Purifying Compressed Air and Steam for use in Food Processing

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Abstract

When compressed air or steam is used in the food processing industry, it is necessary to ensure that the gas does not contain materials that can interfere with the process or lead to an unacceptable product. If the presence of condensation, particulate or compressor oil exists in compressed air; these contaminants can lead to malfunction of the processing equipment or a contaminated product, resulting in a significant economic loss. In the same vein, the presence of chemicals from boiler feed water in steam or microorganisms in sterile air can lead to product contamination and a lack of compliance with regulatory requirements, such as the 3-A regulations.

Filtration using coalescing filters, which consist of a matrix of borosilicate glass microfibers in a fluorocarbon resin binder, can effectively remove 99.99% of 0.01 µm particles of oil, water and dirt from compressed air while coalescing steam filters can remove excess condensate, particles of rust, pipe scale and other contaminants as small as 0.1 µm to an efficiency of 98 %, These filter systems meet various regulatory requirements and provide a number of benefits relative to other purification methods commonly used in the food processing industry including simplicity and ease of operation.

Introduction

Compressed air and culinary steam are commonly used in the food industry in a variety of applications such as the control of a device that is included in the processing operation (e.g. using compressed air to open/close a pneumatic valve), direct contact with the product and or packaging (e.g. ingredients handling, product transfer, a drying operation) or contact with a surface which is in direct contact with the product (e.g. clean in place, using culinary steam to sanitize a component of the processing system).

The presence of materials such as water (in compressed air), particulate matter, compressor oils or microbial contamination in the air or steam employed in these operations may lead to significant problems. Typical difficulties include:

- the presence of water in compressed air used to dry a product might lead to a damaged product or the product may not meet quality assurance requirements.
- the presence of particulate matter in compressed air used for controlling a pneumatic valve could lead to the premature failure of the system leading to the need to stop the production line, with the loss of product and/or lost production time.
- the presence of particulate matter in the direct processing of a foodstuff might lead to an out-of specification product (e.g. taste, color, odor or other quality assurance product issue may result) or to issues related to operational regulatory requirements.

To avoid each of the above situations, the process engineer must determine the characteristics of the air or steam that is required for each operation and then develop the optimum methodology to obtain the gas in the most economical manner. In the same vein, the maintenance manager, facilities manager and various engineering personnel must continually ensure that the compressed air and steam used in the facility meet the requirements of the manufacturing processes.

Removing Moisture, Particulate Matter and Oils from Compressed Air

A number of techniques have been used to remove moisture, particulate matter and oils from compressed air used in food processing activities. In many facilities, the air is simply compressed and then allowed to expand to remove moisture. While this pressure regulation removes some of the moisture, considerable moisture remains in the air (Table 1) and this air is not sufficiently dry for most purposes. To remove additional moisture, separators, chemical dryers, refrigerators, filters and desiccant dryers have been employed to obtain air with the appropriate dew point and moisture content.

Filter systems are employed to remove the deleterious substances from compressed air and steam and are included in accepted practices. As examples, accepted practices which describe filtering systems for air under pressure in contact with Milk, Milk Products and Product Contact Surfaces[1], as well as Culinary Steam[2] have been developed by 3-A Sanitary Standards, Inc. in collaboration with the US Public Health Service and the European Hygienic Engineering& Design Group. In this paper, we describe the use of filter systems that can readily purify the gases to meet the requirements of the accepted practices and present representative applications.

The accepted practice for supplying air under pressure for contact with Milk, Milk Products and Product Contact Surfaces involves the use of a coalescing filter[1]. The practice requires that the final filter efficiency (as measured by the Dioctylphthalate Fog Method (DOP)) should be > 99%, and when commercially sterile air is required, the final filter efficiency should be > 99.999 %.

In addition to the Accepted Practices, a number of other standards have been developed for the level of allowable contaminants in compressed air such as DIN ISO 8573-1; which defines various classes for solid matter, water content and oil content (see Table 1).

Using a Coalescing Filter to Remove Moisture, Particulate Matter and Oils from Compressed Air

A coalescing compressed air filter provides a simple, powerful and reliable method of removing moisture, particulate matter and oils from compressed air with a minimum of maintenance. The filter consists of a matrix of borosilicate glass hollow fibers in a fluorocarbon resin binder and is resistant to water, hydrocarbon lubricants and synthetic lubricants. The filter(s) are housed in an assembly in which the liquids are continuously trapped and are directed to a drain via a passive design so that the filter can continue to remove liquids for an unlimited time without loss of efficiency or flow capacity. The filter system is easy to use on a continuous basis, requires only an annual change of a filter element, and is extremely reliable as it contains no moving parts. A coalescing air filter is typically employed as part of a compressor installation as shown in Figure 1.

A broad range of coalescing filters are available (Parker Hannifin Corporation, Haverhill MA) which are designed to withstand a maximum pressure of 250 psi and cover the flow range from 1 SCFM to 65,000 SCFM with an initial pressure drop of <2 psi. These filters can be used over a temperature range from -150^{o}F to 300^{o}F (-100 ^{o}C to 149 ^{o}C).

Several grades of coalescing filters are available; ranging from a single stage DX filter which is able to remove > 93% of 0.01 µm particles and droplets and is commonly used for general purpose applications such as purifying plant compressed air. For instrument grade air, two stage filtration is used (a DX filter is followed by a BX filter, which can remove 99.99 % of the 0.01 µm particles and droplets) and a three stage filter system (a DX filter followed by a BX filter and a CI filter) which is normally used to remove trace compressor oil vapor. The filter(s) are self gasketing which prevents the need for end caps and offers lower cost element replacement. The filter system requires minimal maintenance, is extremely reliable as it are contains no moving parts and is quiet in operation.

Coalescing filters are often used in conjunction with other devices such as chillers to reduce the workload of the filter. As an example, in many facilities, a DX filter is placed upstream before a refrigerated dryer, desiccant dryer or membrane dryer to remove most of the oil and water from entering the dryer.

Benefits of a Coalescing Compressed Air Filter

A coalescing compressed air filter purification system provides a number of significant benefits:

- **A coalescing compressed air filter does not require any external power.** Many techniques that are used to dry compressed air require a considerable input of power, thereby increasing the cost of the overall process. As an example, when a chiller or refrigerated dryer is employed, the compressed air is cooled to condense the water vapor and then brought back to the desired temperature. A refrigerated air chiller can be quite large and requires valuable floor space in the facility. In addition, refrigerated air chillers may be quite noisy as a fan is used to cool the refrigerant and will require routine maintenance on a periodic basis. Refrigerator based dryers cannot achieve dew points below freezing; the optimum level that can be attained is approximately 36^{o}F (2^{o}C) and it should be noted that the dew point may be difficult to control without sophisticated automatic control systems.
- **The use of the coalescing compressed air filter is a continuous process and requires a minimum amount of maintenance.** Once a coalescing compressed air filter is installed with an automatic trap valve, the operator need not perform any maintenance (other than an annual change of the filter element) activities or constantly monitor the performance. In contrast, when a desiccant dryer is employed, timed valves are employed to switch from one desiccant vessel to another and heat is required to drive the adsorbed water during the recycling process. If heat is used to regenerate the desiccant, a considerable amount of energy is expended.

- **A coalescing compressed air filter system is small and does not require any floor space in the facility.** A variety of filter housings are available and they can be line mounted as part of the overall piping system, thereby saving considerable space relative to the use of a refrigerator or chiller.
- **A coalescing compressed air filter eliminates the need for the use of refrigerants.** Many refrigerants are environmental hazards and are not compatible with food processing facilities. In addition, the fluid level of the refrigerant must be checked from time to time.
- **A coalescing compressed air filter operates silently.** Refrigerated dryers have been used at point of use applications; however their physical size, noise level and electrical requirements often contributed to equipment operator complaints.

Sterile Air Filters (for direct contact with food and food surfaces)

Sterile air filters (SA) are designed to remove all viable organisms from the air at 99.9999+% efficiency for 0.01 µm particles. These filters are at least 30 times better than the accepted standard for sterile air filters. A recent study at the University of Massachusetts[3] indicated that a Balston sterile air filter produced commercially sterile air and to the limits of detection, no viable colonies of microorganisms were found. In this study, a DX filter, a BX filter and an SA filter were autoclaved, dried and cooled. Air from the normal compressed air supply was passed through the filters and allowed to impinge on a Gelman membrane filter for 20 minutes. The filters were subjected to recovery methods for fungi (yeasts and molds), mesophilic aerobic and anaerobic bacteria and thermophilic aerobic and anerobic bacteria. In all instances, the filtered air observed displayed no presence of microbial air contaminants downstream of the grade SA filter.

These filters have been accepted by the US Department of Agriculture for use in federally inspected meat and poultry plants. These filters are easy to use and are readily sterilized and provide the same levels of ease of operation as the coalescing air filter described above.

Steam Filters

Direct steam injection using culinary steam in food processing is an effective method to warm food and reduces the speed of production since the product absorbs the heat more rapidly. Culinary steam "should be free of entrained contaminants (e.g. excess condensate, rust, pipe scale and boiler feed water additives), and relatively free of water in liquid form and is suitable for direct contact[2]. Accepted practices require that the filters used should be non toxic and do not release media, toxic volatiles or other contaminants into the steam. The bonding materials should be non toxic, non-volatile and insoluble under the intended conditions of use[2]. The accepted practices require that the filter be capable of removing 95 % of particles that are 2 µm or larger with an associated condensate trap[3]. Figure 2 presents an overview of a system for direct steam injection[2]. An example of the use of a coalescing filter for the purification of steam for direct steam injection was recently described by Cahoon Farms (Walcott NY), a manufacturer of private label apple sauce. This filter system provides steam with an efficiency of 98 %, removing all particles of rust, pipe scale and other contaminants. These filters are in full compliance with the 3A Accepted practices (3609-04) for producing culinary quality steam. In addition they meet the regulations for Indirect Food Additives used as Basic Components for Repeated Use Food Contact Surfaces as specified in 21 CFR 177, Current Good Manufacturing Practices 21 CFR Part 110 and have been accepted for use by the US Department of Agriculture for use in federally inspected meat and poultry plants.

Conclusions

Specifically designed filters which consist of a matrix of borosilicate glass microfibers in a fluorocarbon resin binder provide a powerful, efficient and effective method of removing impurities from compressed air and steam as well as microorganisms in sterile air. These filters are capable of removing moisture, oil and particulate matter from compressed air as well as rust, pipe scale and other contaminants from steam at a level at levels that comply with 3-A, ISO and other regulatory requirements. The filters meet the requirement of accepted practices and the requirements of regulatory agencies and have been accepted for in use in a variety of production processes ranging from milk, meat, chicken to apple sauce. Use of these filters provides a continuous process and requires a minimum amount of operator interaction. In addition, operating costs are low, since external power is not required.

Table 1 Removal of Water by Compression and Cooling

	Intake	Outlet	Aftercooler
Volume	8 cu. ft.	1 cu. ft	1 cu. ft
Pressure (gauge)	0 psig	100 psig	1 psig
Temperature (example)	68^oF (20^oC)	158^oF (70^oC)	68^oF (20^oC)
Water Content (vapor)	2.1 g	2.1 g	0.6 g
Relative Humidity	50 %	30 %	100%
Dew Point (at pressure shown)	50^oF (10^oC)	97^oF (36^oC)	68^oF (20^oC)

Table 2 Requirements of ISO 8573-1

	Solid			Water		Oil	
Class	Maximum Particle Size (μm)	Maximum ppm	Concentration mg/m^3	Pressure ^oF	Dewpoint ^oC	Maximum ppm	Concentration mg/m^3
1	0.1	0.08	0.1	-94	-70	0.008	0.01
2	1	0.8	1	-40	-40	0.08	0.1
3	5	4.2	5	-4	-20	0.83	1
4	15	6.7	8	37	+3	4.2	5
5	40	8.3	10	45	+7	21	25
6	-	-	-	50	+10	-	-

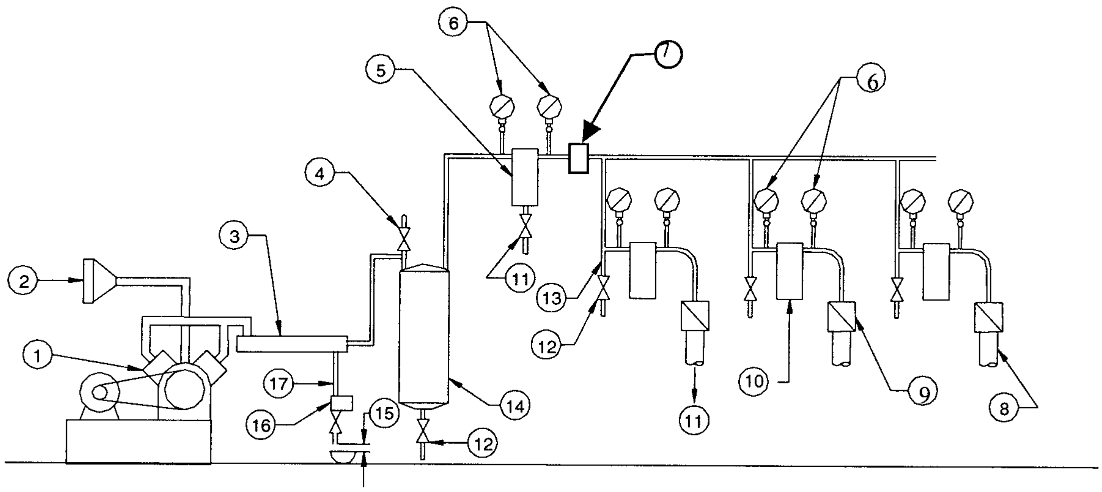

Figure 1: Filter System for the Supply of Compressed air in Contact with Milk, Milk Products and Product Control Surfaces (1: Compressing Equipment, 2: Intake Air Filter, 3: Aftercooler, 4: Sanitary Relief Valve, 5: Air Pipe Line Coalescing Filter and Moisture Trap, 6: Pressure Gauge (Optional), 7: Dryer (when used), 8: Sanitary Piping Downstream from this Point, 9: Product Check Valve (where required), 10: Final Filter, 11: To Point of Application, 12: Drain Valve, 13: Moisture Leg or Trap, 14: Air Storage Tank, 15: Air Cap, 16: Trap and Drain Valve, 17: Condensate Pipe). [Courtesy of 3-A Sanitary Standards, Inc.]

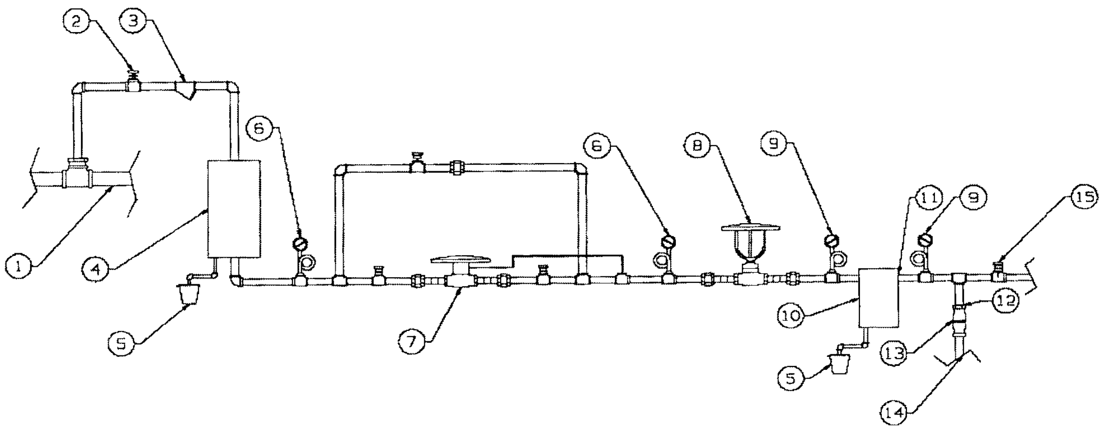

Figure 2: Direct Steam Injection System (1: Steam Main, 2: Stop Valve, 3: Strainer, 4: Entrainment Separator, 5: Condensate Trap, 6: Pressure Gauge, 7: Steam Pressure Regulating (Reducing) Valve, 8: Steam Throttling Valve (Automatic or Manual) or Orifice, 9: Differential Pressure Measuring Device, 10: Filtering Device, 11: Stainless Steel from this Point, 12: Sanitary Piping and Fittings from this Point, 13: Spring Loaded Sanitary Check Valve, 14: Sanitary Piping to Process Equipment, 15: Sampling Means). [Courtesy of 3-A Sanitary Standards, Inc.]

Footnotes:

1 Accepted Practices for Supplying Air Under Pressure in Contact with Milk, Milk Products and Product Contact Services, Number 604-05, 3-A Sanitary Standards, Inc., McLean VA, Nov. 21, 2004.

2 Accepted Practices for A Method of Producing Culinary Steam, Number 609-03, 3-A Sanitary Standards, Inc., McLean VA, Nov. 21, 2004.

3 Evans, D.H., Department of Food Science and Nutrition, University of Massachusetts, Amherst MA 01003.

4 MAP Sterile Air Filters-A, Parker Hannifin Corporation, Filtration and Separation Division, Haverhill, MA, November 2007.