Chapter 7

Hot Water

Chapter 7 discusses five aspects of the hot water system:

1. Sizing hot water pipes
2. Determining quantities of hot water and demand
3. Hot water flow and return
4. Balancing the hot water system
5. Expansion and contraction of pipes

Sizing Hot Water Pipes

The principles of sizing hot water service pipes are the same as for cold water pipes, as detailed in Chapter 4. The main difference when sizing hot water pipes is that the designer must take into account the reduced proportion of hot water required, compared to cold.

For most domestic and commercial projects, hot water is generally delivered to the outlet at a higher temperature than required. To reduce the temperature, cold water is mixed with the hot, thus reducing the quantity of hot water required to achieve the desired temperature while maintaining a satisfactory flow.

The control of hot water temperature at the outlet, together with the controlled temperature at the hot water system, is the key to safe hot water provisions. Water, when heated, is required to be stored at 60°C or above. For domestic use the water is distributed at 55 to 60°C, and 82°C for commercial projects. Safe working temperatures at the outlet are between 35 and 46°C in domestic situations. To achieve this, the hot and cold water are mixed as shown in Figure 7-1. The most effective method involves the introduction of a thermostatic mixing valve.

It is possible that the flow rates for cold water, presented in Chapter 3, may at some time be required for hot or tempered water, in which case the pipe sizes must accommodate the required flow demand, as shown in Table 3-1. It is unlikely the full flow will be required for residential situations.

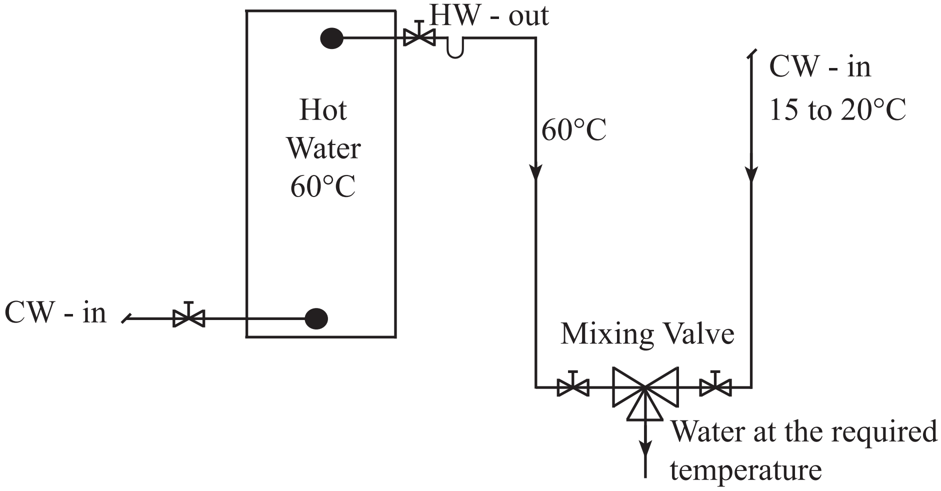

Figure 7-1 Typical Mixing Valve Configuration

It is the designer's responsibility to calculate the proportion of cold water needed to reduce the hot water to the required temperature. Depending on the temperature of the hot water in the supply pipe, the ambient temperature of the cold water and the desired final temperature, the proportion will vary.

These variables will influence the designer's choice of pipe sizes for hot water services. Where a reduced flow can be achieved, it is logical that the size of the pipe should be reduced.

The following formula provides the percentage of cold water required to be combined with hot water in order to achieve a predetermined temperature.

Formula

$$P = \frac{H - M}{M - C}$$

When

P = Proportion of cold water to hot water

H = Temperature of hot water (in the supply pipe)

M = Final temperature of mixed water

C = Ambient temperature of cold water

Exercise 7-1

What is the proportion of cold water to hot water (expressed as a percentage), if the ambient temperature of cold water is 15°C, the incoming hot water is 60°C and the final mixed temperature is to be 30°C?

$$\boldsymbol{P = \frac{H - M}{M - C}}$$

$$= \frac{60 - 30}{30 - 15}$$

$$= \frac{30}{15}$$

= 2.0 parts cold to 1.0 part hot water

= 2.0 litres of cold + 1 litre of hot water.

Total = 3.0 litres of water.

2.0 litres as a percentage of 3.0 litres = 67 %

1.0 litre as a percentage of 3.0 litres = 33 %

P = 67 % cold to 33 % hot

A bath requiring 0.30 L/s will only need 0.10 L/s of hot water, therefore the hot water pipe will be sized on 0.10 L/s flow and the cold water pipe sized on the full 0.30 L/s flow, as it is possible that at times the bath may be filled with 100% cold water.

Exercise 7-2

What is the proportion of cold water to hot water (expressed as a percentage), if the ambient temperature of cold water is 15°C, the incoming hot water is 60°C and the final mixed temperature is to be 40°C?

$$P = \frac{H - M}{\boldsymbol{M - C}}$$

$$= \frac{60 - 40}{40 - 15}$$

$$= \frac{20}{25}$$

= 0.8 of a part cold to 1.0 part hot water

= 0.80 litre of cold water + 1.0 litre of hot water.

Total = 1.80 litres of water.

0.80 as a percentage of 1.80 = 44 %

1.00 as a percentage of 1.80 = 56 %

P = 44 % cold to 56 % hot

A bath requiring 0.30 L/s will only need 0.17 L/s of hot water, therefore the hot water pipe will be sized on 0.17 L/s flow and the cold water sized on the 0.30 L/s flow.

Exercise 7-3

What is the proportion of cold water to hot water (expressed as a percentage), if the ambient temperature of cold water is 15°C, the incoming hot water is 82°C and the final mixed temperature is to be 77°C?

$$P = \frac{H - M}{M - C}$$

$$= \frac{82 - 77}{77 - 15}$$

$$= \frac{5}{62}$$

= 0.08 litre of cold water + 1.0 litre of hot water.

Total = 1.08 litres of water.

0.08 as a percentage of 1.08 = 7.40 %

1.0 as a percentage of 1.08 = 92.60 %

P = 7.4% cold to 92.6% hot.

Mixed Temp.	**Ambient 15°C**	**Ambient 20°C**	**Ambient 25°C**
	Percentage of 60°C Hot Water		
20° C	11.11%		
25° C	22.22%	12.50%	
30° C	33.33%	25.00%	14.30%
35° C	44.44%	37.50%	28.57%
40° C	55.56%	50.00%	42.86%
45° C	66.67%	62.50%	57.14%
50° C	77.78%	75.00%	71.43%
55° C	88.89%	87.50%	85.71%

Table 7-1 Quantity of Hot Water Mixed with Cold Water

Fixture	**Domestic L/s**	**Conserve L/s**
Sink	0.10	0.06
Bath	0.15	0.07
Basin	0.05	0.04
Shower	0.07	0.06
Laundry Tub	0.10	0.08
Washing Machine	0.10	0.08
Dishwasher	0.10	0.06

Table 7-2 Hot Water Flow Rates for Fixtures

The following are considered safe working temperatures by the health care industry. Refer also to local health care guidelines.

44°C for an unassisted bath fill

46°C for an assisted bath fill

41°C for shower applications

41°C for washbasin applications

38°C for bidet applications

46 to 48°C for kitchen sink applications

Determining Hot Water Quantities and Demands

There are two important considerations in determining the quantity of hot water to be stored:

a) The required quantity for a peak period.
b) The highest possible demand over the shortest time during the peak period, expressed in litres per second. (L/s).

Type Of Business	Peak Period	Considerations
Cafe – Hotel Kitchen - Restaurant	5.5 litres per 3 course meal over 2 hours	There is also a 2 hour food preparation time, in addition to the 2 hour peak.
Take-Away Foods	3.1 litres per meal served, over 2 hours	Alternatively: the number of people being served.
Holiday Units – Guest Houses – Hotels - Motels	20 to 25 litres per person over 1 hour	The actual time of day that the peak period occurs will vary.
Caravan Parks – Camping Areas	20 litres per person over 2 hours	Allow 3 people per caravan site.
Hairdressing Salon	10 litres per customer	Check the hourly demand.
Squash Courts	20 litres per player over 4 hours	16 players per court in the 4 hours.
Office Amenities	3.0 litres per person over 2 hour lunch/peak period	The occupancy of the building must be calculated.
Light Industry - Change Rooms	1 litre per person over 1 hour for hand basin 20 litres per person over 2 hours for shower	Shower usage is approximately 30% of total occupancy.
Heavy Industry - Change Rooms	30 litres per person over 1 hour	Shower usage is approximately 70% of total occupancy.
Mining Change Rooms	40 litres per person over 30 minutes. (Must be calculated)	Shower usage is 100% of total occupancy & 16.5 L/m shower rose.
Glass Washers	0.30 litres per glass over 2 hours	25 Glasses per load. Confirm total cycle time and temperature.
Coin-Operated Laundries	70 litres per machine per hour	

Table 7-3 Guidelines for Sizing Hot Water Systems from the Rheem Technical Manual

Exercise 7-4

A restaurant has the capacity to seat 80 people in one sitting and expects to turn over each seat on average twice in one lunchtime or evening period. Based on Table 7-3, what is the required quantity of hot water and what peak period will it cover?

Calculation

= 80 seats x 2 sittings

= 160 people / 3 course meals

= 160 x 5.5 litres per person

= 880 litres over a 2 hour peak period

= 440 litres per hour

The designer must consider the likely pattern of water usage and the working habits of the chefs. It is important to determine whether the 880 litres is required evenly over 2 hours, or in a shorter period. If, for example, 440 litres were required in a 30 minute period, the capacity of the hot water system would need to be 880 litres over a 1 hour period.

Restaurants traditionally have a two hour lead-time for preparation of food, which helps spread the demand more evenly. It is reasonable to conclude that, having covered the peak period, the hot water system will be capable of accommodating the preparation time without the need to increase the capacity of the hot water system.

Commercial laundries are a good example of an industry where there is a high demand over a short peak period. A designer could conclude that six commercial washing machines would be loaded one at a time and activated individually to start their cycle as each is filled with clothes. If the operator followed this procedure the demand on the water service would be spread evenly. However, this is not how most commercial laundries operate. The operator fills all six washing machines with clothing, then activates all six machines simultaneously. The demand is six times greater than is required for the first fill for one machine and the demand is repeated for each of the rinse cycles. It is the demand of all six machines operating at once, that the designer must accommodate.

This demonstrates that the usage over a two, six or twelve hour period is not a multiple of the highest demand in the peak period. In fact there may be no further use during any other time of the day. Conversely, it also demonstrates that although there are industry guidelines regarding peak periods, every project must be closely scrutinised to determine the highest times of demand during the peak period.

Exercise 7-5

Based on Table 7-3, what is the required quantity of hot water and over what peak period, for a caravan park with 120 sites?

Calculation

120 caravan sites x 3 people per van

= 360 occupants

= 360 x 20 litres per person

= 7,200 litres over 2 hours

= 3,600 litres over a 1 hour period

Note: It is unlikely one amenities block would be used for 120 sites. The number of amenities blocks needs to be determined along with the number of van sites per amenities block. The calculation is repeated for each individual situation.

The peak period may vary from one caravan park to another, depending on whether it's classified as a tourist park, which may have a peak period over 3 hours from 7.00am to 10.00am, or a construction workers' caravan park, which is likely to have a shorter peak period of 1.5 hours between 5.00am and 6.30am.

Exercise 7-6

A coalmine amenities block has 20 shower cubicles to service a maximum of 80 miners finishing a work shift at one time. Based on Table 7-3, what is the required quantity of hot water and over what peak period?

Note: The same exercise could apply to a sports stadium.

Calculation

80 miners per shift x 40 litres per person

= 3,200 litres over 30 minutes

An experienced designer will not leave the calculation without further analysis.

In this exercise 20 showers have been provided for convenience and to cover the short period of time the workers have for showering at the end of the shift. Appreciating that workers want to shower quickly, the following is most likely:

$$\frac{\text{80 coal miners}}{\text{20 showers}}$$

= 4 usages of each shower during the period.

First confirm the quantity of water is correct.

In situations as described in this exercise, each shower is generally turned on by the first person and left running until the last person has finished and turns it off.

At 5.5 minutes per shower, which allows for changeover time between each person:

= 5.5 x 16.5 L/m discharge from the shower rose.

Shower roses are usually rated in litres per minute (L/m)

= 90.75 litres per person total hot and cold water

From Table 7-1, it is determined that the correct proportion for 35°C temperature is 44 % hot and 56 % cold.

= 90.75 x 44 % = 39.93 litres per person (rounded to 40 litres) hot water per person.

= 40 litres x 80 miners

= 3,200 litres of hot water

The second step is to determine the actual peak period.

Based on 4 usages of each shower at an average of 5.5 minutes:

= 22 minutes

The heating vessels will need to be capable of delivering 3,200 litres in 22 minutes in this case, not the 30 minute period. This equates to a heating vessel capable of delivering 8,727 litres of hot water per 1 hour period.

$$\frac{\text{3,200 litres}}{\text{22 minutes}}$$

= 145.45 litres per minute x 60 minutes

= 8,727 litres per hour.

This exercise demonstrates the need for the engineer to understand the calculations and not rely solely on industry standards or guidelines. With all the data available to the engineer, he/she is in a better position to reach a ‘best design solution’, balancing the integration of hot water storage with the recovery rate of the heating vessel for the incoming cold water, to reach the required temperature.

Hot Water Flow and Return

A hot water flow pipe is the main supply pipe from the heating vessel to the last branch of the most disadvantaged fixture or outlet, shown as ‘A’ in Figure 7-2, to the point shown as ‘B’.

The return pipe extends from the last branch back to the heating vessel, shown as ‘B’ in Figure 7-2, to the hot water vessel including the circulating pump.

The hot water circulates through the flow pipe due to natural draw-off caused by the drop in pressure when an outlet is opened. If the system is not in use and there is no draw-off, the circulating pump provides the means for the water to move through the flow pipe and return to the heating vessel. During this process, heat will be lost by radiation and it is replaced each time the water circulates through the heaters.

Unlike a cold water ring main, which is capable of flowing from either direction, the hot water flows in one direction only. For a domestic system, the water leaves the heater at approximately 60°C and returns at around 50 to 55°C, depending on the design criteria and heat losses.

The two major benefits of flow and return lines are that they distribute hot water evenly at a constant temperature and reduce the waiting time for hot water at each outlet. It is the author’s opinion that flow and return systems are under-utilised on many projects. Residential houses, motels, medical centres, butcher and baker shops, are just a few examples where more thought should be given to using the flow and return system in preference to a simple dead leg system.

The method for sizing the hot water flow line is similar to that described in Chapter 4 for cold water. The principle of calculating the size of the return line from the last branch (point ‘B’ in Figure 7-2), back to the hot water system, is more complex.

On smaller projects the designer may elect to nominate the return pipe as one size smaller than the flow line at the last branch. On larger projects the following must be considered in the calculations:

a) The heat losses in the flow and return lines, as per the manufacturers' calculations for the pipe insulation to be used.
b) The quantity of water that needs to circulate through the system to replace the heat losses.
c) The number of litres per second that the circulating pump needs to push through the system to deliver the required flow.

Having established this information, the return pipe can be sized to accommodate the flow. It should be appreciated the return line may need to be increased in size as additional branch return lines are connected.

The flow and return layout illustrated in Figure 7-2 is commonly used in apartment buildings and for hotel accommodation. Figure 7-3 is an alternative method used in hospitals and similar buildings.

Balancing the Hot Water System

In the case of a flow and return system being part of a project design, it is necessary for the contractor to balance the system after the installation is completed. Balancing the system forms part of the commissioning process and it guarantees the delivery of hot water to each fixture at a constant and even temperature throughout the building and delivered to each outlet in the shortest possible time.

In order to balance the system, the steps shown below must be followed, using Figures 7-2 and 7-3 as the examples.

Step 1

Install a balancing valve at the top of each hot water riser (HWR) or on the end of each flow line, before the pipe enters the return line. The valve must be of a type that has an adjustment function. Having calculated the size of the circulating pump, the required flow is divided by the number of risers connected to the return line.

For example: Figure 7-2 shows four hot water risers connected into one return line. Therefore, if it has been determined that the pump needs to circulate 0.5 L/s, the setting on each balancing valve is adjusted to allow 0.125 L/s of hot water to pass through it.

Step 2

Commission the hot water system and allow the hot water to circulate through the pipes for 24 to 48 hours. The hot water will settle into a pattern of distribution based on even flow in accordance with the balancing valve adjustment, rather than by temperature.

Step 3

At a time of the day, when there has been no draw-off for approximately six hours, which is most likely to be early morning, the temperature of the pipe is taken adjacent to each balancing valve and recorded.

The temperature on HWR-1 will be much higher than HWR– 4, due to the shorter distance the hot water has to travel, with less heat lost through radiation, compared with the longer runs of pipe.

The balancing valves on HWR-1 and HWR-2 are adjusted to allow less water to pass through, while HWR-3 and HWR-4 will be adjusted to allow more water to pass through. The temperature of the water will become more even as the system settles into a new pattern of distribution.

Step 4

The process is repeated at the same time every day until the temperature differential between the four valves is within 1 or 2°C. Large projects with twenty to thirty risers entering the return line may need the process repeated over twelve or more consecutive days.

Note: It is good practice for flow and return systems to be checked and adjusted annually.

Other considerations (which are not covered in this text) for the designer to take into account when sizing the hot water return line and the circulating pump, are:

a) Heat loss in pipes, which largely depends on the type of insulation to be specified. Insulation manufacturers have formulas and calculations specifically designed for use with their products.

b) An understanding of the threat of Legionella Bacteria in the storage of hot water.

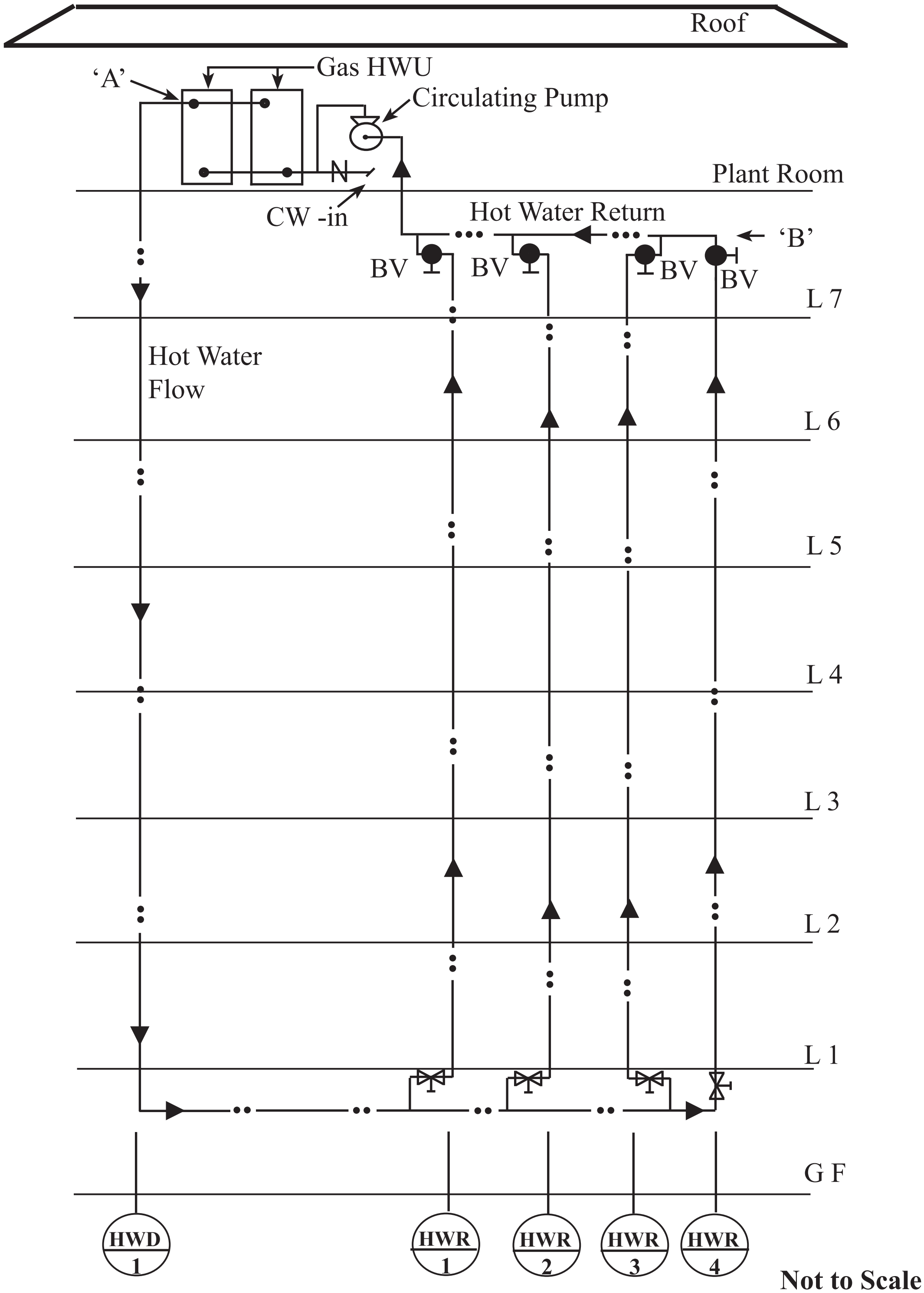

Figure 7-2 Diagrammatic: Typical Hot Water Flow and Return System

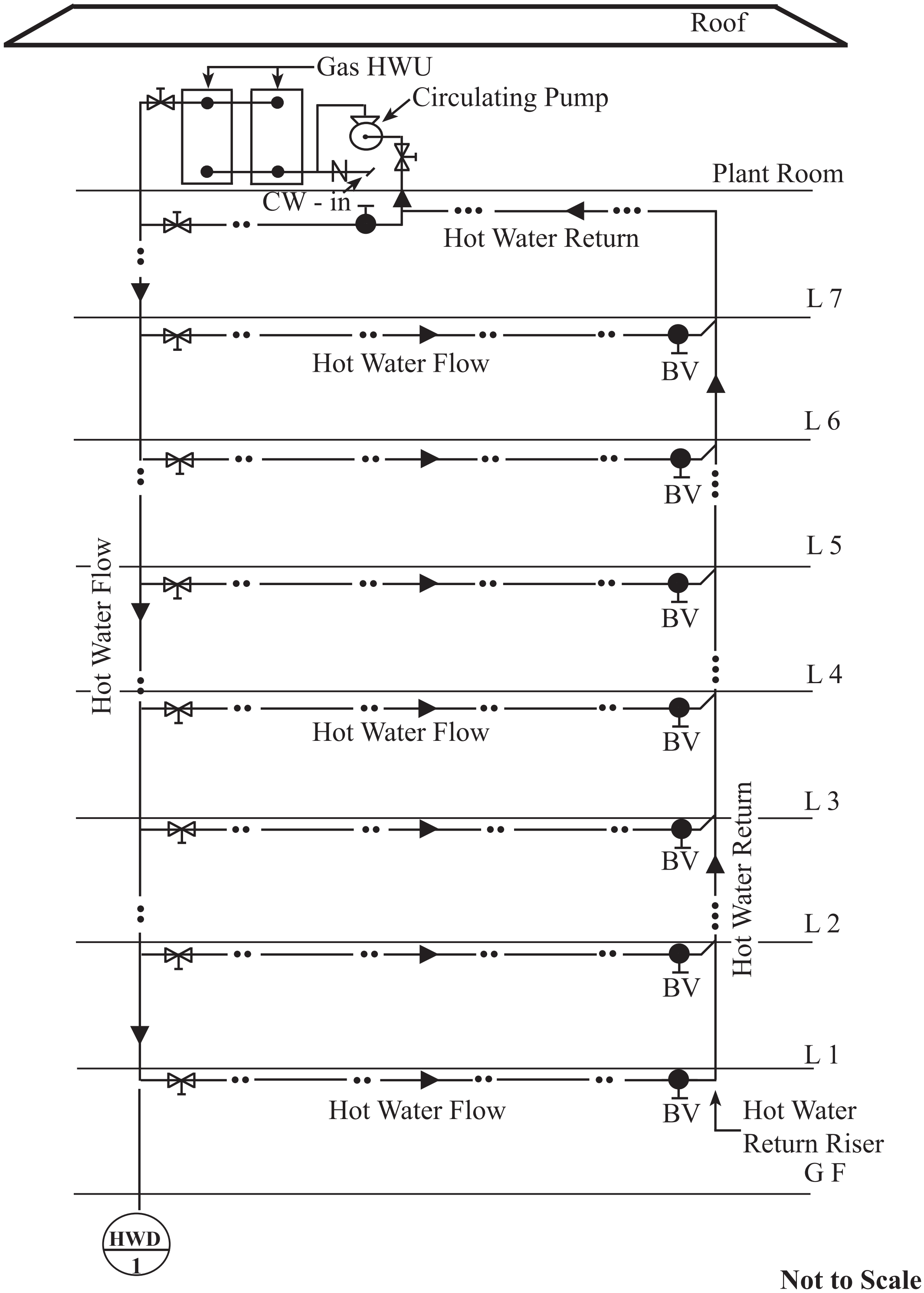

Figure 7-3 Alternative Hot Water Flow and Return System

Expansion and Contraction of Pipes

As the temperature of the water increases or decreases it causes the pipes to expand or contract. Potable water can be used for many purposes, ranging from chilled water for air conditioning and drinking fountains, to hot water for boiling water units. The temperatures can be as low as 4°C or as high as 98°C. While, individual pipe systems are unlikely to have variations in temperature of this magnitude, expansion and contraction will occur to some degree.

Maximum expansion will occur during the initial commissioning of a system, sometimes referred to as 'start up' when the water is being raised from around 15 to 60°C, or chilled to 4°C. There is a line of thought that expansion and contraction does not occur once the water has reached its final temperature. This of course is not correct, due to heat loss occurring in the pipes as hot water circulates, causing the temperature to rise and fall.

The formula for calculation of expansion in pipes, is:

Formula

$$E = L \times T \times C \times 1000$$

Where:

E	=	Expansion
L	=	Length of pipe
T	=	Temperature change
C	=	Coefficient
1000	=	Convert metres to millimetres

The coefficient of the materials listed are:

Copper	0.0000167
Steel	0.0000105
PVC	0.000055
Stainless Steel	0.0000100
Polypropylene	0.0001100

The different methods of accommodating expansion and contraction of pipes can have a significant effect on pipe sizing due to corresponding variations in friction losses through the fittings, expansion loops and expansion bellows.

Expansion and contraction is also important from a building safety aspect. There have been cases where hot water pipes were fixed tightly between two walls, the pipe expanded and with no available space for expansion, the pipe joints broke and water damage occurred.

Figures 7-4 to 7-8 illustrate accepted methods of accommodating expansion and contraction in pipes.

With the large variety of pipe materials available and the variations in composition, the most accurate method of establishing the expected expansion in an individual length of pipe is to refer to the manufacturers' technical data. Each manufacturer provides detailed information on the length of expansion, in millimetres per metre of pipe.

Each pipe must be able to move freely through the pipe brackets. Figure 7-8 illustrates a method of clipping the pipe with a roller that allows such movement.

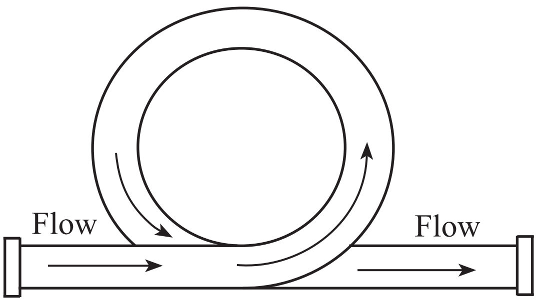

Figure 7-4 Expansion Loop

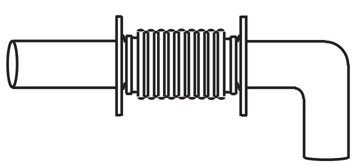

Figure 7-5 Expansion Bellows

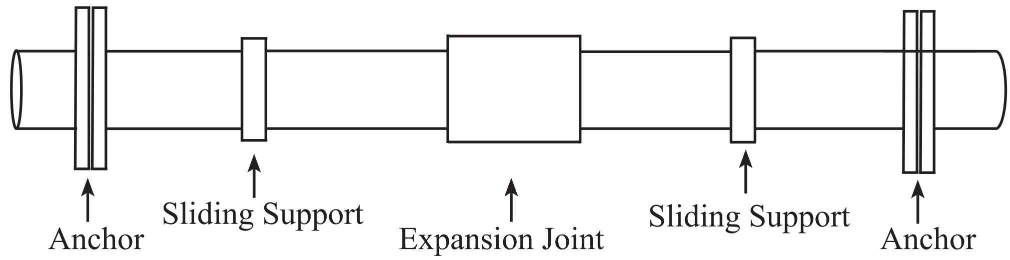

Figure 7-6 Pipe with Sliding Supports, Anchors and Expansion Joint

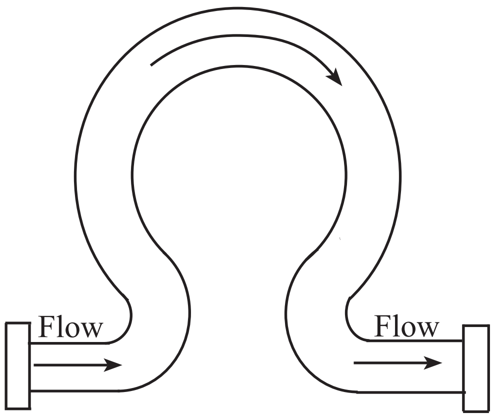

Figure 7-7 Horseshoe Loop or Lyre Bend

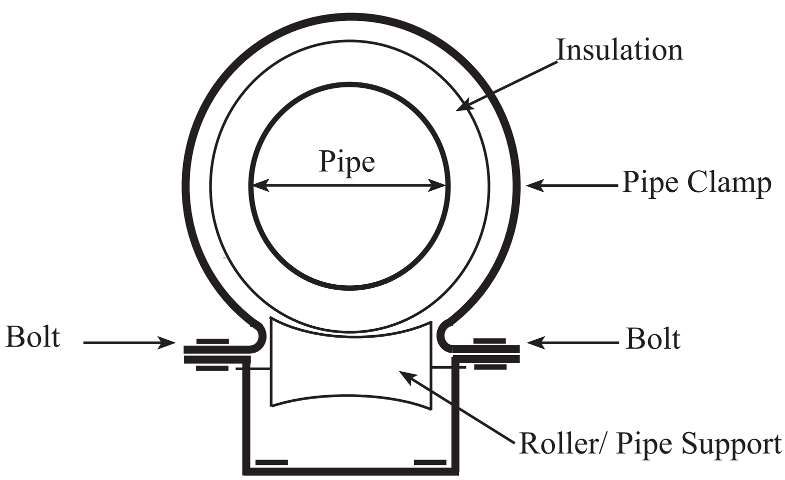

Figure 7-8 Chair Roller Bracket