Humidity Control in Cold Stores Using Sorbtion Technologies

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Abstract

The article will discuss the design challenges faced by designers of cold stores and a possible effective solution by using sorbtion technology.

While designing cold stores, typical challenges faced are how to avoid frosting on evaporators, ice build up on conveyor belts, cold stores and floors due to ingress of moisture in air entering through opening of doors etc. One way to partially overcome some of these challenges is using the defrosting cycle.

However, the most practical solution to tackle challenges while maintaining efficiency of freezing equipment is to incorporate sorbtion based humidity control equipment in the system. Certain quantity of fresh air duly dehumidified is introduced near the loading dock to create positive pressure and to prevent ingress of moisture laden air while opening of the docking doors at times of loading. Also, based on moisture loads inside the cold store, generated thru products stored, a certain quality of air is dehumidified on a close loop basis. In case the cold store is designed with different temperature zones, varied qualities of dry air at appropriate dew points are pumped into these zones to ensure dry floors, no fogging in various areas and preventing/reduced defrosting cycles.

Cold Storage Systems

For the purposes of better understanding of providing proper humidity control in a cold storage, we can divide them into two categories

- Passive stores
- Active stores

Passive stores are built for storage of perishable goods for medium to long term period and are typically used for storage of fresh fruits and vegetables.

Active cold stores are refrigerated warehouses required for dynamic storage applications.

These warehouses have frequent movements of products on a daily basis. Also various temperature zones are created within the same warehouse for storing of different products requiring different temperatures.

While it is comparatively easier to design refrigeration systems for passive

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cold storages, many variables need to be taken into consideration for designing of active or dynamic cold stores.

1. Avoid/eliminate wet floors and ice build up on walls , floors and conveyors

2. Avoid ice build up on evaporator coils to reduce defrosting cycles and thereby improving on efficiency of refrigeration systems.

3. Eliminate frost build up near the loading docks for clear visibility to ensure accident free handling of cargo inside the warehouse

4. Prevent moisture absorption by cardboard cartoons as moist cartons soften and sag making them unstable and hazardous to workers as well as unmarkable. As we can see, all the above issues are basically related to control of humidity in the warehouse. In active/dynamic cold stores, the principal moisture load comes from door openings as product moves in and out of the warehouse, bringing in fresh air with much higher moisture content than that maintained inside the warehouse, leading to frosting in the loading dock area, icing on the doorways and evaporator coils. Please see *Figure 1*.

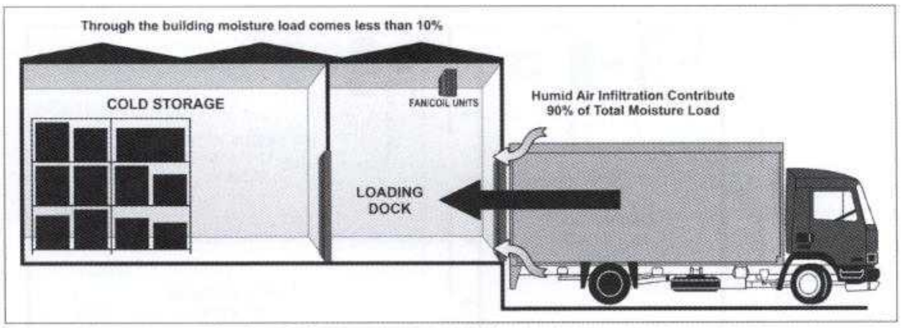


Figure 1: Door openings bring in high moisture content fresh air

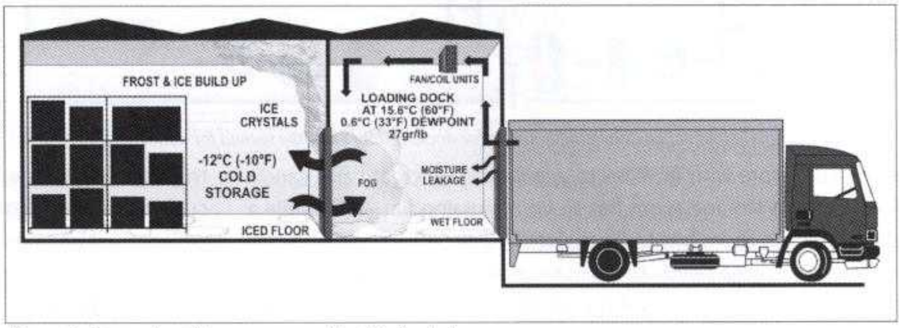


Figure 2: Fog and wet floors are caused by this fresh air

As we all are aware, when air is cooled it contracts, and in a cold store creating negative pressure leading to ingress of fresh air via the product/ conveyor apertures and opening of doorways in loading docks. No trailer door seal is 100% effective at preventing fresh air ingress into the loading dock during loading and unloading. Difference in air density and pressure between the ambient and frozen chamber and estimated time taken in opening and closing of doors are important inputs in estimating the moisture ingress into the storage area. Water vapour within the air is drawn up to the evaporators and forms ice on the coils. Over time this reduces plant efficiency and the evaporator must undergo a defrost to remove the ice. Each time a cooler defrosts, heat is dissipated into the store, which must be removed by the refrigeration plant. Reducing moisture ingress reduces the number of defrosts, which in turn reduces the cooling load on the refrigeration plant. The net result is an increase in efficiency and a reduction in energy usage.

In addition, as warm fresh air that enters the cold store comes into contact with walls, floors, ceilings and other surfaces, it forms ice. Slippery floors and falling ice pose a potential safety hazard for operators within the store. It can also cause fog and wet floors within the loading dock area. Please see *Figure 2*.

Removing moisture from the warm ambient air before it enters the cold store is key to preventing ice and frost formation on evaporators, wall, floors and ceilings.

Dehumidification using sorbtion technologies offers a simple solution to reducing moisture ingress through induction of dry air around loading docks creating positive air pressure thereby preventing moist air to enter the cold store.

Estimation of Moisture Loads

It is important to first establish temperature zones required in a warehouse depending on products to be stored. Typical storage conditions for various candies are given in *Table 1*.

For working out moisture loads, let us take an example of an

Table 1: Storage conditions for various candies

Candy	Moisture Content, %	Relative Humidity, %	Storage Temp. °F	Storage Life (Months)
Sweet Chocolate	0.36	40	48	6
Milk Chocolate	0.52	40	48	2
Lemon Drops	0.76	40	48	4
Chocolate-covered peanuts	0.91	40 to 45	48	4
Peanut brittle	1.58	40	48	1.5
Coated nut roll	5.16	45 to 50	48	3
Uncoated peanut roll	5.89	45 to 50	48	2
Nougat bar	6.14	50	48	3
Hard creams	6.56	50	48	6
Sugar bonbons	7.53	50	48	6
Coconut squares	7.70	50	48	3
Peanut butter taffy kisses	8.20	40	48	3
Chocolate-covered				
Creams	8.09	50	48	3
Soft	8.22	50	48	3
Plain caramels	9.04	50	48	6
Fudge	10.21	65	48	5
Gumdrops	15.11	65	48	6
Marshmallows	16.00	65	48	3

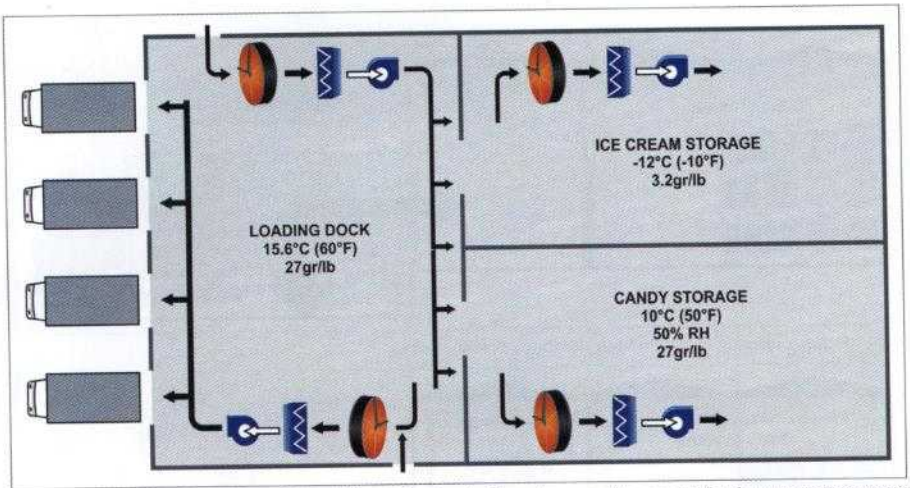


Figure 3: A typical layout of two dehumidifiers. One for docking doors and the second for doors to storage areas

active cold store with facilities to warehouse ice cream and candy. An ice cream storage room has to be maintained at -10°F while a candy storage room has to be maintained at 50°F. In addition, the loading dock area needs to be maintained at 60°F. Condensation and frosting will not occur if the air dew point is below the inside surface temperature of the walls, floors and equipment.

The lowest dew point in the warehouse is (-) 20°F on the evaporator coils for the ice cream storage room. To totally avoid a defrosting cycle, dew point in the room should be (-) 20°F. However, a more practical and economical solution is to maintain (-) 10°F dew point in the room with air supplied from the dehumidifier directly on to the evaporator coils.

In the candy area, to retain carton strength and also preserve product freshness, maximum relative humidity of 50% needs to be maintained (Please see *Table 1*). Dew point at 50°F and 50% RH is 33°F. Maintaining 33°F dew point will prevent softening of cartons and improve the operating efficiency of the refrigeration system by reducing coil frosting at part load conditions.

The loading dock area, which ideally, should be at 0°F dew point, because of the ice cream conveyor, however, typically it is more practical to maintain a dew point of 33°F (same as candy area) to avoid wet floors and fogging in the area while reducing the occurrence of icing on the conveyor.

An air distribution system has to be designed to put the driest air near the conveyor and the loadings doors.

Keeping the above design condition in view, we need to estimate moisture loads.

Loading Dock Area

Since the dock area is the most open to the weather, the load will be highest at this point.

There are various components of moisture load. Major components forming above 90% of total load comes from:

- opening of doors.
- ingress of fresh air.

At this stage, it is important to understand that proper handling of door activity can substantially reduce moisture load on this account and for an economical solution, it should be a focused area by the warehouse management. Taking a typical opening of only one minute for each time a truck docks, moisture load profile of loading dock area is as shown in *Figure 4*.

Moisture load thru ingress of fresh air can be minimized by inducting sufficient fresh air, duly dehumidified, in the loading docking area to keep dry air moving out of the building even when trucks are docked at all the doors. Ventilation air quantity, based on providing enough air to maintain a velocity of 50 FPM thru the cracks between the trucks and the loading dock gasket cushions, comes to about 1000 CFM. This is the fresh air load which must be taken into consideration while arriving at the size of dehumidifier(s) required to maintained desired conditions in the docking area.

As other elements of moisture load are very small, with the induction of 1000 CFM of fresh air for creating positive pressure in the docking area, total moisture load can be reduced to about 90 lbs/hr (630,000 grains/hr). To handle this load and maintain design condition of 60°F at 33°F dew point, a total of 9000 CFM of dehumidifier capacity is required as calculated below:

- Total internal moisture (latent) load = 630,000 grains/hr.
- Absolute humidity at design condition of 60°F & 33°F dew point = 27 grains/lb
- Absolute humidity of fresh air at 95°F DB, 60% RH = 150 grains/lb

a) Estimated air quantity of dehumidifier required to only offset internal latent load (no fresh air)

Required air quantity of dehumidifier =

$$\frac{14 \times 630{,}000}{60\,(27-5)} = 6681 \text{ CFM}$$

b) With the induction of 1000 CFM of fresh air at 150 grains/lb, let us assume dehumidified air quantity required is 9000 CFM.

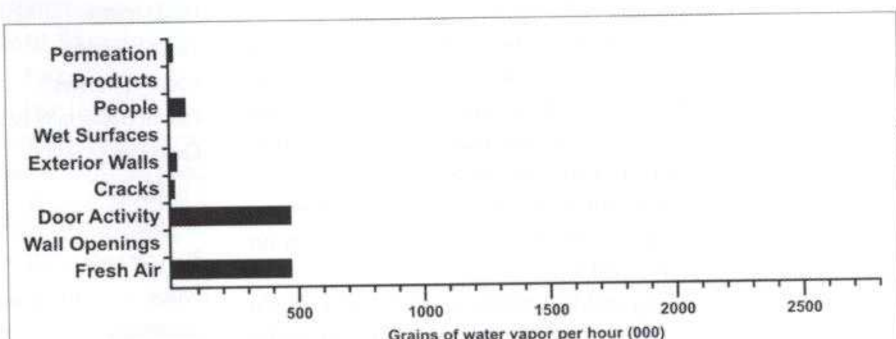
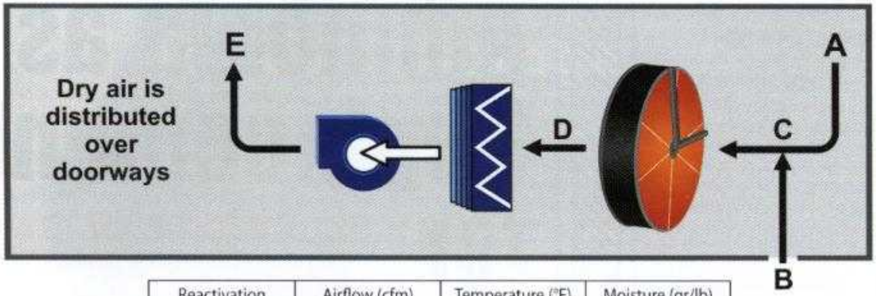


Figure 4: Moisture load profile in a loading dock area



Reactivation	Airflow (cfm)	Temperature (°F)	Moisture (gr/lb)
A	8000	60	27
B	1000	95	150
C	9000	64	40.6
D	9000	110	10
E	9000	60	10

Figure 5: System flow diagram and design conditions at various points

Therefore mixed conditions at the inlet of dehumidifier will be:

$$\text{temperature} = \frac{(8000 \times 60) + (1000 \times 95)}{9000} = 64°\text{F}$$

$$\text{moisture} = \frac{(8000 \times 27) + (1000 \times 150)}{9000} = 40.6 \text{ grains/lb}$$

$$\text{moisture removal} = \frac{60}{14} \times (27\text{-}10) \times 9000$$

$$= 655714 \text{ grains/lb}$$

As our estimated internal latent load is 630,000 grains/lb, dehumidifier of 9000 CFM capacity is sufficient to maintain the desired conditions. System flow diagram and design condition at various points in the flow diagram are shown in *Figure 5.*

Installation Options

There are two options in selecting dehumidifiers:

- Single unit of 9000 CFM with extensive duct work to supply dehumidified air in doorways to the storage areas and docking doors for the trucks.
- Two units of 4500 CFM each with simpler duct work, with one unit supplying dehumidified air on doorways to the storage areas and the second unit supplying dehumidified air on the docking doors for the trucks. This option has been shown in *Figure 3* above.

Summary & Conclusion

Major benefits realized thru humidity control in cold stores using sorbtion technologies are:

- Reduced occupational injuries due to avoidance of slipping and falling and pallet mover accidents due to wet/icy floor.
- Reduction in annual operational costs.
- Reduction in dock evaporator defrosts - summer defrost schedules can be set back to winter schedules.
- Independent temperature control.
- Attractive payback period.
- Improved sanitation in warehouse thru elimination of overhead condensation, snow, and ice.
- Labor cost reduction due to avoidance of chipping ice off floors, racks or products.

References

1. Lewis G. Harriman, *The Dehumidification Handbook.*
2. *ASHRAE handbook of Refrigeration 2006*, chapter 15 & 29.
3. Todd B. Jekel, University of Wisconsin *"Comparison of Dehumidification Alternatives in Cold Storage Warehouse Docks ASHRAE Winter 2001".*