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CASE STUDY

Using CO₂ for Cold Distribution at a Loblaw Supermarket





SUMMARY

For a number of years, Loblaws Inc. has been investing in innovative refrigeration technologies. In 2008, relying on its past success, the multinational company opened in Scarborough (ON) the first Canadian supermarket to use carbon dioxide (CO_2) as a heat transfer fluid for frozen food display cases. Since the opening of the store, a set of operating data has been recorded and analysed. The analysis results confirmed that the CO_2 secondary loop refrigeration system installed at the Scarborough supermarket was a favourable alternative to conventional, direct-expansion (DX) systems found in most Canadian supermarkets.

The Scarborough supermarket greenhouse gas (GHG) emissions are 2,700 t CO_2 eq. lower than those of a conventional Canadian supermarket of the same size. This is attributable to the use of secondary loop refrigeration systems and to the implementation of several energy efficiency measures related to the design and operation of the refrigeration unit. Among others, the energy efficiency measures included: mechanical subcooling, floating head pressure, heat recovery and integration with the building's heating, ventilation and air-conditioning (HVAC) system.

BACKGROUND

REFRIGERATION IN SUPERMARKETS, A SIGNIFICANT SOURCE OF GHGs

Supermarket operations result in significant GHG emissions. The two important GHG emission sources are synthetic refrigerant leaks and energy consumption. Most supermarket refrigeration systems in Canada are DX systems. They employ between 1,000 to 1,500 kg of synthetic refrigerant (HCFCs or HFCs). This refrigerant circulates under pressure from the mechanical room to the refrigerated display cases through kilometers of piping with hundreds of brazed joints. An estimated 10 to 30% of this refrigerant charge leaks into the atmosphere annually. Synthetic refrigerants are powerful GHGs – 1,500 to 4,000 times more potent than an equivalent mass of CO₂.

SECONDARY LOOP SYSTEMS AS AN ALTERNATIVE TO DX SYSTEMS

Secondary loop systems allow a significant reduction in synthetic refrigerant charges in comparison to conventional DX systems. Hence, secondary loop systems offer a very promising alternative for the reduction of GHG emissions. Within the last 10 years, secondary loops using propylene glycol have gained acceptance in supermarket refrigeration systems intended to keep meat, dairy and other food products cool. Such secondary loop systems are now present in approximately 10% of Loblaw's corporate stores. They are usually employed not only for the benefits of refrigerant charge reduction, but also for enhanced product quality and decreased system maintenance.

The use of secondary loop systems for frozen products has, however, been hindered by the lack of a suitable heat transfer fluid. Heat transfer fluids at -28°C (-19°F) are either very viscous or very expensive and corrosive. Since the year 2000, dozens of low temperature systems using brine solutions as secondary fluids have been installed. These solutions have good heat transfer properties but result in premature aging of the surrounding materials, and consequently in an increase of maintenance costs. CO₂ appears to be an excellent heat transfer fluid for secondary loops for frozen products. CO₂ is not viscous, nor expensive, has better heat transfer properties when compared to brines, without being corrosive.

STATUS OF CO₂ AS A SECONDARY COOLANT

CO₂ is increasingly popular in supermarket refrigeration in Europe, especially in Germany and the Scandinavian countries, which have acquired extensive experience with more than 100 secondary loop installations. Loblaw decided in 2008 to continue to innovate by installing a CO₂ secondary loop refrigeration system for frozen products in their new Scarborough Superstore in Ontario.

DESCRIPTION OF THE LOBLAW SUPERSTORE AND ITS REFRIGERATION SYSTEM

DESCRIPTION OF THE SUPERSTORE

The Scarborough Superstore operates under the Loblaw banner. The 13,935 m² (150,000 ft²) building was designed to the LEED silver standard. The sales area is occupied by both food products and non-food products such as electronics, housewares, clothing, photo finishing and pharmaceuticals.

DESCRIPTION OF THE REFRIGERATION SYSTEM

The refrigeration system installed at the Scarborough Superstore consists of a low temperature (LT) compressor rack with a nominal capacity of 46 tons of refrigeration (162 kW), two medium temperature (MT) compressor racks of 67 tons (235 kW) each, and a subcooler rack of 22 tons (77 kW). Cold is distributed to the LT frozen product display cases at around -28°C (-19°F) by a CO₂ secondary loop, and to the MT refrigerated product display cases at around -7°C (20°F) by a propylene glycol secondary loop. All compressor racks use the synthetic refrigerant R-507A. The refrigerant charge, confined to the mechanical room, is only 350 kg. A conventional DX system would typically use between six to eight times this amount. This low refrigerant charge, combined with the low global warming potential of CO₂, results in a significant reduction in the supermarket's GHG emissions.

Several energy efficiency measures related to the design and operation of the refrigeration system were implemented in order to reduce the energy consumption of the store and its GHG emissions. They include mechanical subcooling, floating head pressure, the

integration of the refrigeration system with the building HVAC system, and the recovery of compressor superheat.

CO₂ SECONDARY LOOP

The CO₂ secondary loop constitutes the most innovative aspect of the project. At the time of system commissioning, it was the first commercial installation of this kind in Canada and the largest one in North America. CO₂ in the liquid state is pumped to the frozen display cases where it partially evaporates, and is condensed by the LT compressor rack in the mechanical room. The many advantages of CO₂ compared to the single-phase salt (brine) based fluids include 10 times lower pumping power (because of the phase change), smaller pipe sizes, excellent heat transfer properties and good material compatibility, with the additional benefit of the low cost of the fluid.

The shortcoming of secondary loop systems resides in the addition of a heat exchanger between the refrigerant in the mechanical room and the secondary fluid that is pumped to the display cases. Because of this additional heat exchanger, the refrigeration system evaporating temperature must normally be lowered, resulting in a decrease in the refrigeration system capacity and efficiency. However, the exceptional heat transfer properties of CO₂ allow the LT refrigeration system to operate at the same or a higher evaporating temperature than a DX system.

HEAT RECOVERY CONDENSERS



CO₂ STORAGE AND PUMPING SYSTEM



MECHANICAL SUBCOOLING

At the Scarborough Superstore, mechanical subcooling aims at improving the energy efficiency of the frozen products refrigeration cycle. To achieve this, a compressor rack specifically dedicated to subcooling, has the capacity to reduce the temperature of the LT liquid refrigerant line by 45°C. This is equivalent to transferring 45% of the LT refrigeration charge to the subcooler rack, which is twice as energy efficient.

INTEGRATION OF THE REFRIGERATION SYSTEM WITH THE HVAC SYSTEM

In addition to using secondary loops for cold distribution, an independent secondary loop circulating warm ethylene glycol is used to recover the heat rejected by the MT and LT compressor racks. This heat is then directed to the heat recovery coil inside the rooftop air handling unit and to three indoor air

heating units located in the backstore. The 300 kW heat recovery coil of the rooftop air handling unit heats the Superstore sales area. The three backstore air heating units each have a nominal capacity of 60 kW of heating. The refrigeration system surplus heat is rejected outside the supermarket by fluid coolers.

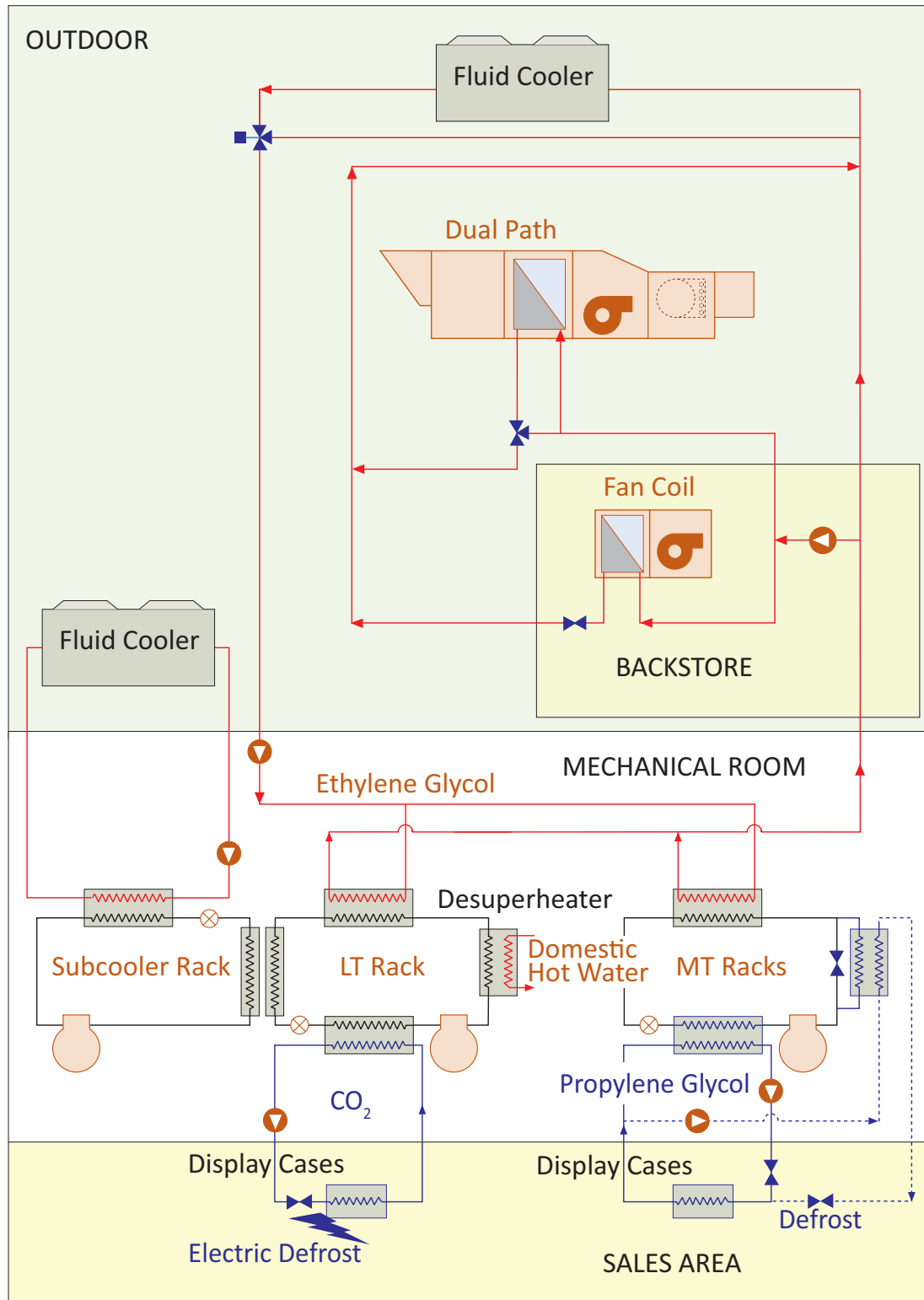
VARIABLE CONDENSING PRESSURE (FLOATING HEAD PRESSURE)

The refrigeration system condensing pressure modulates according to the building's heating requirements and the outdoor temperature, in order to take advantage of the Canadian climate.

RECOVERY OF SUPERHEAT

The heat contained in the compressor discharge of the LT compressor rack is recovered to meet domestic hot water needs.

SCARBOROUGH SUPERSTORE REFRIGERATION SYSTEM INTEGRATED WITH THE HVAC SYSTEM



BENEFITS

After an entire year of operation, the analysis of the Superstore refrigeration system operation data has confirmed the following:

- In terms of performance, the LT CO₂ secondary loop refrigeration system is a very interesting alternative to DX systems that are found in most Canadian supermarkets, with an average evaporation temperature of around -31.5°C;
- The subcooling unit allows for a 20% increase in the cold production efficiency for freezers;
- The heat recovery of the refrigeration system does not impose any measurable penalties on the cold production efficiency.

When compared to a typical Canadian* supermarket of equivalent surface area, the Superstore achieves:

- Energy savings (electricity and natural gas) of 23%, which is equivalent to 2,400 MW/h eq. per year;
- A 59% reduction in GHG emissions, which translates into 2,700 t CO₂ eq.
- Other benefits associated with the system installed include:
- Simpler and more reliable system, and consequently, reduced maintenance costs compared to LT systems using other secondary fluids;
- Greater quality of products.

* Supermarket equipped with a traditional, DX refrigeration system for medium and low temperature, without heat recovery.

TECHNICAL PARTNERS

Hill Phoenix, Refrigeration system and display cases manufacturer

Air Liquide Canada, CO₂ supplier

Micro-Thermo, Instrumentation and control

CanmetENERGY – Natural Resources Canada, Design support and performance analysis

FINANCIAL SUPPORT

TEAM Program (Technology Early Action Measures), under the leadership of Natural Resources Canada, Environment Canada and Industry Canada

Refrigeration Action Program for Buildings (PARB) – Natural Resources Canada

Office of Energy Efficiency (OEE) – Natural Resources Canada, for performance analysis and case study



CoolSolution brings together leading-edge refrigeration technologies and practices enabling the minimization of the energy consumption and carbon footprint of buildings like arenas, curlings, supermarkets and cold warehouses, along three axes:

**Heat recovery
Energy efficiency of refrigeration systems
Reduction of synthetic refrigerant charge**

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