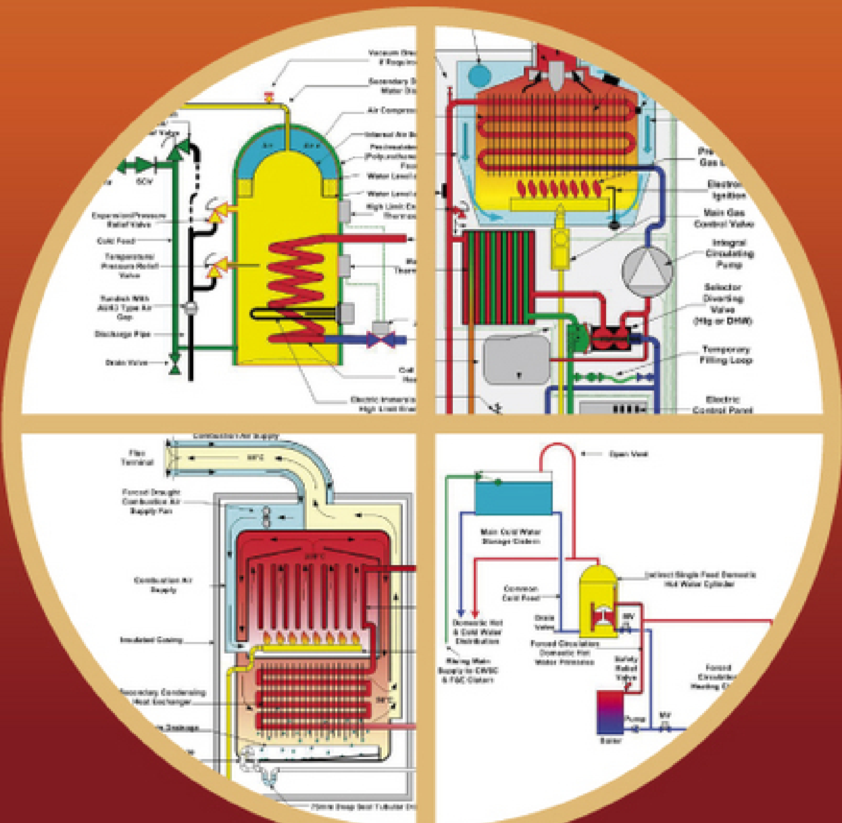
Heating Services in Buildings

David E. Watkins



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Design, Installation, Commissioning & Maintenance

David E. Watkins

I Eng, FCIPHE, FSoPHE, MASHRAE, AffCIBSE, MIfL RP

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Preface

There have been a number of books written on the subject of heating over the years, which would fill a sizable section of any notable library if collected together.

On examining the more recent of these books, that is those published over the last twenty years, it was found that they could be categorised as belonging to one of three groups. These are books written for the DIY market which are of little use to any student who is serious about studying to become a qualified heating professional. Alternatively, there are a number of books aimed at the craft level student concentrating only on the practical aspects of the subject. The third category of technical books, of which there are fewer available, has been written for the qualified professional engineer that assumes the student has previously obtained the basic engineering knowledge that is required to advance to a higher level of their education.

This observation becomes apparent when looking for a suitable technical book to support the NVQ Level 4 Higher Professional Diploma in Building Services Engineering and other design based engineering courses.

The search found that no single book was available to support these courses and the student would have to purchase a large number of publications to cover the subject to the extent required. This would also result in the student incurring a high financial cost to obtain copies of these publications.

The answer to this situation was to produce a number of supporting handout papers that expanded upon the course lectures that eventually developed over the years into a sizable set of notes when bound together.

During the course of developing these supporting notes, the subject of heating buildings, both for domestic residential properties and commercial buildings, has changed enormously, particularly with regard to the need to conserve energy, develop alternative forms of energy and provide controls that are suitable for the system's needs.

This requirement has manifested itself in the form of increased mandatory regulations and improved technology that has been developed to meet these compulsory regulations and conservation targets.

It was that necessity to incorporate explanations and detailed information on these changes that led to the set of supporting notes being developed into the basis of this book.

The aim of this work is to provide in a text and illustrative form a complete guide from basic principles to an advanced level to all the elements that combine to impart the engineering knowledge required on the subject of hydronic heating systems.

The book has been arranged to present the subject matter in a logical order that builds on each preceding chapter and culminates to provide the complete informative material. The book also demonstrates that there is little difference between domestic and commercial heating systems in the approach to the engineering and design of the systems, but makes mention where there is a difference.

This book has been developed over many years from the collection of handout notes to its present volume, where it originally supported a City & Guilds supplementary heating course, which further developed to support the heating design and installation course accredited by the European Registration Scheme (ERS) and other similar academic courses presently run today.

It is also intended that this volume will support Unit 11, 'Space heating technology and design', which is a module contained in the NVQ Level 4 Higher Professional Diploma in Building Services Engineering.

The book is aimed at both craft level plumbing students qualified to NVQ Level 3 standard aspiring to bridge the educational gap to an engineering career, plus school leavers with the necessary academic 'A' level qualifications and employed in a building services engineering consultancy.

Although this volume has been produced to support the NVQ Level 4 course and similar design/engineering courses, it is hoped that it will be of equal interest and use to anyone concerned with the design and installation of hydronic heating systems.

This book has resisted the inclusion of over explaining or illustrating elements in order to provide the information in an affordable manner to all those concerned. This gives the lecturer the opportunity to expand upon each subject and provide further examples in the classroom.

It is also correct to acknowledge that a work of this type has only been possible due to the encouragement and assistance of many other people, most notably Mr David Bantock, whose original set of notes I inherited when I started as a part-time lecturer delivering the course, and who has been instrumental in his encouragement during its development. Also my wife, Jenny Watkins, for proofreading and endless patience, and the many students who encouraged its eventual publication.

Special acknowledgement should also be mentioned for permission to reproduce Figure 5.23, Room Height Temperature Gradients, from Elsevier Publishing, which is based on a similar illustration in their book entitled Faber & Kell's Heating & Air-conditioning of Buildings. Also, for permission granted by Baxi Heating to reproduce Figure 15.8, Illustration of a Micro-Combined Heat and Power Generating Unit and M H Mear Co. Ltd for permission to reproduce Figure 7.3, of a Mear's Slide Rule Heating Calculator.

David E. Watkins

1

Introduction to Heating Services

The broad term 'central heating' is used to describe many types and forms of heating, and some usage is totally misleading and inaccurate, through ignorance of the subject. This chapter is a basic introduction to the mechanics of central heating, which is discussed in greater detail in the following chapters.

If we examine the term, it implies a system where heat is produced from a central source and distributed around the whole building. The method of heat generation and distribution may vary with the type of heating system employed.

Central heating is sometimes referred to as space heating. To be understood fully, this must be described by its type or system arrangement, and may be categorised as being either full, part or background heating.

Full central heating may be defined as being a system of heating from a central source where all the normally habitable or used rooms/spaces are heated to achieve guaranteed temperatures under certain conditions. By today's standards, all heating systems installed in residential dwellings and most commercial buildings should conform to this category, unless there are acceptable reasons for not doing so.

Partial central heating is the term applied where only part of the building is to be heated, but even then the rooms or spaces that are heated should still have guaranteed temperatures under stated conditions. This form of central heating would be a rare occurrence for a residential dwelling but not so uncommon for some commercial buildings, especially where part of the building complex is not normally occupied.

The term 'background heating' is used to describe a form of central heating whereby lower than normal or standard recommended temperatures are aimed at for the type of building involved. The term is sometimes used to refer to heating systems installed in buildings where the room temperatures are not guaranteed. This form of heating is unacceptable by today's standards on both environmental and efficiency grounds.

It should be noted that, unless otherwise specified, full central heating should normally be designed to current regulations and standards and installed in a professional manner. In some instances, usually due to a specific use or financial reasons, the client may only require or specify partial heating to be installed, sometimes with the request that safeguards are included to allow the system to be extended at a later date to achieve full central heating.

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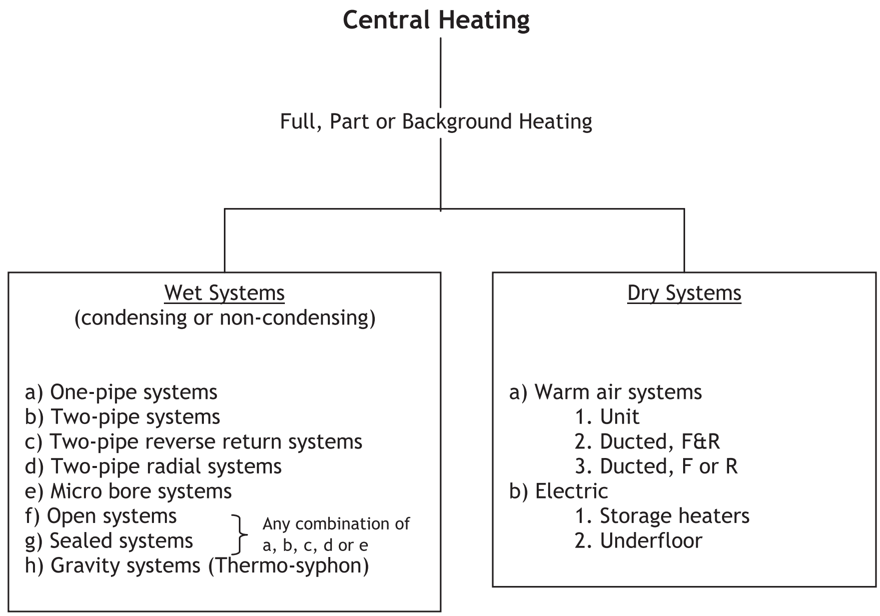

Figure 1.1 Heating system categories

Background heating, where lower than normal or recommended temperatures are aimed at, should only be used when specifically requested by the client for some reason. Even then, agreed temperatures should be incorporated into the design and guaranteed before any installation work commences. Under no circumstances should any heating system be installed without first agreeing specific room temperatures to be achieved when certain conditions exist. These conditions are discussed in Chapter 2.

Having understood the extent of the heating system and its classification, be it full, part or background heating, heating systems may be further divided under the headings of 'wet' or 'dry' systems. The terms wet or dry refer to the medium used to convey the heat from its source of generation to its point of use. Wet systems may be further classified by the piping circulation arrangement, with dry systems being divided into warm air and electric heating.

Figure 1.1 indicates the broad classifications of heating systems.

Heating systems can be sub-divided even further, but this will be explained in Chapter 21.

Wet heating systems

All wet types of heating systems employ a liquid as a medium to convey the heat from its source of generation. It is then distributed around the system to each heat emitter, where it transfers part of that heat through the heating surface of the heat emitters. Finally, the liquid is returned to the source of generation for the process to cycle continuously. The source of heat is commonly referred to as a boiler.

In all domestic heating systems, and most heating systems for other types of buildings, water is chosen as the medium for conveying the heat due to its low cost and being readily available. However, water does have the disadvantages of a low boiling point and high freezing point; it can also be corrosive to metallic materials and has a limited heat carrying capacity. The corrosive nature of the water can be reduced by water treatment, which is discussed later in this volume.

The temperature limitations and heat carrying capacity of water will have to be accepted unless we change the atmospheric conditions of the system, or we can change the liquid. Liquids known as 'thermal fluids' are available and have been used successfully on larger commercial type heating installations. They possess different properties to water, such as being less aggressive to common materials, having higher boiling points and lower freezing points, a greater heat carrying capacity than water and, in some cases, a lower viscosity. The merits of thermal fluids are much superior to those of water but are generally discounted for all domestic heating systems owing to their higher capital cost and not being readily available. They are also rarely used on larger commercial systems for the same reasons, but when conditions are right they can be considered attractive. The difficulty of availability can cause problems when replacement fluid is required immediately, following any emergency maintenance work. Thermal fluids have been used for domestic applications on limited occasions in countries that experience much lower temperatures than in the UK, as the lower freezing point of the fluid can be an important advantage when sub-zero ambient temperatures are experienced for prolonged periods with the heating system in a non-operating mode. They have also been employed as the heat carrying medium for some solar heating systems.

The purpose of the water used in heating systems differs from that used in domestic hot and cold water installations. In those systems, water is the end product or consumable item and after it has been used, it is discharged to waste. The water employed in a heating system is a non-consumable substance. It is the medium used to carry the heat required and, after it has transferred some of the heat, it is returned to the boiler to be re-used over and over again.

Dry heating systems (warm air)

Warm-air dry-type heating systems differ from wet-type heating systems insofar as the fluid employed is not only the medium used to convey the heat, but is also the end product. As the name implies, air is the fluid used to carry the heat from its source of generation, a warm air heater. It is then distributed, usually through a network of ducting, where it is arranged to enter directly into the room under controlled conditions to displace the cooler air. Finally, a mixture of the two is partly returned to the warm air heater for the process to be repeated.

Warm-air heating systems are generally disliked by many occupants of dwellings that have such systems installed, but this is usually because the systems are either not designed correctly, not installed correctly or are, in many cases, incomplete. This is mainly down to ignorance of the fundamental principles of warm air heating, which, if given the respect deserved, can be a very good form of heating. This work exclusively concentrates on wet-type heating systems since it is aimed at students and engineers in the plumbing industry.

Dry heating systems (electricity)

Electrical heating systems may technically be classified as dry systems, but they do not employ a medium as they generate their heat at the point of use. For this reason, electrical heating systems are not included in this book, with the exception of heating systems that use electricity as the source of power to heat the water. Here they are classified as being wet or hydronic heating systems.

Supplementary heating

This is a term applied to describe heating appliances, either fixed or portable, that are used to supplement the central heating system – either during extreme cold spells when the outside air temperature falls well below the base design temperature, or during the heating-off season in spring or autumn, when the outside temperature drops to below that considered comfortable.

Examples of such heating appliances include:

- Radiant electric fires, portable and fixed
- Oil filled radiators
- Oil room heaters
- LPG room heaters
- Gas fires
- Open solid fuel fires.

The list is not intended to be exhaustive, but meant to serve as a general representative selection of supplementary heating appliances.

2

Wet Heating Systems

Wet heating systems, commonly referred to as hydronic heating systems because they use a liquid as a medium, nearly always employ water as the medium to convey the heat from its source of generation, a boiler. This is rather a misnomer, as a boiler must be designed to avoid boiling the water, but is probably a leftover term from the days of raising steam. The heated water is circulated around the system, transferring part of its heat, and returns back to the boiler for the process to be repeated.

The water is fed into the heating system via a fixed piped connection to either a feed and expansion cistern, or a direct connection, as in the case of a sealed heating system. The water is allowed to enter the heating system slowly, thus avoiding creating turbulence, to fill it with all air expelled through the open vent, or by releasing it using manually operated air vents or automatic air release vents.

Water has many advantages as a heat carrying medium when used in hydronic heating systems; not least its plentiful availability. For this reason water is almost exclusively used for domestic heating systems.

Hydronic heating systems are classified by the following basic principles:

- Temperature of medium
- Pressure of system
- Circulation method of medium
- Piping arrangement for distribution.

The classifications are to a certain extent inter-related, as the selection of one of the basic operating principles has an influence on the selection of the others, which is explained in the following discussion.

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TEMPERATURE AND PRESSURE

The classification of hydronic heating systems by the temperature of the circulating water exiting the boiler is closely related to the operating pressure of the system, and the two must be considered together. This is because pressure is required to maintain the water in a liquid form at high temperatures: as water will boil and convert to steam at 100°C at atmospheric pressure when measured at sea level, any increase in that pressure will have a corresponding increase in the boiling temperature of water. Likewise, any decrease in pressure below atmospheric pressure will have the effect of allowing water to boil at temperatures lower than 100°C.

Table 2.1 gives the temperature/pressure classification commonly used in the UK. The minimum pressures listed are those required to prevent the water from evaporating but should not be confused with their vapour saturation pressures, which are lower.

It can be seen from Table 2.1 that water may be retained in liquid form when the operating temperature is above 100°C by pressurising it, giving all the advantages of a liquid and none of the disadvantages of a vapour such as steam. The method of pressurising the heating system is explained later in this chapter.

In contrast to the UK practice of temperature/pressure classification, in the United States of America the classification of heating systems differs slightly, outlined in Table 2.2.

It can be seen from Table 2.2 that the US has higher temperature and pressure classifications than the UK. However, in practice there is very little difference in the operating principles of hydronic heating system either side of the Atlantic.

Almost without exception, all domestic residential heating systems are classified as being low pressure and temperature (LPHW). It is considered safer to install heating systems using materials suitable for working pressures and temperatures below 100°C, therefore avoiding the potential hazard of flash steam occurring in the event of a pipe fracture or valve gland leak.

It has traditionally been the custom to design LPHW systems with a water flow temperature of 82°C and a Δt (temperature difference) of 11–12°C, giving a return water temperature of 71°C. More recently, the Δt has been increased in certain circumstances to take into account the requirements of condensing boilers that are influenced more by lower return temperatures than flow temperatures to function efficiently. This

Table 2.1 Hydronic design operating water temperatures and pressures (UK practice)

Classification	System temperature (°C)	Operating static pressure (bar absolute)
Low pressure hot water (LPHW)	<100	1 to 3
Medium pressure hot water (MPHW)	100 to 120	3 to 5
High pressure hot water (HPHW)	>120	>5*

*Account must be allowed for varying static pressures that would exist in a tall building.

Table 2.2 Hydronic design operating water temperatures and pressures (US practice)

Classification	System temperature (°C)	Operating static pressure (bar gauge)
Low temperature hot water (LTHW)	<120	2
Medium temperature hot water (MTHW)	120 to 175 Normally below 160	<11
High temperature hot water (HTHW)	>175 Normally about 200	<20

has a secondary effect on the increased sizing of the heat emitters, which is discussed in more detail in Chapter 8. Another situation where one should question the return water temperature and the flow water temperature is in heating systems employing underfloor heating sections that require the floor temperature to be limited to an acceptable level.

Low temperature heating systems may be further categorised as being either 'open' systems – where the heating system incorporates an open feed and expansion cistern and operates at atmospheric pressure, plus the static pressure created by the feed and expansion cistern at the traditional flow temperature of not exceeding 82°C – or sealed systems.

With a sealed heating system, the feed and expansion cistern is replaced by a sealed expansion vessel that allows the heating system to operate at a slightly higher pressure above atmospheric pressure and also permits the flow water leaving the boiler to have fractionally higher operating temperatures, in the region of 85–95°C.

If operating water temperatures higher than 82°C are selected for the heating system, then greater consideration must be given to the choice of heat emitters to be used, and all contactable heating surfaces such as traditional panel or column type radiators should be avoided so as to reduce the risk, scalding anyone who comes into physical contact with them.

Low water temperature heating systems are the most commonly used category of operating temperatures and pressures, suitable for all buildings ranging from small domestic residential through to very large and complex developments.

Medium temperature (MPHW) heating systems are favoured where a high heat output is desired so that smaller heat emitters and corresponding smaller pipe sizes can be used. The heat emitters must be of the non-contactable type, such as convectors, low surface temperature radiators and fan coil units. These systems are more suitable to commercial type buildings where the materials used are more robust than domestic low pressure type materials, and the system is more likely to be regularly serviced and maintained. This type of system in a domestic situation would be considered unsafe.

The use of high temperature and pressure systems (HPHW) is normally considered for use in industrial applications as some industrial processes require higher temperatures for manufacturing, or for developments that have a main central plant room that distributes the primary heat at high pressure and temperature to local plant rooms, which then circulate the secondary heat at a lower temperature. This arrangement is ideal for developments that are spread out over a large geographical area, and makes full use of more economical pipe sizes and equipment. As with the medium temperature systems, material selection and maintenance are critical factors.

CIRCULATION

Heating systems can also be classified by the method of circulation employed, i.e. either by gravity (thermosiphon), or forced circulation by a pump, or a combination of both.

Full gravity heating systems have not been installed since the development of the glandless circulating pump. The practice of having a gravity circulation to the domestic hot water cylinder whilst the heating system has a forced circulation, which can have some merit when suitable conditions exist, is no longer permitted by the Building Regulations for residential dwellings, which unfortunately limits the design engineer in the options available. Even where the situation exists that the domestic hot water cylinder is located directly above the boiler at the optimum height, and the occupant's needs are such that heating part of the system is not required for a great deal of the time but domestic hot water is, we are no longer permitted to use this method.

A fully forced method of water circulation for both heating and domestic hot water primaries is by far the most efficient arrangement in the majority of applications and gives freedom in the choice of plant equipment location, but this is not always the best option.

PIPING DISTRIBUTION ARRANGEMENT

Having discussed the temperature, pressure and method of circulating the water, the piping arrangement can be established. The different arrangements listed in Figure 1.1 form the basic systems for which there are numerous variations or modifications, but each may be categorised as belonging to one of the basic forms.

These arrangements each have their own advantages and disadvantages and the final selection should be made on the most efficient and economical method suited to each individual application. Also, a combination of any of the piping arrangements described may be used if it is considered by the design engineer to best meet the needs of the system.

The various piping arrangements depicted on the following pages have been produced to explain the operating principles of each system and are not supposed to be complete. For this reason most control elements and components have been omitted for the sake of clarity as these are dealt with in detail in Chapter 11. Also, the provision to include the means of producing domestic hot water has been included in each case, minus the controls element, to complete the piping arrangement: this may be by gravity primary circulation or by forced circulation. In most cases, either method may be used, unless noted otherwise. It is not the intention here to give the impression that either a gravity primary circulation or a forced primary circulation is the preferred option for satisfying the domestic hot water requirements, but just to show the different options.

ONE OR SINGLE PIPE SYSTEM

Of all the piping arrangements used for heating distribution, the single pipe system is the simplest. It consists of a single pipe main that extends from the boiler around the building as a circuit, or number of circuits, and returns to it with all heat emitters connected to the pipe by their own branch pipe flow and return connections.

Figure 2.1 illustrates the operating principles of the single pipe system and its limitations: a progressive temperature drop around the heating pipe circuit caused by each heat emitter returning its water back into the common circuit pipe. This has the effect of cooling the flow water available to other heat emitters being served by this circuit, which in turn results in subsequent heat emitters having to be oversized to compensate for a lower mean water temperature across the heat emitter.

To avoid heat emitters at the end of each pipe circuit having to be excessively large due to the decreasing mean water temperature available, heating pipe circuits should be limited to supplying water to a few heat emitters each, to restrict the mean water temperature across the heat emitter to no less than 70°C for non-condensing systems, or lower for condensing.

Another effect of pipe circuits suffering from excessive temperature drop is that the piping system on each circuit would also have to be oversized to compensate for the lower circulating water temperature.

The piping arrangement depicted in Figure 2.2 demonstrates that this need not be the case: if the branch circuits supply a minimum number of heat emitters, then the single pipe arrangement is just as suitable for larger domestic residential properties or commercial building applications, as the small domestic heating system.

The object in the design of this system is to limit the temperature drop across each pipe circuit so as to avoid having to significantly increase pipe sizes or heat emitter sizes to compensate, and so lose the lower cost advantage claimed by this system.

From the schematic layout depicted in Figure 2.2, it can be seen that if each piping circuit is limited to a reasonable temperature drop across it, and if each piping circuit is similar in its heat carrying load to each other, then the single pipe heating arrangement is suitable for heating system compositions in larger buildings. It can also be seen that the piping system is fairly evenly balanced in its heat distribution

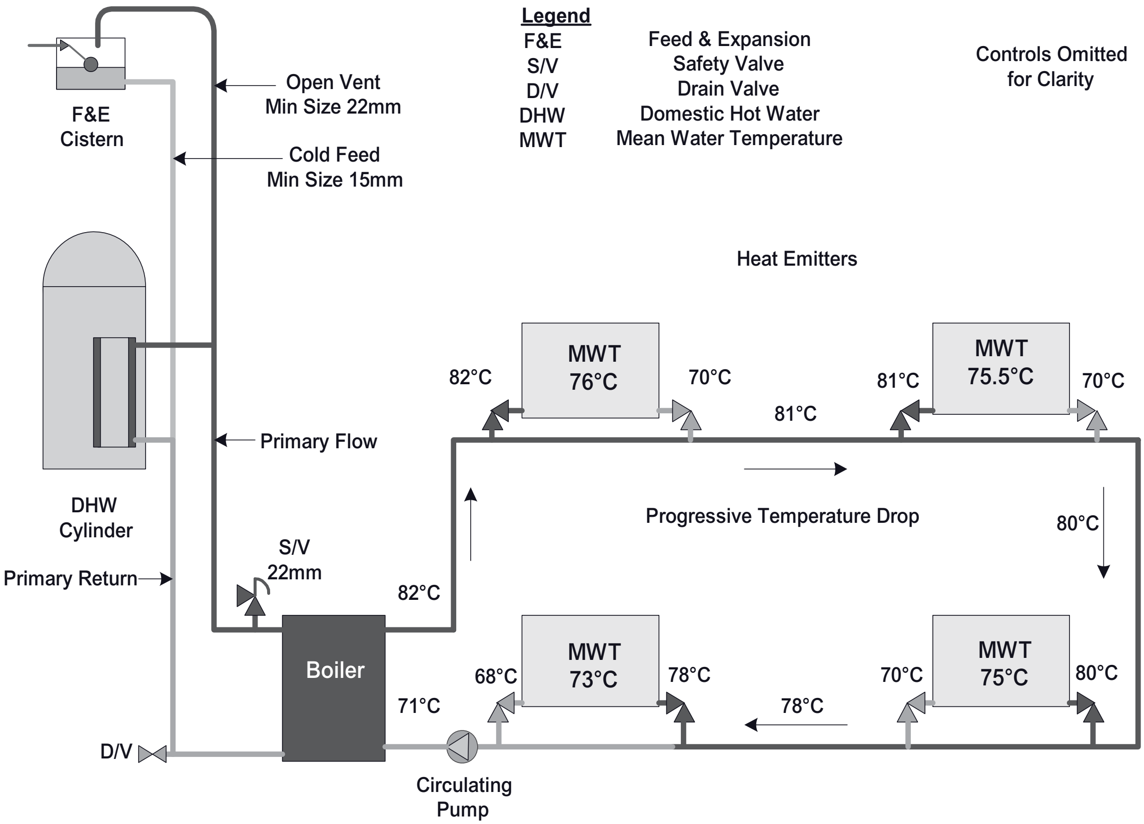


Figure 2.1 Operating principles of single pipe heating system (non-condensing)

in order to achieve the temperature drop required from each heating circuit. This is accomplished by balancing the circulating piping system with the use of regulating valves when the heating system is being commissioned.

The primary flow and return to the domestic hot water cylinder in this illustration is in fact a two pipe arrangement. Lower temperatures may be selected for condensing heating systems.

The single pipe heating system benefits from the employment of special tees, known as 'diverting' or 'inducing' tees. These special fittings are designed to encourage a degree of flow into the heat emitter by creating a resistance to the flow between the flow and return branch connections, in the form of a pressure drop on the single pipe circulating main. This creates the conditions for circulation to occur through the heat emitter, as the resistance of this passage is less than that of the heating main.

The isometric layout illustrated in Figure 2.3 demonstrates the use of these diverting tees, whereby the up feed risers only require one diverting tee to be fitted on the return connection as the thermal head will assist the circulation, but the down feed pipes should be fitted with diverting tees on both the flow and return branch connections because no thermal head exists in this situation.

Diverting tees may be obtained in a copper alloy or malleable iron and are constructed with a venturi shaped restriction inside as shown in Figure 2.4. These tees are similar in design to 'tongued' tees that were commonly used on gravity heating systems.

Figure 2.4 shows how the flow of water through the venturi of the diverting tee induces the flow from the return connection of the heat emitter.

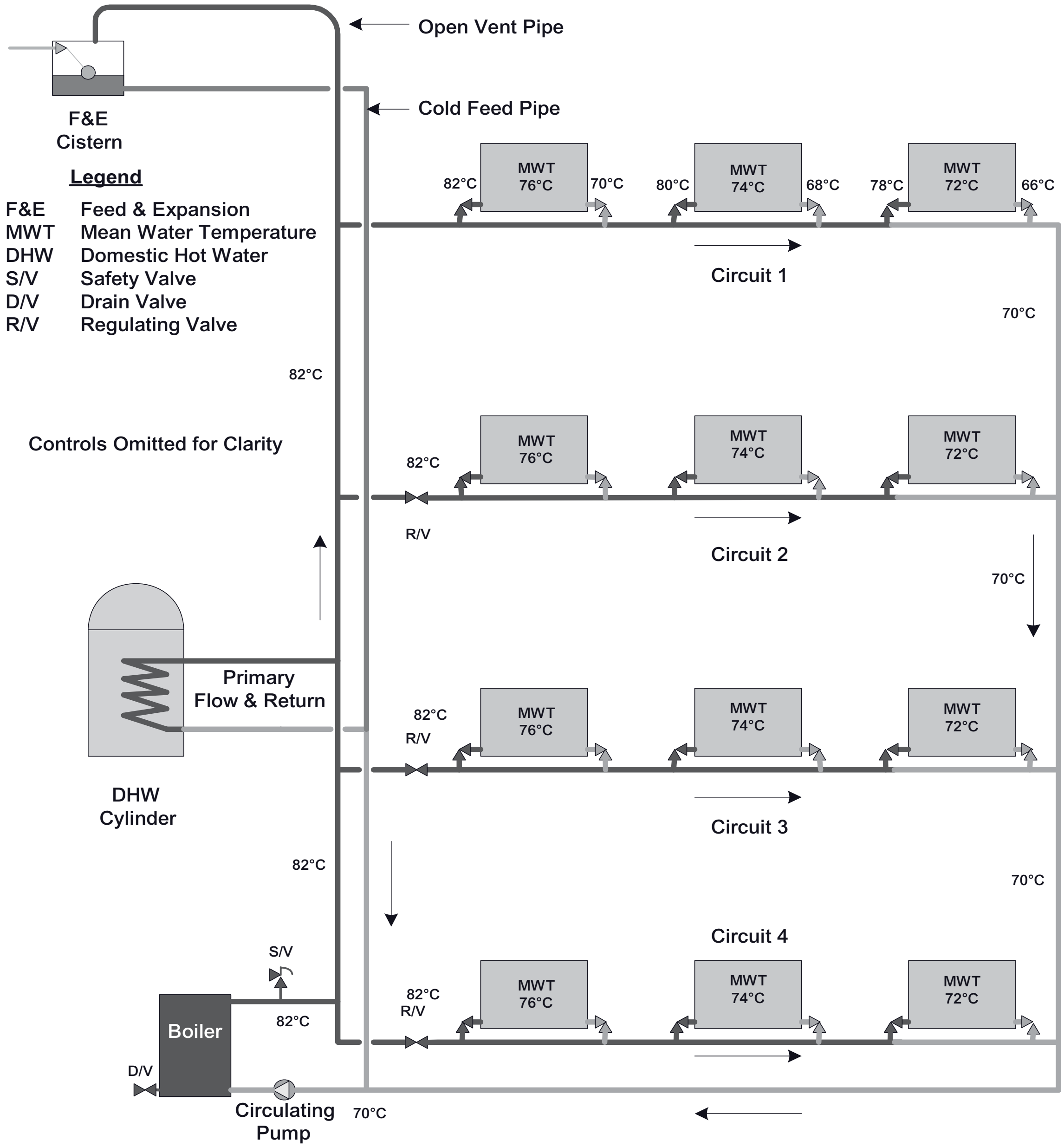


Figure 2.2 Single pipe system for larger building with limited circuit Δt (non-condensing)

Figures 2.5 and 2.6 show how the diverting tees are arranged and how they function for both upward connections to the heat emitters using one diverting tee on the return, and downward connections where diverting tees are employed on both the flow and return connections to the heat emitters.

Diverting tees have been successfully fabricated on site from standard capillary copper pipe fittings, either the end feed type, or integral solder ring type, using a standard tee, a spigot and socket straight reducing fitting, with the larger spigot end cut short but square, which is placed inside one socket end of the tee so that the reduced socket end protrudes past the branch of the tee. The cut spigot end of the reducer must

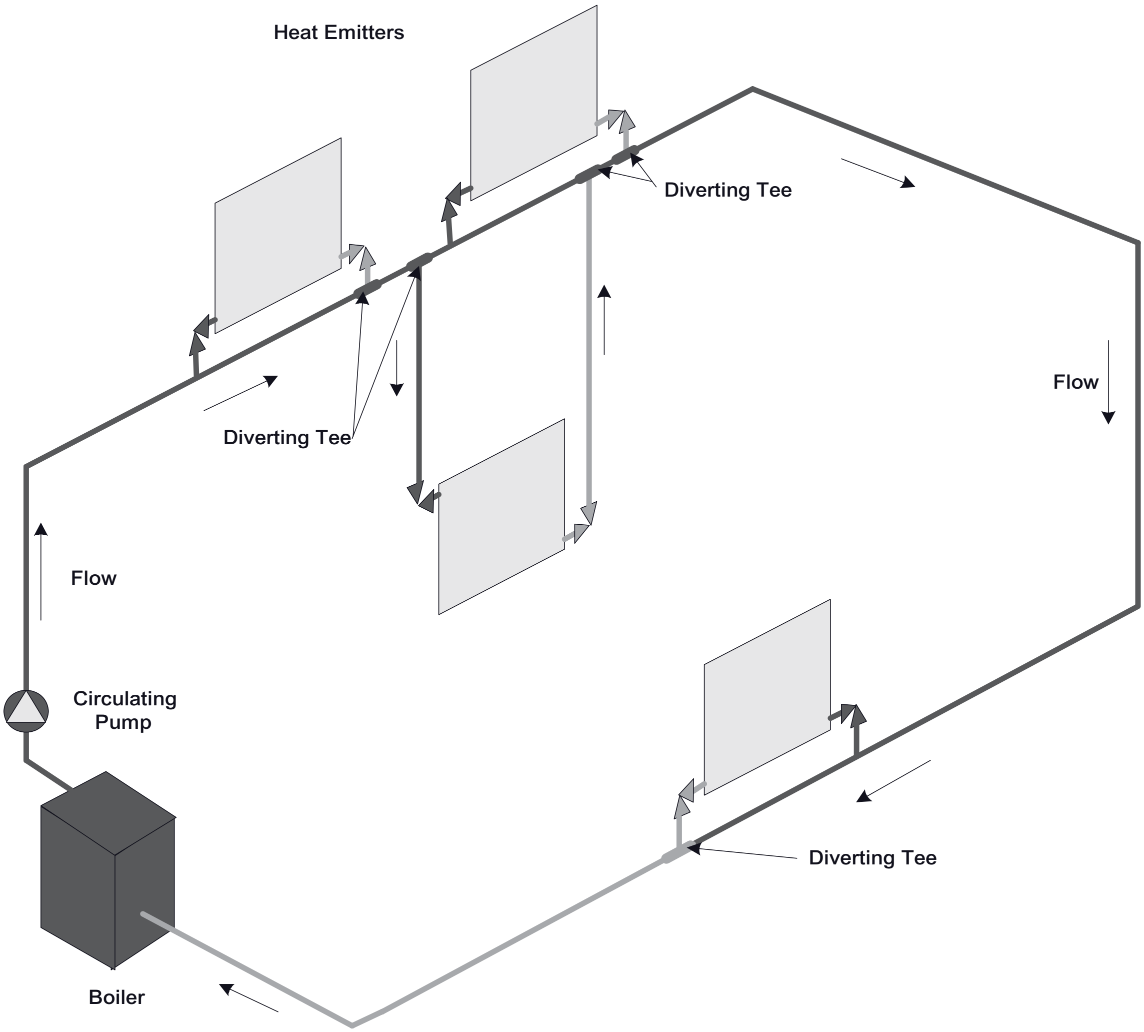


Figure 2.3 Application of diverting tees on single pipe heating system

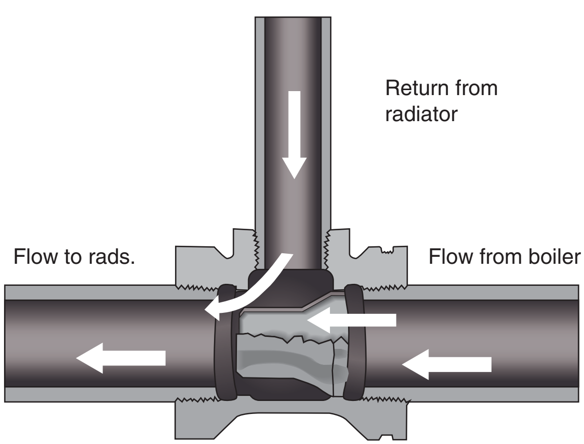


Figure 2.4 Section through a diverting tee fitted on the return connection

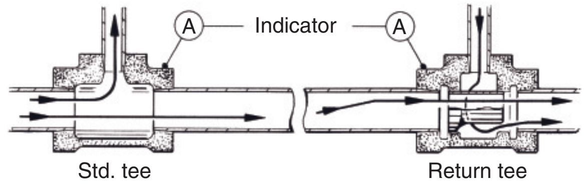


Figure 2.5 Upward branch connections, standard tee on flow and diverting tee on return

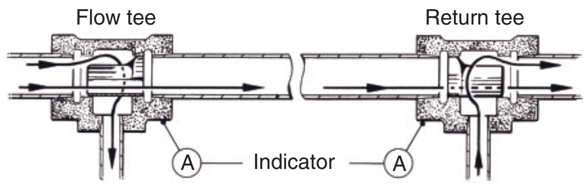


Figure 2.6 Downward connections, diverting tees on both flow and return

be inserted into the tee so that the cut end has cleared the integral ring of solder if this type of capillary fitting has been used. The copper pipe is then inserted into the fitting and the capillary joint made in the normal way.

A 15 mm equal tee would use a 15 mm spigot end × 12 mm socket end reducer, and a 22 mm × 15 mm tee would use a 22 mm spigot end × 15 mm socket end reducer.

A variation of the single pipe system is depicted in Figure 2.8. If compared to the traditional one pipe system illustrated in Figure 2.1, it will be seen that the only difference is the method of connecting the circulating pipework to each heat emitter. The standard pair of radiator valves has been replaced by a single centrally located valve in the bottom of a specially manufactured pressed steel panel radiator that has a single female threaded centrally located tapping incorporated, together with a division baffle plate in the bottom main horizontal water passageway separating the two halves of the radiator. Figure 2.7 shows a cut-through section of this special three-way radiator valve.

The central three-way radiator valve is connected to the radiator via a union radiator tail connection that has a central dividing wall along its length that lines up with the dividing baffle plate incorporated in the radiator, as shown in Figure 2.9. The valve is designed so that when it is fully open it will direct 100% of the flow through the radiator, and when it is closed, it will allow 100% of the flow to bypass the radiator through the valve. Any intermediate position of the valve control will direct an equivalent portion of the flow through the radiator with the remaining portion of the flow being allowed to travel through the valve bypass.

This system heating arrangement was developed in Scandinavia, where it has found most use. Its main merits over the traditional single pipe system are that the three-way valve directs a definite flow of water through the radiator without the aid of diverting tees, and permits individual radiators to be isolated without affecting the flow to the remainder of the circuit. This arrangement, when it has been used with the heating piping installed either below or within the floor, forms a neater appearance with a minimum of pipework on show.

The disadvantages of this system are that the heat emitters are restricted to panel radiators made specifically for use with this valve, which requires confidence that they will continue to be available in the future for replacements, system extensions or alterations. Any thermostatically operated version of this valve yet to be developed would be required to conform to current requirements.

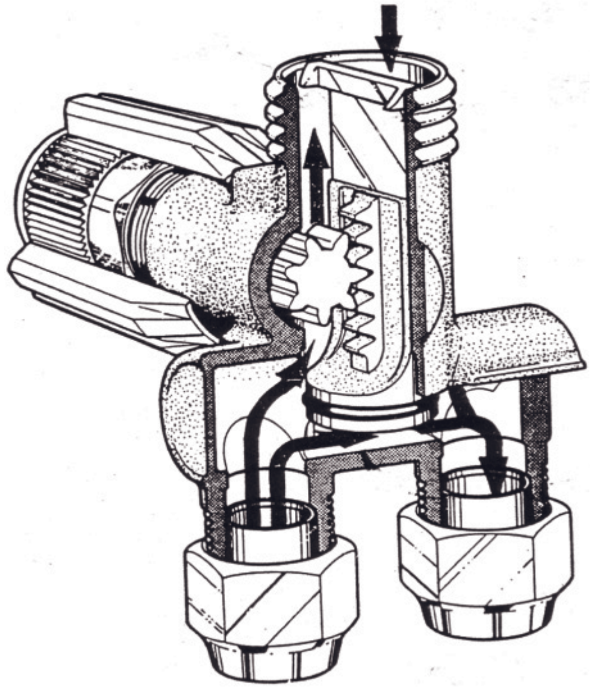


Figure 2.7 Detail of central three-way radiator valve

To summarise, the single pipe heating arrangement continues to be used for heating systems either in part, or in full in commercial buildings when the application is considered suitable, but is rarely installed in domestic residential properties. The reasons for this situation can only be guessed, but one theory is that heating systems installed in commercial properties are normally designed by engineers who approach each building on an individual basis, and consider the client's brief, the architect's design requirements, the structural constraints of the building, the budget available and the energy efficiency targets to be achieved. Only after having considered all of these important design aspects can a decision be made on the piping arrangement to be used, and, quite often the one pipe system meets all of the above requirements.

Unfortunately, this is not normally the situation regarding domestic residential dwellings. A high percentage of installers are also the designers of the heating system and it is quite common for them to install their favourite heating system arrangement in every property because they are familiar with it, regardless of the size or configuration of the building, or the client's own personal requirements.

This text has demonstrated that the single pipe heating system, if selected correctly and after careful design, such as limiting the temperature drop across each piping circuit, will achieve a simpler, less expensive heating system and is suitable for many applications in domestic residential dwellings where normally the installer would not consider it.

It should be pointed out that not all installers of domestic heating systems have this blinkered approach and with ingenuity some very successful one pipe heating systems have been achieved, but for the majority, those who only use one type of heating arrangement regardless of the building layout, more training is required.

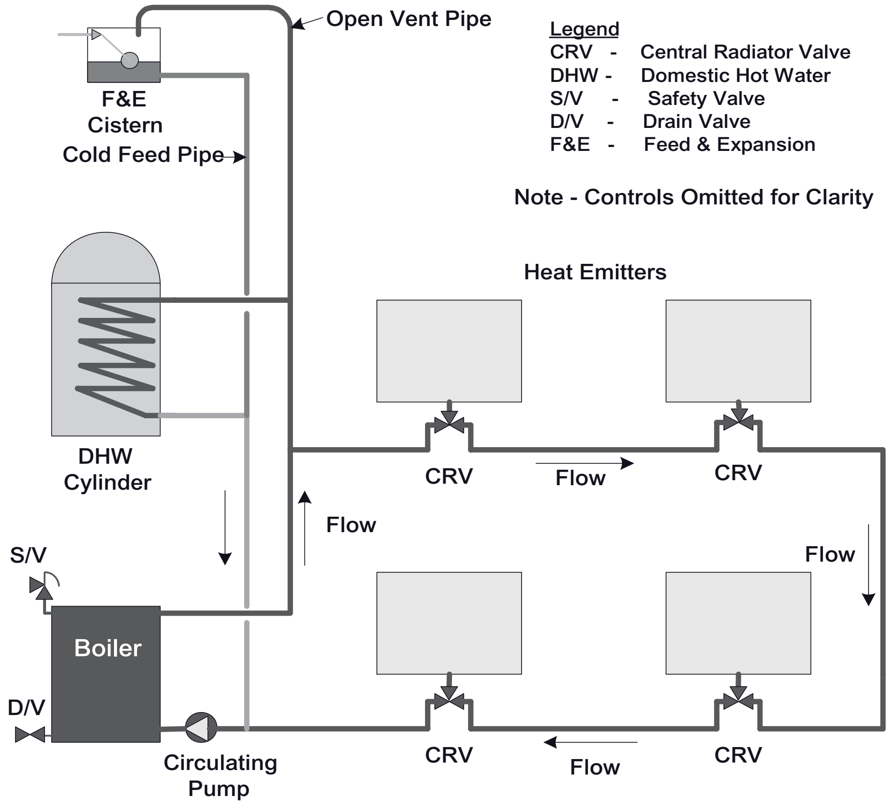


Figure 2.8 Single pipe central valve radiator connection system

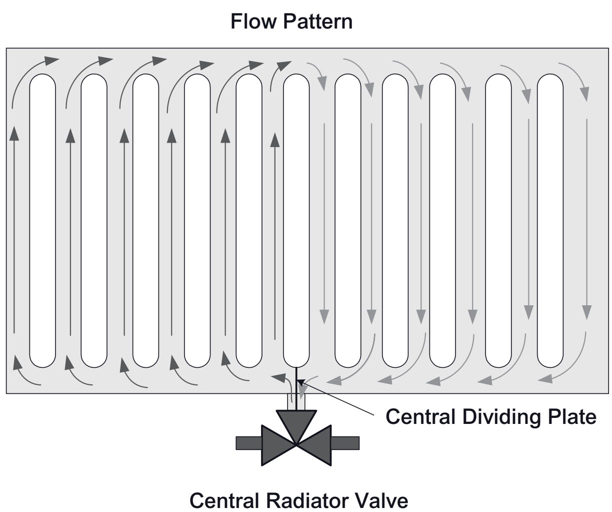


Figure 2.9 Arrangement of central three-way radiator valve and radiator

TWO PIPE SYSTEM

This is by far the most commonly used piping arrangement for wet heating systems, ranging from installations for very large commercial type buildings down to small domestic residential dwellings, due to the versatility of this arrangement.

As the name implies, the two pipe arrangement comprises two main heating distribution pipes in parallel as opposed to one on the single pipe system, see Figure 2.10. One of the pipes is a dedicated flow conveying hot water at boiler temperature to each heat emitter, whilst the other is a completely separate dedicated return that returns the water from each heat emitter, after it has transferred part of its heat, back to the boiler to be reheated.

The main advantage of the two pipe heating system over the single pipe heating system is that water is delivered to each heat emitter at the same temperature as it leaves the boiler, minus any piping heat losses. In turn, the water temperature that exits the heat emitters is the same temperature that is returned back to the boiler, again minus any pipework heat losses, whereas the single piping arrangement suffers from a

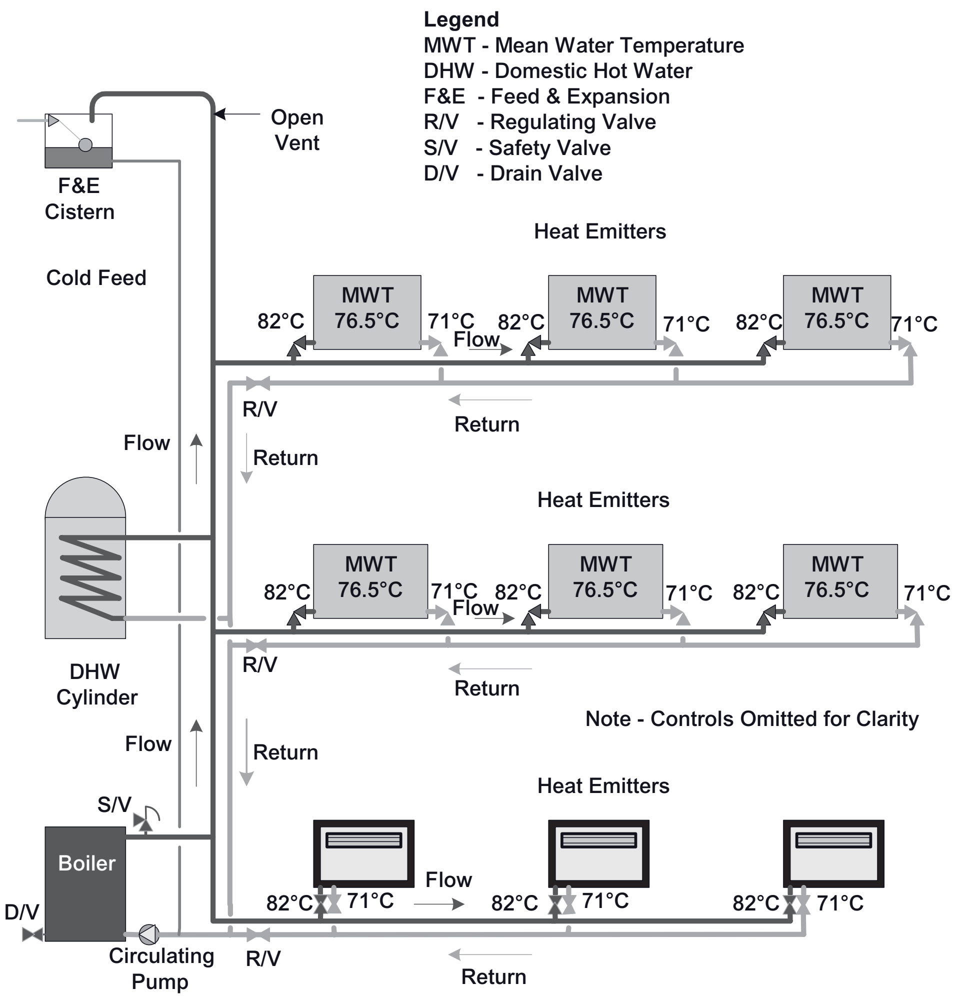


Figure 2.10 Operating principles of a direct return two pipe heating system – non-condensing (condensing systems would employ different flow and return temperatures)

progressive temperature drop across each piping circuit. The main disadvantage is that it is more costly and, with the direct return system illustrated in Figure 2.10, the supply and return lengths are unequal, which results in unbalanced flow and return flow rates.

This imbalance in the system flow rates is due to the tendency for the water to circulate through the heat emitters closest to the boiler, where the resistance to flow is at its lowest, at the expense of those furthest from the boiler where the resistance is at its greatest, resulting in the index circuit heat emitter becoming starved of water. This situation can be rectified by balancing the heating system using balancing devices, such as regulating valves and the lockshield return valves, on the heat emitters during the commissioning exercise on completion of the heating installation: this matter is discussed further later on in Chapter 25.

The direct return method of installing the two pipe heating system, where the flow and return pipes are in parallel to each other is usually simpler, as it is easier to install these two pipes side by side than it is to find alternative routes for them separately.

A variation of the two pipe system is the reverse return two pipe heating system as portrayed in Figure 2.11, which, through its flow path direction of both the flow and return circulating pipes, overcomes the

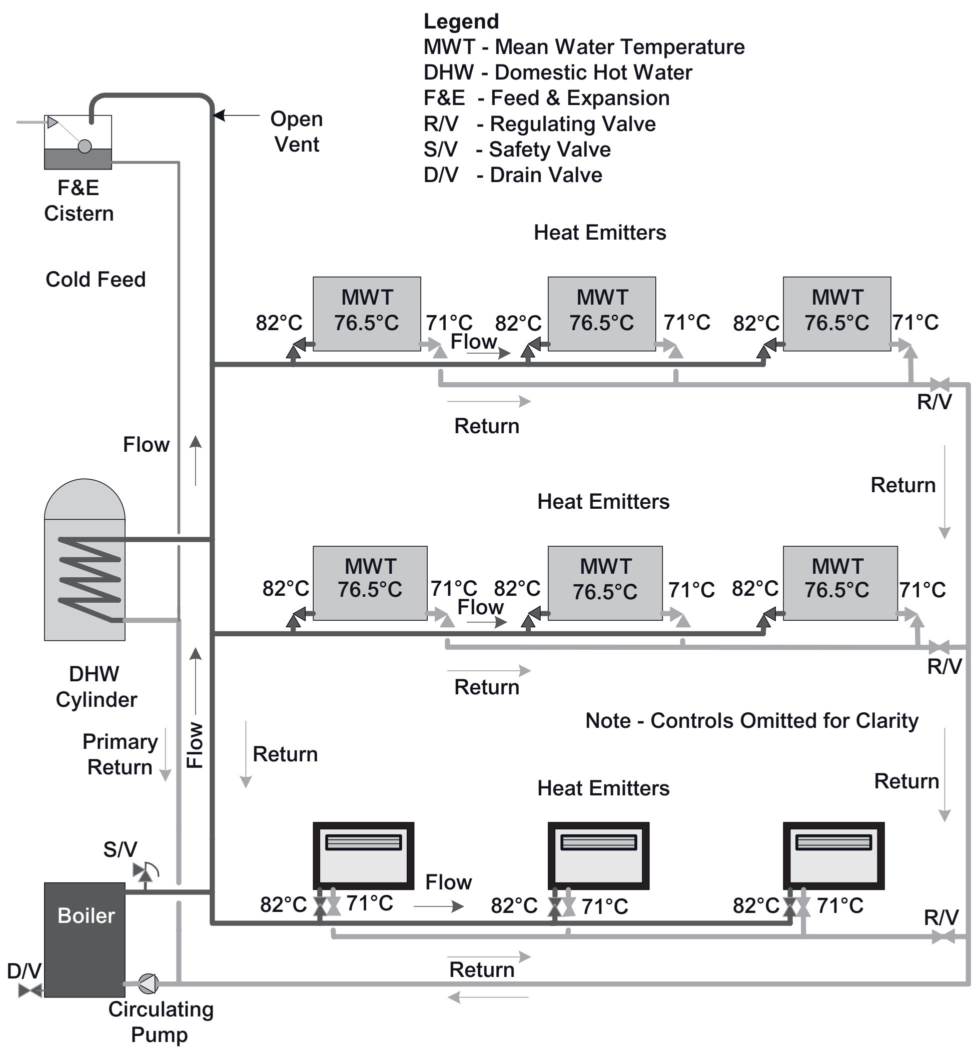


Figure 2.11 Operating principles of a reverse return two pipe heating system (non-condensing)

problem of system flow disparity. It can be seen that the heating system depicted in Figure 2.11 is the same as that shown in Figure 2.10, the only difference being the arrangement of the main return pipe back to the boiler being routed in the opposite direction to that of the main flow pipe. This method of returning the water to the boiler creates an almost equal distance, and also an equal resistance to the flow of water to each heat emitter, thus making the balancing of the system flow much easier.

The reverse return two pipe heating system is more desirable than the direct return system if capital costs can be justified and the building layout does not present complications to the pipe routes, as the heating system will remain in a balanced condition regardless of any tampering with the return regulating valves.

To illustrate the advantage of the reverse return piping system over the direct return arrangement of piping, two identical heating systems are shown in the isometric layout projection in Figure 2.12. Part (a) depicts the heating system with the piping arranged in a standard two pipe direct return layout where it can be seen that the resistance to the flow of heating water from the boiler and back again from heat emitter number 1 is much less than it is to any other of the heat emitters. The flow has to be encouraged by balancing the pipework system by making all the heat emitters have an equal resistance, so forcing the heating water to the index heat emitter and thus preventing the water short circuiting through the nearest heat emitter.

Part (b) shows the same heating system, but the pipework has been arranged as a two pipe reverse return configuration. In this example the resistance of the pipework encountered by the flow is the same to heat emitter number 1 as it is to heat emitter number 4, and all the other heat emitters in between. Therefore, providing that the piping system has been correctly sized, the circulation of the heating water is much simpler.

It can be argued that the additional capital cost of the two pipe reverse return heating system can be justified by the saving of the reduced time spent on balancing the piping network at the commissioning stage and, in turn, offsetting this initial capital cost.

MICRO BORE PIPING SYSTEM

All of the piping arrangements discussed so far have been equally suitable for large commercial heating systems and small domestic residential heating systems, but the micro bore heating system was developed in the 1960s specifically for domestic residential dwellings and small commercial properties, although it has been used successfully on larger building developments where it forms part of the overall larger heating scheme.

There have been a number of myths regarding the terms 'micro bore' and 'mini bore', some of them quite plausible, such as one of them being an open vented heating system and the other one being a sealed heating system, or that one uses imperial sized tubes while the other employs metric diameter tubes, this latter explanation being closest to being correct. The truth, however, is less romantic as they are in fact both proprietary names which have become acceptable to use to describe a heating system that utilises distribution pipes having diameters smaller than the 15 mm (½ inch), which are normally used on small bore heating systems. Mini bore was the first of these names to be used to describe water distribution pipes having diameters of ¼ inch and ⅜ inch, but now micro bore has become generally adopted to describe heating systems employing tubes having diameters of 6 mm, 8 mm, 10 mm and 12 mm diameter.

The micro bore heating system differs fundamentally from any of the heating systems previously described. It employs components that are peculiar to the micro bore system and are not found on small bore heating systems that use conventional pipework and fittings common throughout the plumbing industry.

Figure 2.13 illustrates the basic operating principles of the micro bore heating system, which is still fundamentally a two pipe heating arrangement where the means of circulation is the same as any other form of piping arrangement, but the method of achieving that circulation differs from other piping layouts. The heated water is circulated from the boiler through conventional size pipes arranged as a pair of heating mains to strategically placed manifolds located fairly centrally between a group of heat

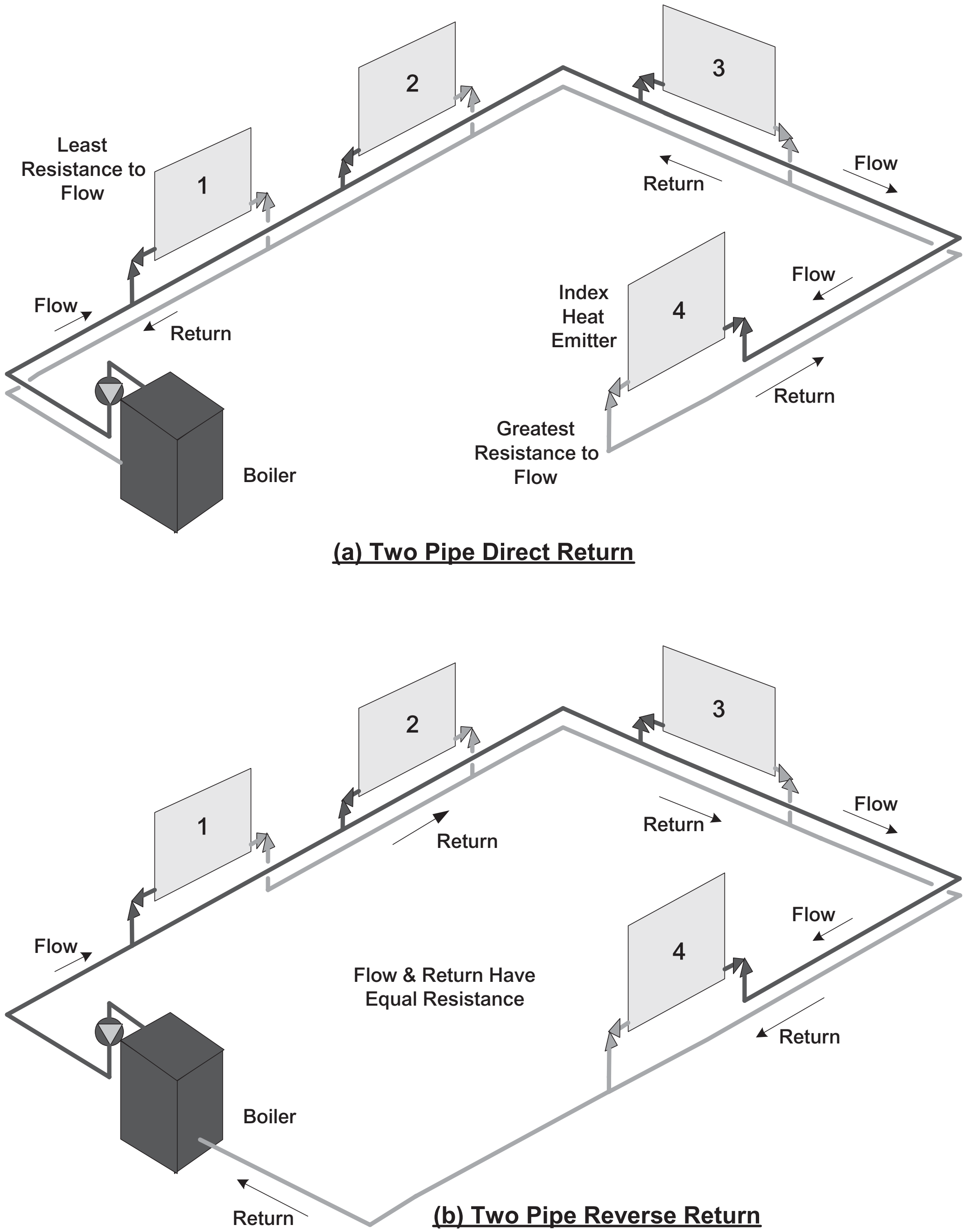


Figure 2.12 Isometric comparison of two pipe direct return and two pipe reverse return

emitters, this location being chosen to try to achieve reasonably equal micro bore branch pipe runs to each heat emitter that it serves. The manifold may be one of a variety of types, such as an inline multiple tee arrangement that incorporates a central blanking plate, or an end of line multiple reducer, or a number of other forms that are commercially available. The difference between this system and the other piping arrangements is that from the manifold, a separate dedicated micro bore flow and return pipe is

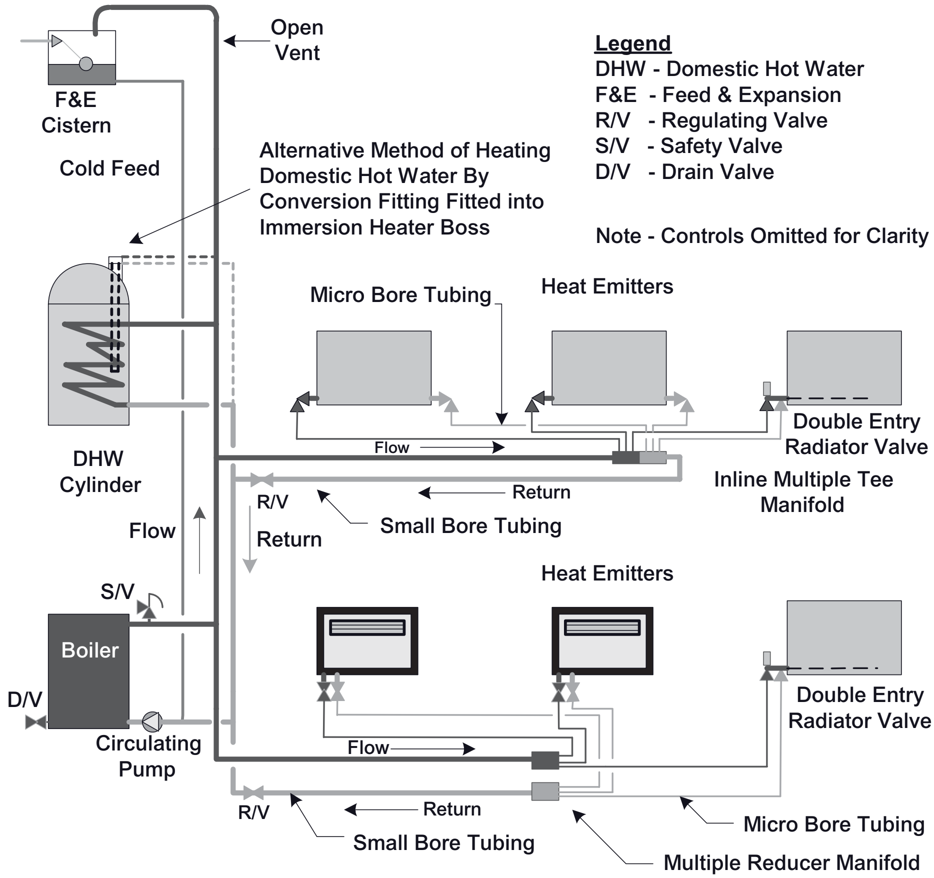


Figure 2.13 Operating principles of a micro bore heating system

extended radially and connected to each heat emitter individually, as shown. There is no limit to the number of manifolds employed, but each pair of micro bore flow and return pipes must be connected to the same manifold.

Heating systems employing conventional pipe sizes, i.e. 15 mm diameter and larger, are designed to have a flow velocity of approximately $1.0\,m\,s^{-1}$: this has been found to be the most economic regarding the optimum velocity that will not cause noise to be generated or erosion to occur at sharp changes in direction. Micro bore piping arrangements do not conform to this convention and are designed to have flow velocities of $1.5\,m\,s^{-1}$, which means that as the speed of the water being delivered to each heat emitter is one and a half times faster than that used on traditional piping arrangements, smaller diameter tubes may be used. This higher flow velocity through micro bore tubing is possible as there are no sharp changes in direction such as elbows, etc – and as the tubing is installed in one continuous length, using flexible coiled pipe of either soft fully annealed copper, or a barrier type plastic material, the same volume of water may be supplied to each heat emitter without any noise or erosion problems.

The following advantages are claimed for micro bore heating systems:

1. In existing buildings it is claimed to be easier to install, as fewer floorboards have to be removed when using micro bore tubing. Also, on new build properties the micro bore tubing can be installed by threading the flexible tube through holes pre-drilled in the floor joists from the ceiling below,

allowing the floor to be laid earlier. This is possible as the micro bore tube – be it soft copper, a barrier thermoplastic material such as PEX, or polybutylene – is supplied in soft coil form that allows the tube to be threaded through in a similar way to electric cable. It should be noted that when working with soft fully annealed copper tube, although it is flexible when supplied in coil form, it quickly hardens if it is threaded through joists or below floorboards involving too many turns in direction and may need to be reheated to recover its original soft condition. Special tools are available to form neat labour-pulled bends and to straighten pipework that will be on show.

2. Double entry radiator valves are available and may be used, resulting in a cost saving compared to a pair of traditional single entry radiator valves that would normally be used. However, the type incorporating the provision to isolate the return connection as well as the flow connection should be selected to aid maintenance and allow the radiator to be removed without draining down the entire heating system.
3. A neater pipework installation is claimed as the piping may be hidden more easily in exposed situations, although, conversely, because the micro bore tubing is soft it may be more easily damaged, either accidentally or wilfully; therefore some form of protection should be considered if this potential exists. The pipework may also be passed through smaller openings or holes in the structure than conventional small bore tubing, which sometimes may be a deciding factor in specifying piping systems in existing buildings.
4. As the micro bore tubing is supplied and installed in one continuous length from the manifold to each heat emitter, the piping system requires fewer joints, which in turn means less possibility of leaks.

Manifolds

Figure 2.14 illustrates a typical inline multiple tee manifold that comprises a section of small bore tube, usually 22 mm or 28 mm diameter, which incorporates a centrally placed blank plate that divides the manifold into a separate flow zone and separate return zone, each with an equal number of compression type tees that convert the small bore tube into micro bore tube.

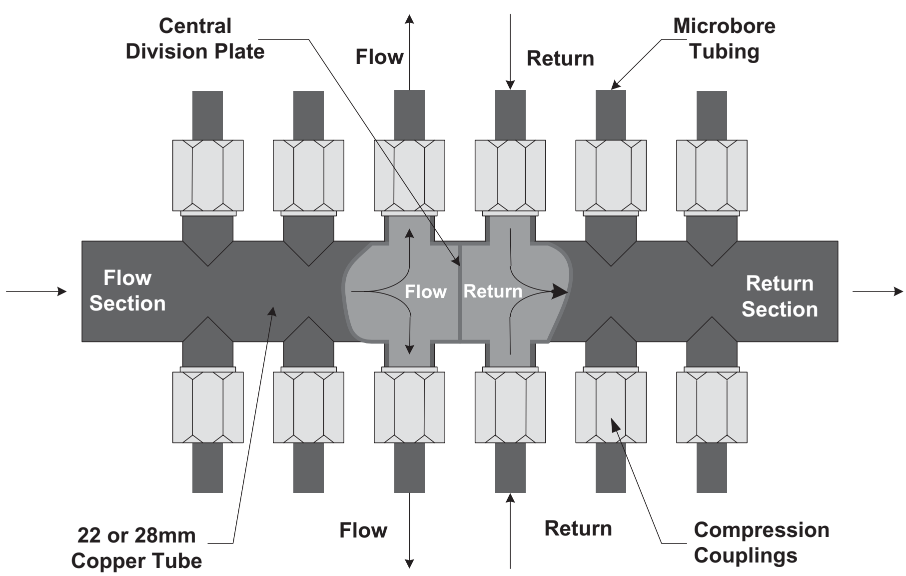


Figure 2.14 Inline multiple tee manifold

Figure 2.15 Linear multiple reducing manifold

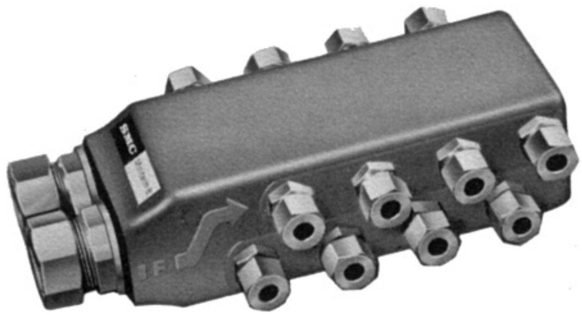


Figure 2.16 Alternative form of micro bore manifold

The inline multiple tee type manifold is the most commonly used manifold of all the different variations commercially available and may be obtained with a varying number of connection tees to suit the application required, with any unused tees being blanked off. It is also where the flow velocity transforms from $1\,\text{m}\,\text{s}^{-1}$ in the small bore tube to $1.5\,\text{m}\,\text{s}^{-1}$ in the micro bore tube.

Figure 2.15 illustrates an alternative type of manifold that is in common use. It comprises either a capillary or compression linear fitting that is arranged to fit on the end of a small bore pipe that serves to divert the flow into a number of reduced size micro bore tubes. A separate linear type multiple reducing manifold is required for both the flow and return connections.

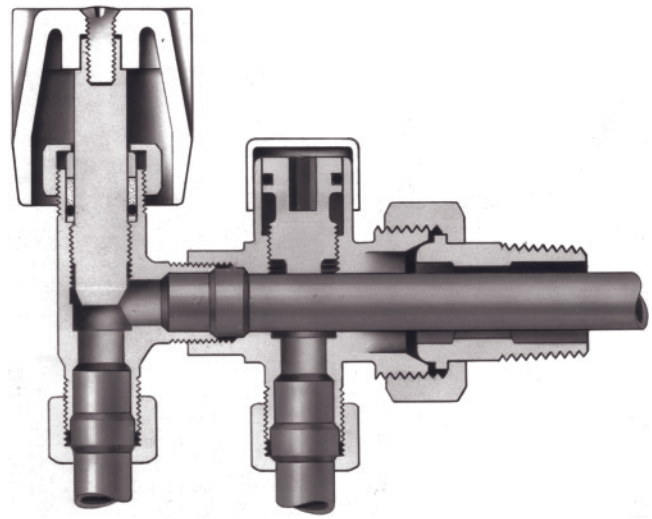
This type of manifold is restricted in physical size to a limited number of branch connections that are available to connect the micro bore tube into, where the inline multiple tee is not hindered.

Another form of micro bore manifold is shown in Figure 2.16; this type was available commercially for a period of time in a few sizes and was manufactured using cast iron for the body with non-ferrous compression pipe connections. There was an internal division plate arranged horizontally that formed two chambers, one for the flow and the other for the return, which meant that both the flow and return micro bore pipes serving each heat emitter were arranged almost one above the other on the same side of the manifold, thus avoiding having to cross over other micro bore pipes serving different heat emitters.

The higher capital cost of this type of manifold limited its use to pipework that would be on show, as a very neat and professional appearance could be achieved when the manifold was fixed to a wall surface in a cupboard or service duct and the micro bore tubing dressed into the manifold pipe connections without any pipe crossovers.

Double entry radiator valve

Figure 2.17 shows a cut through section of a double entry radiator valve illustrating the flow and return micro bore pipe connections and the application of a short cut piece of micro bore tubing used as a rigid insert to prevent the flow of water short circulating through the radiator. The flexible copper insert supplied with these radiator valves should be discarded as it has a tendency to lay flat on the bottom of the steel panel radiator welded seam, which could promote an electrolytic action between the two metals.



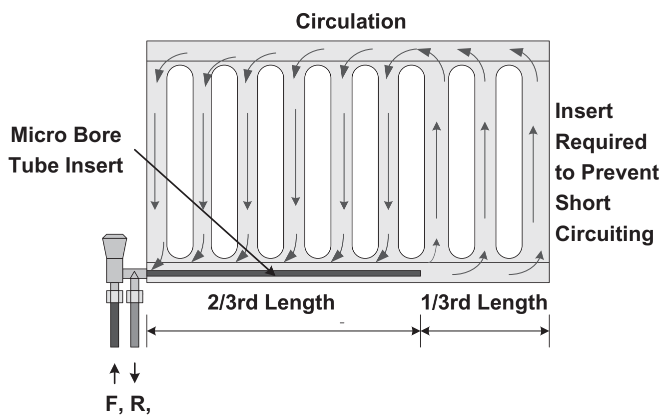


Figure 2.17 Detail and application of double entry radiator valve

The flow enters the radiator through the valve flow connection and into the rigid copper insert where it circulates through the radiator and exits through the body of the valve on the outer side of the insert, as illustrated.

The double entry radiator valve is less costly than a pair of conventional radiator valves but can only be used on single panel radiators, or column type radiators. The construction of double panel radiators and radiators manufactured with back inlet connections prohibits the use of these double entry radiator valves.

TWO PIPE RADIAL SYSTEM

This is the most recent of piping arrangements forming a system of heat distribution that has been derived from the operating principles of the micro bore piping system, but it is not restricted to micro bore tubing or small bore tubing and incorporates components common to underfloor heating (see Chapter 6, Underfloor Heating).

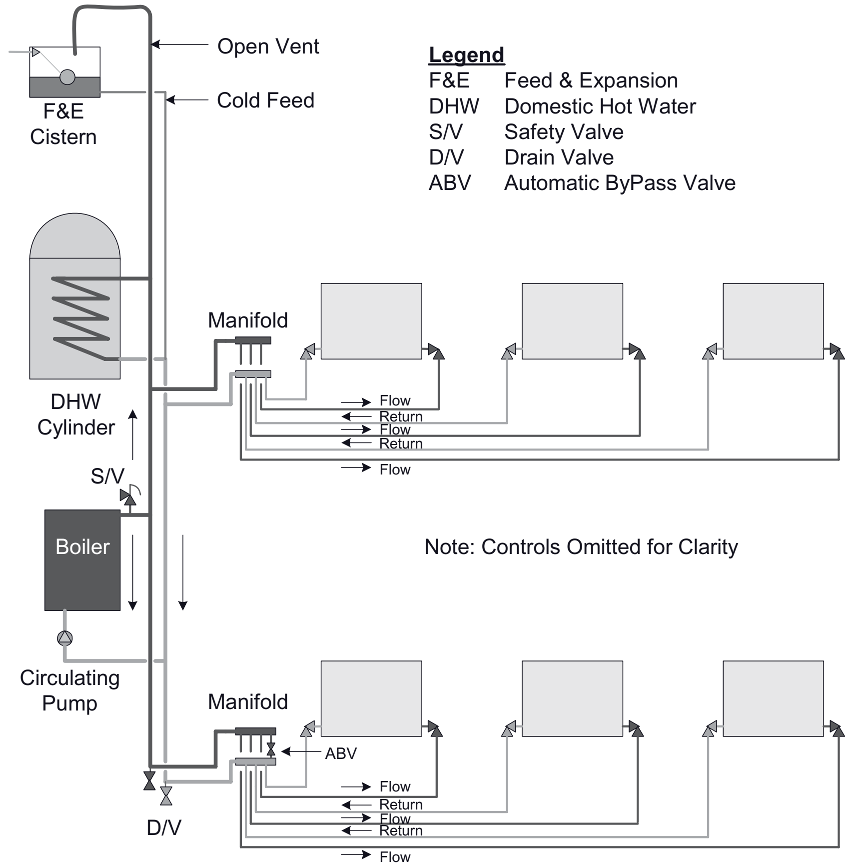


Figure 2.18 Operating principles of two pipe radial system

Figure 2.18 illustrates the piping arrangement of the two pipe radial system. It can be seen that the distribution is very similar to that of the micro bore piping system except that the branch distribution piping may be 15 mm diameter or larger. The configuration of the manifolds used is very similar to those employed for underfloor heating, including the incorporation of individual isolating valves on both the separate flow and return manifolds.

The method of delivering the heat is the same as for the micro bore system. The water is circulated by the pump through the common main flow and return pipes to each manifold located in a service cabinet or service duct, from where it is circulated through individual dedicated branch flow and returns to each heat emitter.

This piping arrangement has been more popular in Northern Europe than in the UK, but has been installed in a number of new housing developments in Britain over recent years. It is more suitable for installing in new build properties that have solid concrete floor constructions, but can be used in existing dwellings and buildings that have raised or ventilated timber floor construction if the property is undergoing a major refurbishment that can help to justify accommodating the building alteration costs.

Figure 2.19 shows a simple floor layout where the heating flow and return pipes are laid in the floor from the manifold and take a direct route below door openings to the heat emitters without any pipe joints, using large radius labour pulled bends.

The piping material chosen for this application is normally either cross-linked polyethylene (PEX), polybutylene or polyethylene, all with an oxygen barrier incorporated within the pipe walls. These pipe

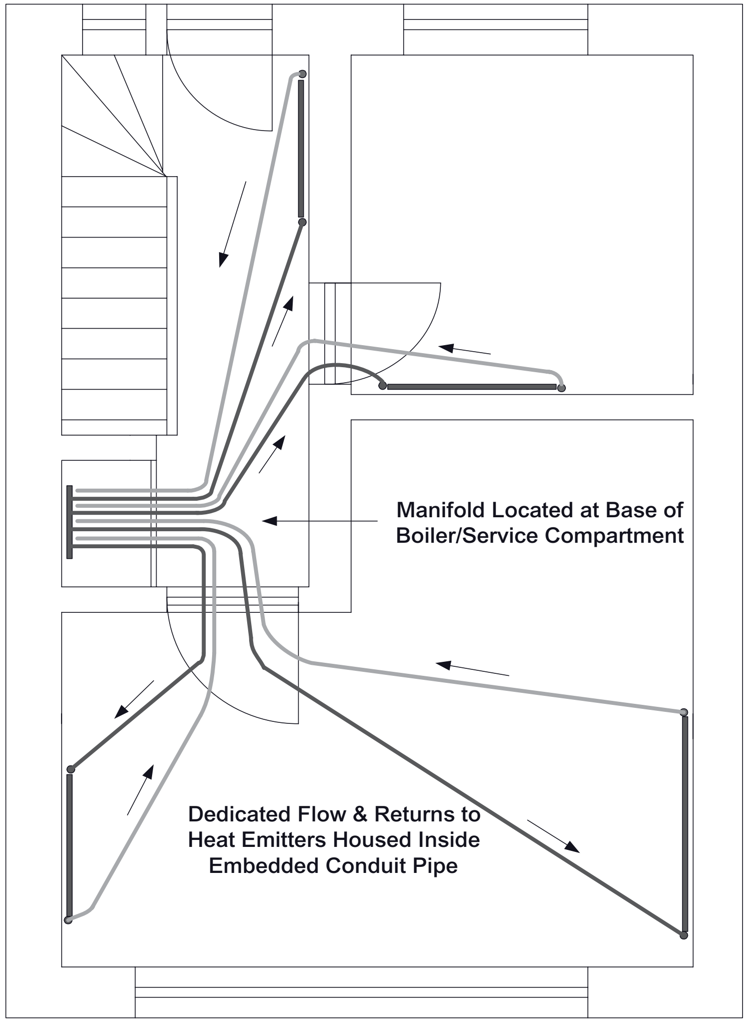


Figure 2.19 Floor plan layout showing radial piping arrangement

materials have the qualities required for this particular application, such as flexibility, and are commercially available in long coiled lengths that allow the pipe to be laid in one continuous length without any intermediate joints. It is good practice to install these pipes inside a second conduit pipe that is directly embedded in the floor screed; see Figure 2.20. This has the advantage of permitting the carrier pipes to remain free to move through thermal movement inside the embedded conduit pipes, and facilitate the removal and replacement of the carrier pipes if necessary for maintenance.

This form of pipework installation makes for a neat and easy to install system, but makes it very difficult for any future alterations such as repositioning of heat emitters and property extensions.

Manufacturers of these systems produce a variety of ingenious components that form a transition from the embedded underfloor pipe to connect up to the heat emitters. Figure 2.21 shows an arrangement that utilises a junction box fitted into the floor screed that facilitates both the transition from a plastic pipe to a metallic pipe riser up to the heat emitter in the normal manner, and provides the access required to withdraw the carrier pipes from the conduit and replace with new if required.

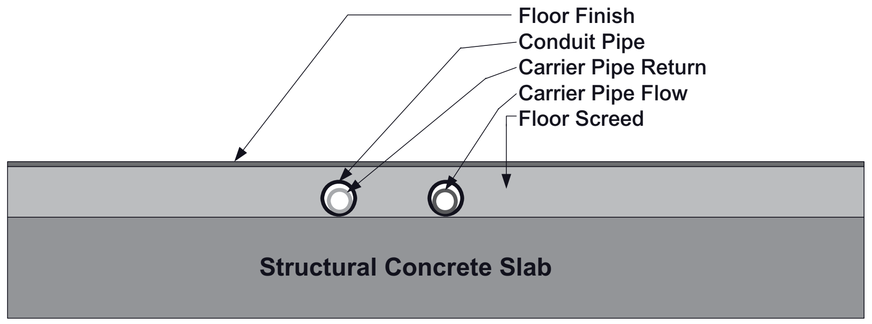


Figure 2.20 Section through solid floor construction showing heating flow and return installed within conduit pipes

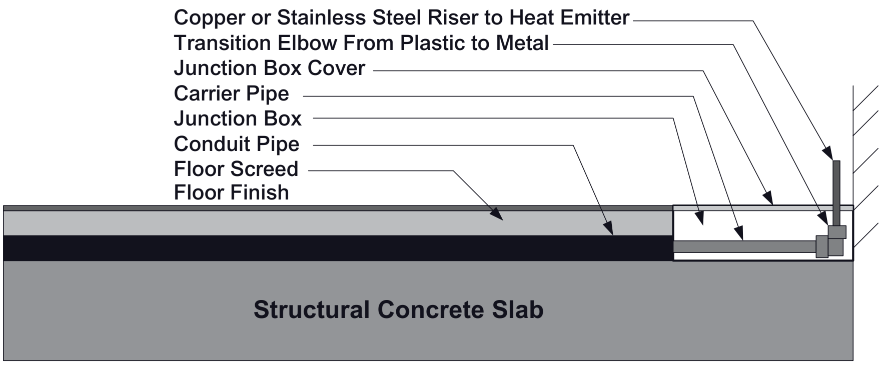


Figure 2.21 Detail of junction box transition for heat emitter connection

The conduit pipe may also be used to contain the flow and return carrier pipes embedded in wall chases or inside the cavity of dry-lined walls; see Figure 2.22. With this arrangement, a commercially available termination junction box, similar in appearance to an electrical power socket outlet cover plate, is fitted flush with the wall behind where the radiator is to be fixed, and the conduit pipes are fixed inside the depth of the walls with the carrier flow and return pipes installed inside them. The wall finish is then made good, and the flexible thermoplastic branch pipes connected to the conduit housed carrier pipes inside the termination junction box before the radiator is fixed to the wall. The flexible branch pipes can then be connected to the radiator valves, making for an aesthetically pleasing installation.

Thermoplastic pipes are extremely suitable for this application, their flexible nature enabling them to be connected from the termination junction box to the radiator.

In newly constructed buildings the radial piping arrangement has a number of advantages, primarily reduced on-site installation time, meaning the time for which other trades are prevented from working whilst the piping system is being installed is reduced. This reduction in programme time results in a lower cost of construction to the developer. The radial piping arrangement also results in a neat, unobtrusive installation. However, the price to pay for these construction phase advantages comes later when the building owner wishes to extend or alter the building, as the resulting pipework alterations involve considerably more work for the builders.

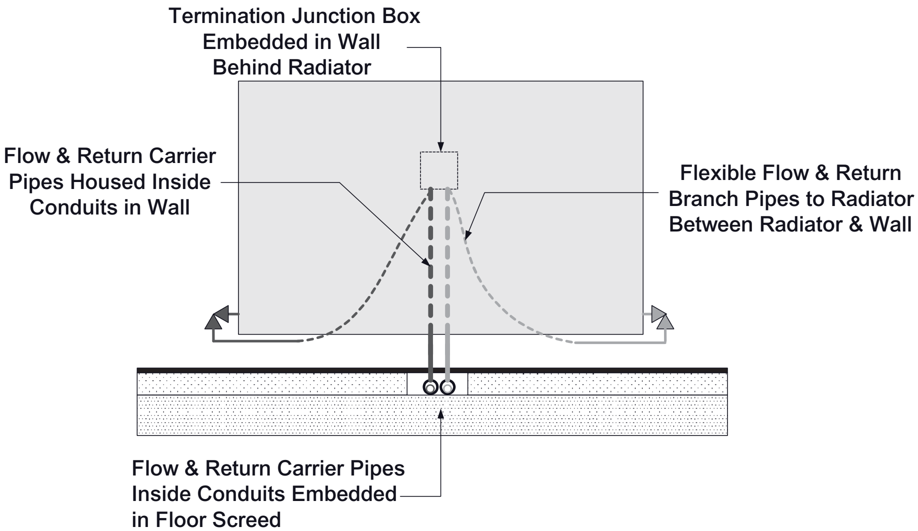


Figure 2.22 Flexible thermoplastic radiator connections from flush mounted termination box

HYBRID (MIXED) SYSTEMS

Figure 2.23 illustrates a somewhat exaggerated example of a mixed piping system arrangement demonstrating the possibilities that are available if the building layout, together with the client's needs, dictate it. It is equally suitable for large or small buildings alike.

Hybrid systems need not just be a mixture of different piping arrangements; they can also be a combination of temperature/pressure configurations.

Figure 2.24 illustrates a hybrid system of sealed heating where there is a mixture of piping arrangements and a mixture of operating temperatures. This form of heating is more common in other parts of Europe than it is in the UK. The system is designed to operate as a medium pressure heating scheme with the water flow temperature leaving the boiler at a temperature of 100–120°C, making it unsuitable for domestic residential dwellings. The high temperature flow water first travels via a single pipe system to pass through a series of low surface temperature radiators or convectors where the high temperature of the water can be exploited to the full, permitting physically smaller heat emitters to be selected. When the high temperature of the flow has been exhausted and the flow temperature falls below 100°C, the water then passes on to a conventional two pipe system, still operating at medium pressure, but permitting standard panel or column type radiators to be employed that have been selected and sized in the same way as for a conventional low pressure heating system. The water is then returned to the boiler at a normal return temperature of 71°C.

This hybrid arrangement has obvious advantages if the building criterion favours it.

OPEN VENTED HEATING SYSTEMS

All the hydronic heating systems depicted so far in this text, with the exception of the sealed heating system illustrated in Figure 2.24, are described as 'open vented heating systems', which is the term used to describe hydronic systems of heating subjected to hydrostatic pressure only. This hydrostatic pressure is determined by the physical height that the water in the feed and expansion cistern is exerting on the rest of the heating system. Heating systems in the past in the UK have traditionally – but not exclusively – been of the open

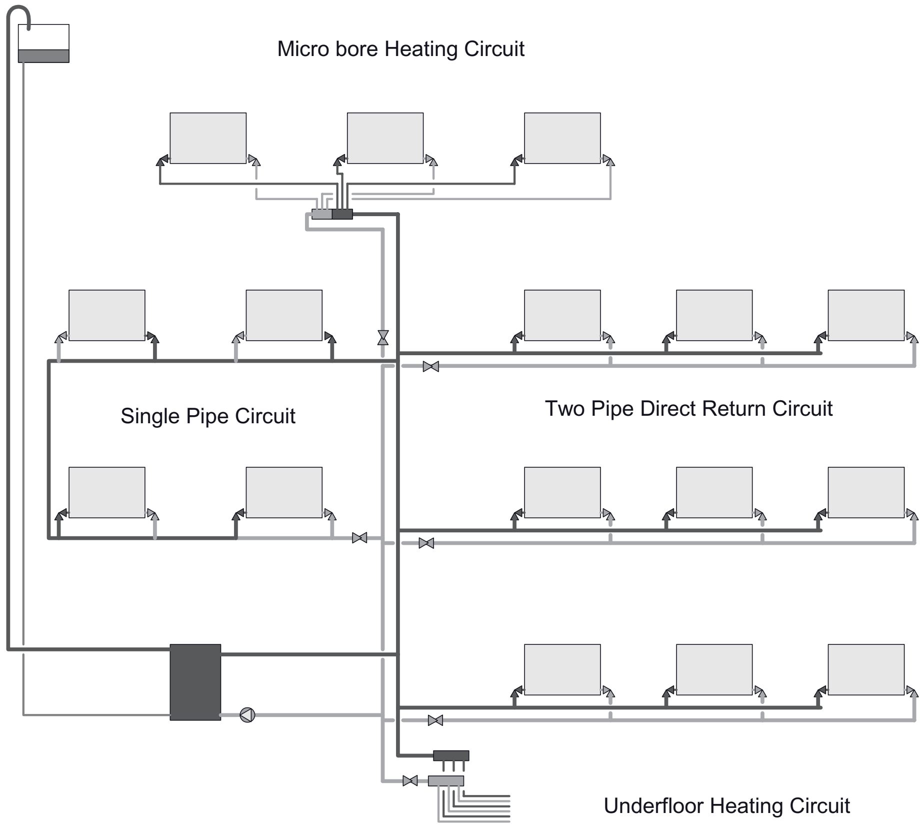


Figure 2.23 Hybrid system of mixed piping arrangements

vented type, and the reason why the drawings used in this chapter of hydronic heating systems are of the open vented type is to show the need for, and method of, accommodating the expansion of the water caused by the application of heat.

One of the main features of an open vented system, and the foremost component that makes it an open vented system of hydronic heating, is the inclusion of the feed and expansion cistern.

The function of the feed and expansion cistern may be explained in three ways:

1. The initial purpose of the feed and expansion cistern is to serve as a header tank to enable the heating system to be filled up with water and then to continue to perform as a reservoir, where any water losses due to evaporation may be automatically replenished. The feed and expansion cistern is the automatic point of introduction of water into the heating system, both on the initial fill and any subsequent fills that may be required during maintenance activities. This is the feed part of the feed and expansion cistern that functions before the heating system becomes operational and is only required when water is to be added to the system.
2. The second function of the feed and expansion cistern is to serve as a means of catering for the volumetric increase in water caused by the expansion of the water that occurs when the heating system boiler is operating at its design temperature, without causing any pressurisation of the heating system. This is the expansion part of the feed and expansion cistern and is performed continually during its normal operation.

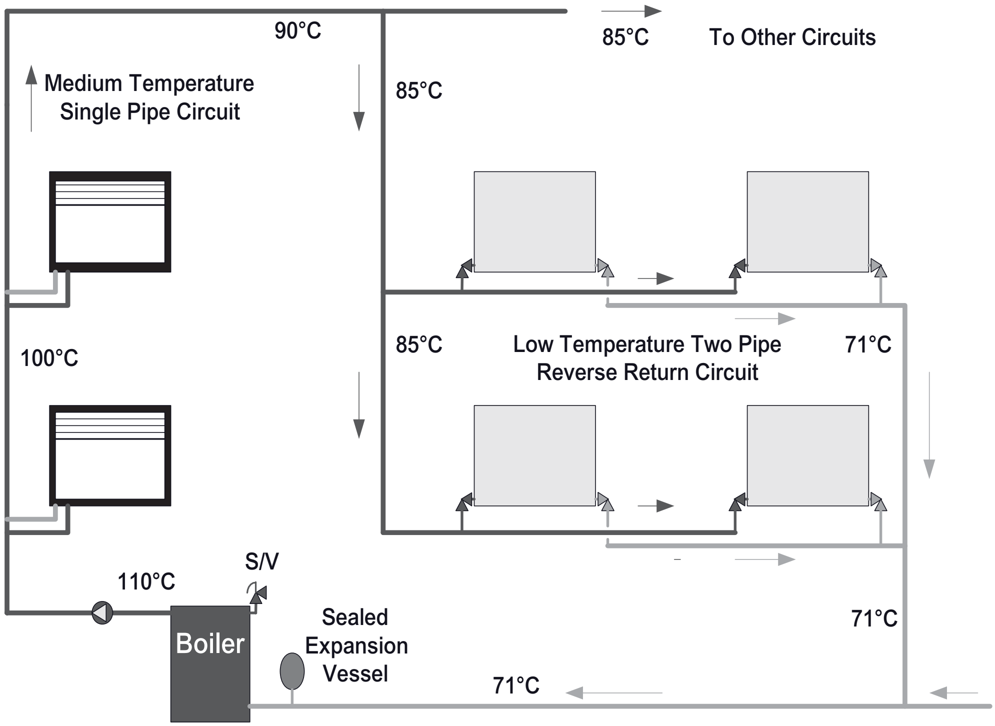


Figure 2.24 Hybrid system of mixed piping and temperature arrangement (not suitable for domestic residential dwellings)

3. The feed and expansion cistern also has a third function, which is equally important but not immediately obvious as the first two points. This third function is one of safety; it serves as a cooling tank in the event of the boiler overheating and high temperature water/steam being discharged into it from the open vent pipe terminating over the top of the feed and expansion cistern. This high temperature water/steam mixes with the water already in the feed and expansion cistern, which is also at a high temperature, but also mixes with any incoming cooler make-up water to replace evaporation losses before returning it back into the heating system to keep the system and boiler wet and thus prevents the boiler becoming dangerous. Because of this safety aspect, it is imperative that the feed and expansion cistern is correctly sized and that it is manufactured from materials capable of withstanding the high temperatures that could exist when this condition occurs. This third function is not always fully appreciated as its importance does not become apparent until something goes wrong with the heating system. If it has not been designed correctly a failure to the feed and expansion cistern could occur compounding a dangerous situation and creating a potentially catastrophic condition.

FEED AND EXPANSION (F&E) CISTERN

When water is heated, as it is in a hydronic heating system, the rising temperature will cause the water to expand. This increase in volume will have to be catered for, otherwise the heating system will become highly pressurised, to a point where it is in imminent danger of fracturing at its weakest part. In the open vented heating system this increase in water volume is accommodated by the feed and expansion cistern.

Table 2.3 Recommended minimum capacities for F&E cisterns and connections

Boiler Rating kW	F&E Cistern Nominal Capacity Litres	Float Valve Size mm	Cold Feed Diameter mm	Open Vent Pipe Diameter mm	Warning Pipe Diameter mm
<25	45	15	15	22	22
<45	70	15	22	28	28
<60	90	15	22	28	28
<75	150	15	22	28	35
<150	225	15	28	35	35
<225	310	22	28	35	35
<300	400	22	35	42	42

Water is at its maximum density at a temperature of 4.4°C; any change in temperature from this point, be it higher or lower, will result in an increase in its volume. If the temperature of water is raised from 4.4°C to 100°C, it will increase in volume by 4.2%, or $\frac{1}{24}$ of its original volume. Therefore the feed and expansion cistern must be sized to accommodate not less than $\frac{1}{24}$ of the heating system volume of cold water, plus the water in the lower part of the cistern required to allow the float valve to operate, a minimum depth of 100 mm and a safety factor.

These requirements are satisfied by allowing a volumetric increase of 5%, or $\frac{1}{20}$ of the heating system's water content when cold and is the figure recommended by BS 5449, and other authoritative engineering guides. This increase in volume should be allowed for above the normal cold water level and below the warning pipe/overflow level as the water should expand into the feed and expansion cistern via the cold feed, but should not overflow through the warning pipe. When the heating system is turned off, the water will cool down and contract back into the heating system by the way it entered, the cold feed.

Table 2.3 gives the minimum recommended nominal capacities for feed and expansion cisterns, together with their service connections, but it should be emphasised that these should only be used as a guide and the final selected size should be calculated, see Box 2.1.

The feed and expansion cistern should conform to the requirements of the Water Regulations exactly as for the main cold water storage cistern, as it is supplied with cold water from the incoming rising main. Figure 2.25 illustrates the general arrangement of the feed and expansion cistern detailing the main points. The construction materials should be suitable for their uses; particularly for the high water temperature that could exist if nearby boiling water is discharged into it during a boiler/system malfunction. If the cistern is not self-supporting, a solid base should be placed under the cistern that extends to a minimum of 50 mm on all four sides and should be of a material that will retain its integrity if wet: marine grade ply is often selected for this use. The float valve that regulates the flow of make-up water into the cistern should conform to BS 1212, either Part 1 or Part 2. Normally a Part 2 copper alloy bodied diaphragm float valve is selected, but a Part 1 Portsmouth pattern float valve may be used provided that a back flow device, such as a double check valve, is installed on the incoming water main, as depicted in Figure 2.25. Care should be taken when cutting any penetration in the wall of the cistern, such as the outlet for the cold feed to the system, to ensure that the flanges of the tank connector do not impose any stress on the base corner of the cistern when the connector back nut is tightened. The cistern cover and warning pipe should be equipped with an insect filter to prevent ingress into the cistern and any penetration in the cover for the open vent should have a flexible seal to permit movement of the pipe through thermal expansion.

The feed and expansion cistern and all pipework in the roof void space, including the warning pipe, must be insulated against freezing, except the space beneath the feed and expansion cistern, which should be left clear so that heat that has passed through the ceiling below will prevent the water temperature dropping below 0°C.

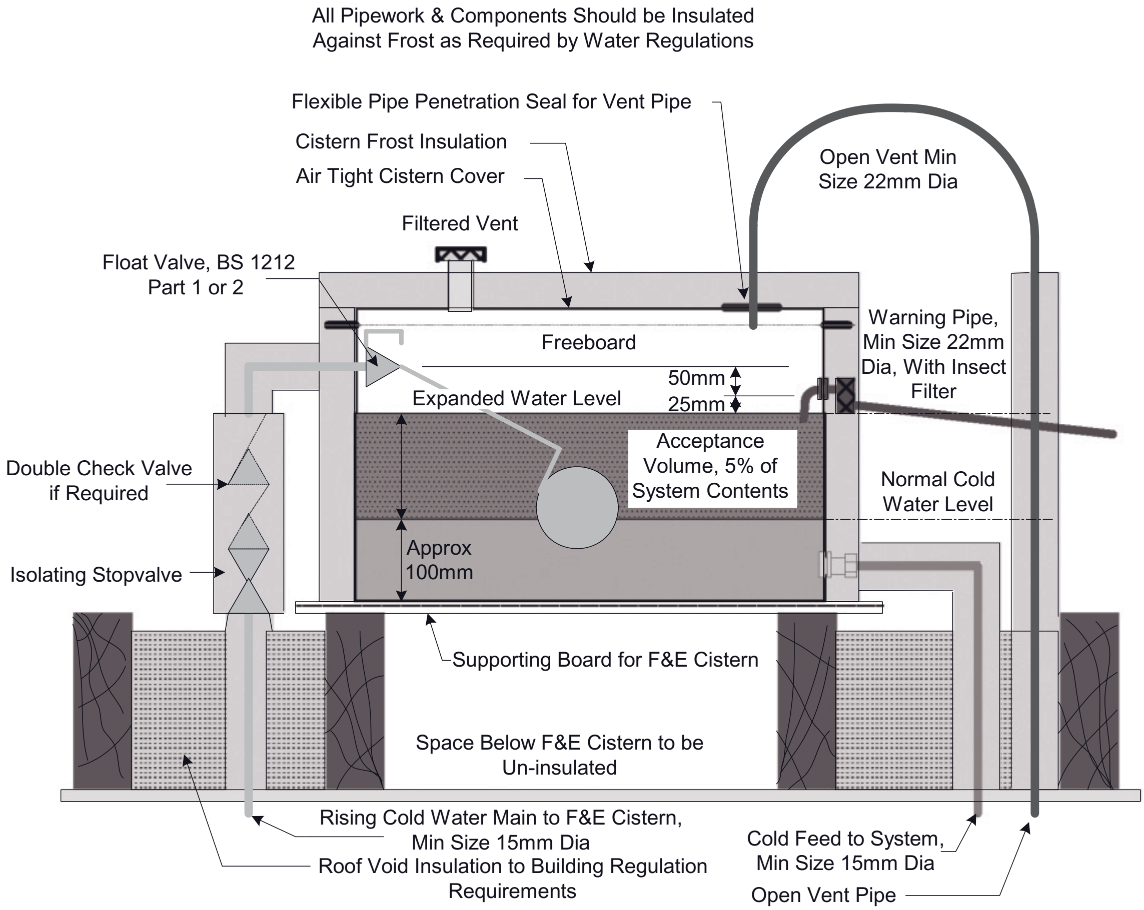


Figure 2.25 Feed and expansion cistern arrangement in roof void

OPEN VENT PIPE AND COLD FEED AND EXPANSION PIPE

The open vent and cold feed and expansion pipe perform an equally important function as the feed and expansion cistern and combine together for the following purposes:

1. When the heating system is being charged with water, either initially, or during any subsequent refilling after any maintenance activities have been completed, the cold water is allowed to enter the heating system under a controlled steady non-turbulent flow via the cold feed pipe from the feed and expansion cistern, whilst air that it displaces is permitted to partially escape through the open vent pipe. Any trapped air is expelled via the manual air vents on the heat emitters, or via automatic air vents incorporated in any non-self-venting pipework on the heating system.
2. When the heating system has been charged with water and the boiler commissioned and fired up, the water as a heating medium in the system will be constantly heated up and cooled down under the dictates of the heating systems control scheme and boiler thermostat. The result of this constant temperature change will cause the water to increase in volume when heated and expand back up the cold feed into the feed and expansion cistern occupying the space calculated for the acceptance volume. When the water in the heating system cools down, the water that entered the feed and expansion cistern will

BOX 2.1 Example calculation of F&E cistern size

Extent of system pipework (Obtained from Engineering Data)		
56 m of 15 mm pipe × 0.1452 litres per metre		= 8.14 litres
38 m of 22 mm pipe × 0.3211 litres per metre		= 12.20 litres
18 m of 28 mm pipe × 0.5399 litres per metre		= 9.72 litres
Heat emitters (Obtained from Manufacturer's Data)		
Rad 1		= 7.2 litres
Rad 2		= 12.4 litres
Rad 3		= 7.2 litres
Rad 4		= 3.6 litres
Rad 5		= 4.0 litres
Rad 6		= 8.6 litres
Rad 7		= 4.0 litres
Convector 1		= 2.0 litres
Boiler water capacity (Obtained from Manufacturer's Data)		
System boiler		= 12 litres
Domestic hot water cylinder (Obtained from Manufacturer's Data)		
DHW cylinder heat exchanger only		= 2.0 litres
Total system water capacity		= **93.03 litres**
Acceptance volume required	5% × 93.03 litres	= **4.65 litres**

Assuming that the F&E cistern measures 500 × 300 mm and that it contains water up to a height of 100 mm, this would equal 15 litres of water when the system is cold.

15 + 4.65 litres = 19.65 litres of water actual capacity.

Assuming an equal volume of 15 litres above the acceptance volume water line then:

15 + 19.65 litres = 34.65 litres of water nominal capacity

Therefore, capacity of the feed and expansion cistern required =

Nominal capacity	**35 litres**
Having an actual capacity of	**20 litres**
Having an acceptance volume of	**5 litres**

contract slowly back into the heating system and return to its original volume. At the same time water will expand up the open vent pipe, raising the level of water in this pipe equal to that of the acceptance volume water level in the feed and expansion cistern, but not overflowing into the feed and expansion cistern, as shown in Figure 2.25. When the water cools down it will return to its original level in the open vent pipe.

3. The two preceding points describe the function of these two pipes together with the feed and expansion cistern during the normal operation of the heating system, but a third and equally important purpose of the open vent pipe, cold feed pipe and feed and expansion cistern transpires in the event of the heating

system overheating due to some malfunction, such as the boiler thermostat failing. In this situation, the open vent, cold feed and feed and expansion cistern combine to form a safety relief and cold fill system that protects the building occupants by preventing the heating system and boiler from drying out and rupturing, or even – as in the case of cast metallic heat exchangers – exploding. Careful consideration should therefore be given at the design stage to deciding on their location and method of connecting into the heating system. All too often this third point is forgotten, especially in domestic heating systems, in order to reduce the amount of pipework being installed and this compromises the safety of the heating system. The design principles to be applied are quite simple if the operating conditions of this safety aspect are understood. If the burner of the boiler fails to switch off for some reason, the water inside the heat exchanger will continue to rise above the design operating temperature, 82°C for low pressure heating systems, until it reaches boiling point and starts to generate steam. This steam should be allowed to escape up the open vent pipe and discharge this high temperature water and steam mixture into the feed and expansion cistern, thus relieving any build up of pressure. Inside the cistern it mixes with the lower temperature water together with any incoming cold make-up water supplied via the float valve to replace the water lost through steam being generated and escaping into the roof space. This cools the water down slightly before it is returned to the boiler by way of the cold feed pipe, thereby keeping the boiler heat exchanger wet and preventing it from fracturing through stress caused to the metal.

To relieve the boiler and prevent the heat exchanger drying out, the open vent should be arranged to rise vertically from the boiler, either as a separate pipe, or forming part of the heating circuit providing that there are no valves, manual or motorised, that could be shut off, with the cold feed extended down to enter the heating system as close to the boiler as possible. The cold feed can also utilise a heating return pipe if there are no valves on the circuit that could isolate the cold feed from the boiler.

Figure 2.26 (a) shows a good arrangement whereby the open vent rises unhindered to allow the high temperature water/steam to be discharged safely into the feed and expansion cistern; the cold feed also has a direct route back to the boiler to supply into the heat exchanger.

Figure 2.26 (b) shows the dangerous practice of combining the cold feed and open vent into a single common pipe. In this arrangement, the cold feed back to the boiler is prevented by the pressure of the high temperature water/steam pushing up the vent and forcing the cold water with it, thus preventing any water re-entering the system with the result that the boiler will eventually become dry and be in a dangerous condition.

Figure 2.27 illustrates two similar alternative methods of connecting the open vent pipe and cold feed pipe into the heating system. These methods are fairly common for domestic heating systems employing high resistance low water content boilers.

Arrangement (a) shows a method known as a 'close coupled system', where the open vent pipe is taken off the heating circuit 150 mm in front of where the cold feed pipe connects into the heating circuit. This provides a clear passage for both the open vent to relieve pressure and the cold feed to supply water back to the boiler to keep the boiler safe, provided there are no valves between the entry of the cold feed and the boiler.

Arrangement (b) is very similar, except that a proprietary fitting known as an 'air separator' is used to connect the two pipes into the heating circuit as shown.

The air separator is designed to allow any trapped air or free oxygen to escape through the open vent as the velocity of the flow of water through this component is much slower than through the enlarged section of the fitting; however, the use of a short section of enlarged pipe, usually one commercial pipe size bigger than the circuit pipe as shown in arrangement (a), has the same effect.

One of the main reasons why the arrangement of the cold feed and open vent pipes, as depicted in Figure 2.27, has become popular, is that it makes the relationship between these two pipes and the

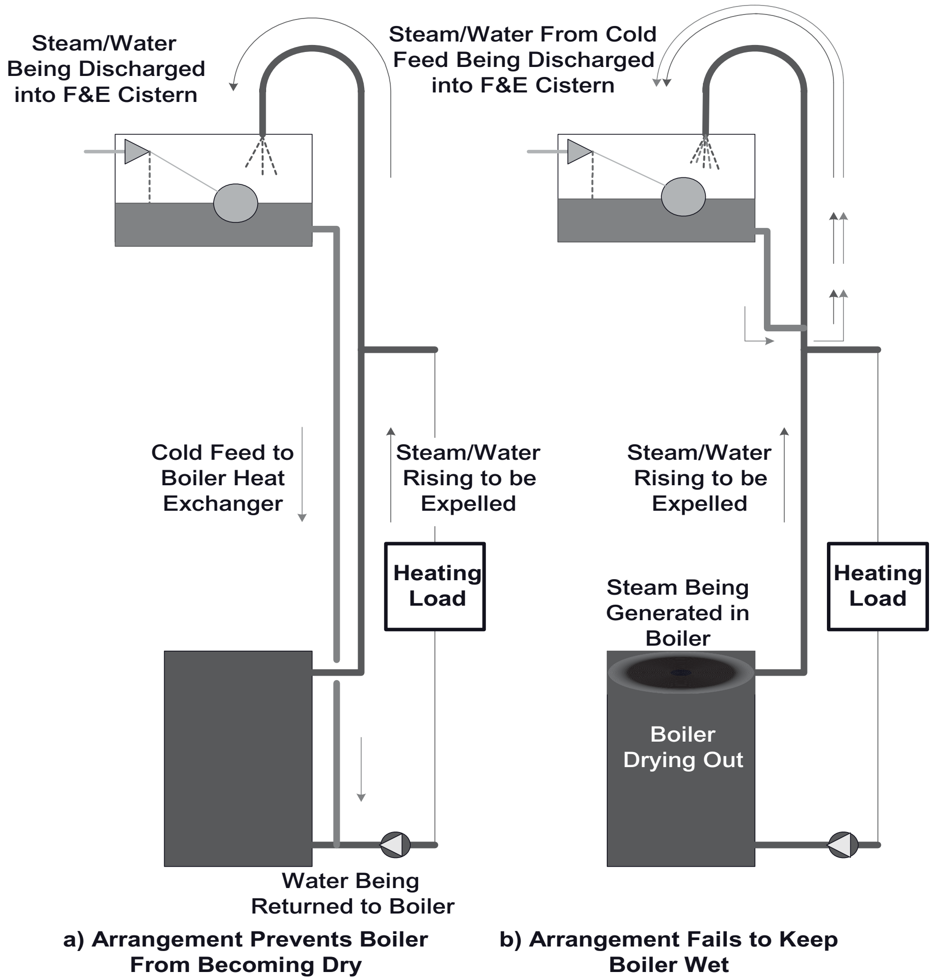


Figure 2.26 Combination of cold feed, open vent and F&E cistern during boiler malfunction

circulating pump much simpler as there is less risk of pumping over the open vent or drawing air into the heating system, and the domestic heating installer does not have to calculate the pump effects.

This section has concentrated on the relationship between the feed and expansion cistern, cold feed pipe and the open vent pipe during their normal operation and how they combine in the event of a boiler malfunction. There is also an equally important relationship between these two pipes and the circulating pump, which is explored further in Chapter 18, Circulating Pumps.

It should be noted that the arrangements illustrated in Figure 2.27, of connecting the cold feed and open vent pipes into the heating circuit, are only acceptable if there is a clear route for them to function correctly: if there are any manual valves, motorised zone valves or diverting valves which could cause them to close the path from or to the boiler, then an alternative route and method of connecting them should be sought. This is more likely to occur on the return path of the cold feed to the boiler.

The simple principle that should be applied in all cases, whether large commercial heating installations or small domestic heating systems for residential dwellings, is that a clear and unobstructed direct path

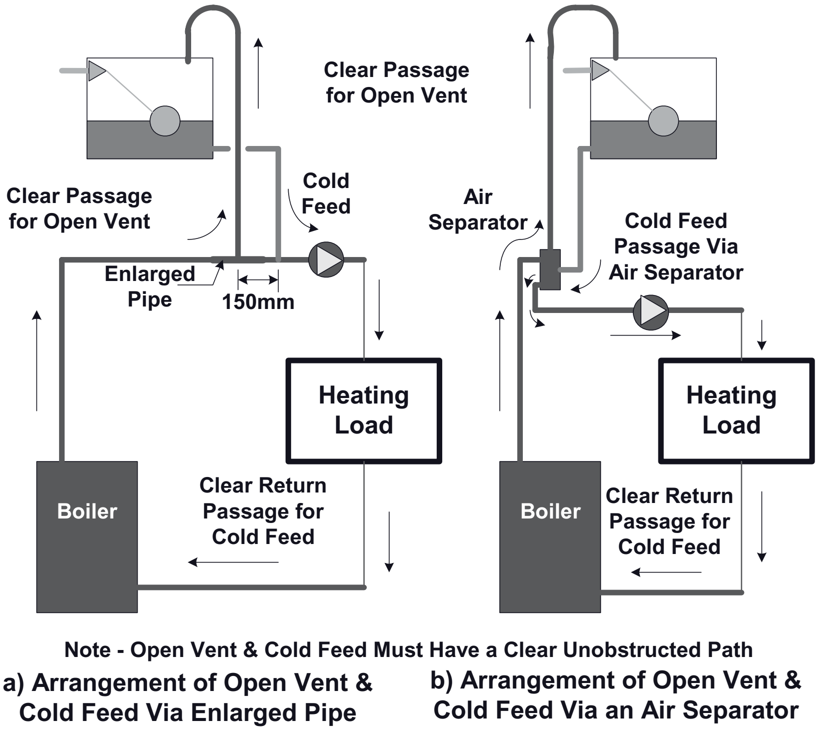


Figure 2.27 Alternative arrangement for open vent and cold feed

should exist for both the open vent pipe and the cold feed pipe from the boiler to the feed and expansion cistern.

INTRODUCTION TO AND HISTORY OF SEALED HEATING SYSTEMS

The subject of this chapter is hydronic heating systems and the preceding text has covered the importance of pressure and temperature within these systems. It has also covered the fundamental principles for the different piping arrangements and included many examples in illustrative form of the various pipework layouts. With one exception, all of the piping illustrations have been depicted as being low pressure open vented heating systems. The purpose of these pipework illustrations is to demonstrate the methods of distributing the heat carrying medium from the point of heat generation to the various heat emitters incorporated within the system and back again. These drawings of the heating systems could just as easily have been depicted as low pressure sealed heating systems as the piping arrangements would be exactly the same. Also, the piping arrangements would be the same if the heating system was classified as being either medium pressure or high pressure, but the system would have to be sealed to ensure that the operating pressure was above the distribution temperature to prevent the water from boiling.

The preceding text has discussed the merits and principles of the open vented arrangement. A sealed system of heating may be employed to achieve the same objectives, the only differences being the method of filling the heating system with water and the means of catering for the expansion of the water when heated.

Sealed heating systems are considered by some to be fairly new to the United Kingdom heating market. However, they were first introduced into Britain by an American, named Jacob Perkins (1766–1849), and

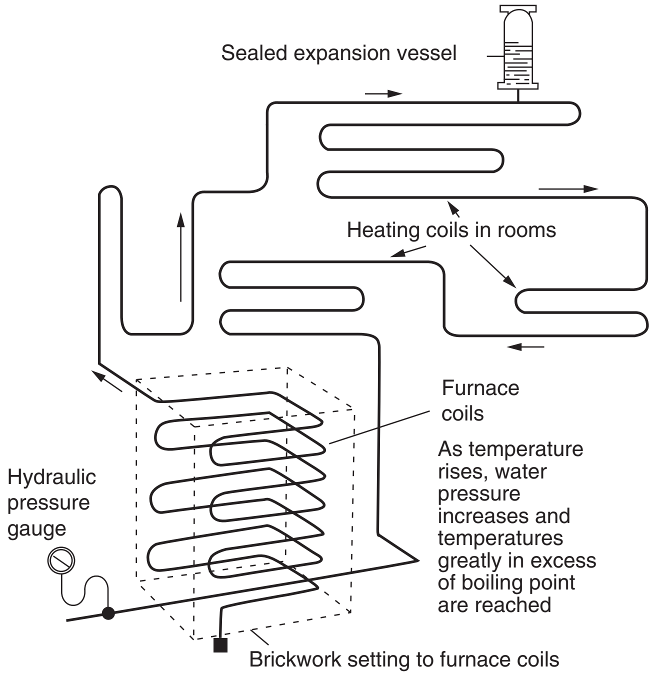


Figure 2.28 Perkins system of heating

his son, Angier March Perkins (1799–1881), who, together with both of their familes had emigrated to England from Massachusetts USA. The exact date of their arrival into this country is believed to be somewhere between 1815–1827, following the end of the Napoleonic Wars. The Perkins family were engineers and inventors and had previously experimented with sealed and pressurised heating systems employing high temperature hot water before they left America to settle in the Midlands of England.

The system that they introduced into Britain was quite new at the time. It comprised a number of continuous single pipe loops that distributed heat around the building. Part of it was coiled around inside a brick furnace and the whole system sealed by means of an upturned enlarged pipe arranged to trap air to act as a cushion, which served as an expansion vessel, see Figure 2.28.

The system, which was known as the 'Perkins system of heating', is believed to have had a working pressure approaching 20 bar, with operating temperatures of nearly 150°C. The system operated by gravity circulation with each pipe loop being limited to about 150 m in length, and 15% of each circuit being coiled inside the furnace as the heat exchanger. If one pipe circuit was insufficient to heat the building, then additional pipe loops were incorporated, each with their own expansion vessel and pipe section coiled inside the common furnace.

One of the more interesting features of the Perkins heating system was the choice of piping materials used to convey the high temperature and high pressure water as the heating medium, and in particular, the method of jointing the piping material. Perkins chose steel as the piping material for his heating system, which by today's standards would seem the obvious choice for the high pressure and temperature involved. It must be appreciated however, that at that time, Henry Bessemer had not yet invented the 'Bessemer converter' to enable mass production of cheap steel for pipes and tubes. Therefore, as steel was in short supply, and what steel was manufactured was mainly aimed at military use, Perkins opted to use steel tubes originally manufactured as gun barrels, hence the term 'barrel' when referring to steel tube. Since gun barrels have not been used for piping materials since the mid 1800s, this term should not be used today.

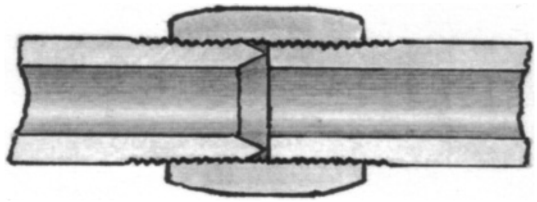


Figure 2.29 Section through a Perkins left- and right-handed thread joint

The steel tube selected had an outside diameter of approximately 1 inch (25 mm), and was made in short lengths of approximately 1–1.5 m long that could be easily bent by the application of heat when placed inside a forge. The only fittings that were required were a straight socket also made from steel for coupling the steel tube together. The steel tube was threaded at both ends, one thread being a right-handed thread and the other being a left-handed thread; one end of the tube was chamfered as shown in Figure 2.29, which when tightened up, and without the aid of any jointing compound or material, would be pulled tight up against the square cut flat face of the mating pipe section forcing the chamfered ended tube to dig in to the flat-faced end.

This type of pipe coupling – having a left-handed thread and a right-handed thread that enabled the pipes to be drawn up together and, if required, to be broken apart without having to undo long lengths of pipeline – may be described as an early form of pipe union.

This joint would have required a high degree of skill on the part of the pipe fitter to ensure that the tube ends were cut perfectly square to make a watertight joint without the aid of any jointing compound when high pressure was exerted. It is believed by many today that this high degree of accuracy in pipe jointing could not be achieved by the majority of today's pipe fitters.

There are still a few remnants of this early form of sealed heating systems in existence in churches and chapels throughout the country.

SEALED HEATING SYSTEMS

Although the sealed system of heating had been first introduced to Britain as far back as the early 1800s, its development took place in North America, Scandinavia and other parts of Northern Europe, where it was considered more important to remove the feed and expansion cistern and its associated pipework from the roof void to reduce the risk of these services freezing in winter. In Britain, designers favoured the open vented low pressure system of heating. The sealed system of heating was still installed occasionally in commercial buildings, but almost never in domestic residential buildings.

As previously established, the only difference between the sealed system of heating and the open vented heating system is the method of catering for the expansion of water due to temperature rise when the boiler is operating. This is achieved by eliminating the feed and expansion cistern, open vent pipe and the cold feed and expansion pipe and replacing them with a sealed expansion vessel. This means that as the feed and expansion cistern no longer exists, an alternative method of filling the heating system with water has to be incorporated.

The earliest form of expansion vessel used was not dissimilar to the method used in the Perkins heating system, which comprised an enlarged pipe with both ends capped off as shown in Figure 2.30, and was located at the highest point of the heating system in an upturned manner to trap air inside when the system was being filled with water. When the water became hot it would expand into the expansion vessel and compress the air at the top of the vessel. It also incorporated a valve at the top to allow the system and vessel to be recharged with air, together with a drain-off valve.

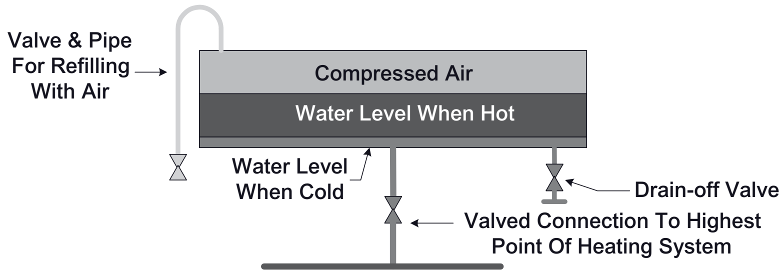


Figure 2.30 Early form of sealed expansion vessel

The common failing of this type of expansion vessel was that the air's oxygen content – approximately 21% – would gradually be absorbed into the heating water as there was no method of separating the air and the water, which eventually led to the air content becoming insufficient to accommodate the expanded volume of water. This absorption of air into the heating water also contributed to corrosion of the heating systems pipework and heat emitters.

There were variations of this type of expansion vessel, including a vertically mounted version and an adaptation that created an air-lock at the top of the boiler heat exchanger by inserting a dip-tube on the flow connection and using the opposite flow connection as the air refilling point. This had the effect of creating an area to trap air at the top of the boiler heat exchanger which would act as a cushion in the same way as the enlarged pipe version of the sealed expansion vessel.

Because of the difficulties in air cushion retention and the potential corrosion problem, coupled with the less severe winters experienced by the United Kingdom compared with countries such as Canada, the USA, Scandinavia and parts of Northern Europe, where it is imperative to remove all services at risk of freezing, it is not difficult to understand why the UK preferred to develop the less troublesome open vented system of heating at that time.

Interest in the sealed heating system re-emerged in Britain during the 1960s, following the resolution of the corrosion problem caused by retention of the air cushion and the elimination of the dissolved oxygen by the development of the sealed expansion vessel, complete with flexible separation diaphragm membrane, which made this system more attractive to heating engineers as an alternative method of heating.

The operation of the sealed heating system is exactly the same as the open vented heating system shown in Figure 2.31. This is a sealed heating system version of the two pipe open vented heating system depicted in Figure 2.10, the only difference being that the increased volume of water caused by expansion is catered for by the sealed expansion vessel in the absence of the feed and expansion cistern, cold feed and open vent pipe. Any of the other open vented heating systems, such as one pipe, two pipe, micro bore or radial piping arrangements previously shown could be arranged as sealed heating systems.

Employing a sealed expansion vessel to cater for the increased volume of water will also result in the heating system becoming pressurised above the normal hydrostatic head, although for a domestic heating system this pressure increase will be only slight.

The advantages claimed for sealed heating systems include:

1. Little if any make-up water is required once the system has been charged and all air vented, because none is lost through evaporation as is the case with the feed and expansion cistern of the open vented system. A feed and expansion cistern with a correctly fitted cover in accordance with the Water Regulations will experience very little evaporation.
2. The absence of the feed and expansion cistern eliminates the possibility of a fresh supply of oxygen being absorbed by the heating water, thus reducing the risk of corrosion occurring in the heating system. Also,

the feed and expansion cistern is an ideal breeding place for bacterial activity, organic impurities and fungi, and the omission of this component eliminates these potential problems.

3. A cost saving is sometimes claimed by the exclusion of the feed and expansion cistern, cold feed and open vent pipe over the installed cost of the sealed expansion vessel, although the cost difference is very small.
4. The removal of the feed and expansion cistern, cold feed and open vent pipe from the unheated roof space eliminates the possibility of these components freezing up in winter. Although they should be insulated in accordance with the Water Regulations to prevent this occurring, if they don't exist, then they cannot freeze.
5. One of the main merits of the sealed heating system, although not normally recommended for domestic heating installations, is its ability to take advantage of the higher operating pressure that occurs and to operate at flow temperatures above the normal 82°C that is used for open vented heating systems. It is possible to operate at temperatures above 100°C without causing the water to boil, or flash to steam. This is possible because the boiling point of water is directly related to pressure: water will boil and vaporise at 100°C, at atmospheric pressure and at sea level. If the pressure is reduced then water will boil at a temperature lower than 100°C and likewise, if the pressure is increased, the boiling temperature will be in excess of 100°C. Therefore, because the sealed heating system is pressurised above atmospheric

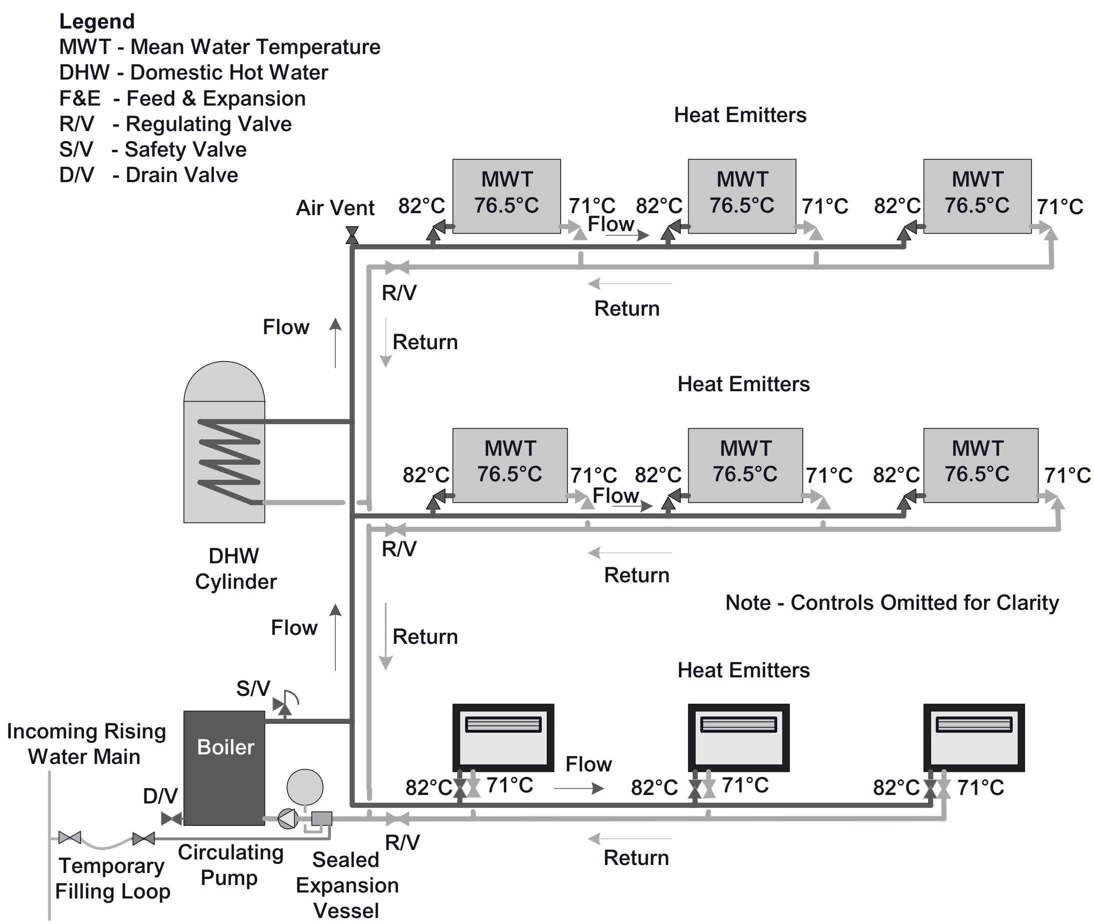


Figure 2.31 Two pipe, low pressure, sealed heating system

pressure, it is possible to operate at temperatures near to or above 100°C without causing the water to vaporise. Operating temperatures higher than 82°C permit the selection of smaller heat emitters and smaller circulating pipe sizes as less water is required to convey the same amount of heat; there is therefore a cost saving compared to an open vented heating system operating at a flow temperature of 82°C and a return temperature of 71°C. Figure 2.32 shows the same heating system depicted in Figure 2.31, but taking advantage of a higher operating temperature.

The version of the sealed heating system shown in Figure 2.32 is still classified as a low temperature and low pressure heating system as the operating temperature is below 100°C and the operating pressure is below 3 bar.

If the operating temperature selected is higher than 82°C flow, which means that the mean water temperature of the heat emitter will be higher than 76.5°C when a return temperature of 71°C is used, then careful consideration should be given to the choice of heat emitters to be used. Standard pressed steel radiators or column type radiators should be avoided as the surface temperature would be high enough to cause skin burns to anybody who came into physical contact with them. The correct choice would be to select convector type heat emitters, or low surface temperature type radiators, explained and detailed in

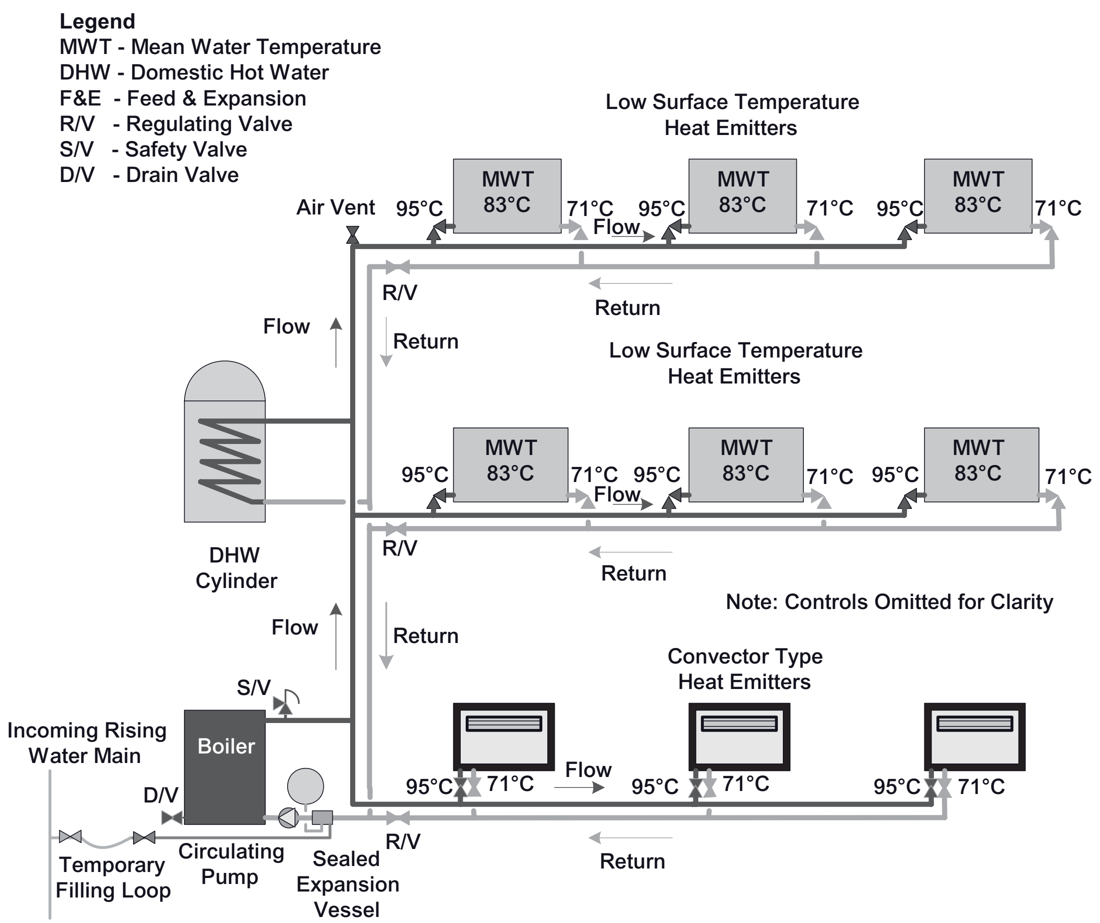


Figure 2.32 Sealed heating system operating at pressure above atmospheric pressure

Chapter 5, Heat Emitters, and illustrated in Figure 2.32, where the mean water temperature in the heat emitters is 83°C.

It also follows that all piping should be installed in a manner that, under normal circumstances, prevents people coming into contact with the surface of the pipe, as the result will be the same as that for standard radiators. Therefore, for safety reasons, the pipework should be installed in service ducts, or in floor or ceiling voids.

It should also be appreciated that the piping material and jointing method specified should be suitable for the higher operating pressure expected and that the standard of workmanship is of the highest quality. If we are operating at temperatures above 100°C, and a fracture of the pipe occurs, or a pipe joint fails, then the release of pressure from the system would cause the water to flash to steam in a violent and dangerous manner. These are the reasons why higher operating temperatures and pressures are not recommended for domestic dwellings as the control of future maintenance to each domestic application cannot be guaranteed.

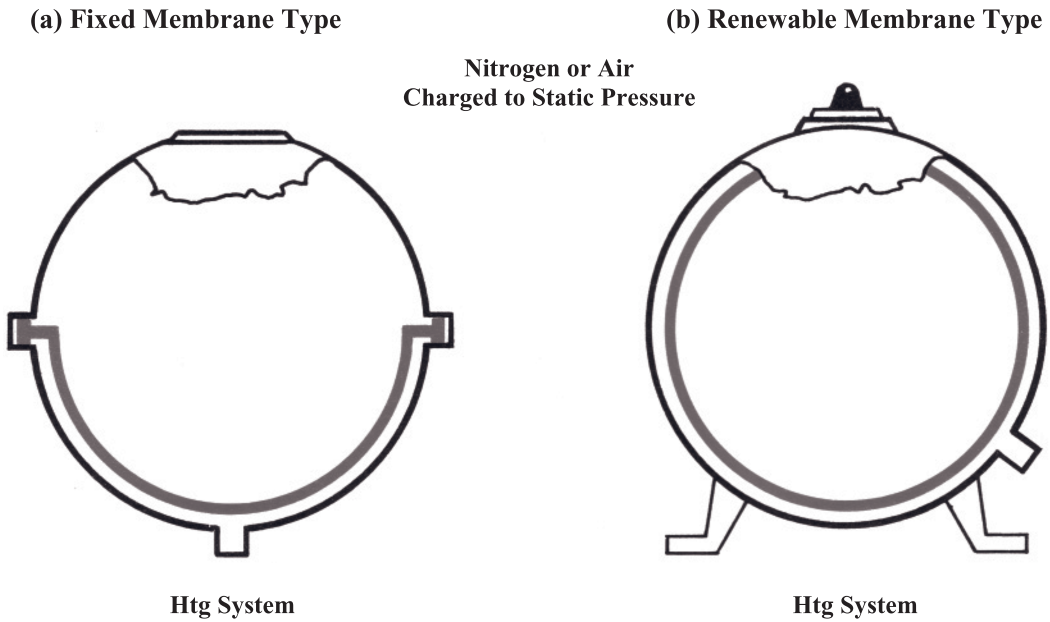
EXPANSION VESSELS

The function of the expansion vessel or compression tank, as it is sometimes known, is to provide a volumetric space for the increased volume of water caused by expansion when heated, and also to maintain the heating system at a positive working pressure. It will also serve to force the water back into the heating system when the temperature of the water cools down.

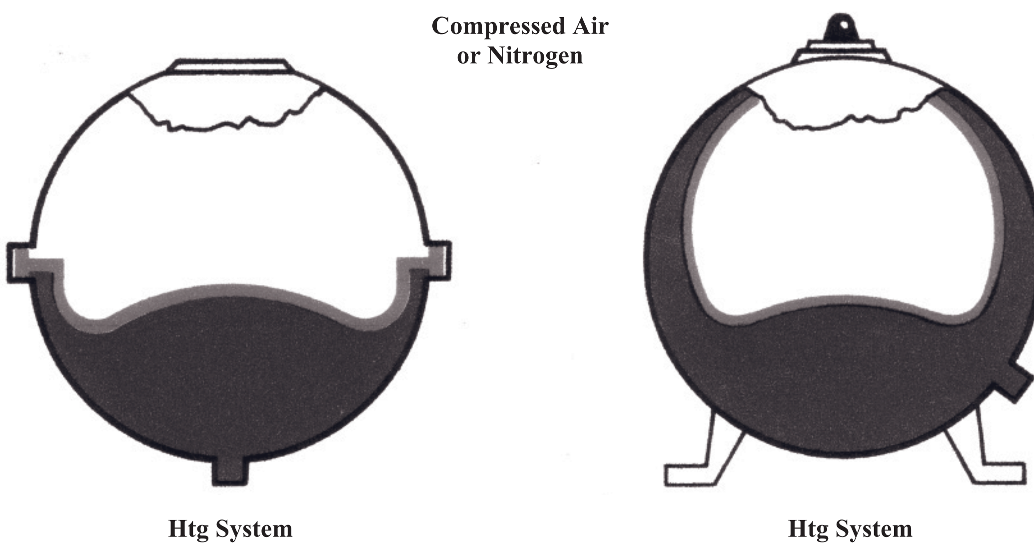
Expansion vessels are available in a variety of shapes and sizes, such as direct pipe mounted, floor or wall mounted, circular, oval or cylindrical, but whatever the capacity or shape of the expansion vessel it may be categorised as being one of two basic styles. Both types take the form of a sealed steel outer vessel divided internally into two compartments by either a centrally permanently fixed diaphragm or separate replaceable membrane, each manufactured from a flexible synthetic rubber material. One side of the flexible diaphragm or membrane is sealed from the heating system and is charged with nitrogen or air; the other side is open and is connected directly to the heating system and arranged to accept entry of the expanded water into the vessel. The advantage of having a membrane within the expansion vessel is to separate the air/nitrogen from the heating circulating water, preventing any of the charged gas being absorbed into the water. This reduces the corrosion potential and permits the vessel to be installed in any plane or position, not just in an inverted position above the pipe, as previously required with expansion vessels prior to the development of the flexible membrane expansion vessel, as the air or nitrogen charge would be lost within the circulating water.

Nitrogen is considered to be the most suitable gas to provide the expansion cushion because it is less soluble in water than air in the event of the diaphragm failing and the charge being partially lost. This is due to the fact that uncontaminated air contains approximately 78% nitrogen and 21% oxygen and it is the oxygen content that is absorbed into the water more readily if air is employed, as pure water consists of two parts hydrogen to one part oxygen, H_2O, so that oxygen is easily absorbed. Nitrogen, in simplistic terms, is said to be an inert gas, but Henry's Law has demonstrated that nitrogen will migrate into the water over a period of time, at a quantity and rate dependent upon the temperature and pressure of the water, but any failure in the membrane of the expansion vessel would have been discovered and rectified long before a migration of nitrogen occurred.

A high percentage of expansion vessels used in the domestic heating market employ air as the expansion cushion as it is readily available and the sealed expansion vessels can be recharged or topped-up using a car foot pump connected to the air valve on the vessel, which is similar to that used for a car tyre. Figure 2.33 illustrates the working principles of the sealed expansion vessel showing the difference between the two types.



The above illustrations show the expansion vessels charged to equal the heating system's static pressure, which for low pressure heating systems should be the cold fill pressure preventing any of the heating systems water entering the vessel when cold.



The above illustration shows the expansion vessels at system operating pressure and temperature whereby the heated expanded water has entered the vessel causing the pre-charged nitrogen or air to compress and so create the increase in pressure.

Figure 2.33 Operating principles of the sealed expansion vessel

AIR SEPARATION

The entry and associated problems of air in the heating system that have been touched upon briefly above and are dealt with in more detail in Chapter 21, Water Treatment. The following paragraphs are confined to the elimination of air in the sealed heating system so that the claimed advantage of reducing corrosion in the heating system can be proved.

Air is a cocktail of gases; the exact composition of unpolluted air is given in Chapter 16, Combustion, Flues and Chimneys, but for these purposes and as established earlier, air may be taken as comprising approximately 78% nitrogen, 21% oxygen and 1% other inert gases. What is often referred to as 'air in the system', is in fact oxygen or nitrogen and, if corrosion is occurring, it could be caused by other gases.

Air will exist in the heating system when the installation has been completed and prior to the initial filling up with water; during this process the tedious task of releasing this air from the system high points and heat emitters should be undertaken, but the release of 100% of the air is not always achieved. Also, additional air is being introduced by the water being used to fill the system in the form of absorption, all of which can lead to potential problems if the air is not completely eliminated.

When the heating system is operating, the circulating water is continually heated up and cooled down, and air is released from the water or re-absorbed back into the water, in direct proportion to the temperature and pressure change of the heating system water. As water is made up of two parts hydrogen and one part oxygen (H_2O), it is normally the free oxygen content that comes out of solution or is re-absorbed back into the water rather than air.

The graph shown in Figure 2.34 demonstrates this temperature/pressure relationship of the solubility of air in water, whereby if we have water at a temperature of 20°C at a pressure of 0.7 bar it will hold a maximum of 3% air by volume in solution, but if we raise the temperature of the water to 95°C at the same

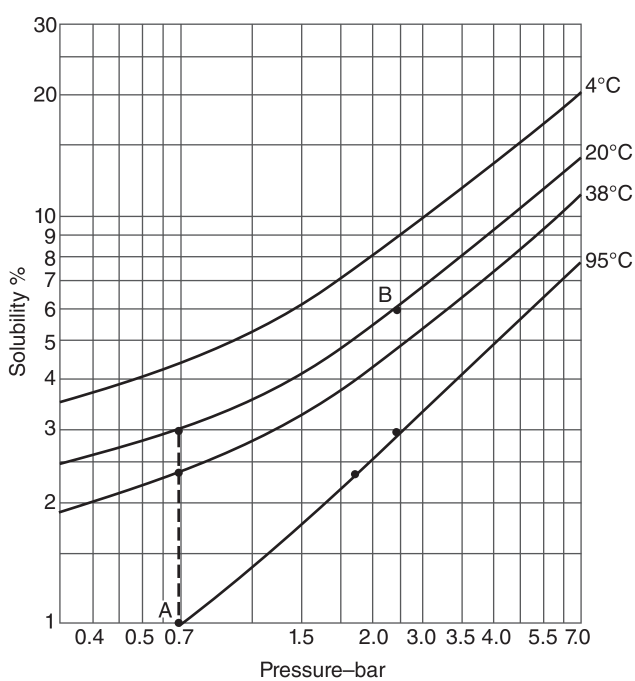


Figure 2.34 Solubility of air in water pressure/temperature graph

pressure it will only hold a maximum of 1% air in solution, having given up 2% of the air that has come out of solution in the form of air bubbles travelling around the heating system. This shows that the colder the water temperature, the greater the capacity to hold air in solution.

Using the same example of water at 20°C and at a pressure of 0.7 bar, if we maintain the temperature of 20°C, but raise the pressure to 2.5 bar the water can now hold a maximum of 6% air in solution. This demonstrates that the greater the pressure of the water, the greater the ability to hold air in solution.

In an open vented heating system this air released from solution by the rise in temperature would be allowed to escape up the open vent pipe to the atmosphere, where it would later be partially re-absorbed when the water cooled back down by surface contact in the feed and expansion cistern. In a sealed heating system if this air is not vented off then it will be re-absorbed into solution when the water cools down where it will remain, only to appear again later when the temperature increases again. If this cycle is permitted to continue unchecked, then the free oxygen content of this air that has come out of solution will contribute to the promotion of corrosion in the heating system, plus the air circulating around the heating system could produce either partial or full air-locking in the piping system and reduce the performance of the heating system.

In a sealed heating system, it is essential that this air is separated out of the circulating water and vented off to the atmosphere. There are two basic components commercially available to perform this separation process, both equally effective and similar to each other.

Air purger

This component consists of a cast iron chamber constructed of two passages. The lower passage permits the flow of water being circulated to pass through the air purger unhindered; the upper passage is designed to channel any air that is being dragged along the pipework in the form of bubbles, to be collected in the domed section at the top where it can then be released via an automatic air vent fitted to the tapping provided.

Figure 2.35 illustrates the application of the air purger whereby the main function is to combine with an automatic air valve to permit any free air to enter the enlarged upper chamber where the velocity will be slower, allowing the air bubbles to escape. It also has additional tappings to allow for a combined high and low pressure switch to be fitted, arranged to cut the boiler out if abnormal pressures occur, plus provision for fitting a pressure gauge so that the pressure can be visually monitored. The air purger can also accommodate the fitting of the sealed expansion vessel in the pendant position, as shown in Figure 2.35, or by extending the connection by piping, as illustrated in Figures 2.31 and 2.32 to an adjacent inverted position. This multifunctional component in addition incorporates the provision to connect the water fill point to the heating system as also shown in Figures 2.31 and 2.32.

The cast iron multi-purpose air purger tee is commercially available for both domestic heating applications and larger commercial sealed heating systems.

Air separator

As shown in Figure 2.27 (b), the air separator arranged for an open vented heating application is a similar device to the air purger and is equally suitable when applied to the sealed heating system to perform the function of separating out the air and eliminating it, but on a sealed heating arrangement the open vent pipe is replaced with an automatic air release valve.

Figure 2.36 shows the operation of an air separator, which consists of an enlarged cylindrical vertically mounted vessel having an inlet connection high up on one side of the cylinder and an outlet located low down on the opposite side of the cylinder. Mounted on the top of the cylinder is a tapping for fitting an automatic air release valve. The circulating water enters the top of the separator where the enlarged area

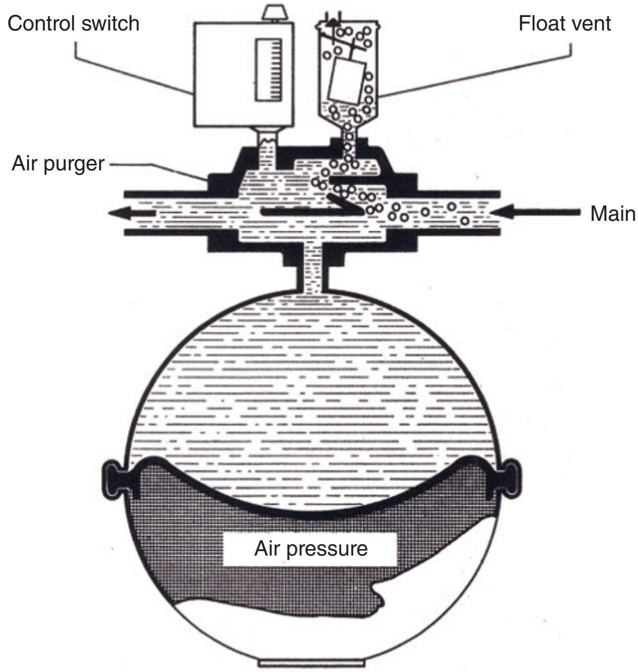


Figure 2.35 Air purger

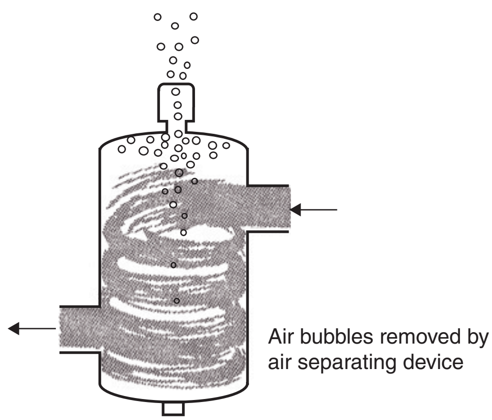


Figure 2.36 Air separator

causes the velocity to slow, allowing the air bubbles to rise and be expelled by the air vent and the water, minus the air that has come out of solution, continues to the outlet to be circulated.

The design of the air separator, or tangential type air separator, is to separate entrained air from flowing system circulating water by the creation of a vortex, allowing free air bubbles to rise vertically in the centre, which is the point of least velocity. Some larger air separators may be constructed incorporating curved vanes, discs or spiral tubes which aid the formation of the vortex and assist the dissolved air to come out of solution. Examples may be seen in Figures 2.37 and 2.38.

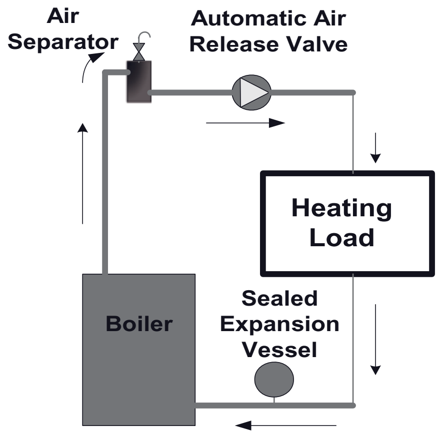


Figure 2.37 Application of spiral air separator/air elimination valve

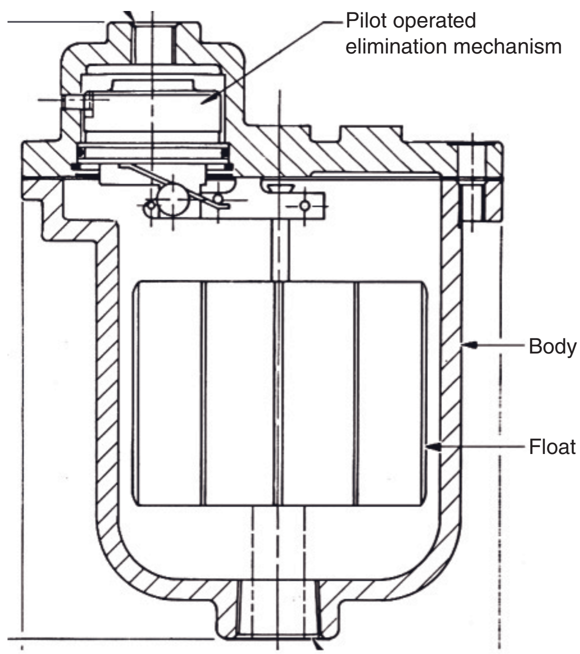


Figure 2.38 Detail of automatic float operated air elimination valve

SYSTEM CHARGING

With an open vented heating system, the feed and expansion cistern is also employed as a reservoir of water to fill the heating system and keep it topped up automatically without the need for any human involvement. For a sealed hydronic heating system, because we have eliminated the feed and expansion cistern in favour of the sealed expansion vessel we have to find an alternative acceptable method of filling the system up with water and keeping it topped up.

The methods used to charge the sealed heating system with water vary from one country to another and here in the United Kingdom the methods permitted have also differed over the years. This is mainly due to the regulations appertaining to water supply in different countries. In England and Wales any connection to the water supply must conform to the 'Water Regulations' and in Scotland to the 'Water Byelaws' as well as the previous water byelaws that were in force at the time of any installation before the current regulations. It should be appreciated that the purpose of these regulations and the previous byelaws is to prevent wastage, misuse and contamination of the water supply and as the water supply in Great Britain is classified as being Fluid Category 1, 'wholesome', which is suitable for drinking water, the quality of this supply should be protected.

The numerous methods, both past and present, of filling the hydronic sealed heating system are reflected in Figure 2.39, but this schematic illustration should not read as a working drawing as it is intended only to demonstrate alternative arrangements: some of the methods depicted are considered no longer acceptable and are only included to help students understand a system if they become exposed to it for the first time.

Box 2.2 summarises three approved filling methods.

Method 'A'

This arrangement indicates a simple form of filling the heating system that was used to a limited degree on small domestic heating systems in the 1960s, but is considered unacceptable by today's standards and is now prohibited. It comprised a clear plastic bodied container with a capacity of 3–5 litres, incorporating a see-through sight contents indicator that was required to be located above the highest part of the heating system. From this container it was connected to the heating system via a flexible hose that included a non-return valve and automatic air release valve. The heating system was filled up from a hose via this container and during normal working operation the system became pressurised by the action of the non-return valve preventing any expanded water returning to the container. Any water loss would be replenished from this container when the heating system cooled down.

This method was dependent upon the occupier of the dwelling frequently checking the water level in the container and topping it up if necessary.

The unit was also described as an automatic top-up container because it would replace any water lost from the system when it cooled down, but as it required manual top-up this was not an accurate description.

Method 'B'

This is another defunct and prohibited method that made use of the main cold water storage cistern serving the domestic hot and cold water for the property where a separate dedicated cold feed was extended from the cold water storage cistern to the heating system.

It incorporated a non-return valve to prevent water expanding back up the cold feed into the storage cistern and was also used in the 1960s before it was common practice to apply chemical treatment to the heating circulating water.

Any existing heating systems found to have this method of water filling should be converted to an approved arrangement as the risk of contaminating the domestic water in the storage cistern is extremely high, with resulting serious consequences to health.

It should also be pointed out that today's practice is to install an unvented domestic hot water system in association with sealed heating systems, so that there is no longer a need for a cold water storage cistern.

Method 'C'

This illustrates what is commonly referred to as a 'temporary filling loop' and has been the most popular method of filling sealed heating systems in domestic residential dwellings as it is an inexpensive, approved arrangement and satisfies the requirement in 'A' above.

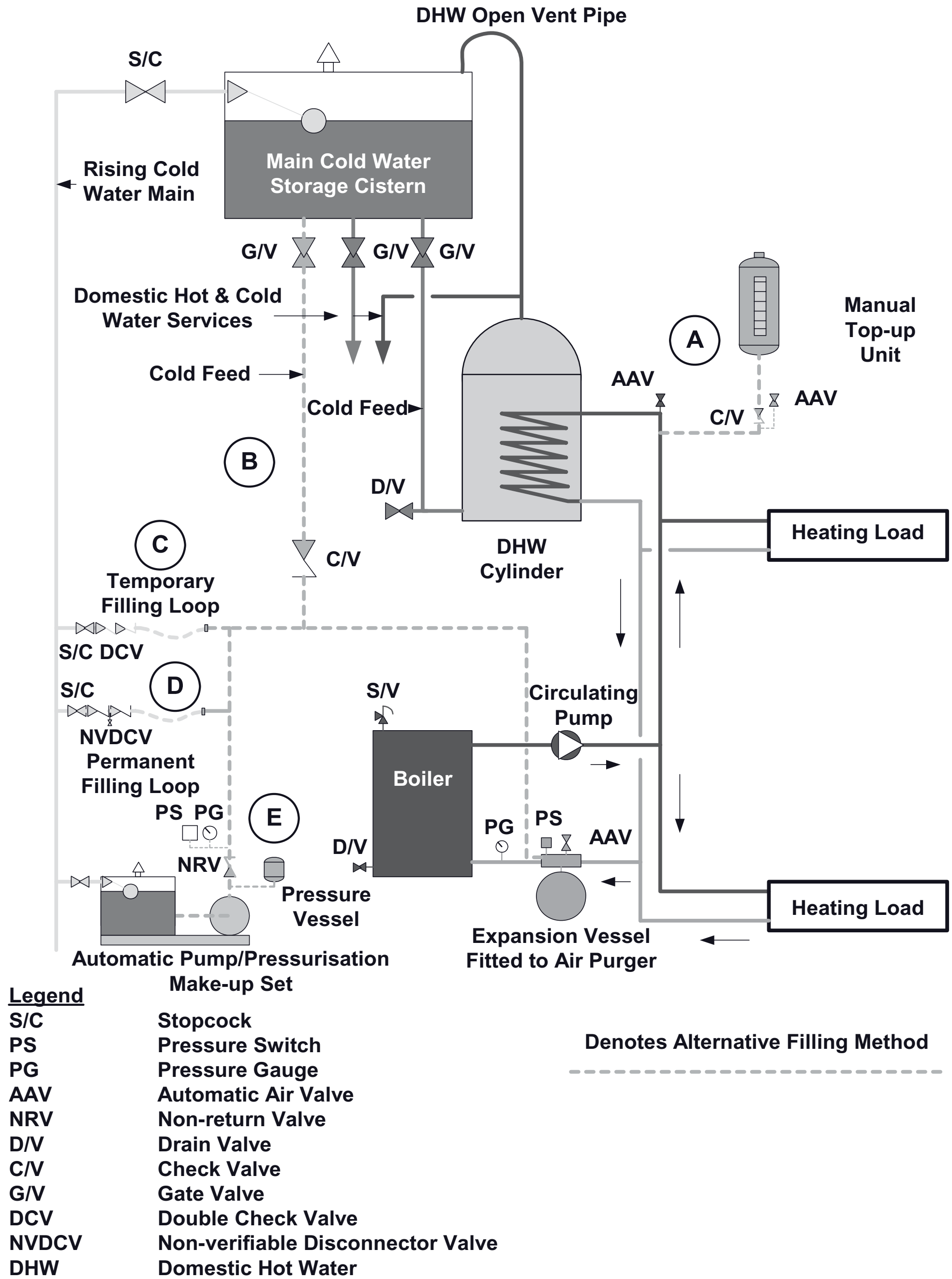


Figure 2.39 Alternative arrangements for filling sealed heating systems

Figure 2.40 illustrates in detail the temporary filling loop arrangement that satisfies the requirements of the Water Regulations. It comprises a braided hose connection made on the pipework with union connections between two resilient seat valves (stopcocks), together with a double check valve. It is permitted on domestic heating systems designated Fluid Category 3 (domestic heating systems are defined as having a heating capacity not exceeding 45 kW). The heating system is filled up by manually opening both of the

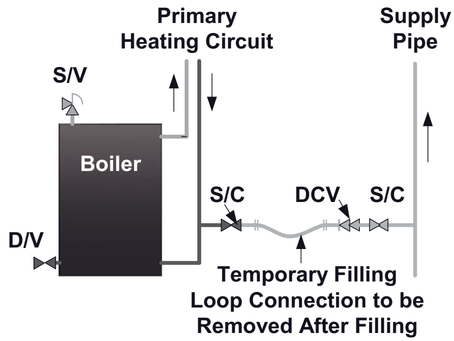


Figure 2.40 Temporary filling loop arrangement

BOX 2.2 Summary of approved filling methods

Approved Filling Methods

The Water Regulations requirements for filling sealed heating systems are:

No supply pipe or secondary circuit shall be permanently connected to a closed circuit for filling a heating system unless it incorporates a backflow prevention device.

A) A temporary connecting pipe which must be completely disconnected from the outlet of the backflow protection device and the connection to the primary circuit after completion of the filling or replenishing procedure.
B) A device which in addition to the backflow prevention device incorporates an air gap or break in the pipeline which cannot be physically closed while the primary circuit is functioning.
C) An approved backflow prevention arrangement.

isolating stopcocks to allow water from the supply pipe to charge the heating system. When the pressure in the heating circuit equals the pressure in the water main the isolating stopcocks are shut off and the temporary filling loop removed immediately after the heating system has been filled or replenished.

Method 'D'

This is a more expensive alternative to the temporary filling loop described in method 'C'. It satisfies the requirements of the Water Regulations stated in 'B' on the previous page for a Fluid Category 3 connection, and is illustrated in detail in Figure 2.41.

This filling method employs a permanently fixed backflow prevention device designated by the Water Regulations as a type CA non-verifiable disconnector with different pressure zones. If this valve fails during charging it will prevent backflow occurring by opening the relief port between the two check valves and discharging the water to drain over a tundish installed with a type AA air gap of not less than 20 mm. This arrangement has the advantage of being permanently fixed and although the two isolating stopcocks should normally be in the closed position and only opened to charge or replenish the heating circuit, it is far more convenient to use.

For filling heating systems in buildings other than houses, or where the heating system capacity exceeds 45 kW, a backflow prevention device suitable for a Fluid Category 4 risk is required, as noted previously in