THE MULTIPACK PROJECT: INSTALLATION AND MONITORING OF INTEGRATED HEAT PUMP SYSTEMS FOR HIGH ENERGY CONSUMPTION BUILDINGS

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INTRODUCTION

In the last years, a significant effort has been talking place to assess the use of natural refrigerants in various applications. When understanding properties of natural working fluids competitive energy efficiency units can be developed and introduced into the market. Enabling society to plan and achieve an overall environmental sustainability. It is widely known that carbon dioxide transcritical cycle is an energy efficient option for tap water heat pumps; CO_2 might also offer an efficient solution if low temperature heating is required, especially if applied to low energy demand buildings.
Awareness of the intrinsic efficiency challenges, which might occur with the transcritical cycle at high return temperatures due to the temperature levels of the heat rejection fluid is important. MultiPACK units include technical solutions to mitigate such losses, i.e. specific design improvements are proposed for space heating and cooling, together with Domestic Hot Water (DHW) production.
For example, CO_2 heat pumps for simultaneous heating and cooling are available on the market. These systems are applied for industrial- or commercial purposes. Heat recovery for space heating is also common practice, as applied in most CO_2 commercial refrigeration plants, in combination with space cooling. To achieve high energy efficiencies, auxiliary compressors are implemented in the traditional booster system design. In this way simultaneous heating and cooling can be performed.
When applying this technology within residential energy related applications, the heating and cooling demand is often not concurrent. As an example, the hot water demand is normally occurring in the morning and evening hours of a day. There are buildings where DHW demand might be extremely high in certain periods of a day, such as gyms, spas, hotels. These buildings have been identified as potentially ideal applications for CO_2 heat pumps and the use of multiejectors has been considered as the appropriate option to properly address the efficiency issue, especially during space cooling operations.
MultiPACK aims at installing three reversible heat pump units with DHW production, and to monitor and evaluate their performances. In this paper, the installation and operations of the first heat pump will be described.

MULTIPACK UNIT IN A HOTEL LOCATED IN NORTHERN ITALY I

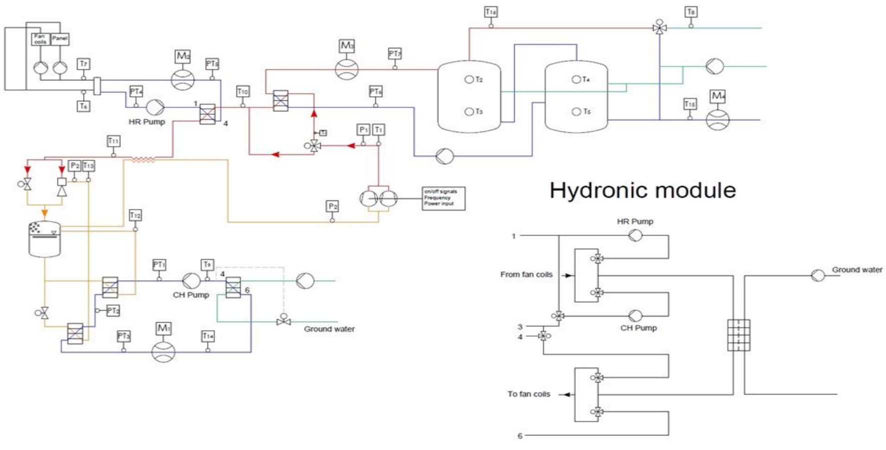

Fig. 1 MultiPACK Northern Italy I site lay-out

The heat pump is installed in a hotel located in a touristic area in North Italy. It is intended to provide heating, cooling and hot water to a hotel, which is open nearly all over the year. The unit can benefit of ground water as heat source or heat sink. The heat pump features a two-phase multiejector as expansion device, able to utilise expansion work. An original two-evaporator lay-out is implemented, where the first one is gravity driven and the second one is ejector driven. The unit is reversible on water side, by means of a hydronic module made by three-way valves that can switch to the ground water or the HVAC plant according to the building request on cooling. Fan coils are installed inside the hotels room providing heating and cooling, supplied via the hydronic water loop implemented inside the building.

Domestic hot water is produced by the MultiPACK unit and accumulated in two hot water storage tanks connected in series to allow stratification. Such an arrangement enables a low water return temperature during charging, see also the proposed hot water storage arrangement in case of a complete rebuilding or new installations in Fig. 3

Two compressors are installed in the MultiPACK unit, one of them is inverter driven. The simplified system layout is presented in Fig. 1. It is represented in the heating configuration mode.

The system is fully equipped with measuring instruments: temperature and pressure probes, energy meters, magnetic mass flow rate meters on water side. Seven PT 1000 temperature probes are placed before and after the three CO_2/Water heat exchangers, on the water side; together with three magnetic mass flow meters, measuring and recording the heat exchanger performance and the unit useful effect. Pressure probes are located on the high pressure side (p_1) at the compressor suction pressure level p_2, and ejector suction nozzle (p_3).

Table 1		*Northern Italy I (winter 2019) DHW*	*Northern Italy I (winter 2019) Heating*
$Q_{cooling}$ *[kW]*		-	-
$Q_{heating}$ *[kW]*		-	15.5
Q_{DHW} *[kW]*		20.1	-
p_1 *[bar]*		100.5	100.6
p_2 *[bar]*		43.1	43.5
p_3 *[bar]*		38.8	38.7
$COP_{heating}$		4.0	3.8
heating	$t_{w,in}$	-	23.7
	$t_{w,out}$	-	47.0
DHW	$t_{w,in}$	17.2	-
	$t_{w,out}$	60.7	-

Several NTC probes are placed in the system to monitor temperature on both the CO_2 and water loop, including the hydronic module also included in the Fig.1. The DHW tank is fully equipped with thermocouples to provide information about water stratification and storage temperature.

A magnetic mass flow rate meter is also installed in the city water side to measure the hotel's DHW water consumption.

Overall results from the site measured during winter 2018-19 are summarised in Table 1.

MULTIPACK UNIT IN A HOTEL IN NORTHERN ITALY II

The unit is currently under installation in a hotel located in North Italy. The unit has the layout presented in the Fig. 2. It provides cooling during the summer season and domestic hot water heating during the whole year.

On the CO_2 side, the MultiPACK system is a reversible heat pump. The heat source during winter time is the ambient air outside the building. This external heat exchanger is applied as heat sink during the summer period to be able to provide chilled water when the hot water storage tanks are fully charged. The innovative feature of the MultiPACK heat pump is the two-phase multiejector applied as the expansion device controlling the high side

pressure level. An original two-evaporator lay-out is implemented, where the first evaporator provides chilled water by evaporating gravity driven CO_2. The second heat exchanger, further cooling the chilled water is at a lower evaporation pressure/temperature level due to the ability of the ejector to compress the suction flow rate towards the pressure level inside the receiver.
The unit has two compressors, one is inverter driven. When DHW is requested by the building, i.e. the charge level of the hot water storage tanks, hot gas flows into the DHW heat exchanger and heats up the water. Thereafter, the refrigerant flows to the external evaporator (heat source in winter) passing to the three-way valve located right after the ejector. A three-way valve placed before the hot side heat exchangers can send the CO_2 to the brazed plate heat exchanger, dedicated to DHW production.

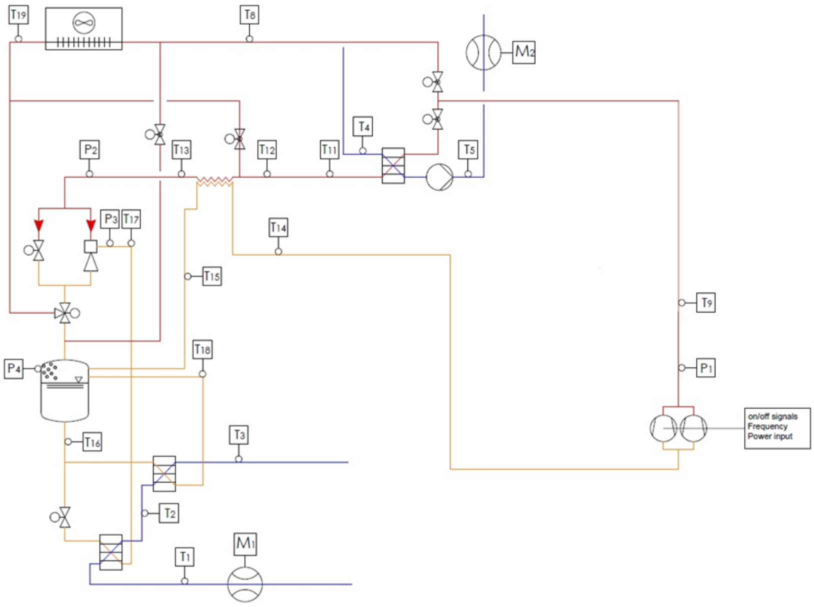

Fig. 2 Northern Italy II, site lay-out

When the cooling mode is activated, the compressed CO_2 flows through the external gas cooler before entering the multiejector. The liquid from the low-pressure receiver flows to the evaporators by natural circulation and by ejector circulation respectively, thus providing cooling effect.
The system is equipped with measuring instruments: temperature and pressure probes, energy meters, magnetic mass flow meters. Four PT 1000 temp probes are placed before and after the two CO_2/Water heat exchanger, on the water side, and two magnetic mass flow meters measure the water mass flow rate that flow through the heat exchangers. Pressure probes are located at the suction pressure level, high pressure side, and ejector suction nozzle. Several NTC probes are placed on the system to monitor temperature on both CO_2 and water loop, such as the water tanks temperatures and hydronic module temperature.

PROPOSED HOT STORAGE TANK ARRANGEMENT FOR MULTIPACK HEAT PUMP UNITS APPLIED IN HOTELS

The hot water storage arrangement shown in Figure 3 indicates that a simple arrangement of standard hot water tanks cannot be applied if high efficiency is the focus of an energy system. In high performance buildings like hotels, hot water is continuously circulated throughout the building to allow instantly taping of hot water at any bathroom, etc. This is the part shown on the left-hand side. Water is typically distributed at 50°C and returns at a lower temperature due to heat losses along the lines. In the proposed concept, the reheat of the circulated water it performed in two ways. When the heat pump (indicated in the part on the right-hand side) is in operation hot water is produced at 85°C, before storing the water inside the stratified tanks arranged in series, the hot water is reheating the circulated water within the heat exchanger located inside the tank of the recirculated water. In case of fully charged storage tanks, Figure 3b, the heat pump stops working until a substantial amount of hot water has been demanded. Now reheating takes place by utilising the temperature difference between the water inside the storage tanks and the returning circulated water. A dedicated pump circulates the hot water through the heat exchanger and heats up the circulated water, the hot water exists the heat exchanger at around 55 °C and is returned to another storage tank as indicated in Figure 3b.

It is important that the hot storage tanks do have a diffuser at the bottom inlet connection. In this case the stratification can be maintained also when a large amount of hot water is tapped during peak demand periods.

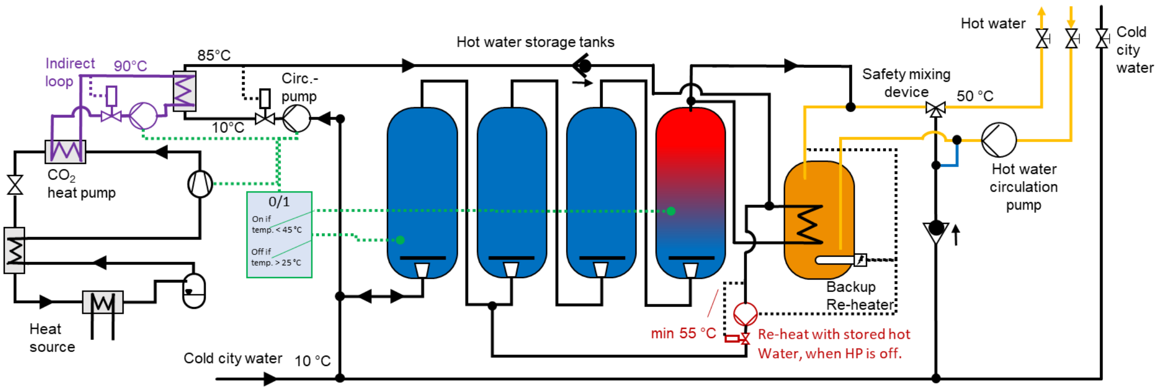

Fig.3a MultiPACK hot water storage tank arrangement. Case: storage empty, HP on.

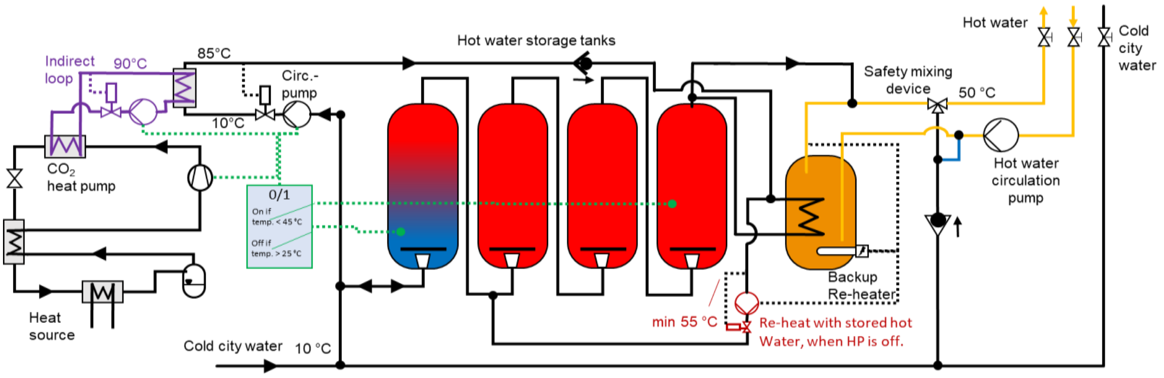

Fig.3b MultiPACK hot water storage tank arrangement. Case: storage fully, HP off.

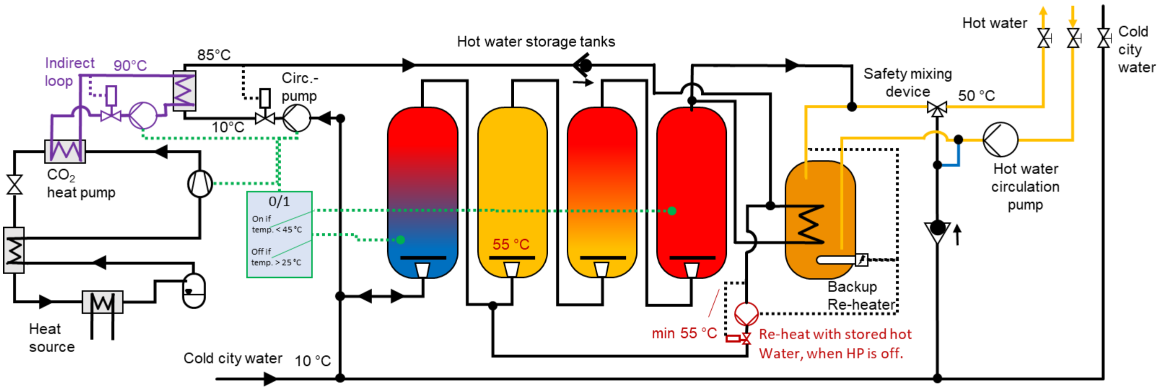

Fig.3c MultiPACK hot water storage tank arrangement. Case: HP off, circulation water reheated by stored high temperature water.

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