Ch.4 HEATING SYSTEMS Heat Emitters

Radiators and convectors are the principal means of heat emission in most buildings. Less popular alternatives include exposed pipes and radiant panels for use in warehousing, workshops and factories, where appearance is not important. Embedded panels of pipework in the floor screed can also be used to create ` invisible ' heating, but these have a slow thermal response as heat energy is absorbed by the floorstructure.

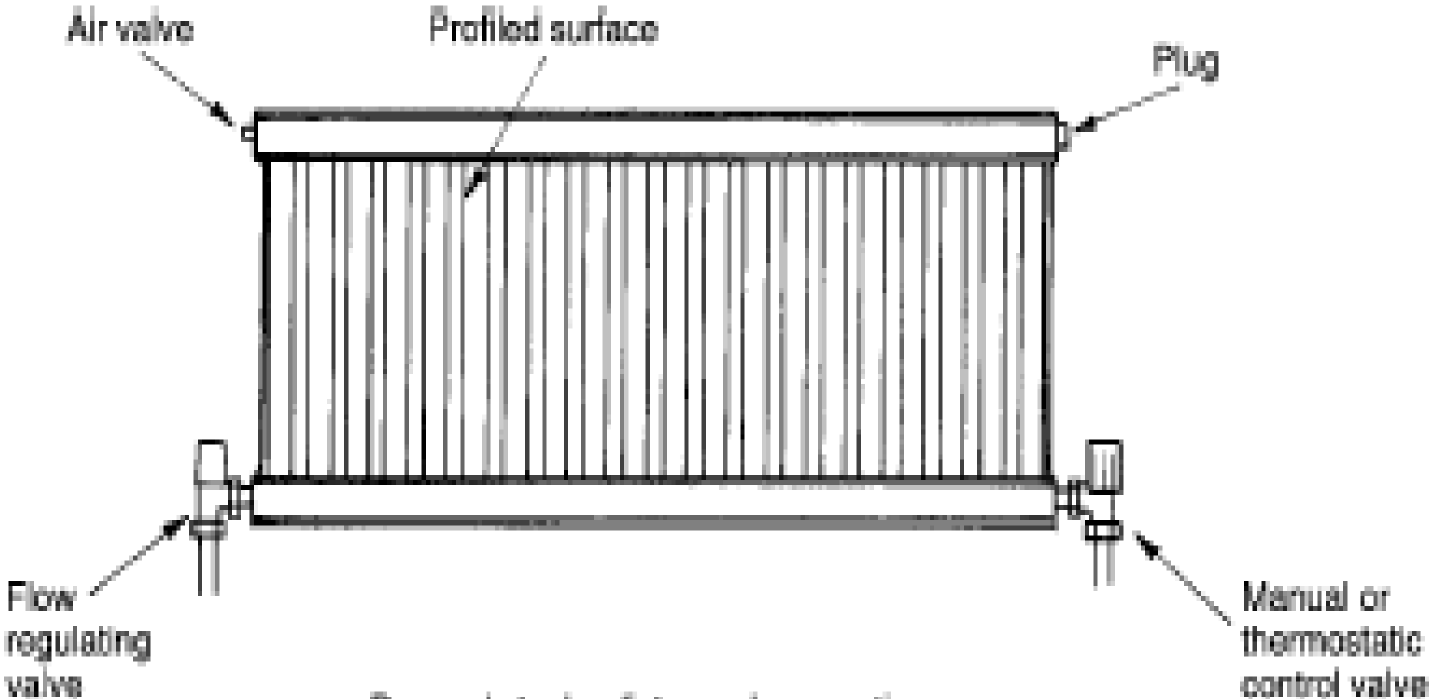
Radiators

Despite the name radiator, no more than 40% of the heat transferred is by radiation. The remainder is convected, with a small amount conducted through the radiator brackets into the wall. Originally, radiators were made from cast iron in three forms: hospital, column and panel. Hospital radiators were so called because of their smooth, easy to clean surface, an important specification in a hygienic environment. Column radiators vary in the number of columns. The greater the number, the greater the heat emitting surface.

Radiators

Convectors have a steel casing containing a finned heat exchanger.

About 90% of the heat emission is convected and this may be enhanced if a thermostatically controlled fan is also located in the casing. They are more effective than radiators for heating large rooms, and in this situation their extra bulk can be accommodated.



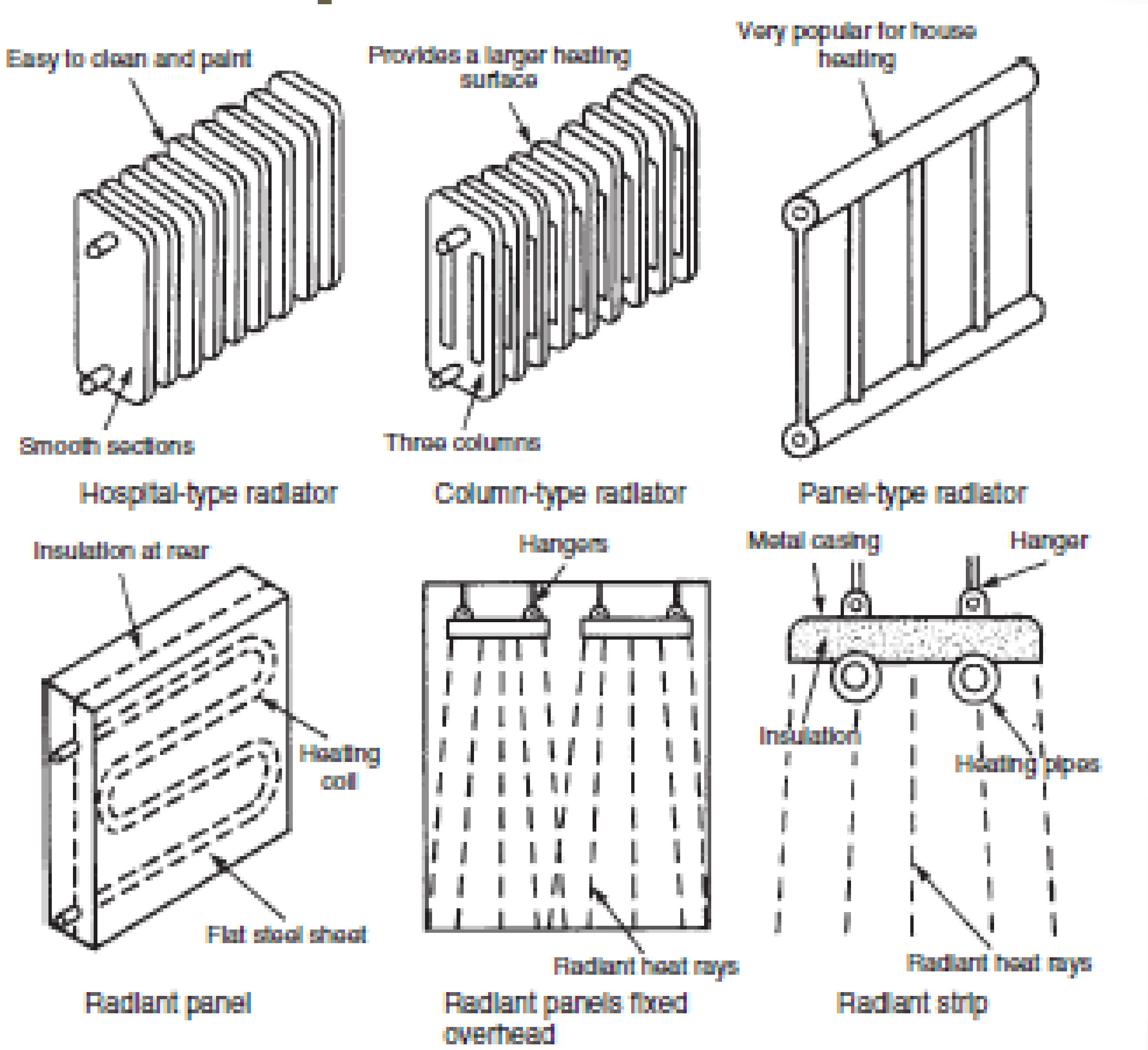
Pressed steel radiator and connections

Radiators (cont.....)

In temperate and cold climates where there is insufficient warmth from the sun during parts of the year, heat losses from the human body must be balanced. These amount to the following approximate proportions: radiation 45%, convection 30% and evaporation 25%.

Internal heat gains from machinery, lighting and people can contribute significantly, but heat emitters will provide the main contribution in most buildings.

Radiant panels



Panel Heating

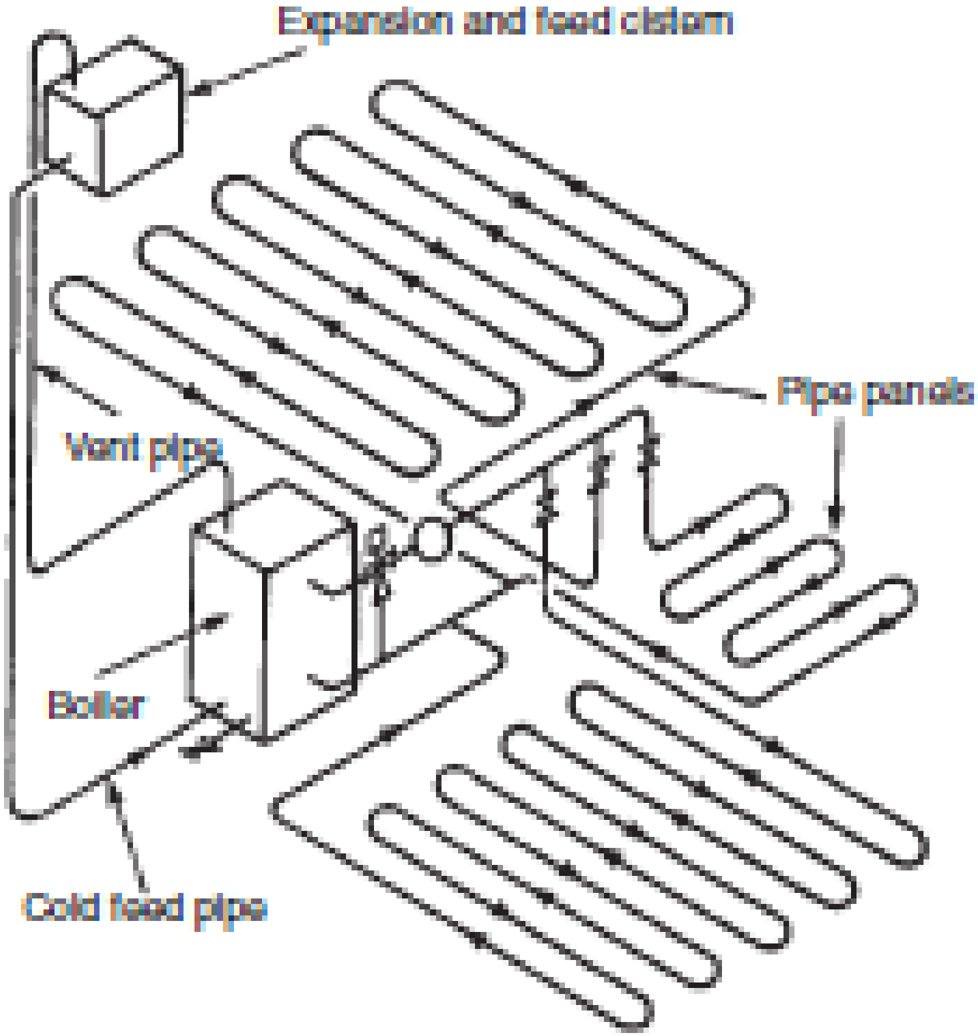
The system consists of 15 mm or 22 mm o.d. annealed copper pipes embedded in the floor, ceiling or walls. This has the benefit of avoiding unsightly pipes and radiators. Heat distribution is uniform, providing a high standard of thermal comfort as heat is emitted from the building fabric. However, thermal response is slow as the fabric takes time to heat up and to lose its heat. Thermostatic control is used to maintain

the following surface temperatures:

Floors : 27 C

Ceilings : 49C

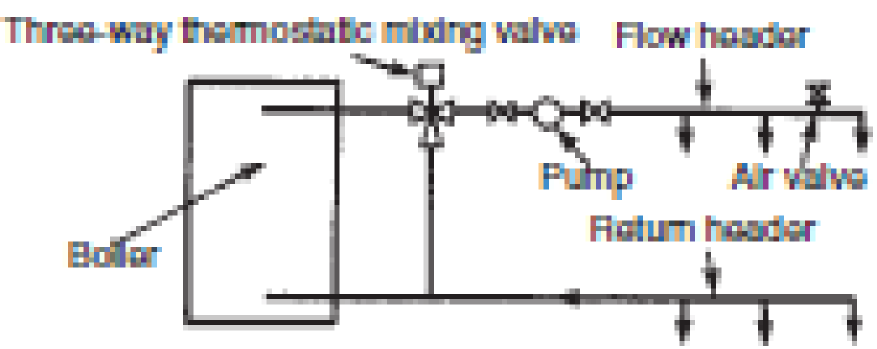
Walls :43 C



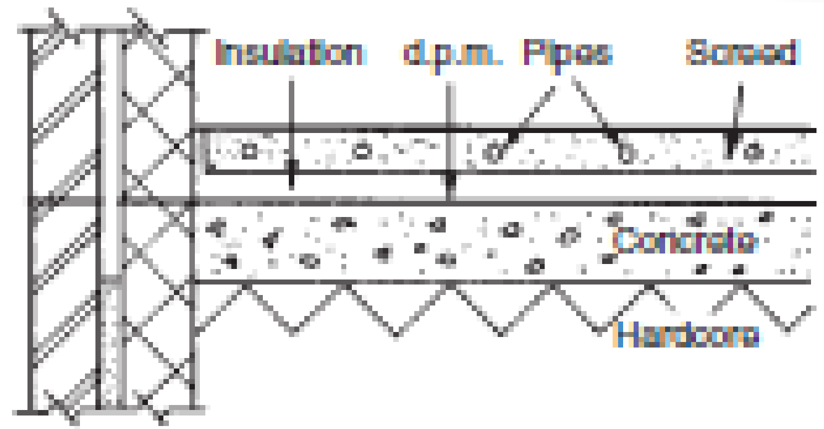
Installation of panel heating system

Panel Heating

Joints on copper pipes must be made by capillary soldered fittings or by bronze welding. Unjointed purpose-made plastic pipes can also be used. Before embedding the pipes they should be hydraulically tested



Detail of boiler and connections



Method of embedding the panels

Underfloor Panel Heating – 1

Current practice is to use jointless plastic pipe in continuous coils.

Pipes can be embedded in a 70 mm cement and sand screed (50 mm minimum cover to tube). In suspended timber floors the pipe may be

elevated by clipping tracks or brackets with metallic reflective support trays, prior to fixing the chipboard decking. Materials include:

PEX: Cross linked polyethylene.

PP: Co-polymer of polypropylene.

PB: Polybutylene.

Underfloor heating(cont...)

These pipes are oxygen permeable, therefore, when specified for underfloor heating, they should include a diffusion barrier.

Boiler flow temperature for underfloor heating is about 50 C, whilst that for hot water storage and radiators is about 80 C. Therefore, where the same boiler supplies both hot water storage cylinder and/

or radiators and underfloor heating, a motorised thermostatic mixing valve is required to blend the boiler flow and underfloor heating return water to obtain the optimum flow temperature.

Underfloor heating (cont….)

Extract from performance tables for a design room temperature of 21°C with a blended flow temperature of 50°C:

Solid floor – Pipe dia. (mm)	Pipe spacing (mm)	Output (W/m^2)
15	100	82
15	200	67
18	300	55
Suspended floor –		
15	300*	47

*Assumes two pipe runs between floor joists spaced at 600 mm centres.

For a room with a solid floor area of $13{\cdot}5\,m^2$ requiring a heating input of 779 watts (see page 158), the output required from the underfloor piping is:

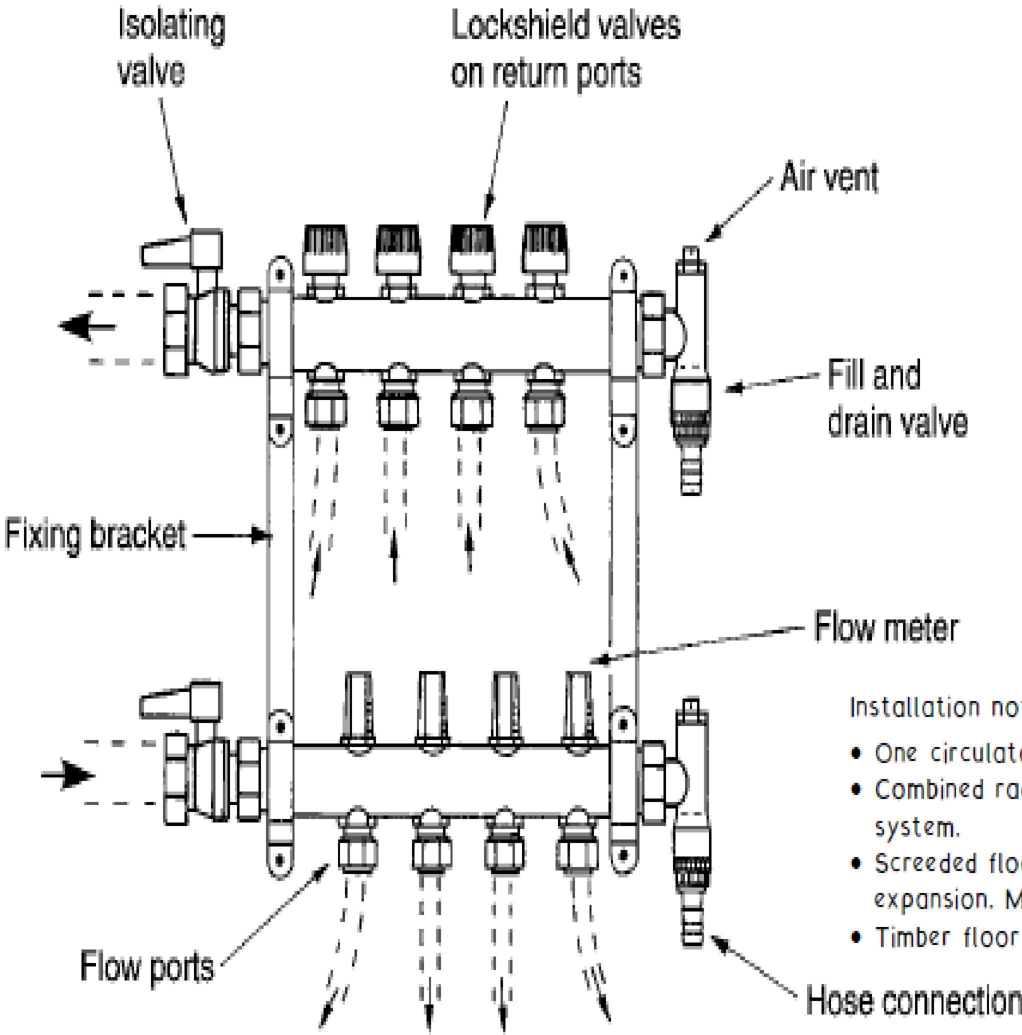
$$779 \div 13{\cdot}5 = 57{\cdot}7 \text{ watts}/m^2$$

Therefore, 15 mm diameter pipe at 200 mm spacing ($67 W/m^2$) is more than adequate, whilst 18 mm diameter pipe at 300 mm spacing ($55 W/m^2$) is just below.

Underfl oor Panel Heating – 2

Manifold or header † manifolds are discretely located on a wall or within a boxed unit. Manifolds comprise:-

- **Flow ports (2† 12).**
- **Return ports (2† 12).**
- **Drain valve and hose connection (may be used for filling).**
- **Air ventilation valve.**
- **Isolating valve to each bank of ports.**
- **Visual flow meters to each flow port.**
- **Lockshield balancing valve on each return port.**



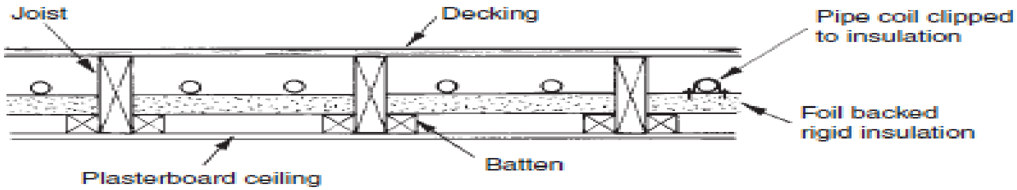
Underfloor heating manifold

Installation notes –

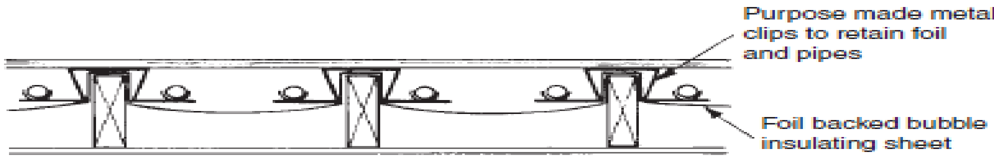
- One circulator per manifold.
- Combined radiator and panel systems, one circulator for each system.
- Screeded floor to have insulation turned up at edge to provide for expansion. Max. 40 m^2 or 8m linear, without expansion joint.
- Timber floor to have 6–8mm expansion gap around periphery.

Under floor installations

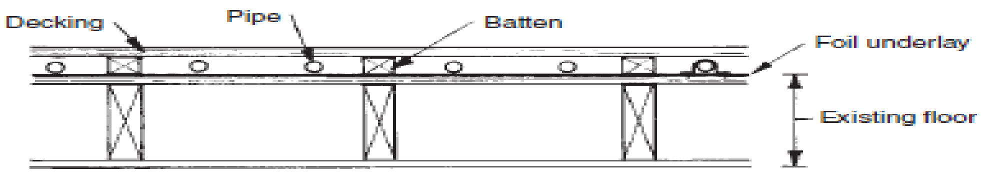
Suspended timber floor – 1



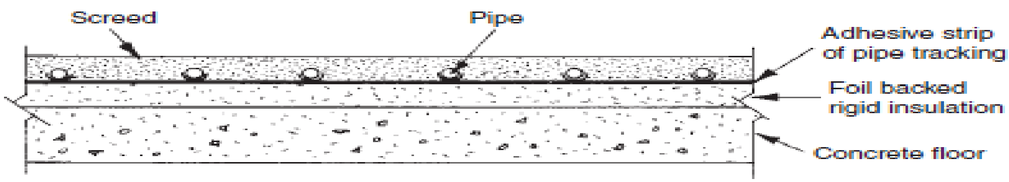
Suspended timber floor – 2



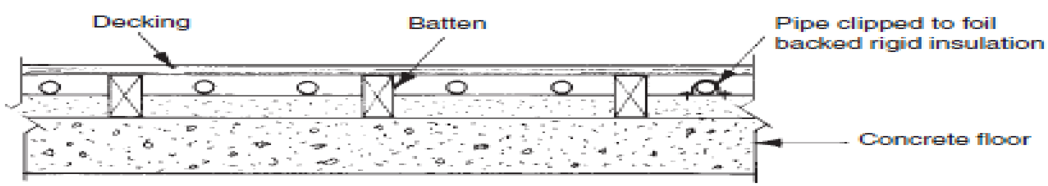
Suspended timber floor – 3 (existing floor structure not disturbed)



Solid floor – 1



Solid floor – 2



Note: In suspended timber floors 1 and 3, and solid floor 2, the void above and around the pipes can be filled with dry sand.

Expansion Facilities in Heating SystemS

In any water heating system, provision must be made for the expansion of water. A combined expansion and feed cistern is the traditional means. This will have normal expansion space under usual boiler firing conditions of about 4% of the total volume of water in the system, plus a further third as additional expansion space for high boiler firing. Although the expansion can be accommodated up to the overflow

level, there should be at least 25 mm between overflow and the fully expanded water level.

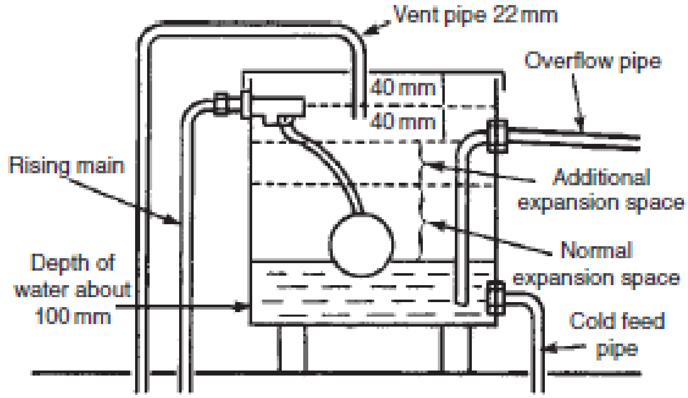
in Heating Systems(cont….)

Contemporary sealed systems have an expansion vessel connected close to the boiler. It contains a diaphragm and a volume of air or nitrogen to absorb the expansion. To conserve wear on the diaphragm, location is preferred on the cooler return pipe and on the negative side of the pump. System installation is simpler and quicker than with

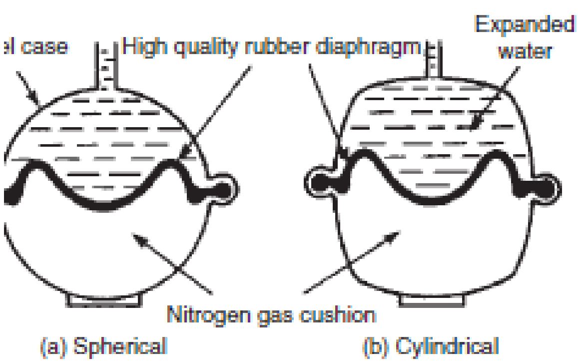
an expansion cistern. The air or nitrogen is pressurised to produce a minimum water pressure at the highest point on the heating system of 10 kPa (approx. 1 m head of water). This is necessary, otherwise when

filling the system, water would fill the vessel leaving no space for expansion.

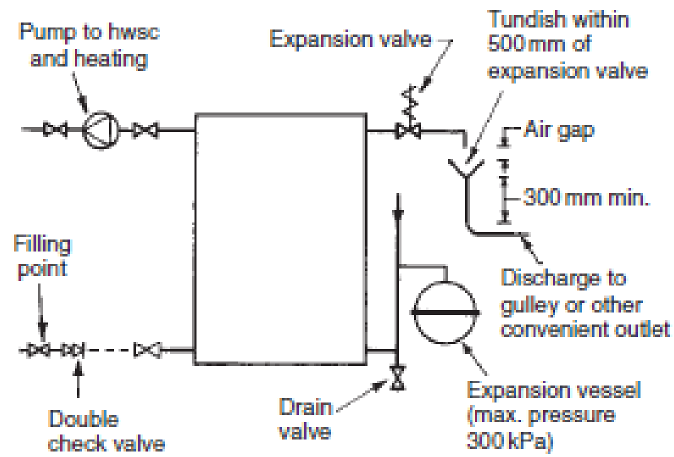
Expansion vessels



Expansion and feed cistern



Diaphragm expansion vessels



Installation of expansion vessel

Expansion vessels

Expansion vessels are produced to BS 6144. They must be correctly sized to accommodate the expansion of heated water without the system safety/pressure relief valve operating. The capacity of an expansion vessel will depend on the static pressure (metres head from

the top of the system to the expansion vessel), the system maximum working pressure (same setting as p.r.v.) obtained from manufacturer's

details and the volume of water in the system (approx. 15 litres per kW of boiler power).

Expansion vessels capacity

Capacity can be calculated from the following formula:

$$V = \frac{e \times C}{1 - P_i/P_f}$$

where: V = vessel size (litres)

e = expansion factor (see table)

C = capacity of system (litres)

P_i = static pressure (absolute)*

P_f = max. working pressure (absolute)*

* absolute pressure is 1 atmosphere (atm) of approx. 100 kPa, plus system pressure.

E.g. C = 100 litres

P_i = 1·5 atm or 150 kPa (5 m head static pressure)

P_f = 1·9 atm or 190 kPa (9 m head static pressure)

Water temp. = 80°C

Temp.°C	Exp. factor
50	0·0121
60	0·0171
70	0·0227
80	0·0290
90	0·0359

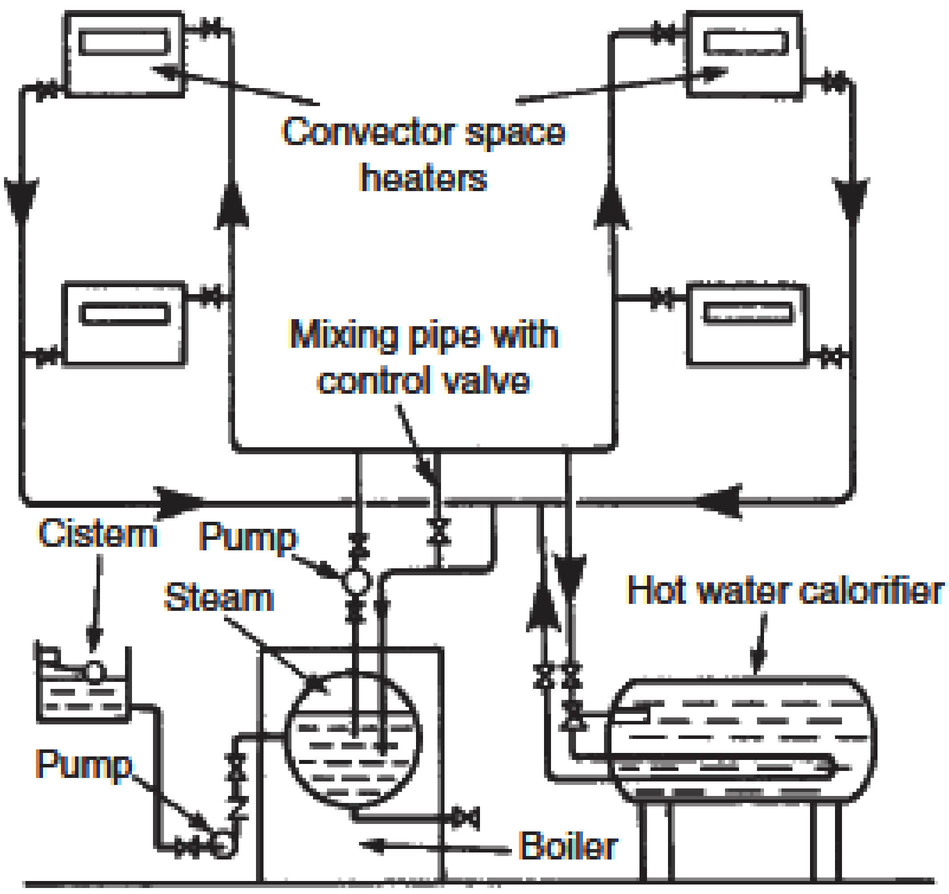
$$V = \frac{0{\cdot}029 \times 100}{1 - 150/190} = 13{\cdot}80 \text{ litres}$$

Water Heating Systems

Pressurization allows water to be heated up to 200 C without the water changing state and converting to steam. This permits the use of relatively small diameter pipes and heat emitters, but for safety reasons these systems are only suitable in commercial and industrial situations. Even then, convectors are the preferred emitter as there is less direct contact with the heating surface. Alternatively, radiators must be encased or provision made for overhead unit heaters and suspended radiant panels. All pipes and emitters must be specified to the highest standard.

Water Heating Systems (cont...)

Water can be pressurised by steam or nitrogen. Pressurised steam is contained in the upper part of the boiler. To prevent the possibility of the pressurised water ` flashing' into steam, a mixing pipe is required between the heating flow and return. Nitrogen gas is contained in a pressure vessel separate from the boiler. It is more popular than steam as a pressurising medium, being easier to control, clean, less corrosive and less compatible with water. Air could be an alternative, but this is more corrosive than nitrogen and water soluble.



Steam pressurisation

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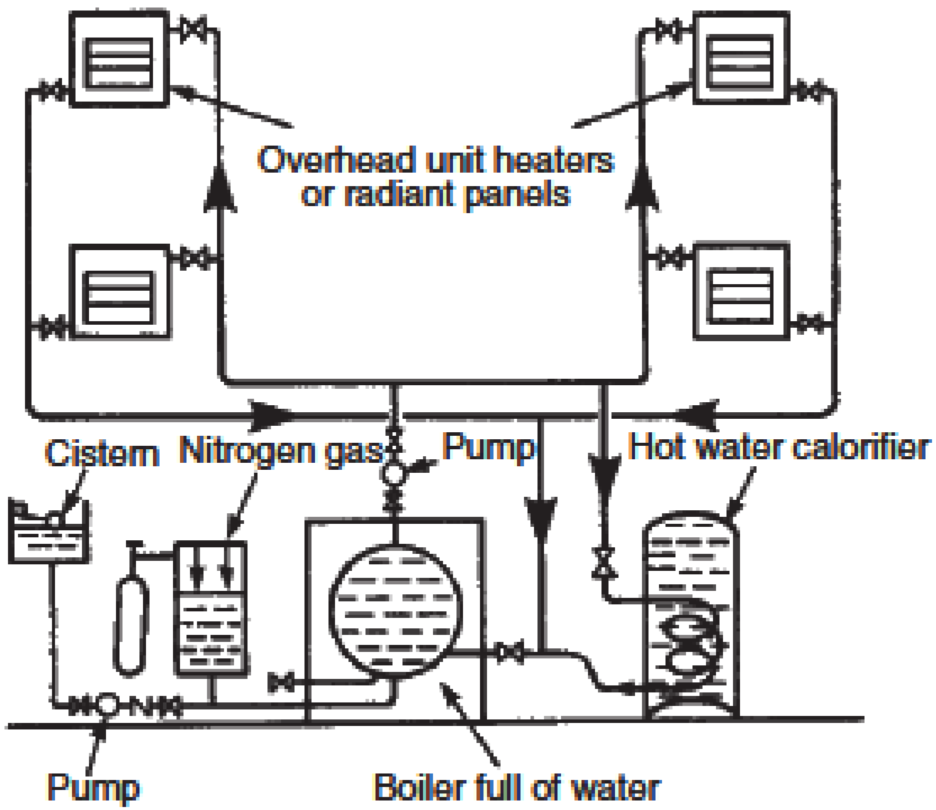


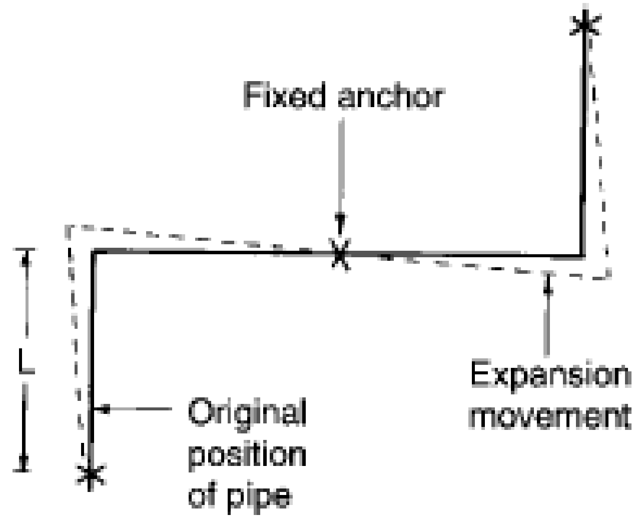
Nitrogen pressurisation

Pipework Expansion – 1

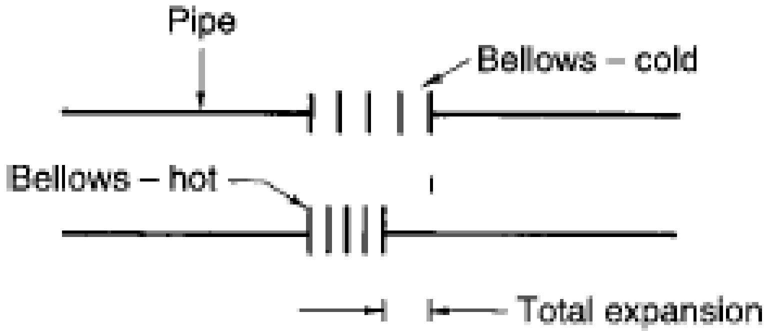
All pipe materials expand and contract when subject to temperature change. This linear change must be accommodated to prevent fatigue in the pipework, movement noise, dislocation of supports and damage to the adjacent structure. Expansion devices:

- Natural changes in direction.
- Axial expansion bellows.
- Expansion loops.

Bellows and loops are not normally associated with domestic installations.



Natural changes in direction or offsets



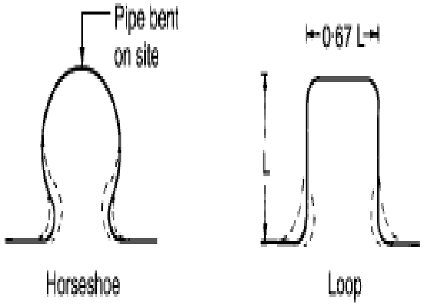
Axial expansion bellows responding to hot water

Bellows

Bellows are factory-made fittings normally installed ` cold-drawn ' to the total calculated expansion for hot water and steam services.

The bellows can then absorb all anticipated movement by contraction.

Where the pipe content is cold or refrigerated fluids, the bellows are compressed during installation.



Site made loops or horseshoe

Pipework Expansion – 2

Coefficients of linear expansion for common pipework materials:

Material	Coeff. Of expansion ($m/mK \times 10^{-6}$)
Cast iron	10·22
Copper	16·92
Mild steel	11·34
PVC (normal impact)	55·10
PVC (high impact)	75·10
Polyethylene (low density)	225·00
Polyethylene (high density)	140·20
ABS (acrylonitrile butadiene styrene)	110·20

Example

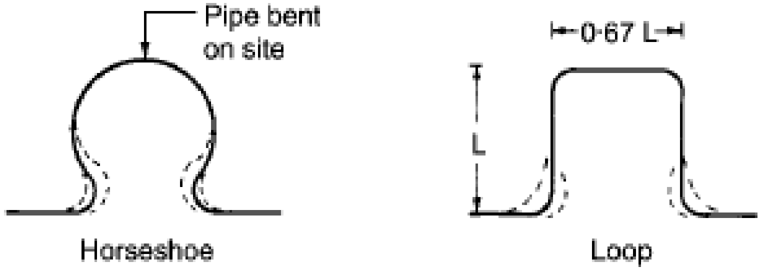
E.g. An 80mm diameter steel pipe of 20m fixed length is subject to a temperature increase from 20°C to 80°C (60K).

Formula:

Expansion = Original length × coeff. of expansion × Temp. diff.

$= 20 \times 11{\cdot}34 \times 10^{-6} \times 60$

$= 0{\cdot}0136$ m or $13{\cdot}6$ mm



Site made loops or horseshoe

Single offset:

$L = 100\sqrt{zd}$

L = see previous page

z = expansion (m)

d = pipe diameter (m)

$L = 100\sqrt{0{\cdot}0136 \times 0{\cdot}080} = 3{\cdot}30$ m minimum.

Loops:

$L = 50\sqrt{zd}$

$L = 50\sqrt{0{\cdot}0136 \times 0{\cdot}080} = 1{\cdot}65$ m minimum.

Top of loop $= 0{\cdot}67 \times L = 1{\cdot}10$ m minimum.

Heating Design – U Values

The thermal transmittance rate from the inside to the outside of a building, through the intermediate elements of construction, is known

as the ` U ' value. It is defined as the energy in watts per square meter of construction for each degree Kelvin temperature difference between inside and outside of the building, i.e. $W/m^2 K$. The maximum acceptable ` U ' values vary with building type and construction method.

Heating Design – ' U ' Values

Typical maximum area weighted average* 'U' values for dwellings:

External walls	0·35
Pitched roof	0·25
Pitched roof containing a room	0·20
Flat roof	0·25
External floor	0·25
Windows, doors and rooflights	2·00 (ave.) Wood/uPVC
Windows, doors and rooflights	2·20 (ave.) Metal

Non-domestic buildings also have a maximum 'U' value of 1·5 for vehicle access doors.

Heating Design – U Values

Window, door and roof-light areas have been limited as a proportion of the overall floor or external wall area to reduce the amount of

heat losses. These areas are no longer defined due to considerable improvements in glazing and sealing techniques. Nevertheless, provision

of glazing should be with regard to adequate daylighting and the effect of solar heat gains in summer.

EXAMPLE

E.g. A room in a dwelling house constructed to have maximum 'U' values has an external wall area of $30m^2$ to include $3m^2$ of double glazed window. Given internal and external design temperatures of 22°C and −2°C respectively, the heat loss through this wall will be:

	Area × 'U' × temperature difference
Wall:	27 × 0·35 × 24 = 226·80
Window:	3 × 2·00 × 24 = 144·00
	370·80

Heating Design, Heat Loss Calculations – 1

A heat emitter should be capable of providing sufficient warmth to maintain a room at a comfortable temperature.

It would be uneconomical to specify radiators for the rare occasions when external temperatures are extremely low, therefore an acceptable design external temperature for most of the UK is 1 C. Regional variations will occur, with a figure as low as 4 C in the north.

Heating Design, Heat Loss Calculations – 1

The following

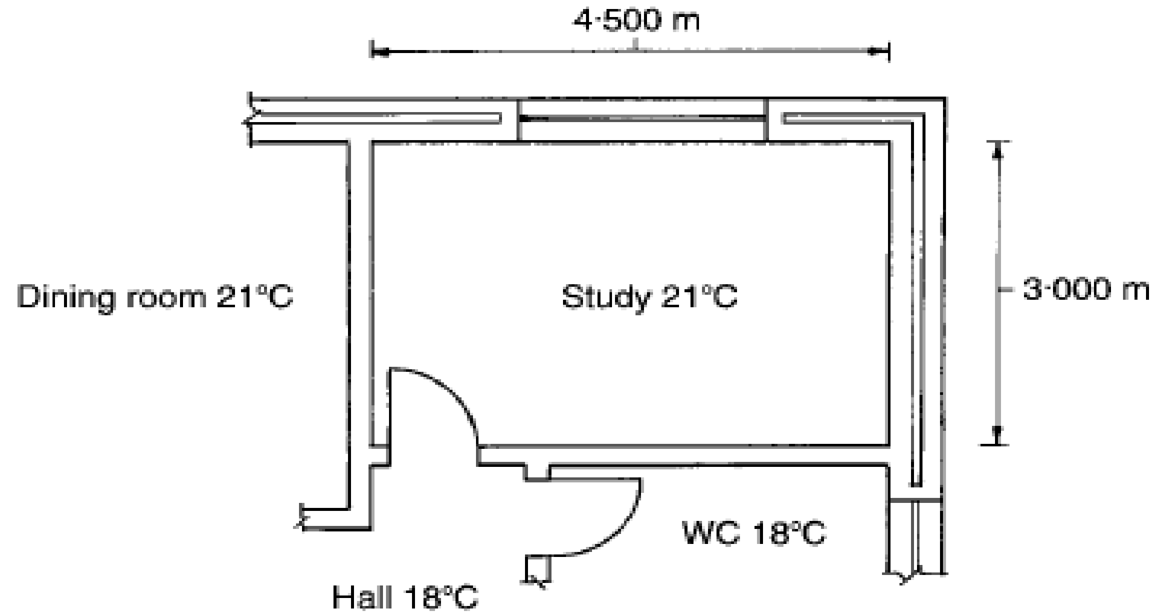
internal design temperatures and air infiltration rates are generally

acceptable:

Room	Temperature 0°C	Air changes per hour
Living	21	1·5
Dining	21	1·5
Bed/sitting	21	1·5
Bedroom	18	1·0
Hall/landing	18	1·5
Bathroom	22	2·0
Toilet	18	2·0
Kitchen	18	2·0

Practical example

The study in the part plan shown below can be used to illustrate the procedure for determining heat losses from a room.



External design temperature –1°C
Room height = 2·3 m
Door area = 2 m^2
Window area = 1·5 m^2
Ventilation rate = 1·5 a/c per hour
Bedrooms above at 18°C

Heating Design, Heat Loss Calculations – 2

To determine the total heat loss or heating requirement for a room, it is necessary to obtain the thermal insulation properties of construction. For the room shown on the previous page, the ` U ' values can be taken as:

External wall	0·35W/m^2 K
Window	2·00
Internal wall	2·00
Door	4·00
Floor	0·25
Ceiling	2·50

Heat is also lost by air infiltration or ventilation. This can be calculated and added to the heat loss through the structure, to obtain an estimate of the total heating requirement.

Heat loss by ventilation may be calculated using the following formula:

$$\text{Watts} = \frac{\text{Room volume} \times \text{A/c per hour} \times \text{Temp. diff. (int.-ext.)}}{3}$$

Example

For the study shown on the previous page:

$$(4{\cdot}5 \times 3 \times 2{\cdot}3) \times 1{\cdot}5 \times (21 - -1) \text{ divided by } 3 = 341{\cdot}55 \text{ watts}$$

Heat loss through the structure is obtained by summating the elemental losses:

Element	Area (m^2)		'U' value		Temp. diff. (int. –ext.)		Watts
External wall	15·75	×	0·35	×	22	=	121·28
Window	1·5		2·00		22		66
Internal wall	8·35		2·00		3		50·10
Door	2		4·00		3		24
Floor	13·5		0·25		22		74·25
Ceiling	13·5		2·50		3		101·25
							436·88

Total heat loss from the study = 341·55 + 436·88 = 778·43, i.e.

779 watts

Heating Design – Pipe Sizes

The size of pipework can be calculated for each sub-circuit and for the branches to each emitter. Unless emitters are very large, 15mm o.d. copper tube or the equivalent is standard for connections to radiators in small bore installations. To illustrate the procedure, the drawing on the previous page allows for calculation of heating flow and return pipes at the boiler, and the supply pipes to each area of a house.

Pipes 1 supply the total heating requirement, 18·9kW.
Pipes 2 supply the upper floor heating requirement, 8·9kW.
Pipes 3 supply the lower floor heating requirement, 10kW.

For each pair of pipes (flow and return) the mass flow rate is calculated from:

$$\text{kg/s} = \frac{\text{kW}}{\text{S.h.c} \times \text{temp.diff. (flow} - \text{return)}}$$

Example

Specific heat capacity (s.h.c.) can be taken as 4·2kJ/kg K. The temperature differential between pumped heating flow and return will be about 10K, i.e. 80°C – 70°C.

Therefore, the mass flow rate for:

$$\text{Pipes 1} = \frac{18\cdot 9}{4\cdot 2 \times 10} = 0\cdot 45\ \text{kg/s}$$

$$\text{Pipes 2} = \frac{8\cdot 9}{4\cdot 2 \times 10} = 0\cdot 21\ \text{kg/s}$$

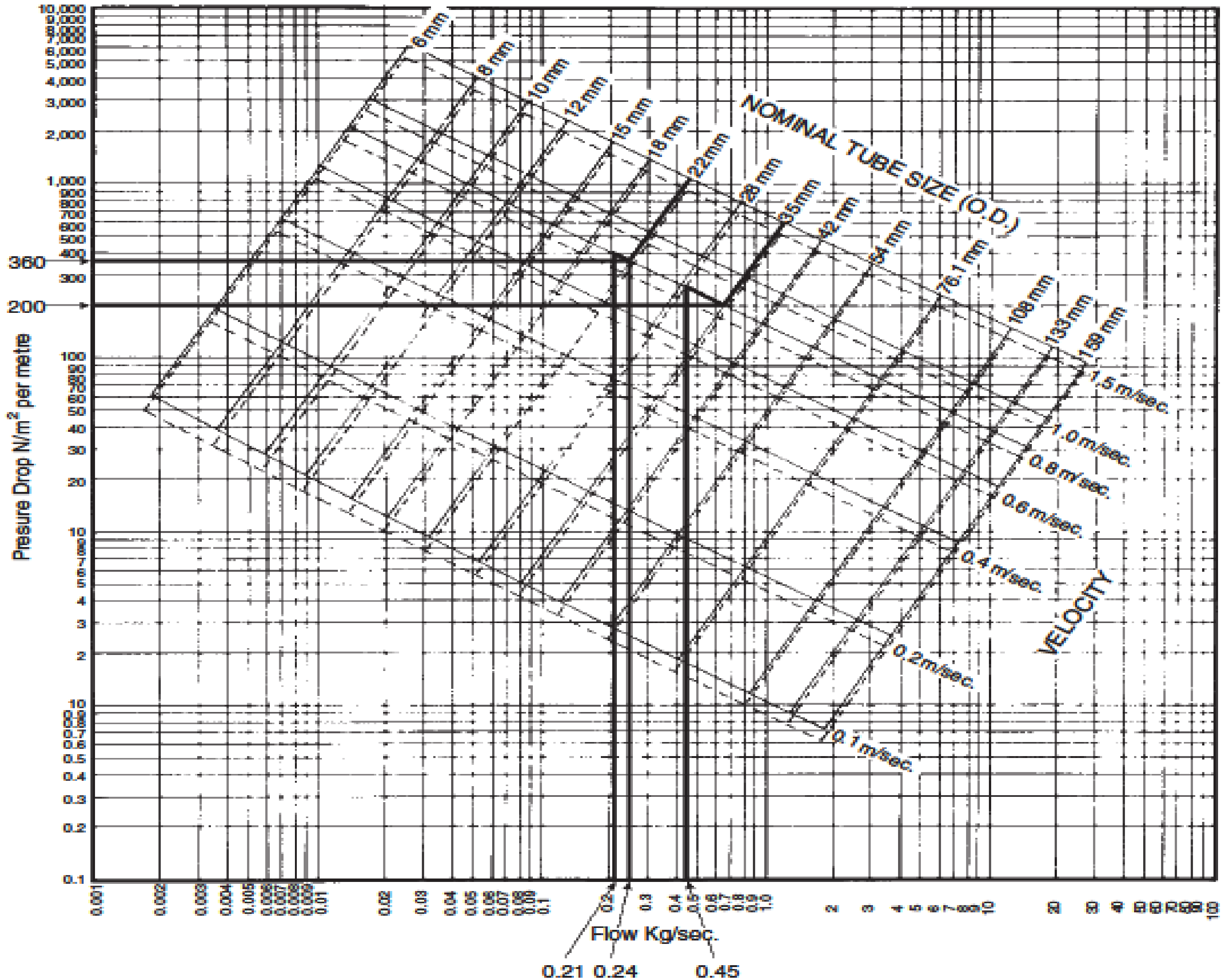
$$\text{Pipes 3} = \frac{10\cdot 0}{4\cdot 2 \times 10} = 0\cdot 24\ \text{kg/s}$$

Selecting a pumped water velocity of 0·8m/s (see page 97) and copper tube, the design chart on page 164 indicates:

Pipes 1 = 35mm o.d.

Pipes 2 = 22mm o.d.

Pipes 3 = 22mm o.d.



NOMINAL TUBE SIZE (O.D.)
6 mm
8 mm
10 mm
12 mm
15 mm
18 mm
22 mm
28 mm
35mm
42 mm
54 mm
76.1 mm
108 mm
133 mm
159 mm
1.5 m/sec.
1.0 m/sec.
0.8 m/sec.
0.6 m/sec.
0.4 m/sec.
0.2 m/sec.
0.1 m/sec.
VELOCITY
Presure Drop N/m² per metre
360
200
Flow Kg/sec.
0.21 0.24
0.45

Heating Design – Pump Rating

The specification for a pump is very much dependent on the total length of pipework, summated for each section within a system. In existing buildings this can be established by taking site measurements. For new buildings at design stage, estimates can be taken from the architects' working drawings. Actual pipe lengths plus an allowance for resistance due to bends, tees and other fittings (see page 55), provides an effective length of pipework for calculation purposes.

Example

Using the previous example, given that pipes 1, 2 and 3 are 6m, 10m and 12m effective lengths respectively, the design chart shown on page 164 can be used to determine resistance to water flow in each of the three sections shown:

Pressure drop in pipes 1 = 200N/m^2 per metre (or pascals per metre).

Pressure drop in pipes 2 and 3 = 360N/m^2 per metre (Pa per m).

Therefore: Pipes 1 @ 6 m × 200 Pa = 1200

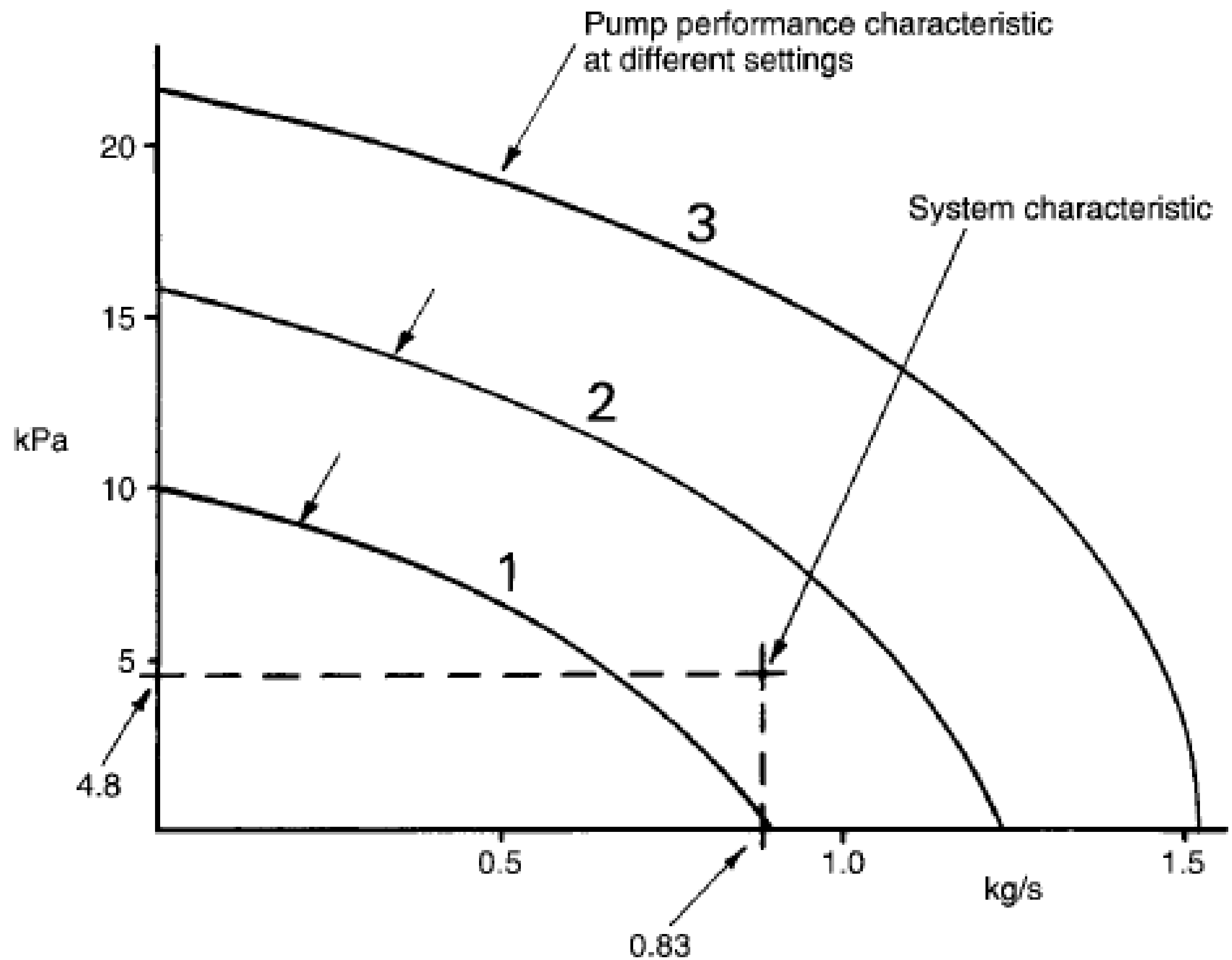
Pipes 2 @ 10 m × 360 Pa = 3600

Pipes 3 @ 12 m × 360 Pa = 4320

9120 Pa or 9·12 kPa

From this calculation, the pump specification is 0·45kg/s at 9·12kPa.

Pump performance chart:



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