MEBS6000 Utility Services
Worked Example on Hot Water System

Question

A centralized direct hot water system for a service apartment is drafted as shown in the diagram. Water is supplied at 65°C from the hot water storage tank to the water points. The design flow rate is 1.4 L/s at peak simultaneous demand. The hot water storage tank is located 5m above the boiler.

i) Determine the hot water boiler capacity and the size of the hot water storage tank.
ii) Properly size the primary circuit if the flow is to be driven by natural convection.
iii) Size the secondary circuit supply and return pipes.

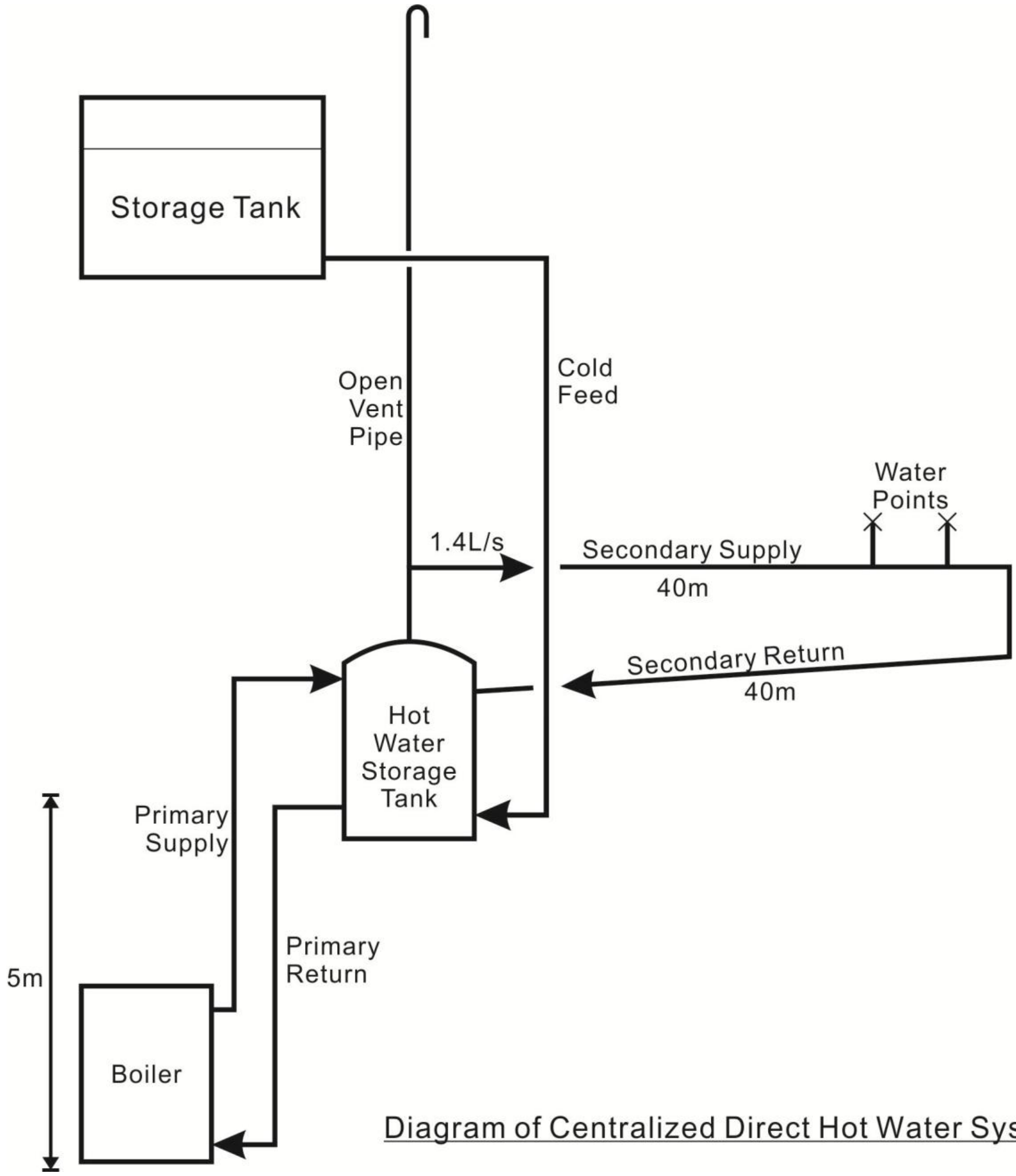

Diagram of Centralized Direct Hot Water System

Solution

i)

It was just given that the hot water design flow rate = 1.4 L/s.
It is reasonable to assume a water storage tank size for 1-2 hours consumption, and the boiler will recover the hot water before the next peak demand, which is usually around 5 hours from the last one.

Consider the storage can last for 1.5 hours,
Hot water storage = 1.4 L/s x 1.5 hours x 3,600s = **7,560L**

The total heat input to heat up 7,560L of water
= 7,560 kg x 4.2kJ/kg°C x (65-20)°C
= 1,428,840 kJ

Consider heating time = 5 hours
Thus the effective heating capacity of the boiler
= 1,428,840 kJ / (5 x 3,600s)
= 79.4kW (say 80kW)

ii)

The difference in pressure between the primary return and supply is given by
$\Delta P = (\rho_r - \rho_s)gh$
At 65°C and 20°C supply and return temperature, the relevant densities are 980kg/m^3 and 998kg/m^3 respectively
$\Delta P = (998 - 980) \times 9.8 \times 5 = 882$ Pa
This is the driving force for the natural circulation between the boiler and the hot water storage tank

Let the total measured distance of the primary circuit = 20m (vertical 5m supply and return)
Equivalent pipe length = 20 + 30% = 26m

Thus the pressure drop available = 882Pa/26m = 34 Pa/m run
Take the density = 997.5kg/m^3 (at average temperature 42.5°C)
Pressure drop = 0.0035mH/m run
From copper pipe sizing chart, **suitable pipe size = 76mmØ** (1.4L/s, 0.0024mH/m run)

iii)

At 1.4L/s, if the pressure drop $\approx$ 0.1mH/m run
From copper pipe sizing chart, suitable pipe size = 35mmØ (1.4L/s, 0.09mH/m run)

Consider,
Supply temperature = 65°C, and
Allowable temperature drop from the supply to the return of the water storage tank = 10°C
The supply pipe contributes to 60% of the heat loss of the secondary circuit, i.e. 6°C drop at the supply pipe

Since 35mmØ pipe is used, the heat loss per m run of the pipe = 17W/m
Total heat loss = 17W/m x 40m = 680W
Using $Q = mc\Delta T$
680 = m x 4200 x 6, thus **m = 0.026 kg/s** (**minimum flow rate**)

At m = 0.026 kg/s, use the smallest **pipe diameter 15mmØ for secondary return**,
pressure loss < 0.02mH/m (pressure loss is acceptable)

Heat loss of 15mmØ pipe = 9W/m
Total heat loss = 9W/m x 40m = 360W
360 = 0.026 kg/s x 4200 kJ/kgK x ΔT
ΔT = 3.3°C (<4°C)
Therefore, the total temperature drop = 6°C + 3.3°C = 9.3°C (<10°C, acceptable)