Downsides of Refrigeration

Defrost Cycle

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This article is the eighth in a series exploring refrigeration and heat pump concepts without using jargon. We start to look at some of the unsavory things that creep into refrigeration plants. The first of these is the defrost cycle.

Any air-cooling equipment that runs at a temperature below 32°F (0°C) will tend to form ice on the heat exchange surfaces, even if the air itself is above freezing. The physical science behind frost building is extremely complicated, but the result is very simple: a ball of ice that fails to deliver the required cooling effect. Building ice to this extent can cause structural damage if the steel was not designed to cope with the excess weight—the ice can weigh as much as the cooler. It can also create health and safety hazards in the store including slippery floors and chunks of falling ice.

When to defrost is a classic optimization problem. Defrosting puts heat into the cold store, and as always in these situations you pay for it twice; once to put it in, and once to take it back out again. Running the plant with too much frost on the coils is also inefficient. It widens the temperature difference (rolls the piano further down the hill than necessary [*ASHRAE Journal* March 2012]) and increases the temperature lift. So the right time to defrost is not too soon after the last one, but before the system performance falls off a cliff.

The simplest defrost is using ambient air—either the air in the room, or in some tropical climates, ducting air from outdoors into a closed chamber. This is almost free. You are only paying for the fan power to blow the air through the coil, and the electricity required to bring the metalwork back down to operating temperature when refrigeration restarts. The latter cost may be substantial, depending on the structure of the air cooler, and it is well-nigh impossible to avoid, since the frost has to be melted, and the melt water then has to run off the metal surfaces and down the drain.

Dr. Zhivago would have liked a few more defrosts.

Another simple defrost system is the use of electric heater elements built into the air cooler. This is generally very effective and easy, but it requires a hefty electrical supply and might cause extensive damage if a heater element fails. In larger systems so-called "hot gas defrost" is often preferred to electric elements. This is a bit of a misnomer because the temperature of the gas at inlet to the coil is not important and it does not need to be hot. The important thing is that the pressure is high enough to make the gas condense at a temperature higher than the freezing point of water. It is the latent heat that transfers to the surroundings when the gas condenses (exactly the same as when the gas is reliquefied in the condenser) that heats up the frost and melts it. This can be done very effectively at a condensing temperature of 50°F (10°C), which is colder than the minimum condensing condition for most systems.

There are many ways in which a poorly maintained defrost system can kill the efficiency of the system. Defrosting too often is every bit as bad as not defrosting enough. Forcing the compressor discharge pressure up during defrost (perhaps to make sure that the gas really is "hot") wastes compressor power for the whole system and overheats the metalwork in the air cooler, increasing the cooling required to restart the system.

Gas that passes through the air cooler without condensing (perhaps because the flow control is based only on pressure) can put a false load on the compressors. Even worse, gas that leaks through the control valve when the air cooler is not being defrosted (perhaps when one of the other units is on defrost) puts a huge load on the compressors and can increase the energy used by the system by more than 10% without giving any obvious symptom.

This type of internal leakage can be detected by looking for signs of gas flow at the control valves when coolers are not supposed to be defrosting. Typical signs include higher temperatures in the pipes leading to the valve, lack of frost on the valve and the sound of gas whistling through the valve. Apart from the damage this does to the electricity bill, it can also erode the valve, and in severe cases it can lead to liquid hammer and condensate-induced shock which can cause major plant failure. Defrost efficiency is also affected by convention currents through the air cooler, which can be reduced by fitting fans socks or hoods.

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