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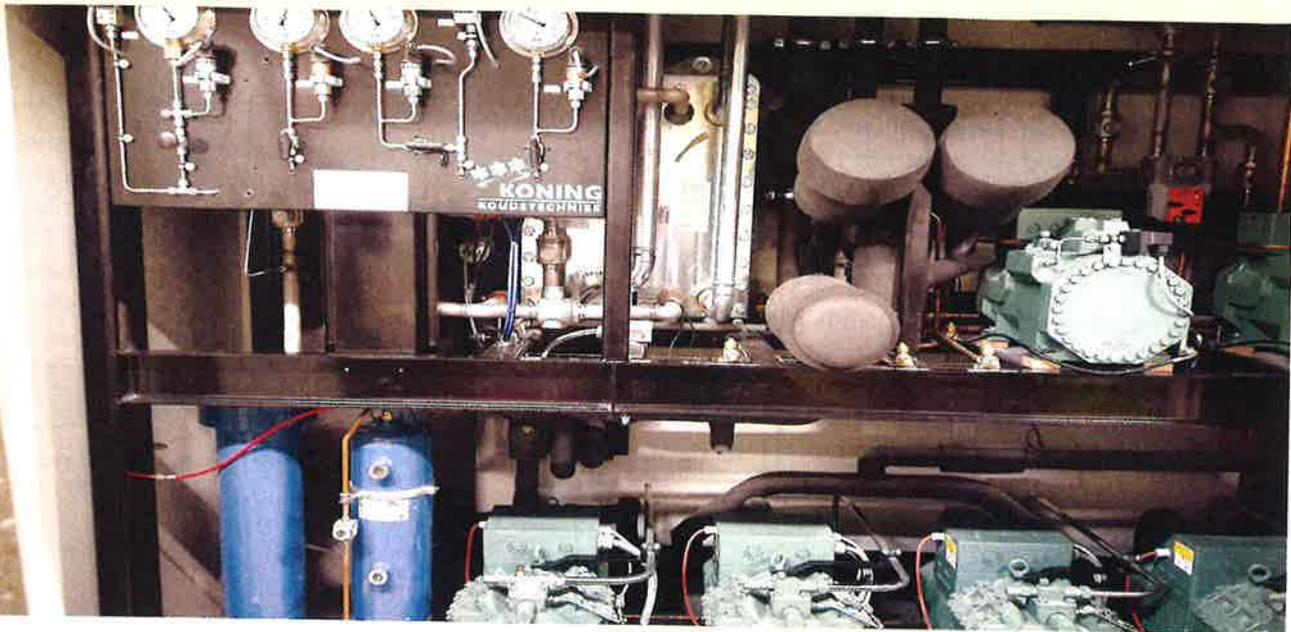
Safety in Ammonia Plants

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The plant at Plus Supermarket

CO₂ Booster with Heat Recovery System

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Introduction

Plus, a leading Dutch retailer with over 260 supermarkets in the Netherlands, has committed to installing adiabatic gas coolers in all new CO₂ transcritical systems. Since 2016, Plus has been

installing adiabatic gas coolers in all its new CO₂ transcritical-based supermarkets.

Now the Dutch retailer, in its latest CO₂ transcritical installation in Gorinchem, has moved from a standard spray system gas cooler to the latest generation of gas coolers. The coefficient of performance (COP) of the CO₂ transcritical system has increased by 30%, thanks to the use of second-generation of such coolers. It performed even on the hottest day of the year in Gorinchem (August 2018, outlet CO₂ gas cooler temperature was 32°C at ambient temperature 38°C).

What is unique about this gas cooler? It is important that the water system can drain all used water after each working cycle and during winter time (no legionella and freezing risk). The big advantage of the system is that no water treatment is required. The water can always be taken directly from the drinking water line.

The Gorinchem supermarket also employs heat recovery. The advanced heat-recovery system (which works with the CO₂ transcritical system) has a high and low temperature water circuit for heating the air curtains and floor heating system.

Principle Installation

The principle drawing of the installation is shown in Figure 3. A standard CO₂ booster system is used for the cabinets and the cold rooms; in this case 4 MT compressors, 2 LT compressors and a high pressure and flash-gas bypass regulation were used.



Figure 1 and 2: Plus Supermarket (Gorinchem, Netherlands)

CO₂ Booster with Heat Recovery System

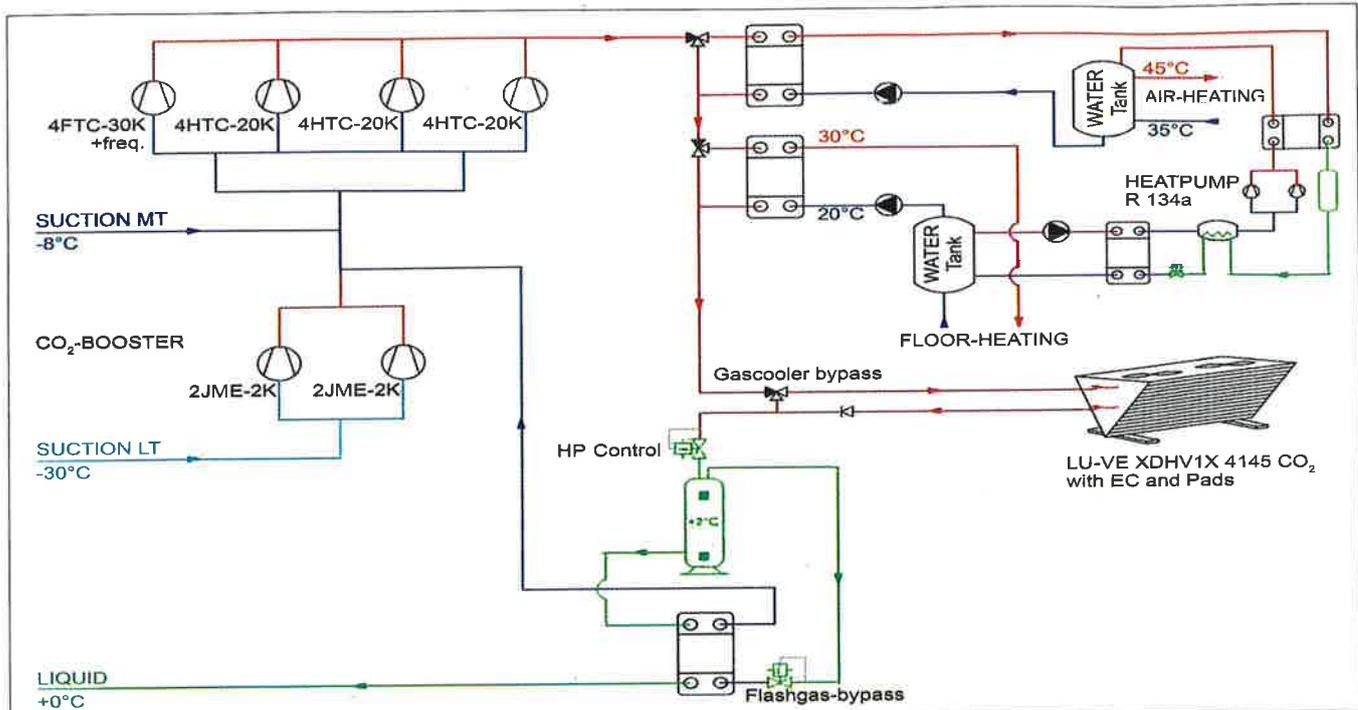


Figure 3: Principle drawing of the installation

During winter time the supermarket, warehouse and social rooms are completely heated with the heat recovery system, which is connected to the CO₂ booster system. No extra heating system is needed to keep the rooms and the supermarket at the right temperature during winter time. The heat-recovery system has a high and low temperature water circuit for heating the air-curtains and floor heating system. The working of the heat recovery system will be explained in the next section. A V-shape gas cooler (LU-VE model XDHV1X) with EC fans and adiabatic panels was used for this supermarket. This gives a better efficiency of the installation.



Figure 4: Gas cooler (with adiabatic panels and EC motors)

The Gas Cooler

Starting January 1, 2016 all new installed transcritical CO₂ systems in supermarkets from the Plus retail organization, have been equipped with an adiabatic humidification system on the gas cooler.

The First Generation

The first generation is based on a spray system with spray nozzles injecting spray water counter-flow to the air inlet.

When the spray system is used for maximum of 50 to 70 hours a year, the water can be taken directly from the drinking water line. In the Netherlands, this means that the water valve for the spray system opens at approx. 27°/28°C. When the spray system is used for more number of hours, there must be a water treatment system before the water goes to the spray system.

Water quality must accomplish the European Union 'Drinking Water Directive' 98/83/EC:

- pH: > 6.5 and < 8
- conductivity: < 800 µS/cm
- chlorides: < 100 mg/l
- hardness: > 4 and < 6°f

The Second Generation

The second generation is based on factory mounted panels that are irrigated by water through a simple water distribution system as a part of the gas cooler. It is important that the water system can drain all used water after each working cycle and during winter time (legionella and freezing risk). The big advantage of the system is that no water treatment is required. The water can always be taken directly from the drinking water line.

The second generation model is installed in the Plus supermarket in Gorichem. In this case, the water valve for the spray system opens at 28°C. The result on the warmest day

in the Netherlands (7 August 2018) is shown in Figure 5. The ambient temperature on that day was 38°C for several hours. Our measurements showed that the gas cooler pressure (Pgc) at that moment was approximately 80 bar. The gas cooler pressure of 80 bar corresponds to a CO₂ gas cooler outlet temperature of 32°C. With these conditions (suction pressure T_o = -8°C), this gives the MT a COP of 2.

With a comparable installation, in the same region, with a gas cooler without panels and without a spray system, on the same day the measured gas cooler pressure was 95 bar. This pressure of 95 bar corresponds to a CO₂ gas cooler outlet temperature of 38°C to 39°C; this gives a COP of 1.5. The COP has increased by 30% in these conditions, thanks to the panels.

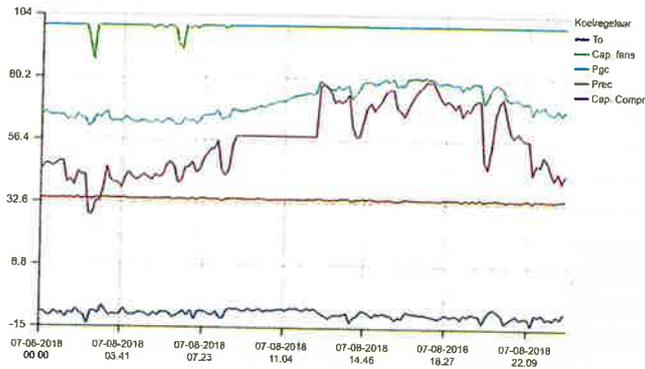


Figure 5: Measurements on the warmest day (August 7, 2018)

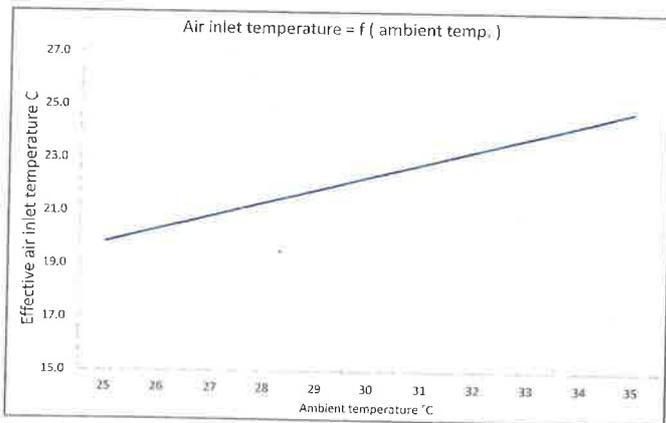


Figure 6: Ambient temperature/ air inlet temperature gas cooler

The Heat Recovery System

As already mentioned, an advanced heat recovery system has been adopted in this supermarket.

The heating for the supermarket during winter time consists mainly of a floor heating system and air curtains. They have their own high temperature water circuit as can be seen in Figure 3. The circuit of the water inlet temperature is regulated with a modulating 3-way valve. The inlet temperature depends on the room temperature in the supermarket. The heating system is supported with a heat pump system for longer cold periods.

The heat-recovery system has the following regulating steps.

CO₂ Booster at Maximum COP

The CO₂ booster (Figure 7) is regulated to a maximum COP. The CO₂ gas cooler outlet temperature is regulated 2K above the ambient temperature. The water inlet temperature for the air curtains and the floor heating system is regulated with a modulating 3-way valve depending on the room temperature in the supermarket.

Cold Ambient Temperatures

At longer cold ambient temperatures it is possible that the system is not sufficient to deliver enough heating capacity to keep the room temperature in the supermarket above 20°C. At that point the air heating system will be supported by a heat pump system. The heat pump withdraws the heat from the cold water return of the floor heating system. The floor heating system is provided with more heat by increasing the pressure of the CO₂ booster installation. The pressure of the CO₂ booster is increased by slowing down or turning off the fan motors of the gas cooler.

Extreme Circumstances

When the circumstances are extreme, it is possible that the heat pump system is also not sufficient to keep the room temperature in the supermarket above 20°C. So, in order to reach such goal, the choice was to bypass the gas cooler to avoid static capacity loss at the gas cooler. A modulating 3-way valve was installed in the high pressure line, before the gas cooler (see Figure 3). This solution provides the possibility to face future possible extreme temperatures, in summer and winter conditions.

Using an additional heat pump depends on the heat balance of the total supermarket. When using floor heating, it is possible to link a heat pump very effectively to the transcritical CO₂ system.



Figure 7: The CO₂ booster system

When only air heating is used, linking of the heat pump to the transcritical CO₂ system may be called an 'expensive post-heater', and instead a simple electrical heater (with enough power) in combination with pressurization of the CO₂ system would be sufficient.

A disadvantage of the heat pump is the use of HFCs with excessive price developments caused by the European quota system. So the use of low GWP refrigerants for the heat pump and the attention to leak-tightness is essential.