ENERGY SAVINGS IN FOOD PROCESSING DEHUMIDIFICATION

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ABSTRACT

Food processors have the unique responsibility of maintaining environmental, process and sanitation standards for government and consumers. Usually the food plant is a large facility with many sources of contamination, all of which must be controlled. Condensation is a significant source of problems and on critical surfaces is not tolerated by the USDA. This challenges the Engineer to provide an energy efficient system to prevent condensation in our hot and humid climate. The problem is intensified because the building is frequently operating below the ambient dew point. Daily sanitation washdowns are a further contributor to condensation, and failure to control condensation may result in product contamination and rejection, plant shutdown, loss of labor and, in extreme cases, litigation.

Past solutions have included excess ammonia refrigeration tonnage, high ventilation rates prescribed by the USDA - often inadequate for this climate - or chemical dehumidification, which is energy intensive and often mechanically unreliable.

For a decade, the authors have utilized

breweries, and HVAC applications. The correct application of these techniques results in improved moisture removal and significant energy savings. Presented here will be the results of a dehumidification test in a low temperature food processing application.

PROBLEM

Food processing plants are often large facilities with the unique responsibility of maintaining environmental process and sanitation standards in what would normally be a haven for bacteria. Rapid propagation of bacteria requires liquid water, air, nutrients, favorable temperature, and the correct amount of light. Since eradication of bacteria is not practical, the goal of the plant engineers and government inspectors is a sanitary environment to process food. By precluding one or more of the conditions favorable to microbial growth, bacteria are limited to a tolerable level.

The USDA inspects meat processing facilities and products to assure a safe finished product. Testing includes sanitation, temperature, and condensation among many other criteria. Much of the inspection procedure is visual; for environment, for daily sanitation, and for condensation. To the USDA, a water droplet is a probable, and intolerable, haven for dangerous micro-organisms. Therefore, if a plant experiences condensation, the current USDA procedure is to halt the production line, discard all possibly contaminated food, and initiate immediate cleanup and washdown. The dollar impact to one high-volume plant was described as $19,000 per hour, including loss of product, labor, and lost production.

Plant engineers are responsible for preventing the occurrence of condensation, and water droplets can be a formidable nemesis in hot, humid areas. Characteristics of water droplets are portrayed in the following excerpt from a paper presented to the Master's Brewers Convention in 1994:[1]

THINKING LIKE A DROPLET OF WATER

1. *I am very small except when joined*

2. *I always want to change my energy level to its lowest state. As a molecule, I have several forms. I may simultaneously exist in several phases at the same time in the same room.*

3. *Highly excited, I am dry steam. Less excited, I am saturated steam. Trap me and I will explode my container.*

4. *I readily become a calm vapor by giving up energy to my surroundings. When able, I yield over 1000 btu per pound and become a liquid. As a gas, I change the density of air. I can rise to astounding heights measured in miles. I can fuel storms which devastate my*

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surroundings. I migrate across and through all types of materials.

5. *When I give up energy, I become a liquid anywhere I please. I gain weight compared to my other forms. I hide in all the wrong places.*

6. *I have an angle of repose when I am small and alone. I take the form of my container when I am with millions of friends. When I am stable in my container, my surface is perfectly flat. When I want - if the moon is right - I can escape my normal boundaries to disintegrate nearby surfaces.*

7. *If I escape my container, I fall instead of rise. Sometimes I return back to a vapor just to be complicated. I readily reach a balanced condition where one grain becomes liquid while, simultaneously, one grain becomes gas. I can be held back, but I NEVER quit trying to break or exert pressure on the container.*

8. *At 32° I am still a liquid unless I give up 144 btu/pound mass. I can become ice at this point if I want. I am strongest and most powerful in the lowest energy state. I can move mountains, wall, or vessels.*

9. *I can be very still and go several degrees below freezing. If disturbed, I violently become ice, growing in size while I lose weight. I can forget the liquid state and move from solid to gas.*

10. *I can move by gravity or against gravity. I can be moved by the wind or go absolutely counter to air flow.*

11. *Sometimes. I like to blend in with other liquids. Sometimes, I will not blend at all. If I go with the flow, I am easy to move.*

12. *I do not allow breathing, yet I can promote oxidation. I can join with gases or liquids to make metal disappear. I make untreated wood fail.*

13. *I can make steel float, corrode, bend, or burst at my leisure.*

14. *I am necessary for life, but I easily kill.*

15. *I can be pumped or I can refuse to be moved.*

16. *If pure, I pass no electricity, but I pass electricity readily if there is any contamination at all. I I especially like Galvanic corrosion.*

17. *ALL IN ALL, I ACT LIKE AN UNDISCIPLINED CHILD! I do what I want, how I want. I leave a mess for others to clean up wherever I go, or I clean up a mess made by others.*

As water, I cannot be intimidated. I can intimidate very easily.

Obviously, the water molecule is a formidable opponent.

Many food plants have areas required by the USDA to be maintained at 50° F or less. Controlling condensation in areas with high ambient moisture conditions adds a new dimension to dehumidification problems because of infiltration loads, and the rate of moisture migration via permeation or through a fixed opening is a function of vapor pressure difference. The greater moisture transfer usually occurs due to openings rather than permeance. Wi = A x d x 60 x Va x (Mo - Mi).[2]

DEFINITIONS:

Wi = Moisture load from air infiltrating through an opening (gr/hr)
A = Area of the opening (sq.ft.)
d = Density of the infiltrating air (lb/cu.ft.)
60 = Minutes per hour
Va = Air velocity through the opening (ft/min)
Mo = Moisture outside the space (gr/lb)
Mi = Moisture inside the space (gr/lb)

A positive pressure equal to 150 FPM outward velocity decreases the influx of moisture at nominal vapor pressure differences.[3]

Food plants often have several rooms with different functions and different environmental requirements. Our test was conducted at a facility containing a 50° F receiving dock open to a 50° F formulation room, doorways into six different cookrooms at ambient conditions, doorways to a packoff area at 50° F, to a spine that connects to a shipping dock or freezer. The resultant temperature swings are from ambient to 50° F (or less) back to ambient. Considering the ambient moisture content for June 22, 1991, was measured at 142 grains versus a room at 50° F/80% RH, or 43 grains the vapor pressure difference or driving force for moisture transfer is substantial. (Moisture = SCFM x .075 x 60 x Gr) Plants with slaughter areas must deal with high sensible and latent loads of freshly killed animals and cross contamination of blood and feces.

Now, the engineer must deal with adjacent rooms with wide moisture swings, continuous moisture from cooking and washing, and people-load of approximately 1/3 to 1/2 pounds of moisture per person per hour. The engineer's nightmare is compounded with the addition of the washdown or sanitation shift. The daily production shutdown and sanitation of the rooms and equipment includes anything that was in contact with the food product. A realistic estimate of room conditions immediately following washdown is 85° F /85° F WB or 185 grains per pound of dry air. This presents a massive latent load to the refrigeration system upon start-up because the USDA requires the room be "dried out" prior to the onset of production.

The ammonia system trying to operate with an evaporator temperature well below freezing, typically from -10 to +10° F begins to build ice from the excess moisture in the room. The moisture first condenses on the coil, then freezes, thus insulating the coil from efficient heat absorption. The next step is defrost - usually hot gas - to melt the ice and allow draining from the drip pan. Net result: with enough tonnage and defrost, the room eventually meets USDA approval and appreciation from TU Electric.

Options available to perform dehumidification are: Ammonia refrigeration, CFC refrigeration, and dessicant systems. Mechanical refrigeration is most often used in food plants because it has the least capital equipment costs. Drawbacks are: operation below freezing, allowance for defrost, and efficiency ratings are often poor. The other end of the spectrum are dessicants with the highest capital equipment cost. Another drawback is the inability to handle extremely high moisture loads in hot, humid climates. The corallary is the inability to control sensible temperature; however, these units can deliver driest air, thereby pleasing Lone Star Gas.

HISTORY

Since the mid 1980's, enhanced mechanical dehumidification has been utilized in specialized situations. Applications with unique humidity problems have been receptive to the customized approach of using sensible exchangers to bias the cooling coil from slightly to dramatically toward latent energy removal. The Parks Mall Shopping Center[4] , with a crawl space experiencing corrosion due to high humidity, removed 200 pounds per hour with 108 KW less electricity than conventional refrigeration systems. Supermarkets control store make-up air moisture by removing 200 pounds per hour of moisture from ambient air before entering the main air handler. These systems dry the outside air to 45° F dewpoint to reduce the latent load on open freezers. Initial savings of 20 tons or 22 KW are realized with better control during off-peak operations. Schools, surgical suites, breweries, swimming pools, and even solvent recovery are some of the applications that have benefitted from this concept.

Biased coils can be done with run-around coils, heat pipes or plate exchangers. Fundamentally, the effect is the same with any of the three systems; removing sensible heat prior to the cooling coil and reheating the air after the cooling coil. The benefit is more dehumidification with less tonnage. The exchangers can be sized to precool a few degrees, as with the heat pipe; to moderate effectiveness, as with the run-round coil; and counterflow heat pipe to high effectiveness, as with the plate exchanger.

Typical sensible efficiencies for each exchanger type are:

Wrap around heat pipe - up to 20%
Run-around glycol system - up to 55%
Counterflow heat pipe - up to 65%
Counterflow plate type - 50% to 80%

Proper equipment selection is important to the success of the project, because the precooling enthalpy is replaced as sensible reheat. If sensible regain is a factor, it should be carefully considered. Commercial HVAC projects benefit from this method with lower efficiencies, or with variable performance.

Exchangers can be arranged to regulate the sensible regain to a constant supply leaving temperature by bypassing the

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incoming air with dampers. This reduces the exchanger effectiveness, allowing the reheat to be constant over a wide range of ambient temperatures.

OBJECTIVES

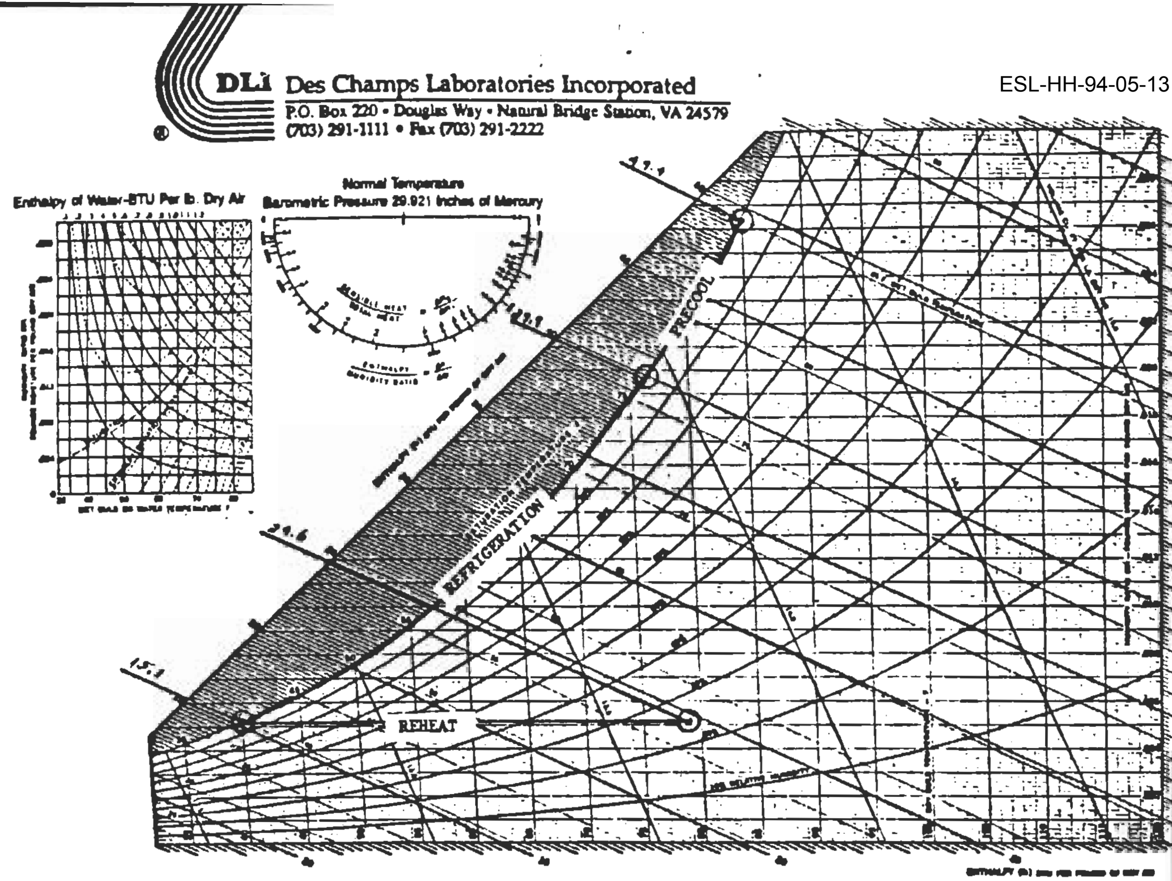
The food processor's objectives differ from commercial ventilation in two ways: (1) internal loads change radically in short periods of time and (2) ammonia systems operating below the freezing point are inefficient at moisture removal. An example of rapid moisture change occurs when a dock door is opened from a 50° F room to a warm, moist ambient. The moisture taken into the room seeks the coldest point to condense. If an ammonia cooler is operating and relatively free of ice, it can be easily removed. If the coil is laden with ice or in defrost, it can condense on a beam or the ceiling or any other cold surface. Wash down presents a different scenario, because the high moisture content of the air rapidly freezes the coil, reducing its capacity until it can be defrosted.

The task then becomes how to handle effectively both types of situations: the rapid influx of moisture and removing part of the washdown load to allow the ammonia system to operate more efficiently. Dehumidification should occur at high rates when the latent load is high, yet remove moisture at a constant rate under normal operation. Ideally, we should tie into the existing ammonia system, not adding additional maintenance or operational problems.

SELECTION

A plate type unit was deemed best suited for a number of reasons: heat exchange efficiency, orientation, pressure drop, cost and simplicity. An ammonia coil constructed of aluminum tubes and fins offered a close approach temperature at a reasonable cost. The blower selected was a backward inclined plenum fan, primarily because of its static efficiency, but also because of compatability with the enclosure. Finally, the box was constructed of galvanneal steel, insulated and lined for outdoor installation. Ducting to and from the space was preferred because of portability. A test air volume of 2000 CFM was selected to measure the results.

From the results of this test we hope to discover an accurate dehumidification rate per cubic foot of process area. The 2000 CFM unit is designed to remove 200 pounds per hour of water at washdown conditions of 85°F saturated and 10 pounds per hour at normal conditions of 50° F/80% RH.



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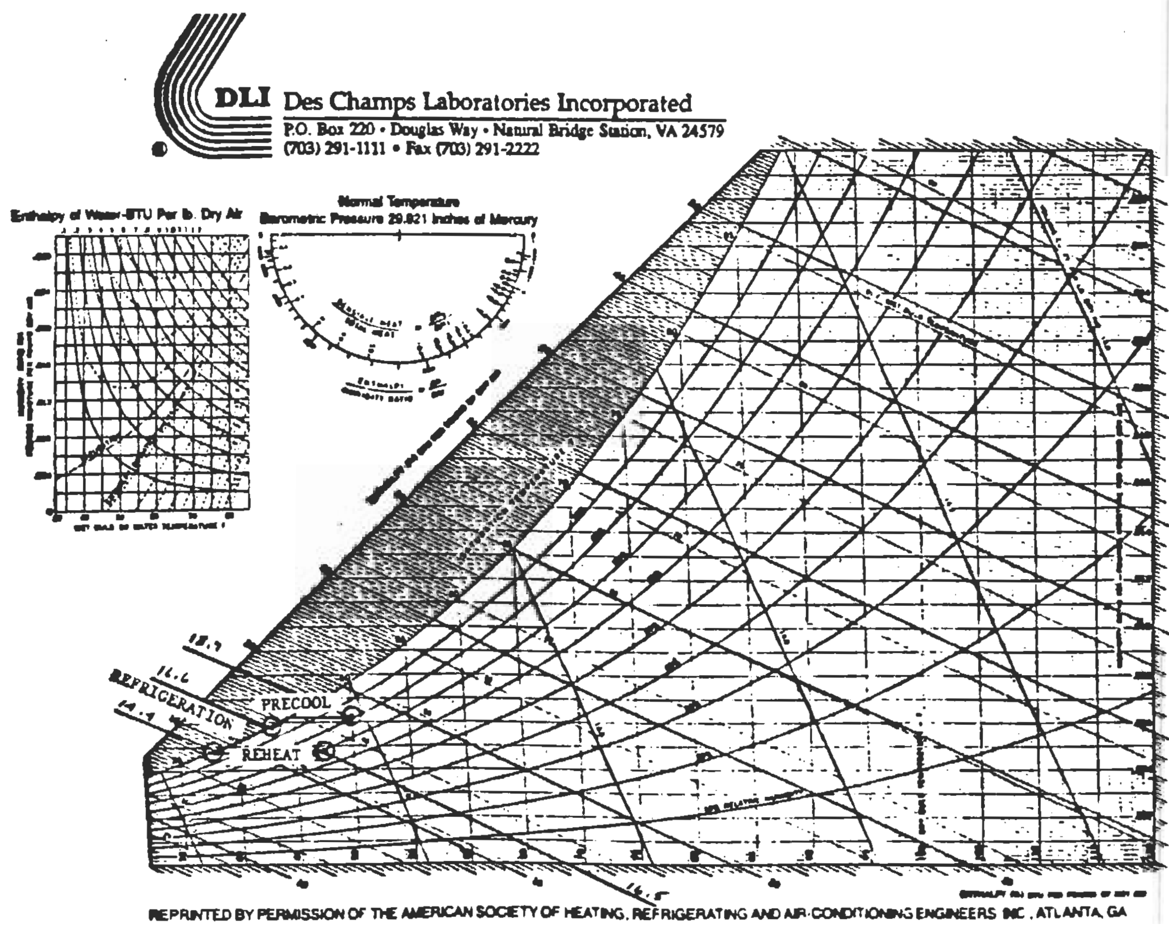

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CONCLUSION

We hope to demonstrate on a reduced scale the potential impact of mechanical dehumidification operating continuously and above freezing on a conventional food processing refrigeration system. The problems of fluctuating latent loads and the reduced efficiency caused by icing and defrost lend credence to the concept of dehumidification.

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