Design Guide

Stored Hot Water Solutions in Heat Networks 2018

hot water association

DEVELOPING HOT WATER

Stored DHW in Heat Networks - Design Guide

Contents

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This guide was written by Ian Robinson, Technical Manager / Special Applications, BAXI HEATING

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1.0 Scope

1.1.00 The ‘HWA Design Guide for Stored Hot Water Solutions in Heat Networks 2018’ provides design guidance and advice for engineers who are looking to specify stored hot water solutions working within a heat network. This document does not provide guidance relating to the heat networks that incorporate instantaneous (hot water) heat interface units.

1.2.00 As heat networks can range from a couple of dwellings running off a central heat source to larger district heating systems that feed thousands of consumers, it is important to note that there is no “one fits all” design solution.

1.3.00 Within heat networks, stored hot water solutions have been used for many years. In recent times there has been a drive in the heat network industry to promote the benefits of generating hot water instantaneously whilst underestimating the benefits of the stored hot water solution. This design guide aims to offer an alternative for designers of heat networks by explaining a design methodology that allows stored domestic hot water solutions due consideration within the design and planning processes.

1.4.00 Although not exhaustive, the guide looks at the different stored hot water solutions that are available. It lists the merits of heat networks with stored hot water solutions and sets out design guidelines for systems that incorporates stored hot water within each dwelling. Designers should be aware that there are a number of other ways of storing energy within heat networks, such as the use of integrated thermal stores within dwellings. This guide however, only concentrates on storing domestic hot water within each dwelling.

1.5.00 The design guide does not aim to provide a specification for manufacturers to design and produce to, but does set out applications advice to systems designers which will enable them to incorporate stored hot water solutions within their heat network design.

1.6.00 The design guide sets out a procedure which takes the designer through the process of sizing the fundamental parts of a heat network that incorporates stored hot water in each dwelling. It is acknowledged at this stage that this may not be appropriate for all systems and dwellings and the designer may have to deviate from the prescribed process. It is also worth mentioning that the increased flexibility that stored hot water solutions offer the designer will undoubtedly mean that no one system will fit all and as such this design guide doesn’t aim to stifle that creativity.

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2.0 Normative References

The following documents are indispensable for the application and use of this HWA specification for thermal stores.

2.1.00 SAP 2016: 'The Government's Standard Assessment Procedure for Energy Rating of Dwellings', 2016 Edition.

2.2.00 Building Regulations 2000 : Approved documents L1 & L2, 'Conservation of fuel and power', 2013 Edition.

2.3.00 Building Regulations 2000 : Approved document G, 'Sanitation, hot water safety and water efficiency', 2015 Edition

2.4.00 Building Services Compliance Guide, 2013 Edition

2.5.00 BS 1566-1:2002, Copper indirect cylinder for domestic purposes. Open vented copper cylinders. Requirements and test methods.

2.6.00 BS 8558:2011, A Guide to the design, Installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages - Complementary guidance to BS EN 806

2.7.00 BS 6920-1:2000, BS 6920-2:2000, Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.

2.8.00 BS EN 12828:2003, Heating systems in buildings. Design for water-based heating systems.

2.9.00 BS En 12831:2003, Heating systems in buildings. Method for calculation of the design heat load.

2.10.00 BS En 14336:2004, Heating systems in buildings. Installation and commissioning of water based heating systems.

2.11.00 VDI 6002 Part 1: Solar heating for domestic water – General principles, system technology and use in residential building.

2.12.00 CIBSE guide TM 13: Minimising the risk of Legionnaires' disease.

2.13.00 CIBSE guide G: Public health engineering.

2.14.00 The Institute of Plumbing – Plumbing Engineering Services Design Guide

2.15.00 Pressure Equipment Directive (PED) (97/23/EC)

2.16.00 CIBSE Guide CP1: 2015 Heat Networks: Code of Practice for the UK

2.17.00 BSRIA AG 16/2002 Variable-flow water systems. Design, installation and commissioning guidance

2.18.00 BSRIA BG62/2015 Heat Interface Units

2.19.00 HWA Performance Specification for Thermal Stores 2010

2.20.00 The Heat Network (Metering and Billing) Regulations 2014

2.21.00 CIBSE AM12 Combined Heat and Power for Buildings 2013

2.22.00 BSRIA Guide 2/2007 Combined Heat and Power (CHP) for Existing Buildings

2.23.00 HSG274 Part 2 The control of legionella bacteria in hot and cold water systems - 2014

2.24.00 BS EN 806 (Parts 1–5) Specifications for installations inside buildings conveying water for human consumption

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3.0 Definitions of Terminology

3.0.01 Aggregated Individual Peak Loads (AIPL)
The sum of all the peak loads within a heat network.

3.0.02 Approach temperature
The approach temperature is the smallest temperature difference between the primary and secondary fluids at any point within a heat exchanger. For a counter flow or cross flow plate heat exchanger it will usually be the difference between the primary flow temperature and the secondary flow temperature. For space heating applications an approach of 5K can be achieved at design output.

3.0.03 Coincidence factor
The coincidence factor is defined as the design flow rate for downstream domestic hot water outlets divided by the maximum possible flow rate for downstream domestic hot water outlets. In a heat network with HIUs the coincidence factor is alternatively expressed in terms of the primary flow necessary to achieve the domestic hot water requirements and used as part of the pipe sizing methodology for the heat network.

3.0.04 Communal heating
Communal heating is a heat network comprising one or more heat sources linked to multiple consumers of heat in one building.

3.0.05 Consumer
The end user of the heating and/or hot water services provided by the heat interface unit.

3.0.06 Delta T
Delta T or temperature differential, is the difference in temperature across a heat transfer system, ie plate heat exchanger, radiator, boiler, CHP etc. It can also be used to refer to the difference in design temperatures between the flow and returns.

3.0.07 Delta P
Delta P or pressure differential, fluid resistance, friction loss is the difference in pressure across a system or component.

3.0.08 Demarcation
Demarcation lines indicate where one parties responsibility ends and another begins. This is particular important in extensive heat networks where a number of organisations and people are stakeholders in the system. Heat exchangers / pressure breaks or isolation valves form natural demarcation points in the system.

3.0.09 Differential pressure control valve
A differential pressure control valve (DPCV) operates to maintain a constant differential pressure between two points in a heating or cooling circuit that is, within limits, independent of the supplied differential pressure.

3.0.10 Direct HIU
A direct HIU is a HIU where water from the heat network is circulated through the secondary heat distribution circuits i.e. there is no hydraulic separation between the heat network and secondary heat distribution circuits such as the radiators or underfloor heating.

3.0.11 District heating
District heating is a heat network comprising one or more energy centres, which provide the heat source that is linked to consumers of the heat in different buildings by above or below-ground pipework.

3.0.12 Diversity factor
Diversity is commonly confused as meaning the same as the coincidence factor. Diversity can be said to be the inverse of the coincidence factor. Therefore the greater the level of diversity allowed in the system design, the lower the level of coincidence.

3.0.13 Fixed orifice control valves.
Fixed orifice control valves regulates the flow of a fluid through a fixed diameter hole. The flow rate will change with dynamic pressure.

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3.0.14 Flushing bypass.
A flushing bypass is a pipework arrangement that temporarily links the flow and return pipes within a heat network to facilitate the flushing of debris from the system. The link pipe may incorporate a lock shield valve so that it can be permanently installed. The arrangement usually includes downstream flow and return isolation valves to protect equipment should as HIUs from the flushing process. Flushing bypass assemblies can also aid service work such as forward and back flushing.

3.0.15 Heat interface unit
In its simplest form the interface is two or four isolation valves that define the boundary of system ownership. However, a heat interface unit (HIU) is a packaged set of components necessary to connect a consumer's heating and/or hot water system to the heat network. It may include isolation and control valves, heat exchangers, pumps and metering devices. A HIU may or may not provide hydraulic separation between the heat network and the consumer's heat emitters and/or hot water generator. HIUs are also known as heat or hydraulic interface units, CIUs (consumer interface units), heat boards, Sub stations, flat stations, fresh water stations. Different forms of HIU are listed below.
- Heating direct connection (with or without remote hot water cylinder).
- Heating direct connection with domestic hot water plate.
- Heating heat exchanger (with or without remote hot water cylinder).
- Heating heat exchanger and domestic hot water heat exchanger.
- Hot water only.
- Chilled water interface units.

3.0.16 Heat network branch
Heat network branches refer to the smaller connections off the heat network mains that deliver the heat into individual dwellings or small subsets of dwellings ie down corridors.

3.0.17 Heat network mains
Heat network mains refer to the main heating flow and return pipes that deliver the bulk heat from the heat sources through the network.

3.0.18 Heat substation
A heat substation is used to connect larger buildings or sub-networks to a heat network. These should not be confused with HIUs. Generally they act as the interface between a district heating system and the buildings being fed by that district heating system. They can also be used as pressure breaks on tall buildings.

3.0.19 High temperature heat network
Heat network operating with a flow temperature that can exceed 120°C.

3.0.20 Indirect HIU
An indirect HIU refers to a HIU where there is hydraulic separation between water in the heat network and water in the secondary heat distribution system. The secondary heat distribution system must therefore include independent provisions for filling, pressurisation, water treatment and necessary safety valves. An indirect HIU for residential consumers may include separate plate heat exchangers for heating and domestic hot water. These heat exchangers are often referred to as the "heating plate" and the "hot water plate" respectively.

3.0.21 Jockey pump
As part of the main distribution pumps, the jockey pump is smaller than the other distribution pumps and its purpose is to operate during periods of low demand thus providing the system with greater turn-down.

3.0.22 Kvs value.
The Kvs value expresses the amount of flow through valve in m^3/hr in a fully-open valve position and with a pressure differential of 1 bar.

3.0.23 Low temperature heat network
Heat network operating with a flow temperature less than 100°C.

3.0.24 Medium temperature heat network
Heat network operating with a flow temperature between 100°C and 120°C.

3.0.25 Operational Diversity
Operational diversity is the fraction of unit that are not likely to be in use at anyone time and takes into account the control method in which the water is heated. For example if the water is heated on a time and temperature basis the operational diveristy is likely to be less than if it was heated on a temperature only basis.

3.0.26 PID control.
Proportional, Integral, Derivative controllers regulate the rate of change of an output, the time intervals that these changes take place and the amount that the system is allowed to stray from the set point.

3.0.27 Pressure independent control valve
A pressure independent control valve (PICV) operates to maintain a controlled flow rate that is, within limits, independent of the supplied differential pressure. A PICV combines the functions of a DPCV, regulating valve and control valve. Generally speaking, PICVs do the same job as the DPCV ie. they both help balance a system and prevent changes elsewhere in the system from affecting the flow rates they are controlling. PICVs work on the principle that to maintain a flow rate in a system with fluctuating pressure differentials you have to be able to increase and reduce the size of the orifice opening area. This is done with an adjustable spring loaded orifice plate within the PICV. PICVs do not provide protection for other valves in the system against high differential pressures generated by the main distribution pumps.
- $Q = Kv * \sqrt{\Delta p}$

Where:
- Q = Flow (m3/h)
- Kv = Opening area
- Δp = Differential pressure (Bar)

3.0.28 Pressure breaks.
A pressure break is simply a heat exchanger to separate two parts of a system.

3.0.29 Primary system.
The primary system is usually the landlord's system. On extensive systems this may be split using pressure breaks.

3.0.30 Power and energy
Power shouldn't be confused with energy. Power is measured in kW and Energy is measured in kWh. Power is the rate that energy is used or drawn from a system, whereas energy is the amount of energy used in a system. If we consider a bath of hot water, the energy used to fill the bath is the same irrespective of how the hot water is generated. However to generate the hot water required to fill the bath you will need far more power to produce it instantaneously than you would if you were using a store as this could be generated over a longer period of time.

3.0.31 Set back regime
A set back regime is a control strategy where the flow temperature of the primary is lowered for extensive periods of the day. Outside the set back period are boost periods where the primary temperature is lifted to allow the stores to fully charge.

3.0.32 Thermal buffer vessels
Thermal buffer vessels simply act as an over sized header and are used to link various energy sources, help control and manage those energy sources, increases peak performance and helps to improve the turn-down and the reaction time of the heat source technology in line with the fluctuating demands of the network.

3.0.33 Thermal storage vessels
In contrast thermal storage vessels acts as an energy bank, where technologies such as CHP are able to run and charge the vessels over extended periods. A thermal store will enhance the output of the heat source to cope with peak demands and allow the heat source to top the thermal store back up during periods when demand is low. Thus providing a load levelling effect to a systems fluctuating energy demands. They tend to be much larger in size than a thermal buffer allowing them to be charged both during times of high and low demand.

3.0.34 Thermostatic bypass valve
A thermostatic bypass (where fitted) is intended to pass sufficient flow to offset the standing heat loss between the branch connection and the HIU when there is no load to provide a fast response to domestic hot water demand. The valve may be thermo-mechanical or electrically operated. These are sometimes called a “Summer Bypass”.

3.0.35 Valve authority.
The ability for a valve to control a fluid flow at different flow rates.

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4.0 General Guidance
There are a number of ways to produce domestic hot water using the energy available from a heat network. That said these can be split into two basic categories:
1) Instantaneous Hot Water
2) Stored Hot Water

4.0.01 Instantaneous Hot Water
Hot water that is produced at the same time and rate as is drawn off at the taps is said to be instantaneous hot water. In general this method of producing hot water requires much more power than that produced using a hot water store. Instantaneous hot water production is not covered in any great detail in this document.

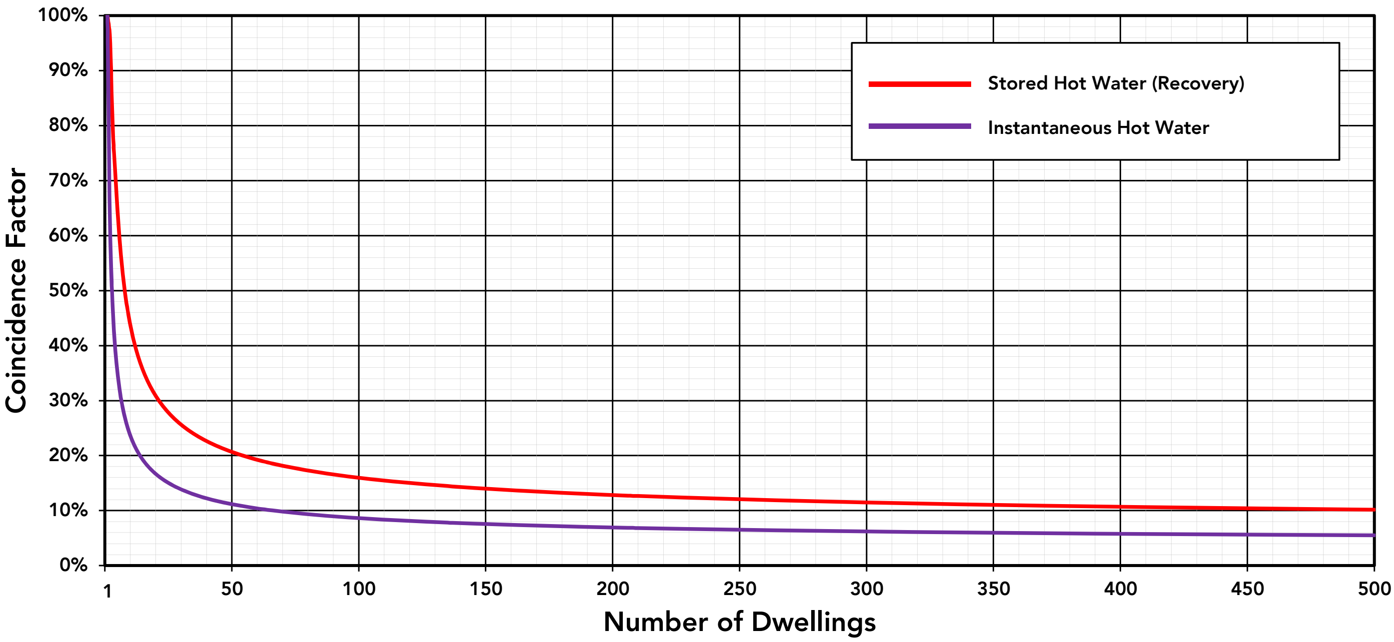
4.0.02 Stored Hot Water
Hot water that is produced and held until a time when it is needed is said to be stored hot water. Unlike instantaneous hot water, stored hot water can be produced at a time and rate that doesn't have to coincide with the water being drawn off at the taps. This means that hot water can be generated using a much lower source of power at times when demands on the system are low.

4.1.00 Peak and Base Loads
When designing a heat network, the success of the system largely lies in it being sized and designed appropriately for the demand of the building. It is therefore very important that both the peak and base loads are understood when designing the system. When looking at peak loads it is critical to apply an appropriate level of diversity (or coincidence factor) to take account of the diversified loads. When considering how the system will cope with the base load it is important that as much system turn down is built into the design as is feasibly possible to avoid the central system cycling.

4.2.00 Diversity
Although it is widely understood that a heat network would never need to be specified to meet the Aggregated Individual Peak Load (AIPL) of all of the dwellings within it, the actual level of diversity within the system is much greater than most people envisage.

In fact, for large multi-residence developments the total instantaneous hot water demand at any one time on the system as a whole is very low. The stored hot water recovery curve is based on temperature only control. This is illustrated in Figure 1.

Figure 1 Hot Water Diversity



4.3.00 The Consequences of Over-sizing
Although it seemingly goes against all logic that such a large number of people could only ever be using a tiny fraction of the AIPL at any one time, consultants should be aware that building in a little extra 'for luck' can result in damaging consequences in the long run. If oversized, it won't just be the boilers that are too big, inevitably every element of the system, from the pipework, distribution pumps, expansion vessels, inhibitor volumes required to protect the system, to name a few, will increase. Greater diameter pipework leads to higher heat losses resulting

from the larger surface area of the pipework.
Communal areas including corridors and foyers can fall victim to overheating caused by such heat losses in the pipework. In some corridors there is little natural ventilation, so heat from lighting, and the opening and closing of doors to individual dwellings where the heat is turned up high can exacerbate the problem. Effective insulation of the distribution network is a necessity and specifiers should be aware that they should go above and beyond the requirements set out in Part L. For guidance see BSRIA guide BG62/2015 and CIBSE guide CP1.

4.4.00 Realistic demands within the dwelling
As previously stated it is important for the designer to understand that are no "one fits all" solutions. With this in mind the designer must establish who will be using the network and what the likely tapping patterns and demands on the system are. Once this is understood the designer can then establish what the likely impact will be on the system as a whole.
In addition to applying a level of diversity to the overall system, the designer must not be tempted to base their design on all outlets in the dwellings potentially being in full simultaneous operation. If they do this will have an impact on the overall size of the central plant and distribution network. This again will lead to an oversized heat network even with a correctly applied diversity factor for the whole system.

4.5.00 The impact on system turn-down
The performance of an oversized system can be further compromised because of its limited ability to modulate down in line with the daily and seasonal load profiles. As mentioned earlier it is important that a strategy to cope with the base loads is built into the system. Sharing the peak load across more boiler modules is one way of doing this.

4.6.00 Turn down at the consumer end of the system
Controlling the supply of primary heat to the network is only one part of the design. Controlling how the demand is met by the primary system is also important for a well designed system. Networks whose design is based on variable flow principles give the best results. Systems that limit and control the flow of primary water to the consumer, ensuring the energy required is all that is delivered, are the most efficient. This is generally achieved using modulating 2-port control valves to match the supply of heat to meet the demand. But maintaining the required flow rate irrespective of the dynamic pump pressure, which can experience some lag time as dwellings come on and off line, requires control through changing system differential pressures. Coping with these changes in differential pressure can be achieved by either using a differential pressure control valve (DPCV) or a pressure independent control valve (PICV).
DPCVs are best suited, but not limited to systems that are connected directly to a heat network. This is because they maintain the differential pressure across two points within the system. So any components within these two points, such as TRVs, 2-port control valves and return temperature limiters are then protected against any fluctuations in differential pressure by the DPCV.
The use of a temperature controlled PICV fitted with an electronic modulating actuator provides a simple solution to balancing and controlling the flow of primary water through an indirect system. This is because a PICV provides the functionality of a flow limiter, a 2 port modulating control valve, and a dynamic balancing valve to cope with the fluctuating differential pressures, all in the one valve.
With both solutions, when there is no heating or hot water demand within the dwelling the modulating 2 port control valve closes and the main distribution system subsequently ramps down as the differential pressure in the network increases. In effect this means that both the apartment's system and the heat network return temperatures can be closely controlled and kept to a minimum, thus maintaining the maximum temperature differential and minimum flow rate across the whole heat network.

4.7.00 Coping with low demand
The use of a jockey pump in systems where the difference between low load and peak load conditions is too great for the main pumps to cover is one way of tackling the turn down issue. However, as heat networks incorporating stored water within the dwelling experience much smaller swings between low load and peak load, jockey pumps are less likely to be required.

4.8.00 Keep warm or pre-heat function
It is important for designers to note that the primary system keep warm function that most instantaneous HIUs have in order to be able to meet the requirements of the legionella and water regulations, are not a necessity when generating hot water using a hot water store. This is because the hot water can be generated at any time and rate and not necessarily when it is actually being drawn off. So depending on the overall system design and control strategy it is possible to allow a heat network that generates hot water using a hot water store to be turned down in flow temperature or even shut down for extensive periods of time when there is no heating demand. Being able to shut the heat network off during the summer periods and heat the stores through low tariff electricity may be advantageous for some schemes. It also allows system designers to stage cylinder recovery through a network of zoned areas and thus managing the overall demand on the heat network.

4.9.0 Hot Water Demand Profiles

4.9.01 Figure 2 show the typical daily and weekly profile of the hot water demand within a large residential buildings.

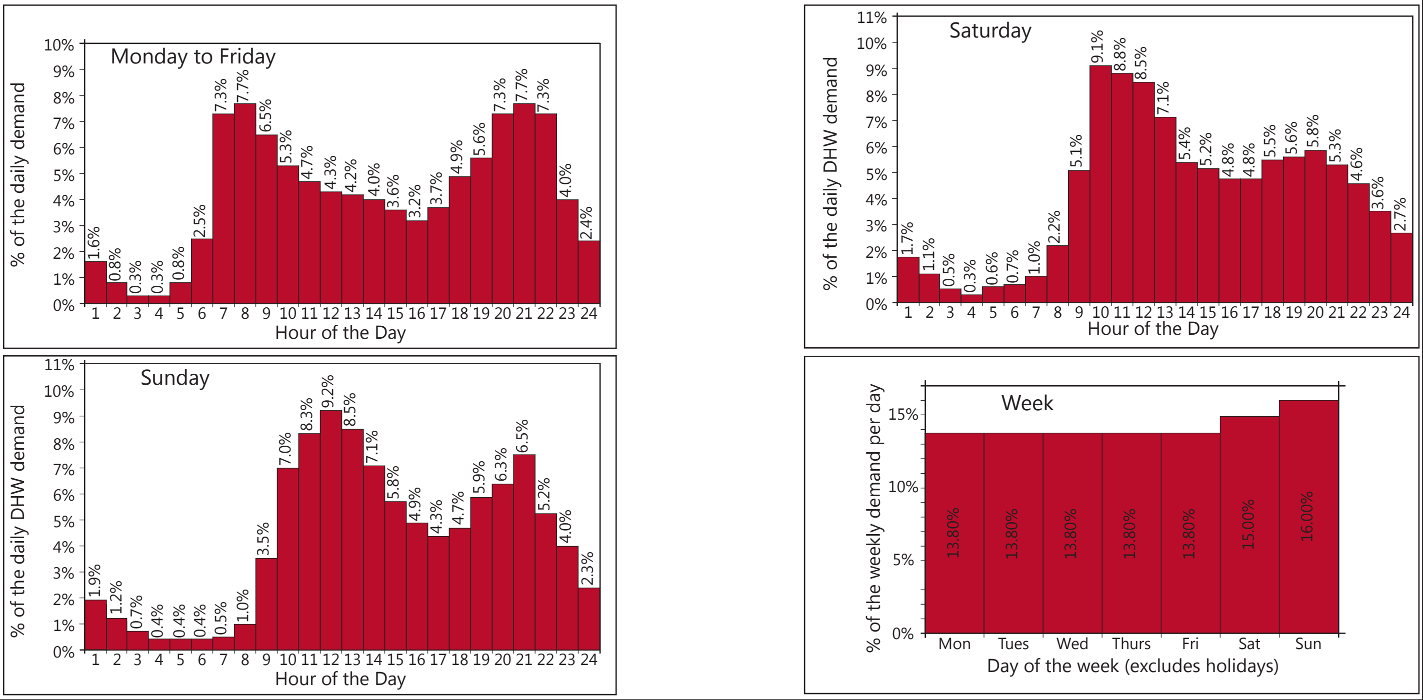
4.9.02 The Daily profile shows two main peaks, one in the morning and one in the evening.

4.9.03 There is a large drop in demand in the early hours and a smaller one in the afternoon.

4.9.04 The weekly profile is relatively constant throughout the week with a slight increase at the weekend and so overall the daily demand can be said to be constant throughout the week.

4.9.05 Figure 2 clearly shows times throughout the day where hot water can be produced to flatten out the demand on the system. Using hot water cylinders allows the hot water to be produced at times when demand on the system is low.

Figure 2 - Daily and weekly profile of the hot water demand in large residential buildings



4.9.06 It is worth pointing out some figures taken from VDI6002 which state that the average daily hot water demand for a person living in a multi-occupancy building which serves over 100 people is 28 litres per person per day. This figure drops to as low as 21 litres per person per day during the summer school holiday period and peaks in February to 32 litres per person per day. These figures are based on hot water at 60°C.

4.9.07 Putting this into central boiler plant terms; a building which houses 100 people (a block of say 40 apartments) would need a central boiler rated at around 8kW to heat the hot water required over a 24 hour period. This is in contrast to the power required to heat the hot water instantaneously when being simultaneously drawn off at one kitchen sink and a shower, which would require around 33kW. Or a diversified instantaneous hot water demand across the block of around 158kW. These figures excludes any heat losses.

4.9.08 Put another way a 33kW instantaneous HIU is capable of producing over 13,500 litres of hot water at 60°C over a 24 hour period. This for an apartment potentially serving 3 people is some 90 times greater than it needs to be. So even if the designer uses a thermal store in the central boiler house / energy centre to reduce the size of the boilers, the distribution network will still have to be capable of delivering the power (kW) to the aparment. This means that the pipes, pumps, expansion vessels, volume of inhibitor used will all be larger compared to a system that uses a store within the apartment.

4.9.09 With this in mind, designers should understand the ratio between the development's fabric, ventilation and domestic hot water loads. This is because when considering the method of hot water generation it is important that the designer is aware of the impact of having an instantaneous hot water load which is likely to be greater than the peak heating load in the winter. This affects the systems ability to save energy during the warm spring to autumn periods as the system has to be sized to cope with the peak demands in the depths of winter.

4.9.10 It is technically possible to provide cylinders sufficiently sized so that their power input can be spread over a full 24 hour period, in many cases it wouldn't be viable due to space limitations. Storage does however offer a solution which undoubtedly flattens out the peaks and troughs that daily hot water demands put on the centralised system. These solutions are considered in more detail later in this document.

4.9.11 The details covered in this section highlight the benefits of separating the supply from the demand by using a stored hot water solution close to the point of use ie within the dwelling. A key benefit to heat networks being the size of the pipework, pumps, expansion vessel(s) and boiler(s) are small and at the same time very high domestic hot water flow rates to outlets such as baths and showers are easily achieved. Thus providing fast filling baths and high performance showers with low impact on the primary network. Again this is covered in more detail later in this document.

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5.0 A Case for Stored Hot Water

5.0.01 The advantages of using stored hot water within a heat network

Using stored hot water solutions within heat networks has many advantages over systems that generate hot water instantaneously. These include:

1) It requires very little power to keep the whole system topped up as it works on the Fly-Wheel Principle.
2) It makes diversity at the taps irrelevant to the heat network. ie separates out supply from demand.
3) The rate of supply against rate of demand can be manipulated to suit each installation.
4) The timing of recovery allows further load levelling by staging recovery of the DHW cylinders connected to the network.
5) It reduces the size of the central plant.
6) Smaller networks are easier, quicker and cheaper to install.
7) Lower capital costs of the network counter the additional cost associated with the cylinder.
8) Lower primary flow rates required, so smaller pumps can be specified.
9) Smaller pipe sizes are required.
10) A smaller network require smaller expansion vessels and less inhibitor.
11) Heat losses in primary circuit are lower.
12) Lower operational cost mean payback is quicker and price per unit of energy is lower.
13) Reduces the designers risk relating to consumer usage pattern being different to diversity curve assumptions.
14) Offers electrical input as standby for increased consumer security and / or last stage heat-up to allow use of low primary temperatures and renewable heat sources.
15) Being able to input electrical energy from renewable sources close to point of use (ie within the dwelling) reduces primary pumping costs.
16) It can provide somewhere for low grade intermittent heat sources such as PV, solar thermal, wind, etc to store energy.
17) Flexibility of design, set-back regime, delta T control, phased charging can all help reduce peak demands and lower heat losses.
18) Ability to purge heat from individual heat network branches using a phased recovery approach.
19) Ability to switch off central plant which will increase the life expectancy of the central plant as it doesn’t run all the time.
20) No need for primary bypasses for keep warm purposes.
21) Controllability of hot water temperature throughout the flow rate range. Valve authority during low demands can be problematic with larger HIUs.
22) Reaction time to changes in demand are less critical.

5.0.02 The disadvantages of using stored hot water within a heat network

1) Greater space required to site the cylinder. This can be countered by fitting the store on a frame so that a washing machine can be fitted underneath a cylinder.
2) Cost of the cylinder including controls.
3) Heat Loss from cylinder. Smart cylinders and no need to keep primary pipes hot counters this argument.
4) Potential to run out of water when the store and its recovery rate does not match the application.
5) The need to heat the stored water to 60^{o}C for 1 hour per day to meet legionella regulations.
6) Cost of cylinder maintenance.

5.1.00 Stored Hot Water Principles

5.1.01 Unlike hot water that is produced instantaneously where the rate of output required from the HIU has to be matched instantly with the rate of input to the HIU, hot water that is produced using a store can be produced and stored at different times and rates to that of the demand. This means that stored hot water solutions offer unique flexibility to the designer when it comes to load levelling the daily peaks in demand on the system.

5.1.02 When using cylinders linked to a heat network it is important that the designer understands the peak 10 minute, hourly and daily hot water draw off. This coupled with the space available to site the cylinder will determine the storage volume and the recovery of the heat exchanger. In some circumstances cylinders with larger volumes and smaller capacity heat exchangers may be beneficial and in others a smaller cylinder with a faster recovery may be required.

5.1.03 Unlike sizing instantaneous units where the focus is on the peak instantaneous load, when sizing stored hot water solutionsit is important that there is enough stored water capacity to cope with at least the peak 10 minute demand. The designer should consider the time it takes to heat the water back to a usable temperature ie. around 40^{o}C. British standards recommend that a time of 25-30 minutes should be allowed to recover enough hot water for the next hot water draw off. For further advice BS8558 gives recommendations of cylinder size in relation its heat input.

5.1.04 Another point to consider is the directly heated cylinder market in the UK. There are millions of homes in the UK whose hot water is generated by a 3kW electrical immersion heater within a store that uses off-peak electricity during the night. Therefore a similar sized cylinder can equally be heated by primary water at a similar rate to serve the same property.

5.1.05 In regards to heat losses, for the purposes of this document, it is worth pointing out that in the UK cylinders tend to be sited in airing cupboards and utility cupboards within each dwelling. Ambient temperatures within these cupboards tend to be several degrees higher than the rest of the dwelling which is useful for airing clothes. As such, in terms of heat losses published by manufacturers under the ErP directive, it is fair to say the test conditions do not reflect normal operating conditions and so actual heat loss figures in the field tend to be lower.

5.2.00 Table 1 gives a guide to the volume of stored hot water required for a given outlet or appliance and is based on a hot water temperature of 60°C.

Table 1 Appliance Hot Water Requirements

Appliance / Outlet	Stored hot water allowance at 60°C
Bath	60 litres
Shower at 6 l/min	30 litres #
Shower at 9 l/min	40 litres #
Shower at 12 l/min	55 litres #
Wash Hand Basin	5 litres
Sink	10 litres

Based on an approx 450 second shower.

5.2.01 Table 1 above can be used to calculate the size of cylinder required. It is beneficial to design a hot water system which has more stored water capacity and less heat exchanger power. This will have the affect of smoothing out the peak demands on the system.

5.3.00 Table 2 below gives a guide to the size of stratifying cylinder and the power required to meet everyday demands. Where non stratifying cylinders are used it is likely that additional storage volume will be required.

Table 2 Cylinder Sizing

Number of Bedrooms / Persons	Number of wet rooms	Outlets	Cylinder Volume (litres)	Power Rating
1 Bed, 1 Person	1 x Shower-room	1 x Shower, 1 x WHB, 1 x Kitchen Sink	75 litres	1 kW
1 Bed, 2 People	1 x Bathroom	1 x Bath, 1 x WHB, 1 x Kitchen Sink	125 litres	1.5 kW
2 Bed, 2 People	1 x Bathroom	1 x Bath, 1 x WHB, 1 x Kitchen Sink	125 litres	1.5 kW
2 Bed, 3 People	1 x Bathroom and 1 x En Suite	1 x Bath, 1 x Shower, 2 x WHB, 1 x Kitchen Sink	140 litres	2 kW
3 Bed, 3 People	1 x Bathroom	1 x Bath, 1 x WHB, 1 x Kitchen Sink	140 litres	2 kW
3 Bed, 4 People	1 x Bathroom and 1 x En Suite	1 x Bath, 1 x Shower, 3 x WHB, 1 x Kitchen Sink	170 litres	3 kW
4 Bed, 4 People	1 x Bathroom and 1 x En Suite	1 x Bath, 1 x Shower, 3 x WHB, 1 x Kitchen Sink	190 litres	4 kW
4 Bed, 5 People	1 x Bathroom and 2 x En Suite	1 x Bath, 2 x Shower, 4 x WHB, 1 x Kitchen Sink	235 litres	4 kW
4 Bed, 6 People	2 x Bathroom and 1 x En Suite	2 x Bath, 1 x Shower, 4 x WHB, 1 x Kitchen Sink	280 litres	4 kW
5 Bed, 6 People	2 x Bathroom and 1 x En Suite	2 x Bath, 1 x Shower, 4 x WHB, 1 x Kitchen Sink	280 litres	5 kW

5.3.01 As mentioned previously it is important for the designer to consider the peak 10 minute and hourly demands. The cylinder sizing in Table 2 is based on keeping the primary load as low as reasonably practicable and assumes that power can be borrowed from that allocated for space heating. Smaller cylinder volumes are possible with larger heat exchangers.

5.4.00 There are three basic ways of heating the hot water using a store linked to a heat network:

Figure 3
1) Directly into the cylinder coil

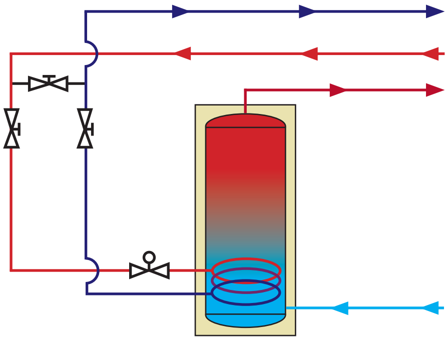


Figure 4
2) Indirectly into the cylinder coil via HIU

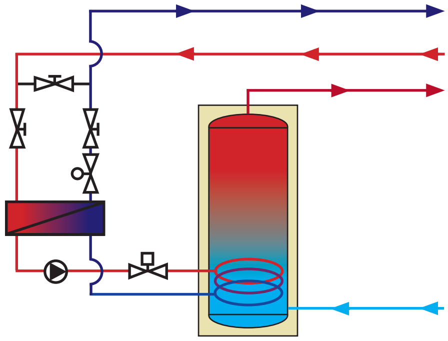
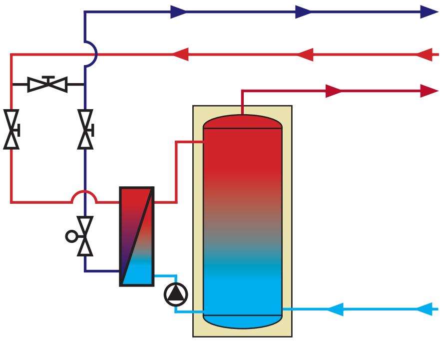


Figure 5
3) Indirectly into the cylinder via PHE

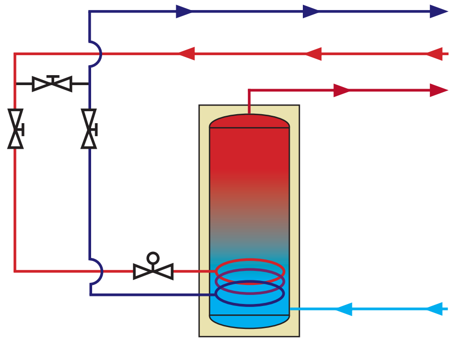
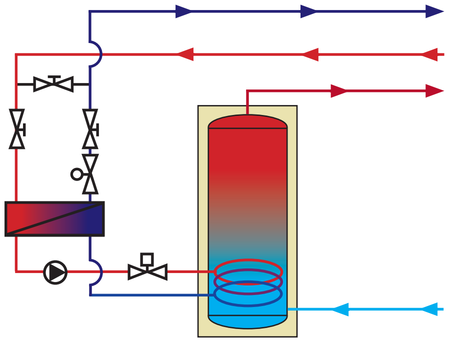
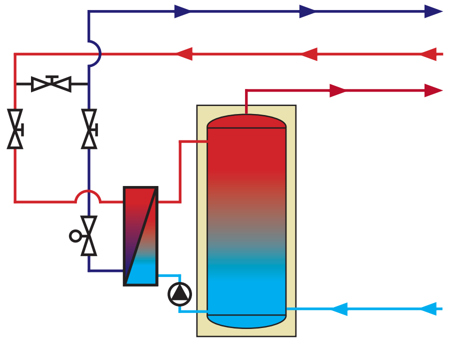


Note: Other methods of heat heating stored hot water are available, but outside the scope of this design guide.

5.5.00 Each of these options offer different advantages and disadvantages as detailed in Table 3.

Stored DHW in Heat Networks - Design Guide

Table 3 Cylinder Heat-up Method Comparison

 1) Directly into the cylinder coil	 2) Indirectly into the cylinder coil via heat inter-face unit	 3) Indirectly into the cylinder via plate heat exchanger
Advantages	Advantages	Advantages
Direct primary connection, therefore simpler and lower cost than 2 and 3	Indirect primary connection with heat exchanger for pressure separation. Heat network can be kept outside the apartment.	Faster recovery of usable hot water than 1 and 2. Low hot water flow rate to tap through plate heat exchanger when tank depleted.
Detaches DHW demand from heat supply and so power input can be manipulated.	Detaches DHW demand from heat supply and so power input can be manipulated.	Detaches DHW demand from heat supply and so power input can be manipulated.
Primary supply turns off when satisfied, i.e. no need for >50°C keep warm primary circuits.	Primary supply turns off when satisfied, i.e. no need for >50°C keep warm primary circuits.	Primary supply turns off when satisfied, i.e. no need for >50°C keep warm primary circuits.
Lower primary flow temperatures required than 2.	Higher Primary flow and return than 1 and 3 increasing heat network loss.	Lower primary flow temperatures required than 2, lower return than 1 and 2.
Smaller heat network pipes than 2 due to higher ΔT (pipe, pump etc) no heat exchanger.	Larger network pipes than 2 and three depending on number of heat exchange steps in network.	Larger ΔT in primary system with lower primary return temperatures (circa 15°C at design) than 1 and 2. Resulting in smaller heat network pipes lower heat loss and pumping costs than 1 & 2.
Can run set back regimes with ΔT control.	Can run set back regimes with ΔT control.	Can run set back regimes with ΔT control.
Can integrate electrical back-up for extra consumer security and turn off heat network in summer.	Can integrate electrical back-up for extra consumer security and turn off heat network in summer.	Can integrate electrical back-up for extra consumer security and turn off heat network in summer.
Store in dwelling negates requirement for primary thermal storage in network or plantroom.	Store in dwelling negates requirement for primary thermal storage in network or plantroom.	Store in dwelling negates requirement for primary thermal storage in network or plantroom.
Can stage cylinder reheat.	Can stage cylinder reheat.	Can stage cylinder reheat.
No extra pump required.	Extra pump required compared to 1.	Small DHW pump for charging and sterilisation of tank compared to 1.
DHW temperature control ok at all flow rates.	DHW temperature control ok at all flow rates.	DHW temperature control ok at all flow rates.
Simple thermostatic control for return temperature limitation.	Simple thermostatic control for return temperature limitation.	Simple electronic temperature control for return temperature limitation.
Uses standard S plan style controls.	Uses standard S plan style controls.	Dedicated controllers for smart system operation with electrical backup.
		Lower peak primary flow rates than 1 and 2. Lower ΔP than 1 and 2.
Disadvantages	Disadvantages	Disadvantages
Higher primary return temperatures than 3.	Higher heat loss across network than 1 and 3	More space required than for 1.
DHW limited to volume of the cylinder before reheat	DHW limited to volume of the cylinder before reheat.	DHW limited to capacity of cylinder mitigated by low continuous potential flow rate through plate heat exchanger and pump circuit to tap.
Longer time to recover to usable hot water temperatures than 3.	Longer time to recover to usable hot water temperatures than 3.	Additional pump required for DHW.
Lower primary ΔTs across network than 3.	Lower primary Δ Ts across network than 1 & 3. Higher primary temperatures than 1 and 3. .	
Ensure primary control valve can cope with ΔPs.	More space required than for 1	More space required than for 1.
	Higher Unit costs than 1,	Higher Unit costs than 1 and 2.
	Two circuits require water treatment and additional pump and controls	

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6.0 Understanding the total diversified load

6.0.01 There are a number of standards and codes which deal with the diversity of hot water systems. DS439 is a Danish standard which has been endorsed by CIBSE in CP1 and is widely used for heat network design. These standards tend to deal with the level of diversity or coincidental hot water load in terms of its peak instantaneous usage. The designer should be aware that irrespective of whether you are using an instantaneous HIU or a hot water cylinder to generate the hot water, the level of hot water used at the taps at any one peak time will remain the same.

6.0.02 That said, instantaneous diversity is not the same as operational diversity, in that operational diversity takes into account the equipment being used, the control strategy being deployed and the occupancy level being served.

6.0.03 When considering operational diversity of a heat network incorporating stored water we need to consider how the recovery of the cylinders is being controlled. Tables 4 and 5 details the coincidence factor which can be applied to a heat network where the cylinder recovery is being controlled on a temperature only basis. If recovery is held off ie by a timer or recovery across the network is either staged or runs on a setback regime the effects of this need to be built into the system design.

6.1 Coincidence factor for stored hot water

6.1.01 In general, for developments with over 40 small apartments, an old rule of thumb of adding 1kW on to the space heating load used to provide more than adequate central boiler power for heating and hot water production across the site. This is providing there is sufficient stored water to meet the peak 10 minute demand. (Above 40 apartments the diversity curve starts to level off).

6.1.02 Firstly and most importantly cylinders detached the demand for hot water from the supply of power, unlike instantaneous system where the power has to be aligned with the maximum simultaneous demand at the taps.

6.1.03 The second point which relates to the first point, is that when the cylinders are recharging they will all be at different points in the heat up process across the network. Some will have more hot water to charge up than others and they will all be at different mean store temperatures. It is worth noting that the primary coil in an indirect cylinder runs at different power ratings depending on the hot water temperature in the cylinder. Where an external heat exchanger is used to charge the store, it will allow the power drawn from the system to remain relatively constant in a good stratifying cylinder through its recovery cycle provided the flow rates through the heat exchanger remain the same.

6.1.04 Thirdly, the peak simultaneous demand of hot water doesn't change irrespective of whether the hot water is produced via a cylinder or a plate heat exchanger, that peak demand remains the same. It is common place that the peak instantaneous hot water load during the day is reached even when the peak daily hot water used is not. In fact due to occupancy levels and peoples different hot water usage, the average daily usage of hot water per person across a development housing around 100 people can be as low as 21 litres per person per day during the holiday season. (See VDI:6002)

6.1.05 The forth point is the position of the cylinder thermostats / temperature sensors, which are approximately a third of the way up the tank. In a stratifying cylinder, this has the effect of holding off the cylinder reheat period until about a third of the cylinders hot water has been used. This is not an insignificant point as this is where the load levelling effect of a cylinder comes into play. So it is quite feasible that someone could take a shower and the temperature at the cylinder thermostat doesn't drop below its set point to activate recharging the cylinder. This leaves approximately 2/3rds of the stored water available at the moment when the thermostat cuts in. This point is supported further by the fact that the store temperature is held around 60^{o}C and then blended down at the taps and so not all of the water used at the shower or bath comes straight from the cylinder.

6.1.06 Another factor is that instantaneous hot water systems are far more sensitive to fluctuations in changes in the heat network than stored water solutions. If the demand on the system can not be accurately met and controlled a drop in performance can be experienced at the taps. Whereas a system that incorporates hot water cylinders is far more forgiving to the fluctuating demands put on the heat network.

6.1.07 Finally, it is common practice when designing a heat network to add the full space heating load of the building to the total diversified hot water load. For systems with a hot water priority function on the HIUs, designers may use the inverse of the hot water diversity factor and apply this to the aggregated space heating load to reduce this slightly. It is worth noting here that even in the highly unlikely event that space heating is activated in every apartment, it is improbable that all apartments will be drawing off full space heating load from the network at the same time. This is especially the case as the building temperature rises and demand cuts in and out on the room thermostats and the HIU control valves modulate down. Diversified space heating loads are not within the scope of this document and so therefore where a designer has calculated the diversified space heating load this can be added to the diversified hot water recovery and communal space heating loads to arrive at a total peak load.

6.1.08 As mentioned earlier stored hot water systems are far more tolerant to the fluctuating demands put on the heat network than instantaneous hot water systems. Therefore when designing a system that incorporates a stored hot water solution, it is accepted that the primary heat supplied to a dwelling for space heating purposes can be used to help recharge the hot water store. This statement is made on the assumption that the primary control valve is common for both space heating and hot water recovery.

6.1.09 Designers should base their calculations on the assumption that prior to any peak draw off, the cylinder is fully charged with hot water.

6.1.10 Therefore:

Total Peak Load (kW) = Diversified Hot Water Recovery Load + Diversified Space Heating Load + Communal Heating Load

6.2 Having arrived at a total undiversified hot water load, apply the coincidence factor associated with the size of the development as detailed in Tables 4 and 5. This will give a peak hot water production load and this can then be added to the space heating loads.

6.2.01 Tables 4 and 5 show the hot water storage recovery coincidence factor. This indicates the percentage of the total output of the system that could be operational at any one time. This can be applied to smaller sections of a larger system for calculating pipe sizes and flow rates.

Table 4 - Diversification Factors for Stored Hot Water Recovery from 1 to 250 apartments

Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor
1	100.00%	51	20.51%	101	15.92%	151	13.96%	201	12.81%
2	96.01%	52	20.35%	102	15.87%	152	13.93%	202	12.80%
3	81.00%	53	20.20%	103	15.81%	153	13.90%	203	12.78%
4	71.78%	54	20.05%	104	15.76%	154	13.87%	204	12.76%
5	64.56%	55	19.91%	105	15.71%	155	13.85%	205	12.74%
6	58.07%	56	19.77%	106	15.66%	156	13.82%	206	12.72%
7	53.20%	57	19.63%	107	15.61%	157	13.79%	207	12.71%
8	49.40%	58	19.50%	108	15.56%	158	13.77%	208	12.69%
9	46.32%	59	19.37%	109	15.51%	159	13.74%	209	12.67%
10	43.78%	60	19.25%	110	15.47%	160	13.71%	210	12.65%
11	41.63%	61	19.12%	111	15.42%	161	13.69%	211	12.64%
12	39.78%	62	19.00%	112	15.37%	162	13.66%	212	12.62%
13	38.18%	63	18.89%	113	15.33%	163	13.64%	213	12.60%
14	36.77%	64	18.78%	114	15.28%	164	13.61%	214	12.59%
15	35.52%	65	18.67%	115	15.24%	165	13.58%	215	12.57%
16	34.40%	66	18.56%	116	15.19%	166	13.56%	216	12.55%
17	33.39%	67	18.45%	117	15.15%	167	13.54%	217	12.54%
18	32.48%	68	18.35%	118	15.11%	168	13.51%	218	12.52%
19	31.64%	69	18.25%	119	15.07%	169	13.49%	219	12.50%
20	30.88%	70	18.15%	120	15.02%	170	13.46%	220	12.49%
21	30.17%	71	18.06%	121	14.98%	171	13.44%	221	12.47%
22	29.52%	72	17.96%	122	14.94%	172	13.42%	222	12.46%
23	28.92%	73	17.87%	123	14.90%	173	13.39%	223	12.44%
24	28.35%	74	17.78%	124	14.86%	174	13.37%	224	12.43%
25	27.83%	75	17.70%	125	14.83%	175	13.35%	225	12.41%
26	27.33%	76	17.61%	126	14.79%	176	13.32%	226	12.39%
27	26.87%	77	17.53%	127	14.75%	177	13.30%	227	12.38%
28	26.44%	78	17.44%	128	14.71%	178	13.28%	228	12.36%
29	26.02%	79	17.36%	129	14.67%	179	13.26%	229	12.35%
30	25.64%	80	17.28%	130	14.64%	180	13.23%	230	12.33%
31	25.27%	81	17.21%	131	14.60%	181	13.21%	231	12.32%
32	24.92%	82	17.13%	132	14.57%	182	13.19%	232	12.30%
33	24.59%	83	17.06%	133	14.53%	183	13.17%	233	12.29%
34	24.27%	84	16.98%	134	14.50%	184	13.15%	234	12.28%
35	23.97%	85	16.91%	135	14.46%	185	13.13%	235	12.26%
36	23.68%	86	16.84%	136	14.43%	186	13.11%	236	12.25%
37	23.41%	87	16.77%	137	14.39%	187	13.09%	237	12.23%
38	23.15%	88	16.70%	138	14.36%	188	13.07%	238	12.22%
39	22.89%	89	16.64%	139	14.33%	189	13.05%	239	12.20%
40	22.65%	90	16.57%	140	14.30%	190	13.02%	240	12.19%
41	22.42%	91	16.51%	141	14.26%	191	13.00%	241	12.18%
42	22.20%	92	16.44%	142	14.23%	192	12.99%	242	12.16%
43	21.98%	93	16.38%	143	14.20%	193	12.97%	243	12.15%
44	21.77%	94	16.32%	144	14.17%	194	12.95%	244	12.13%
45	21.57%	95	16.26%	145	14.14%	195	12.93%	245	12.12%
46	21.38%	96	16.20%	146	14.11%	196	12.91%	246	12.11%
47	21.20%	97	16.14%	147	14.08%	197	12.89%	247	12.09%
48	21.02%	98	16.09%	148	14.05%	198	12.87%	248	12.08%
49	20.84%	99	16.03%	149	14.02%	199	12.85%	249	12.07%
50	20.67%	100	15.98%	150	13.99%	200	12.83%	250	12.05%

Note: The coincidence factors in Table 4 are based on hot water storage recovery under temperature control only.

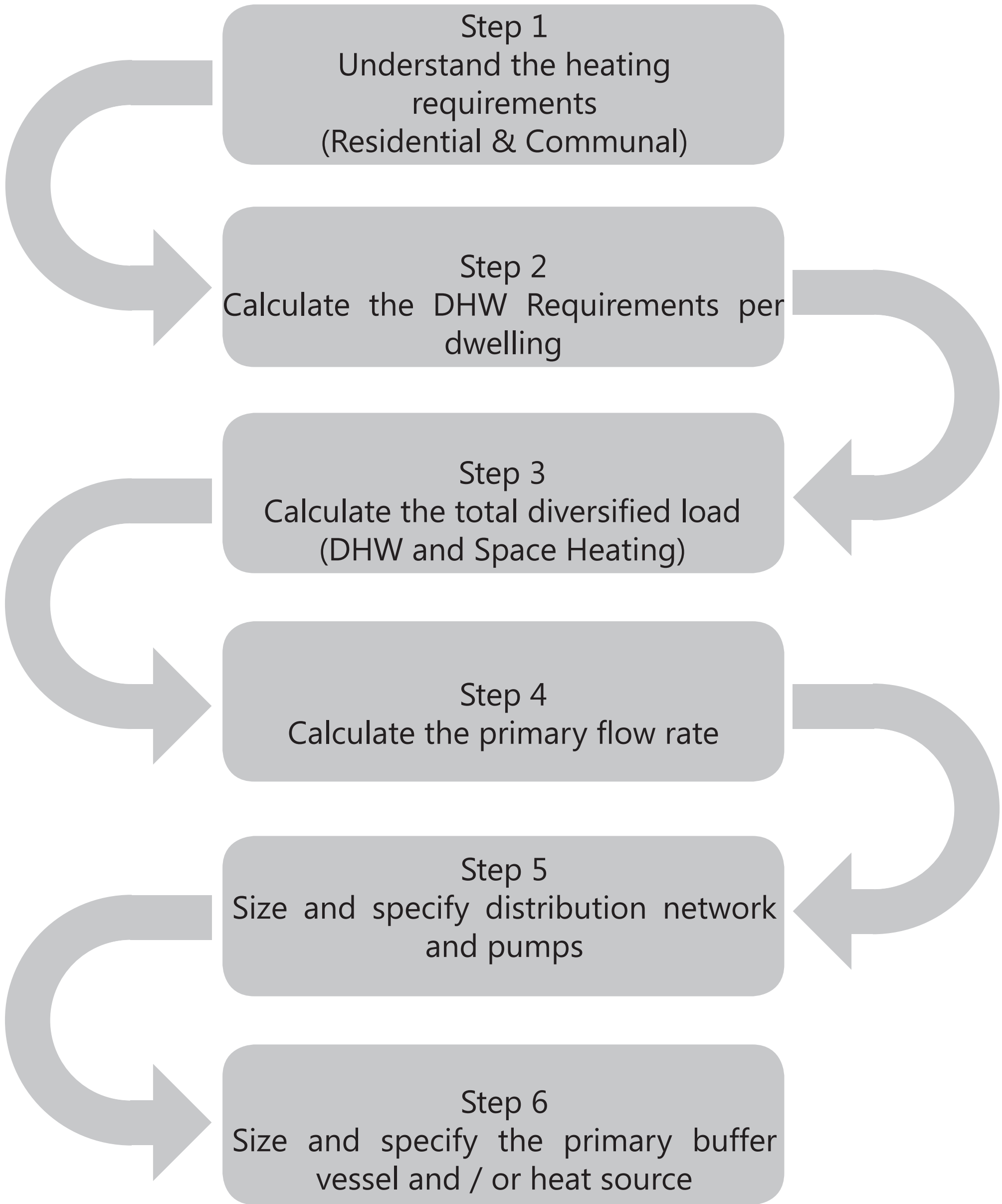
Table 5 - Diversification Factors for Stored Hot Water Recovery from 251 to 500 apartments

Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor	Number of Apartments	Coincidence Factor
251	12.04%	301	11.48%	351	11.04%	401	10.69%	451	10.41%
252	12.03%	302	11.47%	352	11.03%	402	10.69%	452	10.40%
253	12.02%	303	11.46%	353	11.03%	403	10.68%	453	10.40%
254	12.00%	304	11.45%	354	11.02%	404	10.67%	454	10.39%
255	11.99%	305	11.44%	355	11.01%	405	10.67%	455	10.38%
256	11.98%	306	11.43%	356	11.00%	406	10.66%	456	10.38%
257	11.97%	307	11.42%	357	11.00%	407	10.66%	457	10.37%
258	11.95%	308	11.41%	358	10.99%	408	10.65%	458	10.37%
259	11.94%	309	11.40%	359	10.98%	409	10.64%	459	10.36%
260	11.93%	310	11.39%	360	10.97%	410	10.64%	460	10.36%
261	11.92%	311	11.38%	361	10.97%	411	10.63%	461	10.35%
262	11.90%	312	11.37%	362	10.96%	412	10.63%	462	10.35%
263	11.89%	313	11.36%	363	10.95%	413	10.62%	463	10.34%
264	11.88%	314	11.35%	364	10.94%	414	10.61%	464	10.34%
265	11.87%	315	11.34%	365	10.94%	415	10.61%	465	10.33%
266	11.86%	316	11.34%	366	10.93%	416	10.60%	466	10.33%
267	11.84%	317	11.33%	367	10.92%	417	10.60%	467	10.32%
268	11.83%	318	11.32%	368	10.92%	418	10.59%	468	10.32%
269	11.82%	319	11.31%	369	10.91%	419	10.58%	469	10.31%
270	11.81%	320	11.30%	370	10.90%	420	10.58%	470	10.31%
271	11.80%	321	11.29%	371	10.89%	421	10.57%	471	10.30%
272	11.79%	322	11.28%	372	10.89%	422	10.57%	472	10.30%
273	11.77%	323	11.27%	373	10.88%	423	10.56%	473	10.29%
274	11.76%	324	11.26%	374	10.87%	424	10.55%	474	10.29%
275	11.75%	325	11.26%	375	10.87%	425	10.55%	475	10.28%
276	11.74%	326	11.25%	376	10.86%	426	10.54%	476	10.28%
277	11.73%	327	11.24%	377	10.85%	427	10.54%	477	10.27%
278	11.72%	328	11.23%	378	10.84%	428	10.53%	478	10.27%
279	11.71%	329	11.22%	379	10.84%	429	10.53%	479	10.27%
280	11.70%	330	11.21%	380	10.83%	430	10.52%	480	10.26%
281	11.68%	331	11.20%	381	10.82%	431	10.51%	481	10.26%
282	11.67%	332	11.20%	382	10.82%	432	10.51%	482	10.25%
283	11.66%	333	11.19%	383	10.81%	433	10.50%	483	10.25%
284	11.65%	334	11.18%	384	10.80%	434	10.50%	484	10.24%
285	11.64%	335	11.17%	385	10.80%	435	10.49%	485	10.24%
286	11.63%	336	11.16%	386	10.79%	436	10.49%	486	10.23%
287	11.62%	337	11.15%	387	10.78%	437	10.48%	487	10.23%
288	11.61%	338	11.15%	388	10.78%	438	10.48%	488	10.22%
289	11.60%	339	11.14%	389	10.77%	439	10.47%	489	10.22%
290	11.59%	340	11.13%	390	10.76%	440	10.46%	490	10.21%
291	11.58%	341	11.12%	391	10.76%	441	10.46%	491	10.21%
292	11.57%	342	11.11%	392	10.75%	442	10.45%	492	10.20%
293	11.56%	343	11.11%	393	10.74%	443	10.45%	493	10.20%
294	11.55%	344	11.10%	394	10.74%	444	10.44%	494	10.19%
295	11.54%	345	11.09%	395	10.73%	445	10.44%	495	10.19%
296	11.53%	346	11.08%	396	10.72%	446	10.43%	496	10.19%
297	11.52%	347	11.07%	397	10.72%	447	10.43%	497	10.18%
298	11.51%	348	11.07%	398	10.71%	448	10.42%	498	10.18%
299	11.50%	349	11.06%	399	10.71%	449	10.42%	499	10.17%
300	11.49%	350	11.05%	400	10.70%	450	10.41%	500	10.17%

Note: The coincidence factors in Table 5 are based on hot water storage recovery under temperature control only.

7.0 Sizing procedure

Figure 6 - Sizing Procedure



8.0 Sizing example (following the procedure set out in section 7 Figure 6).

8.1.00 Example - Heating and Hot Water Loads / details.
A block of 100 private apartments has follows:
50 No. one bedroom apartments serving 2 people, with each apartment having a 2.0kW space heating load
30 No. two bedroom apartments serving 3 people, with each apartment having a 3.0kW space heating load.
20 No. three bed apartments serving 4 people, with each apartment having a 4.25kW space heating load.
The total undiversified space heating load for the dwellings is 275kW and for the communal areas it is 25kW.
The Stored Hot Water HIUs being used do not have a hot water priority function.
The primary flow temperature is 80^{O}C.
The space heating design temperatures are 60^{O}C flow / 40^{O}C Return.

8.2.00 Step 1 - Understand the space heating requirements - both residential and communal
8.2.01 The total undiversified space heating load for the dwellings is 275kW and for the communal areas it is 25kW
8.2.02 No space heating diversity data is applied.

8.3.00 Step 2 - Calculate the DHW requirements
8.3.01 Using the figures set out in Table 2, we get:

8.3.02 The aggregated individual peak DHW production load is:

One Bed / 2 People Apartments:	50 x 1.5kW =	75 kW
Two Bed / 3 People Apartments:	30 x 2kW =	60 kW
Three Bed / 4 People Apartments:	20 x 3kW =	60 kW
Total:		195 kW

8.4.00 Step 3 - Calculate the Total Diversified Loads - DHW and Space Heating

8.4.01 From Table 4 and 5 the coincidence factor for 100 apartments is 15.98%

8.4.02 Therefore the total diversified hot water recovery load = 195kW x 15.98% = 31.16kW

8.4.03 As mentioned in 8.2.2 No space heating diversity data is applied, therefore use 275kW + 25kW ie 300kW.

8.4.04 For the total peak load on the central plant we then add the total diversified hot water load to the total diversified space heating load and the communal space heating load. Thus:

8.4.05 Total Peak Load = 31.16kW + 275kW + 25kW = 331.16kW

8.5.00 Step 4 - Calculate the primary flow rate

8.5.01 To calculate the total primary flow rate the designer needs to know primary flow temperature and cylinder recovery rate and the diversification factors.

8.5.02 As you move away from the primary heat source in the system, the level of diversity will come down and the coincidence factor percentage will increase.

8.5.03 Should manufacturers be unable to advise what primary flow rate is required to achieve a specific primary flow temperature, use an average delta T of 20K across the primaries to calculate the primary flow rate at the required recovery rate. Where an external plate heat exchanger is used it is likely that a higher delta T can be applied, thus lowering the primary flow rate.

8.5.04 Primary flow Rate PFR_{HTG} (l/s) = Heat Load (kW) / [Density of Water (kg/l) x Specific Heat (kJ/kgK) x Δt (K)]

Refer to Appendix 1 and 2 for the density and specific heat of water at a given mean temperature.

8.5.05 It is important to note that unlike instantaneous hot water HIUs, stored water HIUs do not tend to operate with a hot water priority system. Therefore the primary flow rate for both space heating and hot water recovery should be taken into account.

8.5.06 That said it is worth pointing out that full space heating load and hot water recovery will seldom be required at the same time. Therefore the designer may wish to reduce the central plant capacity by allowing the space heating and hot water recovery to share a lower design load than the aggregated load. This statement is made in the knowledge that using a smaller shared load would result in the space heating and cylinder recovery taking a little longer to get up to temperature during these few and far between times.

8.5.07 The statement made in 8.5.05 is particularly valid where the space heating load is much greater than the hot water recovery load and / or the space heating load is also zoned.

Important: If a reduced space heating allowance is used it is recommended that the storage volume is at least equal to that listed in Table 2.

8.5.08 Calculating the primary design flow rate for stored hot water in the sizing example:

One Bed / 2 People Apartments:	50 x 1.5kW =	75 kW
Two Bed / 3 People Apartments:	30 x 2.0kW =	60 kW
Three Bed / 4 People Apartments:	20 x 3.0kW =	60 kW
Total:		195 kW

8.5.09 Using equation 8.5.04 and based on a mean primary ΔT of 20K we get primary design flow rates for cylinder recovery of:

One Bed Apartments:	[1.5 / 0.978 x 4.19 x 20] = 0.0183 l/s x 50 =	0.915 l/s
Two Bed Apartments:	[2.0 / 0.978 x 4.19 x 20] = 0.0244 l/s x 30 =	0.732 l/s
Three Bed Apartments:	[3.0 / 0.978 x 4.19 x 20] = 0.0366 l/s x 20 =	0.732 l/s
Total:		2.379 l/s

8.5.10 From Table 4 and 5 the coincidence factor (CF) for 100 apartments is 15.98%

8.5.11 Diversified primary flow rate for hot water production $PFR_{\text{DHW RECOVERY}}$ = 2.379 l/s x 0.1598 = 0.381 l/s
Or
Diversified Primary flow Rate $PFR_{\text{DHW RECOVERY}}$(l/s)=Heat Load (kW) x CF/[Density of Water (kg/l) x Specific Heat (kJ/kgK) x Δt (K)]

8.5.12 Note the diversified primary flow rate is based on the required primary flow rate to achieve the diversified peak output of 31.16kW. (ie $q_{\text{DHW RECOVERY}}$ = 195kW x 0.1598 = 31.16kW)

8.5.13 Calculating the primary design flow rate for Space Heating

8.5.14 In general, the approach temperatures in plate heat exchangers used for space heating tend to be low and so a figure of 5K can be used.

8.5.15 Therefore, we can expect a primary return temperature of 5K above the space heating return temperature.

8.5.16 Based on space heating temperatures of F/R 60/40^{o}C and a primary flow temperature of 80^{o}C the subsequent primary return temperatures will be 45^{o}C. Thus giving a temperature differential across the primaries of 35K

8.5.17 The total space heating load for the dwellings is 275kW and the load for the communal areas is 25kW.

8.5.18 Based on a temperature differential of 35K, calculate the total space heating load for the apartments as follows:

Primary flow Rate $PFR_{\text{SPACE HTG}}$ (l/s) = Heat Load (kW) / [Density of Water x Specific Heat (kJ/kgK) x Δt (K)]

Primary flow Rate $PFR_{\text{SPACE HTG}}$ (l/s) = 275kW / [0.9818 kg/l x 4.186 kJ/kgK x 35K]

Primary flow Rate $PFR_{\text{SPACE HTG}}$ (l/s) = 1.912 l/s

8.5.19 Based on a temperature differential of 35K, calculate the total space heating load for the communal areas as follows:

Primary flow Rate $PFR_{\text{Comm HTG}}$ (l/s) = 25kW / [0.9818kg/l x 4.186kJ/kgK x 35K]

Primary flow Rate $PFR_{\text{Comm HTG}}$ (l/s) = 0.174 l/s

8.5.20 Therefore the Total Primary Flow Rate can be calculated as follows:

Total Primary Flow Rate PFR_{Total} = $PFR_{\text{DHW RECOVERY}}$ + PFR_{HTG} + $PFR_{\text{COMM HTG}}$

Total Primary Flow Rate PFR_{Total} = (0.381 l/s + 1.912 l/s + 0.174 l/s)

Total Primary Flow Rate PFR_{Total} = 2.467 l/s

Note: On heat networks where cylinders are fitted in each apartment, there is no need for a continuous flow of water around the system to keep the flow pipework hot. There will be a need to protect the distribution pumps from operating below their minimum limits. In which case protection of the pumps can be achieved by using reverse acting DPCVs.

8.5.21 Primary Design Flow Rates
The design flow rate reduces and the level of coincidence increases as you move towards the extremities of the system.

8.5.22 If we consider the simple diagram in Figure 7, the pipework closest to the heat source needs to carry the greatest volume of water and this is reflected in the size of the pipework.

8.5.23 When sizing the primary pipework, levels of diversity should be applied. For hot water recovery diversity should be applied in accordance with Tables 4 and 5. An example is detailed in Figure 7 and Table 6.

Figure 7 Reference points within the network

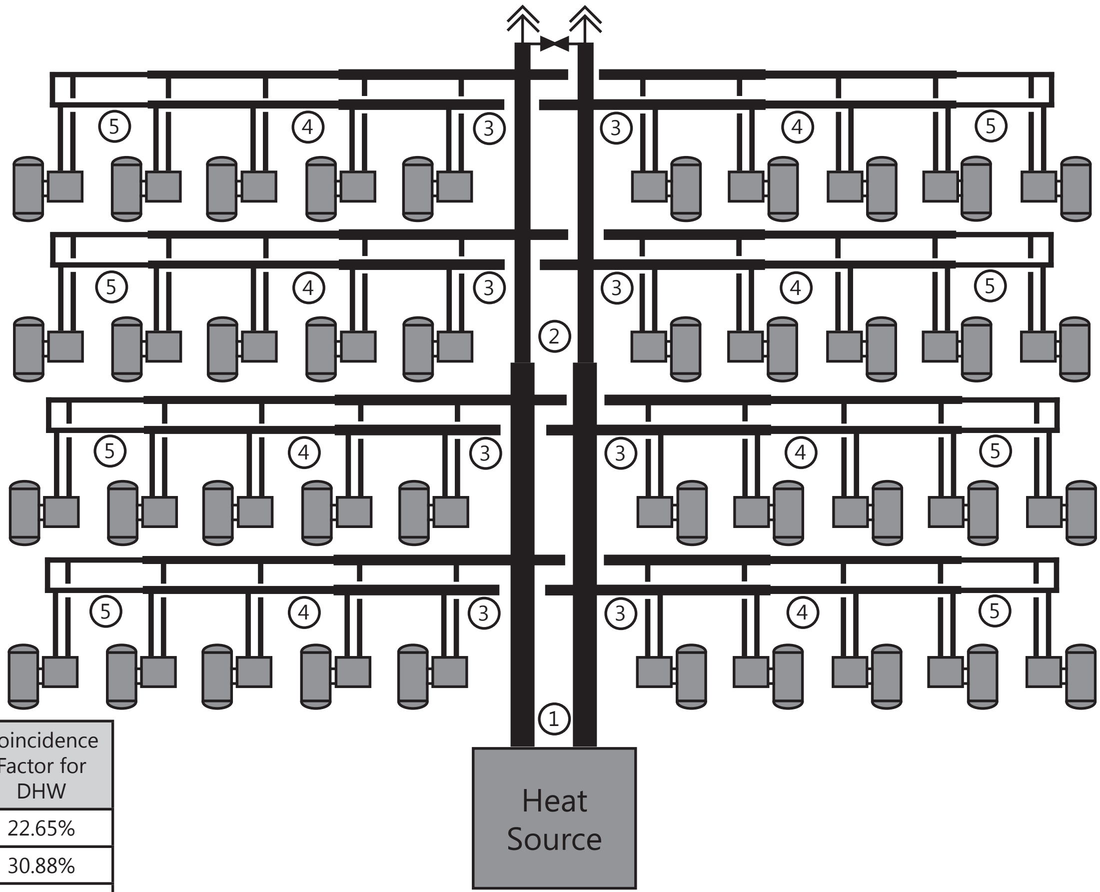


Table 6

Pipework Position	Units Being Served	Coincidence Factor for DHW
1	40	22.65%
2	20	30.88%
3	5	64.56%
4	3	81.00%
5	1	100.00%

Note: This diagram is representative only and does not constitute design.

8.6.00 Step 5 - Size and specify distribution network

8.6.01 Once the design flow rates have been established for all the units within the system, the pipes can be sized and selected depending on how many units each section of pipework is serving.

8.6.02 Designers should be aware that they need to think about the velocity in the different parts of their system and how they design as a function of the delta P they design for in those parts of the system. The method of sizing the pipework will depend on the material that the pipes are made from and the pipe manufacturer's information in relation to velocity, temperature and pressure drop.

8.6.03 In general, but subject to specific site conditions, pipes can be sized on 200Pa/m, however, the smaller diameter pipes (ie. at the consumer end) can be sized to keep velocities below 1.5 m/s during peak flow periods. It is worth noting that fully modulating systems will seldom run in these peak design conditions and so designing the heat network to permit short spells of higher velocities (ie 15%) could result in optimum pipe sizes and lower heat losses.

8.6.04 Using our example and keeping velocities at the terminal end of the network below 1.5m/s:

Apartment Design Flow Rate = Primary flow Rate $PFR_{DHW\ RECOVERY}$ (l/s) + Primary flow Rate $PFR_{SPACE\ HTG}$ (l/s)

One Bed Apartments: = [1.5 / 0.978 x 4.19 x 20] + [2.0 / 0.9818 x 4.186 x 35] = 0.0183 l/s + 0.0139 l/s = 0.0322 l/s
Two Bed Apartments: = [2.0 / 0.978 x 4.19 x 20] + [3.0 / 0.9818 x 4.186 x 35] = 0.0244 l/s + 0.0209 l/s = 0.0453 l/s
Three Bed Apartments: = [3.0 / 0.978 x 4.19 x 20] + [4.25 / 0.9818 x 4.186 x 35] = 0.0366 l/s + 0.0295 l/s = 0.0661 l/s

8.6.05 Using appendix 3 as a sizing guide, the designer may be able to use the following terminal pipework:

One Bed Apartments: 10mm Copper Pipe
Two Bed Apartments: 10mm Copper Pipe
Three Bed Apartments: 12mm Copper Pipe

Note: Provided the main pumps have sufficient head capacity a 15mm pipe could serve 4 x one bedroom apartments, 3 x two bedroom apartments, or 2 x three bedroom apartments.

8.6.06 It is advised that in systems with water that has been artificially softened, velocities are lowered to reduce the risk of erosion (in such cases guidance should be sought).

8.6.07 When sizing the pipework it is also important to understand the impact on pump energy usage. There will always be a trade off between pipe size, which affects heat loss and the pump head and subsequently energy required to move fluid around the system. As such heat networks with extensive index runs may benefit from adopting lower velocity calculations in comparison to shorter runs within the system. Appendix 3 gives details of hydraulic resistance through copper pipes.

8.6.08 Consideration should be made to noise associated with fluid flow especially in more sensitive vicinities.

8.6.09 Pipe materials such as steel, copper, stainless steel and some plastics can be used, but your attention is drawn to the suitability of pipework to cope with the operating pressures and temperatures.

8.6.10 Note friction losses differ depending on the material used.

8.6.11 Wherever possible, always try to keep hot flow pipe lengths and diameters to a minimum, this will help reduce heat loss.

8.6.12 When sizing the DHW storage volumes and heat network pipework sizes, it is also important to understand the cylinder heat up regime. In this document we have covered systems that control the recharging of the stores on a temperature only basis. More advanced control systems can be used which hold off the reheating of hot water to help lower peak demands. In these cases it may lead to larger stores and a different approach to pipe sizing, which is not covered in the scope of this design guide.

8.7.00 Step 6 - Size and specify heat source and buffer vessel

8.7.01 Once the peak heating and hot water loads have been calculated, the centralised plant can be sized and selected.

8.7.02 The load within a heat network will vary during the day and time of year with periods of high hot water use during the winter leading to the highest requirement for power from the central plant / energy centre.

8.7.03 The heat load of a residential building will be determined by the people that are living in it. It is important to note that the diversity factors apply to buildings where people from all walks of life live. If a building's use differs from this such as a prison, student accommodation or a nursing home for example, it is important that the designer understands how the people living and using the building will impact on its services. In such cases important factors such has working shift patterns and tapping patterns may lead to unusually high peak loads which have to be accounted for.

8.8.00 Boiler sizing for heat network using stored hot water within each dwelling

8.8.01 When installing stored hot water systems in every apartment it isn't necessary to provide thermal stores or buffers in the plantroom as the hot water stores themselves act as thermal storage. As such this type of system is very tolerant to fluctuations in demand and as the effect of levelling the load, thus smoothing out the peaks and troughs in demand throughout the day.

8.8.02 However, where technologies such as CHP, biomass, solar thermal and heat pumps are part of the central plant, it may be beneficial to install a thermal store to deal with the intermittency of their operation. In which case the thermal store has to be sized to integrate the technology with the hot water stores in the network.

8.8.03 Therefore taking into account 8.8.1, to calculate the total boiler load for our example:

Total Boiler Output q_{TOTAL} (kW) = $q_{DHW\ RECOVERY} + q_{APT\ HTG} + q_{COMM\ HTG}$

Example:

q_{TOTAL} (kW) = 31.16 + 275 + 25

q_{TOTAL} = 331.16 kW

8.8.04 Therefore using the Bodle Orchard scheme as detailed in Figure 8 one illustrative selection might be:

CHP = 15% of the total load = 50kW
Boiler 1 = 10% of the total load = 33kW
Boiler 2 = 25% of the total load = 83kW
Boiler 3 = 50% of the total load = 166kW

Note: Splitting the load as above will offer a turn-down in excess of 10:1.

Where 100% standby is required it is recommended that an additional boiler at 50% of the total load should be provided.

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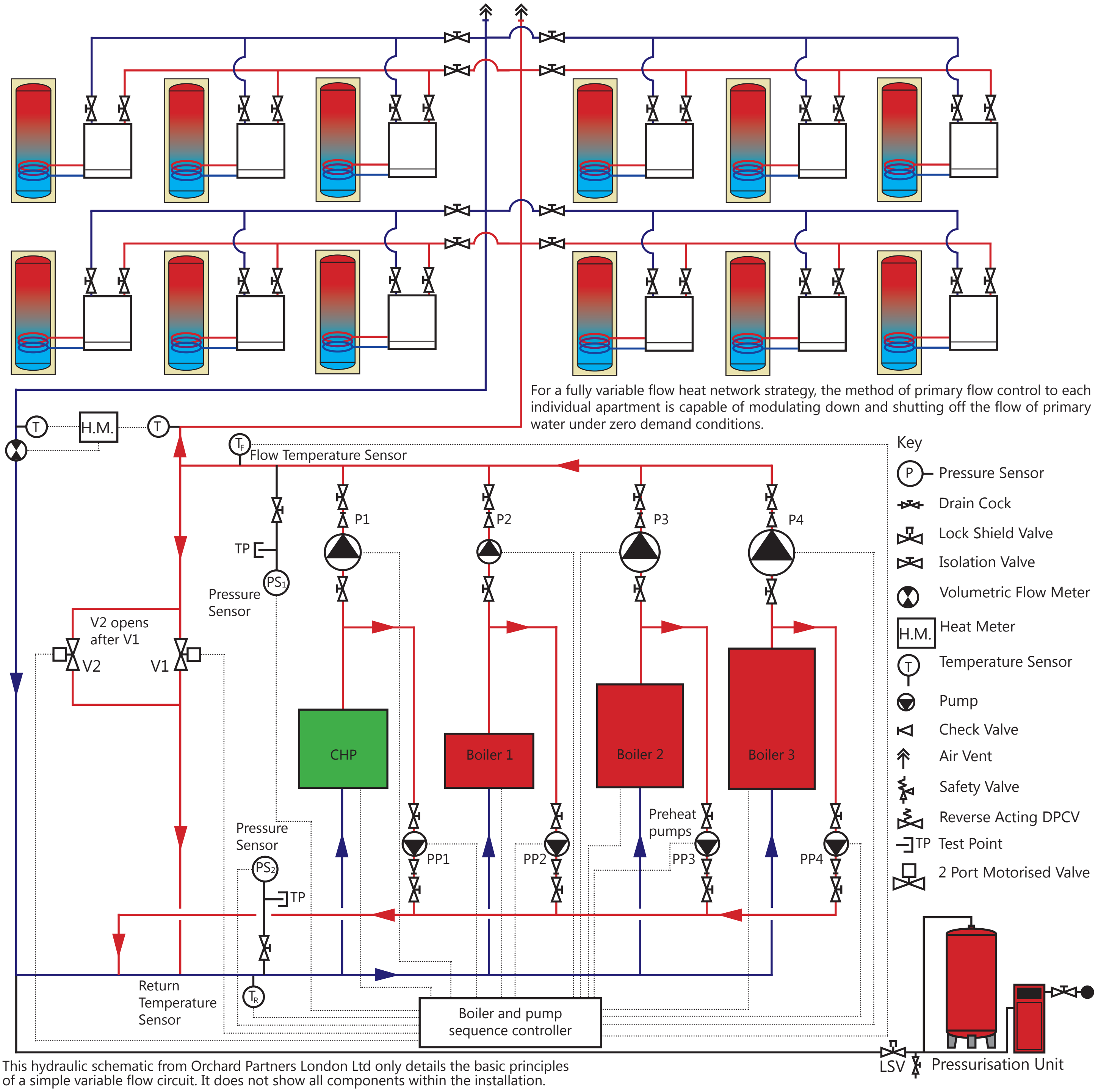
9.0 Heat Network Hydraulic and Control Design

Figure 8 Bodle-Orchard circuit to serve a fully variable flow heat network.



This hydraulic schematic from Orchard Partners London Ltd only details the basic principles of a simple variable flow circuit. It does not show all components within the installation.

9.0.01 Figure 8 shows a simple variable flow system, where the boiler house circuit is designed for constant volume through each boiler to match its design output and flow / return temperatures so that the load is followed by the heat source and its matching pump. This scheme is suitable for non-condensing heat sources such as CHP and Biomass.

9.0.02 The main pumps P1, P2, P3 and P4 and bypass valves V1 and V2 are sequenced to maintain a constant pressure leaving the plantroom i.e. across the pressure sensors PS_1 and PS_2. The main pumps are all specified to deliver the design flow rate to match the load they need to meet at the required system pump head. Fixed speed centrifugal pumps, in the simplest configuration, deliver pumping savings. Variable speed pumps are another option for varying the flow and pressure differential around a network. Condensing systems with variable speed pumps are not covered in this guide.

9.0.03 It is important that the boilers are sized and selected to provide the necessary turn down to closely match the seasonal variation in demand of the system. Note pumping energy in heat networks degrades to heat, which is a costly way to heat water, but not a loss.

9.0.04 The pre-heat pumps PP1, PP2, PP3 and PP4 are part of the sequence control and circulate hot water from the mixed return to warm the next heat source that is due on line. This prevents a slug of cold water being pumped from the initiated heat source, which would result in a reduction in the flow temperature leaving the plantroom as it starts up.

9.0.05 The CHP in the circuit is always in a position to take the lead and is brought up to full output before the boilers are sequenced.

9.0.06 The boilers are then sequenced to normally maintain a constant flow temperature as the flow rate demanded by the system varies.

9.0.07 The primary flow is controlled by 2 port modulating control valve(s) with differential pressure control located in each dwelling. The control valves vary the primary flow in the dwelling and also the overall flow in the heat network.

9.0.08 The control valves shut off the primary flow to the hot water stores and the dwellings heating system when there is no demand and therefore the primary pipes serving the dwellings cool, thus reducing heat and pumping losses.

9.0.09 As the primary control valves open and close around the network, a change in differential pressure is witnessed by the pressure sensors PS_1 and PS_2 and the bypass valves V1 and V2 are opened and closed to make fine adjustments to maintain the differential pressure leaving the plantroom. If the pressure differential continues to fall or rise the pumps and heat sources are either brought on line or taken off line respectively and the bypass valves trim the pressure differential accordingly.

9.0.10 Design of a fully variable flow heat network means that one can design for condensing operation of the boilers because low primary return temperatures can be maintained from emitters such as low surface temperature radiators on part load. Appendix 4 shows how the flow through a radiator at 50% heat load drops to around 20% and subsequently there is a reduction in the return water temperature. Low primary return temperatures can also come from tanks depending on how they are heated and controlled. Tanks that are fed by a plate heat exchanger and a small DHW pump can deliver the same return temperatures when charging as an instantaneous unit. This results in even lower overall system return temperatures because when charged, the primaries can turn off as there is no requirement for “keep warm” mode bypasses.

9.0.11 Further improvements in performance can be achieved by installing return temperature limiters, whether for tanks heating domestic hot water, or for radiators. Return temperature limitation can be done either thermostatically or electronically. But in principle they both control the design return water temperature and thus minimize heat loss from piping and also helps balance systems.

9.0.12 Using the Bodle-Orchard system design for heat networks with stored water in the dwellings means that centralised primary thermal stores / buffers are not required for the domestic hot water load. The designer should be aware that in systems incorporating a CHP unit, it is important that the CHP unit is not over sized. To get the most out of the CHP unit, it may be of benefit to intelligently heat the stores using the primary system when the price of electricity is high and so utilise both the primary system and electricity to heat the stores when the price for electricty is low. It may also be beneficial to dump surplus electrical energy from the grid caused by uncontrolled sources such and PV and wind farms. Hot water stores whose storage temperature set point can be increased, provides additional thermal storage capacity for these intermittent heat sources.

9.0.13 It is worth noting that heat networks that incorporate stored water in each dwelling are far less sensitive to any fluctuations in primary flow rates and flow temperatures when compared with systems that use instantaneous HIUs and therefore the responsiveness of the system is far less critical.

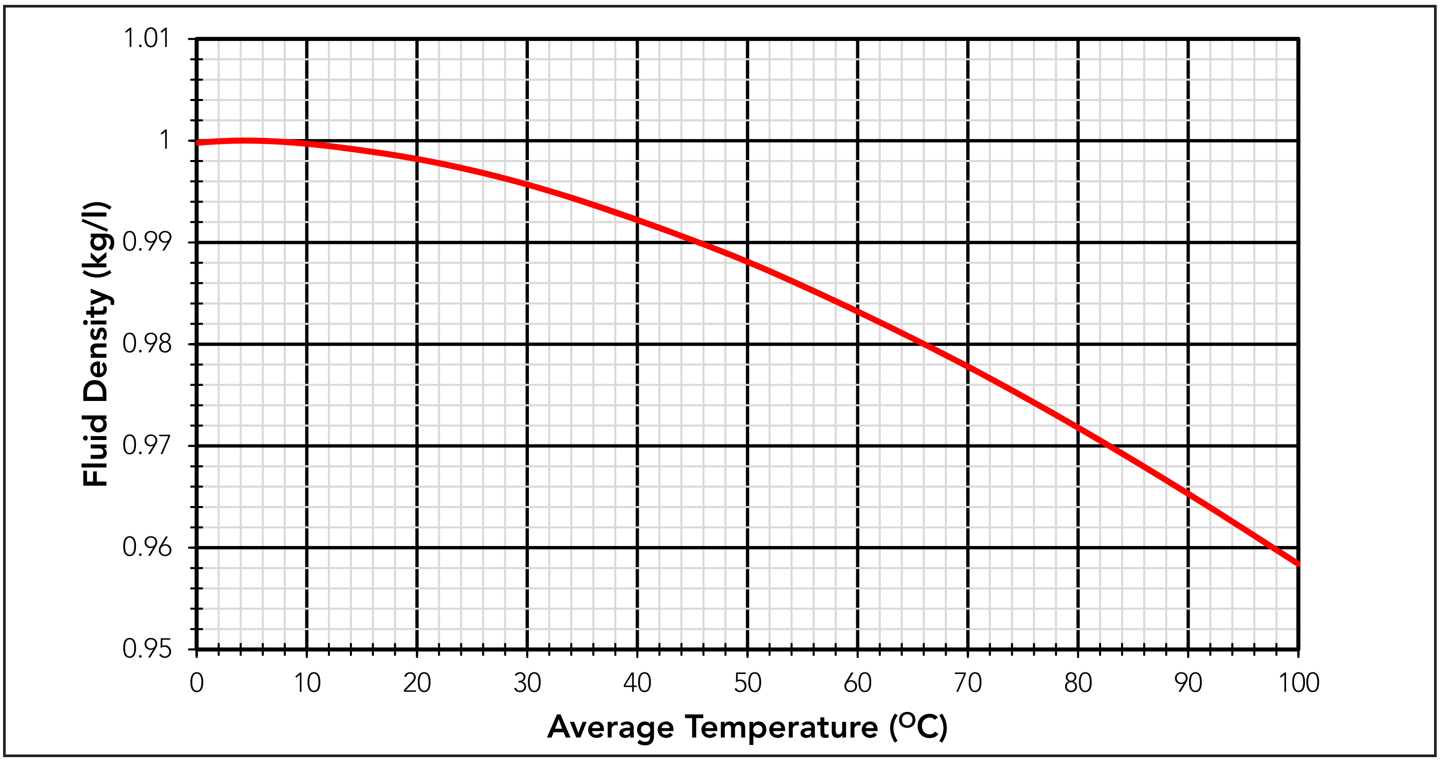
9.0.14 Designers should also be aware of the difference between a thermal buffer and a thermal store. A thermal buffer provides an additional volume of water to dampen down the effects of heat sources / systems that are slow to respond (ie to turn on / off and ramp up / down), such as biomass. Thermal stores on the other hand provide somewhere for heat sources such as centralised solar thermal systems to store their energy when it is available. They also provide somewhere to store energy from heat sources when it is at its lowest costs and use that energy when it is at its highest cost. A thermal store is usually connected in such a way that it is independent of the system and its operating temperatures.

9.0.15 In larger heat networks it may be beneficial for the home owner to fit solar thermal panels on their roof. In which case using a store in their dwelling that has a dedicated solar volume and solar thermal heat exchanger is a good way to make this possible. Advice and consent should always be sought from their heat network provider.

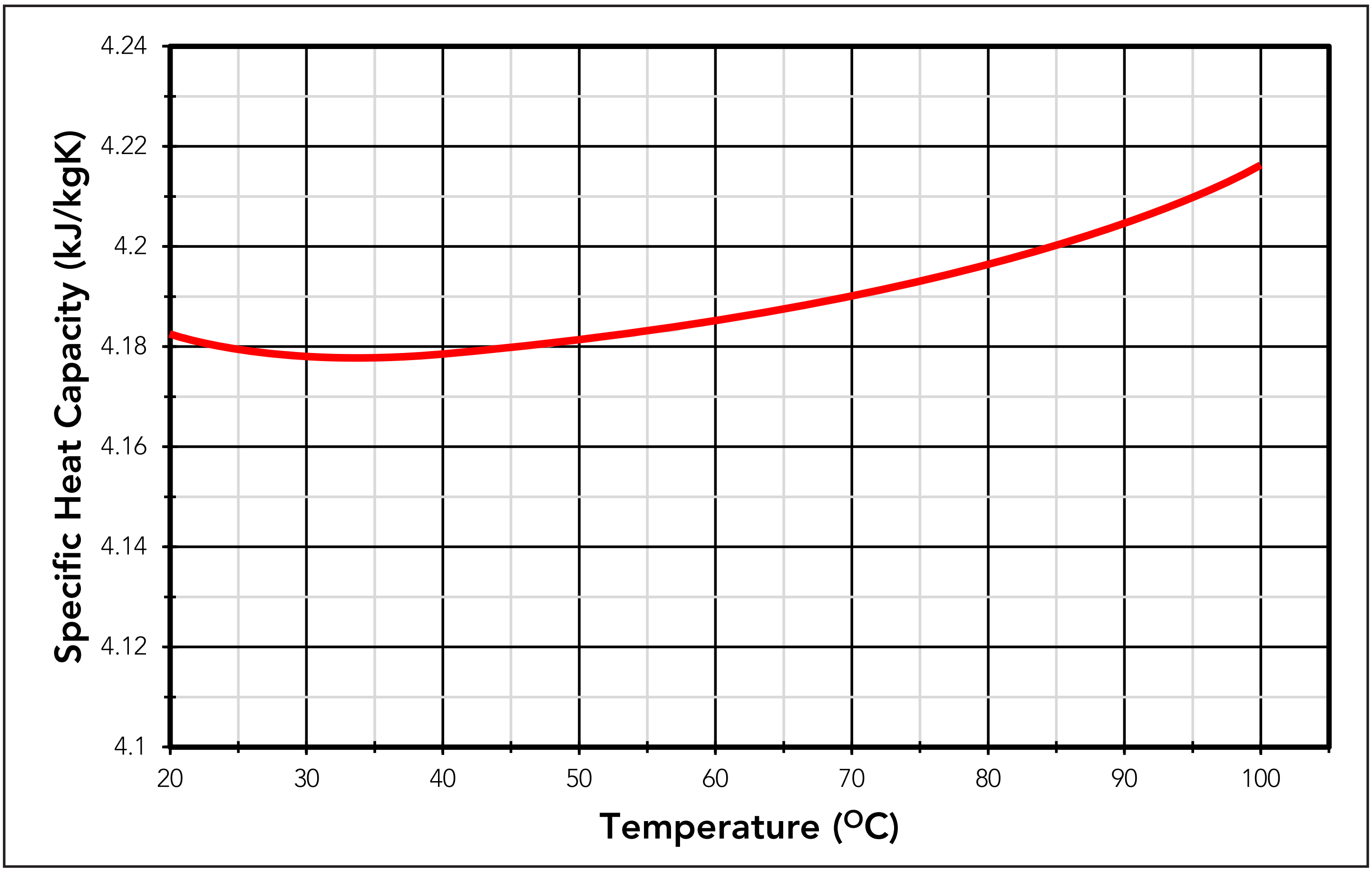
9.0.16 In line with the requirements of the Energy Efficiency Directive (EED), an MID approved heat meter must be provided in all dwellings.

9.0.17 Designers should be aware of the minimum volumetric flow rates that the heat meter is limited by, as this can be an issue in heating mode under part load conditions. However, it is worth noting that as the power required in heating and hot water modes are relatively similar in capacity when using a hot water store, so this is less of an issue in comparison to a high capacity instantaneous DHW HIU.

10.0 Appendix 1 - Water Density



11.0 Appendix 2 - Specific Heat Capacity of Water



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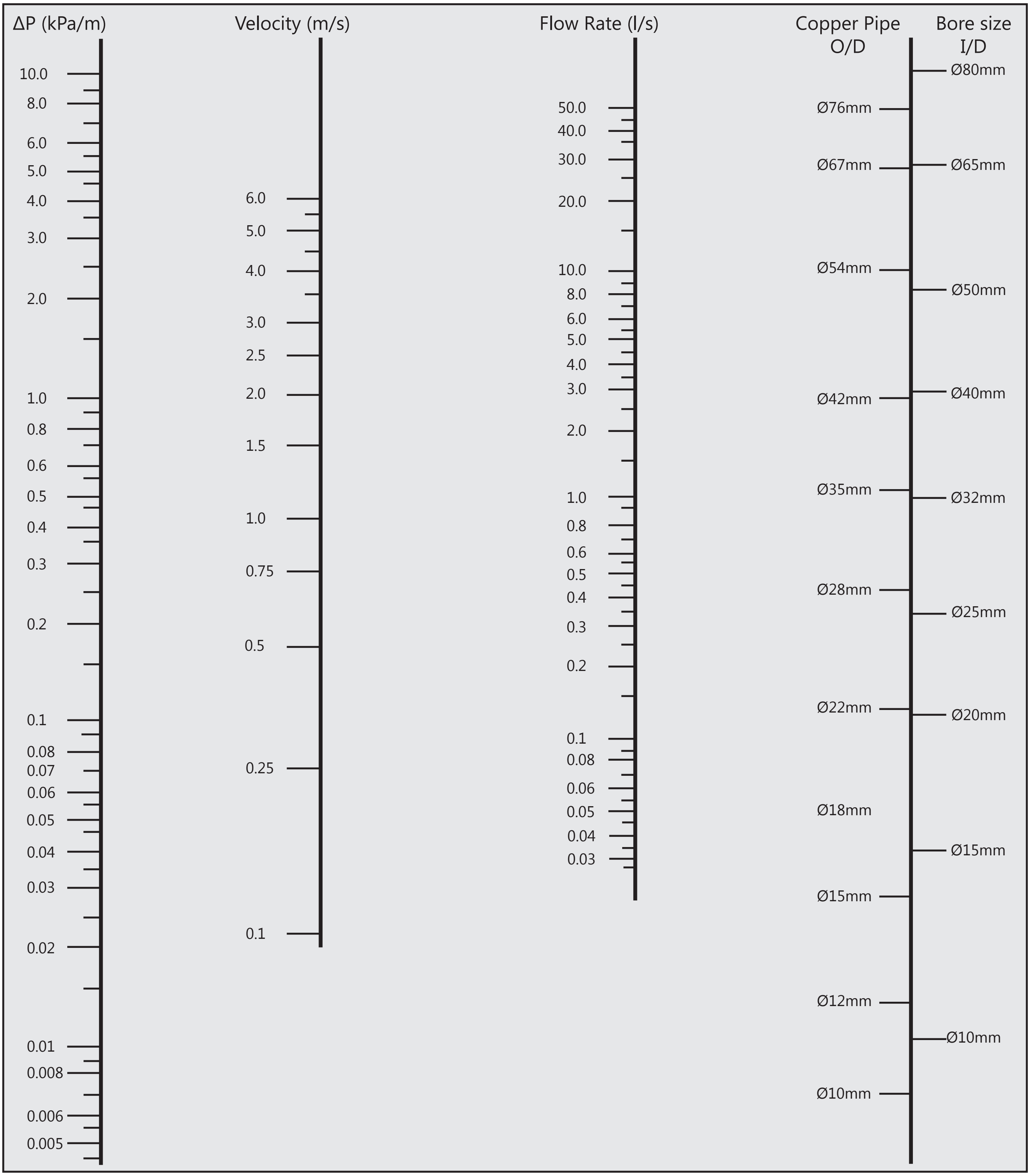
12.0 Appendix 3 - Pipe sizing chart



Figures based on water at 10 deg C

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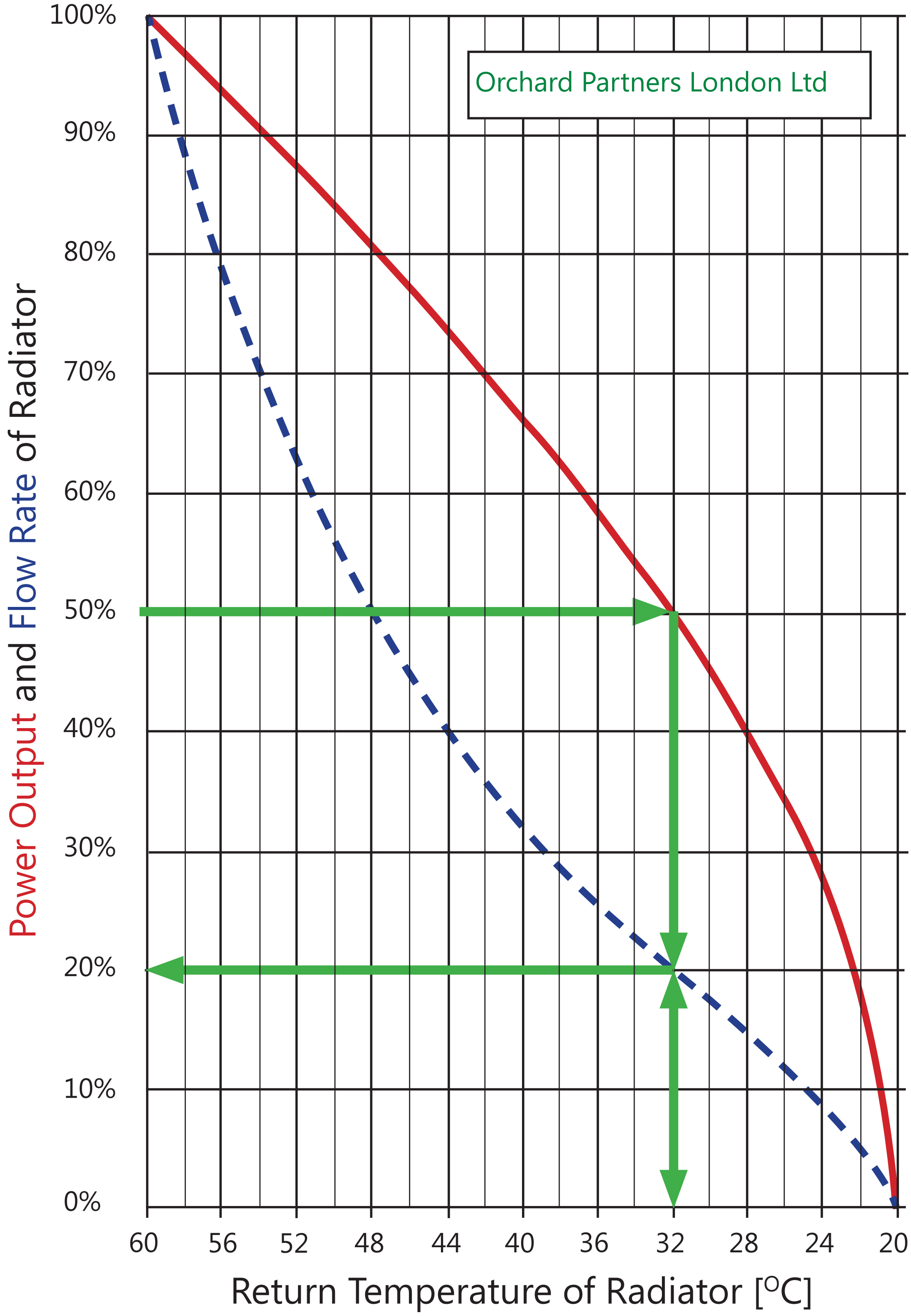
13.0 Appendix 4 - Radiator Return Temperature to Power / Flow Rate Characteristics



The above chart illustrates the potential for condensing operation on part load when radiators are controlled by fully modulating thermostatic valves.

Further improvements in performance can be achieved by installing return temperature limiters. The return temperature limiting valve controls the return water temperature thus minimizing heat loss from pipework and helps balance systems.

As heating systems run for the majority of time at part load, the diagram illustrates how at 50% power from a radiator designed for 80°C flow and 60°C return the flow rate drops to around 20% and the return water temperature is reduced to 32°C.

This demonstrates that a well designed and controlled radiator cicuit will enable the main boilers to condense.

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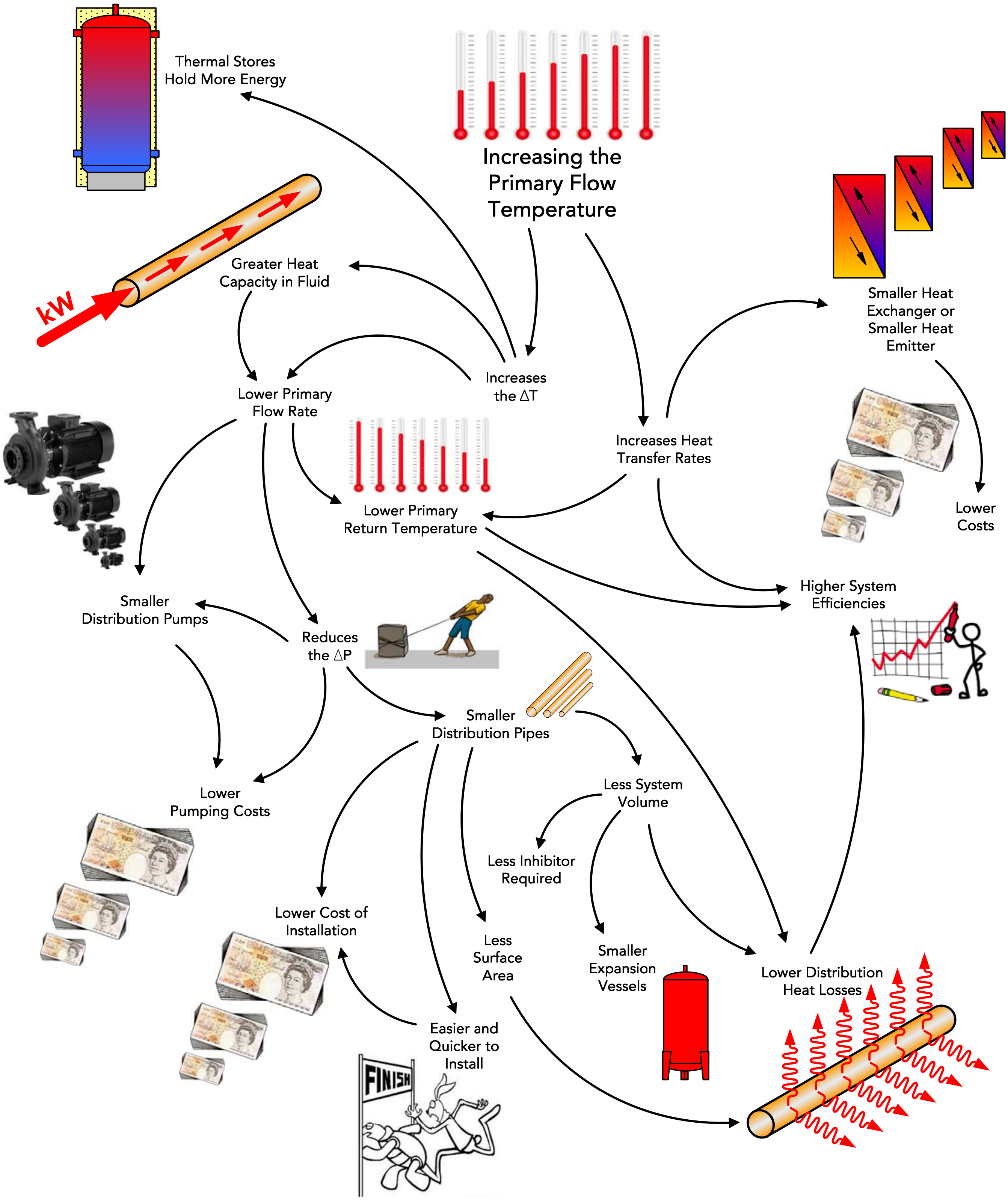
14.0 Appendix 5 - The Paradox of Raising the Flow Temperature to Increase Heat Network Efficiency

In recent years there has been a drive to improve the efficiency of heat networks, reduce their heat losses and utilise more low grade heat sources, such as renewable energy. In order to achieve this, designers have strived to reduce the network's operating temperatures. This has included reducing the primary flow temperature. However, although it may seem counterintuitive, raising the primary flow temperature can have a positive impact on the overall performance of the system. The Rich Picture below illustrates the effects that increasing the primary flow temperature can have on the performance of a heat network.



hot water association
DEVELOPING HOT WATER

info@hotwater.org.uk

01926 513777

@HotWaterAssoc

The Hot Water Association Ltd,
Camden House,
Warwick Rd,
Kenilworth
CV8 1TH