycles back on and runs until the system reaches its set upper pressure limit again. Reciprocating compressors generate a lot of heat and require a cooling period between cycles. They are designed with enough capacity to allow the compressor to supply the required air volume with some excess so that the compressor has an opportunity to cycle off to cool. Reciprocating compressors are most useful with compressed air systems that do not operate at full capacity for more that brief periods.

Rotary compressors use a set of screws to compress a volume of air into a smaller and smaller cavity until the desired pressure is reached. Rotary compressors are designed to run continuously because cycling the compressor on and off can cause damage to the bearings. When the demand on the compressor is not very high, most compressors use a modulation control which regulates the volume of air pulled into the compressor to maintain the required pressure in the compressed air system. The modulation control varies the power consumption of the compressor based on the operating capacity of the compressor. Rotary compressors are most useful when the demands on the compressed air system are consistently near the peak capacity of the compressor.

3.2 AFTERCOOLER

Probably the most important part of any compressed air system is the aftercooler. Usually the aftercooler is placed immediately downstream of the compressor but upstream of the receiver tank and air dryer. The aftercooler takes hot, compressed air from the compressor
and cools it down to a useable temperature, usually 100° F or less. By cooling the air, the aftercooler condenses a considerable amount of the water (and oil) vapor out of the compressed air supply. The cooled air is run through a separator to remove the condensed liquids. The air leaving an aftercooler is assumed to be 100% saturated with water vapor at its exit temperature. Therefore the temperature of the air downstream of an aftercooler is assumed to be the pressure dew point of the compressed air.

The “approach” of an aftercooler is defined as the difference between the temperature of the cooling medium, either water or air, and the temperature of the compressed air at the outlet of the aftercooler. For example, if a water-cooled aftercooler has an approach of 20° F and the temperature of the cooling water is 60° F, then the compressed air run through the aftercooler will be chilled down to no more than 80° F, or to within 20° F of the cooling water.

Continuing to use the previous example illustrates how an aftercooler works. Compressed air leaves a compressor at between 150° F and 325° F with a pressure dew point of 147° F. Each cubic foot of compressed air contains 69.014 grains of water. If the aftercooler described above is used, then the compressed air leaving the aftercooler is cooled to 80° F and is saturated with water vapor. The compressed air is assumed to have a pressure dew point around 80° F when it leaves the aftercooler, meaning that 57.954 grains of water condense out of each cubic foot of compressed air run through the aftercooler. For a powder coating system that uses 200 scfm, this means that 0.025 gallons of water will condense out per minute, or 12.22 gallons during an 8 hour shift.

Although the aftercooler condenses water vapor into liquid down to a certain temperature, some liquid water will still be visible down stream of the aftercooler for two reasons. The first reason is that the mechanical separator used to separate the liquid water from
the compressed air is not 100% efficient and cannot remove all of the liquid water. A typical separator for an aftercooler will have an efficiency of 90%, meaning that 10% of the condensed liquid will get through the separator and travel onto the air dryer. This efficiency is dependent on the pressure and flow of the separator design. The second reason is that the compressed air may continue to cool after it leaves the aftercooler. Since the compressed air leaving the aftercooler is saturated with water vapor, any additional drop in the temperature of the compressed air will cause more water vapor to condense into liquid. Likewise, the compressed air leaving the aftercooler may heat up slightly, reevaporating some of the leftover condensed water and raising the pressure dew point of the compressed air slightly. This is why an aftercooler cannot be used as a substitute for a compressed air dryer.

A well maintained and reliable drain in the aftercooler’s separator is also very important to remove accumulated liquids separated from the compressed air. If the drain is not functioning properly, liquids can build up in the separator until they flood the airlines and get carried downstream with the compressed air. This can cause flooding and contamination of the desiccant in a regenerative air dryer in addition to the other problems noted with liquid water in the compressed air system.

Most air dryer vendors size their equipment for a 100° F inlet temperature. Unless a large receiver tank with a drain is used to allow the hot compressed air to cool before going to the air dryer, an aftercooler will be required to lower the temperature of the compressed air down to 100° F. Using an aftercooler to chill the compressed air to a lower temperature will improve the efficiency of the air dryer and may even allow for a smaller air dryer to be used. No matter what type of compressor or air dryer a plant uses, an aftercooler is a worthwhile investment and will greatly improve the effectiveness of an air dryer.
3.3 RECEIVER TANK

The receiver tank is a large pressure vessel used to store a volume of compressed air. Its primary purposes are to prevent pressure fluctuations in the compressed air system, to allow additional cooling of the compressed air, and to prevent over work by the compressor. If a receiver tank is used, a compressor works to keep the tank full. The compressor can fill the tank when the load on the compressed air system is low. During high load situations, the receiver tank provides a large supply of pressurized air to meet the demand where a compressor alone might not have been able to maintain adequate pressure in the system. The receiver tank also dampens out pressure fluctuations from the compressor to the rest of the system, allowing the air dryer and other equipment to see a more steady pressure and flow of compressed air. A receiver tank also provides additional time for the compressed air to cool and vapors to condense. An automatic drain should always be used with a receiver tank to eliminate any accumulated liquids that settle to the bottom of the tank.

3.4 AIR DRYER

3.4.1 HOW COMPRESSED AIR DRYERS WORK

The purpose of all compressed air dryers is to reduce the amount of water vapor in the compressed air to a level that will prevent liquid water condensation in the compressed air piping system. The water vapor content in the compressed air exiting the dryer is expressed as the pressure dew point, which is the lowest temperature the compressed air can reach before condensation can occur at a specific pressure inside of the compressed air piping system. Since the pressure dew point applies to the compressed air, an air dryer should be sized to provide the pressure dew point required to prevent condensation in the compressed air system. If the output dew point of an air dryer were expressed as an atmospheric dew point, the dryer may not lower
the water vapor content of the compressed air enough to prevent condensation in the air at pressure. Therefore, when determining the “dew point” produced by an air dryer, be sure the manufacturer is advertising a pressure dew point.

Compressed air dryers typically work either by lowering the temperature of the compressed air to just above the freezing point of water, allowing the water vapor (and oil vapor) to condense and be separated from the compressed air, or by adsorbing water vapor (and some oil vapor) directly from the compressed air using a desiccant. These two methods of reducing the water vapor content of compressed air also help to reduce the oil vapor content of the compressed air. However, since the main purpose of a compressed air dryer is only to reduce the amount of water vapor in the compressed air, the oil vapor reduction capability of an air dryer is difficult to determine and define. Few air dryers vendors will advertise the ability of their dryer to reduce oil vapors, relying instead on dedicated oil vapor filters to perform this task.

Two types of air dryers, refrigerated and regenerative, are generally suited for powder coating systems. Although other types exist, they are generally not used because they lack the effectiveness or capacity of the refrigerated and regenerative air dryers.

3.4.2 REFRIGERATED AIR DRYERS

Refrigerated air dryers work by reducing the temperature of the compressed air to just above the freezing point of water. Excess water vapor condenses into liquid and is separated from the air stream. A “typical” refrigerated air dryer is shown in Figure 3.4-1. Compressed air enters the air dryer (1) and is run through a pre-cooler/reheater (2). The pre-cooler/reheater is an air-to-air heat exchanger which uses the cold compressed air that has already run through the air dryer to cool the warm compressed air entering the air dryer. The compressed air then
travels to the air-to-refrigerant heat exchanger (3) where its temperature is lowered to about 35°F by the refrigerant. Excess water vapor condenses into liquid and travels with the compressed air stream. The cold compressed air and liquid water enters a water-air separator or coalescing filter (4) which separates the liquid water from the compressed air stream. The cold air then runs through the cold side of the pre-cooler/reheater (2) where it is heated to around 70°F. Any liquid water not separated by the water-air separator or coalescing filter usually evaporates as the compressed air is warmed before exiting the air dryer (5).

Most refrigerated air dryers require a particulate prefilter to remove particulate and large amounts of liquid water upstream of the dryer. Removing particulate and liquid contaminants is important because they can block the air-to-air heat exchanger used to cool the incoming compressed air and warm the outgoing compressed air. An additional coalescing filter downstream of the dryer is beneficial for removing any remaining oil or water aerosols from the compressed air.

Many refrigerated dryers today are equipped with a hot gas bypass valve or demand control circuitry. The hot gas bypass valve maintains constant refrigerant temperature in the air-to-refrigerant heat exchanger by mixing hot refrigerant with cold refrigerant. Refrigerated dryers equipped with a hot gas bypass valve do not cycle the refrigerant compressor on and off. Demand control circuitry loads or unloads the refrigerant compressor to maintain constant temperature of the compressed air in the air-to-refrigerant heat exchanger. Both devices allow the dryer to chill the compressed air to a consistent temperature at flows under the rated capacity of the dryer while preventing overcooling and freezing of the condensed liquids.

The pressure dew point of the compressed air when it leaves the refrigerated air dryer depends on the efficiency of the heat exchangers, the efficiency of the separator or coalescing
filter, and the proper operation of the drain. Refrigerated air dryers are designed for specific compressed air flow, pressure, and temperature conditions. The water-air separators or coalescing filters are usually designed for specific compressed air flow and pressure conditions. If the flow or pressure of the compressed air entering the dryer is not at the design conditions, the efficiency of the separator will decrease, allowing liquid water to pass through the separator and increasing the pressure dew point of the air leaving the dryer. Usually, airflow higher than the design conditions will decrease the efficiency of the separator more than lower flows. If the temperature of the compressed air entering the dryer is higher than 100° F, then the compressed air entering the dryer probably contains more water vapor than the dryer is sized to eliminate. As a result, the dryer will not be able to deliver compressed air at its advertised pressure dew point. The lowest pressure dew point available from refrigerated dryers is about 38° F at its optimum design flow and inlet pressure and temperature.

The ongoing CFC controversy will affect refrigerated dryer systems well into the next century. For decades, R-12 (freon) has been the main refrigerant used in the industry. R-12 has decades of use to demonstrate its reliability and efficiency, and it is relatively safe to handle by technicians and refrigeration specialists. In an effort to reduce deterioration of the Earth’s ozone layer, R-12 has been banned from all future refrigeration systems and current equipment using R-12 requires special handling to prevent inadvertent CFC release. R-22 is a temporary replacement for R-12, but R-22 will be phased out in 1995. A CFC-free refrigerant, R-134a, is currently being used but is only useable until 2005. R-134a is also about 30% less efficient than R-12 freon. As a result, larger and more costly refrigeration systems are required when using R-134a to obtain the same performance as was obtained with R-12. Only limited testing has been performed to determine the reliability of R-134a refrigeration equipment and the effect
of R-134a on seals and lubricants, so it is unknown how long these systems will provide adequate service. The toxicity of R-134a has also not been determined, and it must be carefully handled by a licensed refrigeration mechanic using dedicated equipment. All of these issues mean that refrigeration systems will increase in price and be more costly to operate and maintain in the future. After 2005 when R-134a is to be eliminated, no new refrigerant has yet been developed. No drop-in replacement exists for any of the existing refrigerants, so existing equipment will have to be scrapped and new equipment purchased for the new refrigerant. The best advice is to stay away from refrigerated air dryers until an adequate long-term refrigerant has been developed and tested.

3.4.3 REGENERATIVE AIR DRYERS

Regenerative air dryers lower the pressure dew point of the compressed air by directing a flow of compressed air saturated with water vapor through a container filled with desiccant beads. The desiccant adsorbs water vapor directly from the compressed air. Adsorption, when used to describe a compressed air dryer, is when vapor adheres to the surface of a desiccant or other hydroscopic material. Because the water vapor adheres only to the desiccant surface, the adsorbed water vapor can be easily shed, allowing regeneration of the desiccant. A material that absorbs, or soaks up moisture like a sponge, usually dissolves as it absorbs moisture and is difficult to regenerate. The desiccant most commonly used in regenerative air dryers is activated alumina, which is an abrasion resistant, tough, porous, hydroscopic material. Silica gel and molecular sieve materials are sometimes used under certain conditions, such as variable temperature or variable moisture load conditions. The desiccant is shaped into small spherical beads which offer the highest surface area for adsorption of water vapor.
The desiccant is usually contained in two separate but identical containers or “towers.” This is where regenerative air dryers get the name “twin tower” or “dual tower.” Compressed air saturated with water vapor flows up through the “on-line” tower. While the first tower is on-line drying the compressed air, the second tower is “off-line” regenerating using dry purge air bled from the on-line tower as shown in Figure 3.4-2. When the first tower has adsorbed its limit of water vapor, the second tower comes on-line to take over the drying function and the first tower goes off-line to regenerate the desiccant. A timer circuit is used to control the switching of the on-line and off-line towers at regular intervals. This allows continuous drying of the compressed air and continuous regeneration of the desiccant.

Normally the towers are oriented vertically with compressed air entering at the bottom of each desiccant tower and exiting at the top. This allows gravity to pull any liquid water or oil that enters the dryer to the bottom of the tower and away from the desiccant. The flow of purge air is from the top of the tower to the bottom, opposite the direction of the on-line compressed air, to ensure the driest desiccant is always at the exit end of each tower.

Pressure dew points ranging from +50° F to -100° F are possible, depending on the design of the regenerative dryer. Most regenerative air dryers are designed to provide a -40° F pressure dew point, which may be too dry for most powder coating systems.

Regenerative air dryers are relatively simple and usually very trouble-free. The most complex components of most regenerative air dryers are the valves and timer circuits. The part of the dryer which requires the most care is the desiccant. The desiccant used in regenerative air dryers usually lasts several years, depending on how much oil vapor and aerosols the compressed air contains. The desiccant in regenerative dryers adsorbs oil vapor along with water vapor. Over time, the adsorbing surface of the desiccant becomes clogged with oil vapor.
and oil aerosols from the compressed air. Oil vapor is more difficult to purge than water vapor, so any oil vapor adsorbed by the desiccant will not be completely eliminated by the regeneration cycle. Any liquid oil or oil aerosols which reach the desiccant will contaminate and quickly ruin the desiccant. For this reason, a coalescing filter is always required upstream of a regenerative dryer to eliminate any oil aerosols from the compressed air. An oil vapor filter may be used ahead of a regenerative dryer, but an aftercooler usually reduces the amount of oil vapor to a level considered acceptable for long desiccant life. When the desiccant is too dirty to be efficient, it should be replaced according to the manufacturers procedures.

The main disadvantage of regenerative dryers is that the purge air used to regenerate the desiccant requires 10% to 20% of the air volume going through the dryer with 15% being the norm. This requires an increase in compressor size to accommodate the extra compressed air requirement. In addition, the purge air consumed can add significantly to the operating costs of the system. Several devices have been developed to help reduce the amount of purge air consumed. These devices usually switch towers by sensing the pressure dew point of the compressed air exiting the dryer. Although these devices can save significantly on the cost of purge air, they are usually expensive. Several variations of the basic “heatless” regenerative dryer have also been developed in an effort to reduce the amount of purge air required to regenerate the desiccant. Two of these variations are heating the desiccant of the regenerating tower (heated regenerative dryer) and using an external blower to regenerate the desiccant (blower purge regenerative dryer). Both of these designs reduce the amount of purge air required, but they add significantly to the cost, size, and complexity of the dryer.

Like refrigerated air dryers, regenerative dryers are designed around some specific parameters such as inlet air temperature, inlet air pressure, inlet moisture content, pressure dew
point required, and amount of air to be dried. If the flow through the dryer is less than the
design flow, then the pressure dew point of the compressed air leaving the dryer is usually
lower than the design dew point because the desiccant has more contact time and is able to
adsorb more water vapor from a smaller volume of air. Conversely, if the flow through the
dryer is more than the design flow, then the pressure dew point out of the dryer will increase.
The desiccant in a regenerative air dryer is usually just loose inside of the tower. Parameters
such as compressed air velocity through the tower and contact time with the desiccant are used
to determine the size of the tower and the amount of desiccant required. The vessels of a
regenerative dryer are sized to allow for the design flow through the dryer without fluidizing the
desiccant bed. If a flow higher than the design flow is sent through the dryer, then the desiccant
bed will likely fluidize, causing the desiccant beads to abrade each other and break up into fine
desiccant dust. The desiccant dust particles are carried downstream and can contaminate the
powder or guns. In addition, since the desiccant is grinding itself, its useful life is shortened. A
particulate filter is usually required downstream of the dryer to catch any desiccant dust which
escapes from the desiccant beds. Compressing the desiccant beds with compressed air pistons
avoids this problem by compacting the desiccant beads and preventing them from fluidizing or
generating dust. This allows as much compressed air to be run through a desiccant bed as
desired, allowing the dryer to be sized to the pressure dew point required rather than being sized
to the flow required.

Each powder coating system has its drying requirements that affect the dryer selection.
With the current CFC issues surrounding refrigerated dryers, regenerative dryers are likely to
see more use in the future.
3.5 FILTRATION

Filtration of compressed air is necessary to remove any particulate, liquids, or water and oil aerosols that are in the compressed air. Additional filtration may also be required to remove oil vapors, depending on the intended use of the compressed air and the amount of oil vapor present. Types of filters include mechanical separators, particulate, coalescing, and oil vapor.

A mechanical separator is a device which separates condensed, liquid water from a compressed air stream using a mechanical device. They are typically used where large amounts of water are present in the compressed air, such as downstream of an aftercooler or at the coldest point in a refrigerated air dryer. Two types of separators are common, centrifugal and direct interception. A centrifugal separator has a series of vanes that spin the compressed air as it travels through the separator, throwing the liquid droplets against the outside of the device where they can gather and run down to a drain. Direct interception separators have sharp turns, which the compressed airstream must follow. Since the liquid droplets are heavier than air, they have trouble following the airstream around sharp corners, so they impact the walls of the separator, gather and run to a drain. Mechanical separators are usually very maintenance free and should rarely require replacement or repair. Since all of the collected liquid and debris are drained off, there is little opportunity for the separator to become clogged.

A particulate filter is designed to trap solid contaminants in the compressed air stream. Solid contaminants include rust, scale, dirt, pollen, dust and other debris either generated inside of the compressed air system or pulled into the system by the compressor. Contaminants in the compressed air become trapped in the fibers of the media. Eventually these particles block the media, increasing the pressure drop across the filter. Particulate filters should include a differential pressure gauge or pressure indicator to show when the filter element requires
changing. These filters may also be changed based on their time in service, if a regular schedule of filter changes is set up and strictly followed. Particulate filters should also be equipped with a drain to allow accumulated liquids to be removed periodically. Usually lower efficiencies are adequate for particulate filters when used as prefilters for coalescing filters. Higher efficiencies are required for particulate filters used alone or downstream from a regenerative dryer.

A coalescing filter traps tiny solid particles and microscopic aerosols in a network of fibers. The aerosol particles combine or “coalesce” to form larger liquid droplets. Eventually they grow large enough to run down the fibers to the bottom of the filter where they can be drained. A coalescing filter should be equipped with an automatic drain to remove the accumulated liquids. The tiny solid particles usually remain trapped in the filter media. Eventually these solid particles block the filter media, increasing the pressure drop and requiring the filter to be changed. A coalescing filter should include a differential pressure gauge or pressure indicator to show when the filter element requires changing. Coalescing filters may also be changed based on their time in service, if a regular schedule of filter changes is set up and strictly followed. It is best to use a particulate filter upstream of the coalescing filter to capture the larger dirt and debris particles to extend the life of the coalescing filter. Typical coalescing filters should provide high filtration efficiencies well into the submicron range. A coalescing filter which eliminates all water and oil aerosols down to 0.03 micron should be adequate for powder coating applications. Because coalescing filters also trap solid particles, this same coalescing filter should have an efficiency of 99.9% for 0.3 micron particles.
Oil vapor filters can be installed into an airline, if oil vapor or other hydrocarbons are a problem or if your process cannot handle any oil vapor. An oil vapor problem will be most apparent at any nozzles or sharp bends in pneumatic fittings where condensed oil vapor can gather. Usually electronic devices have a small oil vapor filter attached to prevent any contamination of fragile electronics by oil vapors. Typical oil vapor filters use an adsorption media, usually activated carbon, which pulls oil vapor molecules from the compressed air stream and traps them on the surface of the media. Sometimes this media is contained in a clear housing, and it changes color as it adsorbs oil vapor. These filters are usually the last stage of filtration before any point of use in a compressed air system. They should always be used with particulate and coalescing filters, because the media in an oil vapor filter cannot handle any liquid oil or water and oil vapor filters do not usually include a drain. Particulate will build-up in the media and shorten the life of the filter. If oil vapor is contaminating a regenerative air dryer, oil vapor filters can be used upstream of the dryer to extend the life of the desiccant.

3.6 DRAINS

Filters and separators designed to capture liquids and solid contaminants should be equipped with a drain valve. A drain valve allows accumulated liquids and particulate to be drained out of the compressed air system, preventing the liquids from flowing downstream and contaminating the rest of the compressed air system. Manually operated drains require someone to open the drain periodically to allow contaminants to drain out of the filter. The draw back of this type of drain is it is either neglected and not opened regularly, or it is left open all of the time, allowing tremendous amounts of compressed air to be wasted. Manual drains are best used where little liquid accumulation occurs, such as in a particulate filter
downstream of a regenerative air dryer. Automatic drains are becoming very common on many filters and separators. They allow for continuous operation with little more than regular maintenance checks. Automatic drains are most useful in filters and separators that tend to accumulate a lot of liquids; such as the first filter in a compressed air system, coalescing filters, and separators. Float drains are simple automatic devices which rely on a float to open and close the drain valve. Automatic drains with electronic timers allow the opening and closing of the drain to be set in specific time intervals. This allows the maintenance crew to set how often the drain opens and for how long. Electronic timer drains are sometimes expensive but may be worth the investment. If the drain is opened on a regular “as needed” basis, the air consumption can be reduced by limiting excess purge air escaping through the drain.

4.0 COMPRESSED AIR SYSTEM SIZING

The pneumatic functions of a powder coating system are designed to operate at specific pressure and flow conditions. The plant compressed air system has to be designed, sized, and installed or upgraded to meet the requirements of the powder booth. This process is usually not as simple as running an additional pneumatic pipe to the powder paint booth. Factors such as the amount of compressed air, pressure dew point, and level of filtration provided by an existing or planned plant compressed air system have to be evaluated. If these parameters are not adequate to meet the requirements of the powder coating system, then additional or larger compressors, dryers, and filters may need to be purchased and installed into the system. An evaluation of the plant compressed air system should be performed each time equipment is added to the plant’s compressed air system.

4.1 COMPRESSOR AND AFTERCOOLER
When designing a compressed air system for a powder coating application, the first thing that must be determined is the amount of compressed air that is required for the application. The powder system uses compressed air in many locations. The air usage from each of the components (i.e. guns, fluidizing, powder transfer, blow-down valves, and controls) must be determined and totaled. The maximum or “worst case” airflow in scfm from the components should be used to determine the required capacity of the supply air.

If the compressor is being used to supply compressed air to the entire plant, the worst-case airflow to all of the other equipment requiring compressed air in the plant must be determined. An additional safety margin should be added to account for leaks in the system as well as misuse and waste by workers. Usually 15% to 25% is adequate for this safety margin. The compressor should be sized properly for both the current and future compressed air needs, if any future equipment is planned. A compressor should be specified which is energy efficient and economical under normal operation. Because of the heat and noise generated by most compressors, it should be located in an isolating enclosure away from the powder booth and air dryer.

The aftercooler should be sized to match the compressor output. It should also be designed with adequate capability to reduce the temperature of the compressed air to 100° F or less because this is the highest inlet temperature most air dryers are designed for. An adequate separator and drain should also be included to eliminate any accumulated liquids which will condense inside the aftercooler.

4.2 AIR DRYER SIZING

An air dryer is sized based on the airflow through the dryer, the inlet conditions of the compressed air, and the pressure dew point required.
4.2.1 AIRFLOW REQUIREMENTS

The worst-case airflow requirements in scfm should be determined for all of the equipment downstream of the air dryer requiring compressed air. If the air dryer is only being used for the powder coating system, then only the powder coating system should be installed downstream of the air dryer. Consideration should be given to both the current airflow requirements as well as any additional equipment that may be installed in the future. If an entire additional powder coating line is planned for installation a year from now, it may be more economical to purchase an air dryer sized for the future powder coating booth as well as the current system.

4.2.2 AIR DRYER INLET CONDITIONS

Inlet conditions determine how hard the air dryer will have to work to eliminate excess water vapor in the compressed air. Because air’s ability to hold water vapor approximately doubles with each 20° F increase in temperature, the temperature of the compressed air entering the dryer determines how much water vapor it contains as well as what size air dryer is required to obtain the required pressure dew point. Compressed air with an inlet temperature of 80° F will require a smaller dryer than air with an inlet temperature of 100° F simply because the lower temperature air contains approximately half the water vapor of the higher temperature air. Therefore, a lower inlet temperature could reduce the dryer size required. Pressure has the opposite effect from temperature. Higher pressure air has less ability to hold moisture than lower pressure air. Therefore, the best inlet conditions for an air dryer are high pressure and low temperature. Pressure and temperature fluctuations in the compressed air system during normal usage should also be considered. During a normal day, the pressure as well as the
temperature of the compressed air is likely to fluctuate, and the air dryer should be sized to handle the worst case fluctuation, i.e. the highest temperature and the lowest pressure.

The inlet conditions to the air dryer should be measured to be sure the dryer is not under sized or over sized for the application. If the inlet conditions cannot be measured, then they are usually assumed to be 100° F inlet temperature, 100 psig inlet pressure, and 100% water vapor saturation. A good aftercooler is extremely important for obtaining and maintaining proper inlet conditions for the compressed air dryer.

4.2.3 PRESSURE DEW POINT REQUIREMENTS (HOW DRY IS “DRY?”)

Two factors must be considered when determining the pressure dew point requirements for a powder coating system. The pressure dew point required to prevent condensation or freezing of the air lines is important for the entire compressed air system, and the pressure dew point required to promote proper powder conditioning and improved transfer efficiency is important for the powder coating system.

When a vendor sizes an air dryer for a compressed air system, their sole intent is to reduce the pressure dew point of the compressed air enough to prevent condensation anywhere in the compressed air system. They do this by determining the lowest temperature the compressed air is likely to reach and then they subtract an extra 10° F or so of safety margin. In addition, vendors usually consider the cooling effects of rapid air expansion to prevent condensation when the compressed air is expanded through pneumatic equipment. For example, a plant in Wisconsin has a compressed air line running outside of the building. Since the temperature can drop to -20° F on the average in winter, the plant must have an air dryer which will lower the pressure dew point of the compressed air to at least -60° F. The design pressure dew point of -60° F takes into consideration the lowest temperature the compressed air
could see (-20° F), the cooling effects of rapid air expansion, and an additional safety margin. Similarly, if a compressed air system is run entirely indoors and lowest temperature the compressed air is likely to see any time of year is only 60° F as it runs in front of a HVAC vent, then the air dryer must provide a pressure dew point of no more than 30° F to prevent condensation with an added safety margin. Many air dryer manufacturers size their equipment in this manner.

For powder coating systems, compressed air should be dried for reasons other than preventing condensation and freezing. Since compressed air is used to fluidize, pump, and spray powder, the amount of water vapor in the compressed air will be carried directly into the powder. Maintaining proper water vapor content helps dry powder in a fluidized bed, aiding fluidizing and spraying. Powder tends to attract moisture if it is just sitting. Fluidizing powder with relatively dry compressed air helps to condition the powder, preventing agglomeration and aiding powder flow.

Transfer efficiency is also affected by the pressure dew point of the compressed air, depending on the application method used. Research has shown that, in general, better transfer efficiencies can be obtained using compressed air at a pressure dew point of between 35° F and 40° F with corona type guns. Conversely, the transfer efficiency of powders applied with a tribomatic type of powder spray gun seems to increase using compressed air with a pressure dew point of around 20° F. These results are generalizations only, and the precise pressure dew point required for optimum transfer efficiency varies greatly depending on the powder being sprayed.

In summary, for a powder coating system, “dry” compressed air means that there should be no liquid water in the compressed air lines leading to the powder coating equipment. In
addition, the pressure dew point of the compressed air should be reduced enough to prevent condensation both in the compressed air lines as well as when the compressed air is expanded to atmospheric conditions. The pressure dew point of the compressed air should also be at a level to promote proper powder conditioning.
4.3 AIR DRYER LOCATION

An air dryer should be installed downstream of an aftercooler and as far from the compressor as possible. This will allow the compressed air to cool as much as possible before reaching the dryer. For a refrigerated air dryer to work properly, it has to be located indoors in a well ventilated area away from heat sources like air compressors or ovens. The heat exchanger must be allowed to cool the refrigerant adequately to keep the dryer operating at peak efficiency. The heat exchanger in a refrigerated dryer will also decrease in efficiency if it gets covered by dust. Regenerative air dryers are a little more robust and can usually handle a variety of conditions. Heat and dust will not affect these dryers, as long as the inlet temperature of the compressed air is under 100° F and the dust does not get into the valves. Likewise, cold will not affect these dryers as long as the drain valves are heated to prevent freezing if the temperature drops below 32° F. Whichever air dryer is used, it should be placed as close to the powder coating room as possible because the dryer is usually where the filters are located. If the air dryer is too far from the powder equipment, then additional filtration may be required to ensure no particulate contaminants break loose down stream of the dryer and contaminate the paint line. Because of the moisture-laden purge air exhausted from regenerative dryers and the effect dust has on a refrigerated dryer, these dryers should be kept out of the powder coating room unless it is open or extremely well ventilated.

4.4 FILTRATION SELECTION (HOW CLEAN IS “CLEAN” AND HOW OIL FREE IS “OIL FREE?”)

The filtration as described previously removes contaminants such as liquid water, liquid oil, and solid particulate. But how clean and oil free does the compressed air really need to be for a powder coating system? As a general rule, the filtration for any compressed air system is
done with multiple stages of filtration. The filtration system relies on a good aftercooler and air dryer to adequately cool the compressed air and to remove excess water vapor, a majority of the oil vapor, and most of the liquid contaminants. A particulate filter, designed to remove particles 40 microns in size and larger along with bulk liquids, is a good prefilter to remove the large rust, dirt, and scale particles that appear in compressed air systems. Next, a coalescing filter designed with a 99.9%+ D.O.P. efficiency will remove liquid aerosols down to 0.03 microns and solid particulate down to 0.3 microns. This coalescing filter is intended to remove any remaining liquid in the compressed air as well as a majority of the sub-micron solid contaminants.

For most powder coating applications, a multi-stage filtration system that eliminates all liquid oil and oil aerosols down to 0.03 microns is size can be considered “oil free.” In addition, oil vapor content should be reduced to a level adequate to prevent condensation of vapors into liquid oil aerosols. The overall oil content of the compressed air after drying and filtering should be about 0.1 ppm. A multi-stage filtration system which eliminates all solid contaminants 0.3 microns and larger can be considered “clean.” Some powder coating applications may require more stringent filtration efficiencies, depending on the finish required.

5.0 MAINTENANCE

After the plant compressed air system is installed, proper attention has to be given to maintaining and upgrading to ensure the system continuously provides the quality and quantity of compressed air required by the powder coating system. Regular maintenance to the compressed air system can help to prevent powder booth problems, down time, and rejected parts. In addition to the manufacturer’s maintenance schedules and recommendations, the
following paragraphs highlight some of the maintenance tasks that will reduce compressed air problems and usage.

The operators of a powder coating system should constantly look for indications that something is wrong with the compressed air systems. Usually these signs are very blatant, such as liquid oil or water downstream of the air dryer or filters. Other indications may be more difficult to detect, such as reduced transfer efficiency, blemishes on the powder-coated product, or gun nozzles that clog repeatedly. Any suspected problem with the compressed air system should be investigated and remedied immediately before it becomes a major problem and shuts down the powder coating line.

5.1 FILTRATION/SEPARATION COMPONENTS

The filters and separators in the system must be properly maintained to preserve the system efficiency and reduce the contaminants going to the powder system. The most commonly overlooked filter is on the intake of the compressor. This filter is very important as it prevents airborne dust, dirt, and pollen from entering and contaminating the compressed air. This filter should be inspected regularly and replaced when necessary. The need for filter replacement elsewhere in the system can be determined by monitoring the filter pressure gauge (if the filter is equipped with one), inspecting the filter media color/condition, or following a regular schedule set up by the vendor. When the pressure reaches a specified level on the pressure gauge, usually indicated with a red portion on the gauge, the filter media should be replaced. Most oil vapor filters change color to signal the need for replacement. Automatic and manual drains can become clogged or jammed with debris. Any liquid water or oil downstream of any filter equipped with a drain is usually a good indication that the drain is clogged. Since
most mechanical separators are relatively trouble-free, the most important maintenance item for a mechanical separator is to keep the drain in good working order.

5.2 SYSTEM PIPING

All of the airlines, pipes, fittings, couplings, and pneumatic equipment should be regularly checked for leaks, stuck open drain valves, unused equipment, or misuse by plant employees. The more joints and couplings there are in a compressed air system, the more potential for leaks. Stuck open drain valves just waste compressed air. Some employees have been known to leave manual drain valves open to reduce water contamination of their equipment. This only increases the airflow through the compressed air system, decreasing the efficiency of the air dryer and filters and generating an even higher pressure dew point. The real answer is to get an air dryer capable of providing an adequate supply of compressed air at the required pressure dew point.

5.3 AIR DRYERS

Each air dryer type has its own set of maintenance procedures to optimize the system performance. Refrigerated dryers should be kept clean because any dust covering the refrigeration equipment will cause the dryer to operate inefficiently, resulting in an increased pressure dew point. As discussed in the air dryer section, the drain valves in the separator must function properly and be checked on a scheduled basis. Any maintenance to the refrigeration equipment must be performed by a licensed refrigeration mechanic.

Regenerative dryers are usually simpler to maintain than refrigerated dryers. Because the desiccant can be contaminated by oil vapors, attention must be given to the desiccant beds and the condition of the compressed air downstream of the dryer. If the desiccant is contaminated and saturated with oil vapor, condensed oil should be visible at the purge exhaust
nozzles. In addition, any liquid water or oil downstream of a regenerative dryer is a good indication that the desiccant needs replacement.

Regular maintenance and proper attention to the compressed air system will ensure a steady supply of clean, dry, and oil free air will be available for the powder coating system. For compressed air systems, preventative maintenance is a lot more cost effective than repairing and replacing damaged equipment and contaminated powder.
BIOGRAPHY

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