Application Analysis:
Meat and Poultry Processing - Level 2
Design Concerns

From the eviscerating area to the cut-up room to the loading dock, the key to condensation control in meat and processing facilities is to blanket the targeted surfaces with dry air. Focus the solution at the source of the problem.

For many condensation control situations the distribution of the dry air is as important as the supplied volume and humidity (dew point) level. Success comes from balancing the need to keep overhead surfaces dry against the risk of drying out the product being processed below.

Control Level

Production

In a typical production area the target set point for condensation control is fairly simple to identify – the delivered dew point must be less than the surface temperature of the components that are experiencing external condensation. Obtain surface temperatures of evaporators, ammonia lines, drain pans, etc. and select the lowest temperature, or slightly below it, as the target dew point.

Sanitation

Every evening the entire production floor goes through an extensive sanitation cycle with every surface in the facility being hosed down with high temperature, high-pressure water or steam. Processors are not expected to have zero condensation during sanitation. However, after sanitation is complete the processor must pass a USDA Pre-Op inspection before the next production shift can start. Water and condensation must be removed from every surface before the facility passes this inspection.

The objective of a condensation control system in this case is to reduce turnaround time. The same system parameters that meet the condensation control requirements during production likely will be sufficient for the post-sanitation mode as well. Some customers have incorporated a purge or washdown mode into their air handler design to facilitate the purging of the production areas of fog, condensation, and steam.

See Design Considerations for additional information.

Ice Prevention

In some ice prevention applications, the temperature is so low that it would be economically impractical to maintain the dew point low enough to prevent all ice formation. In those cases, determine what is economically practical, and expect that there will be some ice formation, but at a much reduced rate. Setting reasonable and achievable performance expectations with the customer is key to success in this application.
Loads

Moisture comes from several sources in meat and poultry facilities – infiltration, evaporation off wet surfaces, product load, and personnel.

Infiltration Air

Outside air entering the controlled space is one of the two largest moisture loads. Large volumes of air (often in excess of 100,000 scfm) are pulled through the facility in a counterflow direction (opposite to product flow) from clean to dirty (see Figure 1). This results in large amounts of untreated outside air (OA) being brought into processing areas with temperatures that can be 50˚F or lower.

If 100,000 scfm of untreated outside summer air (in Atlanta, GA for example) infiltrates into a processing facility then approximately 600 gallons of water per hour would condense on surfaces that are ≤50˚F. The magnitude of this moisture load justifies a thorough evaluation and optimization of the facility’s outside air requirements by a qualified engineer. A condensation control system then can be designed and integrated within the overall facility plan.

Evaporation off Wet Surfaces

A tremendous amount of water is utilized in a meat and poultry processing facility. Water is constantly being used to hose down floors and equipment and is the typical cooling medium for lowering the product temperature to regulatory limits. Approximately 8 gallons of water are required per bird for complete processing. For a facility that processes 300,000 birds per day the total water consumption exceeds 2 million gallons.

Of course not all of this water evaporates into the controlled space. Quite a lot of the water is captured in floor drains and pumped out of the plant. However, it is reasonable to assume that nearly every square foot of floor space has a thin film of water on it, and plant personnel are constantly replenishing the water film through steady spraying. Furthermore, unless the plant operates in a perpetual 100% RH condition (fog) then there must be a differential vapor pressure between the water surface and the surrounding air. As a result there is a continuously high evaporation load off the floor and other wet surfaces.

Additional evaporation occurs from bird chillers. In poultry facilities the bird core temperature is lowered to regulatory limits (≤40˚F) by immersing the product in large, water filled chillers. These chillers contain 35˚F water that is constantly being agitated with an auger or paddles that drag the product from one end of the chiller to the other.

Product Moisture

The product itself is a source of moisture after it exits the bird chiller. It has a thin film of water...
over the entire surface that will evaporate due to differential vapor pressures between the surface and the surrounding environment. One of the challenges that the system must address is the critical balance of preventing condensation against over drying the product.

**Personnel**

The processing of meat and poultry is a labor intensive operation. There are workers hanging product on the line, hosing down the floors, eviscerating, cutting and deboning the product, and packing the finished product into boxes. At any given time there are likely to be one to two hundred workers on the production floor. Within the context of the major load sources noted above, however, the moisture load contribution from personnel respiration is not likely to significantly affect the final equipment sizing and component selection.

**Space Temperature**

There are several steps involved in the processing of meat and poultry products. Typically, the process starts out at elevated temperatures (70-80°F) during the slaughter, hide/feather removal, and evisceration stages. The carcass then moves into increasingly cooler environments (~50°F) for the subsequent steps (cut-up, debone, pack-out, etc.).

There are a couple reasons for the drop in temperature as the process continues. In the case of poultry processing, for example, the primary driver is USDA regulations that require the core temperature of the product to be ≤ 40°F by the time it leaves the facility. This is the reason for the bird chiller noted earlier. The core temperature is lowered below the regulated 40°F temperature after being immersed in the bird chiller for 90 minutes. The low core temperature is established with food safety in mind since low temperatures retard bacteria / allergen growth. If the product must be at a low temperature then the space in which it is being processed also must be cool to prevent raising the product temperature above set point.

Traditionally, the upstream processes (slaughter, hide/feather removal, and evisceration) are conducted in unconditioned areas. Some evisceration spaces are conditioned, but this appears to be driven more by worker comfort issues than by regulations. All of the further processing steps (cut-up, debone, pack-out, etc.) are performed in areas maintained at 50°F.

The most common method of temperature control in the conditioned spaces is through the use of ammonia evaporators installed near the ceiling. They are self-contained units with blowers and vanes to distribute the cold air across the ceiling.

**System Components & Design Considerations**

**Process and Reactivation Filters**

Whether the system is designed for return air, outside air or a combination of both it is likely that high dust levels will be present on both airstreams of the desiccant wheel. Meat and poultry processes are typically dust-laden operations. Reactivation inlet filters should be at least 30%, possibly supplemented with 55% filters if the system is installed near the very dusty live loading / slaughter process.

Systems designed to handle return air should have 30/55% process air prefilters at a minimum due to the presence of particulate loads and oils. Supply air postfilters should be rated for 95% efficiency unless the client requires HEPA filtration.

**Reactivation Energy**

Reactivation energy must be proportional to the moisture load. Since there is a large internal moisture load that is not weather dependent (evaporation off wet surfaces) the load will be relatively constant all year long. This means the designer should size the reactivation heaters based on the air entering temperature in...
the winter rather than the summer. Otherwise, the heaters will lack capacity to fully reactivate the unit.

Washdown during sanitation has important implications for the sizing of the reactivation heaters. A dehumidifier sized for a smaller “running load” of standard operating conditions must remove this large, intermittent moisture load. So a larger heater selection is justified but a modulating heater control with high turndown capability should be specified. This will prevent the extra capacity of the heater from wasting energy during normal operations.

**Materials of Construction**

The USDA subjects the meat and poultry processing environment to regular washdowns. Some customers are electing to purchase equipment with washdown capabilities because the equipment is servicing a processing area, even though the equipment is located outside the controlled space.

For this reason, condensation control systems have been designed with the double-wall, no-through metal platform. Stainless steel interior surfaces are typical and floor drains should be evaluated for all component plenums.

**Outside Air vs. Return Air**

In many meat and poultry processing facilities there is a large amount of outside air required to meet several facility constraints. Among these constraints are outside air requirements to make-up for process equipment exhaust and to dilute CO₂ and chlorine levels.

The first step in the overall solution for the facility is to determine and optimize outside air requirements. Once the outside air requirement has been estimated then it can be compared to the airflow required for condensation control. The larger of the two airflow requirements establishes the total airflow for the HVAC system. Return air is required if the outside air volume is less than the total airflow. Since the outside air component is less than the total flow there must be a return air mixing box designed into the system.

To facilitate the sanitation process (and reduce the pulldown time) some meat and poultry processors incorporate a purge or washdown mode into their HVAC systems. Regardless of the previous mode of operation (100% return air, 100% outside air or combination of both), the system switches to 100% outside air operation. Return air dampers shut, outside air dampers open, and an exhaust fan is energized. Depending on the system requirements the exhaust fan may pull more air from the conditioned space in the purge mode than during the operating mode. The idea is to evacuate as much of the water and steam-laden air from the facility as possible. The exhaust fan may operate on a VFD or multi-speed controller.

**Pre-/Post-Cooling**

Determining if pre-cooling and/or post-cooling is required will vary and needs to be determined on a case-by-case basis. If a 100% outside air system is required then it is safe to design pre-cooling into the system. Most likely an ammonia system will be utilized at the plant so an appropriate coil construction is warranted. Determine if the facility has a coil specification or standard that needs to be incorporated. Target a leaving air temperature of 45-50°F off of the cooling coil.

Conversely, return air systems may not require pre-cooling, especially in the downstream, temperature controlled processes. With 50°F air returning to the system then adequate dew point depression can be achieved with no additional pre-cooling. However, if an outside air component is needed for any reason (process equipment exhaust, CO₂ or chlorine control, etc.) then the system may need to incorporate a pre-cool coil to reduce the process inlet air temperature to 45-50°F. Evaluate the costs and benefits of pre-cooling the outside air only versus the blended air.
Post-cooling requirements are another challenge. The introduction of low dew point air into a moisture-laden environment, like that of a meat and poultry processing operation, has several advantages.

First, the dew point differential provides a buffer against condensation for any low temperature surface. Second, evaporative cooling occurs. As mentioned previously, there is an almost infinite moisture load provided by the constant washing of floors and equipment in these facilities. Furthermore, energy is required to evaporate water and change its state from liquid to vapor.

So, for every pound of water that evaporates into the processing space, approximately 1000 Btu is consumed, thereby cooling the environment by this amount. So, although a desiccant based system without post-cooling likely would deliver air at an elevated temperature (90-100°F) to a processing space, the evaporative cooling effect significantly dampens the impact on space temperature. Again, a case-by-case approach is warranted, but post-cooling may not be required on any particular project.

**UV Lights**

The food processing industry has a strong emphasis on food safety. Sanitary facility and equipment design practices are being promoted through various industry channels including engineering committees that act as liaisons between the industry and its regulatory agencies. Within the processing areas there is heightened awareness on sanitizing any surface or equipment that has direct product contact. For this reason consideration needs to be given to incorporating a UV light section in the condensation control system as a means of meeting this increasingly likely industry requirement.

**Other Considerations**

- **System maintenance:**

  This is critical for condensation control systems. Inherently very dusty and dirty environments place a burden on regular filter maintenance and replacement. Filter clog alarms (photohelic gauges) should be considered to aid the facility’s maintenance staff. It is not uncommon for a facility to experience a spike in their airborne particulate and cause premature loading of the system filters. Filter clog alarms provide advance warning to the staff should this occur in between their regular filter replacement schedule.

  Also, the most common time of the day for performing maintenance is when the systems are OFF, and at many facilities this is in the middle of the night. Therefore, plenum lights are recommended to provide the maintenance staff with adequate lighting. At a minimum, GFI receptacles should be provided so the staff can bring drop lights to the system.

- **Coil design:**

  Attention needs to be given to the ammonia coil design as mentioned previously. Identify if the plant has a coil construction specification that needs to be followed. Remember that existing industry standards may be driven by the fact that low temperature evaporator coils are subject to freezing. As a result, fin spacing may be very low (4 to 6 fins per inch) to facilitate ice removal and cleaning. Likewise, coil depth is frequently kept below 6 rows.

  If the condensation control system is properly designed, however, there should be little risk of ice formation on coils that are in the conditioned space. Proper filter maintenance will keep the coils clean. Therefore, smaller, more cost effective coils are likely available if the customer or engineer permits higher fin spacing.

  If coils are incorporated into the condensation control system then connection details need to be specified (flanged, stubbed, materials of construction, etc.).

**Controls**

In many meat and poultry processing applications the conden-
A desiccation control system operates at full capacity. With the high internal moisture load inherent in many processes there is usually low risk of over drying the controlled space. If the desiccant wheel is not sized to handle the entire system airflow then a fixed bypass is sufficient.

If a particular project needs tighter humidity control then a modulating feature needs to be incorporated. This feature can modulate a face & bypass configuration on the process air stream or reactivation energy. In either scenario a rise in humidity above set point triggers increased dehumidification (by opening the face damper and closing the bypass damper or increasing reactivation energy). The reverse occurs upon a drop in humidity below set point.

### Cost Considerations

Minimizing the installed cost of the system is largely a question of eliminating unnecessary moisture loads. There is little that can be done to reduce the evaporation load off wet surfaces since water consumption is critical to the process.

The biggest overall variable that the system design can address is the outside air infiltration load. The individual systems requiring outside air (CO₂ and chlorine control, equipment exhaust, etc.) need to be evaluated and reduced as much as possible. If any particular system requires a disproportionate amount of outside air then separate, dedicated make-up air systems may be justifiable, especially in unconditioned areas of the facility that may not require desiccant-based solutions (see Figure 2).

Operating costs can also be minimized through various design modifications. For example, energy recovery should be considered on 100% outside air systems since they are inherently energy inefficient. Many operations in a processing facility are performed in conditioned (≤50°F) spaces. Before this conditioned air exits the space it can be brought through a heat exchanger to pre-condition the entering air.

It takes approximately 8 tons of refrigeration for every 1,000 scfm that is cooled from 95°F, 130 gr/lb to 50°F. A 20,000 scfm system would require more than 160 tons of cooling. Recovering just 25% of this energy (a conservative estimate) would save 40 tons of cooling.

One constraint of such a system is that the exhaust air needs to be brought to a single point to facilitate the energy exchange between the two airstreams. Any additional duct requirements need to be included in the cost-benefit analysis.

### Modified Poultry Plant Configuration (After Condensation Control System)

![Modified Poultry Plant Configuration](image)

* Served by separate, dedicated DH or MUA system

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*Application Note - Level II Page 7*
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