UNDERSTANDING CONDUCTION CASE COOLING

Discover how conduction-cooling applications can improve product integrity, food storage and display.

BY BILL KATZ

All images courtesy of Hill PHOENIX.

An alternative approach to supermarket display-case cooling uses conduction heat transfer instead of convection cooling used in most other types of cases.

Traditional supermarket refrigerated display cases rely on a process called convection heat transfer to keep the products cold. Convection works by circulating cooled air through the case. As the cooled air flows over the product, the difference in temperature between it and the product causes heat to move from the product to the air.

Most convection-cooled display cases accomplish this heat transfer in one of two ways. The first, and most common way, uses fans to drive the circulated air—this method is called forced convection. The second approach relies on the natural tendency of cold air to sink and warm air to rise. A particular type of evaporator called a gravity coil is mounted at the top of the case instead of at the bottom as is typically used in forced-air cases. This latter approach is referred to as natural convection. Either way, the process is the same: cooled air flowing over the product to maintain the desired temperature.

Even though convection heat transfer has been used to refrigerate perishable products for decades and remains the most widespread method used throughout the industry, forcing air over unpackaged products has certain significant drawbacks.

Air, it turns out, is not necessarily a good conductor of heat. In fact, dry air is actually a very good insulator. That might seem surprising since air circulation is widely used in so many different approaches to heating and cooling. But, to take just one example common to many homes, the air between the two panes of glass in a thermal-pane window provides the insulating capability of the window. Without the air between them, the two panes of the window would be hardly any more effective than its single-pane counterpart. Fiberglass insulation in the walls of the home also works in a similar way to trap dry air and retain heat.

On display

So the natural thing to wonder at this point is that if air is such a good insulator, why is it the standard cooling medium in refrigerated display cases?

The answer is that air is available everywhere; it is free, is extremely easy to use, and does not require any special preparation or handling. For most display cases, fans are all that are needed to move the air. And on those cases that use natural-circulation gravity coils, fans are not even used since the air moves by itself. Finally, even though air is not a good

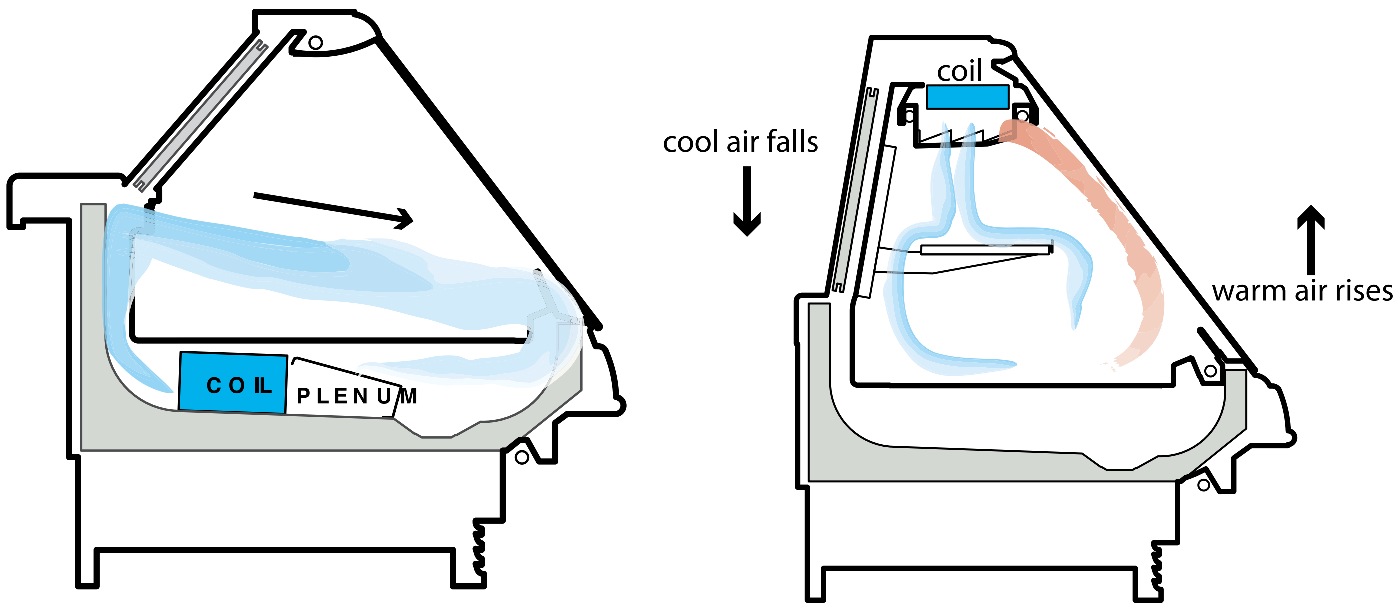

Figure 1 **These images illustrate how air is moved through a display case using forced-air circulation (left) and natural circulation (right) to keep perishables cold.**

conductor of heat, it still does to some extent conduct heat. So, its availability, ease of use and low cost far outweigh its modest heat-conducting properties.

Given its heat-conducting characteristics, using air as a cooling medium requires certain compromises. The effectiveness of convection cooling depends on how cold the air is and how much of it flows over the product. To increase the cooling, the air either can be made colder or the air-flow rate can be increased.

As an example, a typical forced-air circulation case may use air at approximately 28°F to cool fresh meat. But in order to maintain the product at that temperature, a lot of air has to flow over it. The more air that flows over the product, the more surface evaporation of the product occurs. Evaporated moisture from the product is carried as water vapor to the coil where it freezes and forms frost. Moisture that helped to maintain freshness and case humidity becomes frozen on the coil. During the case-defrost cycle, the frost melts and drips to the bottom of the case and down the drain. When a product, such as fresh meat, is sold by the pound the loss of water weight means a lower selling price. Further compounding the situation, high flow rates of air also have the unwanted side effect of cooling the surfaces of the case leading to condensation, or sweat, problems.

The question for the retailer then is how best to cool the product while preserving freshness, maintaining sales weight and wasting as little energy as possible. Until the advent of certain developments, the industry has been unable to adequately answer that question using convec-

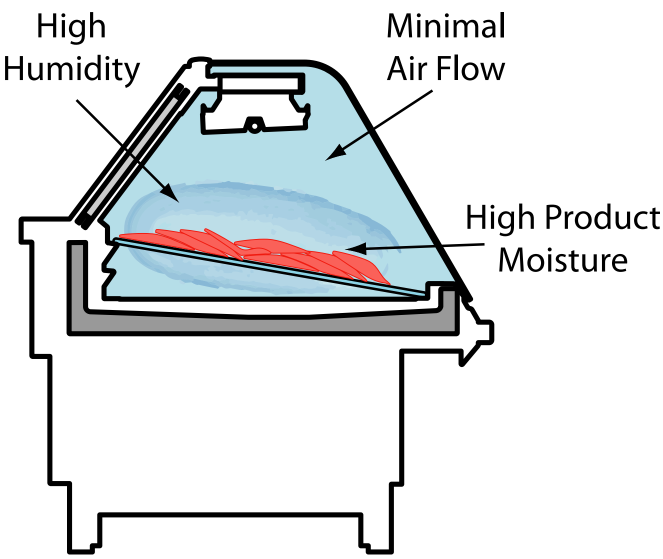

Figure 2 **Conduction cooling accomplishes heat transfer through direct physical contact of two objects or surfaces at different temperatures. Since air flow is minimal, humidity levels can be maintained without the introduction of moisture through misters.**

tion heat transfer. These limitations of forced-air cooling have therefore led to another approach.

Alternative cooling

Along with convection, there are two other ways heat can be transferred: radiation and conduction. The heat given off by an incandescent light bulb is an example of the former. The latter method is the basis for a relatively recent approach to display-case cooling.

Conduction is heat transfer through the direct physical contact of two objects (or surfaces) at different temperatures. When two objects are in contact, heat flows from the warmer surface of one to the cooler surface of the other until both reach the same temperature, or equilibrium. In a display case using conduction, the bottom of the display area is made up of a special type of deck pan through which a chilled fluid flows that cools it to a desired temperature. In this way the deck pans serve as a fully flooded heat-transfer surface, providing 100% cooling efficiency. When product is placed on the deck pans, the product is cooled to the desired temperature by its contact with the deck pans. And since there is no air flowing over the product to cool it, there is very little moisture lost from evaporation.

Another innovation in this approach involves more than just a cold surface. The temperature of the deck pans is not kept constant. Instead, the flow of coolant through them is constantly cycled between a low setpoint of 29°F and a high setpoint of 33°F. This temperature cycling is accomplished through a control system that actuates a solenoid valve to start and stop the coolant flow. When the temperature at the deck pans reaches 33°F, the valve opens allowing coolant to flow through the deck pans. When the temperature reaches a low of 29°F, the valve closes stopping the coolant flow.

The operation of the system in this way is referred to as pulse-flow control since the coolant flow is continuously cycling between either fully on or fully off. It is a simple and effective way of controlling the temperature of the deck pans. But its real benefit comes from the effect it has on tiny amounts of moisture in the air surrounding the deck pans that freezes and thaws as the deck pans cycle. This constant freezing and thawing of minute amounts of moisture creates a high-humidity area immediately surrounding the deck pan and any product sitting on it.

The conduction-cooling design also makes use of a heat exchanger at the top of the case to maintain air temperature. The difference between this heat exchanger and a traditional gravity coil is that it uses pulse-flow-controlled coolant just like the deck pans. Therefore, the same humidity effect surrounding the deck pans occurs around the heat exchanger to keep case humidity high.

With traditional convection-type cases, the only way to reduce the loss of moisture is by use of misting systems. But

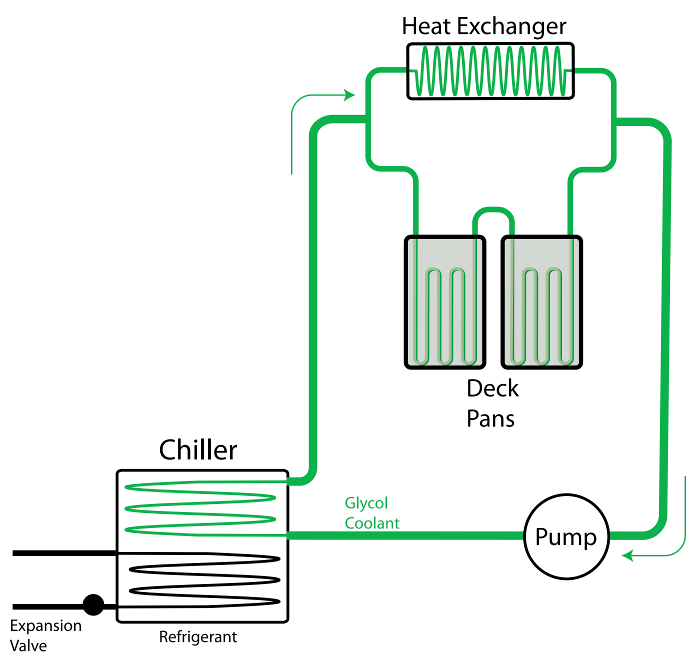

Figure 3 **This image shows how glycol coolant gets circulated through piping in the display case, to the deck pans and back to the chiller.**

with the ability of conduction cooling to maintain high levels of humidity, product quality is greatly prolonged and enhanced without having to resort to adding moisture. High moisture levels keep the product fresher longer and reduce shrinking. The potential for bacteria growth that misting systems are subject to also is greatly reduced. This also is the case with conventional seafood displays that rely on ice to help maintain product freshness. With conduction cooling, ice is not needed. In fact, use of it is actually counterproductive in these cases since it interferes with the pulse-flow control strategy. Artificial ice, however, is available for merchants who feel that customers associate ice with freshness.

By eliminating the use of ice, seafood departments can reduce their labor costs and streamline their merchandising procedures. Additionally, product can be kept in the case overnight due to the continuous cooling provided by the system, resulting in further labor savings for merchandisers. Unlike those in traditional convection-type cases, displays do not have to be moved to a cooler every night. In fact, many retailers will keep product up to three days in conduction cases.

Moist and even cooling are hallmarks of the conduction approach to refrigerated display-case design. Conduction cooling is an efficient way to cool merchandise. Nearly every Btu of cooling that flows through a conduction-cooling deck-pan goes to cool the product in contact with it. Very little of it is wasted cooling the surrounding surfaces.

An example of a conduction-cooling display case.

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