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FOOD PROCESS FACILITIES AIR MANAGEMENT

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Food Processing Facilities Air Management

Food processing facilities require environmental control (frequently referred to "HVAC" or "industrial ventilation") to support process equipment, protect exposed finished goods, and provide safe worker conditions. There are three main types of HVAC systems: *(1)* outdoor/outside air exchange ventilation (with seasonal heating), *(2)* mechanical cooling ("air conditioning"), *(3)* a hybrid of the two. Historically the type of system installed was based on if the process required temperature and humidity control. While a consideration, worker heat stress and positive space pressurization took a backseat due to perceived capital and operational cost. Significant recommended changes over the past decade have influenced facility ventilation requirements with increased focus on food safety, product shelf life, and attention to worker heat stress conditions. The recommendations suggested achievement of these objectives through positively pressurizing facilities, increasing air filtration efficiency, and providing more precise environmental control. Additionally recent cultural and economic shifts in the workforce are contributing to labor shortages. Many prospective employees cite a "comfortable" workspace as desirable even above income compensation.

The purpose of this "brief" is to share the "big picture" providing accurate information to assist facility engineers with their decision making process. There is no one-size-fits-all solution applicable to all facilities. This brief will examine pros and cons by first asking "why" are we are considering a new system. Then we may determine "what" the overall project objectives are. Finally "how" these objectives can be balanced with available capital and ROI which may include removing some false perceptions.

How Much Air Exchange?

One of the most common questions we hear is "how many air changes per hour". The answer is: it depends! There are multiple dynamics involved. In food processing applications internal space heat gain can be a driving factor. If the objective is to solely remove heat gain radiating from processes, outdoor air exchange is acceptable. With proper sizing, equipment locations, and control devices outdoor air exchange can maintain indoor temperatures within ten degrees Fahrenheit higher than outside. There are a few challenges associated with outdoor heat exchange. In most "warm month conditions outdoor ventilation does not provide a positive impact on space humidity. Whatever grains of moisture are in the outside air will be brought inside and internal moisture gains will only add to this level unless exhausted (product release, process steam/water, sanitation). Humidity is a primary component influencing occupant heat stress. Additional internal humidity gain is through the product cooling process where there is an evaporative component which per production line can be 200 pounds of water or more per hour into the production space. This is also a main ingredient for microbial growth (molds).

In facilities where potential for dangerous worker heat stress is a concern, the question often is "can't we just add more airflow?" to the system. Scientifically the answer is "no, not really". Increasing the rate of air exchange to achieve lower temperatures provides a negligible benefit. To provide a five degree lower temperature differential between indoors and outdoors requires twice the airflow along with twice the operational costs. Regardless of the amount of air exchange, without a mechanical cooling process thermal dynamics will not allow indoor temperatures to get below the outdoor temperature. Worker heat stress is calculated using Wet Bulb Globe Temperature (WBGT), not the dry bulb "air" temperature. 70% of WBGT is calculated based on wet bulb temperatures which takes into account humidity which allows a calculation for how effectively a human body can to cool itself through perspiration (evaporative cooling). Introducing humid air into a facility through air exchange reduces the ability for sweat to evaporate and cool the body leading to excessive heat stress. This why hot and dry desert areas may actually have a lower heat stress rating than humid climates where the outside air temperature may be 15°F lower.

To reduce outside air exchange, we turn to mechanical cooling equipment. Now mechanical cooling in food processing facilities does not typically provide the same environment as a commercial office. Systems are engineered for operation at much higher (or lower) temperatures and moisture removal capabilities depending on the requirements. This allows a 50-70% or greater reduction in air exchange as there is a mechanical process creating that larger temperature differential between outdoors and indoors – typically between thirty and forty degrees Fahrenheit. Outside air is used only to maintain positive space pressurization. Much lower outside air and a mechanical process to remove moisture greatly reduces that wet bulb component of heat stress. Lower space humidity means less potential for molds growth. Considering a smaller amount of outside air exchange that may be only 10% also equals less opportunity for spore introduction into the facility (see How Does Ventilation Effect Food Safety section) mechanical cooling may be a previously unconsidered option based on your geographic, process, and overall risk management requirements.

What Level of Filtration?

Much like the air exchange question, material type and rating of air filtration does not have a single solution for all facilities. While there are food safety specific design criteria for filter media itself, the focus of this brief is on filtration efficiency. It is critical to communicate your process and risk management requirements to an experienced partner to help establish accurate filtration expectations. Defaulting to the highest level of filter efficiency may carry a substantial price tag through initial capital investment along with higher (and more frequent) replacement cost. With higher filtration efficiencies also is the need for higher fan motor energy requirements to overcome the added resistance. If retrofitting existing equipment with higher efficiency filters existing fan motors may not be able to maintain the same airflow capacity reducing outside air causing space pressurization to drop (or go negative!). In a negative pressurization scenario there is more exhaust than filtered make up air into a facility. Because the pressure inside is lower than outside air, the air from outside will infiltrate through any opening such as docks, unpowered relief dampers, building cracks, anywhere air could push into the building. All of this airflow which can be substantial is not filtered. An experienced design partner can help you avoid negative pressurization situations while meeting your filtration objectives.

To assist with understanding filtration efficiency requirements, it may be helpful if you view your facility as having separate sections. Areas you determine to be "Sanitary Zones", sections where finished product which may be exposed to atmosphere (not in sealed packaging) should be established as requiring one type of filtration. Areas such as Cleanrooms (Wrap / Packaging) and Spiral Conditioning Systems require a more protective environment through a focused air management system. Areas designated as "Sanitary Zones" should have a higher filtration rating to reduce potential airborne mold spores and particulate levels which can otherwise contaminate finished goods prior packaging.

Minimum Efficiency Reporting Value (MERV) is the professional measurement scale for air filtration efficiency based on how much of a specific particle size is captured in a single pass. Depending on your final protection requirements, a MERV-14 or 15 rated filter may be recommended in "Sanitary Zones". Other process zones in the facility may not require the same high level of protection if finished product is not exposed and may able to use MERV-8 filtration with no meaningful loss in final product protection. Using a zone-specific strategy will contribute a long term ROI through energy, maintenance, materials, and in new installations initial capital costs while providing an easier method for controlling the environmental variables effecting product quality.

How Does Ventilation Effect Food Safety?

A main risk to food safety is potential for interaction and/or contamination of finished product from materials in the air. Since we are filtering the incoming air after selecting our filter efficiencies in the above section, the goal is now to make sure unfiltered air will not enter the building. This is accomplished through positive space pressurization – which means the amount of filtered makeup air coming into the facility is higher than the amount of exhaust air. This "extra" air will push out through small building openings to prevent uncontrolled air containing particulates, spores, and insects from entering the facility. In facilities with freezers and refrigerated docks pressurization may also with help icing and condensation issues from warm and comparatively very humid unconditioned air infiltrating into and even passing through low temperature zones where condensation can occur and increase the potential for a food borne illnesses.

Returning to ventilation systems, the type of equipment chosen has a direct impact on food safety risk. In previous sections we reviewed the two main types of ventilation systems with a focus on their outside air exchange requirements. In the previous section was a brief explanation of air filtration efficiency. Now we bring systems and filtration together to understand how filtration and airflow impacts food safety.

Medium levels of air filtration such as MERV-8 filter are a good balance between filter efficiency and long term ownership cost in most areas where finished product is not exposed. A MERV-8 filter will remove approximately 70% of the mold size particles from the air stream, meaning approximately 30% are able to pass through and enter the facility. If product molds exposure is a concern, especially during peak periods in spring and fall through early winter, a decision will be required how to offset the 30% of mold size particulates which pass through a MERV-8 filter. If using outside air exchange only where airflow requirements are five to ten times higher than mechanically cooled equipment, then that same filtration is bringing in 5 to 10 times the amount of mold sized particulate. One frequently suggested solution is reducing air exchange. However any reduction in make-up air must have a matching percentage decrease in exhaust air or positive pressurization will be lost. This in turn increases interior heat gain and also allows additional moisture to remain in process areas, negatively impacting both product and occupants. The simple fact is a facility using outside air exchange only ventilation systems, the molds particulate exposure risk is many times higher than a facility using mechanical cooling.

Mechanical cooling systems with their much lower airside air requirements (remember they only need outside air for positive space pressurization as they can supply cool dehumidified air) also provide two other big food safety benefits. First, mechanically cooled systems have the capabilities of recirculation which allows them to capture some of those mold sized particulates which may have previously passed through the filter. Secondly, mechanically cooled equipment has built in drains for condensate removal which along with typically having better accessibility, makes for easier and more complete sanitation. Ironically the condensate is also the inherent food safety disadvantage for mechanically cooled equipment. Since the cooling coil removes moisture from the airstream which falls into the condensate containment below, there is potential for standing water inside the drain pans. Where water and darkness exist there is potential for microbial growth.

This is where UV lighting systems are beneficial in air systems applications. UV lighting requires microbes to be continuously exposed with a dwell time ranging from several seconds to hours. With example air velocities of 500 feet per minute, particulates which pass through filtration are gone from this area in fractions of a second intact. However when focused on interior areas which can be wet, UV lighting is highly effective preventing potential growth. Careful planning and evaluation is required when considering UV lighting additions to existing equipment. There are personal safety protocols to be followed as workers must never be exposed to an active ultraviolet light. Additionally "off the shelf" and standard OEM ultraviolet systems are not designed with food safety components as they include glass bulbs in the supply. Mounting brackets and conduits to install these systems are also not meant for sanitary applications and may themselves potentially become a location to collect dirt and foster bacterial growth. Finally in retrofit applications the ventilation equipment must itself be resistant to ultraviolet radiation. There are specialty UV lighting systems designed for food safe operation and we strongly suggest only these qualified manufacturers be considered.

What about direct evaporative cooling systems? Short answer: unless your facility is located in a very dry climate the entire year, they are not for applications with food processing where moisture is a concern. By design they reduce the temperature by adding moisture into the space which is unwanted in food processing facilities and does nothing for the total heat content of the incoming air. Depending on the climate they may also not only be ineffective in providing consistent cooling but could potentially add to worker heat stress.

What is the *Real* Cost?

Positive space pressurization and all this additional filtration in the name of food safety increases ventilation operational costs. Air filters which capture more particulate are more expensive than "mesh" materials you could see through or washable screens somewhat common even a decade ago – and require much more frequent changing. There is also a very large energy component. Consider the fan energy it takes to move air through the "old style filters" and compare them to the high MERV-15 filtration recommended in "Sanitary Zones". The higher fan motor horsepower requirements for high level of filtration – and their associated energy costs – are usually the largest part of overall cost of ownership.

Most of the main components in full cost of ownership are easy to calculate:

Real Cost = Initial Capital + ((Labor + Preventative Maintenance Materials + Repairs + Energy Costs) * Unit Life Expectancy)

Other significant costs to be included including: (reducing unsaleable product), (longer product shelf life), (reduced risk of recalls from particulate contaminants), (increased worker efficiency/heat stress reduction), (ability to attract new workers/work space conditions), and (administrative costs for vendor activities, addressing internal complaints, processing purchase orders, and related activities). Your organization may have further values. These amounts require a more extensive discussion and may be best reviewed on an individual facility level.

Real Cost presents a "big picture" financial view of facility ventilation systems. The results show a food processing facility is almost certainly going to spend more on energy and maintenance then initial project capital. Considering airflow requirements with outdoor air exchange ventilation systems are many times higher than mechanical cooling systems, far more maintenance materials and maintenance labor is required. The operational cost gap between outdoor air and mechanically cooled systems begins to shrink considerably.

Outdoor air exchange ventilation systems have a lower initial capital investment than mechanically cooled systems. *Real* Costs however are much closer. Along with the previously outlined differences, additional considerations beyond cost include the reducing the overall number of systems required, amount of roof penetrations above process safe, and required electrical feeds. The below table provides a comparison for a Chicago based food processing facility using 2022 present dollars over the course of a simple 15-year ASHRAE life cycle. The first column represents a mechanically cooled system (HVAC is used for simplification) design to manage heat stress while improving food safety. The second column advances the system a step further with what may be considered “full air conditioning”. The far right column is a representation of the same facility using ambient outside air ventilation. Seasonal heating requirement costs are not included in this evaluation.   Please note the difference in airborne mold exposures with systems utilizing the lower outdoor air requirements while still maintaining the same level of positive pressurization.

Chicago Industrial HVAC, 100,000Ft^2			
Factors	HVAC	HVAC	Ventilation
Maximum Airflow CFM	133,333	266,667	466,667
Outdoor Maximum CFM	66,667	66,667	466,667
Space Temperature °F	90	79	101
Operations Cost Ft^2 (MERV-8)	$2.28	$4.41	$2.25
Operations Cost Ft^2 (MERV-15)	$2.60	$5.06	$3.38
Outdoors Molds (MERV-8)	6.1	6.1	42.8
Outdoors Molds (MERV-15)	0.3	0.3	2.1
Capital Investment	$2,000,000	$4,000,000	$2,333,333
Life Cycle 15 Year MERV-8 Ft^2 [1]	$3.61	$7.08	$3.81

<u>Setting Expectations</u>

In existing facilities where mechanical cooling is replacing ambient outdoor air exchange, it is extremely important to clearly communicate plant condition expectations with workers. Unless process requirements dictate, food processing facilities are typically not cooled to “air conditioning” temperatures. The words “air conditioning” may create the perception of 72°F work space. This perception is at odds with what may be design intent of 85-90°F with lower humidity. The implemented design greatly improves their work environment, but absent any prior discussion anything less than “air conditioning” temperatures may lead to frustration.

Additionally many outside ventilation systems operate at capacity when outdoor temperatures reach a certain high limit. This allows for significant seasonal and daily fluctuations to take place which may interfere which this process and should consider some predetermined acceptable range. With mechanical and hybrid systems this variation is less but may be perceived as a negative by occupants accustomed to this variation in the past. Communicating with workers anticipated facility temperature ranges at different times of the year along with sharing the objective is to balance needs between occupant heat stress and food safety will help reduce the potential for worker misconceptions.

<u>Dynamic versus Static Space Pressurization</u>

Space pressure differential is essential to prevent infiltration of airborne particulates through unfiltered openings such as loading docks, entry doors, and other common leakage points in the facility envelope. It is standard to have a fixed static pressure setpoint to manage this condition which ranges from 0.5 to 0.11 that is based on wind speeds of 10-15mph. Since these parameters are based on a fixed setting for the “worst case”, Air Management Technologies developed dynamic control for food processing facilities which adjusts the pressure setpoint based directly on wind speed with predetermined low and high limits. This translates into decreased “blasts of air” when entering a facility, prevents door opening/closing issues, and provides significant fan and thermal energy savings while still maintaining adequate pressurization.

Protecting the Investment

The purpose of the ventilation system is to protect the product and protect the people, but properly protecting the investment is frequently skipped. Both types of systems represent a considerable investment with both initial capital and ongoing operational maintenance. With most maintenance budgets focused on process operations, one area frequently overlooked is performing regular professional preventative maintenance. By extension the ventilation system is part of the process and should be regarded with the the same care. Having preventive maintenance performed at the correctly scheduled intervals should not be an afterthought. This includes the facility ventilation control system to ensure all components are cohesively working together efficiently and not as individual pieces of equipment which may negatively impact performance and safety.

Like any other process equipment, even the best systems will fail due to improper maintenance and controls operation. The need for system performance verification is “why” monitoring Environmental Performance Indicators (EPI’s) is essential in food processing facilities. Air Management Technologies’ EPI Vision System is the solution which is able to provide push notification when any of the established EPI’s are outside acceptable parameters and, when connected to a facility air management control system, can in many cases execute commands to correct.

- Space pressure with wind speed compensation
- Space to outdoors mold level %
- Facility air filtration effectiveness
- Space dewpoint monitoring to prevent condensation
- Carbon Monoxide detection
- Particulate matter PM2.5 and PM10
- Occupant heat stress measurements
- Space temperature and humidity
- Outdoor temperature and humidity

Summary

Each facility is different. Critical objectives in one food processing facility may not be important to another. We stress again there is no one-size-fits-all solution applicable to all facilities. Our intent with this brief was to prompt additional thought which may have been previously overlooked when investing in air management. However there are some constants which must be adhered no matter the system choice. Proper maintenance along with performance measurement and verification is required or the system is unlikely to achieve operational objectives. So while we proclaim impartiality as Air Management Technologies designs, installs, and maintains industrial ventilation systems in food processing facilities throughout North America, Our goal is to evaluate each application and share the information with the client so that they have the required information to make an informed decision but in all cases recommend EPI Vision or similar monitoring and verification system to protect the investment. No matter your choice it is critical to recognize solutions in food processing applications are more than “comfort cooling”, and emphasize the need to partner with an organization which understands “what” your specific requirements and “why” they are the right choice for your facility.

We want to thank you for taking the time to examine our White Paper “Brief” on Air Management for Food Processing Facilities and hope that the information was beneficial. We look forward to hearing from you and please feel free to contact us with any questions or comments.

THANK YOU!

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