TECHNICAL BULLETIN

CHP Thermal Store Management

Introduction

The arrangement and management of stored heat is critical when designing CHP systems.

In a basic system, a “buffer vessel” acts as an oversized header to avoid short-cycling of the CHP unit.

In a sophisticated, optimized CHP system, a real “Thermal Store” meets specific objectives and brings significant operational and economic benefits to the system.

Thermal store objectives

- **To provide a substantial displacement between the time of heat production and heat usage**
  When heat demands are lower than CHP capacity, the unit could produce more heat than immediately required by the heating system. The excess production of ‘high-grade heat’ is stored at the CHP flow temperature of 80˚C until required by the heating system. This allows continued power generation and avoids engine short-cycling.

- **To enable the CHP unit to meet peak heating loads greater than the CHP heat output**
  The ‘high-grade’ stored heat can supplement the direct CHP production to satisfy a short-term demand that is greater than the output of the CHP unit alone. This helps to maximize the CHP heat share and minimizes the operation of back-up gas boilers.

- **To allow heat demands lower than the minimum output of the CHP to be met**
  Limited low demands can be met using the stored 80˚ heat, again reducing boiler use.

- **To optimize CHP operating time**
  The CHP system can operate during high-tariff electricity periods, even if there is no site heat demand, by diverting heat to the thermal store.

Thermal Store Volume

The optimal volume of the thermal store should be calculated based on a consideration of the following factors:

- Volume necessary to meet heating demands at times when the CHP is not operating
- Volume necessary to maximise CHP operating hours, storing surplus heated water that can be used later. This can be determined most accurately by creating a thermal model of the building load to compare the CHP heat available with the heat required by the system.

NOTE: SAV Systems can recommend the most appropriate thermal store for a project, based on 24-hour profile data.

Heat capacity of thermal stores

In operation, thermal stores can be thought of as time limited heat sources i.e. capable of generating large kW outputs but only until they run out.

For example, a 1000 litre store can supply 100kW of heat for 28 minutes in a system with a 40°C design delta T and consequent flow rate of 0.6l/s

Supporting theory:

P(kW) = mass flow (kg/s) x SH (kJ/kg°C) x ΔT (°C)

Where:

P = heat output (kW)
SH = specific heat capacity of water (= 4.2 kJ/kg°C)
ΔT = temperature differential between store inlet and outlet temperatures (°C)

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Poorly functioning buffer stores

Figure 1 illustrates some of the most common features of poor functioning buffer stores.

In this arrangement, the three-port mixing valve only controls the temperature of the CHP primary circuit. Beyond the plate heat exchanger, the supply circuit flow and returns are dampened by the 4-connection buffer. The flow rate and temperature of the water returning from the site are both variable depending on the system load.

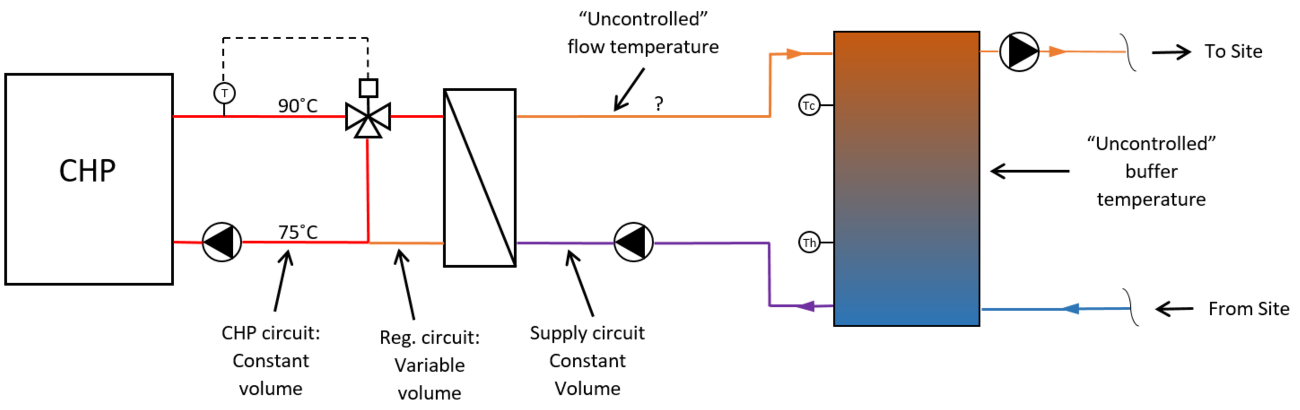


Figure 1: Poorly configured CHP buffer store

The main problems with this approach are as follows:

Problem 1: The site return flow rate and temperature will vary depending on system load. Since the flow through the system side of the PHE is constant, the PHE outlet temperature will be 'uncontrolled' and will vary depending on the site return temperature. Hence, the water entering the store and being circulated to the site will also have an uncontrolled temperature.

Problem 2: The buffer acts as a very large 'header'. The four connections to the buffer will cause turbulence in the store, thereby preventing stratification. The temperature gradient will be gradual with no clear boundary layer between hot water from the CHP and cooler return water from the site. This will make it impossible to use temperature stratification for CHP start/stop control, so an alternative, more expensive control solution will be required (such as energy metering of primary and secondary circuits).

Problem 3: To achieve the required design temperature in the store, water will need to circulate multiple times through the PHE. This will inevitably cause a rise in the return temperature to the CHP unit, potentially causing early switch off due to lack of engine cooling.

Problem 4: Controlling the three-port valve to maintain a constant flow temperature on the CHP primary circuit can introduce serious valve and temperature oscillations. This is due to the delay as the coolant travels through the CHP (typically > 30 seconds). This can be particularly severe when secondary return temperatures are low.

Problem 5: Without control of the supply circuit flow temperature, it is not possible to maximise the CHP heat share.

Optimised management of a thermal store

Figure 2 shows a thermal store configured to enable optimal operation.

In this arrangement, the temperature of the water from the CHP unit is allowed to vary within the CHP's own limits. The three-port mixing valve is located on the supply side of the plate heat exchanger to ensure a constant temperature of 80°C is always available to the system, regardless of the temperature and flow rate of the water returning from the site.

The 2-connection thermal store enables 'stratified storage operation' where a narrow layer separates the hot flow water at the top, from the cold return water at the bottom. The full flow temperature of 80˚C is maintained in the store until it is emptied, so the stored water is always either 'hot' or 'cold'.

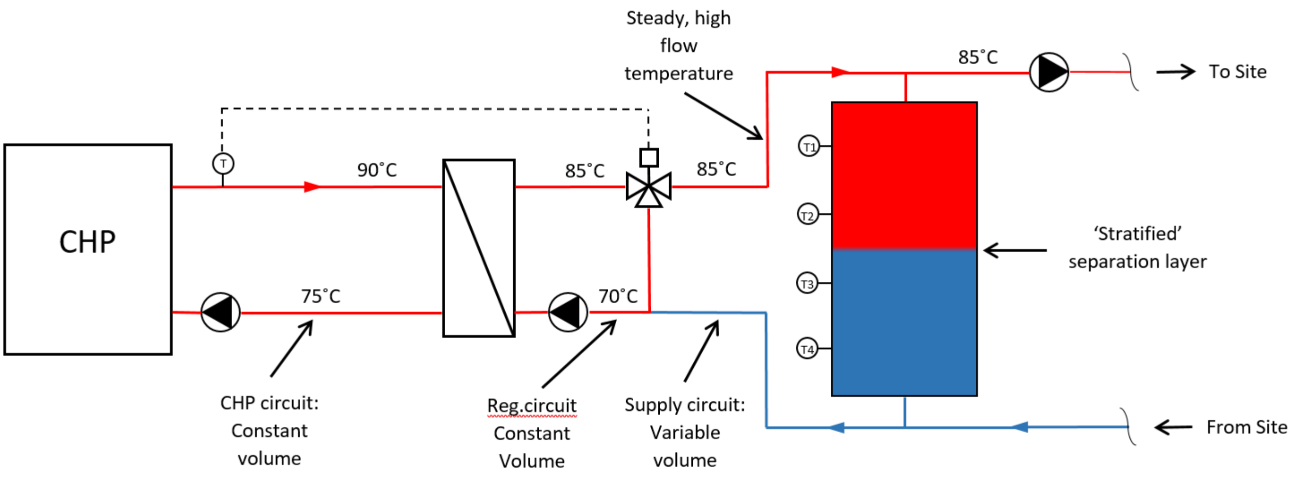


Figure 2: Optimised thermal store arrangement

The main benefits of this approach, relative to that in Figure 1, are as follows.

Problem 1 solved: Locating the three-port mixing valve on the supply side of the PHE means that the water entering the store and being circulated to secondary circuits will be maintained at a steady 80˚C.

Problem 2 solved: The connections to the thermal store are configured to encourage thermal stratification and the formation of a clear layer between hot water from the CHP and cooler return water from the site. This means that the full volume of the store is available. It also means that temperature stratification can be used for CHP start/stop control.

Problem 3 solved: Water entering the thermal store will not need to be heated multiple times in order to reach the required storage temperature. Therefore, the temperature of the water entering the PHE will remain at a value low enough to ensure the CHP can operate at its intended design temperature differential under all conditions.

Problem 4 solved: To maintain a constant CHP flow temperature, the return temperature set point needs to vary depending on the flow rate and CHP output. This set point serves as basis for regulating the 3-port valve. A specialised control system is required for this purpose as explained in the next section.

Problem 5 Solved: By controlling and stabilizing the system flow temperature independently of the return temperature, the CHP heat share is maximized.

LoadTracker Q20/Q80 Heat Interface Unit

LoadTracker CHP systems are supplied pre-packaged with all the components necessary to facilitate effective management of the CHP and thermal store, as detailed and explained in the notes accompanying Figure 2 above.

The Q-Network control package provides the following automatic functions:

- All relevant temperatures are monitored
- Flow-rates on both sides of the PHE are continuously calculated
- The heat transfer capacity of the PHE is continuously calculated
- CHP primary return set-point values are continuously calculated and updated based on the CHP output and flow-rate
- Valve control parameters are continuously adjusted in accordance with the temperature differential between secondary circuit and CHP return temperature
- High-efficiency variable speed pumps are automatically controlled to achieve the required ΔT across the plate heat exchanger

All of the above combine to achieve very fast, stable and precise regulation

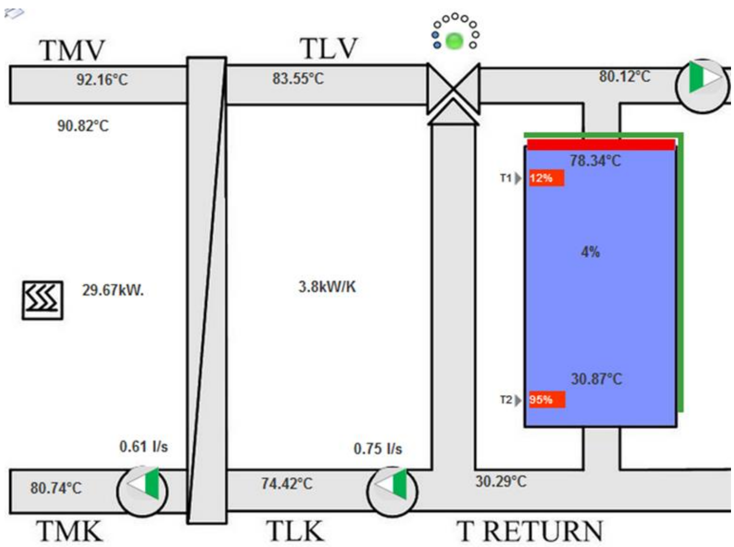
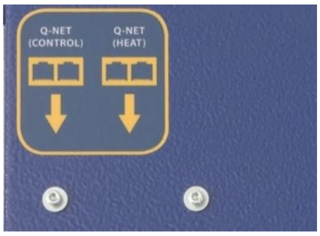


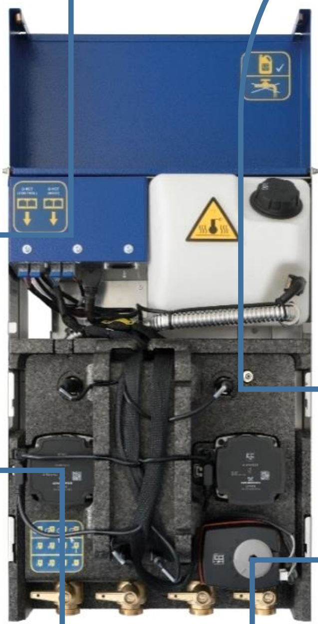
Figure 3: Arrangement of PHE and Thermal Store control on a LoadTracker CHP

LoadTracker Q20/Q80 Heat Interface Unit

Control



Q-Network control of circulation, flow and thermal store



Measurement

PHE temperatures measured at five points

Quality

Grundfos UPM3 circulating Pumps

Temperature

ESBE 3-Port mixing valve on supply side of PHE

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LoadTracker Thermal Stores

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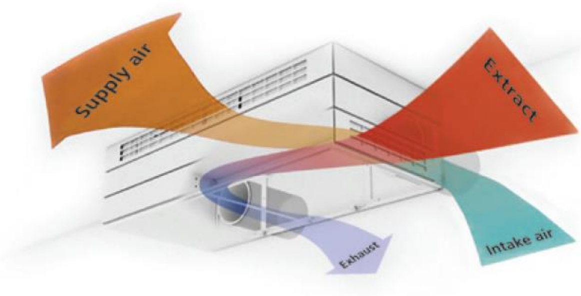

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LoadTracker CHP