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Cold Storage Facilities

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The continuing popularity of certain coverages, such stock throughput policies, and in particular penetration into new markets such as Latin America, has given rise to queries about certain exposures beyond the traditional cargo lines. Earlier this year, I was asked by ALSUM (Asociacion Latinoamericana de Suscriptores Maritimos) to conduct a webinar on risks and exposures found in refrigerated warehouses and the latter forms the basis for this paper.
The demand for food products drives the need to build logistical centres and warehouses for refrigerated or frozen food products, necessary for distribution to various points of consumption. It is estimated that cold storage warehouses are used to store approximately 200 billion dollars of refrigerated or frozen food products each year (Barhrns.com 2015). However, the use of cold storage warehouses is not limited to food products, as they are also used in the pharmaceutical, petrochemical and high-tech electronic industries.

The Building:

Cold storage buildings have been referred to as heated buildings turned inside out. In essence, traditional construction turned inside out, where the cold side becomes the warm side and the warm side becomes the cold. Instead of designing to keep heat in during cold weather, they are designed to keep it out (O'Brien 2009). Consequently, warmer air infiltration is one of the primary concerns in cold storage buildings. Although cold stores can be built using conventional building materials, such as bricks, cement or galvanized sheet metal, they require thermal insulation and a vapour barrier. It is estimated that 92 per cent (Aragues, Garcia 2007) of the panels normally used in these systems are polyurethane or polystyrene insulated panels (an organic polymer with foam like consistency and thermal characteristics), which are manufactured as sandwich panels. As this material is combustible, there is a fire risk in the event of fire reaching the nucleus of the panel.
Concerning the necessity of having a vapour barrier, it should be noted that the air inside the cold store is denser and less humid than air from the outside. The vapour barrier is tasked with preventing warmer air from the outside, which carries more humidity from shedding its moisture as it meets the cold surface of the building. Essentially, the vapour barrier prevents or retards the process of moisture passing through breathable building materials like drywall and insulation. Said moisture, which condenses at it cools down, will eventually freeze and turn into ice. Long term accumulation of ice can affect the thermal effectiveness of the panelling as well as weaken the structure of the building (FAO 2017).

Mechanical vapour- compression systems:

Although nearly 200 years old, the most commonly used method of cooling cold stores is through vapour-compression cycles. Any liquid, in order to pass to a gaseous state, needs to absorb heat from its surrounding environment. A refrigerant is any liquid that acts as a cooling agent thus removing heat from one area as it evaporates. For large cold storage facilities, ammonia remains the refrigerant of choice as it is known to have the highest refrigerating capacity/effect per pound of any other refrigerant, in spite of being toxic, explosive and flammable within certain conditions (Brighthubengineering.com 2017). It should be noted that the temperature at which a liquid evaporates depends on the pressure exerted on the liquid. Similarly, all vapour can again condense becoming liquid if properly compressed and cooled. The system includes several key pieces of hardware, a compressor, a condenser, a thermal expansion valve and an evaporator. The refrigerant is pushed through the system and undergoes state changes (from liquid to gas and back) and in doing so absorbs and removes heat from the space to be cooled, as it evaporates and subsequently rejects that heat elsewhere.

As noted above, ammonia is toxic and can be explosive and flammable in large concentrations. Due to its irritating odour, it is easily detected in cases of a leak or spill, giving staff an early warning to evacuate. Ammonia has a high affinity for moisture and is readily absorbed by many materials. As many food products contain water, they will become contaminated upon contact with ammonia. The level of contamination depends on the level of ammonia concentration in a gaseous state, the moisture level of the product, the length of time the product is exposed and the type of packaging. For instance, in sealed plastic bags, cardboard boxes or no packaging at all (IMUA 2007). In a study done by the University of Nebraska - Lincoln (Prajitna 2011), it was noted that frozen meat had a slower ammonia uptake rate which resulted in an ammonia concentration six times lower than the ammonia level in fresh meat samples after 12 hours exposure. The said study recorded that meat qualities affected by external ammonia contamination included colour, flavour, odour, water holding capacity and tenderness. Any leak or spill can injure or kill employees and easily damage millions of dollars in product in storage. For example, in March 2015, it was reported that an ammonia spill in the engine room of a KLM catering building resulted in the evacuation of three hundred employees with four having to be checked by medical staff. As a precaution, all prepared meals had to be destroyed due to health risks, affecting both European and intercontinental flights (Flyertalk 2015).

Airflow and air distribution:

Despite having a properly sized refrigeration system, it becomes inefficient if it is unable to deliver air to areas that need it. Consequently, airflow and air distribution are important factors to take into account, as is the case when stowing cargo in reefer containers, one needs to consider the fact that air follows the path of least resistance. Consequently, loading patterns in particular, as well as fan capacity, should be carefully calculated to ensure that there is uniform distribution throughout the cold chamber. With respect to air cooler design in refrigerated warehouses, this paper will refer to three basic designs, as discussed by Jackmann (2008).

The first is the ceiling air cooler with horizontal air flow. This is an economical design, popular in smaller warehouses. The design requires high-speed fans with high driving force. The air throw from the fans needs to be at least the length of the room to provide adequate coverage of the product. For larger warehouses, it has obvious limitations. It also does not allow for intrusive girders or lighting fixtures in the ceiling area. The second design is that of air coolers with air ducts. The benefit of this system is that it provides good air distribution because the ducts guide the air exactly where it is most needed.

However, the distribution ducts occupy room within the refrigerated space, which could be used for pallets, as well as carry higher investment costs. The third type is an air cooler without air ducts but one where air circulation is supported by thermal activity. In contrast with the other types, air enters from above and comes out below. This design distributes air to the space via a cold air lake. Air circulates by natural convection. As walls and product heat up the cold air, the warmer air rises to the top of the room and flows in a small layer under the ceiling back to the cooler.

Warehouse configuration:

Modular Curtains:

In a cold storage environment, reconfiguring space is not as simple as in a conventional warehouse, as temperature is a factor that must be taken into account. Different products require different temperatures, leading to the warehouse requiring different temperature zones. Also, the mix of product may vary according to the season. Consequently, the use of modular curtains (flexible fabric curtains) that can be easily installed, dismantled and reinstalled provide more flexibility and adaptability than permanent solid walls.

Air curtains:

It is critical to conserve cold air. Every time a door is opened, an interchange with warmer air takes place, which increases the temperature of the cold zone. It is important to minimise the amount of warm air that penetrates into the cold zone. By forcing a continuous stream of air over the entrance, an air curtain can create a barrier across the doorway, creating a seal between two temperature zones, thus keeping the chilled air inside the cold store and the warm air out, effectively reducing the load on the refrigeration equipment and energy consumption (Prentice 2017). The air current moves at such a speed and angle that it is able to push back the warmer air that tries to penetrate the space. Curtain efficiency in preventing infiltration oscillates between 60 and 80 per cent. According to the ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers), an air curtain can be up to 80 per cent effective (Blue Giant 2017).

Rapid Closing Doors:

Slow doors allow warm air spikes to enter the cold storage facility. Consequently, many cold storage facilities use rapid closing doors. With speeds of up to 120” per second (Assa Abloy 2017), another way to enhance temperature control and minimise temperature variations is through use of high-speed/rapid roller doors.

Automated Storage and Retrieval Systems:

The use of automated storage and retrieval systems is an effective way to control warm air from entering the cold zone or expensive cooled air from escaping. This type of automation allows for the pallets to pass in and out through a small opening, which is then sealed once the products have passed through, effectively minimising the amount of warmer air that enters the temperature controlled area (Modern Material Handling 2012).

Fruit and vegetables/special consideration:

Small rooms are a good option for storage of fruits and vegetables. Once harvested, fruits and vegetables continue to generate chemical reactions that consume oxygen, generate heat, release carbon dioxide, water and ethylene. Certain fruits and vegetables are not compatible. One must take into account optimum temperature, relative humidity, ethylene production levels and tolerance, as well as odour. Ethylene-sensitive vegetables (such as arugula, lettuce, cauliflower, celery) should not be mixed with ethylene-producing fruits and vegetables (such as apples, kiwi fruit, peaches, avocados, tomatoes), as this can lead to ripening and decay, resulting in changes in colour, flavour and texture. Some of the odour transfers to be avoided include avocado odour that is absorbed by pineapple; green onion odour is absorbed by figs, grapes, mushroom, rhubarb and corn, and odours from apples and pears are absorbed by cabbage, carrots, celery, figs, onions and potatoes (Thompson, Brecht, Hinsch, Kader 2000).

Effects of the cold environment on equipment:

Constant exposure to the cold environment has a negative effect on batteries. In reference to fork lift trucks, the average life cycle of a battery can decline by 20 to 50 per cent. Consequently, an eight-hour cycle battery used in a conventional warehouse, will only last four to six hours in the cold environment. Therefore, cold storage facilities tend to use longer lasting batteries, such as 12-hour cycle ones. Considering the 25 per cent reduction, the battery will last for a full eight-hour shift. Similarly, handheld devices should be used built with seals designed to withstand temperature changes from the freezer to ambient conditions that can lead to condensation (Rogers, 2012). Special consideration must also be taken with product labels such as barcode labels and rack labels. In the cold environment, conventional adhesives harden and labels will detach, leading to unidentified product placed in the racks or the actual warehouse location being misidentified, thus affecting the entire traceability system.
It must also be taken into account that personnel working in the cold chamber are dressed for extreme cold. For instance, use of gloves makes it more difficult to operate electronic equipment. Consequently, the buttons on scanning devices designed for cold storage warehouses need to be big enough to be felt through gloves with touch screens being sensitive to respond to the gloved touch (Bahrns.com 2015). Unlike conventional commercial flooring, the flooring in cold chambers should be of the type able to withstand prolonged periods of low temperature without embrittlement. Cold environments pose challenges, whereby most repair materials become unworkable, there being a need to repair concrete in temperature above zero. This can lead to additional expenses when the product has to be temporarily relocated and stored elsewhere to allow for repair work (O’Brien, 2009).

Ice and condensation:
Sources:

When cooling goods, humidity in the air can lead to problems in the formation of ice and condensation. Some of the sources of humidity in the cold storage environment are as follows: points of entry into the cold chamber where doors or barriers are opened for too long or close too slowly. Inappropriately sealed doors or openings in the outer structure. Merchandise stored within the facility, particularly when packed with hydroscopic material (paper, cartons and wooden pallets), capable of absorbing and releasing moisture from the surrounding air. Personnel and equipment working within the facility. The level of humidity in loading areas where goods are in transition (Cotes 2014).

Problems in the cold store facility caused by unwanted ice and condensation:

Melting ice or pooled condensation can damage the packaging of goods in the storage facility and may lead to growth of mould and bacteria. Humidity can condense on the strip curtains through which people/vehicles move product, which can lead to contamination of product entering or exiting the cold storage. Ice formation can lead to slippery floors. resulting in accidents and injury. Ice can also form on the barcodes of products, packaging and pallets, which can lead to falling labels or difficulties in scanning product. Ice prevents doors from closing properly. When levels of humidity are high in the cold working environment, personnel experience a colder working environment, which feels colder and more uncomfortable than being in an environment with the same temperature but with low humidity. (Cotes 2014).
Once ice has formed, it needs to be removed and condensation needs to be dried up before it freezes to ice. This in turn leads to non-productive use of manpower, as well as additional energy consumption for defrosting of fixtures, fittings and refrigeration equipment. Evaporators will work inefficiently when they are iced up, leading to additional energy consumption.
In summary, ice formation and condensation are inevitable in a cold store setting, but the problem can be mitigated. Cotes (2014) refer to two fundamental approaches when it comes to dealing with the formation of ice and condensation. Once it has formed, one must deal with the problem via de-icing and defrosting. The second approach is to prevent ice and condensation from actually forming through humidity management. This is done by preventing the actual entry of moisture into the refrigerated/frozen storage area or through use of dehumidifiers, aiming to bring humidity under control and prevent the formation of ice and condensation, thus establishing conditions where these cannot arise. Furthermore, as previously noted in this article, the use of automated storage and retrieval systems (AS/RS) is an effective way in reducing the amount of warm air that enters the temperature controlled area. Despite having a higher investment cost, one additional advantage of automated storage and retrieval systems is that they allow for use of high-rise facilities (deep and tall designs) that permit storing of high volumes thus maximising the cube of the facility and in turn minimising a facility's foot print (per square foot). (Modern Material Handling 2012)

Basic necessities:

A cold storage facility must have continuous and reliable electric power supply, allowing the generator to maintain critical temperatures within the facility. There must be continuous monitoring of temperature and humidity levels through use of automated alarm systems capable of detecting if the temperature or humidity falls outside the acceptable parameters. There must also be gas detection alarms that will be activated if there is an ammonia leak, as well as fire sprinkler systems specifically designed for cold storage facilities.

The emergency plan should address items such as an alternative source of power supply, repair facilities, independent contractors, availability of temporary cold storage sites, which can include staging empty reefer containers and/or trailers to move product to other facilities (IMUA 2007). With respect to ammonia leaks, evacuation routes must be planned and designated employees tasked with assuring proper evacuation and contacting emergency response personnel (Brogan 2017).

In summary, the field of refrigeration and cold storage is both interesting and challenging. It is one that has become interconnected to traditional marine cargo lines of business and therefore worthy of review and study by marine insurance practitioners.

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