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Compressed Air Audit Services

Drainage of condensate from a compressed air system is one of the most troublesome and least understood components to be dealt with properly.

The current methodology of handling water carry over problems and compressed air piping contamination in most industrial plants is to buy bigger and more expensive dryers rather than dealing with the root cause, bad drainage which slugs dryers with liquid phase water when these devices are actually designed to deal with vapor phase water entrainment and contamination.

First it is important to understand that all air compressors ingest moisture entrained in vapor form in the air entering the suction of the machines. The amount is always changing depending on the humidity at the time of the year, the elevation above sea level, weather conditions, temperature (impacting dew point levels), entrainment of moisture from nearby steam exhaust and many other variables.

In the southern area of the country, for instance, a general rule of thumb is that compressors ingest an average of about 18 gallons of water per 100 cubic feet of capacity per 24 hour period.

The actual calculation for entrained suction moisture is:

V = compressor capacity in CFM
C= Temperature of the atmospheric air converted to grains ((1/7000 of a pound) based on dew point
GH = Gallons/HR
H = Hours
M = 60 minutes/HR
P = 7000 Grains/LB
R = Relative Humidity
W = .1198, Pounds to Gallons (Water)

GH = G x R x V x M x H/P x W

The compressors also ingest any chemicals in the air, along with particulates that aren't removed by suction filters. It is not uncommon to find solvents, acids, butane, methane, hexane, hydrocarbons, black liquor vapors, white liquor vapors and other chemical compounds, and particularly mixes of one or all of those used in a specific facility's manufacturing processes are ingested by the compressors. Once these chemicals enter the compressor and when subjected to the pressure and heat of compression in the presence of ambient air water vapor, create a laundry list of other chemical contaminants.

If these compounds aren't efficiently removed, they exit the compressor's discharge port and travel downstream and wreak havoc with the reliability of pneumatic equipment and the quality of the end product produced in that facility.

Once in the system, the heat of compression, coupled with the compression factor (ratio of volumetric reduction from the suction volume to the finally smaller volume at final exit pressure) of the unit combines to increase the percentage of entrained water per cubic foot based on volume. Fundamental to understanding this is the fact of physics that while air, a gas, can be

compressed, water cannot. Therefore the ratio of contaminants to air increases the as a factor of rising compressed air pressure diminishes the volume of each cubic foot of air entering the suction of the compressor.

Once the air exits the discharge of the compressor, and the air begins to cool, the water and other contaminants begin to precipitate out.

The liquid condensate, unless removed efficiently at the earliest time in the flow stream, will travel downstream creating corrosion in piping and machinery, contaminating products and process areas, creating quality problems in the finished product, and degrading equipment, causing premature failure and higher maintenance costs.

Where the compressor is oil flooded and lubricated, oil vapors also carry over downstream and are exhausted to atmosphere at point of use discharge from equipment actuation or through leak points, creating breathing and health hazards to employees. The mechanism of the entrainment of carryover of condensate with mixed oil and other chemicals turns to microscopic aerosol vapors when the high velocity compressed air expands to atmospheric pressure.

These microscopic droplets are easily breathed in by workers in the area. They also contribute to product contamination when they settle on equipment and products.

There are actually two components to the effective removal of condensate from a compressed air system.

The first is the cooling and condensing which gets the contaminants into a liquid state and prepares them for removal, and the portion of the equipment that does the actual removal, often described as ‘drainage equipment’.

Intercoolers and after coolers, both water cooled and or air cooled, should be properly sized and configured for the flow and pressure of the system at the exit temperature, approach temperature, and worst case seasonal humidity from the compressor discharge to adequately drop the temperature of the air and cause the entrained vapor to condense into a liquid phase.

It should be kept in mind that this portion of the condensate removal process is interdependent on the velocity of the compressed air stream through the clean up equipment. The faster the air moves, the less time is available for the laws of thermodynamics to apply to contact the air, and to cool it sufficiently to cause the water molecules to coalesce and reach a sufficient size to be precipitated out through the mechanical removal process. The slower the air moves through the device, the better the opportunity to remove greater amounts of contaminants due to increased contact time in the heat exchange portions of the equipment.

Issues such as leak rate and sudden event demands are a consideration in this exercise, as well as true process demands.

When feasible, these pieces of equipment should be installed high enough of the floor to allow installation of drainage devices 18” to 24” below the lowest collection point.

The after cooler should be followed by a separator which will separate out the now condensed larger particles of condensate and pool them in a place convenient for removal.

There are other areas where condensate pools, such as pre and final filters, air receiver tanks, refrigerated dryers, chilled water condensers, and system of overhead transmission and distribution piping.

Refrigerated dryers further chill the air to a design dew point and expedite the further condensation and preparation of moisture and contaminants that bypassed the intercoolers and after coolers for removal.

Of course, desiccant dryers use hygroscopic media to trap and hold moisture subject to purge or regeneration through heat or air passing through the media.

Naturally, pre and final filters are installed to further remove contaminants by mechanical means if dictated by process considerations. These components are generally selected on the basis of how small an entrained particle the facility desires to remove in terms of micron size. These filters are of several designs, ranging from paper filter elements, cyclonic units with or without integral sintered metal or composite filter elements, coalescing filters, and high efficiency particle accumulating (HEPA) filters. Each constitutes a collection point constituting a potential drain point.

Extreme care should be exercised to minimize pressure drop through filters so as not to restrict flow to points of use when filters accumulate the particulates they are designed to trap. Oversizing the filter body above pipe run diameters is a suitable option.

Consult with manufacturers or their representative to ensure accurate data on pressure drops through these components at maximum anticipated flow.

Air receiver tanks should always be placed downstream from after coolers and dryers to as much as possible preclude condensate falling out and accumulating in them. The ongoing wetting and drying of condensate in high pressure air receivers that are fabricated from steel weldments creates corrosion. Over time, the wetting and drying of the internal surfaces, and in particular the areas of the welds, causes corrosion which in turn results in flaking and diminution of the thickness. At some point, when the diminished thickness exceeds the retiring thickness and the walls become becomes thin enough, there is the possibility of catastrophic failure, and explosive rupture. There are many recorded instances of these types of failures, all too many of which resulted in injuries and deaths.

At the very least, the products of corrosion such as rust particles can be carried forward downstream into the plant piping and or stop up drainage piping and devices at the tank as well as process equipment. This type of problem can be slowed if it exists, though not eliminated, by placing air exit piping at the top, rather than the middle or bottom of a receiver.

Tanks outside of plant building walls, especially in colder climates, are more susceptible to this problem that those in warmer climates or inside of the controlled environment of a facility.

The overhead transmission piping can also be a point of condensation precipitation where moisture and contaminants have not been effectively removed by prior properly sized and correctly operating clean up equipment. For this reason, you should avoid down slopes or drooping ‘bellies’ in piping. Taps for side runs should, whenever possible, be on top of the header pipe.

Each point where condensate can accumulate must be identified and equipped with proper drainage.

This leads us to the least understood and most often inadequately configured part of this equation, that of the drainage device or “traps” and their proper installation configuration.

The drainage devices are not the entire system, by merely an integral part thereof.

All too often the selection and placement of the traps is based on lowest cost and quickest installation, regardless of the impact on long term system reliability.

Traps such as electrically operated timer drains or electrically operated float, mechanical float/needle or poppet valve drains, or those modified from steam trap designs are attractive due to low cost.

However, the additional pipe, wire and labor costs associated with electric traps should be taken into account. Of further concern is the limitation of those devices due to inability to handle contaminated condensate with entrained solids or higher condensate removal flow quantities.

Timer traps and similar conductivity driven traps have another short fall. The open whether or not condensate is there to remove, and closed whether or not the condensate load has been voided. While the trap is closed, condensate merely bypasses that point and goes farther downstream

Of equal concern is that the timer traps and capacitance traps exhaust full pressure compressed air to atmosphere creating an associated energy waste cost factor for both lost high pressure air and electricity consumed to operate the trap, and at the same time, often cause a sudden pressure drop which is read by nearby air compressor controls as a false low pressure signal causing the compressor to load up or remain loaded when it should be unloaded.

A typical timer drain which opens for a period of 10 seconds every 10 minutes and exhausts 100 PSIG air along with condensate expels 19.9 CFM for that 10 second period. If the facility has an electrical cost of $.05 per KW per hour, and operates rotary screw water cooled compressors actuates 6 times per hour or 52,560 times per year, the equivalent cost in terms of overall operational cost of compressor operation is about $525.00.

Stated differently, an inexpensive $110.00 timer drain costs 5 times its purchase price to operate on an annual basis.

Full pipe sized, pneumatically controlled devices such as that manufactured by Drain-All of Louisville, Tennessee, are more desirous since they void water and other contaminants, including entrained solids without electricity or exhausting high pressure air. They are far more reliable over the long haul since they have full diameter internal porting and operate without the need for electrical supply unless heaters to prevent freezing are necessary in outside installations.

Avoid traps with small internal passages whenever possible.

Select traps that have external manual override to ensure proper operation.

Installing drainage devices should receive equally detailed scrutiny. First and foremost, you should provide a full ported ball valve as an isolation valve and ground joint union so the device may be easily serviced or removed without shutting down the system. The valve should be at the bottom of an 18”-24” drop pipe to provide holding capacity while servicing the trap and so condensate doesn’t bypass that point during servicing. The drop pipe can and should be generously sized in terms of cross section. Just because the tank fitting is, for instance, 1 ½” doesn’t mean the drop can’t be 3”, or even larger. Utilize unions both above and below the trap for ease in removal and reconnection. If traps must be out of the line for more than a short time, initial piping should include a valved bypass line.

Once again it is good practice to install unions and isolation valves before and after the device and on the bypass line to facilitate removal for service, if required.

If funds and space permits, double window look-through sight glass can be installed above the trap for visual inspection and to insure the device is working properly and the drop pipe is collecting condensate for removal.

The additional benefit is to assure a quiet zone for the liquid so foaming of oils or other contaminants doesn’t occur and create carryover by re-entraining vapor in the air stream. Smaller pipe drops cause high velocities and undesirable turbulence.

Be sure traps you acquire are shipped dry from the factory so residual moisture doesn’t create corrosion due to oxidation or fouling.

When piping the sump line from the trap, piping larger than the outlet connection of the trap, to allow for rapid flow without clogging and creating a pre-trap storage point, is also a wise choice.

Where ever possible, you should avoid piping more than one trap into a sump line to preclude back pressuring the other devices or damming in the lines. If there is no alternative to a single line, place a check valve in each trap discharge line to preclude backflow.

Keeping these strategies in mind when working with your compressed air system will substantially reduce problems in operation of that utility area and downstream problems from entrained contaminants.

In the final analysis, keep in mind that the sooner one removes condensed water at the earliest drain point, you will prevent that liquid from traveling downstream and accumulating with what ever condensed liquid the next component creates, and thereby making it even more difficult to efficiently remove the greater quantity of liquid.

This is especially important to keep from 'slugging' dryers which are designed to handle vapor phase entrainment with large quantities of liquid phase condensate and seriously depleting the ability to do their job to a level of excellence they were intended to do.

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