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LEADING THE TRANSFORMATION IN GREEN HEATING AND COOLING

Achieving 30°C return for CO_2 heat pumps

July 2023 //

WHY CO2 NEEDS A 30°C RETURN //

There are two key values for a working fluid that give rise to its behaviour; the critical point and the triple point.

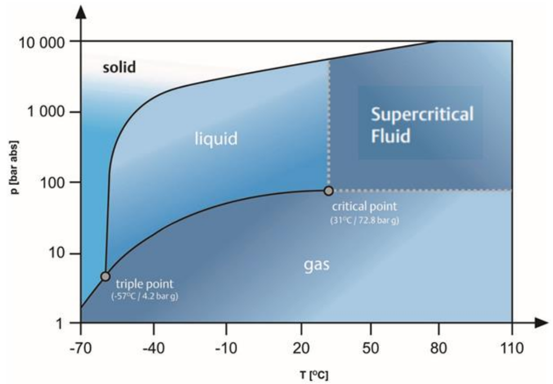
- The triple point is the only temperature and pressure where all three phases will exist. It is unique to a substance and can be used to identify it.
- The critical point is the highest temperature and pressure at which a pure material can exist in vapor/liquid equilibrium.

When compared to other working fluids, CO_2 has a high triple point and a low critical point.

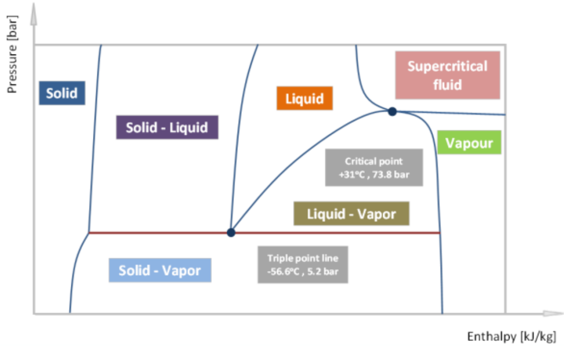
The critical point occurs at 31 °C. Above this point the CO_2 is a supercritical fluid. This means that there is no phase change when heat is removed from the transcritical fluid – this is called gas cooling and is what enables a high flow temperature at high efficiency.

In a heat pump system, supercritical CO_2 will not condense until the pressure has dropped below the critical pressure. Conversely not extracting the energy from the gas leads to extreme pressures. No other commonly used working fluid has such a low critical temperature.

Managing the temperature, pressure and therefore phase of CO_2 is the reason why 30°C return temperature is important for efficiency and operation.



Log p - h diagram of CO_2



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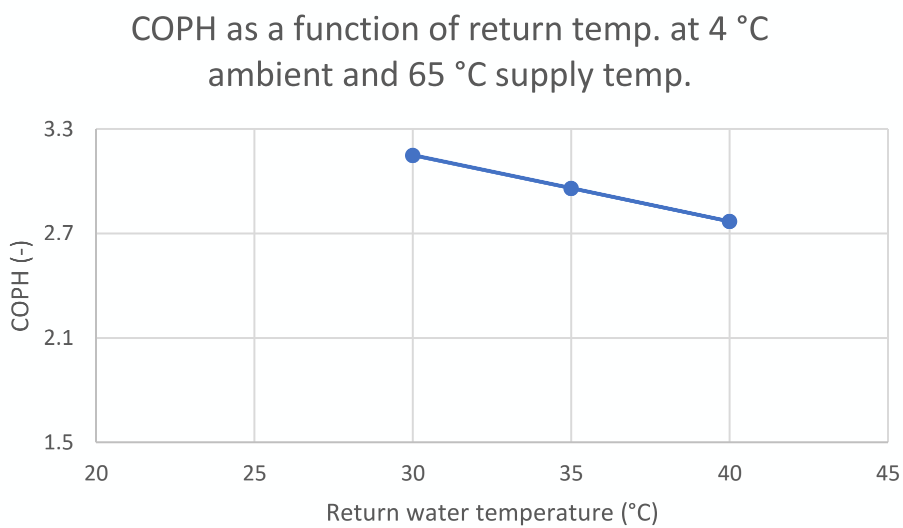
ACTUAL REQUIREMENT //

The optimal design point for a CO_2 heat pump is 65-70/30°C this is where the greatest efficiency can be achieved.

Design return temperature shall be 30°C

Clade heat pumps will accept a higher return temperature, after starting, up to 37°C, for short periods. For example as transitory rises due low demand. This is more flexible than other manufacturers which makes them suitable for a wider range of applications.

Clade advanced control CO_2 heat pumps (available at 700KW+) can accept a permanent 40 °C return temperature.



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HOW TO ACHIEVE A 30C RETURN TEMPERATURE //

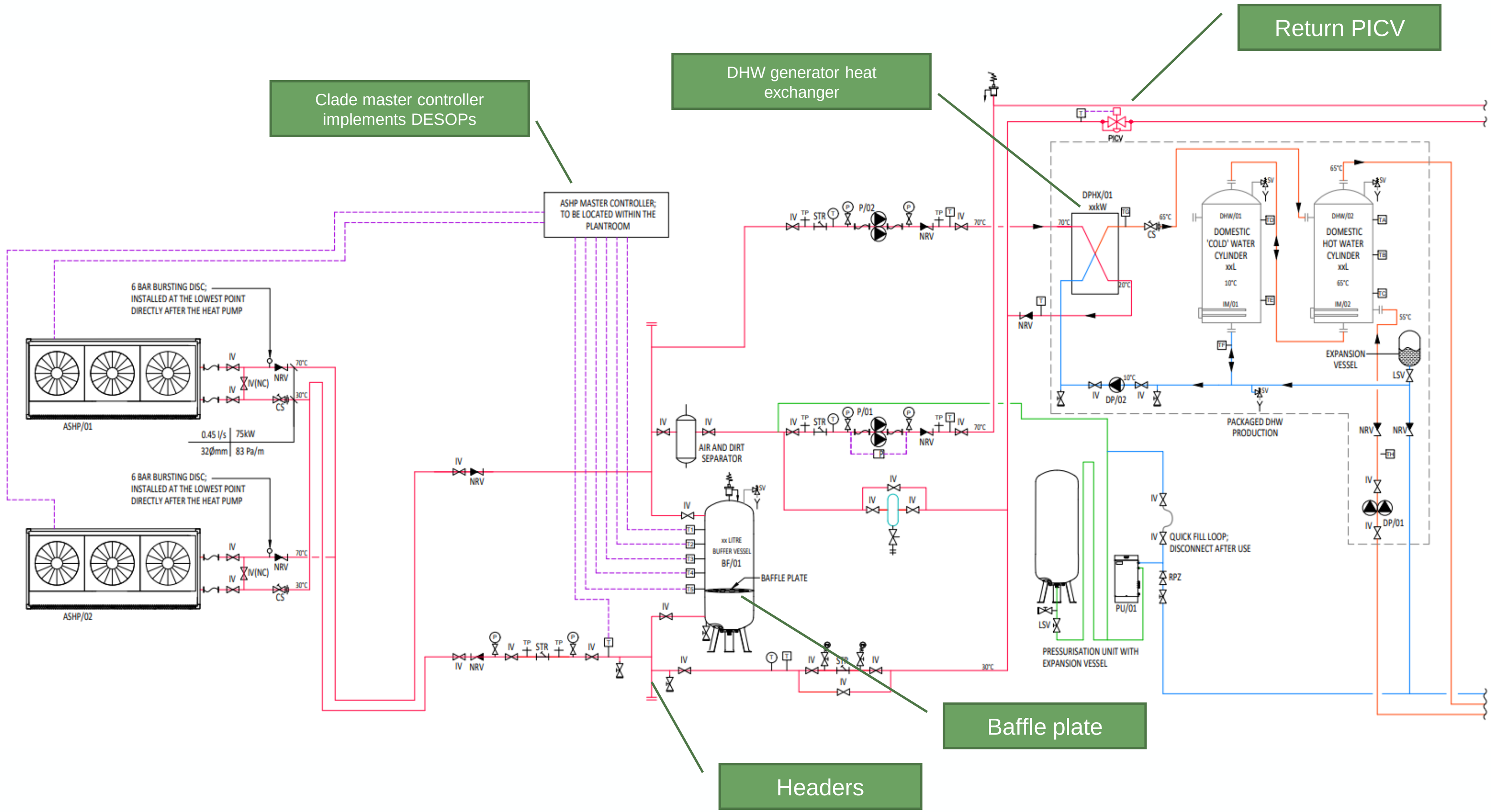
Designing a heating system to achieve a wide DT with a low return temperature is straight forward and follows established variable flow principles that will be familiar to process and control engineers.

1. Heat emitters

   The heat emitters shall be sized for the correct mean water temperature. All types of heat emitter are available for wide DTs. Existing emitters shall be assessed for their capacity and changed where necessary.

2. Control valves
   1. TRV – Pressure independent TRVs shall be used on large systems to ensure flow is reduced such that the emitter creates the correct DT.
   2. Circuit – PICV valves shall be used at circuit level for smaller systems, the designer shall determine the settings.
   3. Return - one additional PICV shall be fitted on the main return line to the buffer which will provide a secondary protection against temperature rise. This will close down on receipt of seeing a higher return temperature, this will maintain secondary pressure but will reduce the flow rate of the pump.
3. Pump control - the main distribution pumps shall operate on pressure control which is commissioned to provide the minimum service level at the index point and no more.
   1. During low demand conditions – where the heating demand is lower than the pump minimum turn down, a differential pressure relief control valve shall be installed to allow the pump to re-circulate water without increasing the return temperature
4. Buffer control
   1. Flow in or out of the buffer shall be minimised to preserve stratification. External headers shall be used, see schematic.
   2. Buffers shall have baffle plates to protect the lower portion of cool water
   3. The heat pump control strategy shall follow that in the Clade DESOPs
5. Domestic hot water
   1. Only plate heat exchangers shall be used to generate DHW in the arrangement show on the standard schematic.
   2. It is paramount to keep water from dropping below 55°C within the distribution pipework. This is maintained with a hot water return pump which will take the 65°C hot water round to a minimum of 55°C back to the first ‘hot’ cylinder.
   3. The pump will be a variable flow pump which will modulate to maintain a return temperature of 55°C by use of temperature sensor TH.

SCHEMATIC //



Return PICV
DHW generator heat exchanger
Clade master controller implements DESOPs
Baffle plate
Headers
ASHP MASTER CONTROLLER; TO BE LOCATED WITHIN THE PLANTROOM
6 BAR BURSTING DISC; INSTALLED AT THE LOWEST POINT DIRECTLY AFTER THE HEAT PUMP
ASHP/01
ASHP/02
0.45 l/s
75kW
32Ømm
83 Pa/m
AIR AND DIRT SEPARATOR
BAFFLE PLATE
PICV
DPHX/01
DOMESTIC 'COLD' WATER CYLINDER
DOMESTIC HOT WATER CYLINDER
EXPANSION VESSEL
PACKAGED DHW PRODUCTION
QUICK FILL LOOP; DISCONNECT AFTER USE
PRESSURISATION UNIT WITH EXPANSION VESSEL
PU/01

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ABREVIATED DESOPS //

Buffer Vessel Control

The buffer vessel shall be set to maintain 70°C as a common setpoint. T1 to T5 temperature probes shall be used to monitor the stored heating capacity within the buffer vessel as 70°C water migrates down the vessel. As each probe reaches the 70°C setpoint starting from T1, this will decrease the 0-10v heat pump capacity signal until the bottom temperature probe T5 is triggered and the output is set to 0v. A differential of -1°C shall be included within the setpoint to stop hunting around the setpoint. As stored capacity is reduced within the vessel, cooler water will migrate up the vessel. As each temperature probe falls below 69°C, starting with T5, the heat capacity signal is increased until T1 is triggered giving a 10v signal.

A baffle plate will be installed just below the final T5 sensor, this will aid in the separation between 70°C and the 30°C required at the bottom.

P/01 – Secondary Main LTHW Pump

The main LTHW circulation pump will serve the new building heating circuit. This will become activated on the main buildings heating controls calling for heat.

The pumps will be controlled via differential pressure sensors maintaining constant pressure and the new BMS controller will monitor the return temperature of the pumps circuit, this will cause the return legs PICV valve to close, reducing pump flow rate, in order to maintain a return temperature of 30°C.

P/02 – Secondary LTHW Domestic Hot Water Plate Pump

This is the LTHW pump to supply the plate heat exchanger for domestic hot water generation. This will be a constant speed pump on a 70/20 flow and return which can modulate down if the BMS senses a return temperature above 30°C.

This pump will be activated once the domestic hot water shunt pump DP/02 has been activated.

Domestic Hot Water Shunt Pump - DP/02

The shunt pump will be activated once temperature sensor TB sees a temperature < 45°C and turn off once TC ≥ 65°C. The shunt pump will not be able to be activated if the water from the cold cylinder is ≥35°C

Pressure Control Valves

Introduction

UFH – Pressure independent control valve

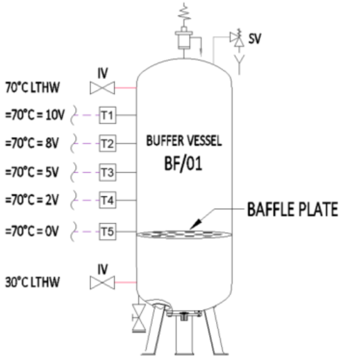
For closer control of the UFH circuits to maintain a 30°C return temperature then PICVs will be used before each UFH circuit.

PHX – Pressure independent control valve

For closer control of the PHX circuits to maintain a 28°C return temperature then PICVs will be used before each PHX.

TRV c/w Differential pressure control

For closer control of the radiator circuits to maintain a 30°C return temperature then thermostatic radiator valves c/w differential pressure controller will be used for each radiator.



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THANK YOU //

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