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Field data of integrated CO_2 heat pump systems for Italian hotels in the MultiPACK project

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ABSTRACT

The EU project MultiPACK supports the design, construction, installation and monitoring of reversible heat pump units using CO_2 as the refrigerant, providing air conditioning, heating and domestic hot water. The design includes the use of two-phase ejectors and natural circulation evaporators to improve efficiency and can use both external air and water as heat source/sink.

Two units were installed in Italian hotels to provide full energy services in a water/water configuration, or to provide cooling and domestic hot water in an air/water lay-out.

After an extensive test campaign, data from the field, illustrating operating conditions and quantifying performance, are presented in this paper.

INTRODUCTION

The European Commission (European Commission, 2020) has recently stated that a renovation wave is needed to green the EU building stock, being buildings responsible for about 40% of the EU's total energy consumption and for 36% of its greenhouse gas emissions from energy. One of the key principles for building renovation towards 2030 and 2050 is energy efficiency, which is classified by EU as the "horizontal guiding principle of European climate and energy governance and beyond to make sure we only produce the energy we really need". The decarbonisation of heating and cooling is identified as one of the seven areas of intervention. Heat pumps are an opportunity to replace fossil fuels for heating purposes. On the other hand, the F-gas regulation and international protocols, like the Kigali amendment to the Montreal Protocol, demand for long-term, sustainable and global solution in terms of energy direct and indirect emissions. These concurring needs push research and industry to evaluate the use of CO_2 also in heat pumps for comfort heating and cooling. CO_2 might offer an efficient solution if low temperature heating is required, especially if applied to low-energy buildings and in case of large demand of Domestic Hot Water, being this application perfectly suited to the characteristics of the transcritical cycle.

The EU funded H2020 project MultiPACK takes the challenge of installing in the field integrated units for heating, cooling and DHW production, based on CO_2 and adopting two-

phase ejectors to improve efficiency at high gas cooler outlet temperature. MutiPACK has the main goal of installing 6 units in the field, amongst which 3 units for hotels, able to satisfy the energy needs with a high standard of environmental sustainability. These units are fully monitored to prove their performances in the field, thus increasing the confidence of stakeholders in the technical solutions and helping in overcoming also non-technological barriers that can hinder the adoption of available energy efficient solutions in the HVAC&R sector, as demonstrated by the earlier SuperSmart EU project.
This paper presents the lay-out of two units installed in Italian hotels; the units are different in size, service and lay-out, thus showing how CO_2 integrated systems can actually satisfy the peculiarities and the needs of the sector. Data collected during the test campaign are presented to show field operations and to quantify real performances.

MULTIPACK SITES DESCRIPTION

The selected sites are both hotels located in touristic areas in North Italy, namely on the Garda Lake (Site I) and in Val Gardena, Dolomites (Site II). The main design characteristics are summarised in Table 1.

Table 1: Design specifications for SITE I and II

	SITE I	**SITE II**
location	Garda Lake	Val Gardena
Requirement	Cooling/Heating/DHW	Cooling(+DHW)
Source/Sink	Ground water	Air
Design load	Cooling 20 kW @ 12/7°C Heating 25 kW @ 30/55°C DHW 30 kW @ 65°C	Cooling 150kW @ 12/7°C DHW. Heat recovery @60°C

Both systems are fully equipped with measuring instruments: temperature and pressure probes, energy meters and magnetic mass flow rate meters on water side.

Figure 1a: Garda Lake unit (SITE I) as installed in the field

Figure 1b: Val Gardena unit (SITE II) as installed in the field

SITE I

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. The simplified system layout is presented in Fig. 2.

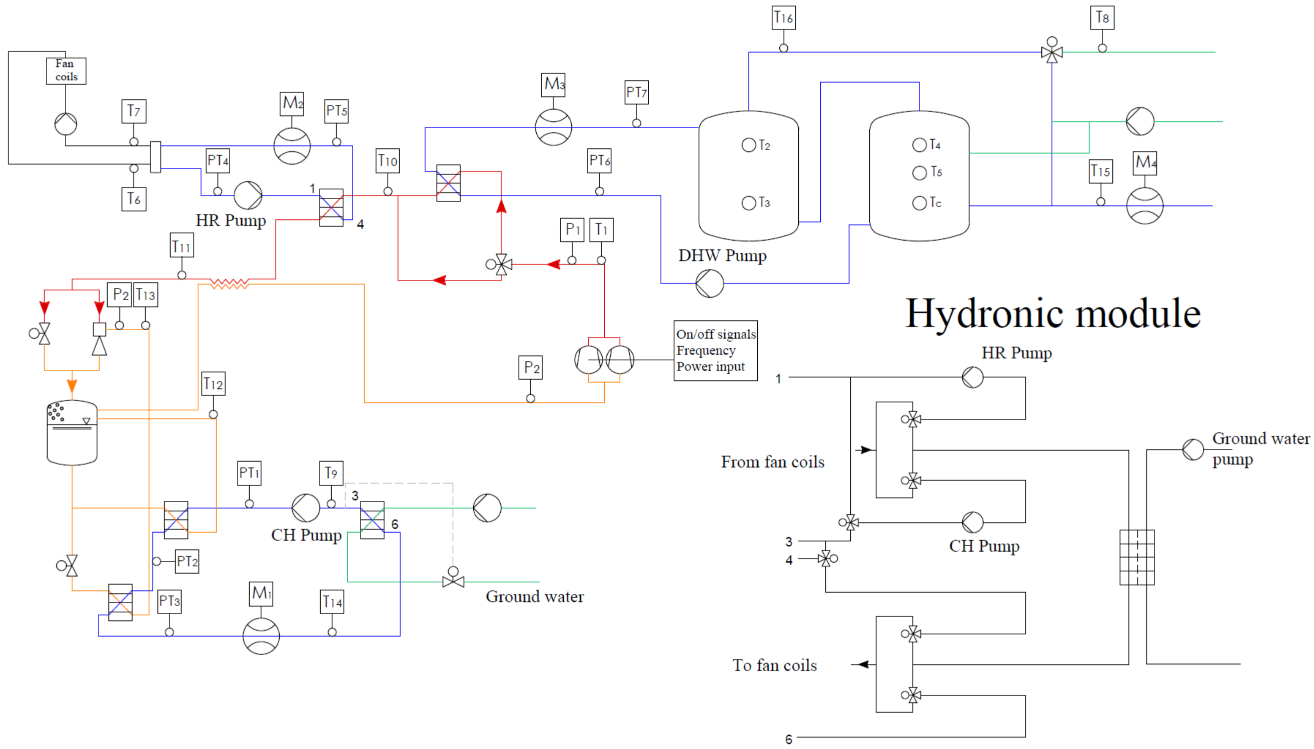

Fig. 2 MultiPACK Garda Lake- SITE I

SITE II

The installed unit works as a chiller with the possibility of simultaneous DHW production at 60°C. The purpose is to provide chilled water for comfort cooling in specific areas of the luxury hotel, while recovering heat for DHW, if necessary. Domestic hot water is accumulated in stratification tanks and integrates the heating service, based on fossil fuels. A remote gas cooler is rejecting heat outdoor when no DHW is required. The two-evaporator lay-out is implemented also in this system: the first one is gravity driven and the second one is ejector driven, being the expansion provided by a multijet system. The simplified system layout is presented in Fig. 3.

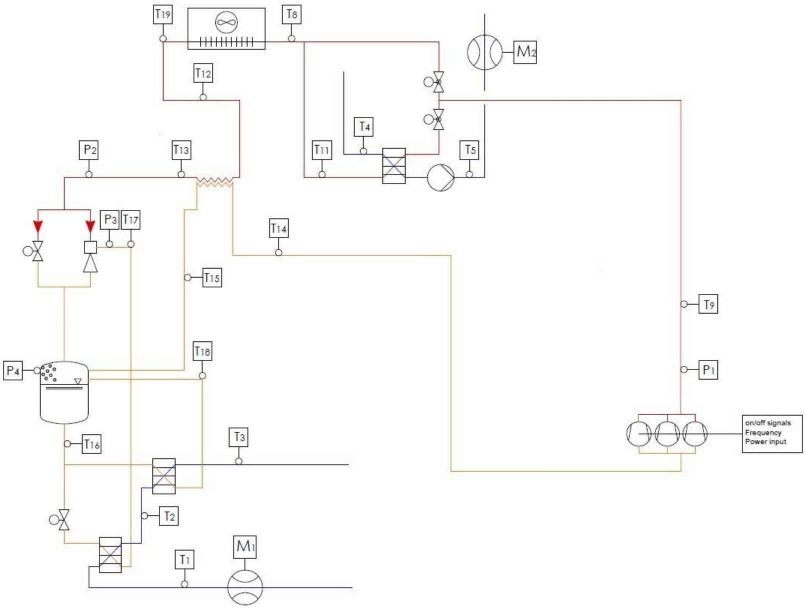

Fig. 3. MultiPACK Val Gardena- SITE II

RESULTS FROM THE FIELD

SITE I

The collected data have been processed and heating and DHW operations are shown in Figures 4a and 4b, as for the 15th of October 2020.

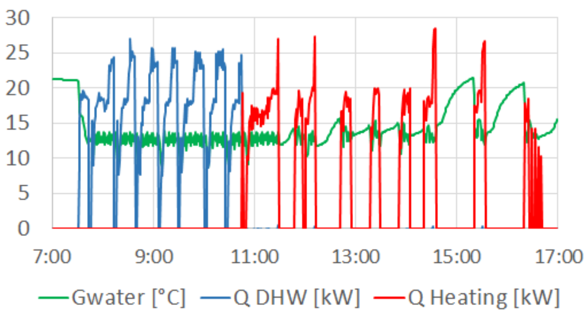

Figure 3a: SITE I-DHW (q DHW), Heating demand (Q Heating) and Ground water temperature (Gwater) on 15th October 2020

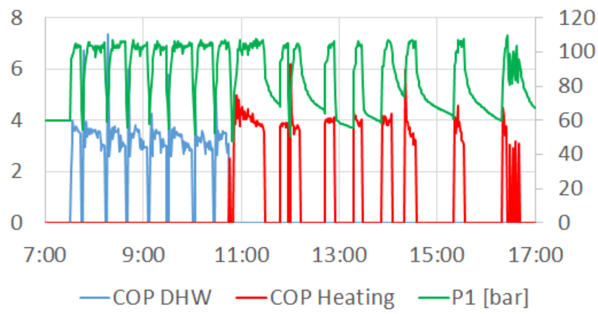

Figure 3b: SITE I- COP in DHW and Heating mode, and high pressure (P1) on 15th October 2020

Both DHW and Heating are provided under on/off mode, being the demand significantly lower than the design values. The heat source temperature (ground water) is stable, while the high pressure is increased up to 100 bar in both operations. The performance is defined in terms of COP, considering the measured power input to the compressor rack.

SITE II

The chiller operations are active only during summer months, starting in June 2020 through August 2020, for the considered period. The COP includes all useful effects (Cooling power and DHW power) and accounts for compressor rack power input. However, during 2020, no DHW requirements are registered. Due to the reduced thermal load, with respect to the design cooling demand (150 kW), the ejector driven evaporator are not operating, therefore the chiller only relied on the natural circulation evaporator.

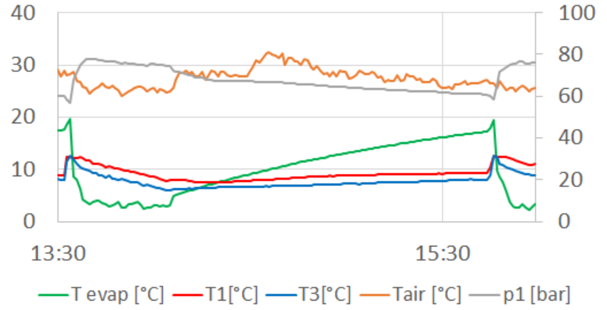

Figure 5a: Saturation temperature at natural circulation evaporator (T evap), chilled water in (T1) and out (T3) temperature, external air temperature (T air) and compressor discharge pressure (p1) on August, 7th, 2020

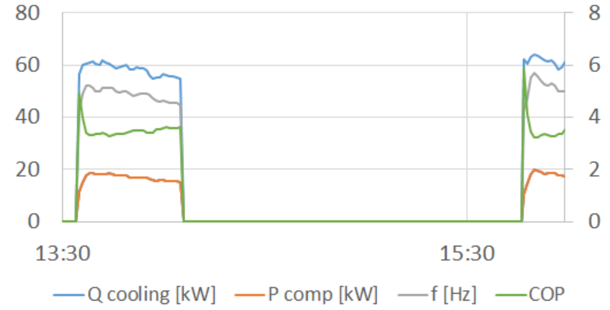

Figure 5b: Cooling power (Q cooling), compressor power input (P comp) and compressor inverter frequency (f), on August, 7th, 2020

An on/off cycle, registered on August, 7th 2020, is represented in Figures 5a and 5b, showing operating temperatures and pressure and the corresponding cooling power and compressor power input. When the compressor switches on, after a transient period, stable conditions in operations are kept for about 20 minutes.
All collected data during the summer period (Jun-Aug 2020) are processed to identify stable intervals and calculate the resulting COP. Figures 6a and 6b show the Cooling Capacity and COP, evaluated under stable operations, as functions of the external air.

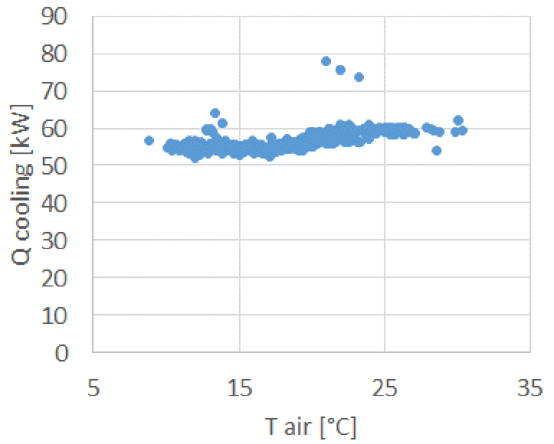

Figure 6a: Cooling capacity under stable operations, summer 2020

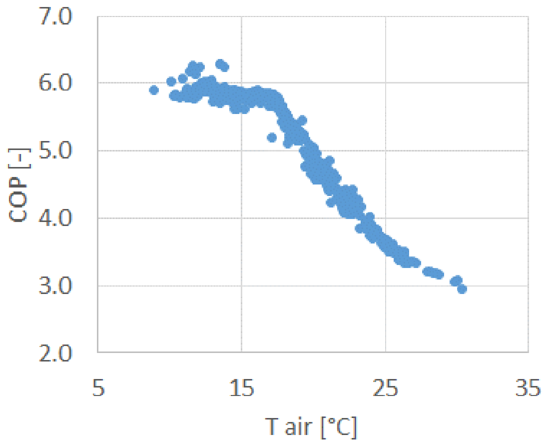

Figure 6b : COP under stable operations, summer 2020

CONCLUSIONS

The MultiPACK project has given the opportunity of installing and monitoring integrated HVAC systems for hotels installation. The test campaign has demonstrated their operations and performances, together with the reliability of single components and entire units.

ACKNOWLEDGEMENTS

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