TEWI COMPARISON BETWEEN INTEGRATED WATERLOOP AND CASCADE SYSTEMS FOR SUPERMARKET

Biagio Lamanna, Manager dell'HVAC/R Knowledge Center
CAREL INDUSTRIES Spa Brugine (Padova)

Ana Margarida Pinho, Mechanical Engineer, RACE Refrigeration and Air Conditioning Engineering S. A., Matosinhos (Portugal)

This study is focused on an installation, adapted to a new store format in Portugal, with very particular characteristics that follows the actual market trend in the HVAC/R industry. The main need of the involved Retailer was to be adequate to EU legislation to control F-gases emissions, without compromising the quality of products and maintaining the high level of energy efficiency which characterize their installations.

Fig. 1. Continente's Bom Dia store in Perafita (in the outskirts of Oporto, Portugal)

The installer proposed a refrigeration system based on semi plug-in cabinets connected to a waterloop integrated with the air conditioning system.

The main reasons why adopting this kind of scheme were related to a streamlined and flexible layout of the shop, a reduction of the area usually required by technical equipment such as compressor racks, a reduced amount of refrigerant charge and a full recovery of the condenser heat rejected by the display cabinets to be integrated to the building heating system.

The refrigeration system was done with water condensing units equipped with DC inverter compressors, water brazed plate condensers and electronic expansion valves for providing a precise cabinet/cold room temperature regulation with the maximum allowed energy efficiency.

In fact, with respect of compressor rack based systems, semi plug-in cabinets with modulating compressor capacity and refrigerant flow have the capability to keep a constant air/product temperature within +/-0.1K range around the given setpoint without the typical intermittent start-stop behaviour of fixed capacity/flow solutions. Moreover, the independent semi plug-in cabinets and cold rooms are able to run with a continuous control on their evaporation temperature instead of being forced to run all at the same value imposed by being connected to a compressor rack. This provides the lowest compressor ratio achievable in real time (i.e. highest evaporation temperature) for each refrigerated unit with consequent higher efficiency without useless losses.

What above also implies better food and beverages quality due to the almost absence of temperature fluctuations (excluding defrosts of course)

The water loop extracts the heat rejected by the condensers of the refrigeration systems and is provided with both a dry cooler for free cooling operations and a reversible water chiller/heat pump. It is connected to the building air conditioning system and it is also provided with variable water flow control to guarantee system stability and optimized performance/cost ratio.

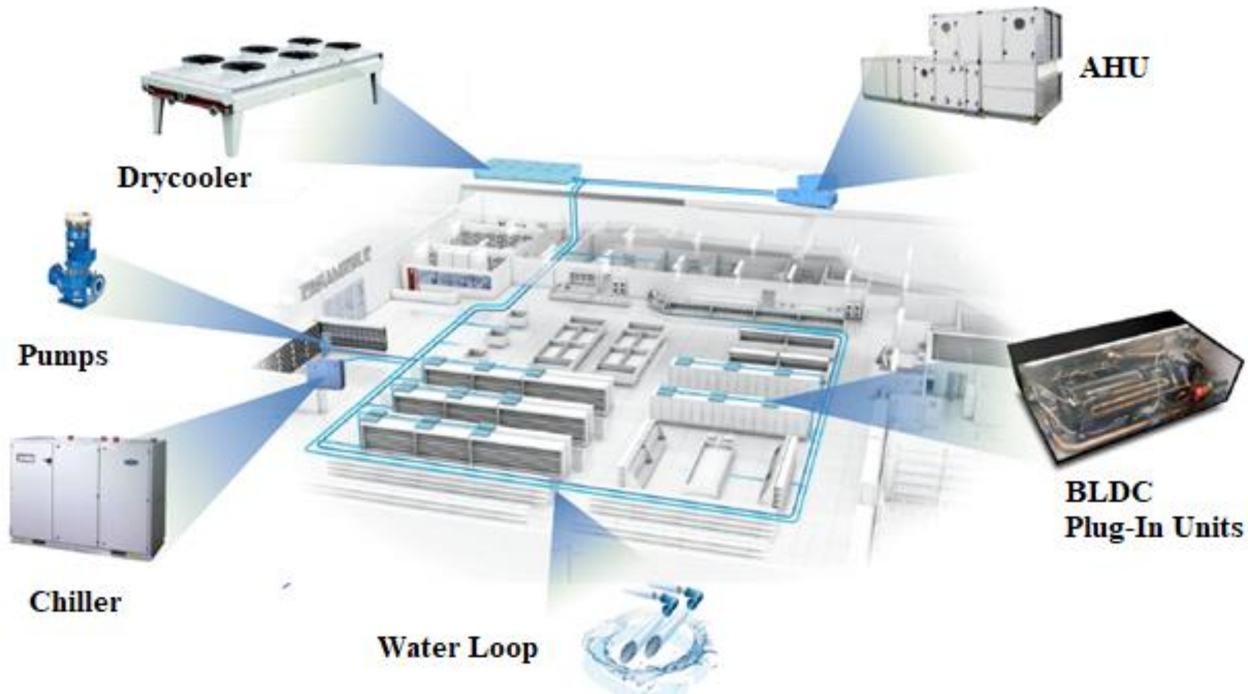

Fig. 2. Refrigeration and air conditioning plant scheme

STORE DESCRIPTION

The sales area of the store in Perafita is around 1.200 m^2 and is equipped with 24 refrigerated units divided as follows:

Type	Refrig. Capacity	Number	Unit
MT	52,4 kW	17	Cabinet
		5	Cold Room
LT	8,5 kW	1	Cabinet
		1	Cold Store

Each unit is provided with a “Cooling Box” in which DC compressor, inverter drive, and water condenser are connected with a typical remote display cabinet, the same used for compressor rack systems, provided with electronic expansion valve, evaporator and fans.

Fig. 3. Cooling boxes on the display cases

The regulation of each individual refrigerated cabinet/cold room is based on the real time adaptation of the compressor capacity and refrigerant mass flow to the internal air temperature with its reference setpoint. Defrost frequencies have been optimised thanks to the increase of the evaporation temperatures related to the reduction of both compressor capacity and flow.

The air conditioning system integrated in the water loop is provided with air handing units and fan coils for the indoor climate control. This system adjusts its configuration according to the climate zones and the weather seasons. There are several working modes, such as:

winter mode, heating (full heat recovery):

- a/w chiller ON in heating mode
- dry cooler OFF
- w/w MT chiller OFF
- w/w LT chiller ON or OFF depending on LT loop temperature

mid season mode (free cooling):

- a/w chiller OFF
- dry cooler OFF
- w/w MT chiller OFF
- w/w LT chiller ON or OFF depending on LT loop temperature

summer mode, cooling (max load):

- a/w chiller ON in cooling mode
- dry cooler ON + evap cooling in case
- w/w MT chiller ON or OFF depending on LT loop temperature
- w/w LT chiller ON or OFF depending on LT loop temperature

STORE COMPARISON

The store in Perafita has been compared with two stores in the same area based on a centralized compressor rack cascade refrigeration system (R134a/CO2) with rooftop/split air conditioning units and similar store area:

Parámetro	Perafita	Store 1	Store 2
Location			
Location	Perafita	10 km from Perafita	30 km from Perafita
External ambient temperature	Minimum: 5ºC Highest: 35ºC	Minimum: 5ºC Highest: 35ºC	Minimum: 5ºC Highest: 35ºC
Size per sales área m^2			
Sales área m^2	$1200m^2$	$1360m^2$	$1590m^2$
Volume of sales			
Volume of sales In this case, it is not necessary the net value, but the % respect each other). This % value will demonstrate how many people could visit each installation, so potential frequency for the door opening/close or variation of quantity of products		-10% compared to Perafita	-12% compared to Perafita
Refrigerated system (Cooling capacity KW)			
Refrigeration Nominal Cooling capacity (KW)	60,9	86,5	91,5
Refrigerated services with or without doors	Total of MT cabinets: 17 MT cabinets without doors: 2	Total of MT cabinets: 20 MT cabinets without doors: 6	Total of MT cabinets: 21 MT cabinets without doors: 9
Refrigerated system MT cooling capacity KW	52,4	73,3	75
Refrigerated system LT cooling capacity KW	8,5	13,2	16,5
Refrigeration system type ς	Waterloop with integrated HVAC	CO_2 Cascade R134a / CO_2	CO_2 Cascade R134a / CO_2
HVAC Nominal capacity	79	65	68
HVAC system type	AHU: 5, 87 kW (inflation). 10 Fan Coils 2 chillers (water-water: 93,8 kW; air-water: 21,2 kW)	Rooftop 1: 52 kW Rooftop 2: 52 kW 7 Splits	Rooftop 1: 52 kW Rooftop 2: 52 kW 11 Splits

Tab. 1. Compared stores data

Due to the different plant layouts and technologies, including refrigerant, the most suitable way to compare the stores is the calculation of TEWI (Total Equivalent Warming Impact) which incorporates both direct emissions of the refrigerant due to leakages and end of life disposal, and indirect emissions related to the elecrticity and energy usage.

The following table shows the TEWI parameters of the different stores and related calculation formula:

TEWI CALCULATION IN EACH CASE	TEWI = Direct Emissions + Indirect Emissions $TEWI = GWP \cdot m \cdot \left(\frac{L}{100} \cdot n + (1-\alpha_{rec})\right) + n \cdot E_{annual} \cdot \beta$ Where: GWP = Global Warming Potential of refrigerant L = Leakage rate p.a. [kg] n = System operating life [years] m = Refrigerant charge [kg] αrec = Recovery/recycling factor from 0 to 1 Eannual = Energy consumption per year [kWh p.a.] β = Indirect emission factor [kg CO2 per kWh] › n = 10 years › αrec = 85% › β = 0,18785 kg(CO2eq) /kWh		
	GWP = 2088 L= 0,02 m = 28 kg	GWP CO2 = 1; GWP R134a= 1430 L=0,125 m R134a = 300 kg; m CO2 = 120 kg	
ENERGY CONSUMPTION AND REFERENCE PERIOD (KWh)	E_{2018} = 202116 kWh	E_{2018} = 251133 kWh	E_{2018} = 321824 kWh

Tab. 2. TEWI calculation parameters

The Perafita store, thanks to the semi plug-in cabinets layout with integrated air conditioning systems, provides a 65% TEWI reduction including both direct and indirect emissions reduction as shows in the following figure.

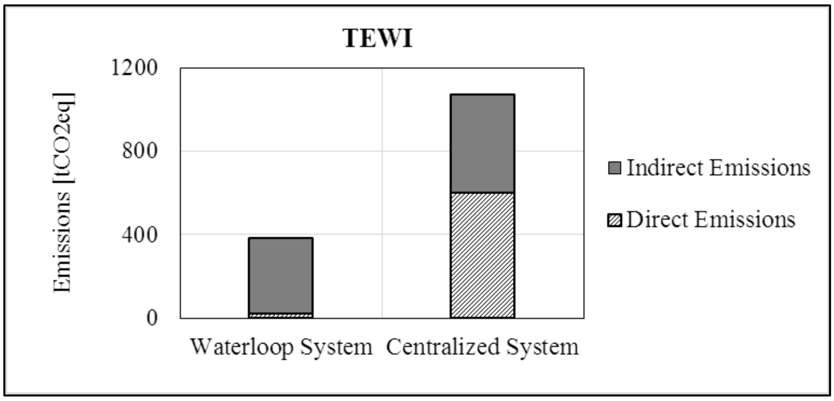

Fig. 4. TEWI comparison between waterloop store and centralized system stores (average)

In terms of direct emissions, this results was achieved despite the higher weighted average GWP (2088) of the Peramita store compared to the others (1022). In fact, both refrigerant charge and leakage rate are definitely lower in a semi plug-in layout compared to the compressor rack cascade which requires long liquid lines with greater refrigerant charge and plenty of brazed potential weak joints which caused a yearly 13% leak rate.

In terms of indirect emissions, the energy consumption of the 3 stores has been compared after being normalized on each store nominal cooling capacity including both refrigeration and air conditioning.

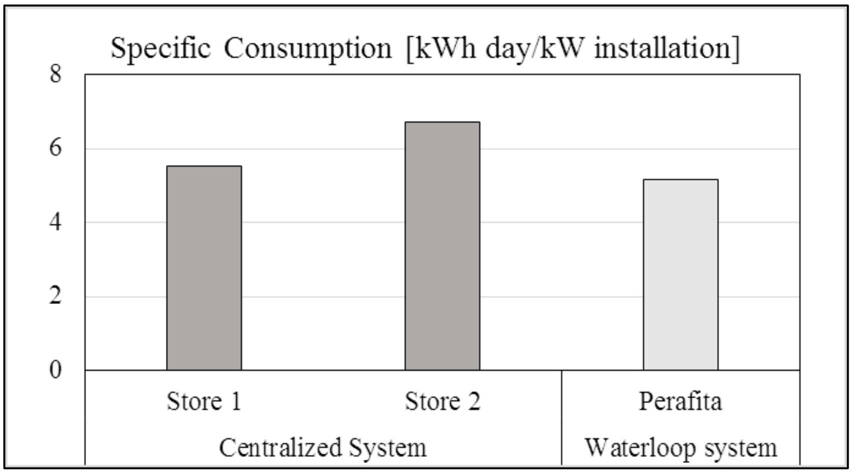

Fig. 5. Specific (normalized) energy consumption of the 3 stores.