Application, selection and installation of expansion vessels and ancillary equipment for sealed water systems —

Part 3: Code of practice for chilled and condenser systems

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Committees responsible for this British Standard

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Associated Offices Technical Committee
Association of Consulting Engineers
Association of Manufacturers of Domestic Unvented Supply Systems Equipment (MODUSSE)
British Marine Equipment Council
Building Services Research and Information Association
Chartered Institution of Building Services Engineers
Heating and Ventilating Contractors' Association
HEVAC Association
Institute of Domestic Heating Engineers
Sealed Expansion Vessel Association
Waterheater Manufacturers' Association

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Contents

Foreword

This British Standard code of practice has been prepared under the direction of the Refrigeration, Heating and Air Conditioning Standards Policy Committee.

The code complements BS 4814 and gives recommendations in its three Parts for the installation of expansion vessels in domestic heating and supply systems (Part 1); low and medium temperature hot water heating systems (Part 2); chilled water and condenser systems (Part 3); and boosted hot water supply systems.[1)]

The code deals with the work involved in the general planning, designing and installation of the various systems when the expansion and contraction of the system water is catered for in a sealed diaphragm type vessel. In all other respects the customary design process should be followed for the appropriate system.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 18, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

[1)] Planned.

Section 1. General

1 Scope

This Part of BS 7074 gives recommendations on the application of expansion vessels complying with BS 4814 having a maximum pressure of 7 bar[2)] for use in the following two types of system. It includes description, design considerations and application.

Sections 1 and 2 cover chilled water systems.

Sections 1 and 3 cover condenser water systems.

NOTE 1 Condenser water systems are normally associated with the heat reject side of refrigeration plant.

Recommendations are also given on:

a) the application and use of ancillary equipment and

b) testing, commissioning and maintenance.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 7074 the following definitions apply.

2.1
charging pressure

the initial pressure to which the gas/air side of the vessel is charged (which is equal to the initial system design pressure)

2.2
closed valve head (P_c)

the maximum head developed by a pump under a no-flow condition

2.3
design acceptance factor (a)

the ratio of the volume of water due to expansion, to total vessel volume

2.4
diaphragm (or membrane)

the flexible means by which the chamber of an expansion vessel is partitioned to maintain separation between the expanding hot water and the gas or air which in consequence becomes compressed. It may be either a literal diaphragm clamped between two parts (or halves) of the vessel, or a bag located by its mouth which is secured to the point of the water connection to the vessel

2.5
expansion percentage (e)

the expansion percentage increase in volume when water is heated to the design ambient temperature

2.6
expansion volume (V_a)

the increase in volume of water due to expansion of water when raised to the design ambient temperature

2.7
final system design pressure (P_f)

the pressure occurring at the mid-height of the expansion vessel at the maximum design system temperature

2.8
initial cold water fill temperature (t_i)

the basic reference temperature is taken to be 4 °C

2.9
initial system design pressure (P_i)

the pressure occurring at the mid-height of the expansion vessel at cold fill. This is equal to the static height pressure plus the pressure margin

2.10
lowest working pressure component (LWPC)

the component having the lowest working pressure in the system

2.11
maximum acceptance factor (A)

the ratio of maximum acceptance volume of the system to total volume

2.12
maximum acceptance volume (V)

the volume of water which the vessel may be allowed to contain

2.13
maximum vessel temperature

the maximum water temperature at which the vessel may be allowed to operate continuously

2.14
maximum vessel working pressure

the maximum pressure that the vessel may be allowed to contain in operation

2.15
pressure depth (P_d)

the vertical distance between the component being considered and the mid-height of the expansion vessel situated above it

2.16
pressure margin (P_s)

the additional pressure imposed on the circuit to exclude air from the system at the highest point

[2)] 1 bar = 10^5 N/m^2 = 100 kPa.

2.17

safety valve set pressure (P_{max})

the pressure at which the safety valve is set for operation

2.18

static height pressure (P_h)

the pressure created by the column of water between the uppermost part of the circuit and the mid-height of the expansion vessel

2.19

system flow temperature (t_f)

the maximum designed temperature of the water circulating in the system

2.20

total system volume (V_s)

the total volume of water in the complete system

2.21

total vessel volume (V_t)

the volume occupied by gas/air when the vessel is empty of water

3 Symbols, designations and units

The symbols for physical quantities, their designations and units used in this code of practice are given in Table 1.

Table 1 — Symbols, designations and units

Symbol	Designation	Unit
A	Maximum acceptance factor	—
a	Design acceptance factor	—
e	Expansion percentage	—
P_c	Closed valve head	bar gauge
P_d	Pressure depth	bar gauge
P_f	Final system design pressure	bar gauge
P_h	Static height pressure	bar gauge
P_i	Initial system design pressure	bar gauge
P_{max}	Safety valve, set pressure	bar gauge
P_s	Pressure margin	bar gauge
t_a	Maximum ambient temperature	°C
t_f	System flow temperature	°C
t_i	Initial cold water fill temperature	°C
V	Maximum acceptance volume	L
V_a	Expansion volume	L
V_s	Total system volume	L
V_t	Total vessel volume	L

4 Connection of expansion vessel to the system

4.1 General

The neutral point of the system is the point of connection of the pipework to the expansion vessel. It is recommended that the expansion vessel is in the system return pipework close to the heat exchanger. The filling position should be into the expansion pipework.

The point of connection of the expansion vessel(s) into the system having been clearly defined, the physical location of the vessel can be anywhere.

4.2 Location of pump relative to expansion vessel

4.2.1 *General.* When the pump in the system is not operating the only pressure existing varies between P_i and P_f depending upon the water temperature. When the pump is started the pressure within the system will change from its original static pressure conditions to a completely new set of pressure conditions. This new pressure condition is defined as the pump head and is indicated by the pressure drop between the suction and discharge of the pump. The pressure at the pump discharge will be higher than the system pressure at the pump suction by an amount equal to the pump head. The pressure drop due to friction within the system will gradually decrease the system pressure from that existing at the pump discharge to the lower pressure existing at the pump suction.

With the pump running, the system pressure will change generally as illustrated in Figure 1, Figure 2 and Figure 3. Attention is drawn to the point of no pressure change being relative to the point of connection of the expansion vessel into the system.

The pump only has the ability to create the pressure difference across itself and therefore there is no reason why the full pump head should not appear on the suction side of the pump as shown in Figure 2. It will be noted that the position of no pressure change (the neutral point) is different from that shown in Figure 1. By dictating the point of no pressure change (the neutral point), system pressure changes by pump operation can be controlled. In Figure 3, where the neutral point has been changed once again, a new set of pressure characteristics pertain.

4.2.2 *Neutral point.* The point of no pressure change, or the neutral point, is the point where the expansion vessel is connected to the system. This is because the air gas cushion in the expansion vessel follows basic gas laws and the change in gas pressure has to be accompanied by a change in gas volume. A change in gas volume in the vessel has to be accompanied by a change of water volume in the vessel.

It follows that a change in water volume in the vessel has to be accompanied by a change of water volume in the system; since water is incompressible, pump operation cannot increase or decrease the system water volume therefore pump operation cannot change vessel pressure. Since vessel pressure cannot change due to pump operation, the junction of the expansion vessel with the system has to be a point of no pressure change regardless of whether or not the pump operates.

4.2.3 *Neutral point at pump suction.* Figure 1 illustrates a system in which the neutral point is located at the pump suction. The pressure changes caused by pump operation are therefore added to the original system static pressure. Because all system pressure changes are additive and positive there is no possibility of pump cavitation or air being drawn into the system.

4.2.4 *Neutral point at pump discharge.* Figure 2 shows a system where the point of no pressure change is located at the pump discharge. All pressure changes caused by pump operation are subtracted from the original pressure and are of a negative type; under certain conditions this can cause unsatisfactory results. If the pressure decrease below the original static pressure is great enough, the system pressure could drop, circulation will be unstable and pump cavitation can occur with a resultant pump failure. If the pressure drops below atmospheric pressure, air can be sucked in at the vent, air pockets are created and circulation blocked, it is strongly recommended therefore that the neutral point should not be located at the pump discharge.

4.2.5 *Neutral point remote from pump.* By locating the expansion vessel at some distance from the pump, the system pressure change due to pump operation would appear as shown in Figure 3. The expansion vessel junction would be the neutral point and all pressure system changes would be referred from that point. Pressure gauge readings at the pump suction and discharge would show partially positive and partially negative readings with reference to the original non-operating static pressure condition. The pressure changes would be a function of the system pipe friction pressure drop between the pump and the vessel. It is emphasized that the problems created in systems where the neutral point is such that the pump head is all under suction (see Figure 2) are more likely to occur in higher head pump systems. Therefore in dealing with microbore systems it is important that the relative position of the neutral point and pump be fully understood in order that the most satisfactory system operation can be effected.

4.2.6 *Recommended arrangement.* If the expansion vessel is placed at the suction side of the pump, the pump suction pressure will not change regardless of whether or not the pump is operated; because the pump suction cannot change, the pump discharge pressure has to change. The pump differential head is then manifested as a positive increase in pressure at the pump discharge as shown in Figure 1.

The pressure increase due to pump head will then decrease around the system, depending upon the various friction losses in the system until at the pump suction the original static pressure is obtained. Because the pump suction pressure is unchanged due to pump operation it is suggested that the chiller be placed at the pump suction; this is the recommended relative arrangement of pump, chiller and expansion vessel within a system.

5 Testing and commissioning

5.1 Pressure testing the system

Expansion vessels, pressure switches, safety valve(s) and fill unit have to be isolated prior to hydraulic pressure testing. This is to ensure that these components are not damaged by over pressurization.

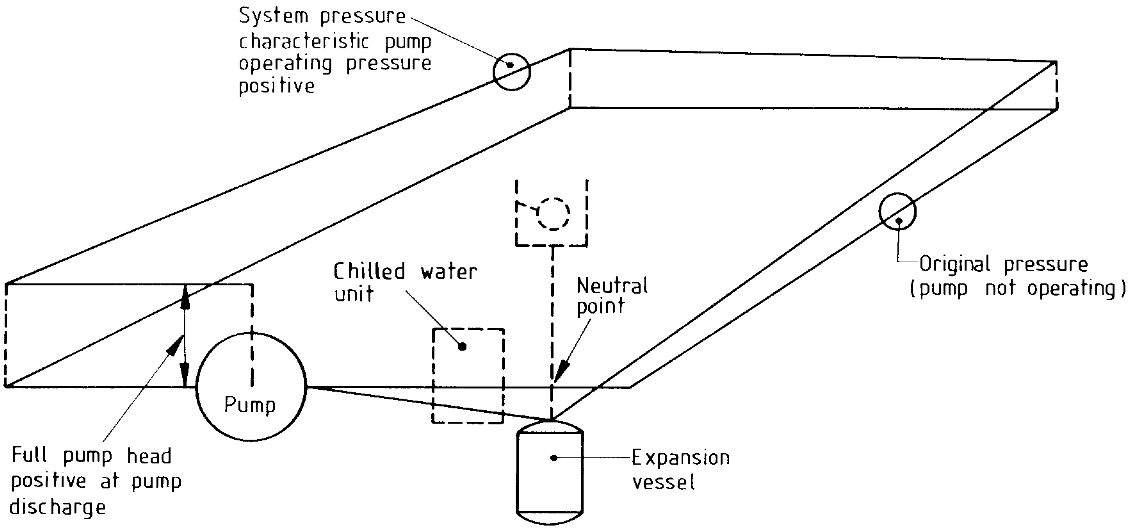


Figure 1 — System pressure variations: recommended arrangement

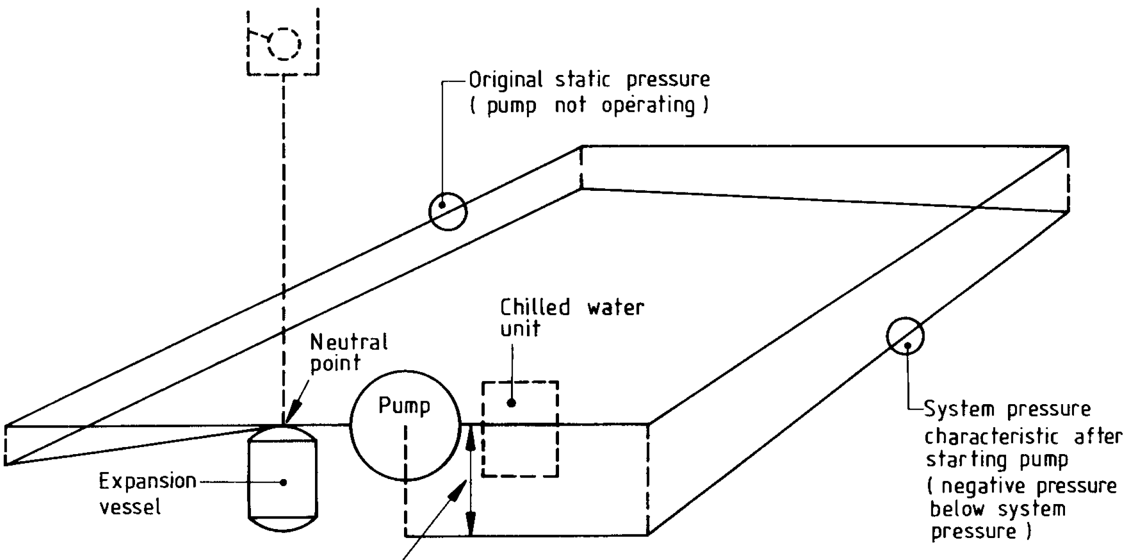


Figure 2 — System pressure variations: neutral point at pump discharge

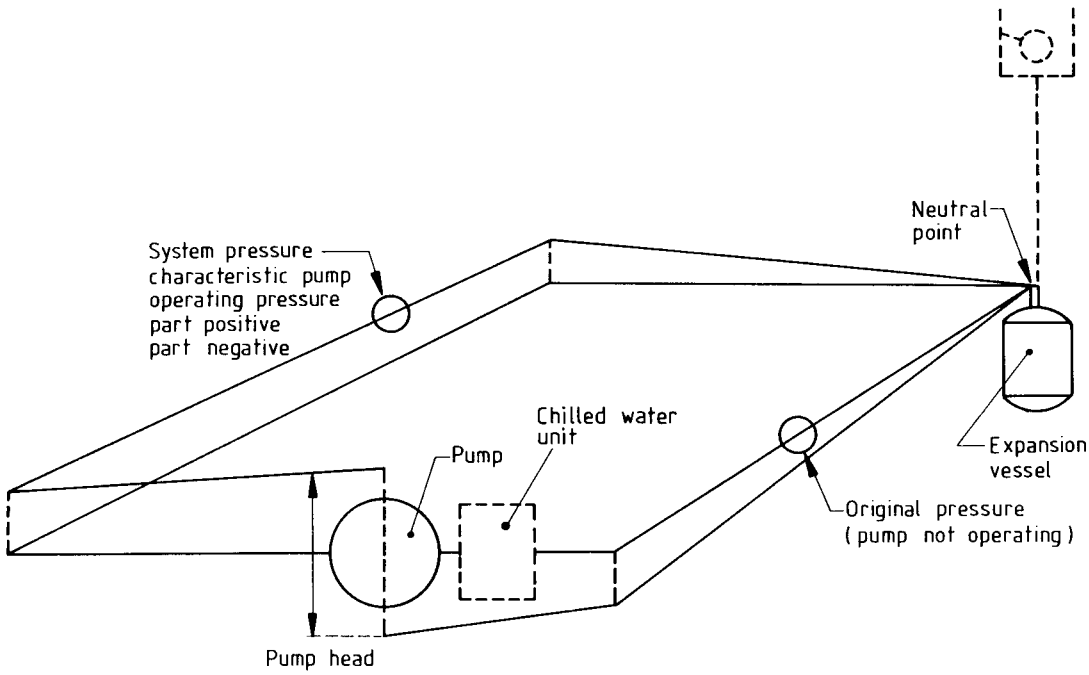


Figure 3 — System pressure variations: neutral point remote from pump

5.2 Commissioning

The recommended procedures given in the Chartered Institute of Building Services Engineers (CIBSE) Commissioning Codes should be followed for the system. For condensing systems the operation of the low and high pressure alarm switch(es) should be checked. The condensing system should be allowed to cool and then be partially drained to allow the pressure to drop such that the setting of the low pressure switch can be checked. For chilled water the system should be allowed to cool to normal operating temperature and then be partially drained to allow the setting of the low pressure alarm to be checked. The pressure should then be raised to the normal pressure consistent with the operating temperature. Then the system should be allowed to return to ambient temperature. The filling unit should be started and pressure raised to check the high pressure alarm switch. The pressure should then be reduced to a pressure consistent with the ambient temperature. This is best carried out when the expansion vessel has been isolated, which reduces the volume of water necessary to raise the pressure.

6 Maintenance

Maintenance instructions provided by the manufacturers of the equipment installed should be closely followed. These should be handed to the user.

7 Workmanship

Work on sealed systems as described in this Part of this code of practice should be carried out by competent persons.

Section 2. Chilled water systems

8 Design considerations

Successful and continuing safe operation of a system (see Figure 4) depends on the use of the correct equipment properly installed to a good design, well engineered and effectively maintained. It is important to note that expansion vessels constructed in accordance with BS 4814 are not to be subjected to a pressure greater than 7 bar.

To ensure satisfactory operation of a chilled water system the following items need to be considered at the design stage, in addition to the customary design procedures applicable to the system.

a) The preferred position of the expansion vessel(s) and ancillary equipment is in the immediate vicinity of the cooling plant whether this be at basement, roof or intermediate level. Provision has to be made for the additional space required.

b) The availability of adequate water supply and the method of filling and maintaining a full system.

c) Maximum allowable working pressure at the expansion vessel(s). Additional pressures will occur at some items of equipment due to static head; circulating pump(s) may also impose additional pressures.

d) The position in the system of the circulating pump(s) relative to the point of connection of the expansion vessel(s) into the system.

e) Pump operating characteristics under all system operating conditions. The pump should not be the type incorporating packed glands.

f) Flow and return temperatures and maximum ambient temperature. If the maximum design system temperature specified by the system designer exceeds the maximum vessel temperature the manufacturer's instructions should be followed with regard to diaphragm protection.

g) Total water content of the system.

NOTE The addition of anti-freeze or similar fluid will affect the expansion percentage coefficient and may also affect the diaphragm material (see Figure 5).

h) Capacity, size and number of expansion vessel(s). It is important that the correct procedure is followed when selecting vessel(s). The vessel(s) and expansion pipework should not be thermally insulated.

i) The need for and position of ancillary equipment such as air separators, air vents, control and safety devices.

j) Provision should be made for automatically maintaining a full system. A unit should be provided with all necessary safety devices, to the requirements of the local water authority.

9 Application

9.1 Assuming that the remainder of the system has been designed following customary design practice, during shut down or failure periods provision for expansion has to be made to accommodate expansion as the water temperature rises to ambient. The procedure for the design of a chilled water system should follow the recommendations given in **9.2** and **9.3**.

9.2 Select a position for the expansion equipment, which should preferably be in the immediate vicinity of the cooling plant.

9.3 Calculation of the sizes of the vessels should be based on the following.

a) Water content of the system in litres (V_s) (this has to include all circulatory pipework, cooling units, chilled water plant and any form of heat exchangers that may be incorporated).

b) Maximum ambient temperature (t_a) in °C.

c) Expansion percentage (e) (see Table 2[3)]).

d) Static height pressure (P_h) in bar gauge.

e) Initial system design pressure (P_i) in bar gauge.

The margin normally added to the static height pressure is 0.3 bar. This added pressure margin (P_s) is necessary to expel air from the system, also to permit system control pressure differentials.

$$P_i = P_h + P_s$$

f) Final system design pressure (P_f) in bar gauge; where the expansion vessel is located:

1) at the lowest point in the installation: P_f is necessary to calculate the design acceptance factor (a). P_f can then be calculated by taking the component having the lowest working pressure (LWPC) and deducting the pump head available at LWPC;

[3)] If an anti-freeze solution is used, the expansion factor will be substantially increased dependent upon the solution strength. Figure 5 shows values for a typical anti-freeze solution. The appropriate expansion factor should be applied when calculating the size of the vessel, see also note to clause **8** g).

2) at high level, i.e. roof plant rooms: in these circumstances P_f will be lower than in 1) and because the entire system is below the plant room a minimum value of 0.7 bar may be adopted for P_i. The expansion vessel volume calculation [see **9.3** h)] should be made using the vessel manufacturer's recommended acceptance factor and the procedure set out in **9.3** i), j) and k) followed to calculate a_1, P_f and P_{max}. To ensure that the working pressure of the unit at the base of the system is not exceeded, calculate P_d. Add P_{max} to P_d and the pump closed-valve-head and compare the result with the unit working pressure. If this is exceeded either re-select a unit with a higher working pressure, or calculate the size of the vessel to achieve a lower working pressure.

g) Design acceptance factor (a):

$$a = \frac{(P_f + 1) - (P_i + 1)}{P_f + 1}$$

where $P_f + 1$ and $P_i + 1$ expresses P_f and P_i respectively in absolute units.

h) The total vessel volume (V_t) in L, can now be calculated as follows:

$$V_t = \frac{V_a}{a}$$

where $V_a = V_s \times e$

To allow for contingencies and operational variances a margin should be added. It is recommended that this should be at least 10 %. A vessel should be selected with a volume equal to or higher than the above final volume (V_t + 10 %).

i) Based on the selected vessel a revised acceptance factor a_1 should be calculated as follows:

$$a_1 = \frac{V_a}{V_t + 10\ \%}$$

if the calculated factor a_1 exceeds the manufacturer's recommended value, a larger vessel has to be selected. a_1 is then re-calculated to obtain an acceptable lower value.

j) Re-calculate the new value of P_f in bar gauge, related to the selected vessel. The new final system design pressure will be:

$$P_f = \frac{P_i + a_1}{1 - a_1}$$

k) Calculate the safety valve set pressure P_{max} in bar gauge.

$P_{max} = P_f + 0.3$ bar, for systems up to 5 bar;

for systems operating above 5 bar:

$P_{max} = P_f + 15\ \%$

9.4 Due account has to be made for the position of the pump/neutral point relative to the heat exchange unit.

NOTE An example of a calculation of the size of expansion vessels for a chilled water system is given in **A.1**.

10 Ancillary equipment

10.1 General

For the satisfactory operation of a system containing an expansion vessel certain items of ancillary equipment will need to be incorporated. **10.2** provides a list and commentary as appropriate, but does not necessarily comprise a complete control or safety system as may be required for certain projects; neither will every system need to incorporate all the ancillaries listed.

Table 2 — Expansion percentages (e) for various flow temperatures (t_f) from 4 °C initial temperature[a]

$$e = \left(\frac{V_a}{V_s}\right) 100$$

t_f	e	t_f	e	t_f	e	t_f	e
°C	%	°C	%	°C	%	°C	%
0	0.02	30	0.44	60	1.71	150	9.06
2	0.01	32	0.50	70	2.28	155	9.64
4	0.00	34	0.57	80	2.91	160	10.20
6	0.01	36	0.64	82.2	3.07	165	10.82
8	0.02	38	0.70	90	3.60	170	11.45
10	0.03	40	0.78	100	4.35	180	12.75
12	0.06	42	0.86	105	4.77	190	14.15
14	0.08	44	0.94	110	5.15	200	15.65
16	0.11	46	1.03	115	5.62		
18	0.14	48	1.12	120	6.01		
20	0.18	50	1.21	125	6.52		
22	0.23	52	1.30	130	7.00		
24	0.28	54	1.40	135	7.50		
26	0.33	56	1.50	140	8.00		
28	0.38	58	1.60	145	8.53		

[a] These values originate from the "Steam tables 1964" of the National Engineering Laboratory (published by HMSO Edinburgh) and were derived from Table C2-2 of the CIBSE Guide 1970 by taking the reciprocal of the density expressed in millilitres per gramme and stating this as a percentage, using the volume of one millilitre of water at 4 °C as unity.
Example: Consider water at 100 °C, density = 958.3 kg/m^3

$$\text{mL/g} = \frac{1 \times 10^6}{958.3 \times 10^3} = \frac{10^3}{958.3} = 1.0435$$

therefore percentage expansion from unity at 4 °C = (1.0435 – 1) 100 = 4.35 %

Ancillaries may be combined; when this is done the composite unit needs to be designed to meet the higher requirements of the individual items included.

All ancillaries should, where practicable, be so constructed that they fail safe.

All ancillaries should comply with any relevant British Standards.

10.2 Components

10.2.1 *System initial fill connection.* Due to the time taken it is preferable not to use the automatic make-up units for the initial filling. To facilitate the initial filling of the system a temporary fill connection may be made from a water mains supply in accordance with water byelaws. For protection of the mains supply to the installation when filling from a temporary connection, the following items should be incorporated at the point of filling: pressure reducing valve, pressure gauge, non-return valve, anti-vacuum valve, stop cocks. The temporary hose connection has to be removed after the system has been filled. Care should be exercised to ensure that the fill pressure does not exceed the calculated value of P_i at the operating temperature or P_f at ambient temperature.

10.2.2 *Automatic make-up unit.* The automatic make-up unit is a device to ensure the initial system design pressure is maintained. A separate small pump and associated cold water break tank is provided for the purpose of introducing water into the system to make up for losses, etc. This may incorporate a small hydraulic accumulator to reduce the frequency of pump starting.

The electrical supply to this unit should not be subject to unauthorized disconnection.

10.2.3 *Safety valve.* A device to ensure that the pressure in the system does not exceed a predetermined level.

10.2.4 *Pressure gauge.*

10.2.5 *Thermometer.*

10.2.6 *High pressure alarm switch.* An audio and/or visual device indicating when a predetermined maximum system pressure is reached. The pressure at which this alarm operates should not be less than 0.35 bar below the safety valve pressure setting.

10.2.7 *Low pressure switch.* A device which causes the chiller to shut off when a predetermined minimum system pressure is reached. A manual reset and/or alarm may be incorporated.

10.2.8 *Temperature controller (thermostat).* A device to control the system water-flow temperature. The thermostat should be set so as to prevent the formation of ice.

10.2.9 *Air separator.* A device that separates air and other gases from suspension in the system water.

10.2.10 *Automatic air vent.* A device that automatically allows air to be vented from a part of a system. Hygroscopic devices are not recommended.

10.3 Pressure and temperature ratings

10.3.1 The maximum operating temperature and/or pressure should be stated on a label affixed to the ancillary, or clearly stated in the instructions for installing and operating the ancillary.

10.3.2 Where the maximum operating pressure is stated in accordance with **10.3.1** the test pressure should be 1.5 times the stated value.

10.3.3 The lift pressure of a safety valve should be determined by the manufacturer and should be clearly stated on a label affixed to the body of the valve. The operating mechanism should be sealed by the manufacturer.

10.3.4 Pressure switches should operate consistently within ± 0.15 bar of the set point and required value. Incremental adjustment is preferable. The switch should be provided with a device to indicate clearly when it has tripped out. Audio alarms should be attenuatable and audio and visual alarms should be positioned where they can be clearly identified.

10.3.5 Temperature limit switches and temperature controllers should operate consistently within ± 2 °C of the set point and required value. Incremental adjustment is preferable. The switch should be provided with a device to indicate clearly when it has tripped out.

10.4 Constructional details

Ancillaries should be selected from those constructed of corrosion-resistant material of adequate strength.

All fasteners should comply with relevant standards.

All electrical wiring and equipment should comply with the detailed requirements of the Regulations for the Electrical Equipment of Buildings (published by the Institution of Electrical Engineers), or be in accordance with appropriate regulations.

Dials or scales, where fitted, should be clearly visible.

All equipment (valves, pipework and fittings) should meet the requirements of the local water authority.

10.5 Installation instructions

Clear instructions regarding installation, operation and maintenance should be included with each ancillary item.

10.6 Marking

Each ancillary item should carry the following information:

a) manufacturer's or agent's name or symbol;

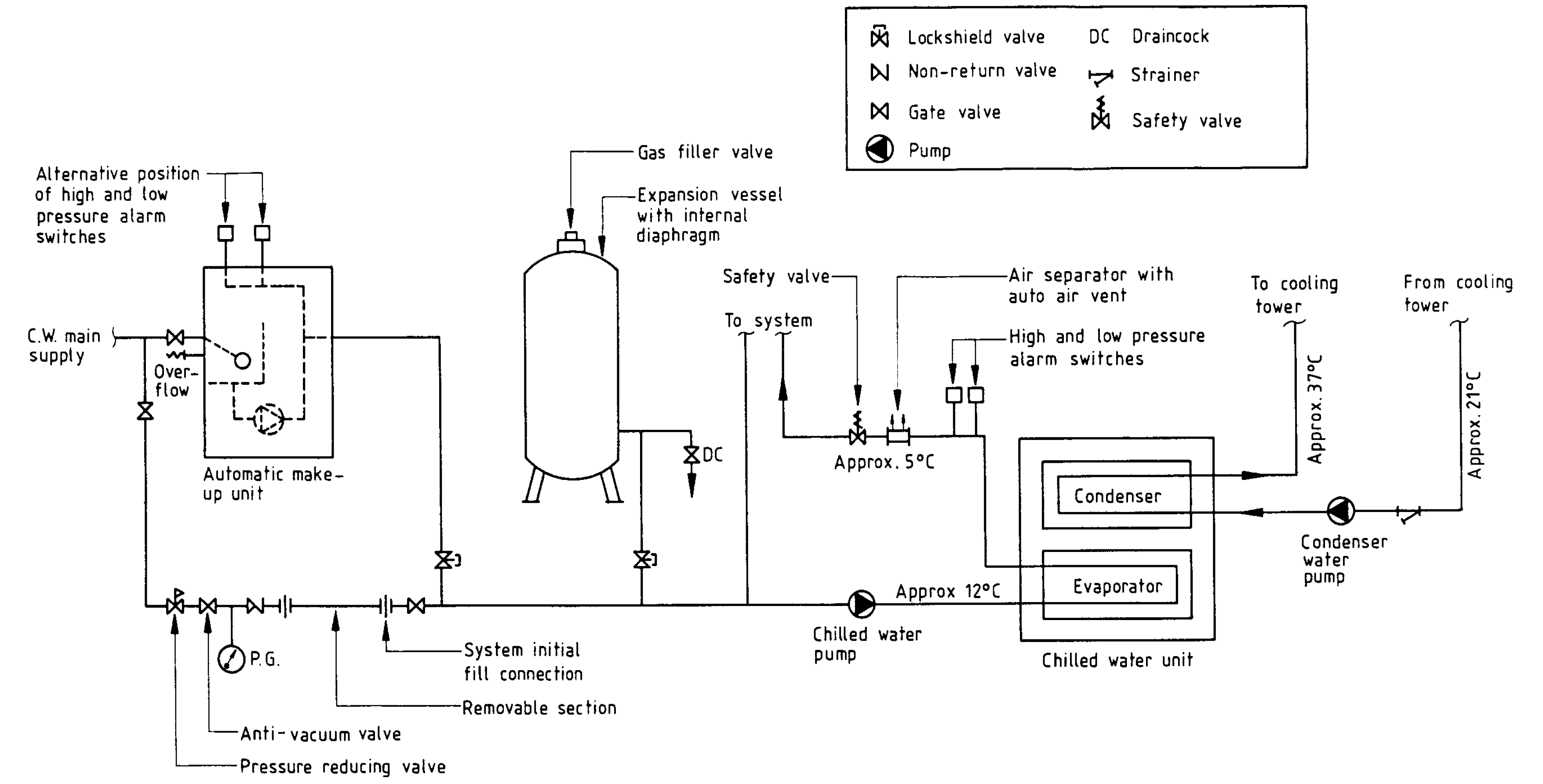
b) serial number or batch number where practicable;

c) temperature rating or pressure rating where appropriate;

d) electrical rating where appropriate;

e) indication of year of manufacture;

f) the number of the relevant British Standard where applicable.



NOTE The temperatures shown are approximate and vary according to climatic conditions and equipment used.

Figure 4 — Chilled water system

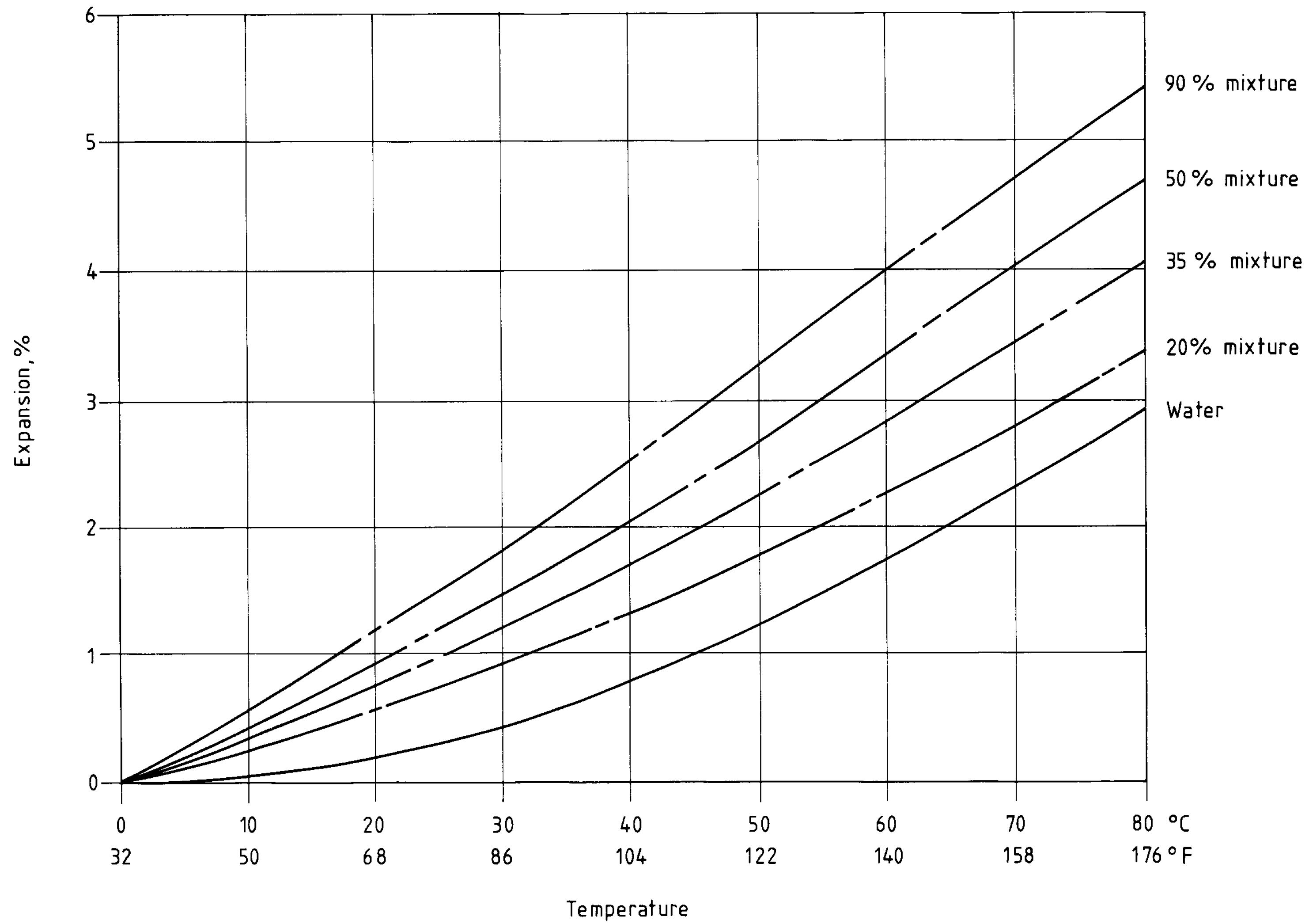


Figure 5 — Typical expansion percentage of water mixed with anti-freezing agent versus temperature

Section 3. Condenser water systems

11 Design considerations

Successful and continuing safe operation of a system (see Figure 6) depends on the use of the correct equipment properly installed to a good design, well engineered and effectively maintained. It is important to note that expansion vessels constructed in accordance with BS 4814 are not to be subjected to a pressure greater than 7 bar.

To ensure satisfactory operation of a condenser water system the following items need to be considered at the design stage, in addition to the customary design procedures applicable to the systems.

a) The preferred position of the expansion vessel(s) and ancillary equipment is in the immediate vicinity of the heat transfer plant whether this be at basement, roof or intermediate level. Provision has to be made for the additional space required.

b) The availability of adequate water supply and the method of filling and maintaining a full system.

c) Maximum allowable working pressure at the expansion vessel(s). Additional pressures will occur at some items of equipment due to static head; circulating pump(s) may also impose additional pressures.

d) The position in the system of the circulating pump(s) relative to the point of connection of the expansion vessel(s) into the system.

e) Pump operating characteristics under all system operating conditions. The pump should not be the type incorporating packed glands.

f) Flow and return temperatures and maximum ambient temperature. If the maximum design system temperature specified by the system designer exceeds the maximum vessel temperature, the manufacturer's instructions should be followed with regard to diaphragm protection.

g) Total water content of the system.

NOTE The addition of anti-freeze or similar fluid will affect the expansion percentage coefficient and may also affect the diaphragm material (see Figure 5).

h) Capacity, size and number of expansion vessel(s). It is important that the correct procedure is followed when selecting vessel(s). The vessel(s) and expansion pipework should not be thermally insulated.

i) The need for and position of ancillary equipment such as air separators, air vents, control and safety devices.

j) Provision should be made for automatically maintaining a full system. A unit should be provided with all necessary safety devices, to the requirement of the local water authority.

12 Application

12.1 Condenser water circuits are often sealed to obtain the following benefits:

a) reduction of corrosion and maintenance to the condenser unit;

b) permits heat reclamation to facilitate energy conservation.

NOTE When an anti-freeze solution is used, e.g. as in a heat reclaim system using run-around coils, the expansion factor will be substantially increased dependent upon the solution strength. Figure 5 shows values for a typical anti-freeze solution. The appropriate expansion factor should be applied in sizing the vessel, see also note to clause **11** g). Heat transfer values are reduced when anti-freeze solution is used and should be taken into account.

Assuming that the remainder of the system has been designed following customary design practice, the procedure for the design of a sealed system should follow the recommendations given in **12.2** and **12.3**.

12.2 Select a position for the expansion equipment, which should preferably be in the immediate vicinity of the heat transfer plant.

12.3 Calculation of the sizes of the vessels should be based on the following.

a) Water content of the system in litres (V_s) (this has to include all circulatory pipework and heat transfer equipment).

b) Flow water temperature (t_f) in °C.

c) Expansion percentage (e) [see Table 2 and note to **12.1** b)].

d) Static height pressure (P_h) in bar gauge.

e) Initial system design pressure (P_i). The margin normally added to the static height pressure is 0.3 bar. This added pressure margin (P_s) is necessary to expel air from the system, also to permit system control pressure differentials:

$$P_i = P_h + P_s$$

f) Final system design pressure (P_f) in bar gauge; where the expansion vessel is located:

1) at the lowest point in the installation: P_f is necessary to obtain the design acceptance factor a. P_f can then be calculated by taking the component having the lowest working pressure (LWPC) and from this deducting the safety valve lifting pressure margin and the pump head available at LWPC

2) at high level, i.e. roof plant rooms: in these circumstances P_f will be lower than in 1) and because the entire system is below the plant room a minimum value of 0.7 bar may be adopted for P_i. The expansion vessel volume calculation [see **12.3** h)] should be made using the vessel manufacturer's recommended acceptance factor and the procedure set out in **12.3** i), j) and k) followed to calculate a_1, P_f and P_{max}. To ensure that the working pressure of unit at the base of the system is not exceeded, calculate P_d. Add P_{max} to P_d and the pump closed-valve-head and compare the result with unit working pressure. If this is exceeded either re-select a unit with a higher working pressure, or calculate the size of the vessel to achieve a lower working pressure.

g) Design acceptance factor (a);

$$a = \frac{(P_f + 1) - (P_i + 1)}{P_f + 1}$$

where $P_f + 1$ and $P_i + 1$ expresses P_f and P_i respectively in absolute units.

h) The total vessel volume (V_t) in L, can now be calculated as follows:

$$V_t = \frac{V_a}{a}$$

where $V_a = V_s \times e$

To allow for contingencies and operational variances a margin should be added. It is recommended that this should be at least 10 %. A vessel should be selected with a volume equal to or higher than the above final volume (V_t + 10 %).

i) Based on the selected vessel a revised acceptance factor a_1 should be calculated as follows:

$$a_1 = \frac{V_a}{V_t + 10\ \%}$$

if the calculated factor a_1 exceeds the manufacturer's recommended value a larger vessel has to be selected. a_1 is then re-calculated to obtain an acceptable lower value.

j) Re-calculate the new value of P_f in bar gauge, related to the selected vessel. The new final system design pressure will be:

$$P_f = \frac{P_i + a_1}{1 - a_1}$$

k) Calculate the safety valve set pressure

$P_{max} = P_f + 0.3$ bar, for systems up to 5 bar;

for systems operating above 5 bar:

$P_{max} = P_f + 15\ \%$

12.4 Due account has to be made for the position of the pump/neutral point relative to the heat exchange unit.

NOTE An example of a calculation of the size of expansion vessels for a condenser water system is given in **A.2**.

13 Ancillary equipment

13.1 General

For the satisfactory operation of a system containing an expansion vessel certain items of ancillary equipment will need to be incorporated. **13.2** provides a list and commentary as appropriate, but does not necessarily comprise a complete control or safety system as may be required for certain projects; neither will every system need to incorporate all the ancillaries listed.

Ancillaries may be combined; when this is done the composite unit needs to be designed to meet the higher requirements of the individual items included.

All ancillaries should, where practicable, be so constructed that they fail safe.

All ancillaries should comply with any relevant British Standards.

13.2 Components

13.2.1 *System initial fill connection.* Due to the time taken it is preferable not to use the automatic make-up unit for the initial filling. To facilitate the initial filling of the system a temporary fill connection may be made from a water mains supply in accordance with water byelaws. For protection of the mains supply to the installation when filling from a temporary connection, the following items should be incorporated at the point of filling: pressure reducing valve, non-return valve, anti-vacuum valve, stop cocks. The temporary connection has to be removed after the system has been filled. Care should be exercised to ensure that the fill pressure does not exceed the calculated value of P_i.

13.2.2 *Automatic make-up unit.* The automatic make-up unit is a device to ensure the initial system design pressure is maintained. A separate small pump and associated cold water break tank is provided for the purpose of introducing water into the system to make up for losses, etc. This may incorporate a small hydraulic accumulator to reduce the frequency of pump starting.

The electrical supply to this unit should not be subject to unauthorized disconnection.

13.2.3 *Safety valve.* A device to ensure that the pressure in the system does not exceed a predetermined level.

13.2.4 *Pressure gauge.*

13.2.5 *Thermometer.*

13.2.6 *High pressure switch.* A device which causes the heat source to shut off when a predetermined maximum system pressure is reached. The pressure at which this switch operates should not be less than 0.3 bar below the safety valve pressure setting. A manual reset and/or alarm may be incorporated.

13.2.7 *Low pressure switch.* A device which causes the heat source to shut off when a predetermined minimum system pressure is reached, normally 0.3 bar below P_i.

13.2.8 *Temperature controller (thermostat).* A device to control the system water-flow temperature.

13.2.9 *Air separator.* A device that separates air and other gases from suspension in the system water.

13.2.10 *Automatic air vent.* A device that automatically allows air to be vented from a part of a system. Hygroscopic devices are not recommended.

13.3 Pressure and temperature ratings

13.3.1 The maximum operating temperature and/or pressure should be stated on a label affixed to the ancillary, or clearly stated in the instructions for installing and operating the ancillary.

13.3.2 Where the maximum operating pressure is stated in accordance with **13.3.1** the test pressure should be 1.5 times the stated value.

13.3.3 The lift pressure of a safety valve should be determined by the manufacturer and should be clearly stated on a label affixed to the body of the valve. The operating mechanism should be sealed by the manufacturer. Adjustable safety valves, or safety valves that allow the opening pressure to be increased deliberately or otherwise, would not be in accordance with the recommendations of this standard.

13.3.4 Pressure switches should operate consistently within ± 0.15 bar of the set point and required value. Incremental adjustment is preferable. The switch should be provided with a device to indicate clearly when it has tripped out. Audio alarms should be attenuatable and audio and visual alarms should be positioned where they can be clearly identified.

13.3.5 Temperature limit switches and temperature controllers should operate consistently within ± 2 °C of the set point and required value. Incremental adjustment is preferable. The switch should be provided with a device to indicate clearly when it has tripped out.

13.4 Constructional details

Ancillaries should be selected from those constructed of corrosion-resistant material of adequate strength.

All fastenings should comply with relevant standards.

All electrical wiring and equipment should comply with the detailed requirements of the Regulations for the Electrical Equipment of Buildings (published by the Institution of Electrical Engineers), or be in accordance with appropriate regulations.

Dials or scales, where fitted, should be clearly visible.

All equipment (valves, pipework and fittings) should meet the requirements of the local water authority.

13.5 Installation instructions

Clear instructions regarding installation, operation and maintenance should be included with each ancillary item.

13.6 Marking

Each ancillary item should carry the following information:

a) manufacturer’s or agent’s name or symbol;

b) serial number or batch number where practicable;

c) temperature rating or pressure rating where appropriate;

d) electrical rating where appropriate;

e) indication of year of manufacture.

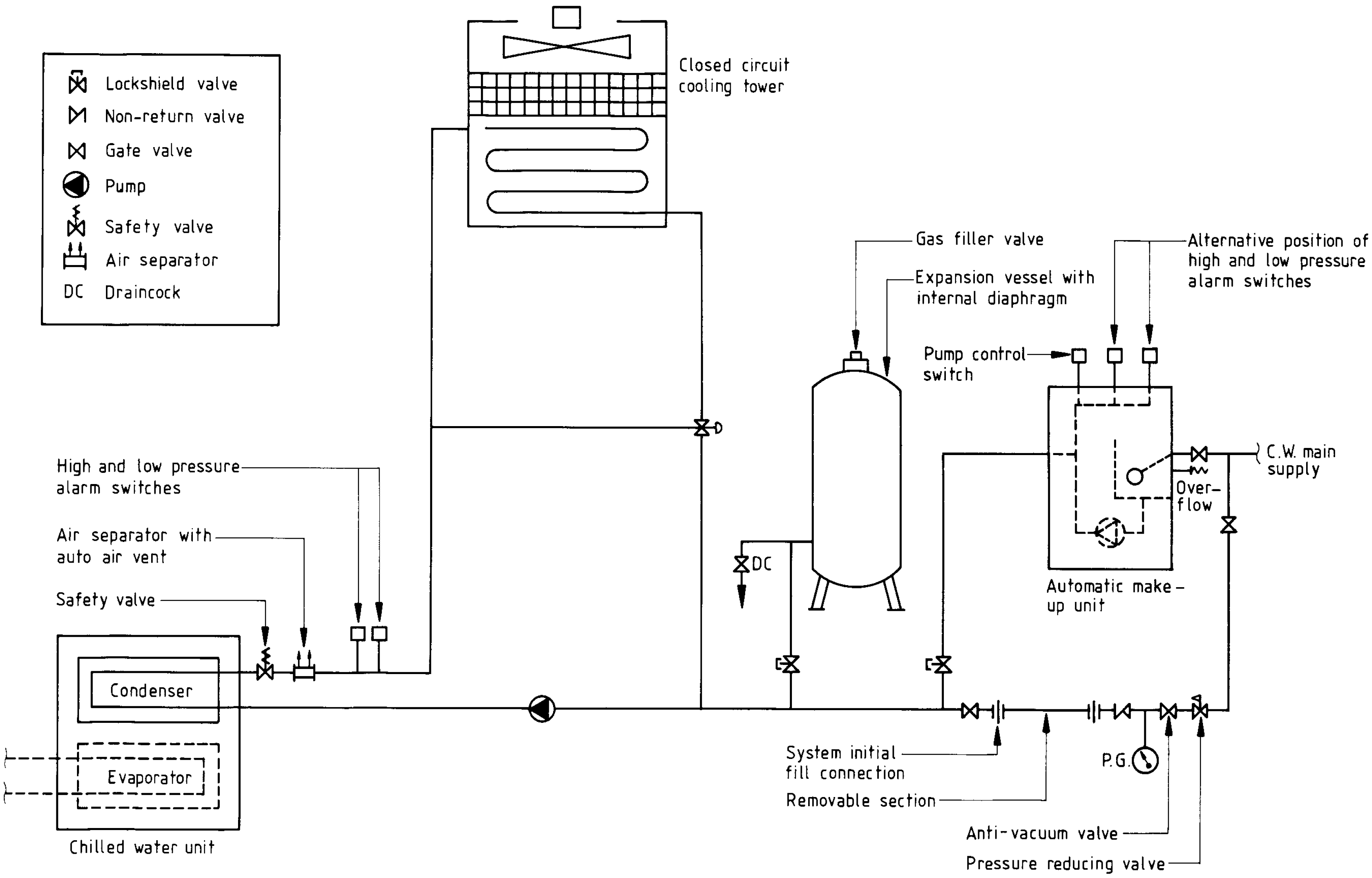


Figure 6 — Condenser water (heat reclaim) system

Appendix A Examples of recommended procedure for the calculation of the size of expansion vessels

A.1 Example 1: Chilled water system

A four storey building is to be cooled by provision of air conditioning units through which chilled water is to be circulated from a central plant room situated on the roof. The height of the plant room at roof level is 2 m and from ground floor to roof is 14 m. The capacity of the system is 6 000 L and the working solution will be 35 % anti-freeze and 65 % water. The flow and return temperatures at the evaporator will be 4 °C and 10 °C respectively. The maximum ambient temperature is taken to be 24 °C. The circulating pump will be situated as shown in Figure 4 and the anticipated head is 100 kN/m^2. Because a roof top plant room is used pressures exceeding P_f will occur at other points in the system. After taking account of clause **8** and referring to **9.3**, the calculation of the size of the vessel is undertaken as follows.

The system water content (V_s) is 6 kL; the maximum ambient temperature (t_a) is 24 °C; from Figure 5, e will be 0.9 %. The highest point in the system cannot exceed the height of the roof top plant room which is 2 m, therefore $P_h = 2 \div 10.2$[4)] giving 0.196 bar.

The initial system design pressure $P_i = P_h + P_s$, where P_s is 0.35 bar; therefore $P_i = 0.196 + 0.35 = 0.546$ bar.

In practice it has been found advantageous to ensure that P_i is always at least 0.7 bar.

The roof location of the plant room requires a different approach to the calculation of P_f. The total vessel volume (V_t) is calculated using the manufacturer's recommended design acceptance factor a):

$$V_t = \frac{V_a}{a}$$

where V_a is $\frac{6000 \times 0.9}{100}$ giving 54 L

and a is 0.35 as a manufacturer's recommendation.

$$V_t = \frac{54}{0.35} = 154.28 \text{ L}$$

To this is added a 10 % margin giving a calculated vessel volume of 169.70 L.

The manufacturer's literature is consulted to select an appropriate sized vessel (s), which, for this example could be 180 L capacity, providing a 16.67 % margin.

The new acceptance factor a_i, will be

$$a_i = \frac{V_a}{V_t} \text{ or } \frac{54}{180} = 0.3$$

The final working pressure (P_f) is now calculated:

$$P_f = \frac{P_i + a_1}{1 - a_1} = \frac{0.7 + 0.3}{1 - 0.3} = \frac{1}{0.7} = 1.4285 \text{ bar}$$

The safety valve set pressure (P_{max}) will be 1.4285 + 0.5 = 1.9285 bar and the nearest practical valve setting would be 2 bar.

The ground floor air conditioning units will experience maximum pressure when the safety valve is about to open and this could coincide with an isolating valve being closed on the suction side of the pump so that the pump closed-valve-head is imposed on the system.

Maximum working pressure = $P_{max} + P_d + P_{cv}$ where P_d is 13 m ÷ 10.2[4)] giving 1.275 bar and P_{cv} is 100 kN/m^2 + 15 % giving 1.15 bar.

Therefore maximum working pressure = 2 + 1.275 + 1.15

= 4.425 bar

It is recommended that the system be filled to P_f, i.e. 1.4285 bar, before the chiller is put into service so that the pressure may drop to P_i when at normal working temperature.

4) The factor **10.2** is used to convert static height pressure of water to pressure in bar gauge.

A.2 Example 2: Condenser water system

The system is to have a closed condenser water circuit for the chiller having a capacity of 450 L and a cooling tower located close by. The heat transfer medium is a solution of 35 % anti-freeze and 65 % water with flow and return temperature at the condenser of 21 °C and 37 °C respectively. The pump is located between the expansion vessel connection and the condenser with a head of 70 kN/m^2. After taking account of clause **11** and referring to **12.3**, the calculation of the size of the vessel is under-taken as follows.

The system content (V_s) is 450 L; the flow water temperature is 37 °C; from Figure 5, e will be 1.6 %.

For P_h and P_i the minimum value for P_i of 0.7 bar is used.

The roof location of the plant room requires a different approach to the calculation of P_f. The total vessel volume (V_t) is calculated using the manufacturer's recommended design acceptance factor a):

$$V_t = \frac{V_a}{a}$$

where V_a is $\frac{450 \times 1.6}{100}$ giving 7.2 L

and a is 0.35 as a manufacturer's recommendation.

$$V_t = \frac{7.2}{0.35} = 20.57 \text{ L}$$

To this is added a 10 % margin giving a calculated vessel volume of 22.62 L.

The manufacturer's literature is consulted to select an appropriate size vessel(s), which for this example could be 25 L capacity, providing a 21 % margin.

The new acceptance factor a_i, will be:

$$a_i = \frac{V_a}{V_t} \text{ or } \frac{7.2}{25} = 0.288$$

The final working pressure (P_f) is now calculated:

$$P_f = \frac{P_i + a_1}{1 - a_1} = \frac{0.7 + 0.288}{1 - 0.288} = \frac{0.988}{0.712} = 1.3876 \text{ bar}$$

The safety valve set pressure (P_{max}) will be:

$P_{max} = P_f + 0.5 = 1.3876 + 0.5 = 1.8876$

and the nearest practical valve setting would be 2 bar.

blank

Publications referred to

BS 4814, *Specification for expansion vessels using an internal diaphragm, for sealed hot water heating systems.*

Chartered Institution of Building Services Engineers — Commissioning Codes — Guide, 1970.

Institution of Electrical Engineers — Regulations for the Electrical Equipment of Buildings.

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