Diploma 6th SEM

ADVANCED CONSTRUCTION TECHNIQUES & EQUIPMENT

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Fibres and plastics

fibers:-

A fiber is a thin thread of a natural or artificial substance, especially that is used to make cloth or rope.

Types:-

There are two types of fibers

(i) Natural fibers

(ii) Artificial fibers

i) Natural fibers

The fibers which are obtained from natural resource like living things i.e. plants, animal and mineral is called as natural fibers.

For example:- Jute, cotton, rubber, concrete, Shale etc.

ii) Artificial fibers

An artificial fiber is thread like material invented by human researchers.

Carbon fibers

These fibers are about 5 to 10 micrometer in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages. including high stiffness, high tensile strength, high strength to weight ratio, high chemical resistance, high temperature tolerance and no thermal expansion.

→ These property have made carbon fiber very popular in aero space, civil Engg. military and motor sports.

→ These are relatively expensive when compare with similar fiber such as glass fiber, basal fibers or plastic fibers. To produce a carbon fiber, the carbon atoms are bonded together in crystal that are ~~bonded~~ ~~&~~ more unless aligned parallel to the long axis of the fiber as the crystal allignment gives the fiber high strength to volume ratio.

several thousand carbon fibers are bundel together to form a row which may be used by itself or oven into a febric.

Glass fibers

It is a material consisting of numerous exteremely fine fibers of grass.

Glass fibers has roughly comparable mechanical property to other fiber such as polymers and carbon fiber. Although not as rigid as carbon fiber, It is much cheaper and segnificantly less brittle when used in composite.
Glass fiber reinforced composites are used in marine industry and piping industry because of good environmental resistance, batter damage tolerance for impact loading, high specific strength and ~~sticknesss~~. Stiffness.

Uses of fiber as concrete material

Fiber is a small piece of reinforcing material possessing certain characteristics Properties. They can be circular or flat.

The fiber is ~~obtain~~ often described by a convenient parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter typical aspect ratio ranges from (30 to 150.

Fibers have been used as reinforcement to enhance the properties of the materials. Dating back to the egyption period, natural fibers like straw and horse hair were incorporated in the formation of mut bricks. late 1800s, The us adopted straw material as main component of bearing wall.

For roughly 50 years, fibers have been added to concrete applications in the construction and civil industry. More recently fiber, reinforced polymers have been used in the construction industry for over two decades, demonstrating positive benefit such as increased strength and being light weight and resistance to corrosion.

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some type of fiber produce greater impact, abrasion and shatter resistance in concrete. Larger steel or synthetic fibers can replaced rebar or steel completely in certain situation. Fibers reinforced concrete has all but completely replaced bar in underground construction industry such as tunnel segments where all tunnel linings are fiber reinforced in lieu of using rebar.

Plastics

Plastics is an essential component of many item, including water bottle, combs and beverage containers.

Types of plastic:-

(i) polythylene teraphthalate (PETE or PET)

ii) High-density polythylene (HDPE)

iii) poly vinyl chloride (PVC)

iv) low-density polythylene (LDPE)

v) poly-propylene (PP)

vi) polystrene (PS)

vii) Miscellaneous plastics (including - Poly carbonate, poly lactide, acrylic strene, fiber glass)

(i) Polythylene Teraphthalate (PETE or PET)

Introduced by J. Rex Whinfield and James T. Pickson in 1940, this plastic is one of the most commonly used on the planet. It took another 3 year before it was used for crystal clear beaverage bottles, such as the ones produced by coca-cola and pepsi.

High density polythylene (HDPE)

In 1953, Karl ziegler and Erhard holz kamp used catalysts and low pressure to creat high-density polythylene. It was first used for pipes in storm sewer, drains and culverts.

iii) polyvinyl chloride (P.V.C):

PVC is the one of the oldest synthetic material in industrial production. It was discovered in 1838 by french physicist henry victor ~~regnault~~ regnault.

iv) Low density polythylene (LDPE):-

LDPE was the first polythylene to be produced, making in the grand father of material. it has less mass than HDPE, which is why it is considered a separate material for recycling.

v) Poly propylene (PP):-

J. paul Hogan and robert L. banks of Phillips petroleum company discovered poly propylene in 1951. At the time, they were simply trying to convert propylene into gasoline but instead discovered a new catalystic process for making plastic.

polysterene

It is a polymer made from monomer steren. a liquid hydro carbon i.e. commercial manufacture from petrollium. It is principally used in solid, foam and expended PS form many of the application for PS are single use and disposal.

Miscellaneous plastic

These are usually found back in nylon baby milk bottle, sunglasses, computer cashing, compact discs.

Use of plastic as construction material

plastic are manufacture in diff. forms such as moulding pipes, sheets and film they are form or expanded materials of low density. dissolved in solvents or distensed and emulsion they are used in paints, vernishes and adhesives. plastics find used in building mainly in thin covering pannels, sheets, foams, pipes etc. skillful used of plastic will expand the usefulness and live of conventional building material and help them to function more efficiently and economically.

Artificial tember

Artificial made material having property of tember also term as poly tember or artificial tember. The artifical tember is made up enhanced wood. The artifical tember is made up enhanced wood and thermo plastic material that is modified and thermo plastic material that is filled with wood fiber and plant fiber. It carried combining advantages of tember and plastic.

properties

i) The artifical tember have batter corrosion resistance to water and acid with no decrease in mechanical properties.

ii) It also have better thermal insulation and fire retardancy.

iii) The artifical tember stand out from other Engg. material and aerogels in terms of specific strength and thermal insulation properties.

iv) The ~~artifif~~ artifical tember is made up enhanced, modified and thermo plastic material i.e. filled with wood fiber and plant fiber.

v) It ~~carried~~ carries combining advantages of tember and plastic it is good in corrosion ~~resi~~ ressistance and warp free.

Uses

i) Artifical tember are used to manufactu different wood product like plywood, black board etc.

plywood is used for doors, partation wall ciling, panelling wall form work for concrete etc. in architectural purpose.

iv) fiber bords are used as sound insulating material.

v) impreg. tember is used for making wood moulds, furniture decorative product etc.

vi) Glulam. tember is very much suitable in the construction of chemical factories, long span roofs in sports stadium, indoor swimming pool.

Types of Artifical tember

Artifical tember is nothing but tember product manufacture scientifically in factories because of Its scientific nature, It is stronger and durable than ordinary tember materials, it also contains desired shape and size. following are the diff. form of artifical tember

(i) veneers

veneers are nothing but thin layer of wood which are obtained by cutting the wood with sharp knife in rotary cutter in rotary cutter the wood log is rotated against the sharp knife or saw and cuts it into thin sheets these then sheets are dried in kiln and finally verneers are obtained.

verneers are used to manufacture different wood product like plywood, black board etc.

plywood

plywood means thin, plywood is a board obtained by adding thin layers of wood or veneers on one above each other. The joining of successive layer is done by suitable adhesives.

The layer are glued and pressed with some pressure either in hot or cold condition. In hot condition, 150 to 200°c temperature is marinated and hydraulic pres. is used to press the layers. In cold ~~con~~ conditions, room temperature is maintained and 0.7 to 1.4 N/mm^2 pressure is applied. plywood is used for door partition walls, ceilings, panelling walls, form work for concrete etc.

Fiber Board

fiber board are made up wood fiber, vegetable fiber etc. they are rigid board and called as reconstructed wood.

Impreg timber

Impreg timber is a timber cover fully or partly with resin. Thin layer of wood or veneers are taken dipped in resin solution generally ~~used~~ resin is Phenol formaldehyde. The resin solution feels of the voids in the wood and consolidated mass occours. Then it is heated at 150 to 160°c and finally impreg timber developed. This is used for making wood moulds furniture decorative product etc.

Compreg timber

It is similar to impreg timber but in this case the timber is cured under pressure condition so it is more strengthened than impreg timber. Its specific gravity lies fr 1.30 to 1.35.

Hard board

It is ~~used~~ usually 3mm thick and mad from wood pulp. Wood pulp is compressed with some pressure and made into solid board. The top surface of board is sm and hard while the bottom surface are ru

Glulam

Glulam means glued and laminated wood. Solid wood veneers are glued to form she and then laminated with suitable resins. This type of sheets is very much suitabl in the construction of chemical factories long span roof in sports stadium, indoor swimming pool etc; curve wood structure can also be constructed using glulam sheet.

Chip board

Chip board are another type of industrial timber which are made up wood particles or rise huska ash or bagasse. These are dissolved in resins for some time and heated. After then it is pressed with some pressure and board are made, these are also called particles board.

Block board

Block board is a board containing core made up wood strips. The wood strips ~~the~~ are generally obtain from the laft over from solid timber conversion etc. These strips are glu and made into solid form.

MISCELLANEOUS MATERIALS

Acoustics materials

When the sound intensity is more than it gaves the grade trouble of nuisance to the particular area like auditorium, cenema hall, studio, recreation center, entertainme hall, college reading hall. hence it is very important to make that area or room to be sound proof by using a suitable material. It is measure in decible.

Acoustic material play vital role in the various are of the building constructi in studio, reading hall, cenema theater. More concentration is required to listeen, hence the acoustic treatment is provided so as to control the outside as well as inside sound of various building? until such that sound will be audible without disturbance.

properties

→ Sound energy is capture and absorve.

→ It has low a low deflection and high absorption of sound.

→ Heigher density improves the sound absorption at lower frequency.

→ Heigher density material helps to mantain a low flameability performance. Hence acoustic material should have heigher density.

→ It controls the sound and noise level from mesonnary and other source for environmental amelirition and regulatory complaince.

→ Acoustic material reducess the energy of sound wave as they pass through. It suppresses echoes, reverbation, resonance and reflection.

Uses

i) Acoustic material can be used for noise production and noise absorption.

ii) It makes the sound more audible clear to listeen without and disturbance.

iii) It supresses echoes, reverbation, resonance

iv) imp specification for noise reduction and absorption ~~including~~ include noise attenuat and noise production coefficient.

v) A viny acoustics barrier block control air bun noise from noise from passing through a wall ciling or floor.

vi) Acoustic foam and acoustic ciling tiles absorb sound so as to minimize echo and reverbation with in a room.

vii) Sound proof doors and windows ~~and~~ are designed to reduce the transmission of sound.

- Building technique such as double wall construction and cavity wall construction and staggering wall
- Studs can improve the sound proofing of a room.
- A sound proofing wall can incorporated sound proofing and acoustic materials to meet desired sound transmition class value.

Wall cladding

Wall cladding is the process of layring of one material on the top of another material which will creat a skin layer over the layer. cladding is use for preventing the wall and the internal working of a room or building from being damage by worker or allowing the leakage of worker that put potentially become a hazard for people who are working around inside of structure.

Wall cladding is avilable in several types and forms with diff. material texture dimension wall cladding are use in the interior and exterior of a building.

Plaster board

Plaster board is a pannel made up calcium, sulphate. dehydrate with or without additives typically expruded between thick sheet of facer and backer, used in the construction of interior walls and ciiling. The Plaster is mixed with fiber, plasticizer foamic agent and additives that can reduce mild, flammability and water absorption.

Micro silica

Micro silica also known as silica fumes is an amorphous polymer of silicon dioxide, silica It is an ultra fine powder, collected as a biproduction and consist of spherical particle with in an avarage particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete.

Performance

→ The diameter of a silica fume particle ranges from 100 to 200 nm. → Its particles are spherical in shape.

→ The density of condensed silica fume required to be used as additive in concrete must be about 500 to 700 Kg/m^3

- It contains 85 to 97% of silicon dioxide
- The other constituent present in micro silica are carbon, sulpher along with the oxides of aluminium, Iron, calcium, magnesium, sodium Potassium.
- Replacing the cement with about 10% silica fume, subsiquently result in of increase of compressive strength of the concrete.
- Reinforcement corrosion is greatly reduced due to increase resistivity. high tensile strength and less permeability.

uses

- Because of its extreme fineness and high silica contain, silica fueme is a very effective effective pozzolanic material.

- Silica fume is added to portland cement concrete to improves its properties, in particular its comp. strength, bond st. abrassion resist.

- Addition of microsilica also reduce the permeability of concrete to chloride ions which protect the reinforcing steel of concrete from corrosion.

- Micro silica reduce bleeding segnificantly because the free water is consume in wetting of the silica fuem.

Artificial Sand

It is also called as manufactured sand or crushed sand, the artifical sand are manufa by crushing rocks, stone or large aggre into small size particles in the quarry.

Uses

i) Artifical sand ~~are~~ was mainly used in the construction of hydropower system.

ii) It can be used in concrete, brick work flooring.

Bonding agent

Bonding agent are natural or synthetic material used to join the old and new conc surface. This agent can also be used to join the successive concrete layers. This chem helps to allow different concrete surface behave like a single unit.

Properties

The main purpose of bonding agent are :-

i) Bonding agent are easy to use and apply.

ii) They reduce the crack formed in shrinkage.

iii) The permeability of concrete is reduced.

iv) The use of bonding agent improves adhesion between the layer of concrete.

v) The tensile flexural and bond strength of the concrete or mortar are increased.

vi) Bonding agents have high resistance against frost and chemical action.

Adhesive

i) Adhesive also known as glue, cement, mucilage or paste, is any non-metalic substance applied to one or both surface of two separated items that binds them together and resist their separation.

ii) The use of adhesive offers certain advantages over other binding technique such as sewing, mechanical fastening or welding

These include the ability to bind different materials together, the more efficient distribution of stress across a joint, the cost-effectiveness of an easily mechanized process and great flexibility in design.

<u>Properties</u>

i) Abrasion resistant
ii) creep and fatigue resistant
iii) Dimensionally stable
iv) Flexibilized and toughened
v) Hardness
vi) Low shrinkage
vii) low stress
viii) Rigid curing
ix) Strength
x) vibration, impact and shock resistant

<u>Uses</u>

i) Door and window assembly
ii) In the transportation industry
iii) construction material assembly.

(iv) prefabricated houses.

v) packaging

vi) wood working

CONSTRUCTION PLANNING

- planning is the starting point of all management function.
- planning leads to organising and staffing followed by directiong, controlling and co-ordinating.

Importance of construction planning

- For any construction work planning is necessary to execute the work properly. planning is the first step of construction management. The construction planning of a civil Engg. project must consider aspect of side investigation market surveying.
- Monitoring and continueing the process of work during the execution of work. ~~Maintain~~ Mantainance of work during the stipulated period the entire process of planning.

required deep knowledge an skill of construc management.

For effective Planning it is necessary to breakdown the total project into subsection and activities, each activities may be sub divided into smaller job for Planning adverious level.

Work break down structures

Stage of planning

For efficient impiimentation of project activities planning is essential at various stages.

- There are two stages of planning
  i) pre-tender stage
  ii) Contract stages or post-tender stages.

pre-tender stages

1) pre-tender planning is carried out by contractor in this stage the contract has best opportunity of planning for

the future contract.

ii) This stage enables the contractor to make a proper platform and prepare him for completing the work in specified time.

iii) In this stage before a contract is under taken the contractor visit the side of constructing work.

iv) A pre-tender project is prepared which described the complete work and the conditions under which the work is to be carried out.

v) The report describes the details of side investigation geography of the area local weather reports avilability of sources.

vi) pretender planning include the following steps.

(a) To examine the drawing and specification of different work.

(b) side investigation and market survey.

(c) To identify alternative methods.

(d) To estimate the quality of diff items and time for finishing the work.

(e) To prepare a construction schedule.

(f) To decide the tenders price for compliting the work with in the time.

post-tender stage

After tender stage start when the tender is accepted and it extends till ~~completing~~ completion of the contract.

- After the pre-tender stage the contracto has to undertake details planning to organise the activity construction work.

- In this stages good communication syster between member or the construction tear is established for smooth planning of the project.

- In this stage alternative construction method which is more economical efficient are selecte.

- In this stage requirement of constructi material are calculated.

prefabrication:

Introduction

prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site and transporting complete assemblies or sub assemblies to the construction site where the structure is to be located.

The tearm prefabrication also applies to the manufacturing of things other than structure at a fixed site. It is frequently used when fabrication of a section of a machine or any movable structure is shifted from the main manufacturing site to another location and the section is supplied assemble and ready to feat.

~~Nacessit:~~

Nacessity and scope of pre-fabrication of building

prefabricated structure are the based fit for emergency needs. people look for it when they are in need of quick and robesd accumulation structure.

A risen example of these can be pre-fabricated - hospitals which saved the live of several people during this pendemic

As a unit they are cost effective and are attractive module building

Not only cost effective, these structure robust, portable and can be reframed as per the need of the situations.

Advantages of refabrication:-

prefabrication structural steel building wastage:-

prefebricated building reduce material, is don at a factory potential waste material can be recycle and used as and when required.

Wastage fabricated buildings

prefabricated buildings reduce mater wastage by a big margin. since all the material is done at a factory potential waste material can be recycle and used as and when required with good planning and design material waste can be reduce virtually nothing.

Faster execution:-

All component of prefabrication buildings are made to suit. think of it similar to building a LEGO model Right pices of to right locations and jug gets done faster. good and throughly detail drawing in an obvious requirement site for errections. Avoiding hard works at the site has a whole other list of benifits.

Quantity

The quality of the work will on daubtly be batter as every thing is done in a control environment. The welds and cuts are consistent and can be controlled to should requirement components are double checked for accuracy befor dis packing than to site which leads to un intructed execution of site.

Reusability

A prefabricated building can easily be dismantled and moves to a different location without having to being in new material.

Disadvantages

(1) Transportation :-

Transportation is a problem if the prefabricated modules has been constr[illegible] is large and might be hard to maneuve[illegible] to hard to reach location

(2) Cost cost tends to be still slightly higher compare to traditional method.

(3) Lack ~~of~~ Customization

pre-fab modules to be more rigid wi[illegible] regard to design and usually the ~~clint~~ client whose ~~h~~ to feet their requirement around what the construction metho[illegible] can do rather than the other way arroun[illegible]

History of pre-fabrication

Wave their own prefabricated building ~~leave their~~ there origin during late europlain colonial period and the post first world war period, when numerical temporary of emergency pre-fabricated edificial such as houses and school were built.

- Between the ~~wall~~ world war as, several prefabricated system were developed, such as the dorlonco system that was used to buid 10,000 houses in doncaster.

- After a second world war housing and educational buiding were again prefabricated and numerous Buiding system were defined such as the british consortium of local authorities special programme (LASP).

- The majority the system were used to built edifices at minimal cost. in short time often at the expense on quality.

- Most of prefabricated building from this period go far beyond what one would consider today to be architecture with some notable exception such as J. prove, Le ~~corbusi~~ corbusier, and P. Jeannerets emergency school.

- Since the 1970 architecture have become more intrested in new building technologies and induastrialised construction

- The 1980 saw a emphasis on the added value of industrialized architecture and technology. These included the ability to provide heigher quality with in minimum construction time frame, increased possibilities for customization and a new capacity to produce and assemble any building.

- During the 1990, totally mechanised construction system were also developed and applied such as the japanees T-up system.

- Since 2000 pre-fabricated architecture have seen move to reduce environmental impact new coefficient technology and building have been design and build.

Current uses

- The mostly widely use form of pre-fabrication in building and civil engg. is the use of pre-fabricated concrete and pre-fab ~~steel~~ steel sections in structure where a particular part or form is repeated many time.
- prefabricating steel section reduce on site cutting and welding cost as well as the associated ~~to~~ regard.
- prefabrication techniques are used in the construction of appartment blocks and housing developments with repeated housing unit.
- ~~pre fabricated~~ prefabricated steel and glass sections are widely used for the exterior of large building.
- Detached house, cottage loug cabins, saun etc are also sold with pre-fabricated elements. pre fab of modular wall elements allows building of completes thermal insulation, window frame components etc.

→ prefabrication can also help minimize the Impact on traffic from bridge building. Additionally small commonly used structures such as concrete. lilons are in most case prefab.

- Radio tower for mobile phones and other services often consist of multiple prefabricated section.

- prefabrication has become widely used in the assembly of air craft and space craft with components such as wings and fasclage section.

Types of pre-fabricate system

panelized framing

- used typically for roofs, these are lo pices of frame build from laminated timber, cover either by a plywood or some board roof deck.

panelized fram can be up to 72 ft. long these roop panels can save construction time and make roof construction as much safer activity

Sandwitch panels

Made from two thils facing of material like concrete, plywood or stainless steel. The facings are then stouck to an insulating core made typically of material like foam, clocth or rubber.

Steel panel

For ages steel have been one popular and trusted building material for commerci- al residential construction. Steel framing uses this strong and durable material to creat pre-fab panels which can be used to construct buildings.

Timber framing

Not very common in India, timber framing panels are quite popular in other conl countries where timber foames are

are common. These framing are build in factories and then used in erecting timber frames.

Concrete system

Having concrete fragments of a fabrica building cast in the factory provid more versality and also saves time even though architectural elements like concrete panels are havier than other building components they are typically sturdier and can improve a building asthetics.

Modular system

These system use all pre-fab styles and creat a whole building structure typically made from factory construction unit. The buildings are transported to the final constructed side and then simply connected to a prepare foundation.

Classification of pre-fabrication

i) Small pre-fabrication

ii) Medium pre-fabrication

iii) Large pre-fabrication

iv) Cast inside pre fabrication

v) off side pre fabrication

vi) open system of pre-fabrication

vii) close system of pre-fabrication

viii) partial pre-fabrication

ix) Total fabrication

1) Small pre-fabrication

These fabrication is done in a smaller scale.

2) Medium prefabrication

The fabrication is done in moderate scale.

3) Large fabrication

- The fabrication is done in the large scale
- In large fabrication most of the member like wall panel, roofing / flooring system,

beams and columns are pre-fabricated

- Here degree of pre cast element are high.

- Here degree of precast element are high.

- one of the main factor which affect the factory pre-fabrication is transport.

iv) cost - inside pre fabrication

It is prefer for the following reasons.

i) Factory situated at a long distance from the construction site.

ii) vehicle have to crush a conjusted traffic.

iii) Heavy weighted element to transport.

v) Off site prefabrication

The sub assembly system is the process which the building component are constructed.

at the off site location before they are parmanently erected at the site.

These element include the buiding compnent material equipment and fabricated part.

vi) open system

There are two catagories of open pre-fab system depending on the extend of pre-fabrication used in construction those are.

(a) Partial pre fab onpen system

(b) Full pre fab open system

vii) close system

In these system the whole things are casted with fixing and ~~erecting~~ erected on their position.

viii) partial pre fabrication

These system emphasized the use of prefabricated roofing and flooring and other minor element like linters, sun set, kitchen sells in conventional where section previously assemble at the final point of manufacture are assemble else where instead, before being deliver for final assemble.

The theory behind the method is that time and cost is save if similar construction task can be grouped and assembly line techniques can be employed in prefabrication at a location where skilled labour is avilable which congestion at the assembly site which — time can be reduced. The method finds application particularly where the structure is composed of repeating unit or form or where multiple copies of the same basic structure are being constructed.

Pre-fabrication avoids the need to transport so many skilled worker to the construction site and other restricting condition such as a lack of power, lack of water, exposer to harsh weather or a hazardous environment are avoided

Against these advantages must be weighed the cost of transporting pre-fabricated section and lifted them into position as they will usually be larger, more fragile and more difficult to handle then the materials and components of which they are made.

Design principle of prefabricated system

i) Economy in large scale project with high degree of repeatation in work execution.

ii) Special architectural requirements in finishing

iii) First speed of construction.

iv) Consistency in structural quality control

v) Constraints in avilability of site resource.

E.g:- Material and labour etc.

vi) Other space and environmental constraints

vii) Overall assessment of some or all of the above factor which point the superiority of adopting pre cast construction over conventional method.

Modular co-ordination

It means the inter dependent arrangement of a dimension based on a primary value accepted as a module. The strict observence of rules of modular co-ordination facilitate.

i) Assemble of single component into large component.

ii) Fewest possible different type of components.

iii) Minimum wastage of cutting needed.

- Modular coordination is the basic for meeting the requirement of conventional and pre fabricated construction. These rules are adoptable for.

(a) The planning greed in both direction of the horizontal plan shall be

i) 3m for residential institutional building

ii) For industrial building.

* 15m of span of to 12m

* 30m for span between 12m & 18m

* 60m for span above 18m.

* The center line of a load bearing wall shall co-inside with the greed line

(b) In case of external wall the greed line sheel co-inside with the center line of the wall on a line on the wall 5c.m from the internal face of the wall.

(c) The planning module in the vertical direction shell be 1m upto and including a height of 2.8m

(d) pre-fabricated increament for the sill height door, window and other fenestration shall be 1m.

(e) in case of internal column the greed line shall coinside the center line of column. in case of external columns the greed line shall coinside with ~~C.L~~ center line of the columns in the storie or a line in the column from the internal face of the column in the top most storiey.

Earth quake resistance construction

Building configuration

It may be defined as the overall size and shape of a building, together with the size, nature and location of those elements of the building that are significant to its seismic performance.

Building configuration are extremly varied but are not random.

There are 3 major influences; The requirement of site, The requirement of a building occupancy and the requirement of emagery or asthetic aims.

Lateral road resisting structure

The tall building needs a lateral load resisting system to mantain

The structure stable when lateral load are applied to them. lateral loads from winds and earth quake are mainly applied to buildings.

When building become taller and toller, horizontal load applied to them increase further the effect of lateral load become more serious with the increase of the height of the structure. The following type of load could be observe.

1) Window load
2) Seismic load
3) Water pressure
4) Earth. pressure

Different structural system are introduced depending on the nature of the building to resist the lateral load out of those method the following [illegible] are widely used in build[illegible]

Beam column frame structure can be used upto 15 to 20 storie as a lateral load resisting system.

Bracing

Bracings are used mostly used in steel struct. to improve the lateral load resisting capacity further they are constructed in the concretet buildings also to improve the lateral load resistivity.

The following type of Bracings are used in steel building

- Single
- diagonal
- cross Bracing
- K Bracing
- V Bracing

lateral load applied by wind, seismic load are resisted by these type of Bracing.

Shear Wall

A concrete wall constructed from the based level to the top of the building is consider as a Shear Wall. It carries the lateral loads & V. load applied by the structural element connected to it. The Shear Wall along can resist the lateral load of buildings having about 20 Stories beyond that the contribution of the frame could also be consider.

Shear Wall need to the fixed at the base level in order to carry the lateral loads effictively. Stiffness of Shear Wall is the key factor affecting the lateral load resistivity of the wall. Lengt & width of the wall are the key factors affecting the stiffness of the wall.

EARTHQUAKE RESISTANT CONSTRUCTION

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LATERAL LOAD RESISTING STRUCTURE :-

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The following types of loads could be observed in building design :-

(i) Wind loads (iii) Water pressure (or)
(ii) Seismic load (iv) Earth pressure

Different Structural Systems are introduced depending on the nature of the buildings to resist the lateral loads. out of those methods, the following methods are widely used in buildings :-

(i) frame
(ii) Bracings
(iii) Shear walls
(iv) Wall frame interaction

(i) FRAME :-

If there is a building, there will be a frame in the structure most of the time. Frame structure exist in the majority of the buildings.

Beams and columns connected together create the frame. when the connection of the beam and column is rigid, the frame can transfer the lateral loads to the foundations.

Therefore, rigid frame considered as a lateral load resisting system. Beam column frame structure can be used upto 15-20 stories as a lateral load resisting system.

BRACINGS :-

Bracings are used mostly in steel structures to improve the lateral load resisting capacity. Further, they are constructed in the concrete buildings also to improve the lateral load resistivity.

The following types of bracings are used in steel buildings.

* Single diagonals
* Cross bracings
* K. bracings
* V- bracings.

lateral load applied by wind, seismic loads are resisted by these type of bracings.

SHEAR WALL :-

A concrete wall constructed from the based level to the top of the building is considered as a shear wall. It carries the lateral loads and the vertical loads applied by the structural element connected to it.

The shear wall along can resist the lateral load of buildings having about 20 stories. beyond that, the contribution of the frame could also be considered.

shear wall need to the fixed at the base level in order to carry the lateral loads effectively.

Stiffness of the shear wall is the key factor affecting the lateral load resistivity of the wall. Length and the width of the wall are the key factors affecting the stiffness of the wall.

BUILDING CHARACTERISTICS :-

1. The quality of the Soil is important :-

Even before you start designing a constru-
-ction which will be earthquake resistant, the
first thing to consider is the Soil quality which will
be able to withstand the pressure of the earthquake.
The Soil should have good flexibility and capability.

2. Foundation matters :-

The foundation of a building is one of
the most important things to be kept into consideration
particularly while building a seismic resistant
structure. Incase there are unsuitable features
in the soil, try replacing a section of the Soil.
Another option is designing special foundation
for the structure. You can not compromise with the
foundation as it is the key strength of a building.
with the proper foundation, the structure can
transmit the charges and weights to the nearby
land and distribute them. This prevents damage
to the main building. The structure, size and
characteristic of the foundation will depend
on the initial study of the terrain and the
adjustments that need to be made. The best
foundations are those which are larger than the
structure which they will be supporting. Prefer-
-ably the foundation should be made of
reinforced steel and concrete.

3. Height of the Structure :-

The numbers of storeys in the building and the height of the building will be a major factor in determining the load that will be borne by the foundation and the soil. Proper Calculation should be done in this regard before making the design and planning of the structure. It has been seen that with proper planning and designing, buildings with many storeys have been safe during an earthquake and other natural calamities.

4. Distribution of load and Symmetry :-

There should be symmetry in the structural designing of the building. This not only helps in proper distribution of the load over the foundation but also ~~by~~ helps in maintaining a constant balance.

5. Structural design :-

Structures should have the capacity of withstanding dynamic as well as static forces and be flexible enough to absorb them easily. This is applicable right from the foundation to enclosures from load walls to delays etc. buildings that lack flexibility and are rigid have high chances of breaking and cracking during earthquakes. If there is flexibility, the weight will be shifted accordingly and prevent the building from damage. With precise balance, it is possible to deal with an earthquake as compression, flexion and traction are absorbed and the building remains safe.

6. Quality of building materials :-

The quality of building materials used in the construction of the structure is an impor- -tant thing to consider for establishing strength and toughness in a building. Materials which are certified help in absorbing the energy generated during an earthquake and prevent damage to the building in the best manner. The ideal combination is use of reinforced steel with concrete. This combination is not only strong and resistant but extremely flexible at the same time.

7. Authorizations and procedures :-

There are National and State building ~~Re~~ regulations as well as ~~municipal~~ municipal building law, which have to be followed for construction of earthquake resistant homes. The authorizations must be managed by an architect or engineer who will handle the job. A constructive and executive project has to be submitted in a timely manner.

8. Maintenance post construction :-

After the construction of the structure, it is important that it should be maintained and taken care of well. After an earthquake it is possible to understand how well the structure has been maintained. Many might not agree. but this is one of the basics of having a seismic proof building. Maintenance includes things like reinforcement of columns and gutters incase of detachments and separations, checking deck slabs, insulation restoration in walls, roofs and foundations, checking internal and external leakage etc.

EFFECT OF STRUCTURAL IRREGULARITIES :-

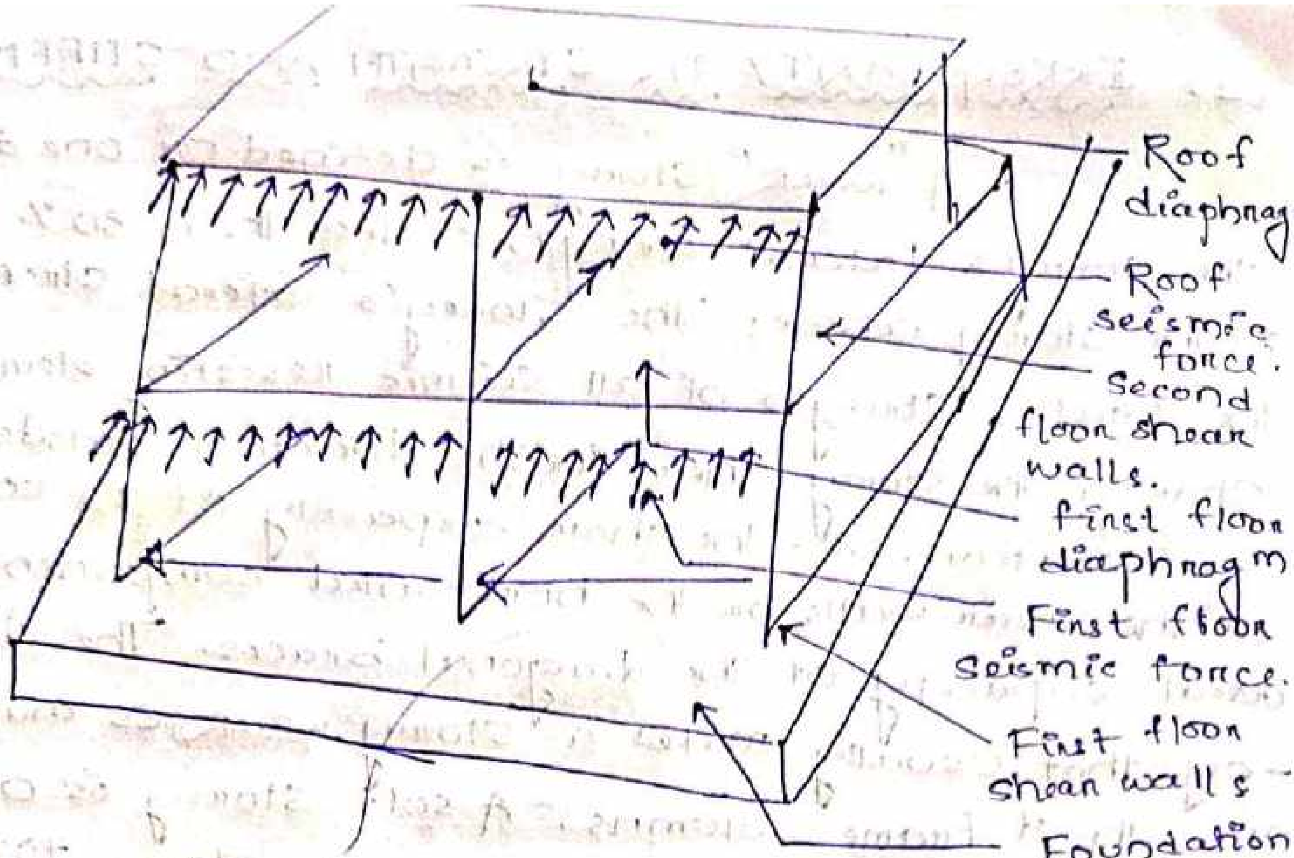
Earthquake resistant design of reinforced concrete buildings is a continuing area of research since the earthquake engineering has started not only in India but in other developed countries also. The buildings still damage due to some one or other reason during earthquakes. In spite of all the weakness in the structure, either code imperfection or error in analysis and design, the structural configuration system has played a vital role in catastrophe. The IS : 1893 (Part 1) : 2002 has recommended building configuration system in Section 7 for the better performance of RC buildings during earthquakes. The building configuration has been described as regular or irregular in terms of size and shape of the building, arrangements of structural elements and mass. Regular building configurations are almost symmetrical about the axis and have uniform distribution of the lateral force resisting structure such that, it provides a continuous load path for both gravity and lateral loads. A building that lacks symmetry and has discontinuity in geometry mass or load resisting element is called irregular.

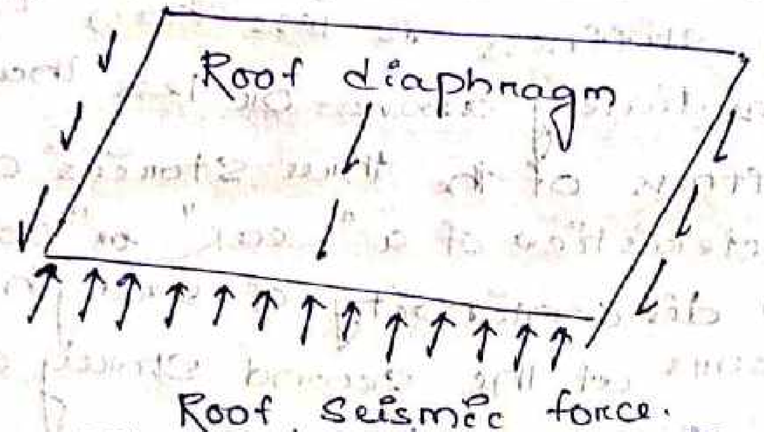
VERTICAL IRREGULARITIES :-

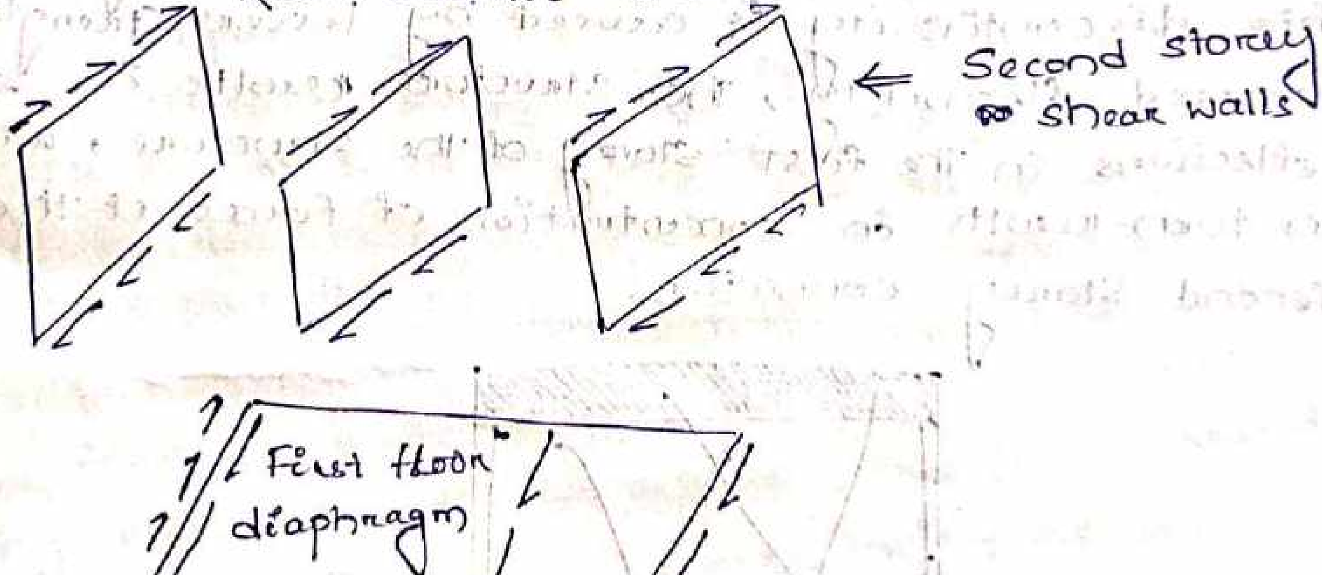
(1.) VERTICAL DISCONTINUITIES IN LOAD PATH :-

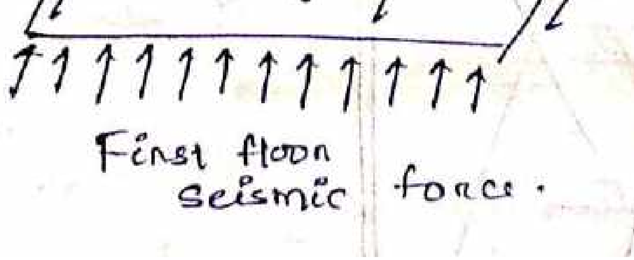
One of the major contributors to structural damage in structures during strong earthquake is the discontinuities / irregularities in the load path or load transfer. The structure should contain a continuous load path for transfer of the seismic force, which develops due to accelerations of individual elements to the ground. Failure to provide adequate strength and toughness of individual elements in the system or failure to tie individual elements together can result in distress or complete collapse of the system. Therefore all the structural and non-structural elements must be adequately tied to the structural system. The load path must be complete and sufficiently strong.

The general load path is as follows: earthquake forces, which originate in all the elements of the building are delivered through structural connections to horizontal diaphragms. The diaphragms distribute these forces to vertical resisting components such as column, shear walls, frames and other vertical elements in the structural system which transfer the forces into the foundation. The diaphragms must have adequate stiffness to transmitting these forces.


Roof diaphragm
Roof seismic force.
Second floor shear walls.
first floor diaphragm
First floor seismic force.
First floor shear walls
Foundation.

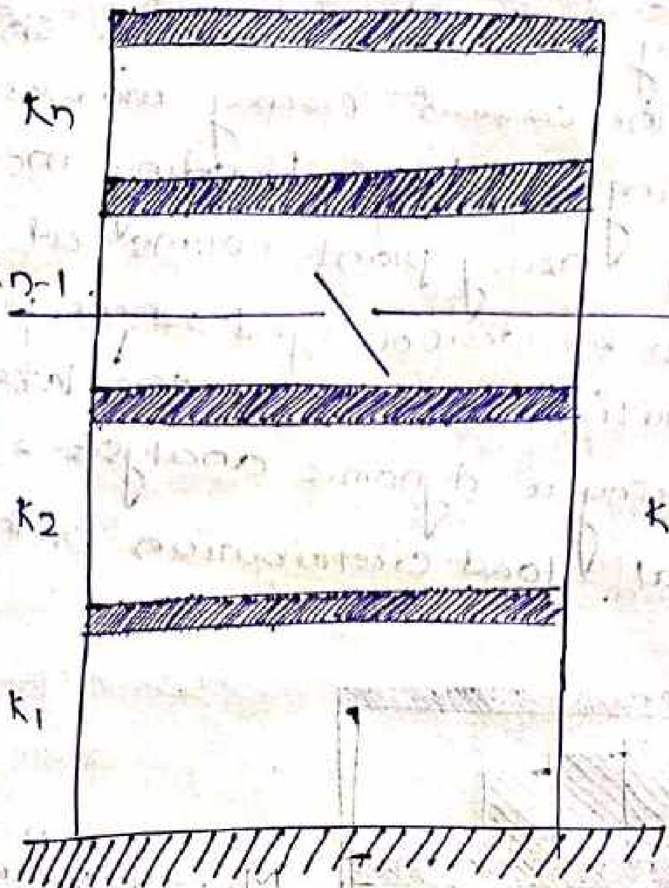

Roof diaphragm
Roof seismic force.


Second storey shear walls


First floor diaphragm
First floor seismic force.

(2) IRREGULARITY IN STRENGTH AND STIFFNESS :-

∴ A "weak" storey is defined as one in which the storey's lateral strength is less than 80% of that in the storey above. The storey's lateral strength is the total strength of all seismic resisting elements sharing the storey shear for the direction under consideration. i.e. the shear capacity of the column or the shear walls or the horizontal component of the axial capacity of the diagonal braces. The deficien-cy that usually makes a storey weak is inadequate strength of frame columns. A soft storey is one in which the lateral stiffness is less than 70% of that in the storey immediately above or less than 80% of the combined stiffness of the three stories above. The essential characteristics of a "weak" or "soft" storey consist of a discontinuity of strength or stiff-ness, which occours at the second storey connections. This discontinuity is caused by lesser strength or increased flexibility, the structure results in extreme deflections in the first storey of the structure, which in turn results in concentration of forces at the second storey connections.



Soft storey when

$k_i < 0.7\, k_{i+1}$

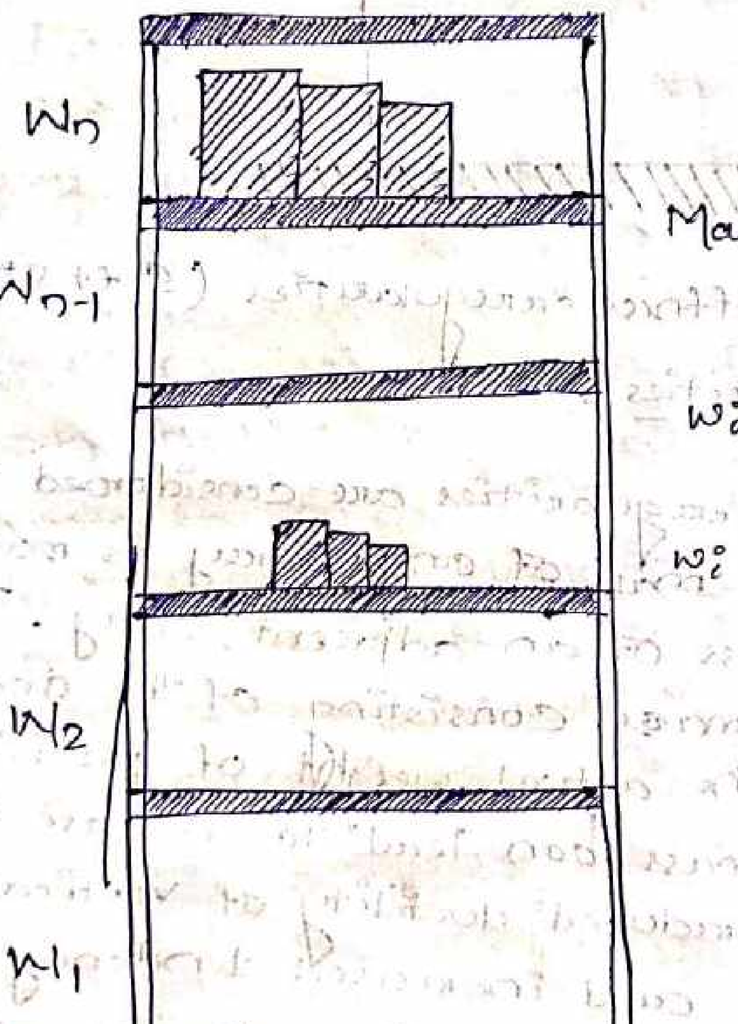
OR

$k_i < 0.8 \left\{ \frac{1}{3} \left(k_{i+1} + k_{i+2} + k_{i+3} \right) \right\}$

Stiffness irregularities (Soft storey)

(3) Mass irregularities :-

Mass irregularities are considered to exist where the effective mass of any storey is more than 200% of the effective mass of an adjacent storey. The effective mass is the real mass consisting of the dead weight of the floor plus the actual weight of partition and equipment. Excess mass can lead to increase in lateral inertial forces, reduced ductility of vertical load resisting elements and increased tendency towards collapse due to P-Δ effect. Irregularity of mass distribution in vertical and horizontal planes can result in irregular responses and complex dynamics. The characteristic swaying mode of a building during an earthquake implies that masses placed in the upper stories of building produce considerably more unfavourable effects than masses placed lower down. The centre of gravity of lateral forces is shifted above the base in the case of heavy masses in upper floors resulting in large bending moments. Massive roofs and heavy plant rooms at high level are therefore to be discouraged where possible. Where mass irregularities exist check the lateral force resisting elements using a dynamic analysis for a more realistic lateral load distribution of the base shear.



Mass regularities when,

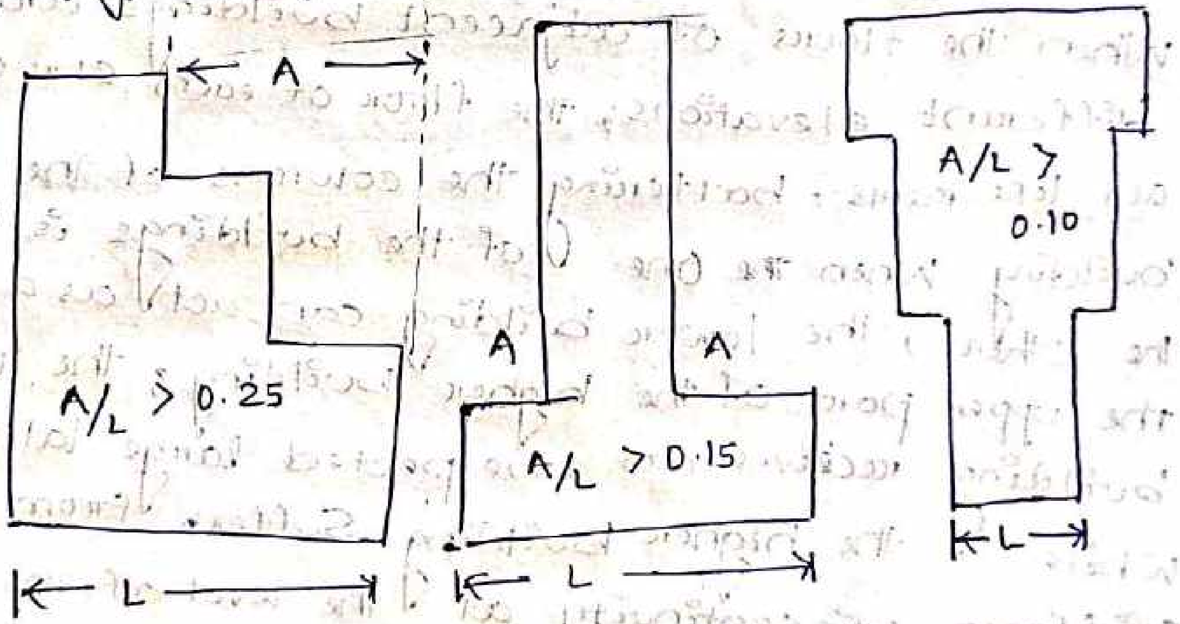
$w_i > 2.0\, w_{i-1}$

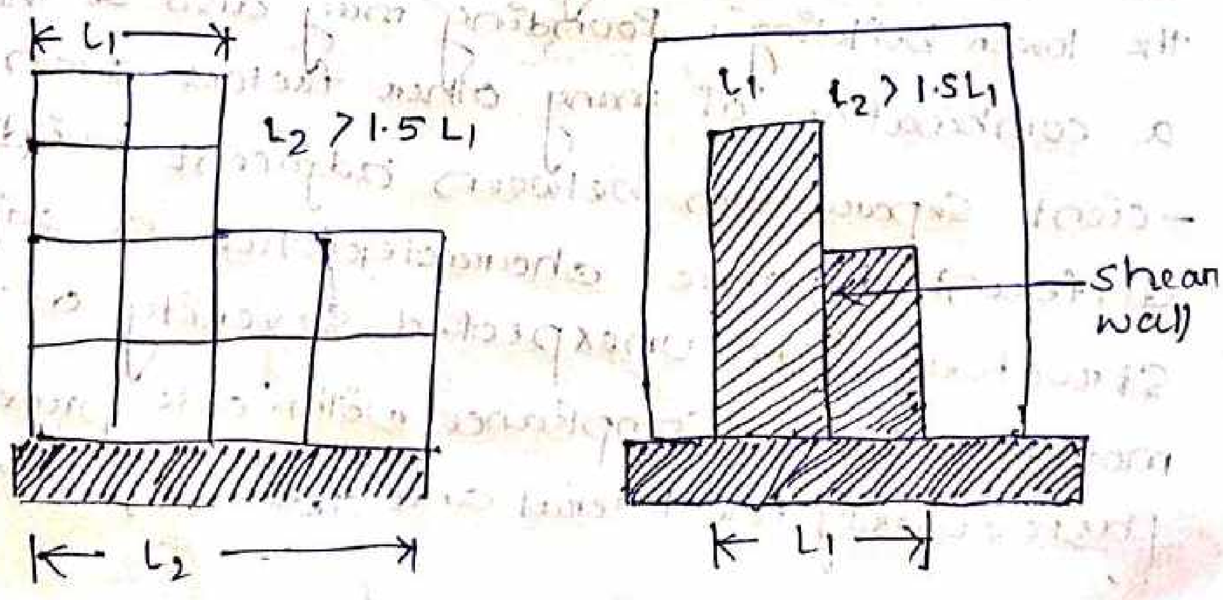
OR

$w_i > 2.0\, w_{i+1}$

(4) VERTICAL GEOMETRIC IRREGULARITY :-

A vertical setback is a geometric irregularity in a vertical plane. It is considered, when the horizontal dimension of the lateral force resisting system in any storey is more than 150% of that in an adjacent storey. The V-setback can also be visualised as a vertical re-entrant or corner. The general solution of a setback problem is the total seismic separation in plan through separation section, so that portions of the building are free to vibrate independently. When the building is not separated, check the lateral force resisting elements using a dynamic.





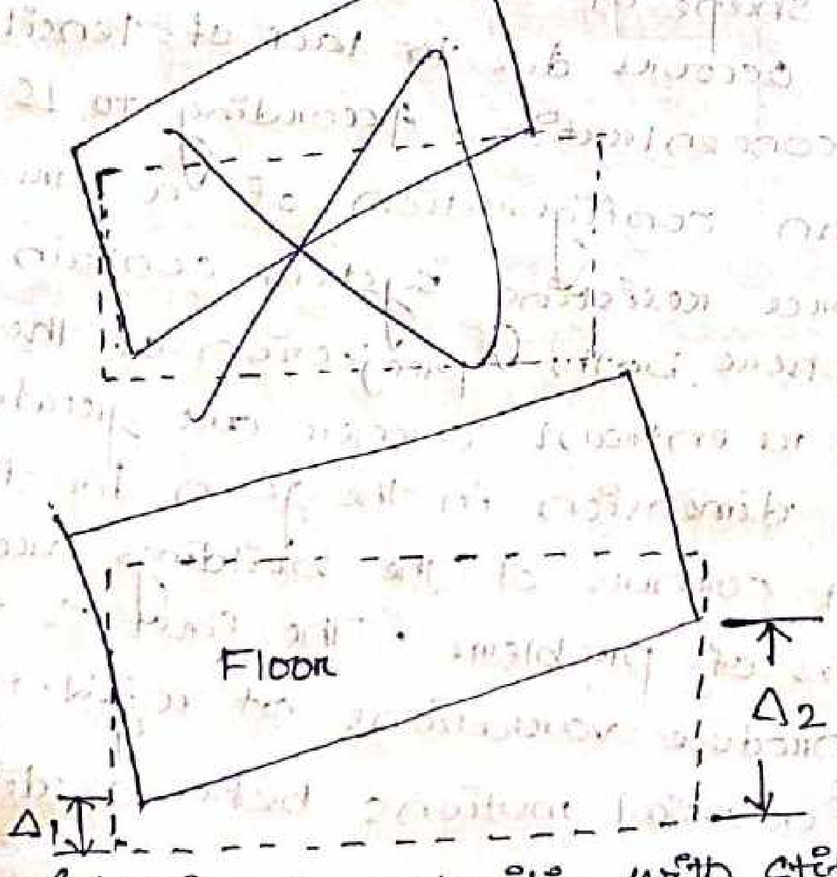
(5) PROXIMITY OF ADJACENT BUILDINGS :-

Pounding damage is caused by hitting of two buildings constructed in close proximity with each other. Pounding may result in irregular responce of adjacent buildings of different heights due to different dynamic characteristics. This problem arises when buildings are built without separation right upto property lines in order to make maximum use of the space. When floors of these buildings are constructed of the same height, damage due to pounding usually is not serious. If this is not the case, there are two problems. When the floors of adjacent buildings are at different elevations; the floor of each structure can act like rams, battering the columns of the other building. When one of the buildings is higher than the other; the lower building can act as a base for the upper part of the higher building; the lower building receives an unexpected large lateral load while the higher building suffers from a major stiffness discontinuity at the level of the top of the lower building. Pounding may also be the result of a combination of many other factors such as insuffi-cient separation between adjacent buildings, different dynamic characteristics of adjacent structures, the unexpected severity of the ground motion, non-compliance with code provisions, particularly for lateral and torsional stiffness due to inadequate building configuration and structural framing system and cumulative tilting due to foundation movement. Damage due to pounding can be minimized by drift control, building separation and aligning floors in adjacent buildings.

PLAN CONFIGURATION PROBLEM :-

(1) TORSION IRREGULARITIES :-

Torsion irregularity shall be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsion irregularity is considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structure transverse to an exist is more than 1.2 times of the average of the storey drifts at the two ends of the structures.

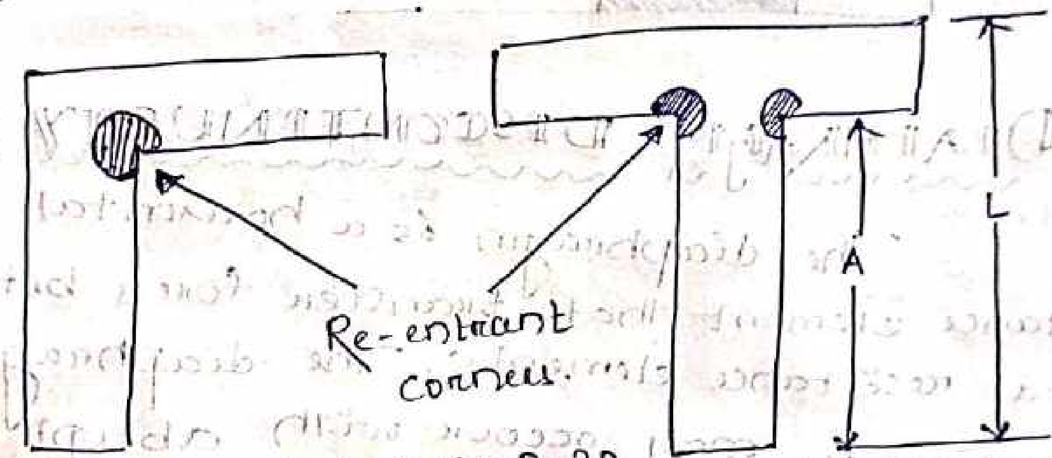


(torsion irregularities with stiff diaphragm)

The lateral force resisting elements should be well balanced system that is not a subjected to significant torsion. Significant torsion will be taken the condition where the distance between the storey centre of rigidity and storey's centre of mass greater than 20% of the width of the structure either major plan dimension. Torsion or eccentric lateral deflection is generated in asymmetrical buildings or eccentric and asymmetrical lay of the bracing system that may result in perman set or even partial collapse.

(2) RE-ENTRANT CORNER :-

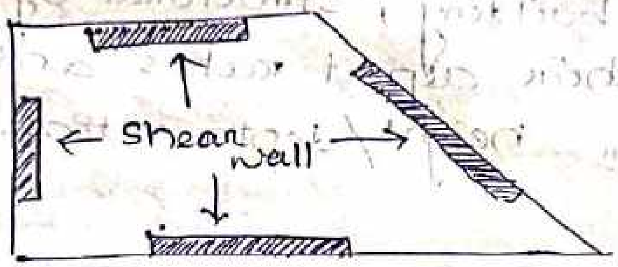
The re-entrant, lack of continuity or inside corner is the common characteristic of overall building configuration that, in plan assume the shape of an L, T, H, + or combinati these shape occours due to lack of tensile capacit and force concentration. According to IS 1893 (Par : 2000, plan configuration of a structure and lateral force resisting system contain re-entrar corners, where both projection of the structure beyond the re-entrant corner are greater than of its plan dimension in the given direction. The re-entrant corners of the buildings are subjecte to two types of probleme. The first is that they tend to produce variations of rigidity and hence differential motions between different parts of the building, resulting in a local stress concentration at the notch of the re-entrant corner. The second problem is torsion, an L-shaped building is subjected to a ground motion of Alaska earthquake 1964 in north-south direction; attempt to move differently at their notch, pulling and pushing each other so the stress concentrations are high at the notch. The magnitude of the induced forces will depend on mass of building, structural system, length of the wings and their aspect ratios and height of the wings and their height/depth ratios.



$A/L > 0.15 - 0.20$

(3) NON-PARALLEL SYSTEMS :-

The vertical load resisting elements are not parallel to or symmetrical about the major orthogonal axis of the lateral force resisting system. These situations are often faced by architects. This condition results in a high probability of torsional forces under a ground motion, because the centre of mass and resistance does not coincide. This problem is often exaggerated in the triangular or wedge shaped buildings resulting from street inter-sections at an acute angle. The narrower portion of the building will tend to be more flexible than the wider ones, which will increase the tendency of torsion. To design these type of buildings, special care must be exercised to reduce the effect of torsion or to increase the torsional resistance of the narrow parts of the building.



(4) DIAPHRAGM DISCONTINUITY :-

The diaphragm is a horizontal resistance element that transfer forces between vertical resistance elements. The diaphragm discontinuity may occour with abrupt variations in stiffness, including those having cut-out or open areas greater than 50% of the gross enclosed diaphragm area or change in effective diaphragm stiffness of more than 50% from one storey to the next. The diaphragm acts as a horizontal beam and its edge acts as flanges. It is obvious that opening cut in tension flange of a beam will seriously weaken its load carrying capacity. In a number of building there has been evidence of roof diaphragms, which is caused by tearing of the diaphragm.

ADDITIONAL STRENGTHENING MEASURES IN MASONARY BUILDING :-

(1) CORNER REINFORCEMENT :-

Corner reinforcement used at wall intersections or near corners of square or rectangular openings in walls, slabs or beams. Metal reinforcement for plaster at re-entrant corners to provide continuity between two intersecting planes.

(2) LINTEL BAND :-

A lintel band is a horizontal member which is placed at the top of the opening like door and window to support the portion of the unsupported wall above it continuously throughout the length of wall.

(3) SILL BAND :-

A sill band is a horizontal member which is place at the bottom of the opening to support the load of the window frame. It is discontinued at the door opening.

(4) PLINTH BAND :-

A plinth band is a horizontal member which is positioned at the plinth level to tie the wall at plinth level.

(5) ROOF BAND :-

A roof band is a load bearing member of a roof at roof level. Sometimes roof band is not required because the roof slab of load bearing wall masonary also play the role of a band. Roof beams are generally provided in the building with flat timber or CGI sheet roof.

(6) GABLE BAND :-

A gable band is a horizontal member which is placed at the top of the ridge of the sloping slab to support the ends of the rafters and transfering loads to posts or gable end walls.

Retrofitting structure

29.1 INTRODUCTION

The aftermath of an earthquake manifests great devastation due to unpredicted seismic motion striking extensive damage to innumerable buildings of varying degree *i.e.* either full or partial or slight. This damage to structures in its turn causes irreparable loss of life with a large number of casualties. As a result frightened occupants may refuse to enter the building unless assured of the safety of the building from future earthquakes. It has been observed that majority of such earthquake damaged buildings may be safely reused, if they are converted into seismically resistant structures by employing a few retrofitting measures. This proves to be a better option catering to the economic considerations and immediate shelter problems rather than replacement of buildings. Moreover it has often been seen that retrofitting of buildings is generally more economical as compared to demolition and reconstruction even in the case of severe structural damage. Therefore, seismic retrofitting of building structures is one of the most important aspects for mitigating seismic hazards especially in earthquake-prone countries. Various terms are associated to retrofitting with a marginal difference like repair, strengthening, retrofitting, remoulding, rehabilitation, reconstruction etc. but there is no consensus on them. The most common definition of these terms may be summarized in Table 29.1.

The need of seismic retrofitting of buildings arises under two circumstances: (i) earthquake-damaged buildings and (ii) earthquake-vulnerable buildings that have not yet experienced severe earthquakes. The problems faced by a structural engineer in retrofitting earthquake damaged buildings are: (a) lack of standards for methods of retrofitting; (b) effectiveness of retrofitting techniques since there is a considerable dearth of experience and data on retrofitted structures; (c) absence of consensus on appropriate methods for the wide range of parameters like type of structures, condition of materials, type of damage, amount of damage, location of damage, significance of damage, condition under which a damaged element can be retrofitted etc. Therefore, a catalogue of available options regarding feasible and practical retrofitting method

TABLE 29.1 Concept of various terms associated with retrofitting

Terms	*CEB, 1995*	*Tomazevic, 1999*	*Newman, 2001*
Repairing To make the existing structure safer for future earthquake *as per* ***IS 13935: 1993***	Reconstruction or renewal of any part of a damaged or deteriorated building to provide the same level of strength and ductility, which the building had, prior to the damage	"*Repair*" refers to the post-earthquake repair of damage, which restricts the seismic resistance of the building to its pre-earthquake state	Repairing is a process of reconstruction and renewal of the existing buildings, either wholly or in part.
Retrofitting To upgrade the earthquake resistance up to the level of the present-day codes by appropriate techniques *as per* ***IS 13935: 1993***	Concepts including strengthening, repairing and remoulding	Increasing the seismic resistance of a damaged building is called retrofitting.	It is an upgrading of certain building system, such as mechanical, electrical, or structural, to improve performance, function, or appearance.
Strengthening To upgrade the seismic resistance of a damaged building *as per* ***IS 13935: 1993***	Reconstruction or renewal of any part of an existing building to provide better structural capacity *i.e.* higher strength and ductility, than the original building	"*Strengthening*" may increase the seismic resistance of a building beyond its pre-earthquake state. Strengthening may be carried out in existing seismically deficient buildings or earthquake-damaged buildings	

TABLE 29.1 Contd.

Terms	*CEB, 1995*	*Tomazevic, 1999*	*Newman, 2001*
Rehabilitation	Reconstruction or renewal of a damaged building to provide the same level of function, which the building had prior to the damage	Increasing the seismic resistance of an existing seismically deficient building is called rehabilitation.	Upgradation required to meet the present needs; it implies sensitivity to building features and a sympathetic matching of original construction.
Restoration	Rehabilitation of buildings in a certain area		More restrictive term than rehabilitation; it suggests replicating the structure as originally built. The term is most commonly applied to the buildings of historical value.
Remoulding	Reconstruction or renewal of any part of an existing building owing to change of usage or occupancy		It is a process of substantial repair or alteration that extends a building's useful life.

is needed by the structural engineer due to great variability of retrofitting requirements differing from building to building. In addition, experimental and analytical research is urgently needed to strengthen different techniques of retrofitting.

The need of retrofitting of existing earthquake vulnerable buildings may arise due to one or more than one of the following reasons *i.e.* (a) the buildings have been designed according to a seismic code, but the code has been upgraded in later years; (b) buildings designed to meet the modern seismic codes, but deficiencies exist in the design and/or construction; (c) essential buildings must be strengthened like hospitals, historical monuments and architectural buildings; (d) important buildings whose service is assumed to be essential even just after an earthquake; (e) buildings, the use of which has changed through the years; (f) buildings that are expanded, renovated or rebuilt. The problems faced by the structural engineer in case of earthquake vulnerable buildings are to obtain sufficient records of buildings such as architectural and structural drawings, structural design calculations, material properties, details of foundation and geo-technical reports, records of at least natural period of the buildings in order to evaluate the increased stiffness of buildings since strengthening techniques most often stiffen the structure reducing its natural period.

Retrofitting of existing buildings and issues of their structural safety have not received adequate attention in India. There are at present no guidelines or codes of practice available in the country for retrofitting. The methods of seismic assessment of existing buildings are not adequately developed. In some developed countries research on repair and retrofitting has been undertaken during the last two decades. Various techniques of seismic retrofitting have been developed and used in practice. The basic concepts of these techniques of retrofitting are aimed at (CEB, 1997): (a) upgradation of the lateral strength of the structure; (b) increase in the ductility of structure; (c) increase in strength and ductility. These three concepts are schematically illustrated in Figure 29.1.

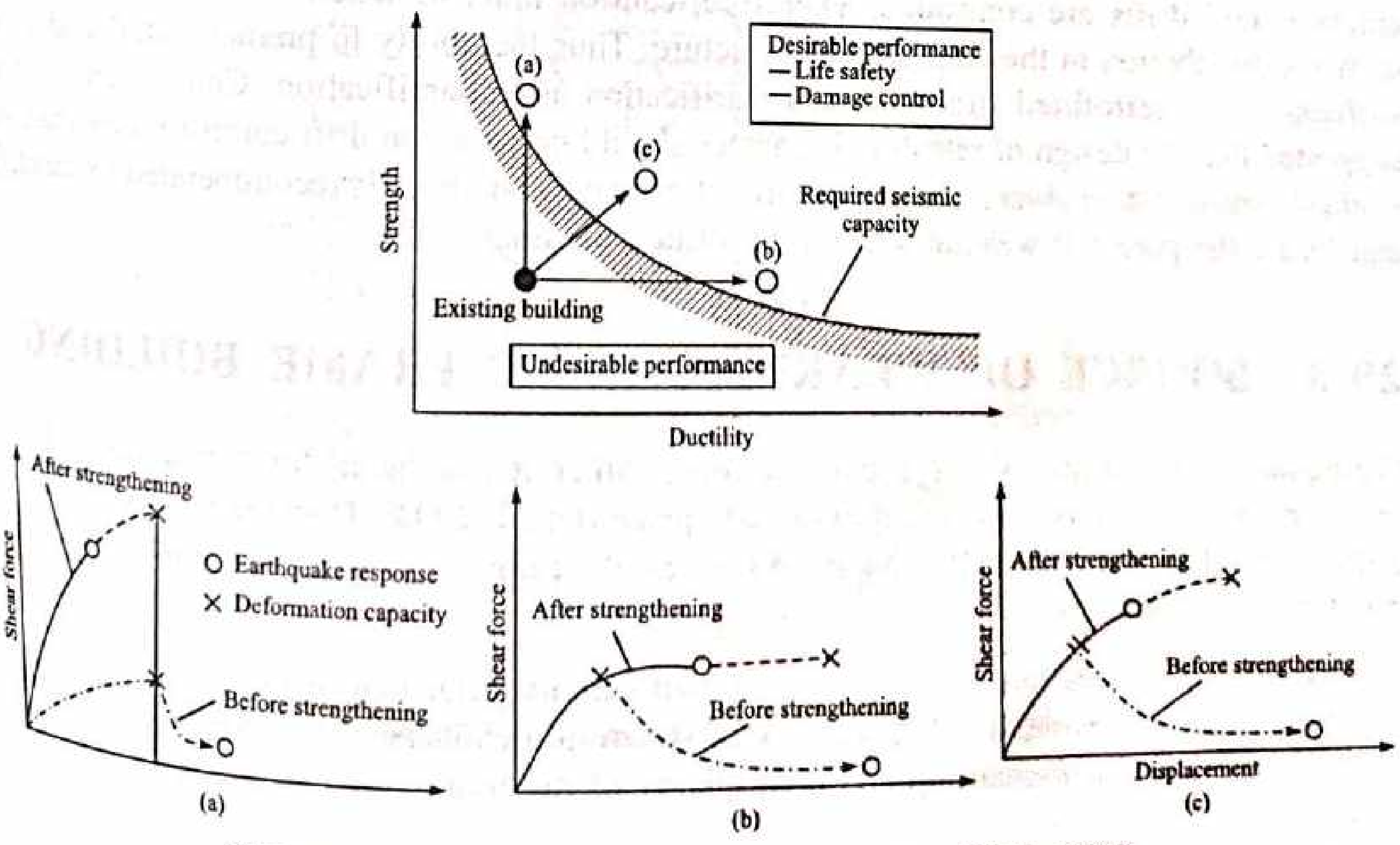


FIGURE 29.1 **Aims of seismic strengthening (CEB, 1997).**

The decision to repair and strengthen a structure depends not only on technical considerations as mentioned above but also on a cost/benefit analysis of the different possible alternatives. It is suggested that the cost of retrofitting of a structure should remain below 25% of the replacement as major justification of retrofitting (Nateghi and Shahbazian, 1992). The present chapter will discuss different aspects of retrofitting scheme and their limitations, side effects as well as cost considerations. The information in this chapter is gathered from the available literature and is based on the experiences of individual authors and their studies.

29.2 CONSIDERATION IN RETROFITTING OF STRUCTURES

The method of retrofitting principally depends on the horizontal and vertical load resisting system of the structure and the type of materials used for parent construction. It also relies on the technology that is feasible and economical. The understanding of mode of failure, structural behaviour and weak and strong design aspects as derived from the earthquake damage surveys exercise considerable influence on selection of retrofitting methods of buildings. Usually the retrofitting method is aimed at increasing the lateral resistance of the structure. The lateral resistance includes the lateral strength or stiffness and lateral displacement or ductility of the structures. The lateral resistance is often provided through modification or addition of retrofitting elements of an existing structure in certain areas only. The remaining elements in the structure are usually not strengthened and are assumed to carry vertical load only, but in an earthquake, all components at each floor, retrofitted or not, will undergo essentially the same lateral displacements. While modified or added elements can be designed to sustain these lateral deformations, the remaining non-strengthened elements could still suffer substantial damage unless lateral drifts are controlled. Therefore, caution must be taken to avoid an irregular stiffness distribution in the strengthened structure. Thus the ability to predict initial and final stiffness of the retrofitted structure need clarification and quantification. Consequently, it is suggested that the design of retrofitted schemes should be based on drift control rather than on strength consideration alone. The use of three-dimensional analysis is recommended to identify and locate the potential weakness of the retrofitted building.

29.3 SOURCE OF WEAKNESS IN RC FRAME BUILDING

Earthquake engineering is not a pure science; rather it has been developed through the observation of failure of structure during earthquake (Otani, 2004). Damage survey reports of past earthquakes reveal the following main sources of weakness in reinforced concrete moment resisting frame buildings.

(i) discontinuous load path/interrupted load path/irregular load path
(ii) lack of deformation compatibility of structural members
(iii) quality of workmanship and poor quality of materials

29.3.1 *Structural Damage due to Discontinuous Load Path*

Every structure must have two load resisting systems: (a) vertical load resisting system for transferring the vertical load to the ground and (b) horizontal load resisting system for transferring the horizontal load to the vertical load system. It is imperative that the seismic forces should be properly collected by the horizontal framing system and properly transferred into vertical lateral resisting system. Any discontinuity/irregularity in this load path or load transfer may cause one of the major contributions to structural damage during strong earthquakes. In addition it must be ensured that each member both of horizontal or vertical load resisting system must be strong enough and not fail during an earthquake. Therefore, all the structural and non-structural elements must have sufficient strength and ductility and should be well connected to the structural system so that the load path must be complete and sufficiently strong.

29.3.2 *Structural Damage due to Lack of Deformation*

The main problems in the structural members of moment resisting frame building are the limited amount of ductility and the inability to redistribute load in order to safely withstand the deformations imposed upon in response to seismic loads. The most common regions of failure in an existing reinforced concrete frame are shown in Figure 29.2. The regions of failure may be in columns, beams, walls and beam–column joints. It is important to consider the consequences of member failure or structural performance. Inadequate strength and ductility of the structural member can and will result in local or complete failure of the system. The different modes of failure in various structural members are reviewed.

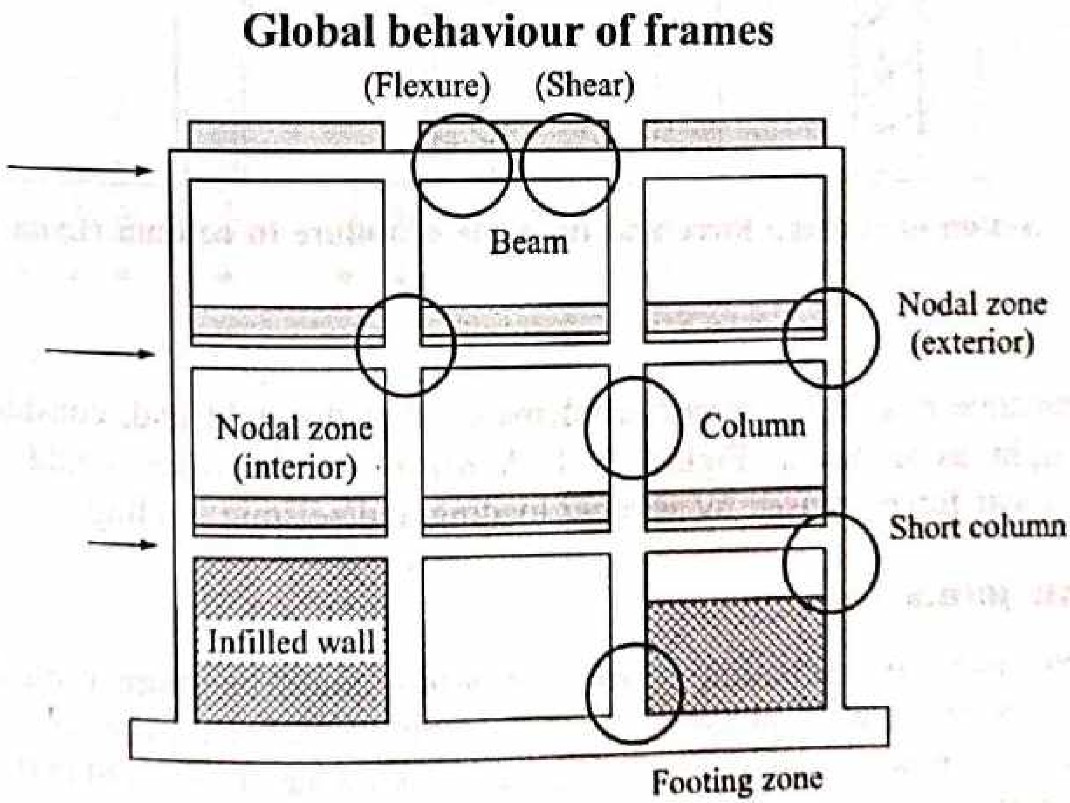


FIGURE 29.2 Possible reason of failure in moment resisting frame (Cosenza and Manfredi, 1997).

Columns

In reinforced concrete columns several interaction mechanism influences its lateral load behaviour. The main actions are associated with axial, flexure, shear, and bond as shown in Figure 29.3. The possible mode of failure and the suggested remedial measures are described in Table 29.2.

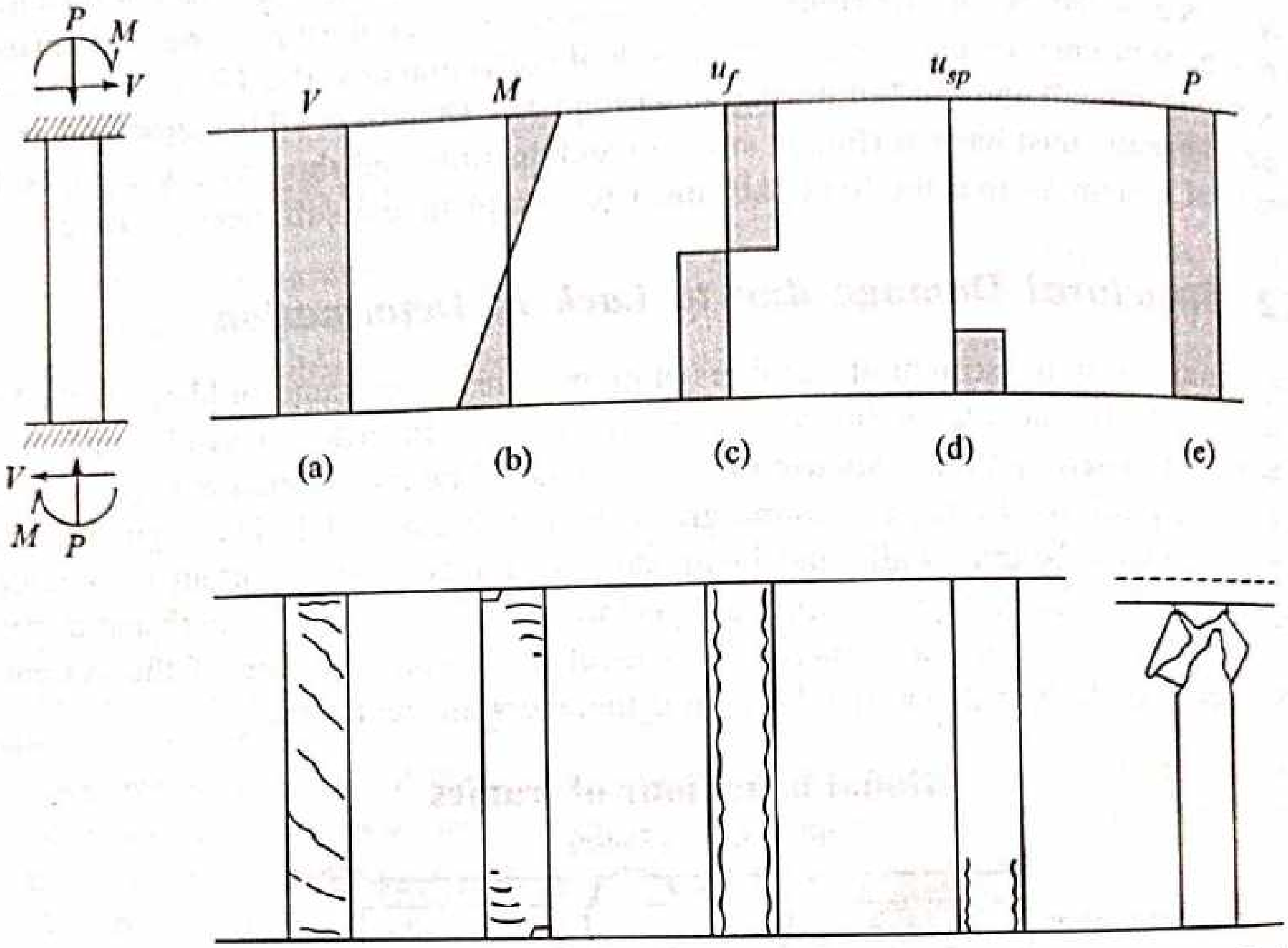


FIGURE 29.3 Action of concern force and its mode of failure in column (Lynn et al., 1996).

Beams

In reinforced concrete beams, the major problems exist at the right end, considering seismic forces left to right as shown in Figure 29.4. A *brittle shear failure* could occur due to superposing of shear forces caused by vertical loading and seismic loading.

Beam–column joints

In beam–column joint, the situation of exterior joints could be more critical if there is inadequate lateral reinforcement. In case of strong column–weak beam behaviour, the joint may be heavily stressed after beam yielding and diagonal cracking may be formed in the connection. Wide flexural cracks may develop at the beam end, partially attributable to the slip of beam reinforcement within the connection. Such shear cracking may reduce the stiffness of a building.

TABLE 29.2 Mode of failure of columns and remedial measures (Otani, 2004)

Action concern	*Failure mode*	*Description of failure*	*Suggested remedial measures*
Axial force and flexural	Flexural compression	• compression failure of concrete • buckling of longitudinal reinforcement • failure takes place near the column ends • hoop fracture	• lateral confining reinforcement can delay the crushing failure of concrete • deformation capacity of column can be enhanced by providing the lateral reinforcement in the region of plastic deformation
Shear force	Diagonal tension/ Brittle shear	• cause diagonal tensile stress in concrete • these tensile stresses are transferred to the lateral reinforcement after cracking in concrete	• provided minimum amount of lateral reinforcement (size, spacing and strength of shear reinforcement)
Shear force	Diagonal compression	• failure of concrete after the yielding of lateral reinforcement • not brittle as the diagonal tension failure or brittle shear failure • deformation capacity of column is limited	• this failure occurs when minimum amount of lateral reinforcement is there but it is not adequate as per requirement • provides adequate lateral reinforcement as per requirement
Shear force	Diagonal compression	• compression failure of concrete takes place prior to the yielding of lateral reinforcement • vertical load carrying capacity of the column is lost, leading to the collapse	• this failure occurs when there is excessive amount of lateral reinforcement • only up to a limit the amount of lateral reinforcement is effective for shear resistance • provides lateral reinforcement as per requirements

Contd.

TABLE 29.2 Contd.

Action concern	*Failure mode*	*Description of failure*	*Suggested remedial measures*
Tensile stresses	Splice failure of longitudinal reinforcement	• splices in older buildings were located in region of higher tensile stress because the implications for earthquake performance were inadequately understood • splices failure reduces flexural resistance of the member	• splicing should be in a region of low tensile stress
Bond stresses	Bond splitting failure	• causes ring tension to the surrounding concrete • high flexural bond stresses may exist in members with steep moment gradient along their lengths • splitting cracks may develop along the longitudinal reinforcement, especially when the strength of concrete is low.	• longitudinal reinforcement of a column should be supported by closely spaced stirrups or ties • not provide large diameters of longitudinal bars with high strength, • provide sufficient concrete cover

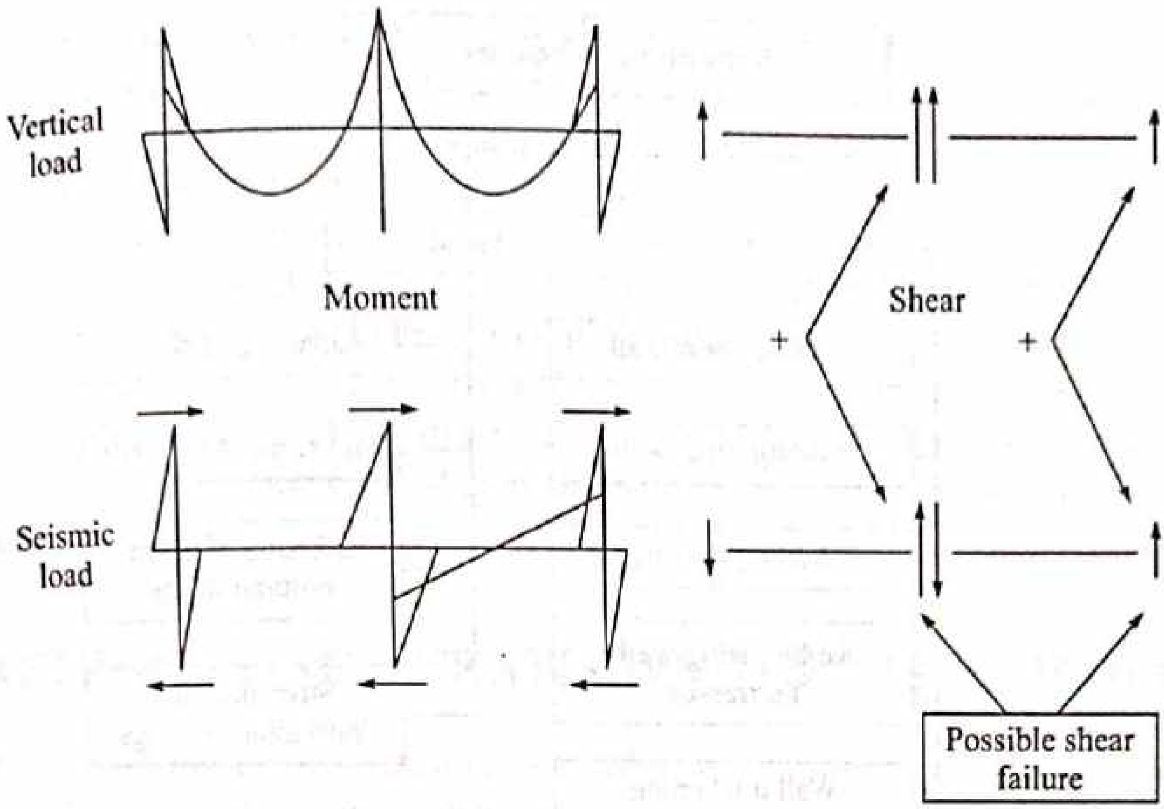


FIGURE 29.4 Behaviour of beams for vertical and seismic loading (Edoardo Cosenza and Gaetano Manfredi, 1997).

Slab

A shear failure has been observed in the case that the slab is resting directly on column capital without having any beam. The critical part of the flat plate slab system is the vertical shear transfer between the slab and column.

29.3.3 *Quality of Workmanship and Materials*

There are numerous instances where faulty construction practices and lack of quality control have contributed to the damage. The faulty construction practices may be like, lack of amount and detailing of reinforcement as per requirement of code particularly when the end of lateral reinforcement is not bent by 135 degrees as the code specified. Many buildings have been damaged due to poor quality control of design material strength as specified, spalling of concrete by the corrosion of embedded reinforcing bars, porous concrete, age of concrete, proper maintenance etc.

29.4 CLASSIFICATION OF RETROFITTING TECHNIQUES

There are two ways to enhance the seismic capacity of existing structures. The first is a structural-level approach of retrofitting which involves global modifications to the structural system. The second is a member level approach of retrofitting or local retrofitting which deals with an increase of the ductility of components with adequate capacities to satisfy their specific limit states. Based on the above concept the available techniques of retrofitting of reinforced concrete buildings may be classified as in Figure 29.5.

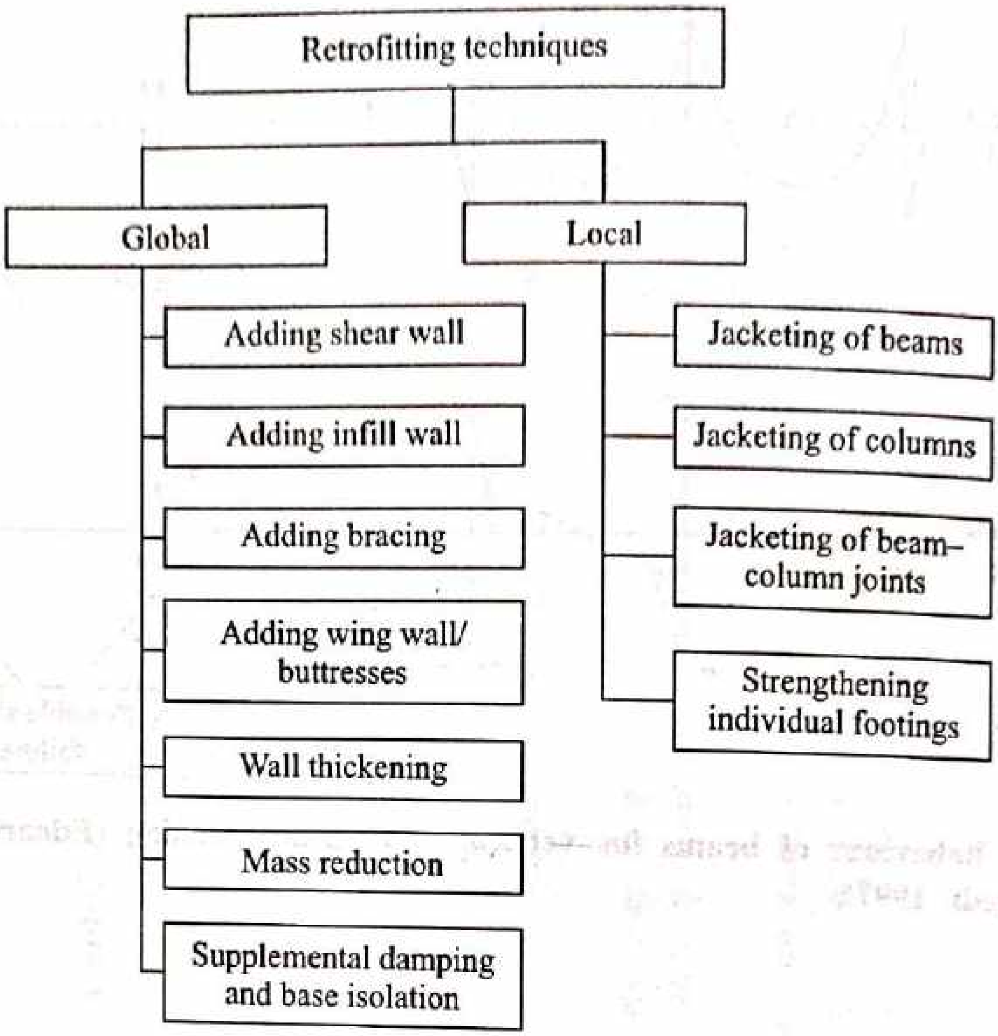


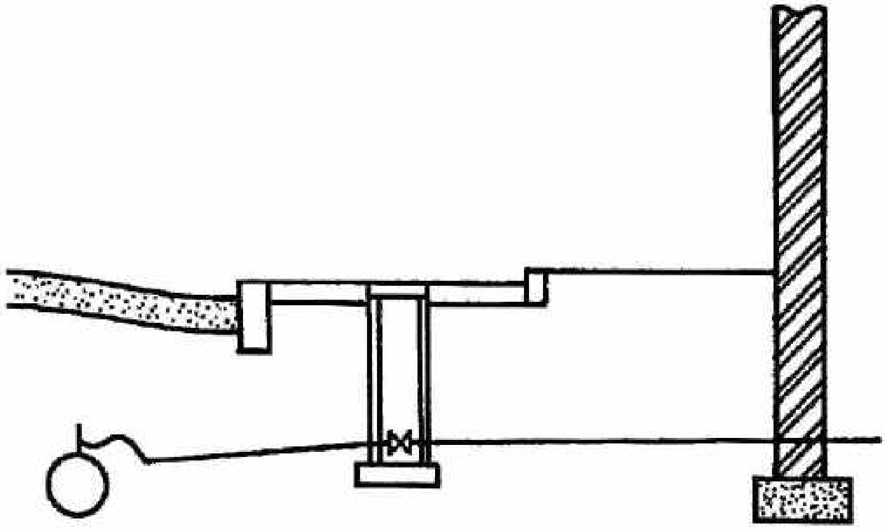
FIGURE 29.5 Global and local retrofitting methods.

Generally structural level retrofittings are applied when the entire structural lateral load resisting system is deemed to be deficient. Common approaches in this regard are employed to increase stiffness and strength with limited ductility. Achieving desired ratio between the additional stiffening and strengthening is the art of seismic retrofitting. The most common modifications include the addition of structural walls, steel braces, infill walls, base isolators or supplemental energy dissipation devices.

The addition of new reinforced concrete shear wall is the most oftenly practised device which has proved to be effective for controlling global lateral drifts and for reducing damage in frame members. Steel braces are used to make the existing buildings stiffen. Concentric or eccentric bracing schemes may be used, in the selected bays of an RC frame contributing to increase the lateral resistance of the structure. Infill wall may be employed for strengthening of reinforced concrete buildings, which has been effective in the case of one to three storey buildings that may be extended up to five stories. The lateral strength of existing columns can be increased by adding wing walls (side walls) or buttresses similar to infilling. These techniques are not so popular because it may require a vacant site around the building, and enough resistance from piles or foundation of the buttress (CEB, 1997). At some occasions it might be possible to achieve the retrofitting objectives by means of global mass reduction. Mass reduction can be accomplished by removal of upper stories, heavy cladding, partitions and stored good. Increasing the strength or stiffness of structural members such as slabs and shear wall can be achieved by thickening of members. The concept of seismic base isolation is based on decoupling of structure by introducing low horizontal stiffness bearing between the structure and the foundation. This is found to be efficient for seismic protection of historical buildings where superstructure has a limited seismic resistance and intervention is required only at foundation level. The supplemental damping devices such as addition of viscous damper, visco-elastic damper, frictional damper in diagonals of bays of frame substantially reduces the earthquake response by dissipation of energy.

Local retrofittings are typically used either when the retrofit objectives are limited or direct treatment of the vulnerable components is needed. The most popular and frequently used method in local retrofitting is **jacketing** or **confinement** by the jackets of reinforced concrete, steel, fibre reinforced polymer (FRP), carbon fibre etc. Jacketing around the existing members increases lateral load capacity of the structure in a uniformly distributed way with a minimal increase in loading on any single foundation and with no alternative in the basic geometry of the building.

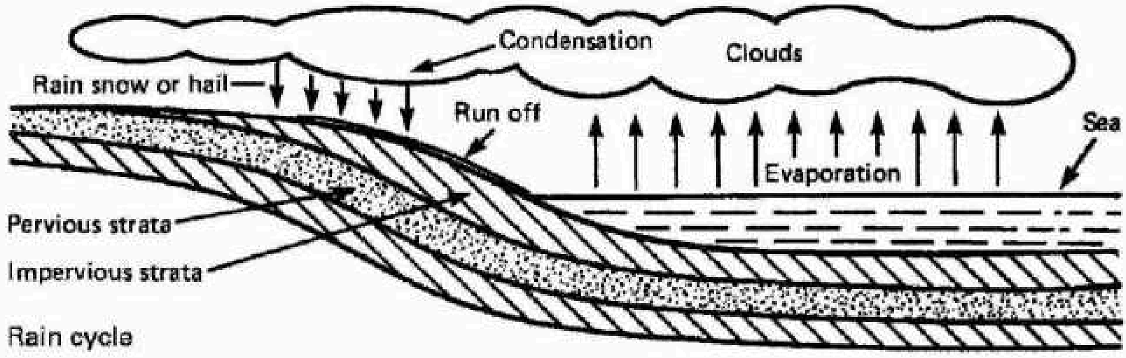
1 COLD WATER AND SUPPLY SYSTEMS



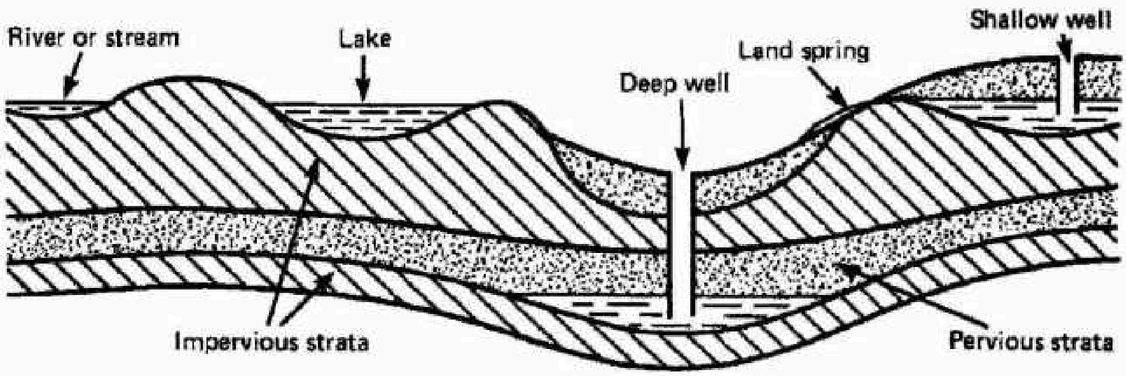
RAIN CYCLE – SOURCES OF WATER SUPPLY
ACIDITY AND ALKALINITY IN WATER
FILTRATION OF WATER
STERILISATION AND SOFTENING
STORAGE AND DISTRIBUTION OF WATER
VALVES AND TAPS
JOINTS ON WATER PIPES
PIPE JOINTING MATERIALS
WATER MAINS
DIRECT SYSTEM OF COLD WATER SUPPLY
INDIRECT SYSTEM OF COLD WATER SUPPLY
BACKFLOW PROTECTION
SECONDARY BACKFLOW PROTECTION
COLD WATER STORAGE CISTERNS
COLD WATER STORAGE CALCULATIONS
BOOSTED COLD WATER SYSTEMS
DELAYED ACTION FLOAT VALVE
PIPE SIZING BY FORMULA
PIPE SIZES AND RESISTANCES
HYDRAULICS AND FLUID FLOW

Surface sources – Lakes, streams, rivers, reservoirs, run off from roofs and paved areas.

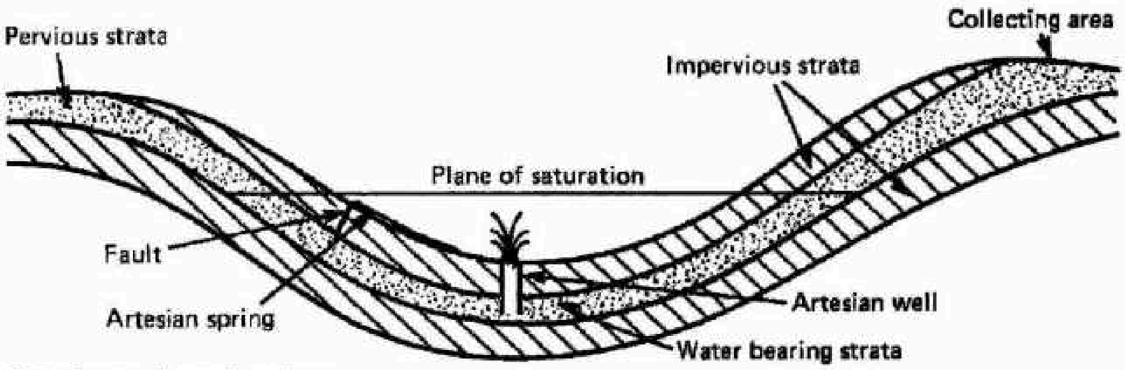
Underground sources – Shallow wells, deep wells, artesian wells, artesian springs, land springs.



Rain cycle



Surface and normal underground supplies



Artesian wells and springs

Acid – a substance containing hydrogen which can be replaced by other elements. Litmus paper in the presence of acidic water turns red.

Alkali – a substance which will neutralise acid by accepting its hydrogen ions (H^+). Litmus paper in the presence of alkaline water turns blue.

More accurate definitions can be obtained by using hydrochemical electric metres. These measure the amount of hydrogen ions (H^+) in a relative proportion of water. This measure of acidity or alkalinity in solution is referred to numerically from 0–14 as the pH value.

- pH $<$ 7 indicates acidity
- pH $>$ 7 indicates alkalinity
- pH = 7 chemically pure

The quality of processed water is unlikely to be pure due to contamination at source.

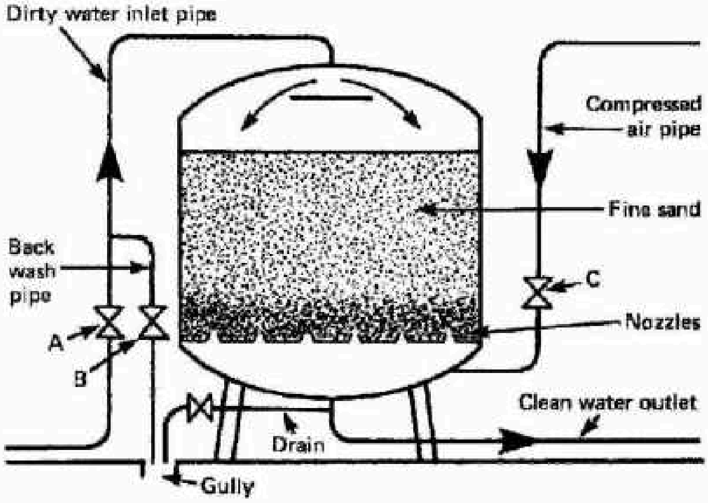
Rainwater – contaminated by suspended impurities as it falls through the air. These impurities are principally carbon dioxide, sulphur and nitrous oxides originating from domestic flue gases and industrial manufacturing processes. The mixture of these impurities and rainfall produce 'acid rain', an occurrence frequently blamed for the destruction of plant life.

Surface and substrata water sources – contaminated by dissolved inorganic materials such as calcium, magnesium and sodium. These are responsible for water hardness as described on pages 5 and 17. Organic matter from decaying vegetation, animals and untreated waste water can also contaminate ground water supplies. These are normally associated with ammonia compounds in the water or bacteria. Certain types of bacteria present in water can be responsible for outbreaks of typhoid, cholera and dysentery. Chlorination, as described on page 5 is applied to filtered water to destroy any remaining bacterial microbes before general distribution through service reservoirs and mains.

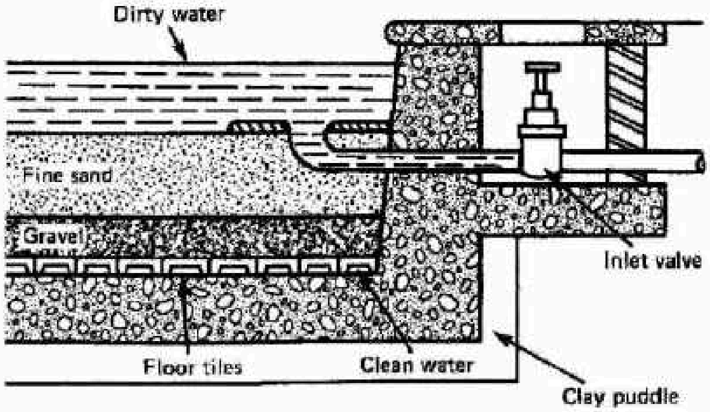
The following table shows the quantity of pollutant microbes present during the stages of water processing, as described on pages 4–6:

Source/process	Typical pollutant microbe count per litre
River	41000
Impounding reservoir	1500
Primary filter	500
Secondary filter	50
Chlorination	0
Service reservoir	0
Distribution main	0

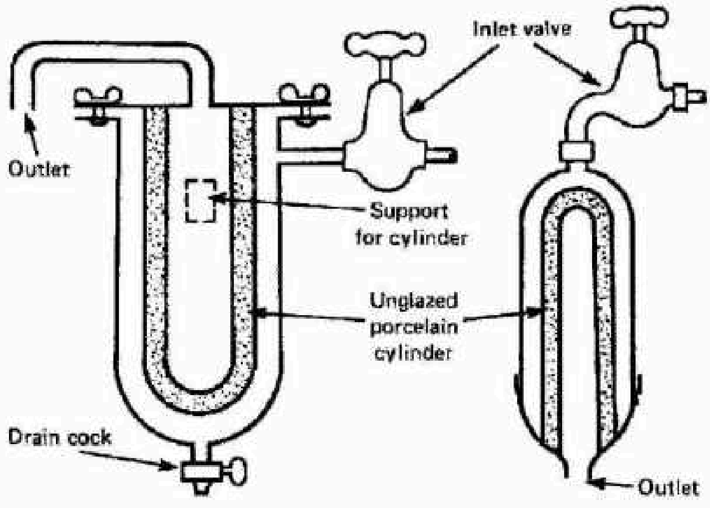
Pressure filter – rate of filtration 4 to 12 m^3 per m^2 per hour. To backwash, valve A is closed and valves B and C opened. Compressed air clears the sand of dirt. Diameter = 2·4 m.



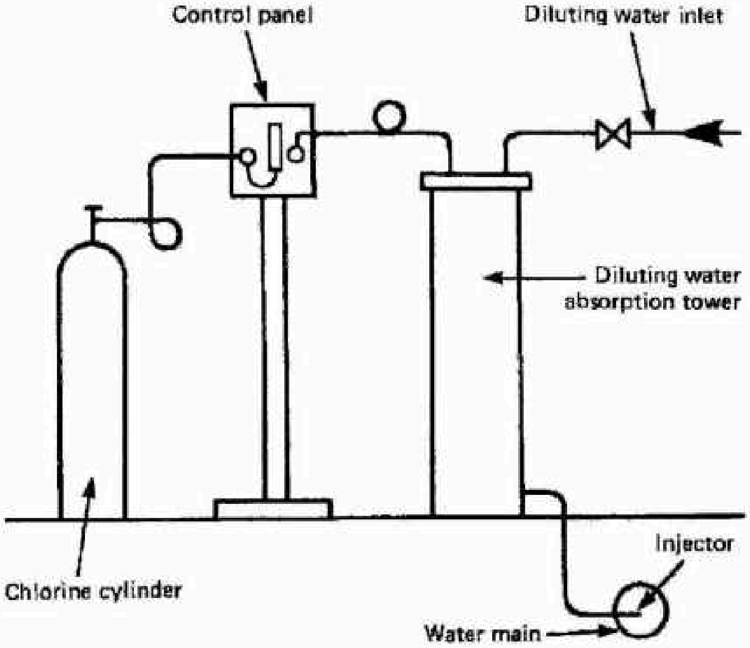
Slow sand filter bed – rate of filtration 0·2 to 1·15 m^3 per m^2 per hour. Filter beds can occupy large areas and the top layer of sand will require removal and cleaning at periodic intervals.



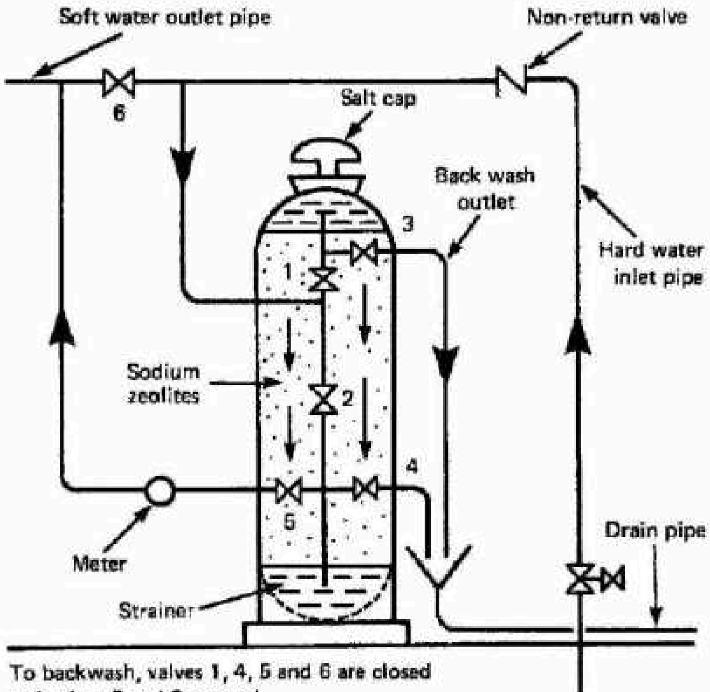
Small domestic filter – the unglazed porcelain cylinder will arrest very fine particles of dirt and even micro-organisms. The cylinder can be removed and sterilised in boiling water for 10 minutes.



Sterilisation by chlorine injection – water used for drinking must be sterilised. Chlorine is generally used for this purpose to destroy organic matter. Minute quantities (0·1 to 0·3 p.p.m.) are normally added after the filtration process.

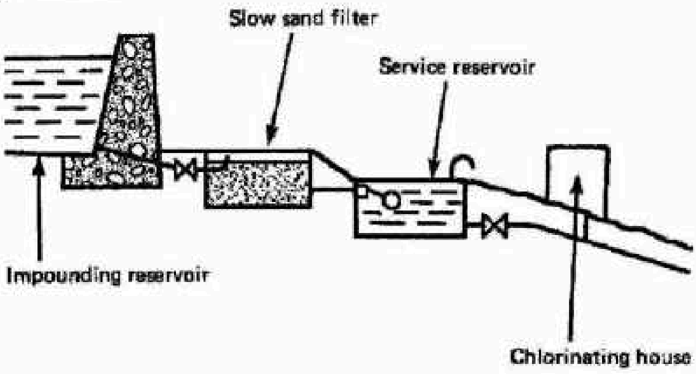


Softening of hard water by base exchange process – sodium zeolites exchange their sodium base for calcium (chalk) or magnesium bases in the water. Sodium zeolite plus calcium carbonate or sulphate becomes calcium zeolite plus sodium carbonate or sulphate. To regenerate, salt is added; calcium zeolite plus sodium chloride (salt) becomes sodium zeolite plus calcium chloride which is flushed away.

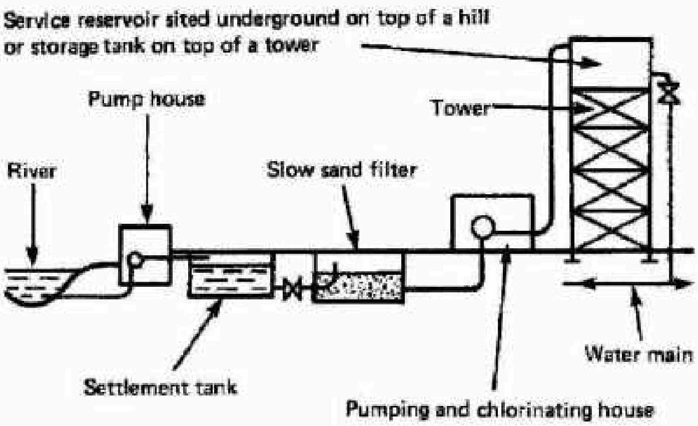


To backwash, valves 1, 4, 5 and 6 are closed and valves 2 and 3 opened

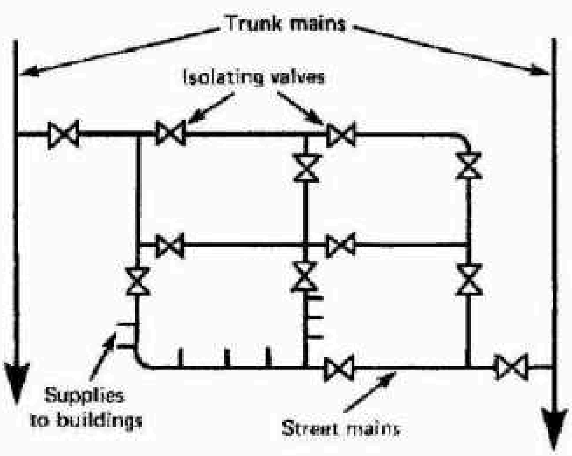
Gravitational distribution – the water from upland gathering grounds is impounded in a reservoir. From this point the water is filtered and chlorinated before serving an inhabited area at lower level. There are no pumping costs.



Pumped distribution – water extracted from a river is pumped into a settlement tank, subsequently filtered and chlorinated. Pump maintenance and running costs make this process more expensive than gravity systems.



Ring main distribution – water mains supplying a town or village may be in the form of a grid. This is preferable to radial distribution as sections can be isolated with minimal disruption to the remaining system and there is no more opportunity for water to maintain a flow.

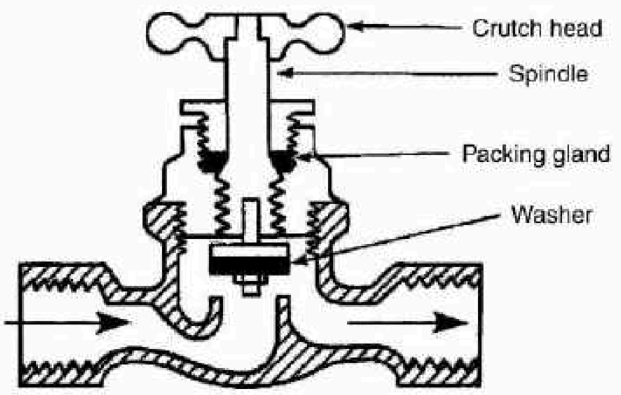


The globe-type stop valve is used to control the flow of water at high pressure. To close the flow of water the crutch head handle is rotated slowly in a clockwise direction gradually reducing the flow, thus preventing sudden impact and the possibility of vibration and water hammer.

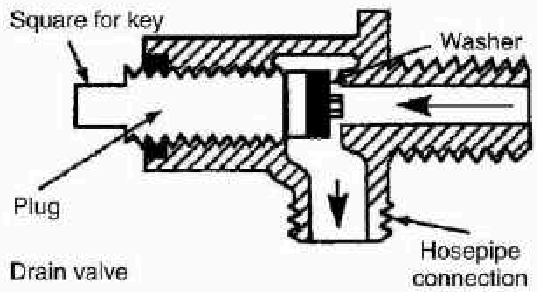
The gate or sluice valve is used to control the flow of water on low pressure installations. The wheel head is rotated clockwise to control the flow of water, but this valve will offer far less resistance to flow than a globe valve. With use the metallic gate will wear and on high pressure installations would vibrate.

The drain valve has several applications and is found at the lowest point in pipe systems, boilers and storage vessels.

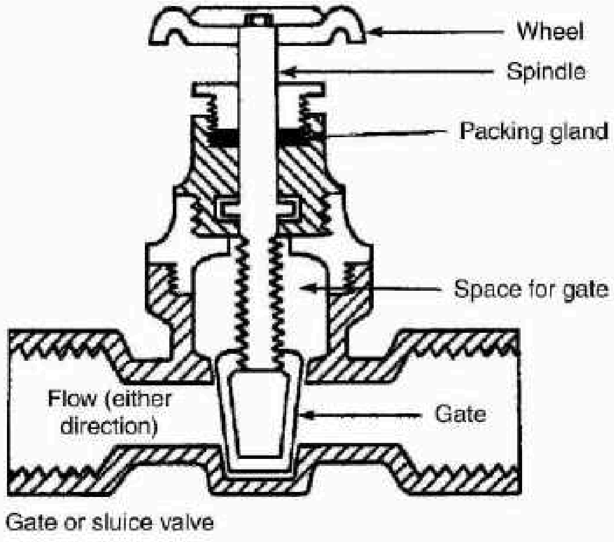
For temperatures up to 100°C valves are usually made from brass. For higher temperatures gun metal is used. Brass contains 50% zinc and 50% copper. Gun metal contains 85% copper, 5% zinc and 10% tin.



Stop valve (globe type)

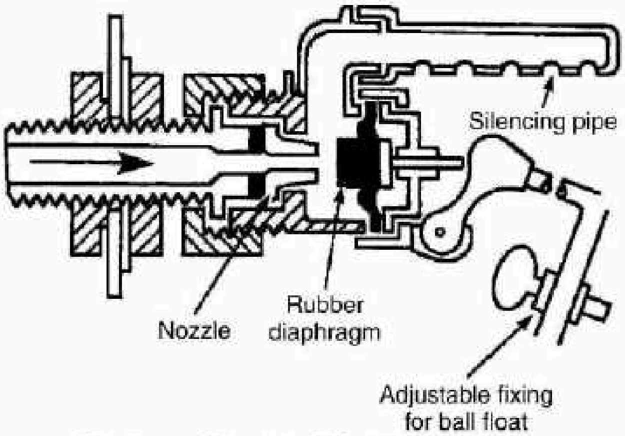


Drain valve

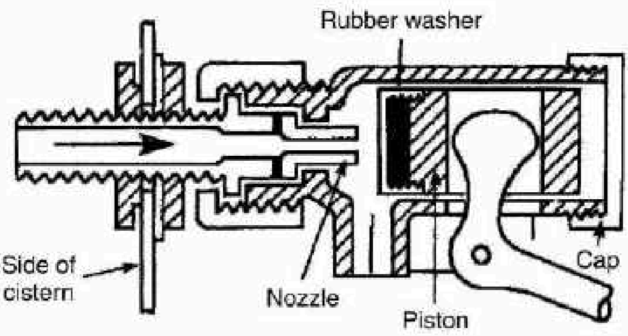


Gate or sluice valve

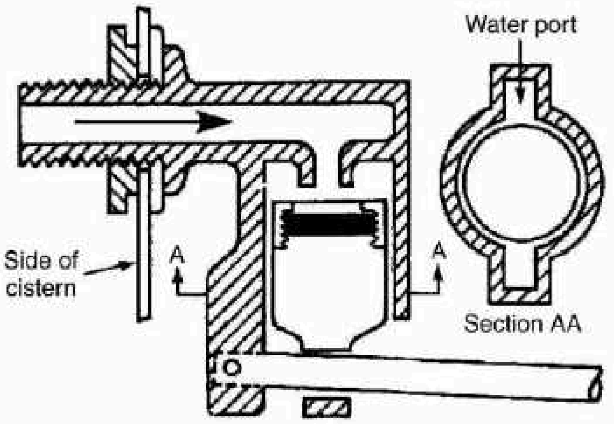
Float valves are automatic flow control devices fitted to cisterns to maintain an appropriate volume of water. Various types are in use. The diaphragm type is the least noisy as there is less friction between moving parts. The Portsmouth and Croydon-type valves have a piston moving horizontally or vertically respectively, although the latter is obsolete and only likely to be found in very old installations. Water outlets must be well above the highest water level (see page 19) to prevent back siphonage of cistern water into the main supply. Nozzle diameters reduce as the pressure increases. High, medium and low pressure valves must be capable of closing against pressures of 1380, 690 and 275 kPa respectively.



Diaphragm float valve BS 1212–2 and 3



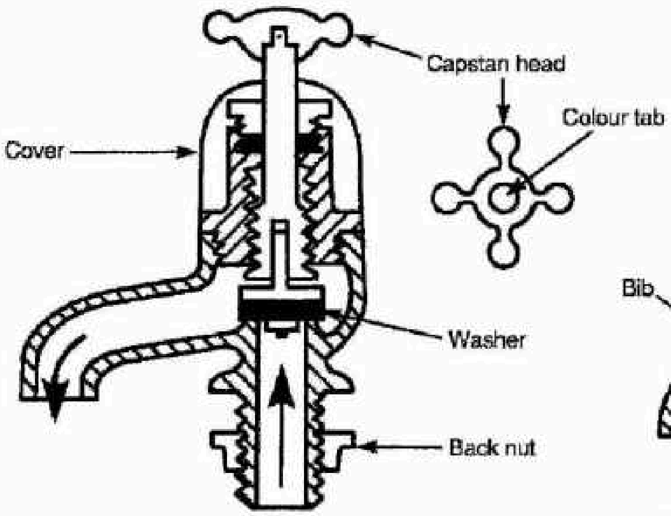
Portsmouth/piston float valve BS 1212–1



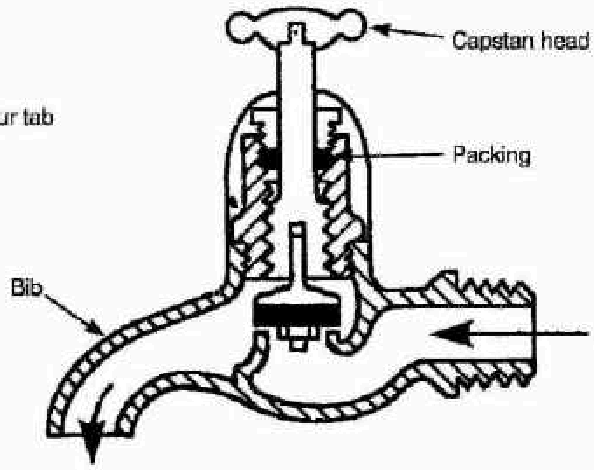
Croydon float valve

The pillar tap is used to supply water to basins, baths, bidets and sinks. Combined hot and cold pillar taps are available with fixed or swivel outlet. The outlet of these taps must be bi-flow, i.e. separate waterways for hot and cold water to prevent crossflow of water within the pipework.

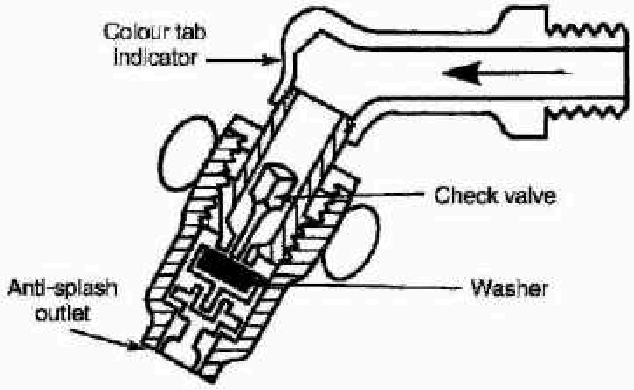
The bib tap is for wall fixing, normally about 150 mm above a sanitary appliance. The 'Supatap' bib tap permits a change of washer without shutting off the water supply. It is also available in pillar format. Quarter-turn taps are easy to operate by hand or elbow, therefore are suitable for use by the disabled and medical practitioners.



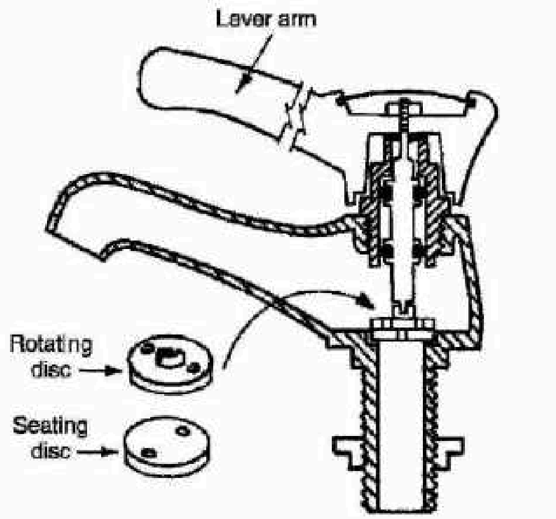
Pillar tap



Conventional bib tap



'Supatap' bib tap



Quarter-turn ceramic disc pillar tap

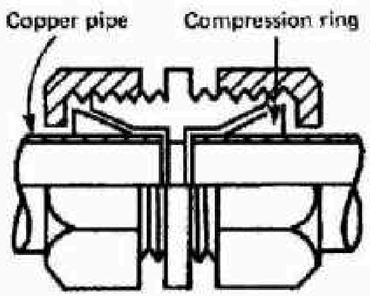
Joints on Water Pipes

Copper pipes may be jointed by bronze welding. Non-manipulative compression joints are used on pipework above ground and manipulative compression joints are used on underground pipework. The latter are specifically designed to prevent pipes pulling out of the joint. Push-fit joints are made from polybutylene. These provide simplicity of use and savings in time. Capillary joints have an integral ring of soft solder. After cleaning the pipe and fitting with wire wool and fluxing, heat application enables the solder to flow and form a joint. Solder alloy for drinking water supplies must be lead free, i.e. copper and tin.

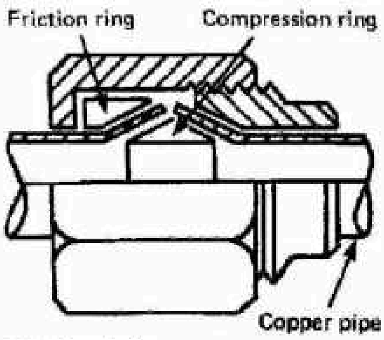
The Talbot joint is a push-fit joint for polythene pipes. A brass ferrule or support sleeve in the end of the pipe retains the pipe shape.

Threaded joints on steel pipes are sealed by non-toxic jointing paste and hemp or polytetrafluorethylene (PTFE) tape. A taper thread on the pipe will help to ensure a water-tight joint. Union joints permit slight deflection without leakage.

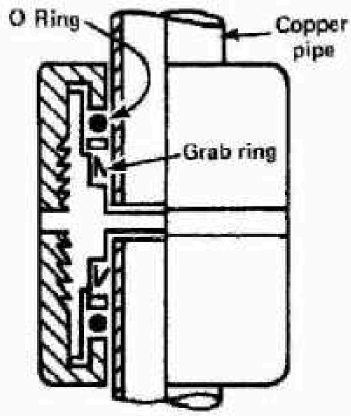
Lead pipes are no longer acceptable due to the risk of poisoning.



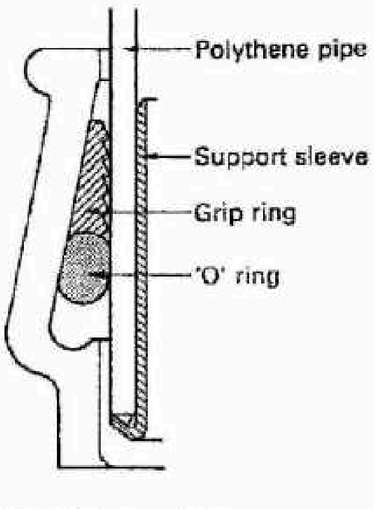
Non-manipulative compression joint on copper pipes



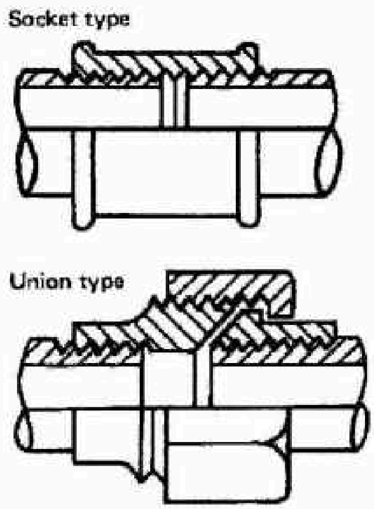
Manipulative compression joint on copper pipes



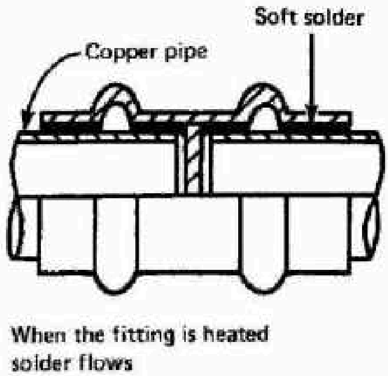
Acorn push-fit joint on copper pipes



The Talbot push-fit joint on polythene pipes



Screwed joints on mild steel pipes



When the fitting is heated solder flows

Soft soldered capillary joint on copper pipes

Linseed oil 'white' jointing paste – a blend of linseed oil and clay which surface hardens to form a strong, dense joint. Used mainly on threaded steel pipework with fibrous hemp reinforcement between the threads. Microbial action can break down the linseed component and the hemp can degrade, therefore not recommended for use on drinking water supplies. Synthetic reinforcement fibres are more durable. Unreinforced paste is suitable for gas and steam pipe lines. Graphite is sometimes added to the paste for use on steam, as this eases joint breakage when undertaking maintenance and alterations. A manganese additive for use on steam pipes provides greater strength.

Silicone oil jointing paste – otherwise known as acetosilane. Combined with synthetic reinforcement fibres, this compound may be used on drinking water supplies. It is also suitable for jointing hot water and gas pipes. Non-setting, non-cracking and flexible, therefore easily broken for maintenance and alterations.

BS 6956-5: Jointing materials and components

Resin-based compounds – these are specified for chemical and oil pipe joints where the liquid conveyed may contain solvents which could weaken oil-based sealants. Resin and fillers are mixed with a catalyst and after application to pipe threads, tightened joints will require time to set.

PTFE tape – wound into threads prior to joint tightening. Chemical and temperature resistant with an element of flexibility. Suitable for water and gas pipe joints. Also available as a liquid, but relatively expensive.

BS 7786: Specification for unsintered PTFE tape

BS EN 751-3: Sealing materials for metallic threaded joints

Solders and fluxes – the established method for economically jointing copper pipe and fittings. Solder types:

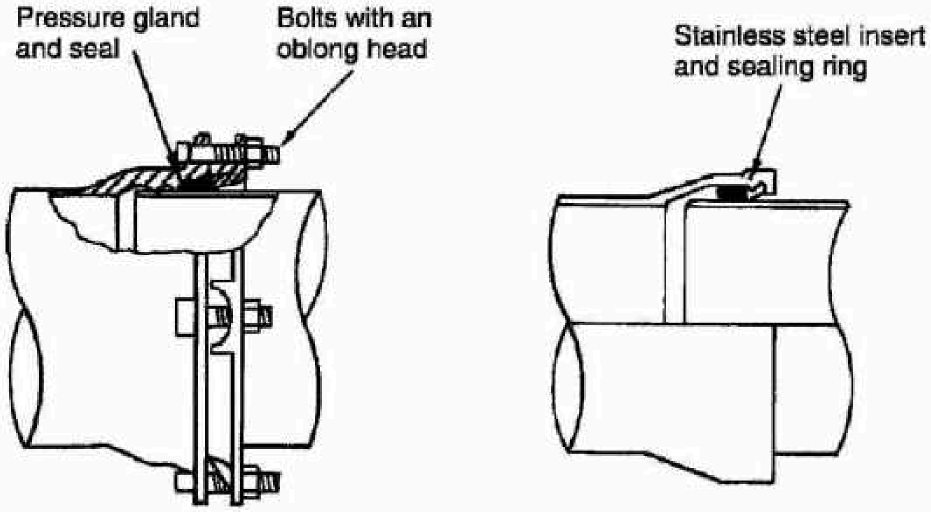
- 29% tin + 71% lead. Traditionally used for all joints but now prohibited on drinking water supplies because of the lead content. Melting point = 210°C.
- 63% tin + 37% lead. Bit solder for electronic applications. Melting point = 185°C.
- 99% tin + 1% copper. Lead-free for drinking water supplies. Melting point = 235°C.

BS 6920: Suitability of non-metallic products in contact with water.

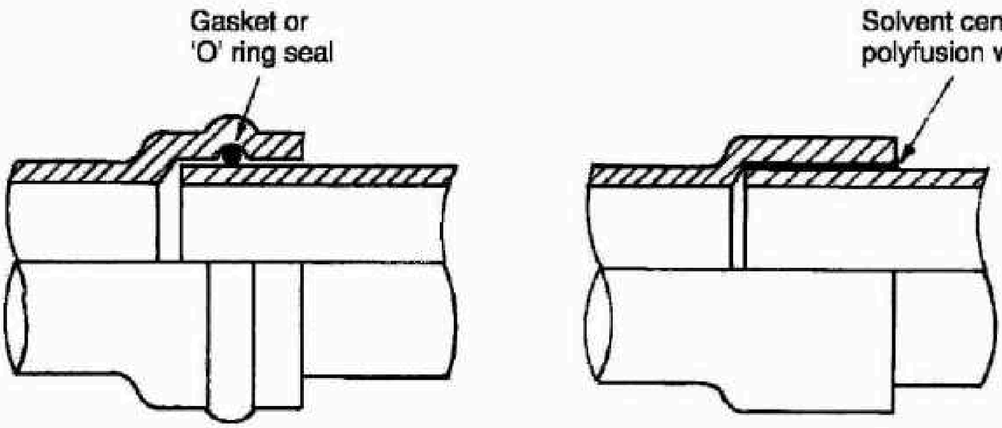
BS EN 29453: Soft solder alloys. Chemical compositions and forms.

Fluxes are classified as passive or self-cleaning. They are available in liquid or paste format and function by preventing cleaned surfaces tarnishing under heat. Passive fluxes do not contain any free acid and will require heat application to effect cleaning. These are generally known as water soluble organic fluxes and are the preferred choice by gas companies due to the flux's non-corrosive properties. Water-soluble fluxes are also preferred for use with lead-free solders and are easily cleaned from finished joints. Self-cleansing fluxes contain an acid, usually hydrochloric. This type of flux begins to clean tarnished copper as soon as applied. Heat application accelerates the process. Any flux residue must be cleaned from the pipe surface to prevent corrosion. Deposits internally are removed by flushing the system.

Water mains have been manufactured from a variety of materials. The material selected must be compatible with the water constituents, otherwise corrosion and decomposition of the pipes may occur. Contemporary materials which suit most waters are ductile cast iron to BS EN 545 and uPVC to BS EN 1452-2. The water undertaking or authority must be consulted prior to laying mains to determine suitable materials, laying techniques and pipe diameter. Firefighting and hydrant requirements will prioritise the criteria with a minimum pressure of 30 m head (300 kPa) from a 75 mm diameter pipe supplied from both ends, or 100 mm diameter from one end only. Bedding of mains is usually a surround of shingle to accommodate any movement. uPVC pipes are pigmented blue for easy identification in future excavations and cast iron has a blue plastic tape attached for the same reason.

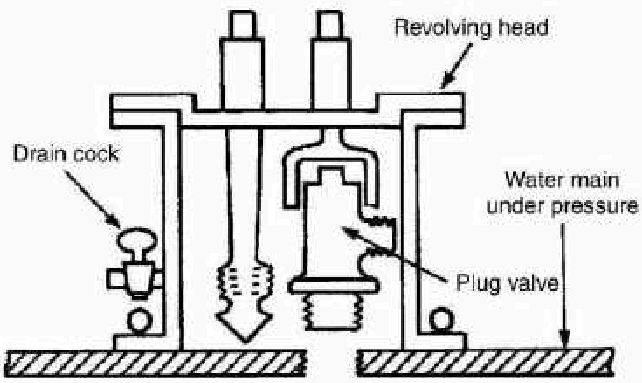


CAST IRON

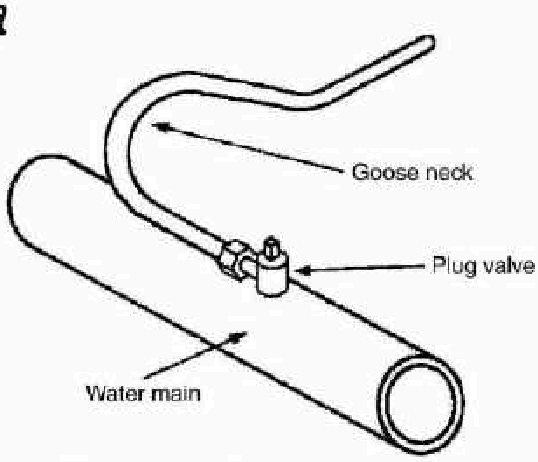


uPVC

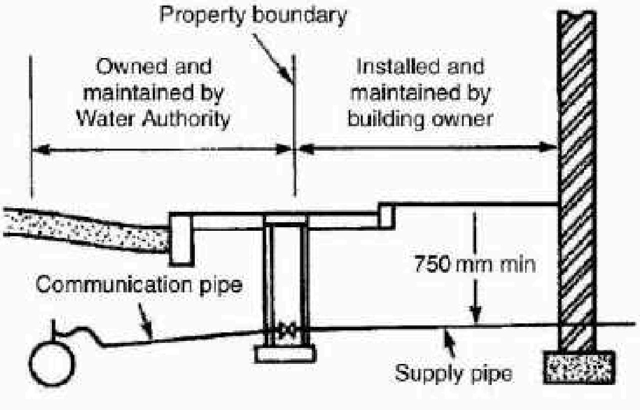
The water authority requires at least 7 days' written notice for connection to their supply main. The main is drilled and tapped live with special equipment, which leaves a plug valve ready for connection to the communication pipe. A goose neck or sweeping bend is formed at the connection to relieve stresses on the pipe and valve. At or close to the property boundary, a stop valve is located with an access compartment and cover at ground level. A meter may also be located at this point. The communication and supply pipe should be snaked to allow for settlement in the ground. During warm weather, plastic pipes in particular should be snaked to accommodate contraction after backfilling.



Tapping of water main

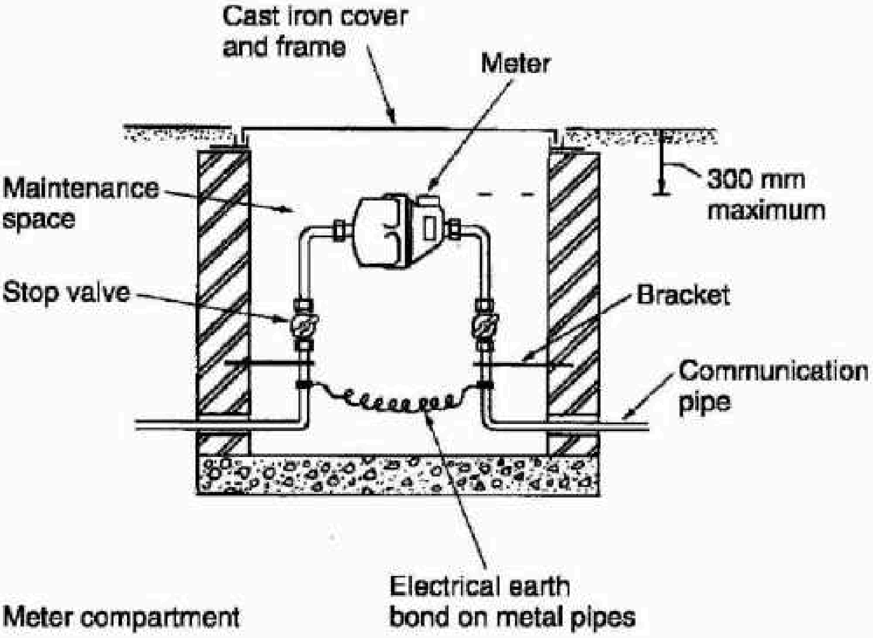


View of water main connection

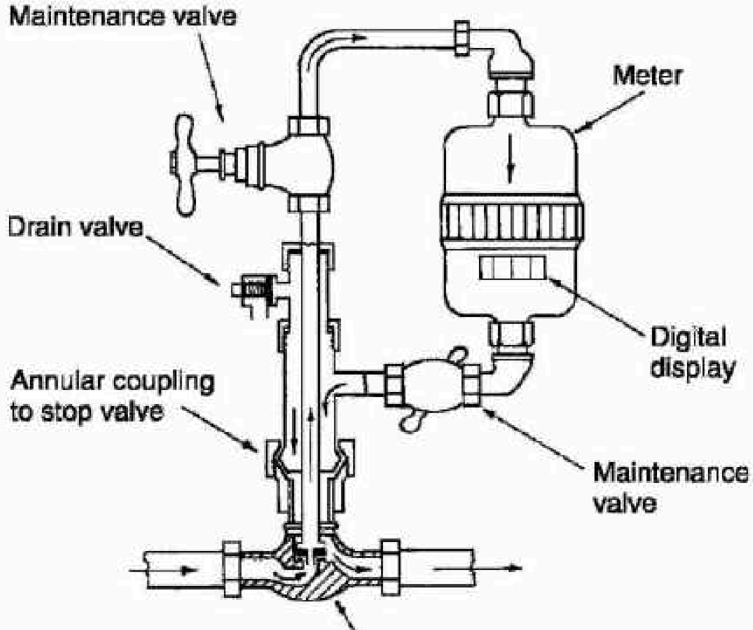


Detail of supply to building

Water meters are installed at the discretion of the local water authority. Most require meters on all new build and conversion properties, plus existing buildings which have been substantially altered. In time, in common with other utilities, all buildings will have metered water supply. Meters are either installed in the communication pipe, or by direct annular connection to the stopvalve. If underground location is impractical, the water authority may agree internal attachment to the rising main.



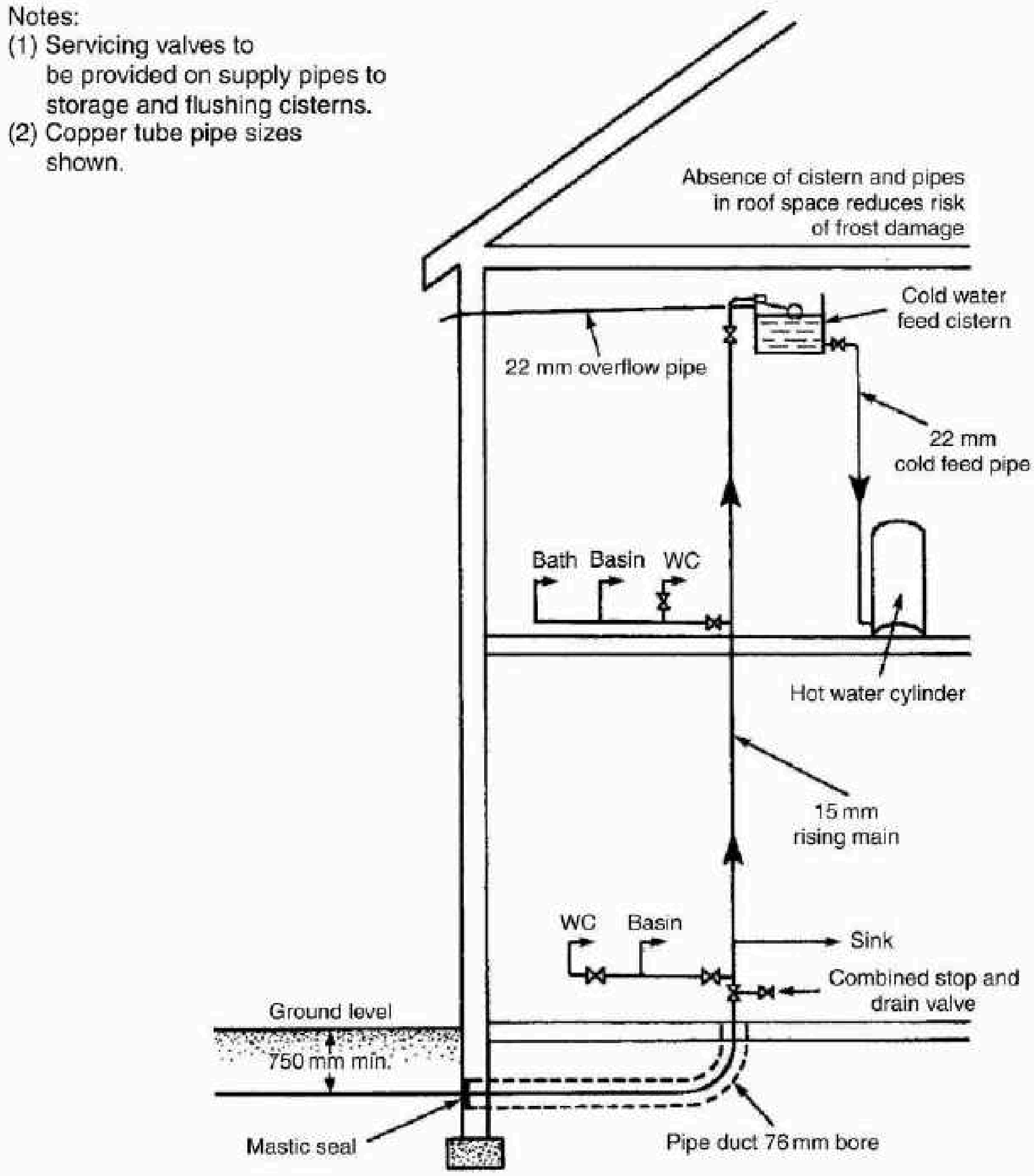
Meter compartment



Patent meter connection

For efficient operation, a high pressure water supply is essential particularly at periods of peak demand. Pipework is minimal and the storage cistern supplying the hot water cylinder need only have 115 litres capacity. The cistern may be located within the airing cupboard or be combined with the hot water cylinder. Drinking water is available at every draw-off point and maintenance valves should be fitted to isolate each section of pipework. With every outlet supplied from the main, the possibility of back siphonage must be considered.

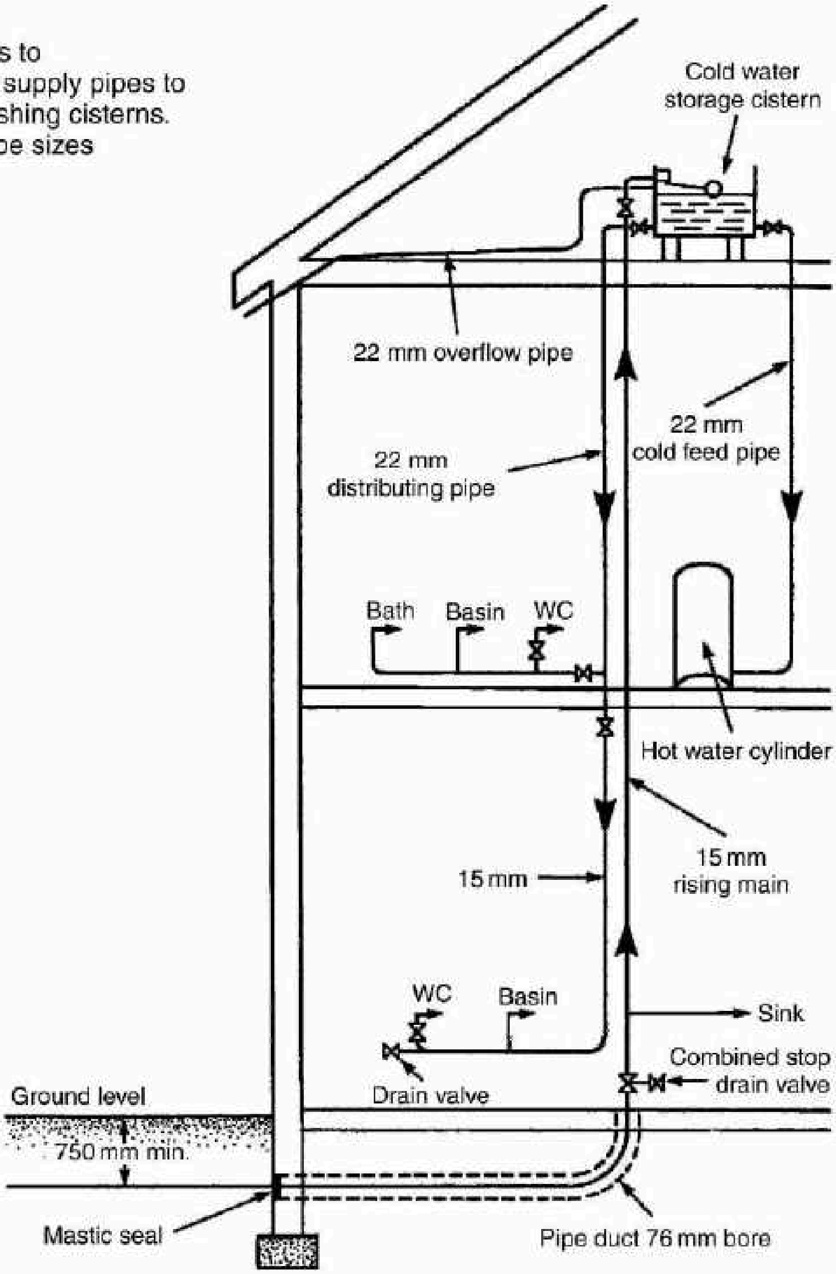
Back siphonage can occur when there is a high demand on the main. Negative pressure can then draw water back into the main from a submerged inlet, e.g. a rubber tube attached to a tap or a shower fitting without a check valve facility left lying in dirty bath water.



Ref.: The Water Supply (Water Fittings) Regulations 1999.

The indirect system of cold water supply has only one drinking water outlet, at the sink. The cold water storage cistern has a minimum capacity of 230 litres, for location in the roof space. In addition to its normal supply function, it provides an adequate emergency storage in the event of water main failure. The system requires more pipework than the direct system and is therefore more expensive to install, but uniform pressure occurs at all cistern-supplied outlets. The water authorities prefer this system as it imposes less demand on the main. Also, with fewer fittings attached to the main, there is less chance of back siphonage. Other advantages of lower pressure include less noise and wear on fittings, and the opportunity to install a balanced pressure shower from the cistern.

Notes:
(1) Servicing valves to be provided on supply pipes to storage and flushing cisterns.
(2) Copper tube pipe sizes shown.



Ref.: The Water Supply (Water Fittings) Regulations 1999.

See also page 5.

Hardness in water occurs when calcium or magnesium salts are present. This is most common where water extraction is from boreholes into chalky strata or chalky aquifers.

Measurement

- Parts per million (ppm), i.e. milligrams per litre (mg/l) e.g.

Location	Typical ppm
Bristol	300
Cardiff	100
Hartlepool	460
London	285
Manchester	<60
Newcastle	160
Scotland	<50

For a general guide to England and Wales, see map on next page.

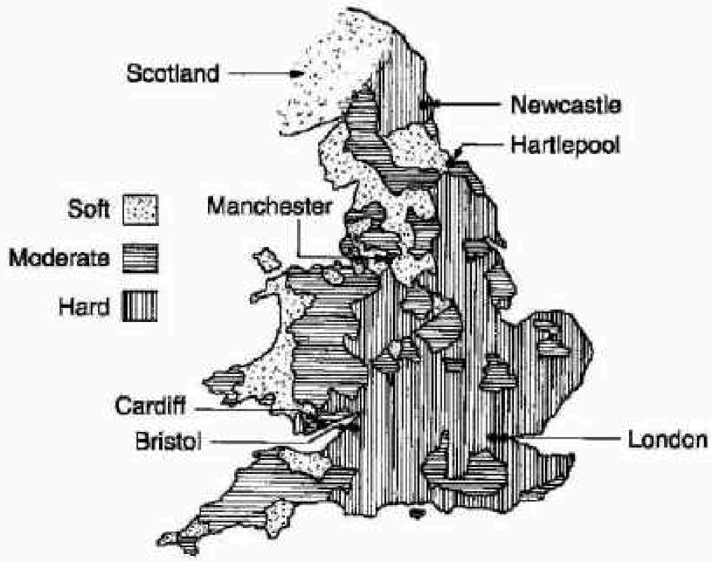
- Clarke's scale – a numerical classification, sometimes referred to as degrees Clarke.

Classification

Type of water	Clarkes	Approx. ppm
Soft	<3.5	<50
Moderately soft	3.5–7.0	50–100
Slightly hard	7.0–10.5	100–150
Moderately hard	10.5–14.0	150–200
Hard	14.0–21.0	200–300
Very hard	>21.0	>300

1 degree Clarke is about 1 part per 70 000.

When hard water is heated, the dissolved salts change to solids and deposit on the linings of pipework, boilers and other ancillaries. Kettle scale is an obvious example, but far more significant is its efficiency reduction of hot water and central heating plant. If enough scale is deposited, pipework systems can become completely blocked or 'furred up'. This can have explosive consequences, as safety valves will also be affected. Chalk build up normally takes years, but in very hard water areas, it may be just a few months depending on the frequency of plant use. Hence the limitations of direct hot water systems (see page 37) where fresh water is continually introduced. Direct systems are only applicable where water hardness is less than 150 ppm and water temperatures do not exceed 65°C. The water temperature in modern hot water and heating systems exceeds 80°C, therefore direct systems are effectively obsolete in favour of indirect installations, (see page 38). Indirect systems have the same water circulating throughout the primary and heating pipework and it is only drained off during maintenance and repair.

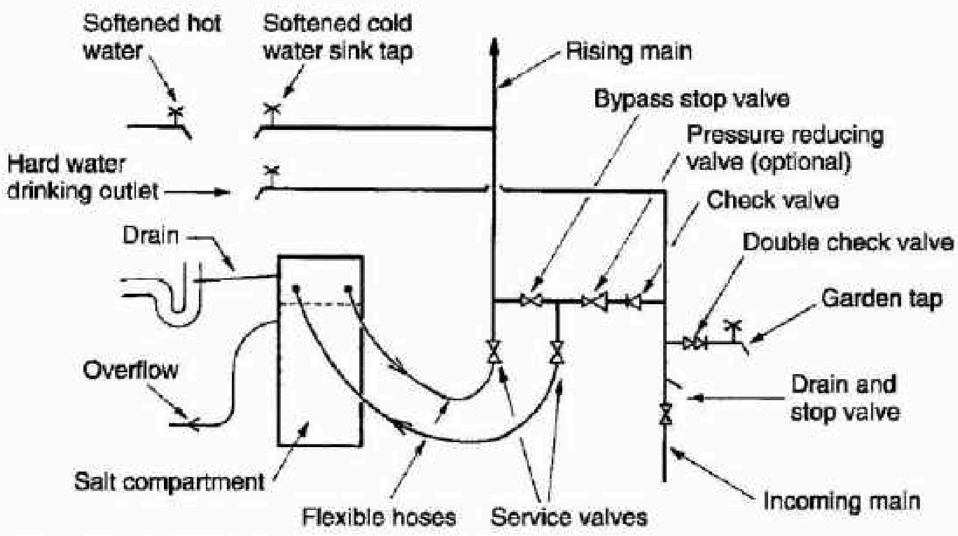


Guide to water hardness in England and Wales

Characteristics of hard water are:

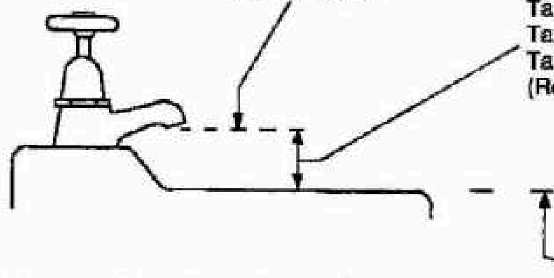
- difficult to create a lather with normal soap
- scum and tide marks in baths and basins
- chalk staining or streaking on washed glassware.

In hard water areas, these problems can be overcome with the installation of a water softener. These devices are relatively compact and will fit conveniently within the housing under a domestic sink. This location is ideal, as the housing will normally accommodate the rising water main and stop valve. It also provides simple access for replacement of salt granules or blocks. The unit contains a resin bed of sodium chloride or common salt. The salt exchanges calcium and magnesium ions for non-scale-forming sodium ions. Regeneration can be by electric timer, but most domestic softeners have an integral water volume metering device.



Typical installation of a domestic water softener

Domestic sanitary appliances – all potable (drinkable) water supplies must be protected against pollution by backflow or back siphonage from water that could be contaminated. Protection is effected by leaving sufficient space or air gap between the lowest point of the control device or tap discharge and the appliance spill over level.



Air gap to domestic sanitary appliances

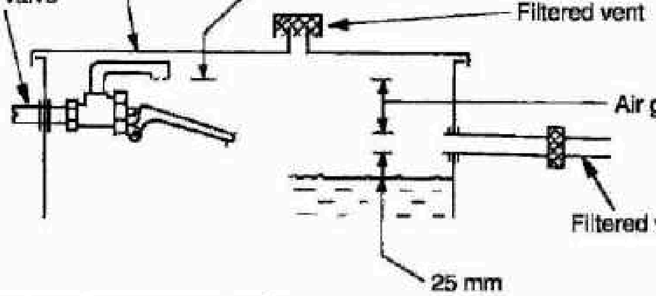
British Standard determination of air gap to domestic sanitary appliances:

- Single feed pipe, i.e. one tap, air gap ⩾20 mm or 2 × internal diameter of tap orifice (take greater value).
- Multiple feed pipe, i.e. hot and cold taps, air gap ⩾20 mm or 2 × sum of orifice diameters (take greater value).

For example, a bath with two taps of 20 mm internal diameter inlet orifice:

20 mm or 2 × (20 + 20 mm) = 80 mm. Air gap = 80 mm minimum.

Water cisterns or storage vessels – pipework supplying potable water must discharge into an unobstructed air gap between the regulating device water inlet to the vessel and the overflow or warning pipe.



Air gap to water storage vessels

In this situation the air gap should be ⩾20 mm or 2 × internal diameter of the regulating valve inlet orifice (take greater value).

For example, a 20 mm internal diameter orifice:

20 mm or 2 × 20 mm = 40 mm. Air gap = 40 mm minimum.

Refs: Water Supply (Water Fittings) Regulations.

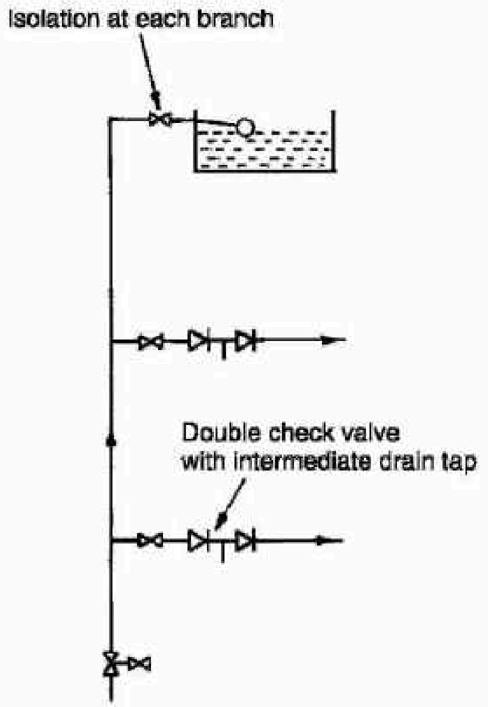
BS EN 1717: Protection against pollution of potable water in water installations and general requirements of devices to prevent pollution by backflow.

Secondary Backflow Protection

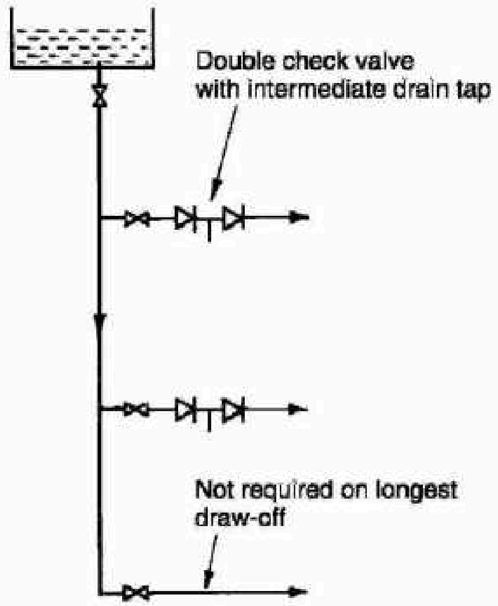
Secondary backflow or back siphonage protection is an alternative or supplement to the provision of air gaps. It is achieved by using mechanical devices such as double check valves or a vacuum breaker in the pipeline. Special arrangements of pipework with branches located above the spill level of appliances are also acceptable.

Ref: BS 6282. Devices with moving parts for the prevention of contamination of water by backflow.

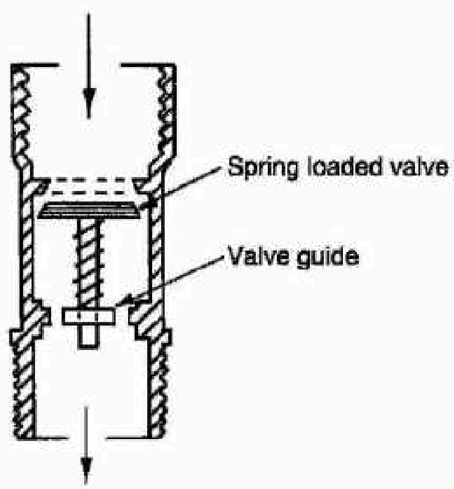
Typical applications – primary heating circuits, washing machines and garden taps.



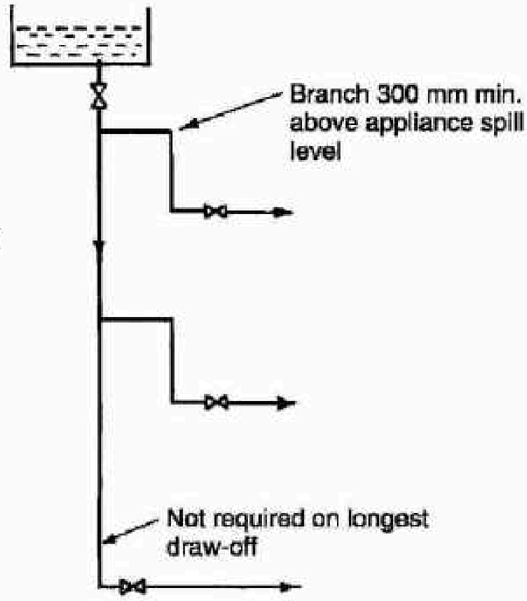
Direct mains water supply



Gravity distribution



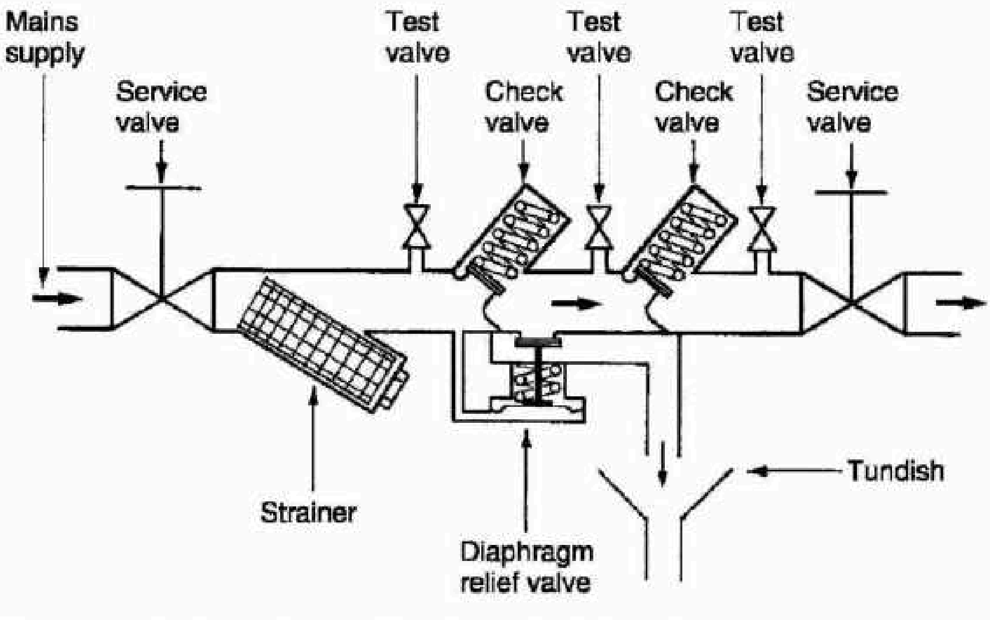
Check valve



Gravity distribution (alternative)

Mains water supply to commercial and industrial premises must be protected against the possibility of contamination by backflow. Where toxic processes exist, e.g. dyeing, chemical manufacture, insecticide preparation, car washing, irrigation systems, etc., it is imperative that the effects of a pressure reduction on drinking water supplies be contained.

Contamination of domestic water supply situations is prevented by installing double check valves to appliances or systems which could be a risk. In the interests of public health, the water authorities require greater security measures on mains supplies to industrial processes. Hitherto, a device containing two check valves with an intermediate pressure relief valve discharging visibly to a tundish has been considered adequate. Current requirements include a modification to verify or check through test points that the fitting is functioning correctly. This modified device is known as a 'Verifiable backflow preventer with reduced pressure zone'. It contains three pressure zones separated by differential obturators (two positively loaded check valves). Each pressure zone has a test point to verify that the valve is functioning correctly.



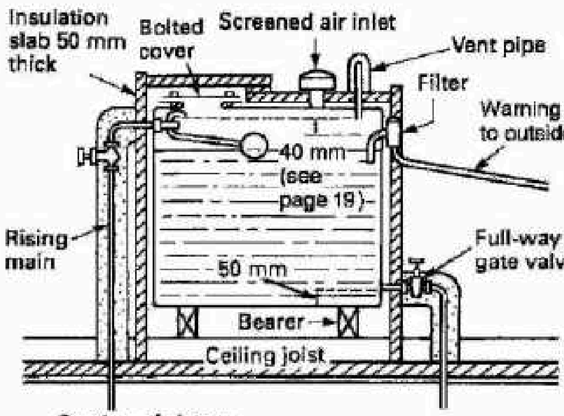
Operating principle and installation of a verifiable backflow prevention device with reduced pressure zone

Refs. The Water Supply (Water Fittings) Regulations.
BS EN 1717: Protection against pollution of potable water in water installations and general requirements of devices to prevent pollution by backflow.

Cisterns can be manufactured from galvanised mild steel (large non-domestic capacities), polypropylene or glass reinforced plastics. They must be well insulated and supported on adequate bearers to spread the concentrated load. Plastic cisterns will require uniform support on boarding over bearers. A dustproof cover is essential to prevent contamination.

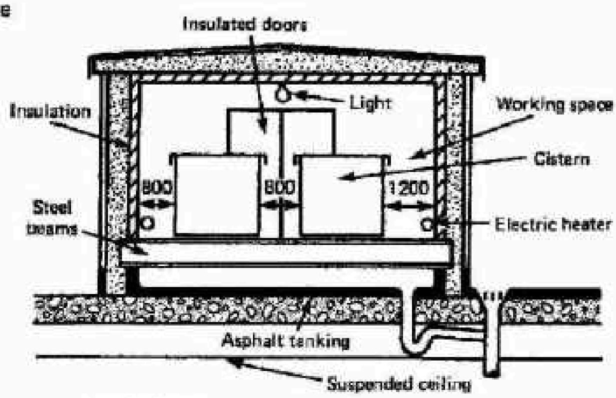
For large buildings, cisterns are accommodated in a purpose-made plant room at roof level or within the roof structure. This room must be well insulated and ventilated, and be provided with thermostatic control of a heating facility.

Where storage demand exceeds 4500 litres, cisterns must be duplicated and interconnected. In the interests of load distribution this should be provided at much lower capacities. For maintenance and repairs each cistern must be capable of isolation and independent operation.

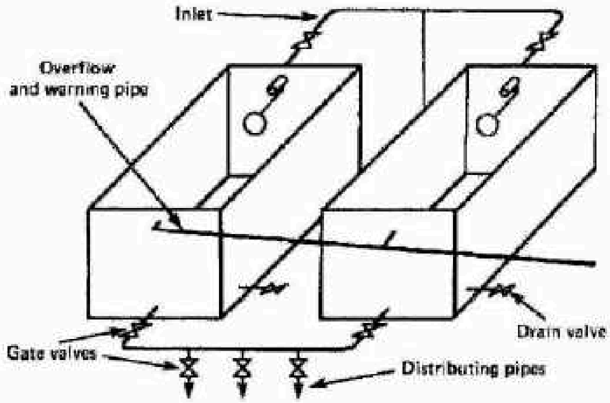


Section of cistern

Ref. BS 7181: Specification for storage cisterns up to 500 l actual capacity for water supply for domestic purposes.



Detail of cistern room



Duplicated cisterns

Refs. BS 417-2: Specification for galvanised low carbon steel cisterns, cistern lids, tanks and cylinders.
BS 4213: Cisterns for domestic use. Cold water storage and combined feed and expansion (thermoplastic) cisterns up to 500 l specification.

Cold water storage data is provided to allow for up to 24 hour interruption of mains water supply.

Building purpose	Storage/person/24 hrs	
Boarding school	90 litres	
Day school	30	
Department store with canteen	45	(3)
Department store without canteen	40	(3)
Dwellings	90	(1)
Factory with canteen	45	
Factory without canteen	40	
Hostel	90	
Hotel	135	(2) (3)
Medical accommodation	115	
Office with canteen	45	
Office without canteen	40	
Public toilets	15	
Restaurant	7 per meal	

Notes: (1) 115 or 230 litres min. see pages 15 and 16

(2) Variable depending on classification.

(3) Allow for additional storage for public toilets and restaurants.

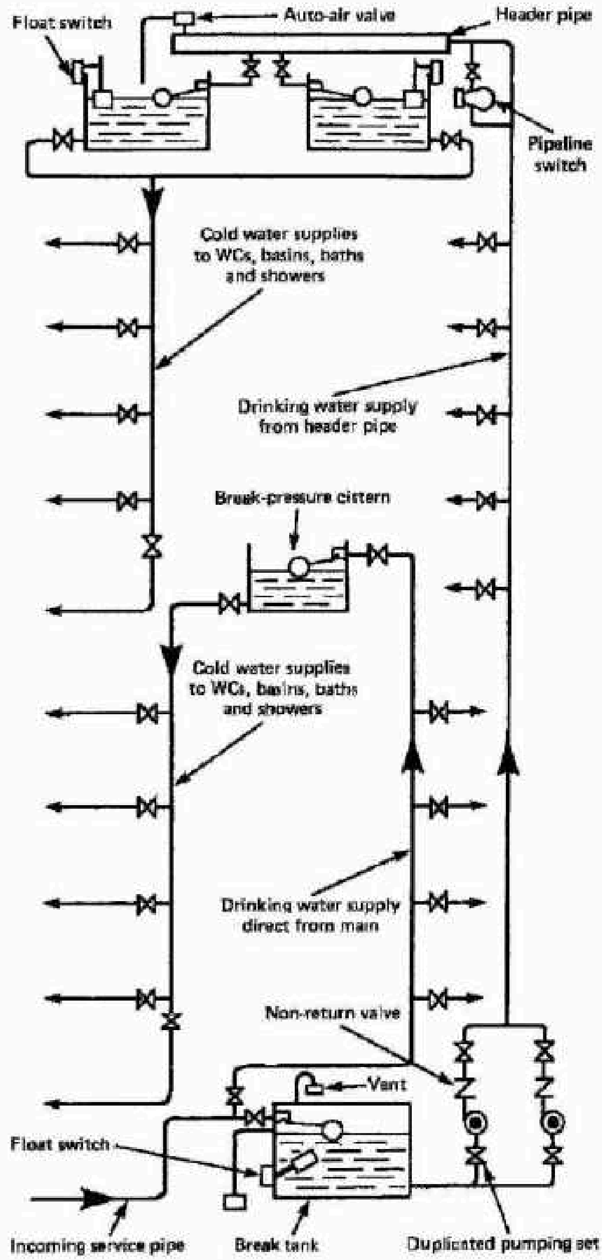
At the design stage the occupancy of a building may be unknown. Therefore the following can be used as a guide:

Building purpose	Occupancy
Dept. store	1 person per 30 m^2 net floor area
Factory	30 persons per WC
Office	1 person per 10 m^2 net floor area
School	40 persons per classroom
Shop	1 person per 10 m^2 net floor area

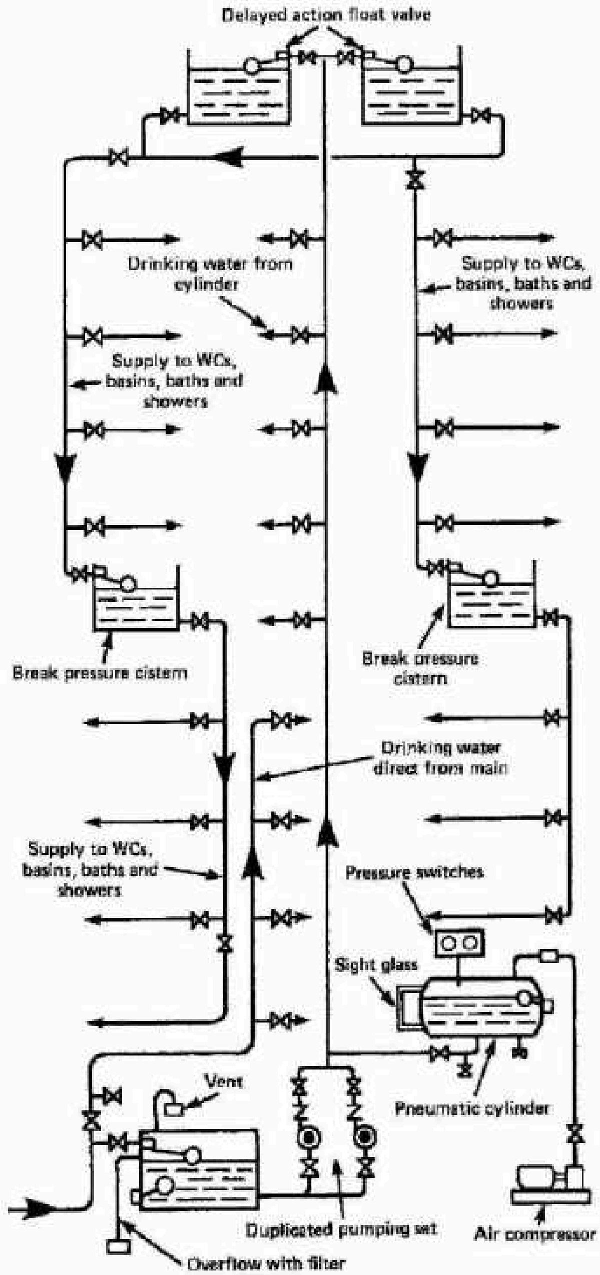
E.g. A 1000 m^2 (net floor area) office occupied only during the day therefore allow 10 hours' emergency supply.

1000/10 = 100 persons × 40 litres = 4000 litres (24 hrs)
= 1667 litres (10 hrs)

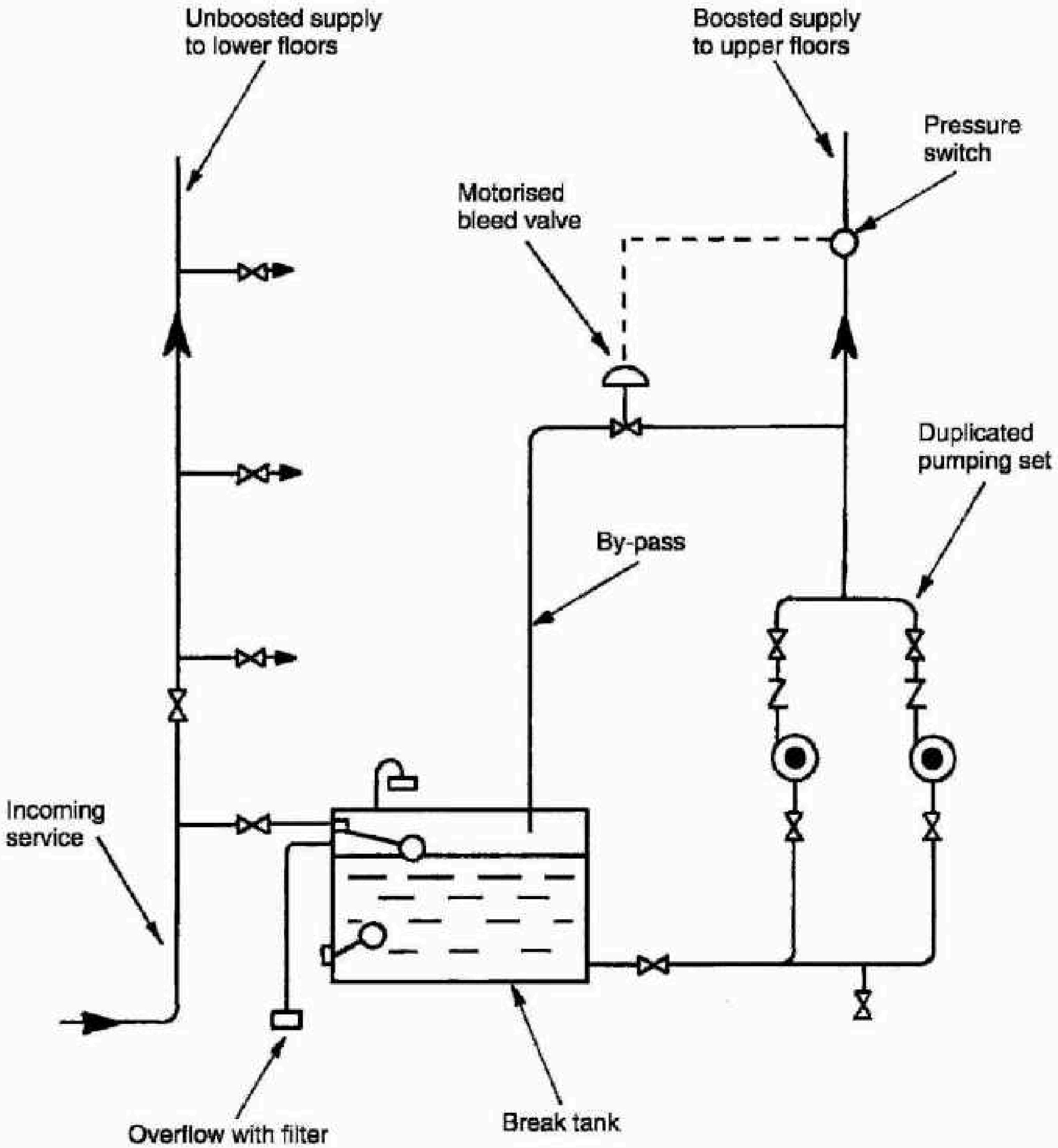
For medium and high rise buildings, there is often insufficient mains pressure to supply water directly to the upper floors. Boosting by pump from a break tank is therefore usually necessary and several more of these tanks may be required as the building rises, depending on the pump capacity. A break pressure cistern is also required on the down service to limit the head or pressure on the lower fittings to a maximum of 30 m (approx. 300 kPa). The drinking water header pipe or storage vessel supplies drinking water to the upper floors. As this empties and the water reaches a predetermined low level, the pipeline switch engages the duty pump. A float switch in the break tank protects the pumps from dry running if there is an interruption to mains supply. The various pipe sections are fitted with isolating valves to facilitate maintenance and repairs.



As an alternative to the drinking water header pipe, an auto-pneumatic cylinder may be used. Compressed air in the cylinder forces water up to the float valves and drinking water outlets on the upper floors. As the cylinder empties a low pressure switch engages the duty pump. When the pump has replenished the cylinder, a high pressure switch disengages the pump. In time, some air is absorbed by the water. As this occurs, a float switch detects the high water level in the cylinder and activates an air compressor to regulate the correct volume of air. Break pressure cisterns may be supplied either from the storage cisterns at roof level or from the rising main. A pressure reducing valve is sometimes used instead of a break pressure cistern.



In modest rise buildings of several storeys where water is in fairly constant demand, water can be boosted from a break tank by a continuously running pump. The installation is much simpler and less costly than the previous two systems as there is less need for specialised items of equipment. Sizing of the pump and its delivery rating are critical, otherwise it could persistently overrun, or at the other extreme be inadequate. Modern pumps have variable settings allowing considerable scope around the design criteria. The pump is normally scheduled to run on a timed programme, e.g. in an office block it may commence an hour before normal occupancy and run on for a couple of hours after. Water delivery should be just enough to meet demand. When demand is low a pressure regulated motorised bleed valve opens to recirculate water back to the break tank.

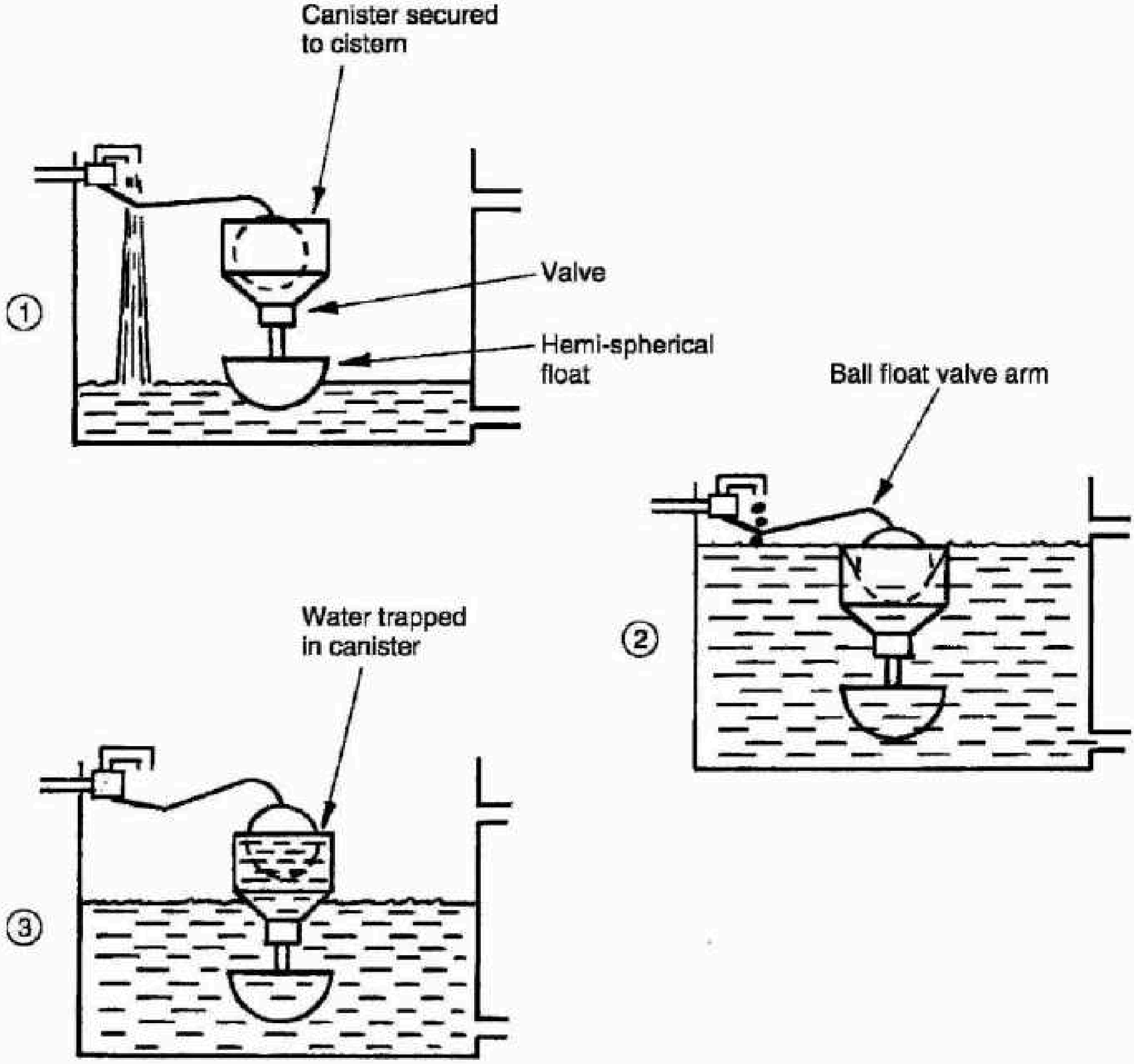


If normal float valves are used to regulate cistern water supply from an auto-pneumatic cylinder (page 25), then cylinder and pump activity will be frequent and uneconomic. Therefore to regulate activity and deliveries to the cistern, a delayed action float valve mechanism is fitted to the storage cistern.

Stage 1. Water filling the cistern lifts hemi-spherical float and closes the canister valve.

Stage 2. Water overflows into the canister, raises the ball float to close off water supply.

Stage 3. As the cistern empties, the ball float remains closed until low water level releases the hemi-spherical float. As this float valve drops, water is released from the canister to open the ball float valve to replenish the cistern from the pneumatic supply.

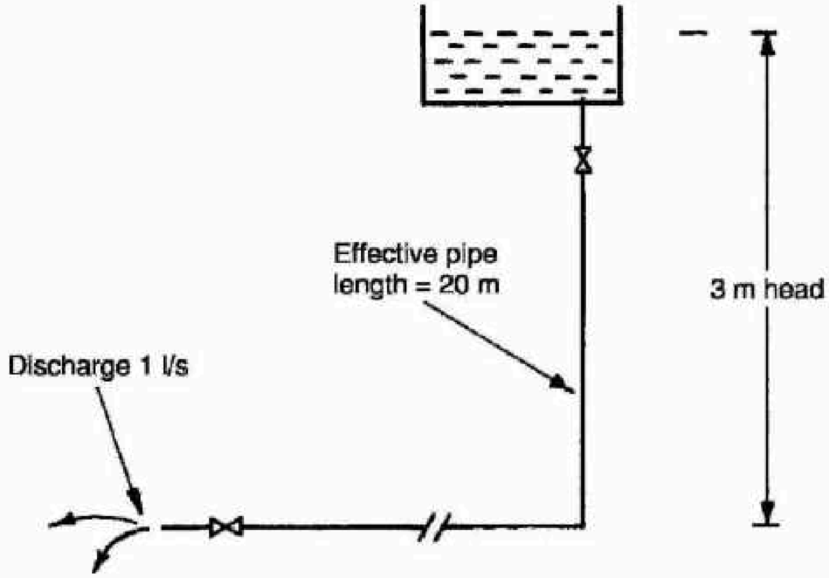


Thomas Box formula:

$$d = \sqrt[5]{\frac{q^2 \times 25 \times L \times 10^5}{H}}$$

where: d = diameter (bore) of pipe (mm)
q = flow rate (l/s)
H = head or pressure (m)
L = length (effective) of pipe (m)
(actual length + allowance for bends, tees, etc.)

e.g.



$$d = \sqrt[5]{\frac{(1)^2 \times 25 \times 20 \times 10^5}{3}}$$

$$d = \sqrt[5]{16\,666\,667} = 27{\cdot}83 \text{ mm}$$

The nearest commercial size above this is 32 mm bore steel or 35 mm outside diameter copper.

Note: Head in metres can be converted to pressure in kPa by multiplying by gravity, e.g. 3 m × 9.81 = 29.43 kPa (approx. 30 kPa).

Steel pipe (inside dia.)		Copper tube (mm)		Polythene (mm)	
Imperial (")	Metric (mm)	Outside dia.	Bore	Outside dia.	Bore
½	15	15	13·5	20	15
¾	20	22	20	27	22
1	25	28	26	34	28
1¼	32	35	32	42	35
1½	40	42	40		
2	50	54	51·5		
2½	65	67	64·5		
3	80	76	73·5		

Approximate equivalent pipe lengths of some fittings (m).

Pipe bore (mm)	Elbow	Tee	Stop valve	High pressure float valve
15	0·6	0·7	4·5	75
20	0·8	1·0	7	50
25	1·0	1·5	10	40
32	1·4	2·0	13	35
40	1·7	2·5	16	21
50	2·3	3·5	22	20

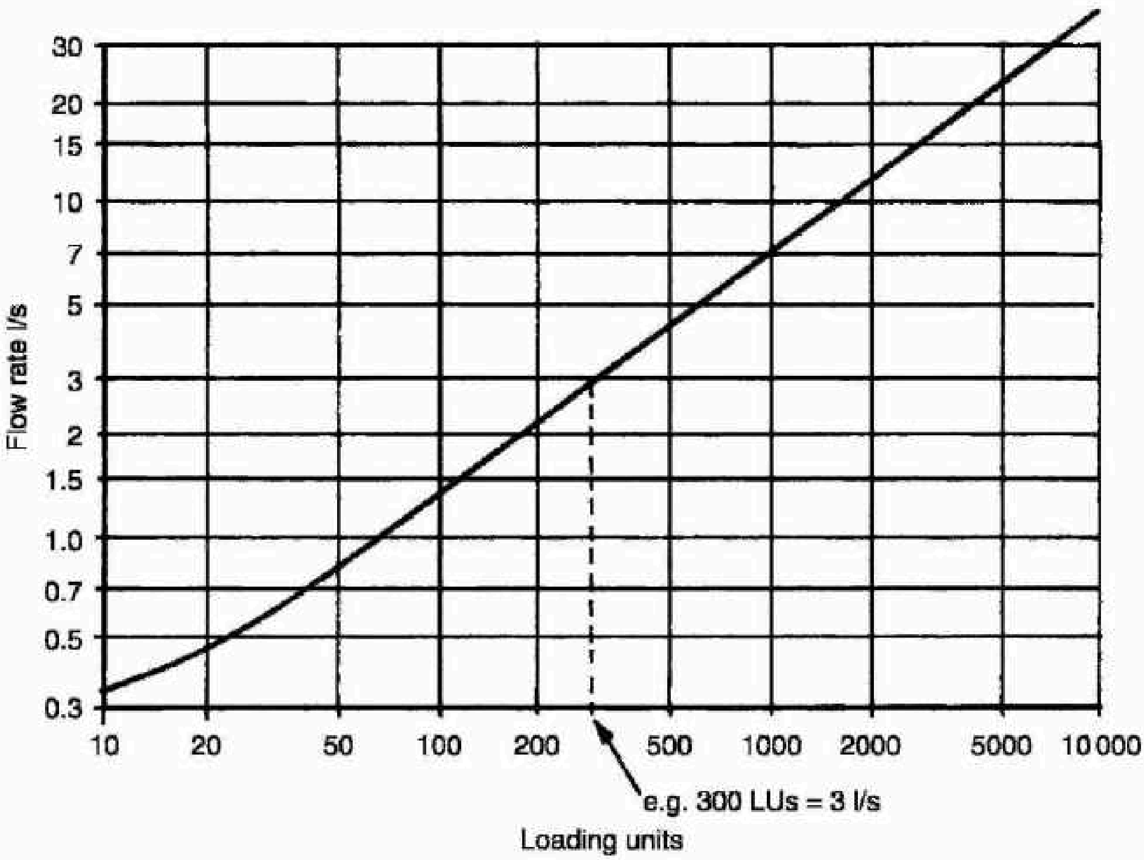
Notes: Figure given for a tee is the change of direction; straight through has no significant effect. These figures are only intended as a guide, they will vary between materials and design of fittings.

Recommended flow rates for various sanitary appliances (litres/sec)	
WC cistern	0·11
Hand basin	0·15
Hand basin (spray tap)	0·03
Bath (19 mm tap)	0·30
Bath (25 mm tap)	0·60
Shower	0·11
Sink (13 mm tap)	0·19
Sink (19 mm tap)	0·30
Sink (25 mm tap)	0·40

Loading units are factors which can be applied to a variety of appliances. They have been established by considering the frequency of use of individual appliances and the desired water flow rate.

Appliance	Loading units
Hand basin	1·5 to 3 (depends on application)
WC cistern	2
Washing machine	3
Dishwasher	3
Shower	3
Sink (13 mm tap)	3
Sink (19 mm tap)	5
Bath (19 mm tap)	10
Bath (25 mm tap)	22

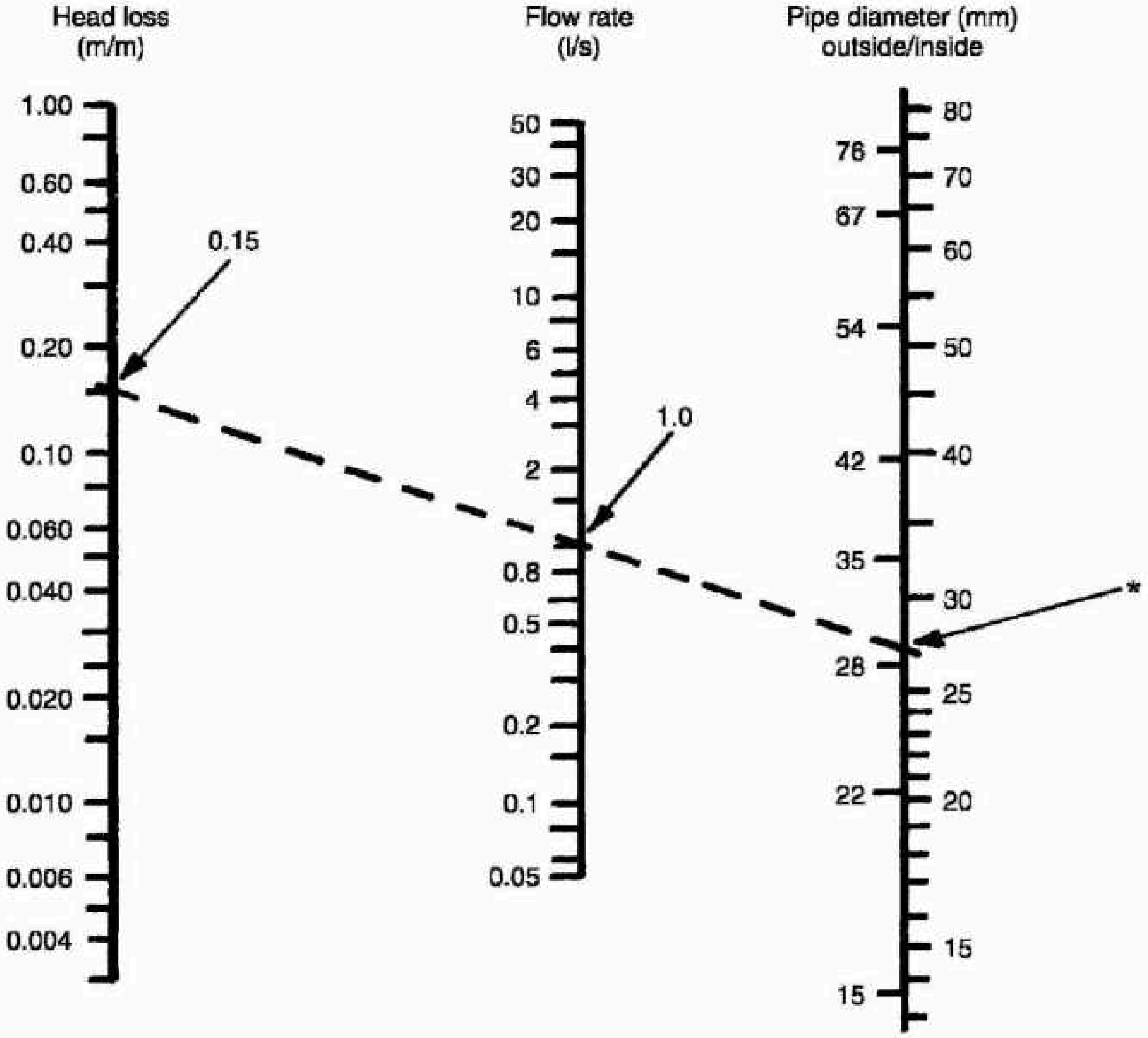
By determining the number of appliances on a pipework system and summating the loading units, an equivalent flow in litres per second can be established from the following conversion graph:



Pressure or head loss in pipework systems can be expressed as the relationship between available pressure (kPa) or head (m) and the effective length (m) of pipework. The formula calculation on page 28 can serve as an example:

Head = 3 m. Effective pipe length = 20 m. So, 3/20 = 0·15 m/m

By establishing the flow rate from loading units or predetermined criteria (1 l/s in our example), a nomogram may be used to obtain the pipe diameter. The chart below is for illustration and general use. For greater accuracy, pipe manufacturers' design data should be consulted for different materials and variations in water temperatures.



* Inside diameter = 27.83 mm (see page 28)

Ref. BS 6700: Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilage.

Hydraulics is the experimental science concerning the study of energy in fluid flow. That is, the force of pressure required to overcome the resistance to fluid flowing through pipes, caused by the friction between the pipe and liquid movement.

The total energy of the liquid flowing in a pipe declines as the pipe length increases, mainly due to friction between the fluid and the pipe wall. The amount of energy or pressure loss will depend on:

- Smoothness/roughness of the internal pipe wall.
- Diameter of pipe or circumference of internal pipe wall.
- Length of pipe.
- Velocity of fluid flow.
- Amount of turbulence in the flow.
- Viscosity and temperature of fluid.

Theories relating to pressure loss by fluids flowing in pipes are diverse, but an established relationship is that the pressure losses (h) caused by friction are proportional to the square of the velocity of flow (v):

$$h \propto v^2$$

From this, for a pipe of constant size it can be seen that by developing the proportional relationship, a doubling (or more) of pressure will increase the velocity accordingly:

h (m)	v (m/s)
4	1·5
8	2·12 $(1{\cdot}5 \times \sqrt{2})$
12	2·60 $(1{\cdot}5 \times \sqrt{3})$
16	3·00 $(1{\cdot}5 \times \sqrt{4})$ or $(2{\cdot}12 \times \sqrt{2})$
24	3·66 $(1{\cdot}5 \times \sqrt{6})$ or $(2{\cdot}60 \times \sqrt{2})$
32	4·24 $(1{\cdot}5 \times \sqrt{8})$ or $(3{\cdot}00 \times \sqrt{2})$ etc., etc.

Also, it can be shown that if the condition (temperature and viscosity) of a fluid in a pipe remains constant, the discharge through that pipe is directly proportional to the square root of the fifth power of its diameter:

$$\sqrt{d^5}$$

This relationship can be identified in the Thomas Box pipe sizing formula shown on page 28.

Reynolds number – a coefficient of friction based on the criteria for similarity of motion for all fluids. Relevant factors are related by formula:

$$\frac{\text{density} \times \text{velocity} \times \text{linear parameter (diameter)}}{\text{viscosity}}$$

This is more conveniently expressed as:

$$R = \frac{\rho v d}{\mu}$$

Where: R = Reynolds number
ρ = fluid density (kg/m^3)
v = velocity (m/s)
d = diameter of pipe (m)
μ = viscosity of the fluid ($Pa\ s$) or (Ns/m^2)

Whatever the fluid type or temperature, an R value of less than 2000 is considered streamline or laminar. A value greater than 2000 indicates that the fluid movement is turbulent.

E.g. 1. A 12 mm diameter pipe conveying fluid of density 1000 kg/m^3 and viscosity of 0·013 Pa s at 2 m/s flow velocity has a Reynolds number of:

$$\frac{1000 \times 2 \times 0{\cdot}012}{0{\cdot}013} = 1846 \text{ (streamline flow)}$$

D'Arcy formula – used for calculating the pressure head loss of a fluid flowing full bore in a pipe, due to friction between fluid and pipe surface.

$$h = \frac{4\,fL\,v^2}{2\,g\,d}$$

Where: h = head loss due to friction (m)
f = coefficient of friction
L = length of pipe (m)
v = average velocity of flow (m/s)
g = gravitational acceleration (9.81 m/s^2)
d = internal diameter of pipe (m)

Note: 'f', the D'Arcy coefficient, ranges from about 0·005 (smooth pipe surfaces and streamline flow) to 0·010 (rough pipe surfaces and turbulent flow). Tables can be consulted, although a mid value of 0·0075 is appropriate for most problem solving.

E.g. 2. A 12 mm diameter pipe, 10 m long, conveying a fluid at a velocity of flow of 2 m/s

$$\text{Head loss} = \frac{4 \times 0{\cdot}0075 \times 10 \times 2^2}{2 \times 9{\cdot}81 \times 0{\cdot}012} = 5{\cdot}09\text{m}$$

Depending on the data available, it is possible to transpose the D'Arcy formula for other purposes. For example, it may be used to calculate pipe diameter in this format:

$$d = \frac{4\,f\,L\,v^2}{2\,g\,h}$$

Flow rate (Q) – the discharge rate or flow rate of a fluid in a pipe is expressed as the volume in cubic metres (V) flowing per second (s). Q (m^3/s) is dependent on the pipe cross-sectional area dimensions (m^2) and the velocity of fluid flow (m/s). Q may also be expressed in litres per second, where 1 m^3/s = 1000 l/s.

A liquid flowing at an average velocity (v) in a pipe of constant area (A) discharging a length (L) of liquid every second (s), has the following relationship:

$Q = V \div s$ where $V = L \times A$ and $v = L \div s$

So, $Q = L \times A \div s$ where $v = L \div s$, $\therefore$ $Q = v \times A$

Q = flow rate (m^3/s), v = velocity of flow (m/s) and
A = cross-sectional area of pipe (m^2)

E.g. 1. The quantity of water flowing through a 12 mm diameter pipe at 2 m/s will be:

$Q = v \times A$, where $A = \pi r^2$
$Q = 2 \times 0{\cdot}000113 = 0{\cdot}000226\ m^3/s$ or 0·226 l/s

Relative discharge of pipes – this formula may be used to estimate the number of smaller branch pipes that can be successfully supplied by one main pipe:

$$N = \sqrt{(D \div d)^5}$$

where N = number of short branch pipes
D = diameter of main pipe (mm)
d = diameter of short branch pipes (mm)

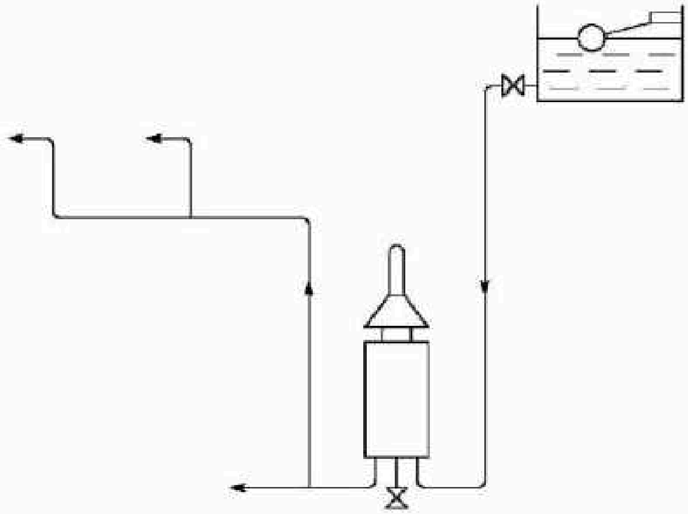
E.g. 2. The number of 32 mm short branch pipes that can be served from one 150 mm main will be:

$$N = \sqrt{(150 \div 32)^5} = 47$$

E.g. 3. The size of water main required to supply 15, 20 mm short branch pipes will be by formula transposition:

$D = d\ \sqrt[5]{N^2}$
$D = 20\ \sqrt[5]{15^2} = 59$ (65 mm nearest standard)

2 HOT WATER SUPPLY SYSTEMS



DIRECT SYSTEM OF HOT WATER SUPPLY
INDIRECT SYSTEM OF HOT WATER SUPPLY
UNVENTED HOT WATER STORAGE SYSTEM
EXPANSION AND TEMPERATURE RELIEF VALVES
HOT WATER STORAGE CYLINDERS
PRIMATIC HOT WATER STORAGE CYLINDER
MEDIUM AND HIGH RISE BUILDING SUPPLY SYSTEMS
TYPES OF BOILER
SECONDARY CIRCULATION
DUPLICATION OF PLANT
ELECTRIC AND GAS WATER HEATERS
SOLAR HEATING OF WATER
HOT WATER STORAGE CAPACITY
BOILER RATING
PIPE SIZING
PRESSURISED SYSTEMS
CIRCULATION PUMP RATING
LEGIONNAIRES' DISEASE IN HOT WATER SYSTEMS
SEDBUK
GALVANIC OR ELECTROLYTIC ACTION
WATER TREATMENT

Water expands with changes in temperature. At 4°C water is at its most dense. At temperatures below 4°C down to zero or freezing, water expands about 9% (approximately 1/10) by volume. This is why underground supplies require adequate ground cover and externally exposed water pipes require insulation to prevent damage. At temperatures between 4°C and 100°C or boiling, water expands by about 4% (approximately 1/25) by volume and is significantly less dense – see table below. This degree of expansion and reduction in density is the principle of convective water circulation in elementary hot water systems.

Temperature (°C)	Density (kg/m^3)
0	999.80
4	1000.00
10	999.70
20	998.20
30	995.00
40	992.20
50	987.50
60	983.20
70	977.50
80	971.80
90	965.60
100	958.00

The following formula can be used to calculate the amount that water expands in a hot water system:

$$E = C \times (\rho_1 - \rho_2) \div \rho_2$$

Where: E = expansion (m^3)

C = capacity or volume of water in system (m^3)

ρ_1 = density of water before heating (kg/m^3)

ρ_2 = density of water after heating (kg/m^3)

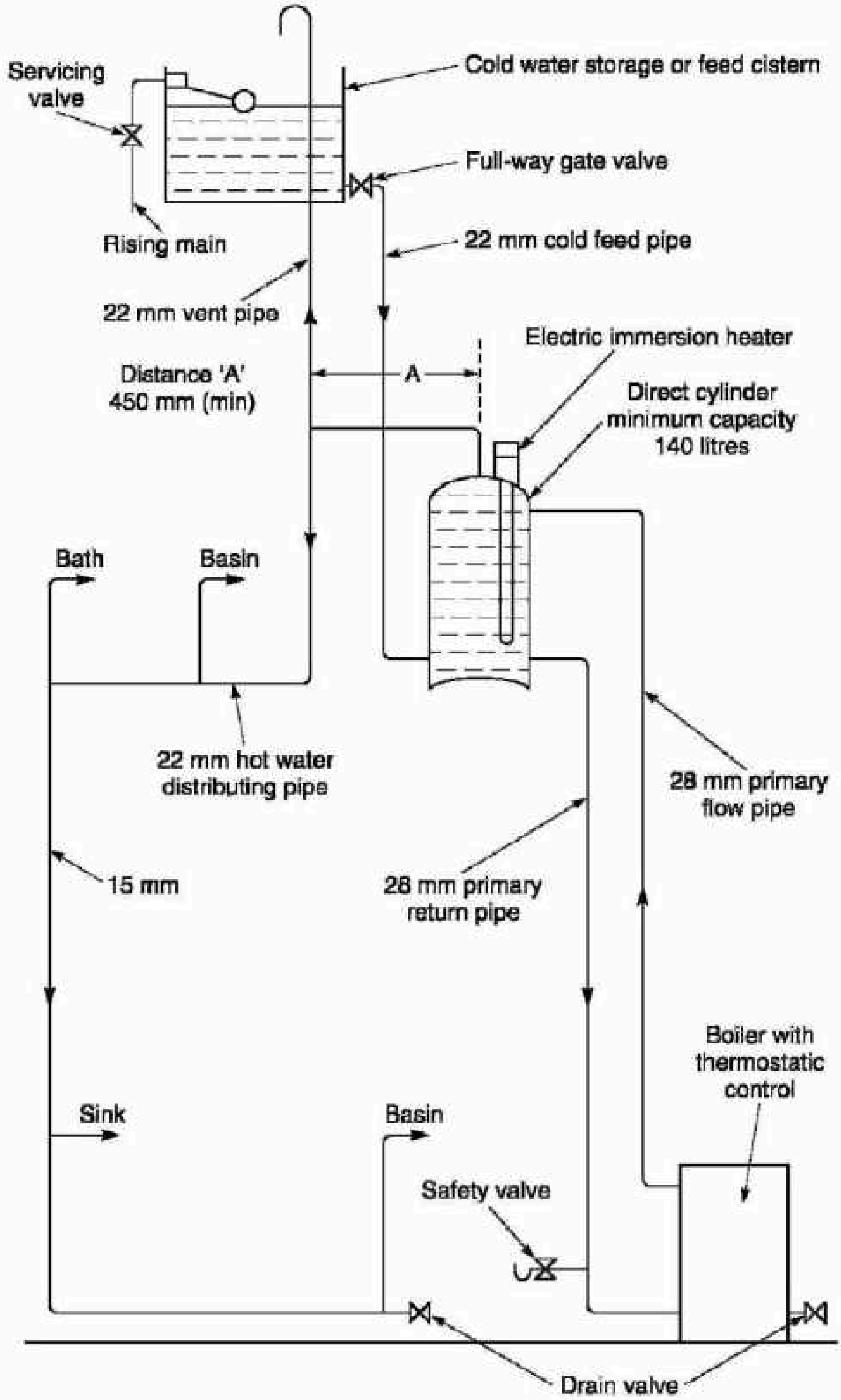
Example: A hot water system containing 15 m^3 of water, initially at 10°C to be heated to 80°C.

$$E = 15 \times (999{\cdot}70 - 971{\cdot}80) \div 971{\cdot}80$$

$$E = 0{\cdot}430\ m^3$$

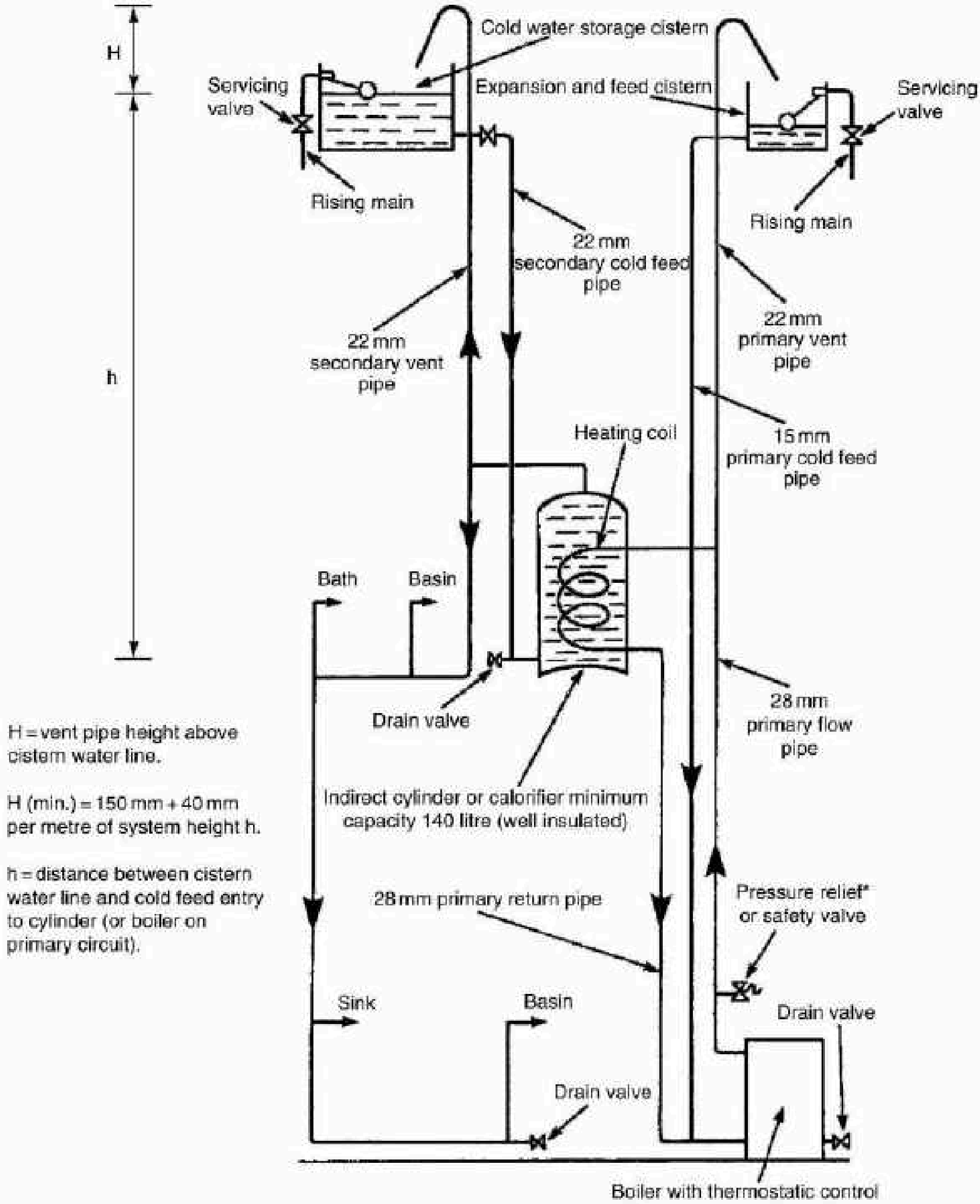
Hot water and heating systems must incorporate a means for accommodating expansion. A fail safe mechanism must also be provided should the initial provision malfunction.

The hot water from the boiler mixes directly with the water in the cylinder. If used in a 'soft' water area the boiler must be rust-proofed. This system is not suited to 'hard' waters, typical of those extracted from boreholes into chalk or limestone strata. When heated the calcium precipitates to line the boiler and primary pipework, eventually 'furring up' the system to render it ineffective and dangerous. The storage cylinder and associated pipework should be well insulated to reduce energy losses. If a towel rail is fitted, this may be supplied from the primary flow and return pipes.



Note: All pipe sizes shown are for copper outside diameter.

This system is used in 'hard' water areas to prevent scaling or 'furring' of the boiler and primary pipework. Unlike the direct system, water in the boiler and primary circuit is not drawn off through the taps. The same water circulates continuously throughout the boiler, primary circuit and heat exchange coil inside the storage cylinder. Fresh water cannot gain access to the higher temperature areas where precipitation of calcium would occur. The system is also used in combination with central heating, with flow and return pipes to radiators connected to the boiler. Boiler water temperature may be set by thermostat at about 80°C.

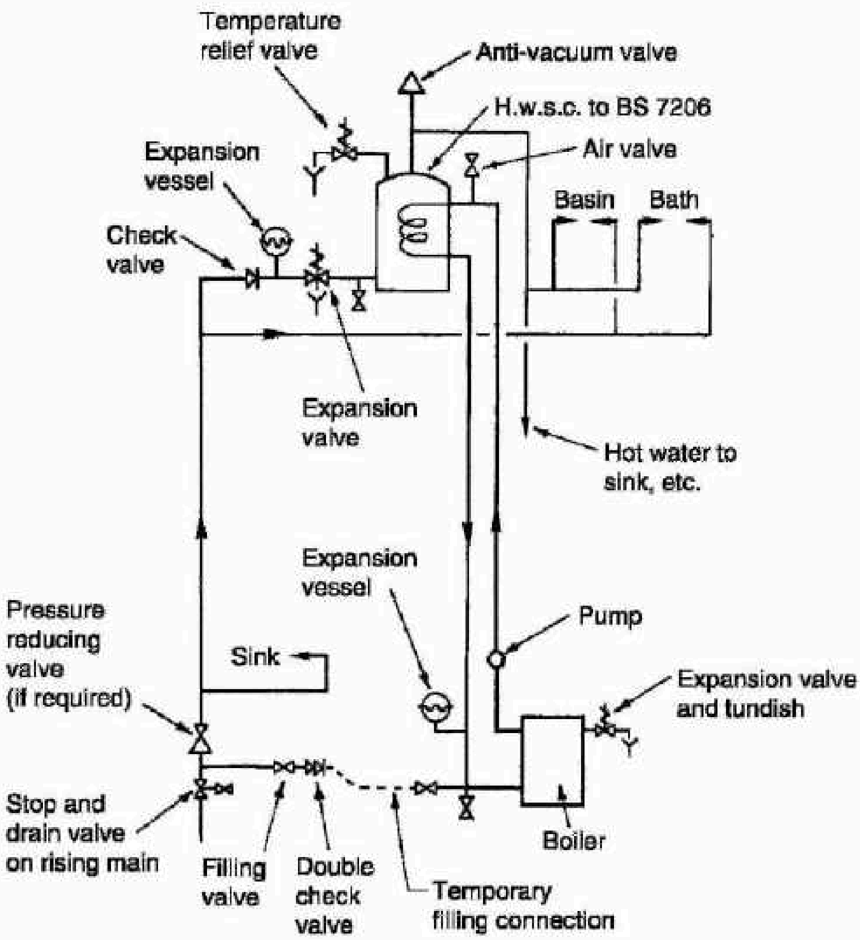


*A safety valve is not normally required on indirect open vent systems, as in the unlikely occurrence of the primary flow and vent becoming obstructed, water expansion would be accommodated up the cold feed pipe.

The Building Regulations, Approved Document J, permit the installation of packaged unit unvented hot water storage systems which have been accredited by the British Board of Agrément (BBA) or other European Organisation for Technical Approvals (EOTA) member bodies. Components should satisfy BS 7206: Specification for unvented hot water storage units and packages. A system of individual approved components is also acceptable. Safety features must include:

1. Flow temperature control between 60 and 65°C.
2. 95°C limit thermostat control of the boiler to close off the fuel supply if the working thermostat fails.
3. Expansion and temperature relief valves to operate at 95°C.
4. Check valves on water main connections.

The system is less space consuming than conventional systems and saves installation costs as there are no cold water storage and expansion cisterns. In addition to satisfying the Building Regulations, the local water authority should be consulted for approval and to ensure that there is adequate mains pressure.



Unvented system with hot water storage capacity in excess of 15 litres, with a sealed primary circuit

Installation – by suitably qualified person in possession of a registered operative identity card/certificate, issued by a recognised assessment body such as the Institute of Plumbing and Heating Engineering or the Construction Industry Training Board.

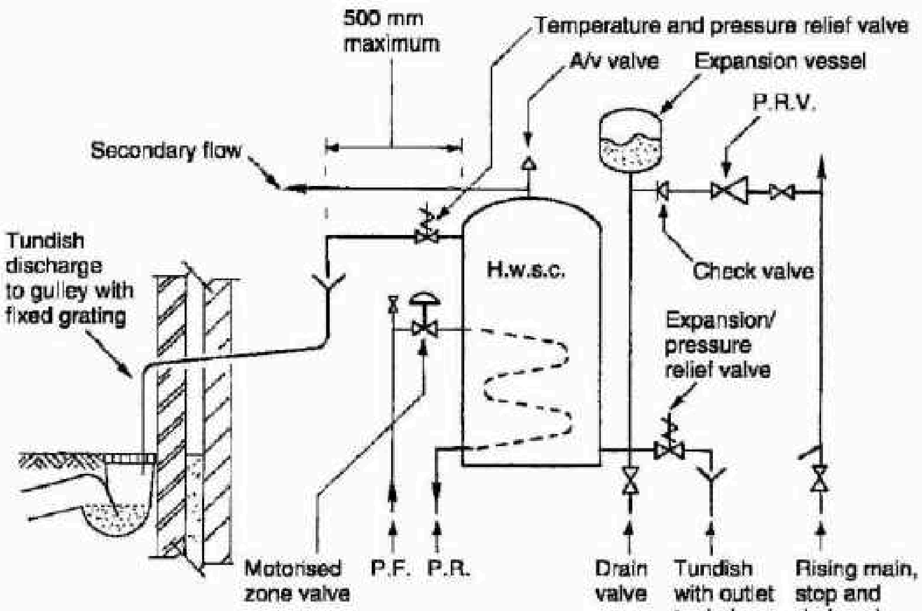
Notice of installation – given to the local authority Building Control Department. Building Regulation G3 – Hot Water Storage, requires a competent installer, precautions to prevent water temperature exceeding 100°C and any hot water discharge from safety devices to be conveyed safely and visibly.

Water supply – direct feed from water main, therefore no atmospheric vent pipe and no cold water storage cistern.

Water expansion – accommodated by suitably sized expansion vessel. Some units operate with an internal air gap (see next page).

Systems – direct heated by immersion heater, or indirect from a central heating boiler.

Storage cylinder materials – stainless steel, glass/vitreous enamel coated steel or heavy gauge copper.



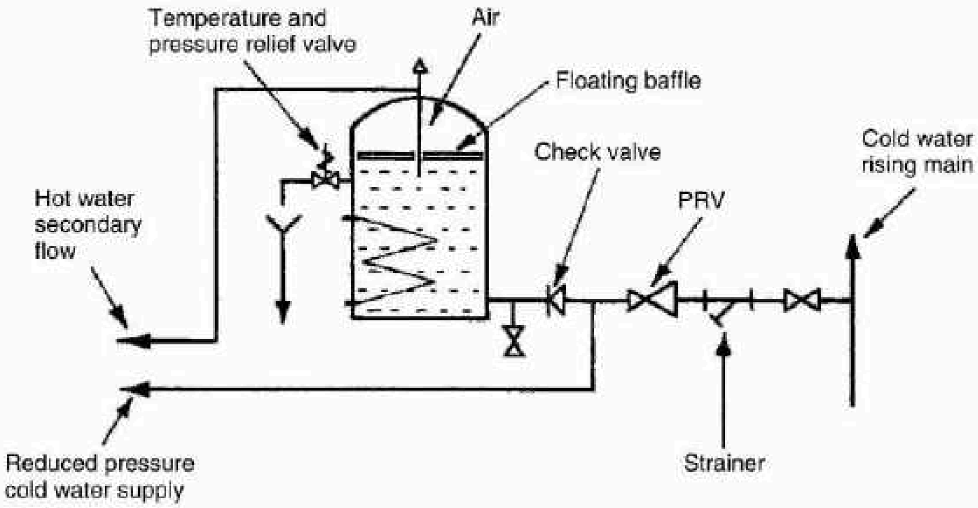
Unvented hot water storage cylinder and tundish detail

Controls –

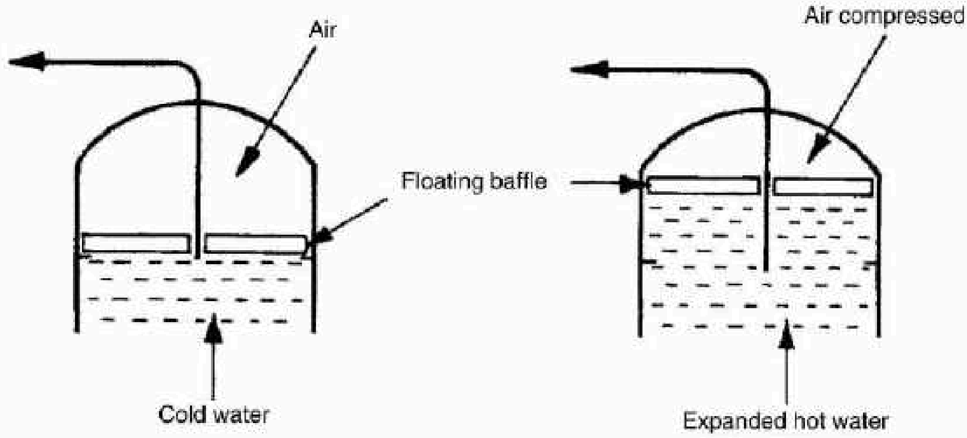
- Temperature and pressure relief valve.
- Expansion/pressure relief valve.
- Cylinder temperature regulating thermostat manually set to operate the zone valve at 60–65°C.
- Over-temperature cut out thermostat, pre-set to operate the zone valve at 85°C.

For all hot water systems, especially those exceeding 15 litres storage capacity, a purpose made hot water storage cylinder designed with provision for an 'air gap' or 'bubble top' is an effective alternative to installing a separate expansion vessel.

Typical installation –



Unvented hwsc incorporating an air gap



Function of the internal air gap

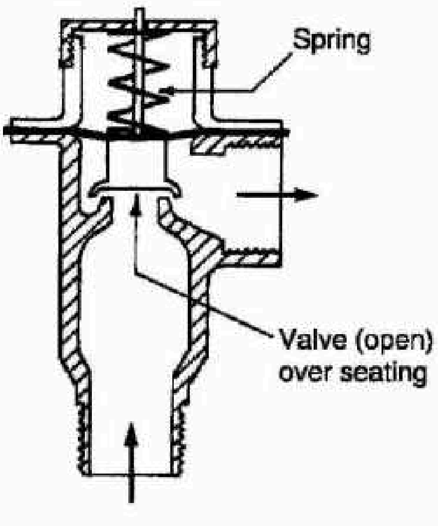
As the water expands on heating, the volume of trapped air is compressed to provide adequate delivery pressure and flow. After some time, the air may become depleted due to turbulence by water movement through the hot water storage cylinder. This will be noticed by the pressure relief valve discharging. The 'air gap' is re-charged by draining the system and refilling. Some manufacturers fit a floating baffle between the water and the air, to reduce the effect of turbulence.

Expansion devices in hot water systems are designed as a safe means for discharging water when system operating parameters are exceeded, i.e. in conditions of excess pressure and/or temperature.

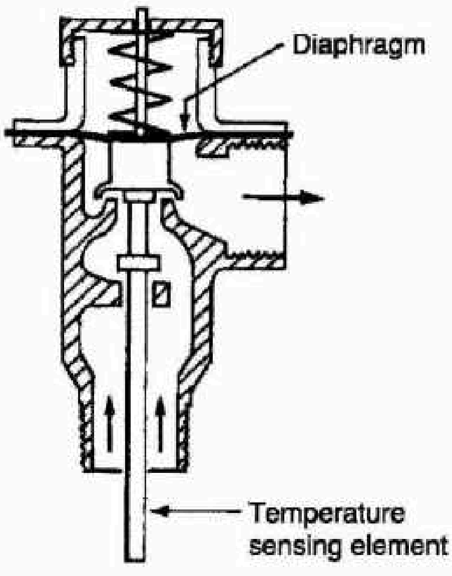
Expansion valve - Care should be taken when selecting expansion or pressure relief valves. They should be capable of withstanding 1.5 times the maximum pressure to which they are subjected, with due regard for water mains pressure increasing overnight as demand decreases.

Temperature relief valve - These should be fitted to all unvented hot water storage vessels exceeding 15 litres capacity. They are normally manufactured as a combined temperature and pressure relief valve. In addition to the facility for excess pressure to unseat the valve, a temperature sensing element is immersed in the water to respond at a pre-set temperature of 95°C.

Discharge from these devices should be safely controlled and visible, preferably over a tundish as shown on page 91.



Expansion valve



Temperature relief valve

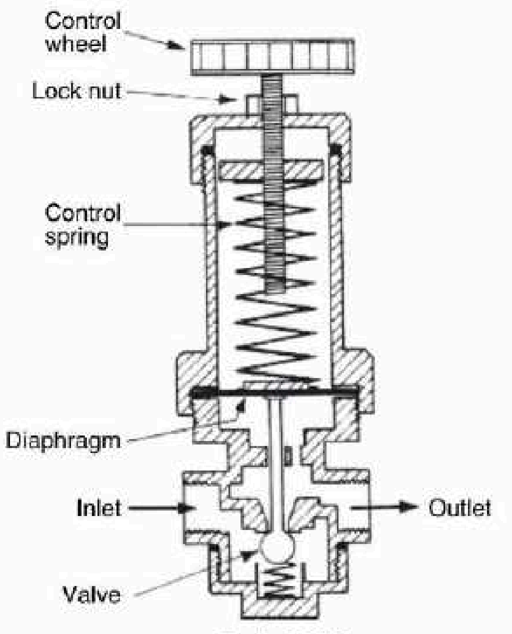
Ref. BS 6283-2: Safety and control devices for use in hot water systems. Specifications for temperature relief valves for pressures from 1 bar to 10 bar.

Pressure reducing valves are otherwise known as pressure regulators. PRV's can be applied to many different piped services including gas, compressed air, water and steam. These applications may range from relatively simple installations such as mains water supplied domestic unvented hot water storage systems, to larger scale industrial steam and district heating schemes.

High pressure is needed to overcome the resistances of long lengths of pipe distribution, changes in direction, valves, etc. For local distribution, the pressure must be reduced to:

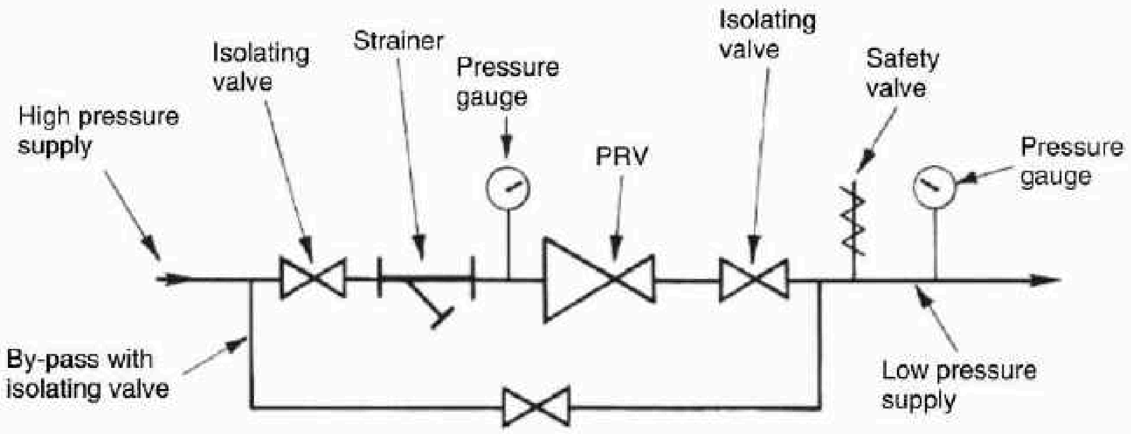
- Prevent undue wear and damage to the lighter gauge fittings and fixtures at the end use.
- Provide a maximum safe working pressure to prevent injury to end users.
- Regulate supplies at a constant value or desirable secondary pressure, irrespective of inlet pressure variations and changes in demand.

Function and installation



Typical PRV

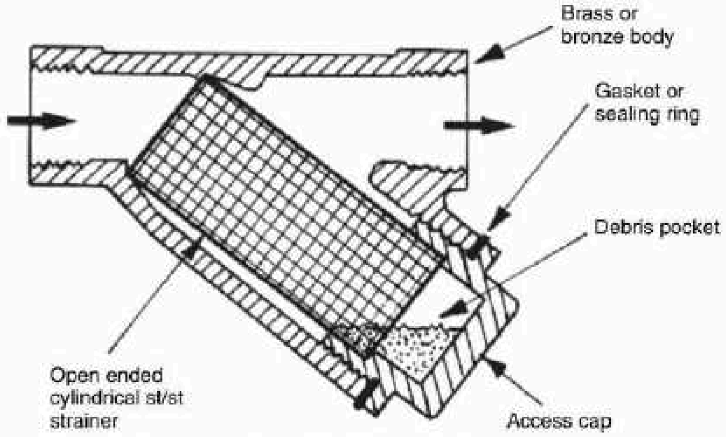
- Outlet reduced pressure acts on the underside of the diaphragm.
- Control spring opposes the reduced pressure.
- Reduced pressure and control spring setting effect the position of the valve and flow condition.



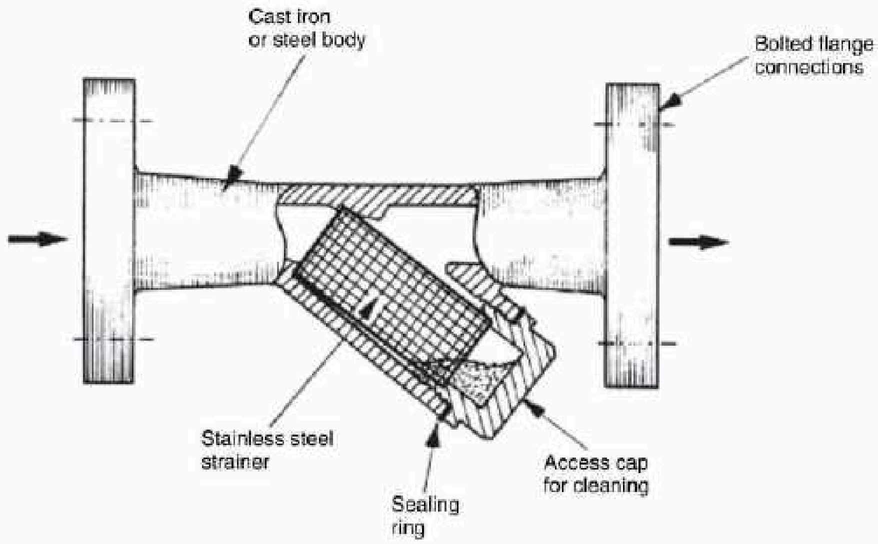
Installation to an industrial situation

A strainer is used to filter out and trap fluid suspended debris, pipe scale and carbonate deposits from hard water. This facility is essential to prevent component wear by erosion and abrasion, and interference with the efficient operation of pipe system controls. Strainers are a standard installation on processing plant and other industrial applications. There has been little need for strainers in domestic systems, until the use of items such as thermostatic mixing valves, shower mixers, check valves and pressure reducing valves have become standard. To protect the sensitivity of these units, most manufacturers integrate a means of filtering within the casting. Otherwise, an independent pipeline strainer of the type shown can be installed upstream of the unit.

Typical pipeline strainers



Threaded for domestic and light industrial services

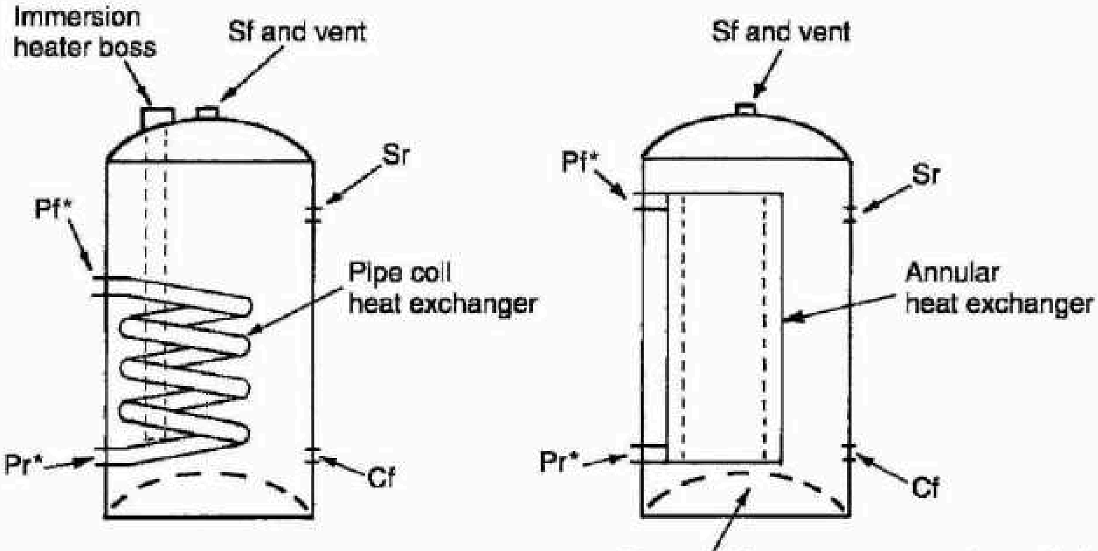


Flanged for industrial applications

BS 1566-1: Copper indirect cylinders for domestic purposes. Open-vented copper cylinders. Requirements and test methods.

BS 1566-2: Copper indirect cylinders for domestic purposes. Specification for single feed indirect cylinders.

BS 417-2: Specification for galvanised low carbon steel cisterns, cistern lids, tanks and cylinders.



* = male thread
key: see next page

Indirect copper, 72–440 litres (domestic)

Indirect galvanised steel, 109–455 litres (domestic)

Direct cylinders have no coil or annular heat exchangers. They can be identified with female pipe threads for the primary flow and return connections. For domestic use: copper – 74 to 450 litres capacity, galvanised steel – 73 to 441 litres capacity. Direct and indirect cylinders for industrial and commercial applications are manufactured in copper and galvanised steel in capacities up to 4500 litres.

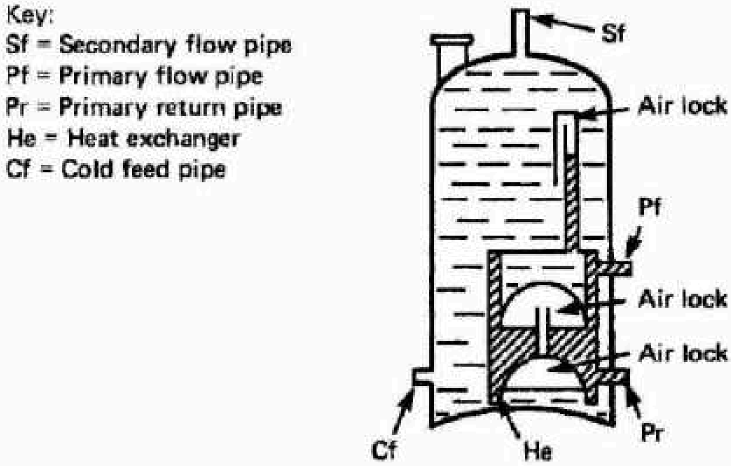
Notes:

(1) Copper and galvanised (zinc plated) steel pipes and components should not be used in the same installation. In addition to electrolytic action between the dissimilar metals, pitting corrosion caused by tiny particles of dissolved copper settling on the galvanising will produce local cells which dissolve the zinc and expose the steel to rusting.

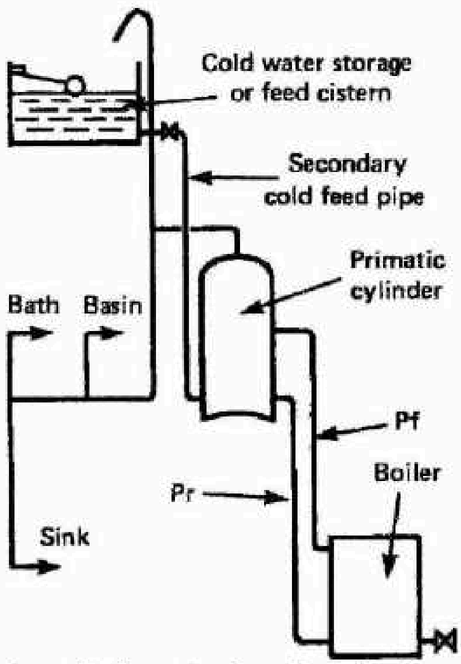
(2) Copper and galvanised steel cylinders normally incorporate an aluminium and a magnesium sacrificial anode, respectively. These are designed to deteriorate over sufficient time to allow a protective coating of lime scale to build up on the exposed surfaces.

BS 1566-2: Specification for single feed indirect cylinders.

An indirect hot water system may be installed using a 'primatic' or single feed indirect cylinder. Conventional expansion and feed cistern, primary cold feed and primary vent pipes are not required, therefore by comparison, installation costs are much reduced. Only one feed cistern is required to supply water to be heated indirectly, by water circulating in an integral primary heater. Feed water to the primary circuit and boiler is obtained from within the cylinder, through the primary heater. The heat exchanger inside the cylinder has three air locks which prevent mixing of the primary and secondary waters. No corrosion inhibitors or system additives should be used where these cylinders are installed.

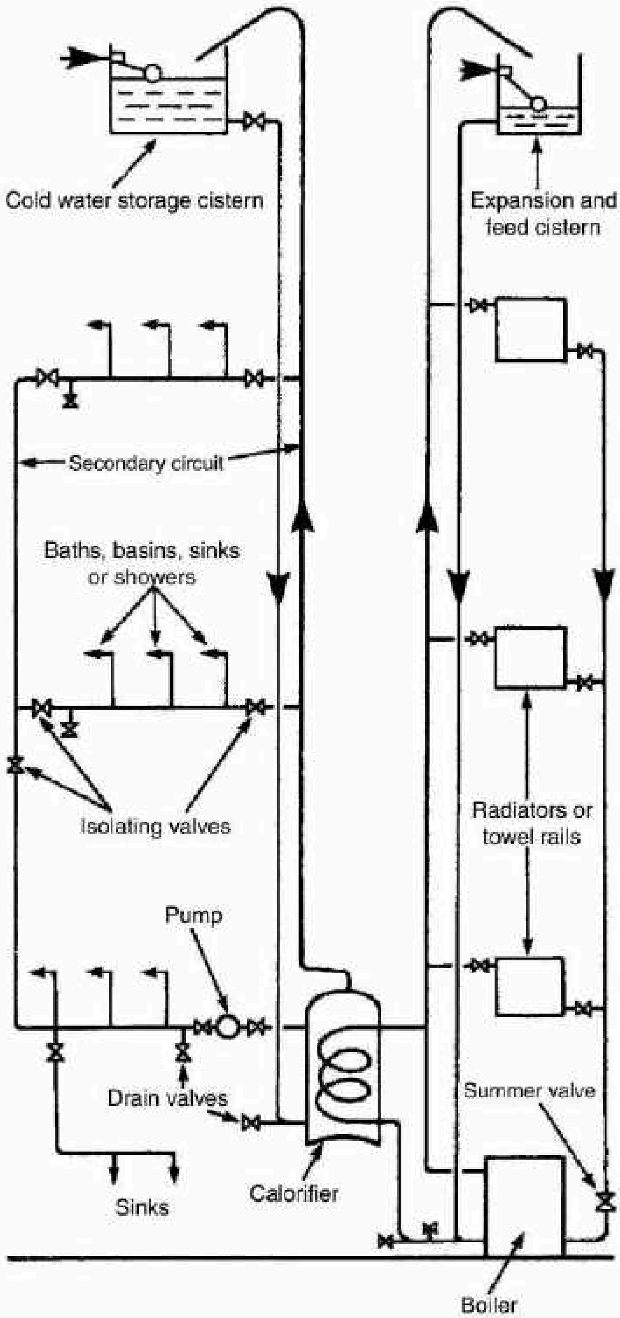


Primatic cylinder

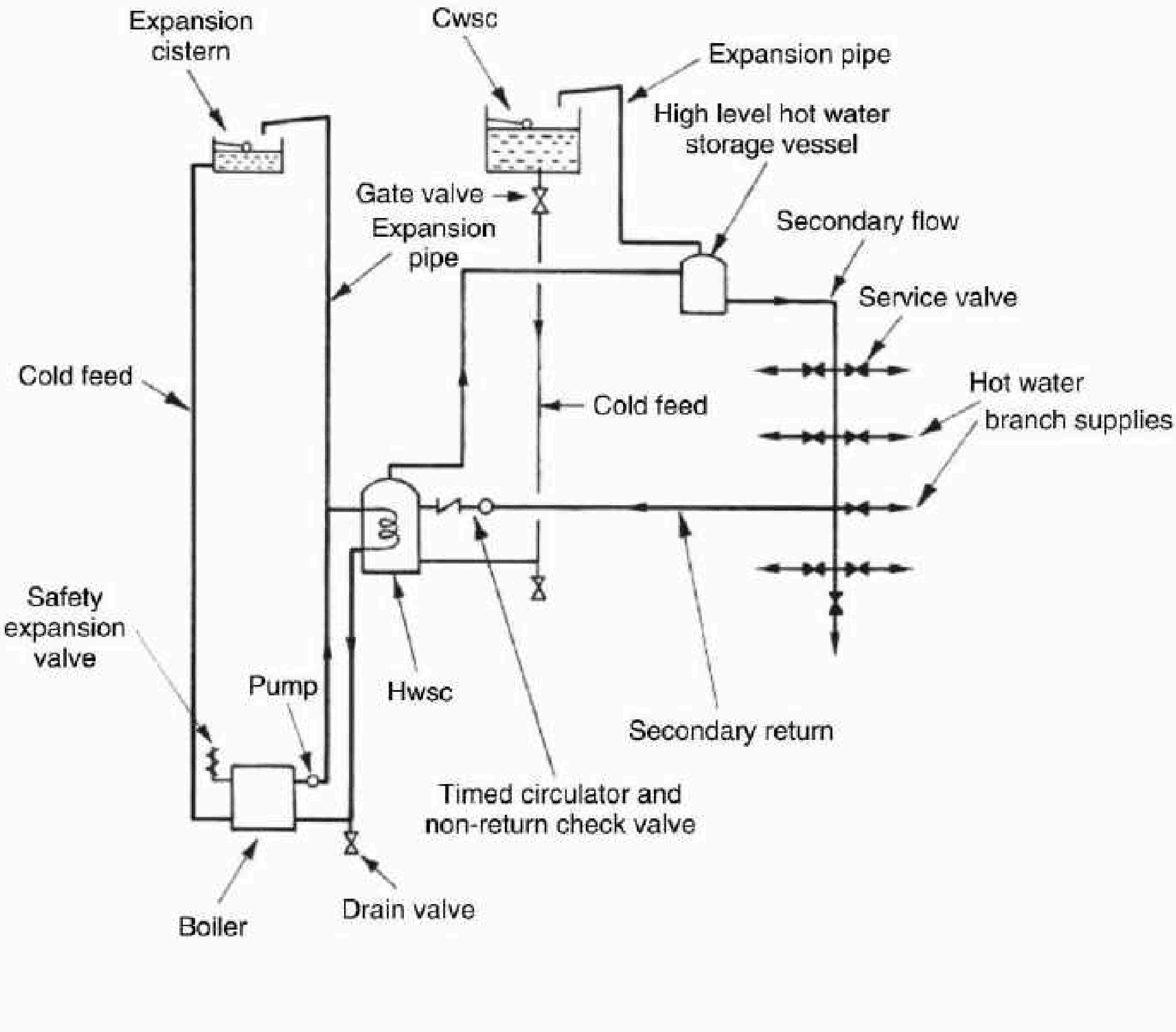


Installation of primatic cylinder

For larger buildings a secondary circuit will be required to reduce 'dead-legs' and to maintain an effective supply of hot water at all outlets. Convection or thermo-siphonage may provide circulation, but for a more efficient service a circulatory pump will be necessary. In buildings which are occupied for only part of the day, e.g. schools, offices, etc., a time control or programmer can be used to regulate use of the pump. Also, one of the valves near the pump should be motorised and automatically shut off with the pump and boiler when hot water is not required. All secondary circuits should be well insulated to reduce heat losses through the pipework. A heating installation can operate in conjunction with this system, but may require duplication of boilers or separate boilers for each function.



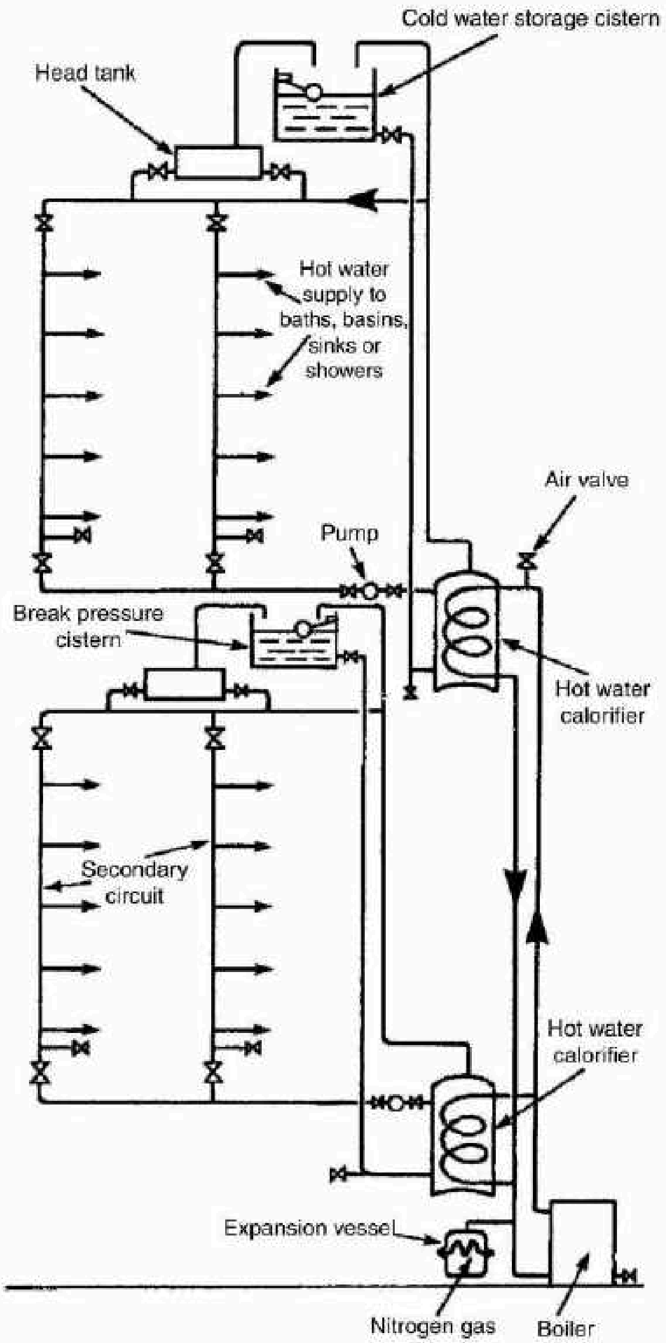
Hot water provision in moderately large buildings such as spacious houses, small hotels, hostels and other situations where demand is periodically high, can be from a large storage cylinder or cylinders installed in duplicate. Alternatively or additionally, depending on requirements, a supplementary storage vessel may be strategically located at high level. This vessel is relatively small, containing no more than 20% of the total design capacity.



Advantages over a single storage facility:

- Smaller secondary flow and return distribution pipes.
- Less concentrated dead load on the structure.

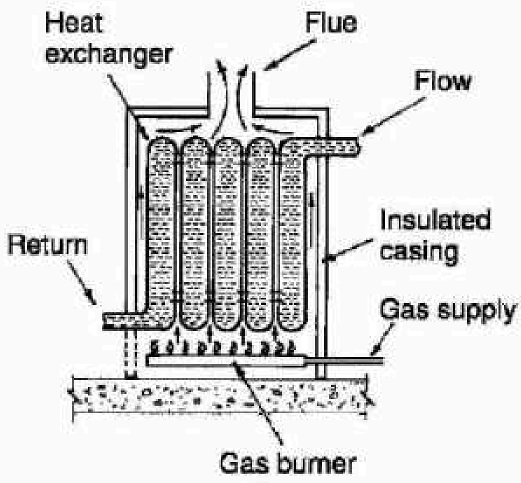
For convenience and to reduce wear on fittings, the maximum head of water above taps and other outlets is 30 m. This is achieved by using intermediate or break pressure cisterns for each sub-circuit. Head tanks are provided to ensure sufficient volume of stored hot water and adequate delivery to the upper floors. Compared with conventional installations a considerable amount of pipework and fitting time can be saved by using an expansion vessel to absorb expansion of water in the primary circuit. However, the boiler and calorifiers must be specified to a high quality standard to withstand the water pressure. All pipework and equipment must be well insulated.



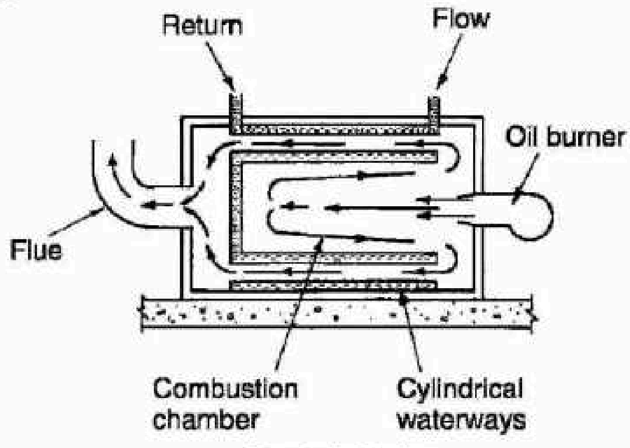
Cast iron sectional – made up of a series of hollow sections, joined together with left- and right-hand threaded nipples to provide the heat capacity required. When installed, the hollow sections contain water which is heated by energy transfer through the cast iron from the combusted fuel. Applications: domestic to large industrial boilers.

Steel shell, fire or flame tube – hot combusted fuel and gases discharge through multiple steel tubes to the extract flue. Heat energy from the burnt fuel transfers through the tube walls into cylindrical waterways. Tubes may be of annular construction with water surrounding a fire tube core. Uses: commercial and industrial buildings.

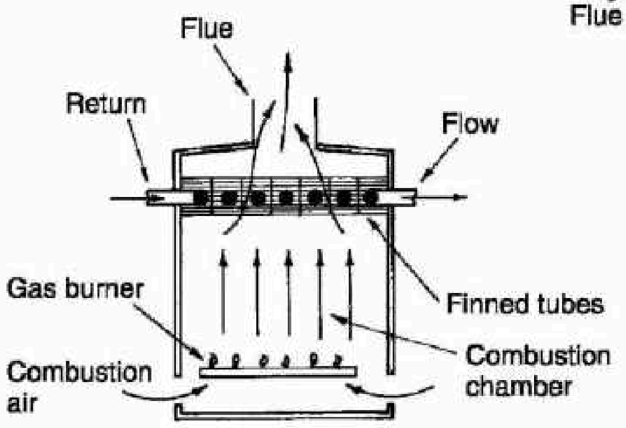
Copper or steel water tube – these reverse the principle of fire tubes. Water circulates in a series of finned tubes whilst the combusted fuel effects an external heat transfer. These are typical of the heat exchangers in domestic boilers.



Cast iron sectional boiler



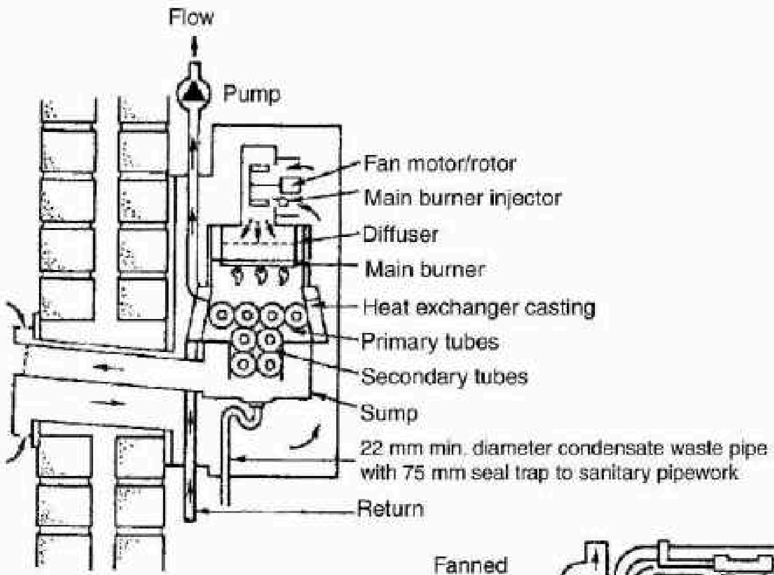
Fire tube boiler



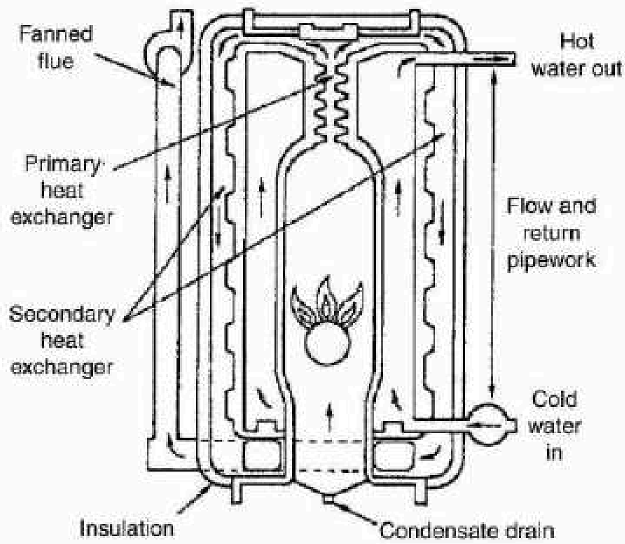
Water tube boiler

All of these boiler types may be fired by solid fuel, gas or oil.

Condensing boilers have a greater area of heat transfer surface than conventional boilers. In addition to direct transfer of heat energy from the burning fuel, heat from the flue gases is used as secondary heating to the water jacket. Instead of the high temperature (200–250°C) flue gases and water vapour discharging to atmosphere, they are recirculated around the water jacket by a fan. This fan must be fitted with a sensor to prevent the boiler firing in the event of failure. Condensation of vapour in the flue gases is drained to a suitable outlet. The overall efficiency is about 90%, which compares well with the 75% expected of conventional boilers. However, purchase costs are higher, but fuel savings should justify this within a few years.



Balanced flue condensing boiler



Conventional flue condensing boiler

Refs: BS 6798: Specification for installation of gas-fired boilers of rated input not exceeding 70 kWnet. Building Regulations, Approved Document H1: Foul Water Drainage, Section 1 – Sanitary pipework.

Otherwise known as high efficiency boilers.

Originally developed in the 1930s. Lack of technological advances and less concern about effect of consuming fuel limited interest until the fuel crises of the 1970s.

Introduced to the domestic market in the early 1980s. Slow to establish due to relatively higher purchase cost. From 2005, virtually compulsory for new installations, to satisfy SEDBUK efficiency bands A and B.

Extracts heat from flue gases to gain from the secondary heating effect.

Heat exchanger must be corrosion resistant, i.e. stainless steel or aluminium to resist the acidity of condensate. Cast iron and copper are only suitable in non-condensing boilers with high flue gas temperatures which are unaffected by condensation.

Non-corrosive plastic condensate waste pipe required. Waste usually connected to a siphon which discharges condensate in one go from a 150 ml sump. This reduces the possibility of a drip discharge freezing.

Least efficient condensing boiler has about the same efficiency as the most efficient non-condensing boiler.

Condensing boilers are at their most efficient with low return water temperatures. This effects most condensation. Therefore, they are best used with modulating controls as described on page 120.

About 80% energy exchange occurs as combusted gas at temperatures above 200°C effect the primary heat exchange. The secondary heat exchange adds about another 5% as the fanned flue gases reduce to about 55°C as they pre-warm the returning system cool water. With this temperature reduction the flue gases condense, dew point occurs (steam turns to water) adding about another 5% in latent energy transfer.

The gas burner has to impart less energy to raise the temperature at the primary heat exchange, hence fuel savings and less CO_2 and NO_x emissions from the flue.

Controls –

Non-condensing boilers are efficiently controlled with thermostatic valves, thermostats and an interlock facility. The boiler is switched on and off relative to internal air temperature. High temperature water is delivered to emitters.

Condensing boilers are at their most efficient when enabled to run for sustained periods with a moderate flow water temperature and low return water temperature. They are ideally suited to modulating, weather compensated control systems.

Flue discharge has a distinct plume or cloud of moisture droplets. May be a problem with neighbouring properties.

Flue slopes back slightly towards the boiler to discharge any condensation from the flue duct into the condensate drain.

Typical SEDBUK factors:

Modern condensing boiler 88%
Modern non-condensing boiler 75%
Older boiler 58%

A non-condensing boiler loses at least 20% of heat energy produced into the flue. Therefore these boilers are 80% efficient at best. Approximately half the heat energy that would be otherwise lost in the flue is recovered by a condensing boiler. Therefore these boilers are approximately 90% efficient.

Approximate number of households in UK = 14 million.

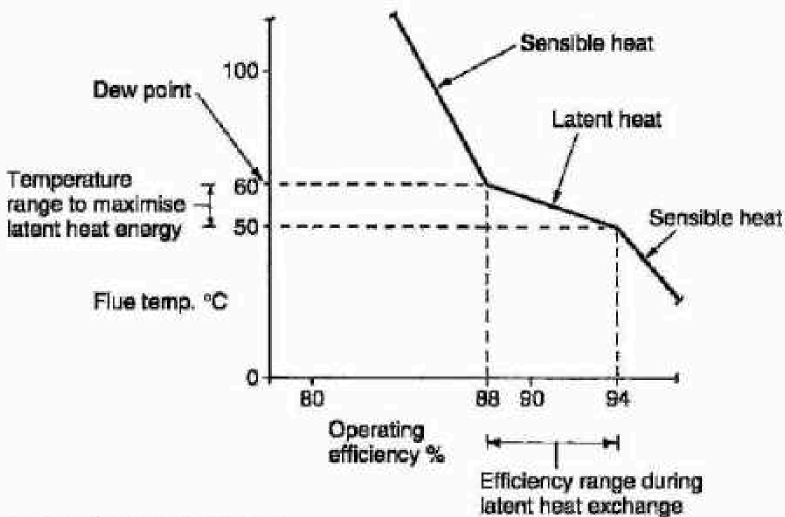
Typical annual household production of CO_2 with a non-condensing boiler = 5 tonnes.

Total potential CO_2 emissions = 70 million tonnes.

Typical annual household production of CO_2 with a condensing boiler = 3 tonnes.

Total potential CO_2 emissions = 42 million tonnes.

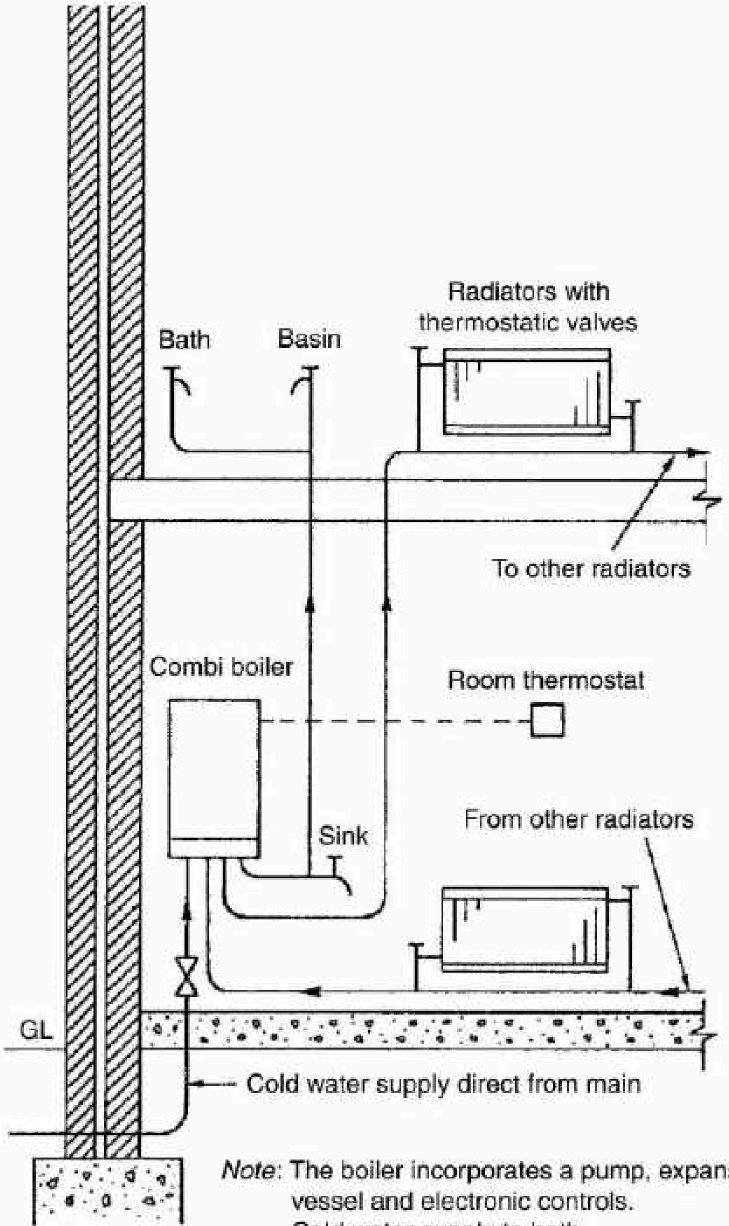
Therefore, in addition to fuel savings, condensing boilers represent a potential for an annual reduction in polluting or greenhouse gases of 28 million tonnes.



Condensing boiler efficiency

Note: Oil-fired condensing boilers are also marketed with specifications to satisfy current energy use requirements.

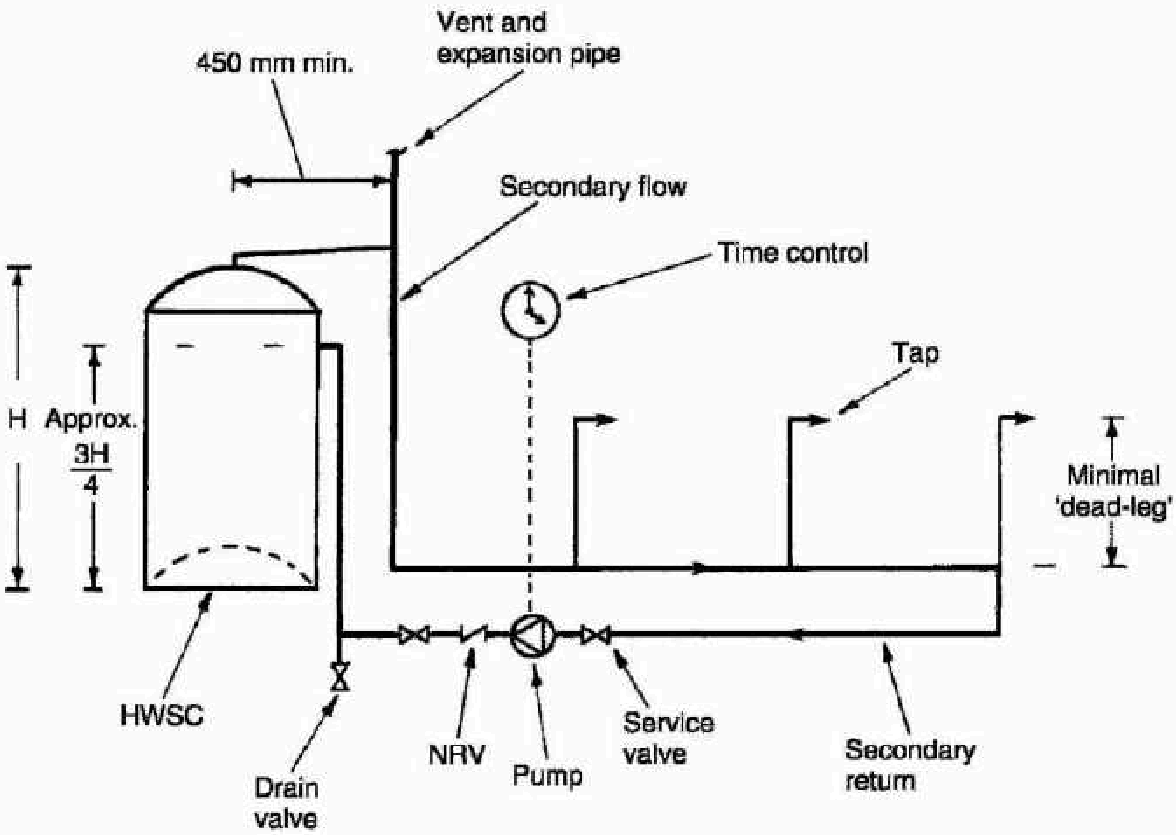
This system saves considerably in installation time and space, as there is no need for cisterns in the roof space, no hot water storage cylinder and associated pipework. The 'combi' gas boiler functions as an instantaneous water heater only heating water as required, thereby effecting fuel savings by not maintaining water at a controlled temperature in a cylinder. Water supply is from the mains, providing a balanced pressure at both hot and cold water outlets. This is ideal for shower installations. Boiler location may be in the airing cupboard, leaving more space in the kitchen. The system is sealed and has an expansion vessel which is normally included in the manufacturer's pre-plumbed, pre-wired package for simple installation. Further control details are shown on page 113.



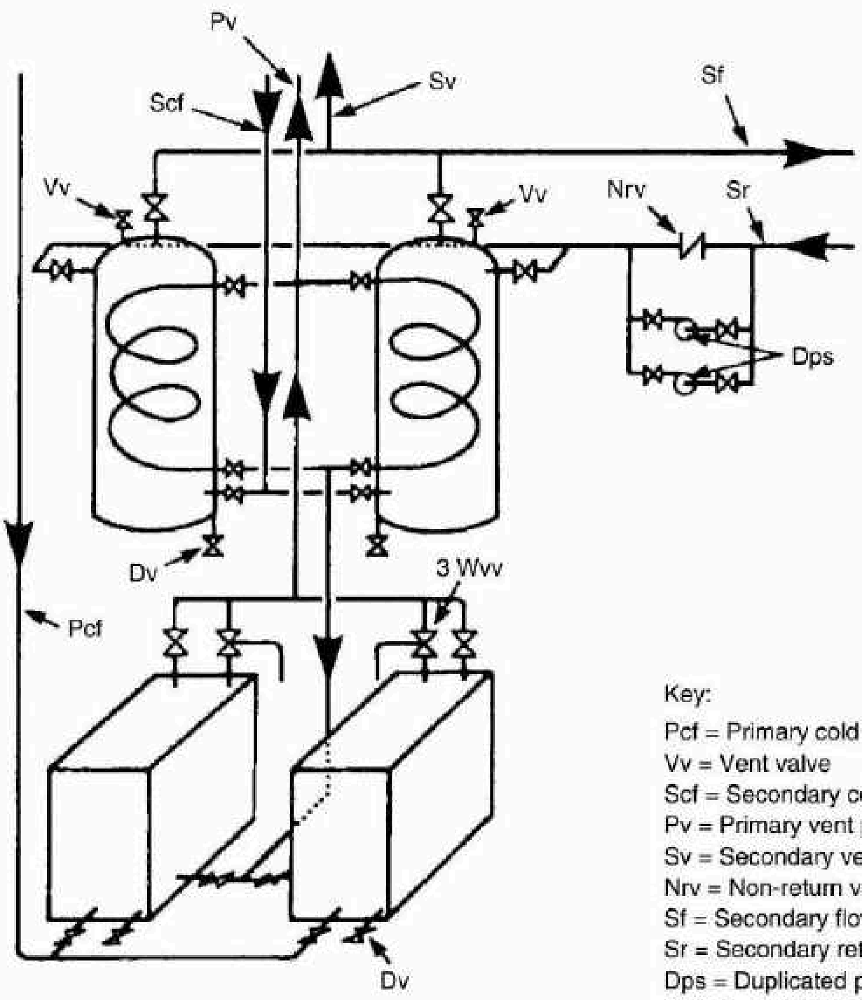
Note: The boiler incorporates a pump, expansion vessel and electronic controls. Cold water supply to bath, basin and sink has been omitted for clarity.

To prevent user inconvenience waiting for the cold water 'dead-leg' to run off and to prevent water wastage, long lengths of hot water distribution pipework must be avoided. Where cylinder to tap distances are excessive, a pumped secondary flow and return circuit may be installed with minimal 'dead-legs' branching to each tap. The pipework must be fully insulated and the circulation pump timed to run throughout the working day, e.g. an office system could be programmed with the boiler controls, typically 8.00 am to 6.00 pm, 5 days a week. A non-return valve prevents reverse circulation when the pump is not in use.

Nominal inside pipe dia. (mm)	Equivalent copper tube outside dia. (mm)	Max. length of secondary flow without a return (m)
10	12	20
>10 to 19	>12 to 22	12
>19 to 25	>22 to 28	8
>25	>28	3



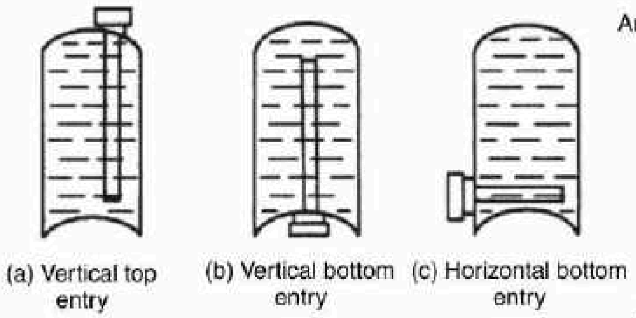
Dual installations or duplication of plant and equipment is required in buildings where operating efficiency is of paramount concern. With this provision, the supply of hot water in hotels, commercial buildings, offices, etc. is ensured at all times, as it is most unlikely that all items of plant will malfunction simultaneously. It may also be necessary to divide the design capacity of plant to reduce the concentration of structural loads. Each boiler and calorifier may be isolated for repair or renewal without disturbing the function of the others. Therefore when designing the system it is usual to oversize plant by up to one-third, to ensure the remaining plant has reasonable capacity to cope with demand. There is also the facility to economise by purposely isolating one boiler and calorifier during periods when a building is only part occupied.



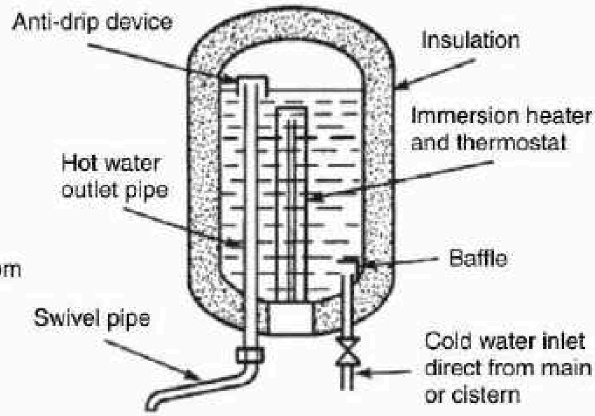
Duplicated plant

Key:
Pcf = Primary cold feed pipe
Vv = Vent valve
Scf = Secondary cold feed pipe
Pv = Primary vent pipe
Sv = Secondary vent pipe
Nrv = Non-return valve
Sf = Secondary flow pipe
Sr = Secondary return pipe
Dps = Duplicated pumps
3 Wvv = 3-way vent valve
Dv = Drain valve

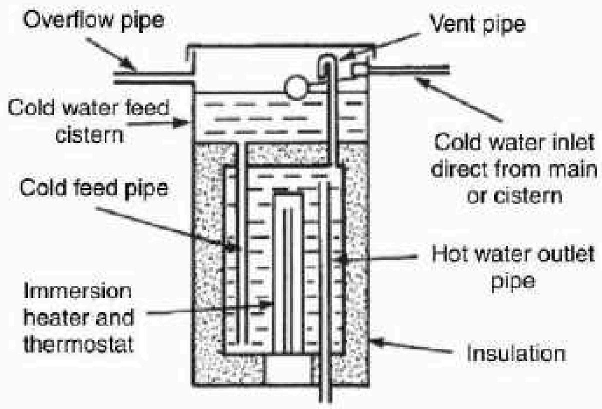
An electric immersion heater may be used within a conventional hot water storage cylinder. Alternatively, individual or self-contained open outlet heaters may be located over basins, baths or sinks. Combined cistern-type heaters can be used to supply hot water to several sanitary appliances. Energy conservation is achieved with an integral thermostat set between 60 and 65°C. This temperature is also sufficient to kill any bacteria. The immersion heater must be electrically earth bonded and the cable supplying the heating element must be adequate for the power load. A cable specification of 2·5 mm^2 is normally adequate with a 20 amp double pole control switch supplied direct from the consumer's unit or fuse box. Overload protection at the consumers unit is a 16 amp fuse or circuit breaker for a 3 kW element and 20 amp for a 4 kW element.



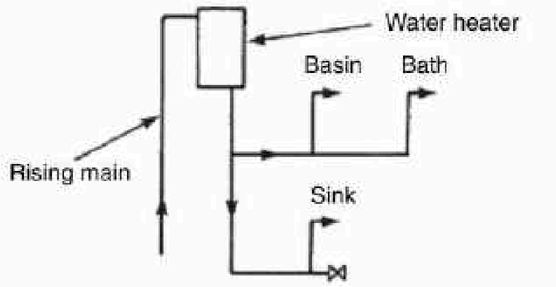
Positions of electric immersion heater inside cylinder



Self-contained open outlet heater



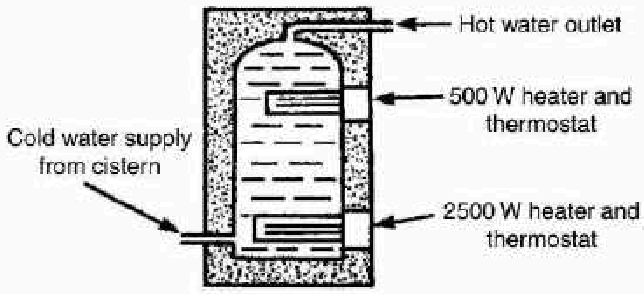
Cistern-type heater



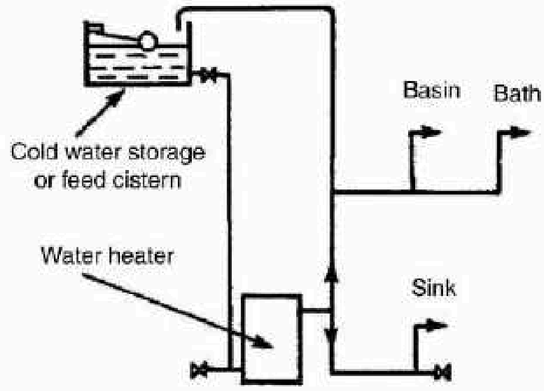
Installation of electric cistern-type heater

Ref. BS 3198: Specification for copper hot water storage combination units for domestic purposes.

The cistern-type heater should be located with the water level at least 1·5 m above the water draw-off taps. If there is insufficient space to accommodate this combination unit, a smaller pressure-type water heater may be fitted. These are small enough to locate under the sink or elsewhere in the kitchen. They have two immersion heaters, the upper element of 500 watts rating is for general use supplying hot water to the basin, sink and other small appliances. The lower element of 2500 watts may be on a timed control to provide sufficient hot water for baths. The pressure heater is supplied with cold water from a high level cistern.



Pressure-type electric water heater



Installation of pressure-type electric water heater

Immersion heaters – safety cut-out. Since 2004, immersion heater manufacturers are required to incorporate an additional integral safety device, independent of the main thermostat. This brings immersion heaters for vented water heating into line with the requirements for unvented water heaters.

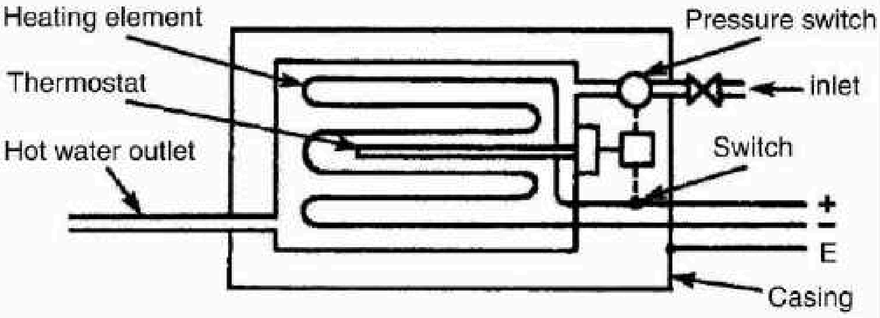
Function – if the main thermostat fails, water will boil, with considerable damage potential to personnel, the installation and premises. The manufacturer's pre-set safety cut-out is designed to prevent water in a hot water storage vessel exceeding 98°C. It must not re-set automatically.

Methods – either:

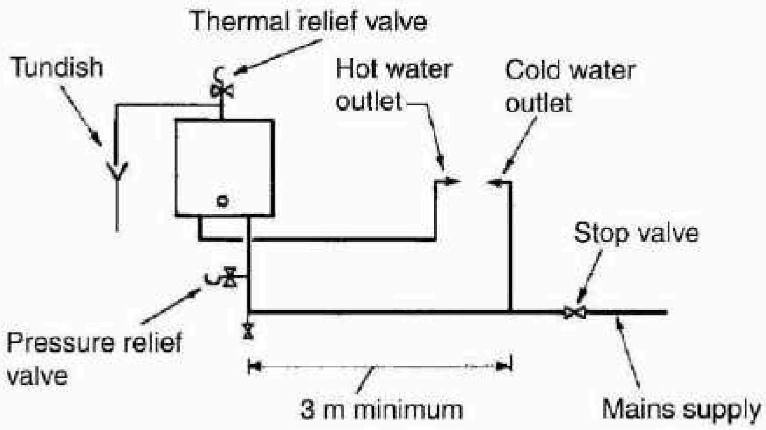
- A 'one-shot' thermal cut-out or thermostat. This is principally a fusible link which melts or ruptures at a pre-determined temperature, or
- A manually re-settable cut-out or thermostat which responds to critical temperature change to break electrical contact.

Ref. BS EN 60335-2-73: Specification for safety of household and similar electrical appliances. Particular requirements for fixed immersion heaters.

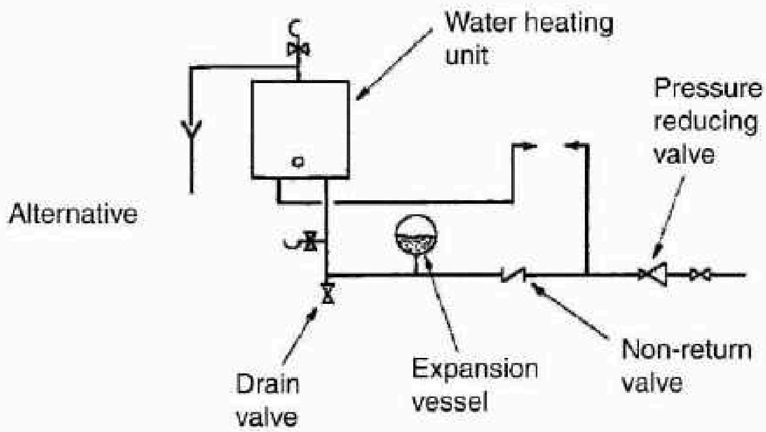
Instantaneous water heaters are relatively compact non-storage units suitable for use with individual sinks, basins and showers. For user safety they are fitted with a pressure switch to disconnect the electricity if the water supply is interrupted and a thermal cut-out to prevent the water overheating. Mains pressure to these units should be maintained below 400 kPa (4 bar). In some high pressure supply areas this will require a pressure reducing valve to be installed on the service pipe. Some expansion of hot water will occur whilst the unit is in use. This can be contained if there is at least 3 metres of pipework before the unit and the closest cold water draw-off. If this is impractical, an expansion vessel may be used. For more details of electric shower installations see pages 286 and 287.



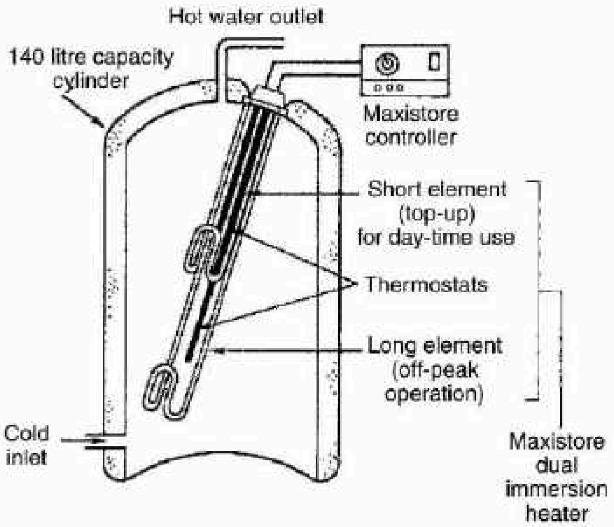
Instantaneous-type electric water heater



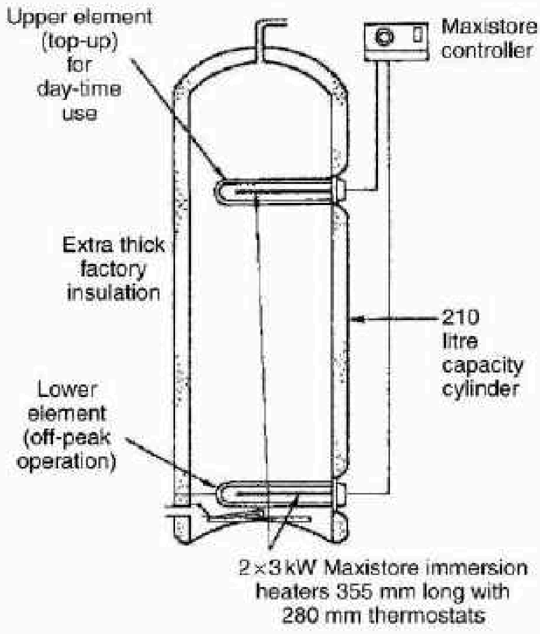
Installation of unvented hot water units of less than 15 litres capacity



Industrial, commercial and domestic demand for electricity is considerably reduced overnight. Therefore during this time, the electricity supply companies can market their spare capacity as off-peak electricity by selling it at a reduced rate – approximately half the cost of standard day time tariff. Supplies are adapted to operate through a programmer or time control which diverts the electricity to a special off-peak or white meter, usually from midnight to 7 a.m. In order to maximise the benefit, slightly larger than standard capacity hot water storage cylinders of 162 or 190 litres are recommended. To conserve energy, these cylinders must be thoroughly insulated and the immersion heaters fitted with integral thermostatic control. If supplementary hot water is required during the day, this can be provided by a secondary immersion heater at standard supply tariff.



Immersion heater for existing cylinder

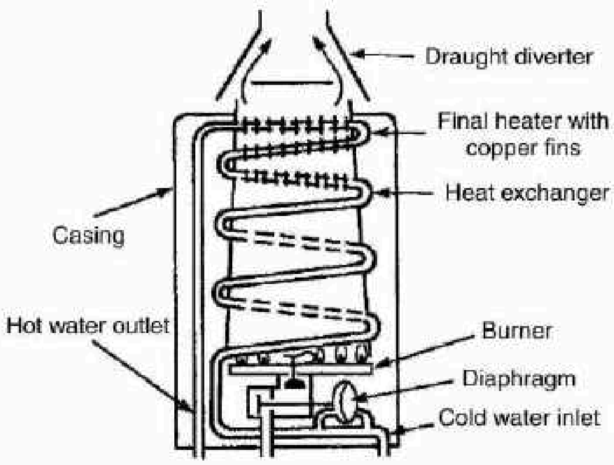


Special package unit

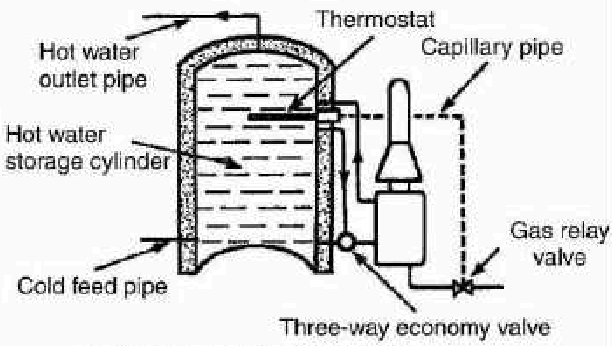
The secondary immersion heater or boost heater is close to the top of the cylinder to ensure that only a limited quantity of water is heated at standard tariff. To maximise economy, the off-peak thermostat is set at 65°C and the boost thermostat at 60°C.

When the hot water outlet is opened, cold water flows through a venturi fitting. The venturi contains a diaphragm which responds to the flow differential pressure and this opens the gas valve. A pilot flame ignites gas flowing through the burner which heats the water as it passes through the heat exchanger. Installation can be direct from the water main or from a cold water storage cistern. A multi-point system has the hot water outlet suppling several appliances.

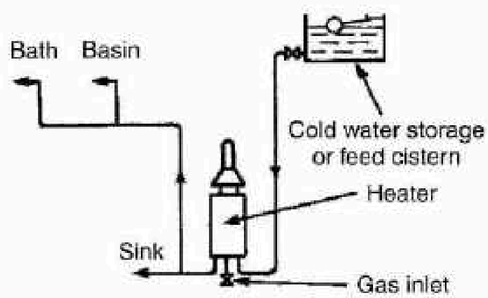
A gas circulator can be used to heat water in a storage cylinder. They are usually fitted with an economy or three-way valve. This gives optional use of water circulation through a high or low return pipe for variable hot water storage volume. Domestic installations may be in the kitchen, with vertical flow and return pipes to a storage cylinder in the airing cupboard.



Instantaneous gas water heater



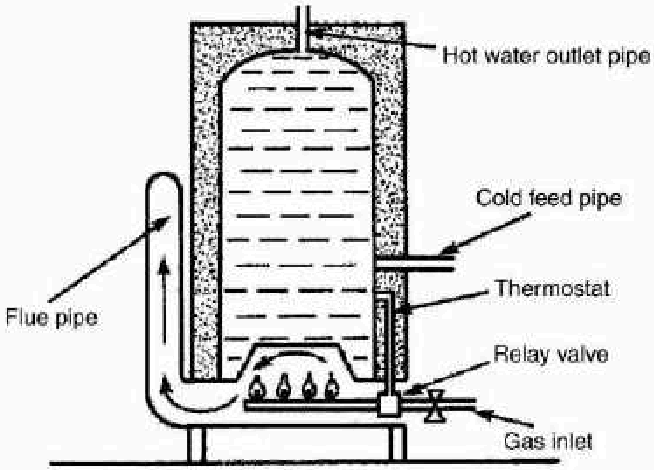
Installation of gas circulator



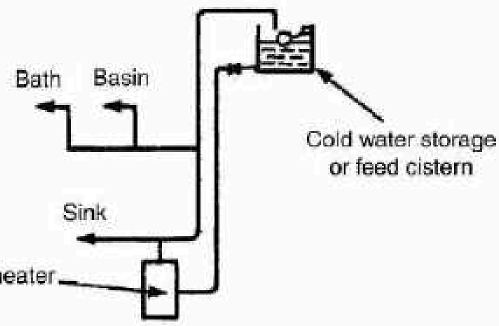
Installation of instantaneous gas water heater

Ref: BS EN 26: Gas fired instantaneous water heaters for the production of domestic hot water, fitted with atmospheric burners.

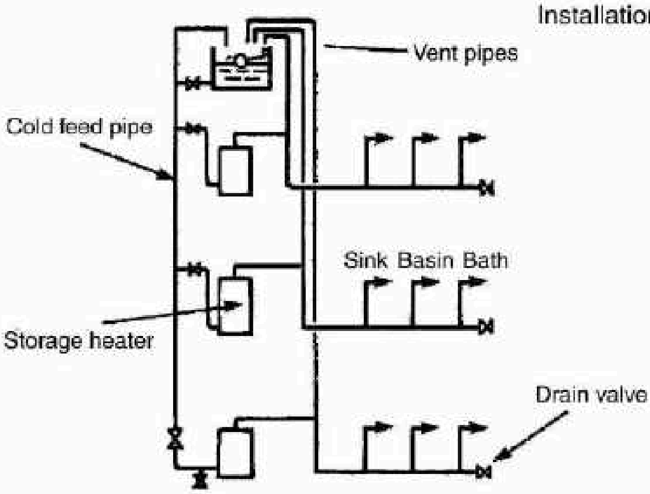
The storage type of gas water heater is a self-contained unit and is therefore simpler and quicker to install than a gas circulator. Capacities range from 75 to 285 litres. The smaller units are single-point heaters for supplying hot water to an individual sink or basin. Larger, higher rated storage heaters can be used to supply hot water to a bath, basin, sink and shower. These are called multi-point heaters. They may also be installed in flats up to three storeys, with cold water supplied from one cistern. A vent pipe on the cold feed will prevent siphonage. To prevent hot water from the heaters on the upper floors flowing down to the heater on the ground floor, the branch connection on the cold feed pipe must be above the heaters.



Detail of gas storage heater



Installation of gas storage heater for a house



Installation of gas storage heaters for three-storey flats (electric pressure heaters may be similarly installed)

Condensing water heater – a variation on the multipoint type heater. The condensing heater is a hot water storage vessel, capable of very rapid heat recovery.

Application – typical examples include small hotels, schools, residential homes, student halls of residence, camp sites and sports centres.

Function – a fanned gas burner discharges into a stainless steel combustion chamber within a cylindrical water storage vessel. From the combustion chamber the burnt gases descend into a stainless steel spiral to exit at low level through a flue. Condensate from the flue is trapped and discharged to a drain.

Controls –

Automatic electric ignition in response to a water temperature thermostat.

Limit thermostat.

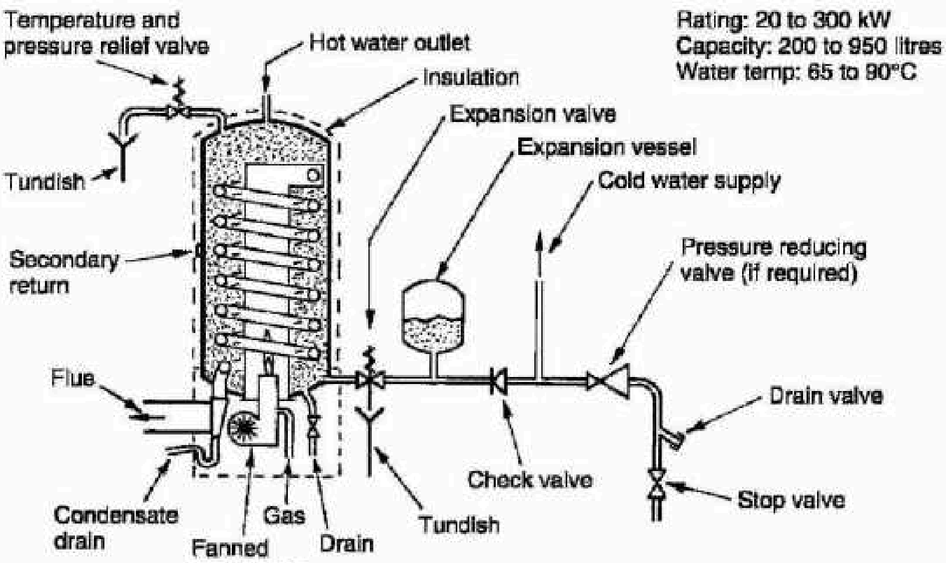
Overheat safety thermostat and warning light.

Fan failure device and warning light.

Manual on/off switch.

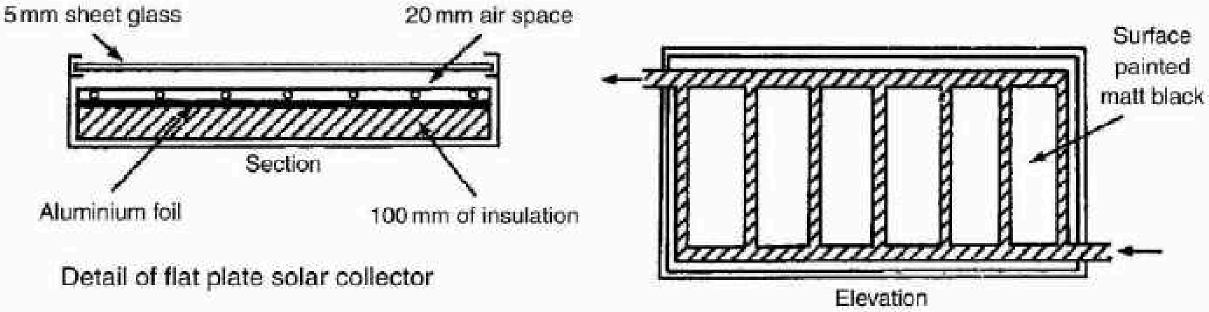
Water supply – either:

- Cistern, gravity feed pipe and atmospheric vent and expansion pipe, or
- Direct connection to an unvented mains supply. Unvented supplies require backflow prevention (check valve), an expansion vessel and an expansion valve. A pressure and temperature relief valve must also be fitted to the hot water outlet to discharge safely into a tundish.

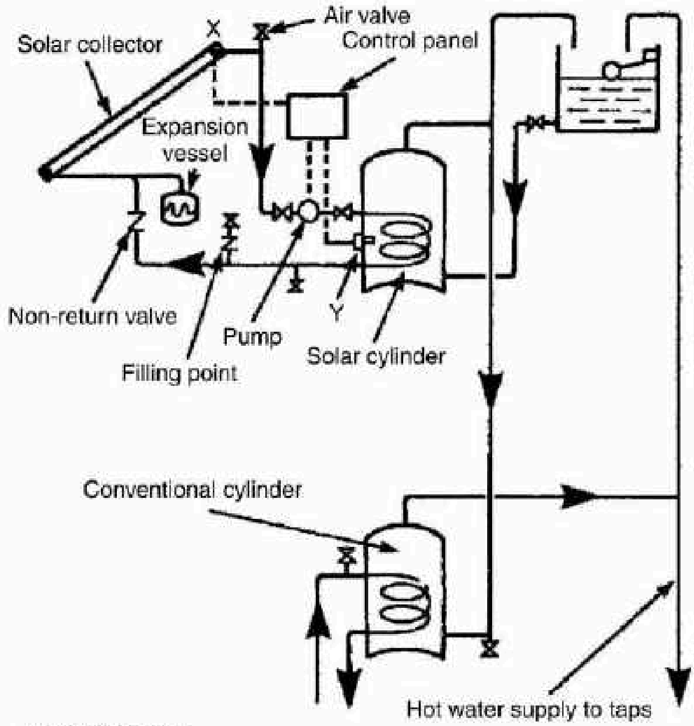


Mains connected condensing water heater

Solar energy can contribute significantly to hot water requirements. In some countries it is the sole source of energy for hot water. In the UK its efficiency varies with the fickle nature of the weather, but fuel savings of about 40% are possible. For domestic application, the collector should be 4 to 6 m^2 in area, secured at an angle of 40° to the horizontal and facing south. The solar cylinder capacity of about 200 litres is heated to 60°C. The cylinder and associated pipework must be very well insulated and the solar part of the system should contain a blend of water and non-toxic anti-freeze. The pump is switched on when the temperature of water at point X exceeds that at point Y by 2 to 3°C. The solar cylinder and the conventional cylinder may be fitted on the same level, or to save space a combined solar/conventional cylinder can be obtained from specialist suppliers.



Detail of flat plate solar collector



Detail of system

The heat energy properties of water are fundamental for determining pipe sizes and component dimensions in hot water and heating systems.

HEAT is a form of energy, otherwise known as thermal energy. The standard unit of energy is the joule (J).

1 joule = amount of energy supplied by 1 watt (W) in 1 second (s).

Other units of energy found in older textbooks and product references include:

1 British thermal unit (1Btu) = 1·055 kJ
1 calorie (1 cal) = 4·187 J
1 kilowatt hour (1kWh) = 3·6 MJ
1 therm (1 therm) = 105·5 MJ

POWER is a measure of work rate.
Power (W) = heat energy (J) ÷ time in seconds (s)
Thus, 1W = 1 joule/second

TEMPERATURE is measured on a scale between two fixed points. These points are chosen at normal atmospheric pressure to represent water at the melting point of ice as zero, and the boiling point at 100, hence the term centigrade. A point on this scale is known as degrees Celcius (°C). The thermodynamic or absolute scale of temperature is represented in degrees Kelvin (K). Temperature intervals are the same as Celcius, but Kelvin originates at −273.15°C, the point at which no more internal energy can be extracted from a body. Temperature change intervals of 1°C and 1K are the same, except that:

thermodynamic temperature (K) = temperature in °C + 273.15

e.g. 1: water at 30°C = 303.15 K

e.g. 2: a hot water system with primary flow and return temperatures of 80°C and 70°C respectively, has a temperature differential of 10 K.

SPECIFIC HEAT CAPACITY (Shc) is the amount of heat energy required to raise 1 kilogram (kg) of a substance by 1K.

Some approximate values of Shc (will vary slightly with temperature and pressure):

Water	4180 J/kg K	Aluminium	910 J/kg K
Ice	2100	Cast iron	500
Nylon	1700	Copper/zinc	385
Air	1010	Lead	126

From the above, it can be seen that it would require over four times as much heat energy to raise 1 kg of water 1 K, than 1 kg of air (4180 ÷ 1010 = 4.14). Conversely, as the Shc of water is relatively high, it is a good medium for storing heat. This is also a reason why hot water plant occupies less space than warm air systems, i.e. pipes are much smaller than air ducts conveying the same amount of energy.

The capacity of hot water storage vessels must be adequate for the building purpose. Exact requirements are difficult to determine, but reasonable estimates are possible. These should include provision for rate of energy consumption (see table below) and the time taken to reheat the water to the required storage temperature (see boiler rating calculation – next page). Many buildings have variable use and inconsistent demands. This often creates an overdesign situation, unless care is taken to establish peak use periods and the system calculations adjusted accordingly. With these building types, non-storage instantaneous fittings may be preferred.

For most buildings the following table can be used as guidance:

Building purpose	Storage capacity (litres/person)	Energy consumption (kW/person)
Dwellings:		
single bath	30	0·75
multi-bath	45	1·00
Factory/Office	5	0·10
Hotels	35*	1·00
Hostels	30	0·70
Hospitals	35*	1·00
Schools/Colleges:		
day	5	0·10
boarding	25	0·70
Sports pavilions	35	1·00

* Average figures

E.g. A student hall of residence (hostel) to accommodate 50 persons.

Capacity: 50 × 30 = 1500 litres
Energy consumption: 50 × 0·70 = 35 kW

The nearest capacity storage vessel can be found from manufacturers' catalogues or by reference to BS 1566. For convenience, two or three cylinders of equivalent capacity may be selected.

Boilers are rated in kilowatts, where 1 watt equates to 1 joule of energy per second, i.e. W = J/s. Many manufacturers still use the imperial measure of British thermal units per hour for their boilers. For comparison purposes 1 kW equates to 3412 Btu/h.

Rating can be expressed in terms of gross or net heat input into the appliance. Values can be calculated by multiplying the fuel flow rate (m^3/s) by its calorific value (kJ/m^3 or kJ/kg). Input may be gross if the latent heat due to condensation of water is included in the heat transfer from the fuel. Where both values are provided in the appliance manufacturer's information, an approximate figure for boiler operating efficiency can be obtained, e.g. if a gas boiler has gross and net input values of 30 and 24 kW respectively, the efficiency is 24/30 × 100/1 = 80%.

Oil and solid fuel appliances are normally rated by the maximum declared energy output (kW), whereas gas appliances are rated by net heat input rate (kW[net]).

Calculation of boiler power:

$$\text{kW} = \frac{\text{kg of water} \times \text{S.h.c.} \times \text{Temp. rise}}{\text{Time in seconds}}$$

where: 1 litre of water weighs 1 kg

S.h.c. = specific heat capacity of water, 4·2 kJ/kgK

K = degrees Kelvin temperature interval

Temp. rise = rise in temperature that the boiler will need to increase the existing mixed water temperature (say 30°C) to the required storage temperature (say 60°C).

Time in seconds = time the boiler takes to achieve the temperature rise. 1 to 2 hours is typical, use 1·5 hours in this example.

From the example on the previous page, storage capacity is 1500 litres, i.e. 1500 kg of water. Therefore:

$$\text{Boiler power} = \frac{1500 \times 4{\cdot}2 \times (60 - 30)}{1{\cdot}5 \times 3600} = 35 \text{ kW net}$$

Given the boiler has an efficiency of 80%, it will be gross input rated:

$$35 \times 100/80 = 43{\cdot}75 \text{ kW}$$

Note: The boiler operating efficiency is the relationship between a unit of fuel energy consumed to produce a unit of heat energy in the appliance hot water. It is not to be compared with the seasonal efficiency of a boiler (SEDBUK), see page 72.

Pipe Sizing – Primary Flow and Return

The water in primary flow and return pipework may circulate by convection. This produces a relatively slow rate of movement of about 0·2 m/s, depending on pipe length and location of boiler and cylinder. Modern systems are more efficient, incorporating a circulation pump to create a water velocity of between 0·75 and 3·0 m/s. This permits smaller pipe sizes and will provide a faster thermal response.

Inside diameter of pipe	Velocity min.	Velocity max. (copper)	Velocity max. (steel)
<50 mm	0·75 m/s	1·0 m/s	1·5 m/s
>50 mm	1·25 m/s	1·5 m/s	3·0 m/s

Exceeding these recommendations may lead to excessive system noise and possible pipe erosion.

E.g. using the Copper Development Association design chart shown on the next page, with the boiler rating from the previous example of 43.75 kW gross heat input and 35 kW net heat input.

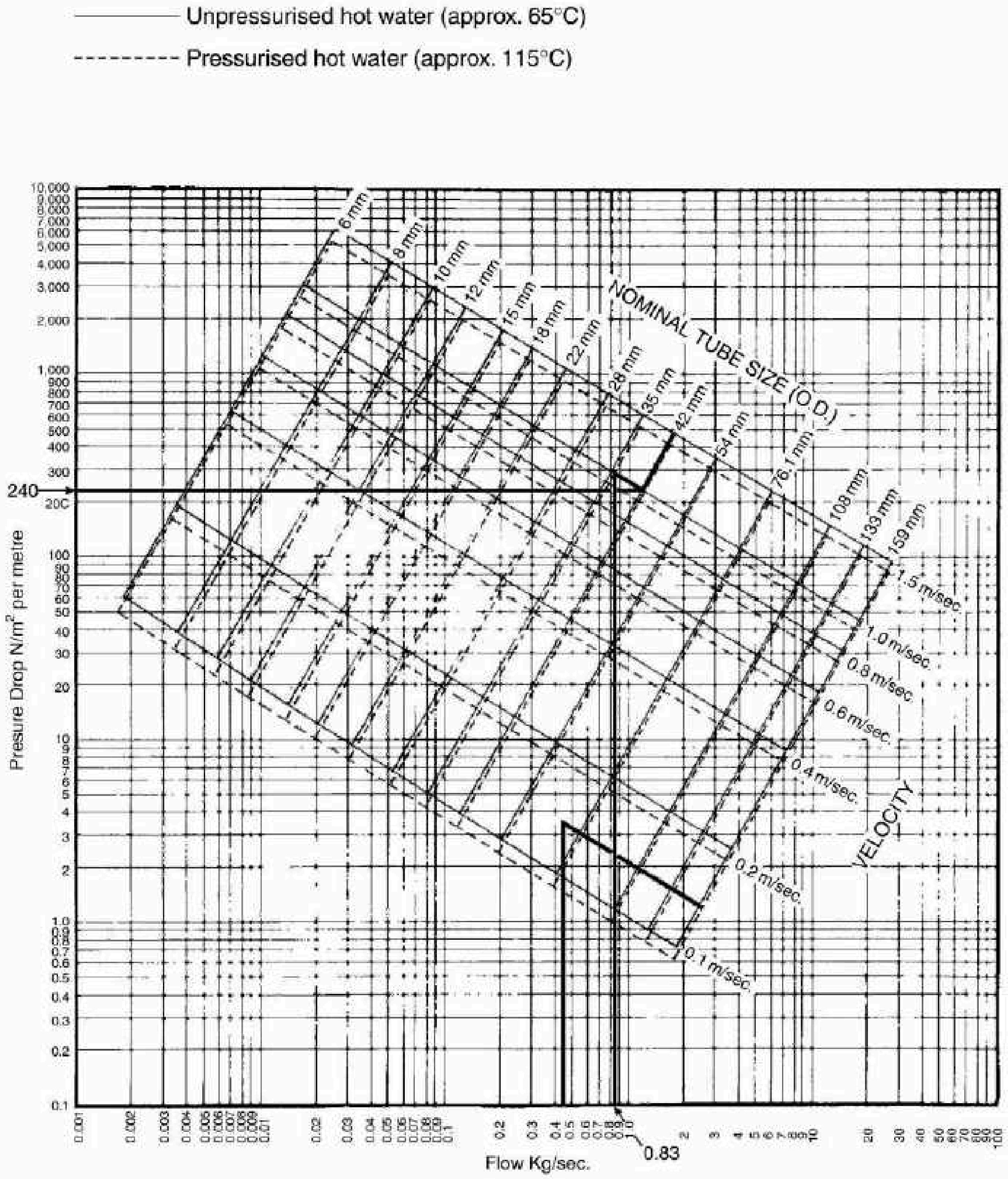
$$\text{Mass flow rate (kg/s)} = \frac{\text{Boiler net heat input}}{\text{S.h.c.} \times \text{Temp. diff. (pf} - \text{pr)}}$$

Temperature difference between primary flow (pf) and primary return (pr) in pumped water circuits is usually about 10 K, i.e. 80°C–70°C. With convected circulation the return temperature will be about 60°C.

$$\text{Mass flow rate} = \frac{35}{4{\cdot}2 \times 10} = 0{\cdot}83\ \text{kg/s}$$

On the design chart, co-ordinating 0·83 kg/s with a pumped flow rate of 1 m/s indicates a 42 mm inside diameter copper tube. (35 mm is just too small.)

By comparison, using convected circulation of, say, 0·15 m/s and a mass flow rate with a 20 K temperature difference of 0·42 kg/s, the pipe size would be 76 mm.



Reproduced with the kind permission of the Copper Development Association.

Circulatory pumps produce minimal pressure in the primary flow and return, but the flow rate is considerably enhanced. The pressure can be ascertained from design charts as a pressure drop in N/m^2 per metre or pascals per metre. 1 N/m^2 equates to 1 pascal (Pa).

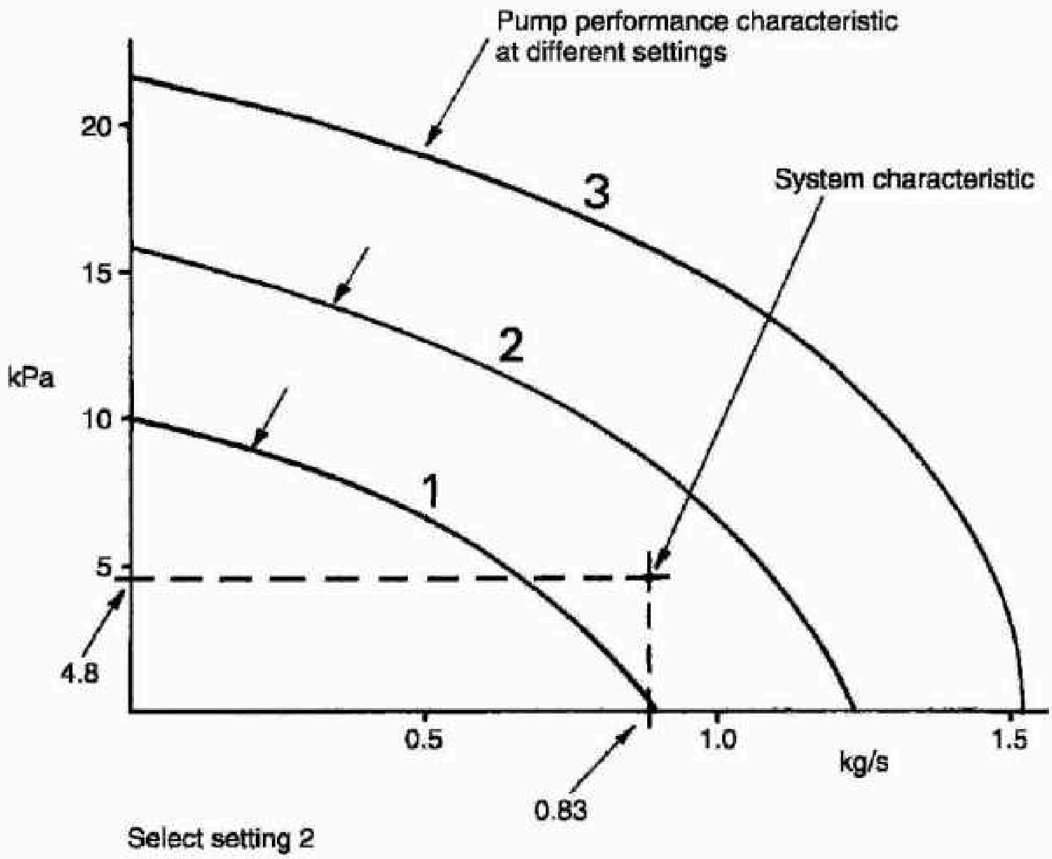
From the design chart, circulation in a 42 mm copper tube at 1 m/s produces a pressure drop of 240 Pa per metre. An estimate of the primary flow and return effective pipe length (see page 29) is required to establish the total resistance that the pump must overcome. For example, if the effective pipe length is 20 m:

240 × 20 = 4800 Pa or 4·8 kPa.

Therefore the pump specification would be 0·83 kg/s at 4·8 kPa.

Manufacturers' catalogues can be consulted to select a suitable pump. To provide for flexibility in installation, a degree of variable performance is incorporated into each model of pump. This range of characteristics can be applied by several different control settings as shown in the following graphic.

Pump performance chart:



Bacterial growths which cause Legionnaires' disease develop in warm, moist, natural conditions such as swamps. They have adapted to living in the built environment in the artificial atmosphere of air conditioning and hot water systems. A large number of outbreaks of the disease have occurred, with some people suffering a prolonged illness similar to pneumonia. The elderly are particularly vulnerable and many have died, hence the name of the illness which was attributed to a group of retired legionnaires who were infected whilst attending a reunion in Philadelphia, USA, in 1976. Numerous other outbreaks and subsequent deaths have led to strict maintenance and installation controls of services installations. This has been effected by the Health and Safety Executive under the Health and Safety at Work, etc. Act and the Workplace (Health, Safety and Welfare) Regulations. The following measures are recommended for use with hot water systems:

1. Stored hot water temperature 60 to 65°C throughout the storage vessel.

2. Routine maintenance involving heating the water to 70°C as a precaution.

3. Changing the design of cylinders and calorifiers with concave bases. These are suspect, as the lower recesses could provide areas of reduced water temperature with little or no movement.

4. Connections to storage vessels should encourage through movement of water.

5. Pipework 'dead-legs' to be minimal.

6. All pipework to be insulated to reduce water temperature losses.

7. Where secondary circulation is required, supplementary trace element heating tape should be applied to maintain a minimum water temperature of 50°C.

8. Showers with recessed/concave outlet roses to be avoided. Other designs to have a self-draining facility to avoid inhalation of contaminated moisture droplets.

9. Spray taps – similar provision to 8.

Note: Cold water should be kept below 20°C.

SEDBUK is the acronym for *Seasonal Efficiency of Domestic Boilers in the United Kingdom*. It has developed under the Government's Energy Efficiency Best Practice Programme to provide a manufacturers' data base which represents the efficiency of gas- and oil-fired domestic boilers sold in the UK. See website: www.boilers.org.uk, or www.sedbuk.com. This voluntary site is updated monthly and it contains over 75% of new and existing products.

SEDBUK must not be confused with the operating efficiencies which are sometimes quoted in manufacturers' literature. These compare gross and net heat input values - see page 67. SEDBUK is the average annual in-use efficiency achieved in typical domestic conditions. The principal parameters included in the SEDBUK calculation are:

- type of boiler
- fuel ignition system
- internal store size
- type/grade of fuel.

Also included are the operating influences:

- typical patterns of usage - daily, weekly, etc.
- climatic variations.

Quoted SEDBUK figures are based on standard laboratory tests from manufacturers, certified by an independent Notified Body which is accredited for boiler testing to European Standards.

Efficiency bands:

Band	SEDBUK range (%)
A	>100
B	86-90
C	82-86
D	78-82
E	74-78
F	70-74
G	<70

See next page for the minimum acceptable band values for different fuel and installation types.

Building Regulations, Approved Document L1: Conservation of fuel and power in dwellings, required, from 2002, reasonable boiler efficiency for installations in new dwellings and for replacement equipment in existing dwellings. The following values applied:

Fuel system and boiler type	Min. SEDBUK value (%)
Natural gas	78
Natural gas back boiler	75
Liquid petroleum gas (LPG)	80
LPG back boiler	77
Oil	85
Oil combination boiler	82
Solid fuel	See HETAS certification

The SEDBUK database is an essential reference when calculating part of the Government's Standard Assessment Procedure for Energy Rating of Dwellings (SAP rating). Additional factors to be considered are: ventilation, heat losses through the fabric (U values) and solar gains. To comply with the Building Regulations, builders are required to submit energy rating calculations to the local building control authority. This data is also available for prospective house buyers and tenants for comparison purposes when assessing anticipated annual fuel costs for hot water and heating. SAP values vary from 1 to 120, with 80 considered the minimum expectation of new dwellings. SAP worksheets are available in the Appendices to Approved Document L1 of the Building Regulations.

Recognised organisations for accrediting 'competent persons' as installers of domestic hot water and central heating systems:

Gas – Council for Registered Gas Installers (CORGI).

Oil – Oil Firing Technical Association for the Petroleum Industry (OFTEC).

Solid fuel – Heating Equipment Testing and Approval Scheme (HETAS).

Refs:

Building Regulations, Approved document L1 – Conservation of fuel and power in dwellings, 2002 and 2005.

The Government's Standard Assessment Procedure for Energy Rating of Dwellings, 2001 and 2005.

(Both published by The Stationery Office.)

The amended Building Regulations of 1990, 1995 and 2002 have made substantial improvements to standards of energy efficiency. Since 2002, several more initiatives have been applied to the installation and use of fuel-consuming appliances and attention to details of construction. Buildings have been specifically identified as the source of about 50% of all atmospheric carbon emissions. Half of this is attributed to emissions from domestic hot water and heating equipment.

The initial objectives are to:

- Reduce the carbon dioxide (CO_2) emissions from boilers by some 60% by around 2050. Real progress to be achieved by 2020.
- Maintain the reliability of fuel energy supplies and resources.
- Promote a competitive energy market in order to encourage sustainable economic growth and productivity.
- Ensure that all homes are adequately and affordably heated.

Effects:

- Domestic boilers – new and replacement appliances of SEDBUK rating A or B only, i.e. high efficiency condensing boilers.
- Insulation standards for new and refurbished buildings improved, e.g. replacement windows and reduced 'U' values.
- Regular inspection and maintenance of air conditioning systems.
- Measures to prevent overheating by solar gain.
- Installation of energy recovery systems, e.g. MVHR and heat pumps.
- Restricted use of inefficient appliances, e.g. gas decorative effect fires.
- Insulation of hot and chilled water pipework and sealing of ductwork joints to prevent air leakage.
- Use of high efficacy electric lamps and power rating limitations on external lighting.
- Calculation of carbon emission limits from dwellings, re. SAP ratings. For other buildings measures required to show improvements, such as renewable energy use, solar systems and CHP.
- Reduced air leakage through the building envelope, max. 10 m^3/hour/m^2.

Government energy policy:

- Reduced oil, gas and coal production.
- Deep mined coal resources exhausted by 2015.
- Coal fired power stations to be phased out.
- Nuclear power stations to be phased out.
- Net importer of gas by 2006.
- Net importer of oil by 2010.
- By 2020, expected that 75% of UK prime energy supplies will be imported.
- Low carbon economy – reduced greenhouse gases.
- Microcombined heat and power (CHP) units to be encouraged. Fuel cells and other renewable energy sources to be developed.

Refs.

Government White Paper: Our Energy Future – Creating a Low Carbon Economy. Published 2003 by the DTI.

Building Regulations, Approved Document L: Conservation of fuel and power, 2005.

Electrolysis – the corrosion or decomposition of different metals in the presence of water. Three criteria exist which will encourage corrosion:

- Neutral or acidic water, pH value $\leqslant 7$
- Warm or hot water
- Metals widely apart on the electrochemical or galvanic series.

Electrochemical series for metals used in plumbing and hot water services:

Protected end (cathode)	Stainless steel
	Copper
	Gunmetal and bronze
	Tin
	Lead
	Steel
	Cast iron
	Aluminium
	Zinc (galvanising)
Corroded end (anode)	Magnesium

Water functions as an electrolyte, i.e. a solution which conducts an electric current between a cathode and anode of dissimilar metals. Therefore, in water services systems materials must be compatible, otherwise decomposition of pipework and equipment will occur. For example, galvanised steel and copper pipes should never be used together, particularly in hot water installations.

Plumbo-solvency – term used to describe the breakdown of lead pipes conveying water with 'soft' characteristics. This should not be a problem, as for health reasons lead is no longer acceptable as a water services material. However, exposed lead flashings could be affected in areas of 'soft' rainwater.

Cupro-solvency – term used to describe the breakdown of copper pipes where soft water contains dissolved carbon dioxide. This type of water is generally associated with private wells and springs.

Dezincification – this affects brass pipe fittings and valves. Brass is an alloy of copper and zinc (50:50). Electrolytic reaction between the two metals, particularly in high chloride waters, causes corrosion of the zinc. This leaves the fitting unchanged in appearance, but with no strength and possibly porous. Installations in areas known to be prone to this problem should be specified with gunmetal fittings, an alloy of copper, tin and zinc (85:10:5).

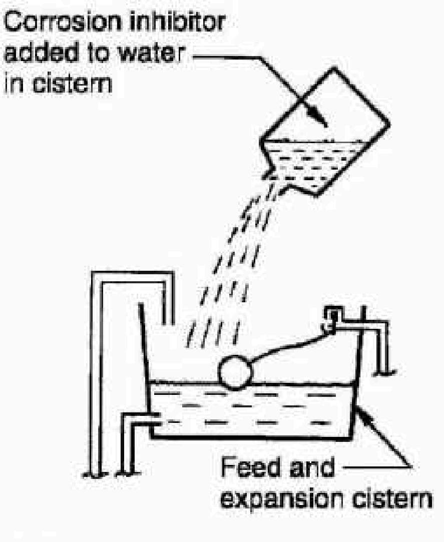
Anodic protection – before the introduction of plastic storage cisterns it was common practice to fit a sacrificial anode of magnesium into galvanised cold water storage cisterns if copper pipes were used. As magnesium is below zinc in the electrochemical series, the magnesium dissolved away instead of the galvanising. Sacrificial anodes are fitted as a precautionary measure to the inside of copper hot water storage cylinders.

Bacteria – the most common bacteria in water systems is *Pseudomonas* bacteria. It occurs where there is lack of water circulation or stagnation in discontinuous lengths of pipes and storage vessels. The latter is typical of expansion and feed cisterns in indirect hot water and central heating systems. High ambient temperatures between 20 and 40°C and poorly ventilated roof spaces or compartments are ideal for its development. First indications are usually its highly putrid odour. Inspection usually reveals a brown slimy film lining the water surface and storage cistern. Eradication is by flushing and disinfection with biocides in solution.

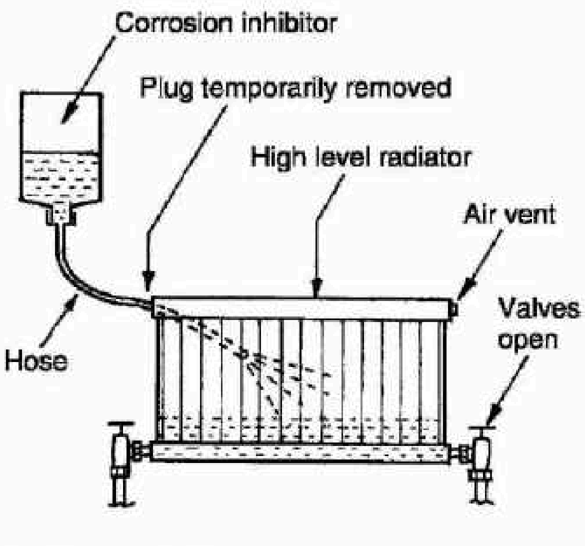
Corrosion Inhibitors – see also page 134. Boiler and associated equipment will only operate effectively and efficiently if water in the system is maintained clean and free of impurities. The minimal build up of scale or magnetite sludge will significantly reduce boiler efficiency and increase its contribution to carbon emissions.

New systems should be flushed to remove debris such as metal filings, flux and loose solder deposits. Filling is with clean water and the manufacturer's recommended dose of corrosion inhibitor, as shown in the illustrations. Following maintenance, repair or modification, existing systems should be treated similarly.

Proprietary corrosion inhibitors may be compounds of sodium silicate, benzoate, nitrite and chromate. Sodium pentachlorophenate is a bacteriacide or biocide which can be used to prevent the accumulation of hydrogen gas in radiators.

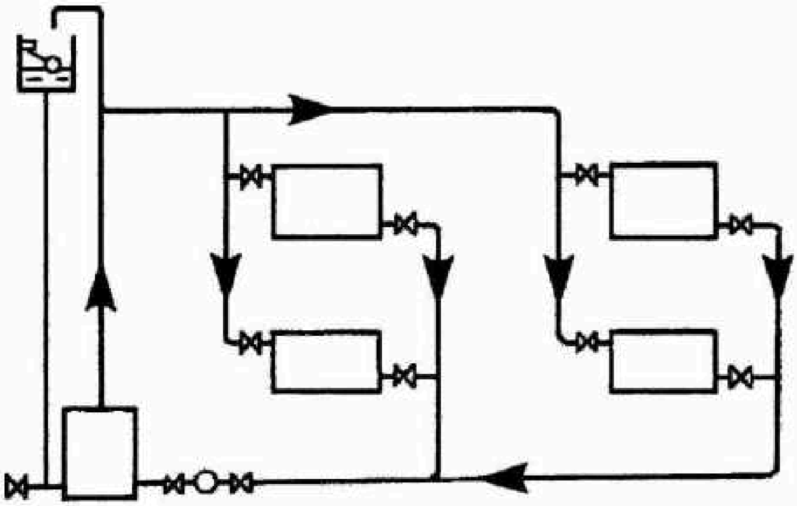


Dosing an open vent system



Dosing a sealed system

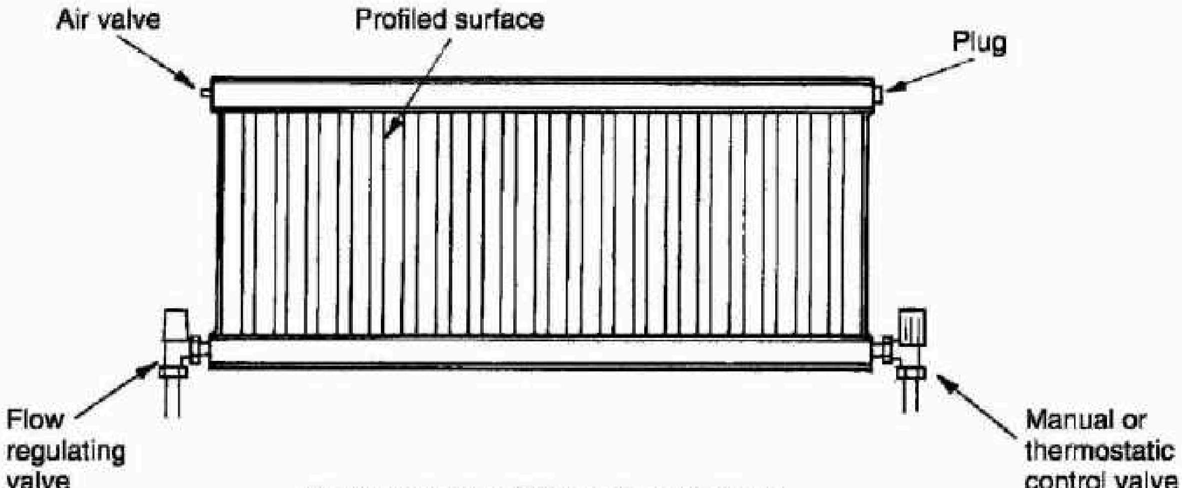
3 HEATING SYSTEMS



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

Despite the name radiator, no more than 40% of the heat transferred is by radiation. The remainder is convected, with a small amount conducted through the radiator brackets into the wall. Originally, radiators were made from cast iron in three forms: hospital, column and panel. Hospital radiators were so called because of their smooth, easy to clean surface, an important specification in a hygienic environment. Column radiators vary in the number of columns. The greater the number, the greater the heat emitting surface. Cast iron radiators are still produced to special order, but replicas in cast aluminium can be obtained. Cast iron panels have been superseded by pressed profiled steel welded panels. These are much slimmer and easier to accommodate than cast iron in the modern house. In addition to the corrugated profile, finned backing will also increase the heating surface and contribute to a higher convected output. Pressed steel radiators are made in single, double and triple panels.

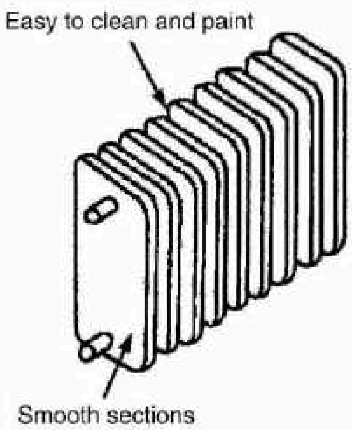
Convectors have a steel casing containing a finned heat exchanger. About 90% of the heat emission is convected and this may be enhanced if a thermostatically controlled fan is also located in the casing. They are more effective than radiators for heating large rooms, and in this situation their extra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



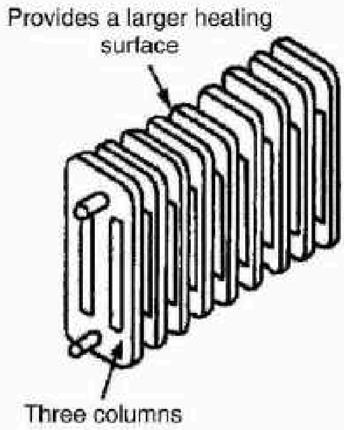
Pressed steel radiator and connections

In temperate and cold climates where there is insufficient warmth from the sun during parts of the year, heat losses from the human body must be balanced. These amount to the following approximate proportions: radiation 45%, convection 30% and evaporation 25%. Internal heat gains from machinery, lighting and people can contribute significantly, but heat emitters will provide the main contribution in most buildings.

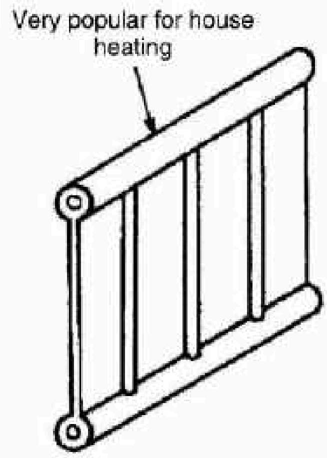
Enhancement of radiator performance can be achieved by placing a sheet of reflective foil on the wall between the fixing brackets. Emitter location is traditionally below window openings, as in older buildings the draughts were warmed as they infiltrated the ill-fitting sashes. With quality double glazed units this is no longer so important and in the absence of a window, locating a shelf above the radiator will prevent pattern staining of the wall due to convective currents. Radiant panels and strips suspend from the ceiling in industrial premises and other situations where wall space is unavailable.



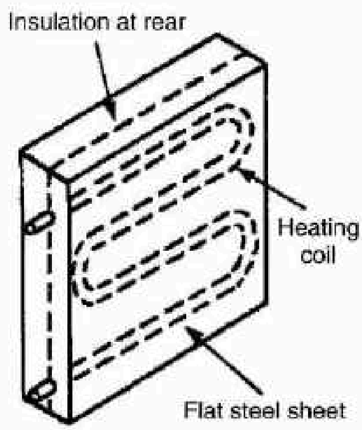
Hospital-type radiator



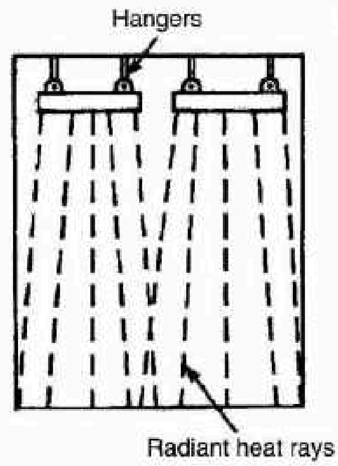
Column-type radiator



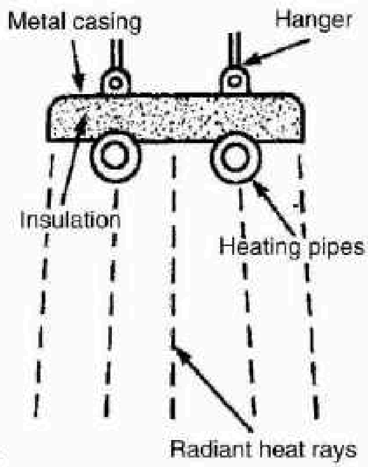
Panel-type radiator



Radiant panel

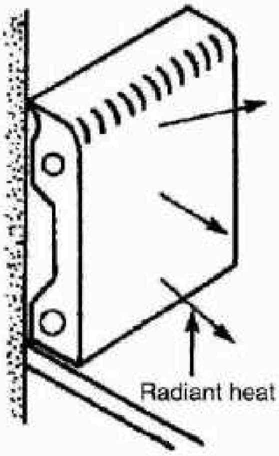


Radiant panels fixed overhead

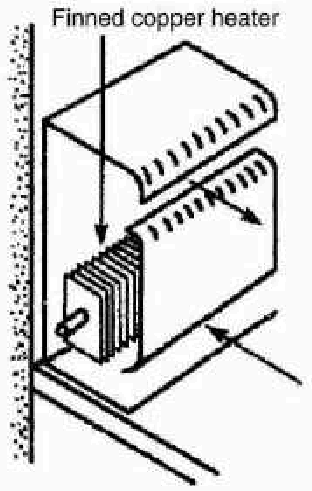


Radiant strip

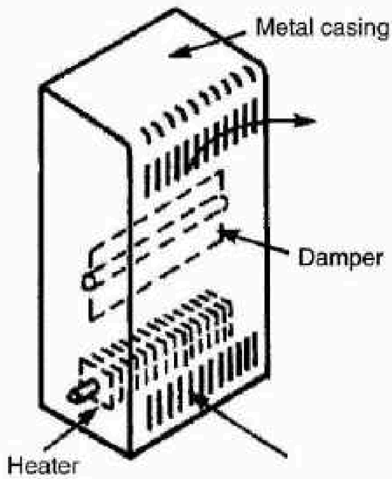
Radiant and convector skirting heaters are unobtrusive at skirting level and provide uniform heat distribution throughout a room. Natural convectors have a heating element at a low level within the casing. This ensures that a contained column of warm air gains velocity before discharging to displace the cooler air in the room. Fan convectors may have the heater at high level with a variable speed fan located below. In summer, the fan may also be used to create air circulation. Overhead unit heaters are used in workshops to free the wall space for benches, machinery, etc. A variation may be used as a warm air curtain across doorways and shop entrances. Individual unit heaters may have a thermostatically controlled inlet valve or a bank of several units may be controlled with zoning and diverter valves to regulate output in variable occupancy situations.



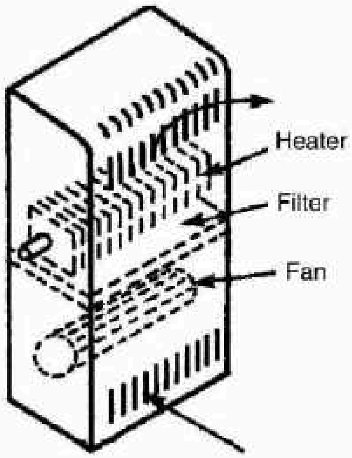
Radiant skirting heater



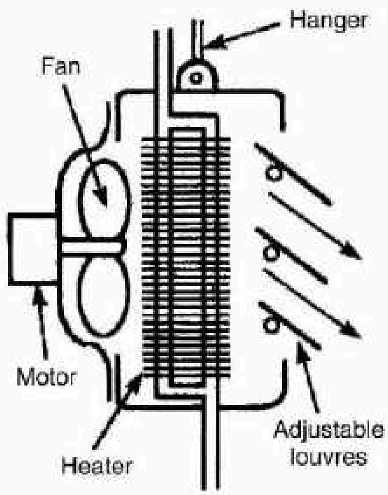
Convector skirting heater



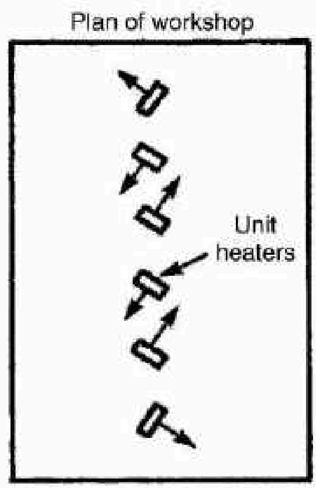
Natural convector



Fan convector



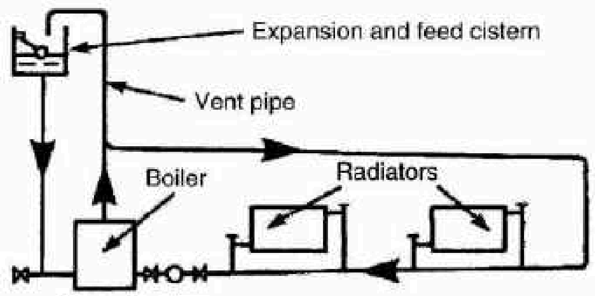
Overhead unit heater



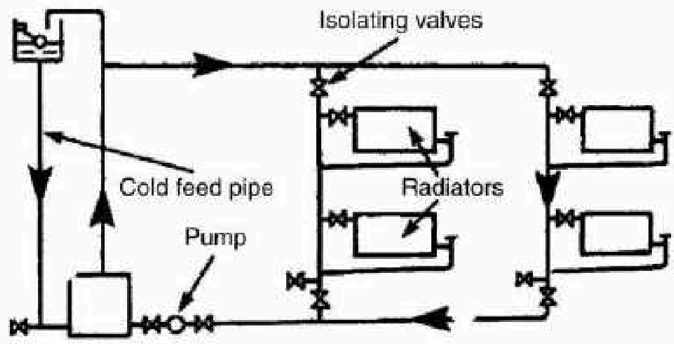
Method of siting overhead unit heaters

In low temperature, hot water heating systems the boiler water temperature is thermostatically controlled to about 80°C. Systems may be 'open' with a small feed and expansion cistern or mains fed 'sealed' with an expansion vessel.

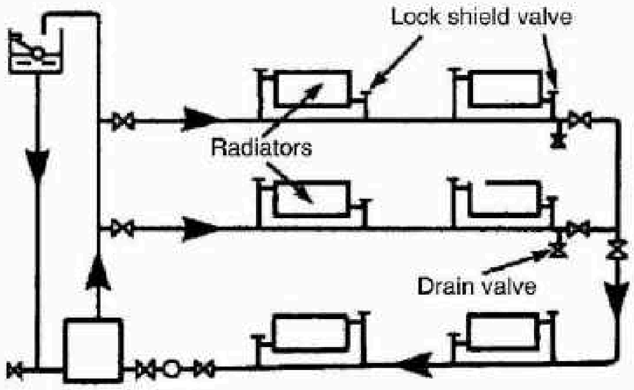
The type of system and pipe layout will depend on the building purpose and space available for pipework. A ring or loop circuit is used for single-storey buildings. Drop and ladder systems are used for buildings of several storeys. The drop system has the advantage of being self-venting and the radiators will not become air locked. Traditional solid fuelled systems operate by convection or gravity circulation (otherwise known as thermo-siphonage). Contemporary practice is to install a pump for faster circulation and a more rapid and effective thermal response. This will also complement modern fuel controls on the boiler and allow for smaller pipe sizes. The additional running costs are minimal.



One-pipe ring

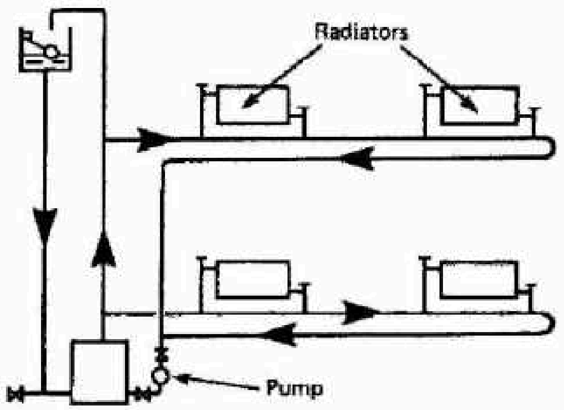


One-pipe drop

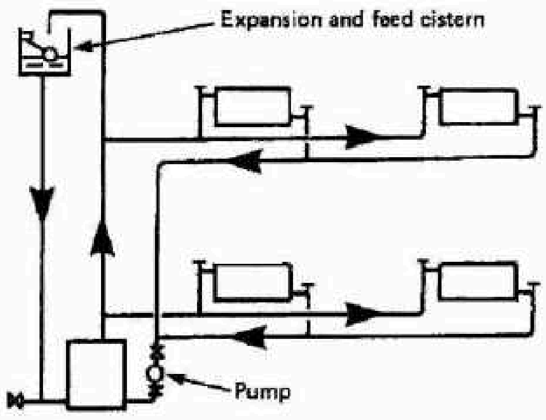


One-pipe ladder

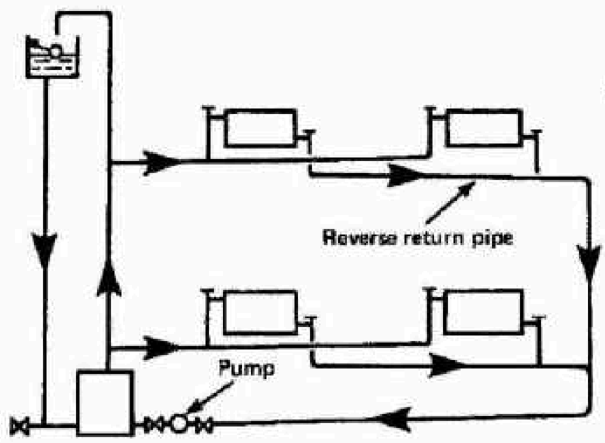
The one- and two-pipe parallel systems are useful where pipework can be accommodated within a floor structure, a raised floor or a suspended ceiling. The disadvantage with all one-pipe systems is the difficulty of supplying hot water to the radiators furthest from the boiler. As the heat is emitted from each radiator, cooling water returns to mix with the hot water supplying subsequent radiators, gradually lowering the temperature around the circuit. Eventually the last or 'index' radiator receives lukewarm water at best, necessitating a very large radiator to provide any effect. Pumped circulation may help, but it will require a relatively large diameter pipe to retain sufficient hot water to reach the 'index' radiators. Two-pipe systems are less affected, as the cool water from each radiator returns directly to the boiler for reheating. However, radiators will need flow balancing or regulating to ensure an even distribution of hot water. The reverse-return or equal travel system requires the least regulating, as the length of pipework to and from each radiator at each floor level is equal. In all systems the circulating pump is normally fitted as close to the boiler as possible, either on the heating flow or return. Most pump manufacturers recommend location on the higher temperature flow.



One-pipe parallel

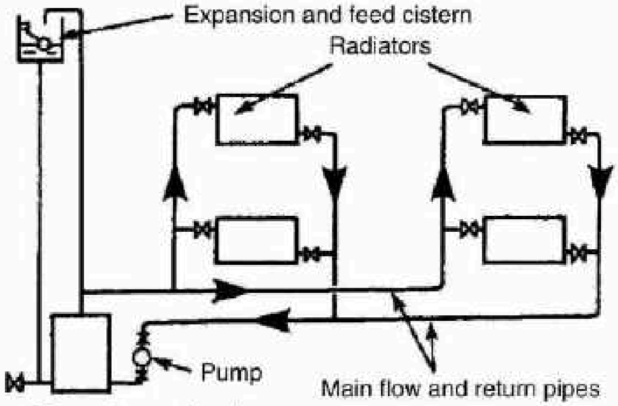


Two-pipe parallel

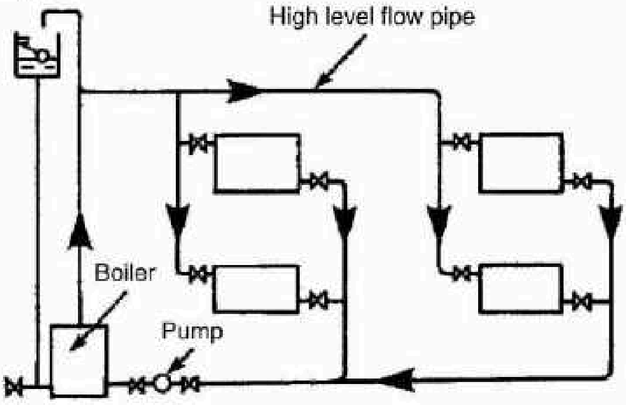


Two-pipe reverse return

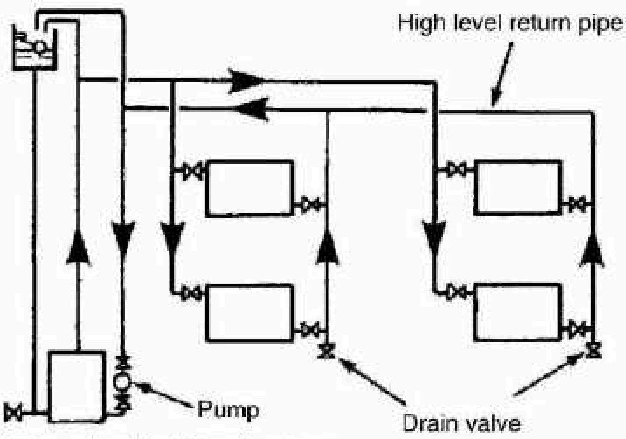
The two-pipe upfeed system is used when it is impractical to locate pipes horizontally at high level. The main heating distribution pipes can be placed in a floor duct or within a raised floor. The two-pipe drop is used where a high level horizontal flow pipe can be positioned in a roof space or in a suspended ceiling, and a low level return within a ground floor or basement ceiling. This system has the advantage of self-venting. The two-pipe high level return system is particularly appropriate for installation in refurbishments to existing buildings with solid ground floors. In this situation it is usually too time consuming, impractical and possibly structurally damaging to cut a trough or duct in the concrete.



Two-pipe upfeed

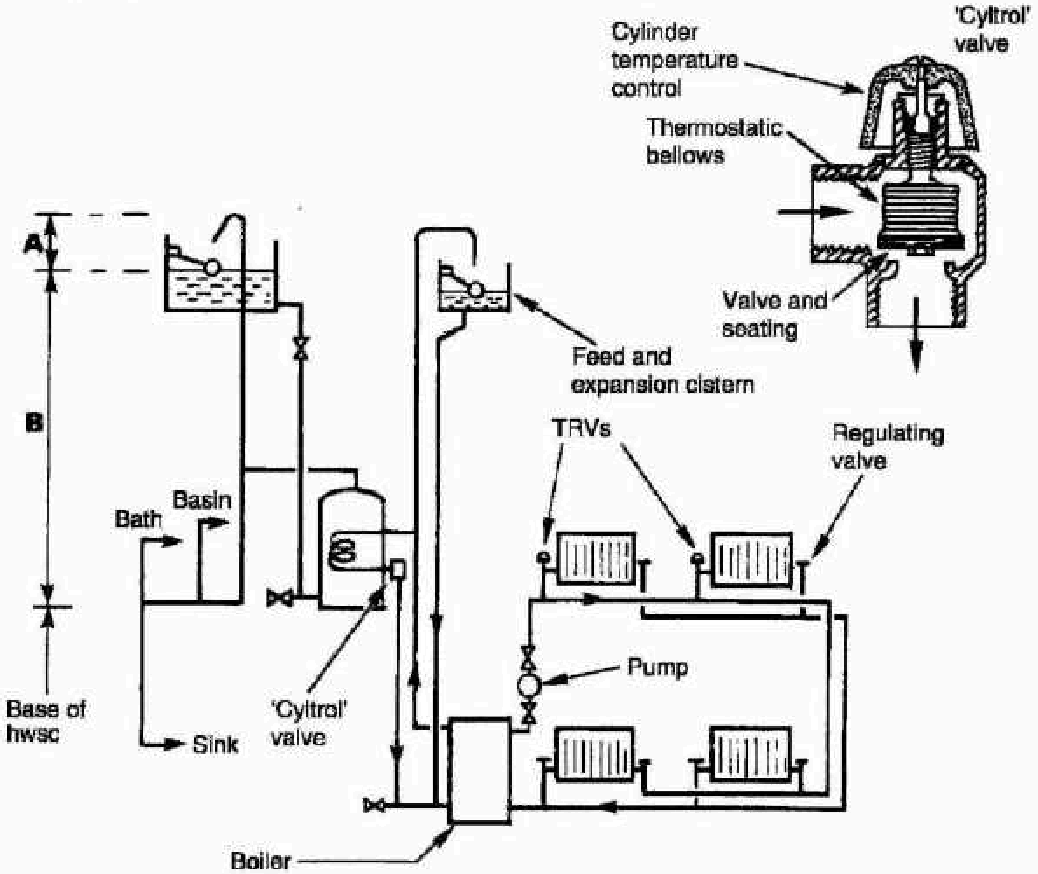


Two-pipe drop



Two-pipe high level return

Pumped small bore heating systems have 28 or 22 mm outside diameter copper tube for the main heating flow and return pipework, with 15 mm o.d. branches to each radiator. This compares favourably with the old gravity/convection circulation systems which sometimes required pipes of over 50 mm diameter to effect circulation. If cylinder and boiler are separated vertically by floor levels, there will be sufficient pressure for hot water to circulate by convection through the primary flow and return pipes. However, most modern systems combine a pumped primary and heating flow with circulation regulated by thermostats and motorised valves. Variations in one and two pipe systems are shown on pages 81–83. Two pipe systems are always preferred for more effective hot water distribution.



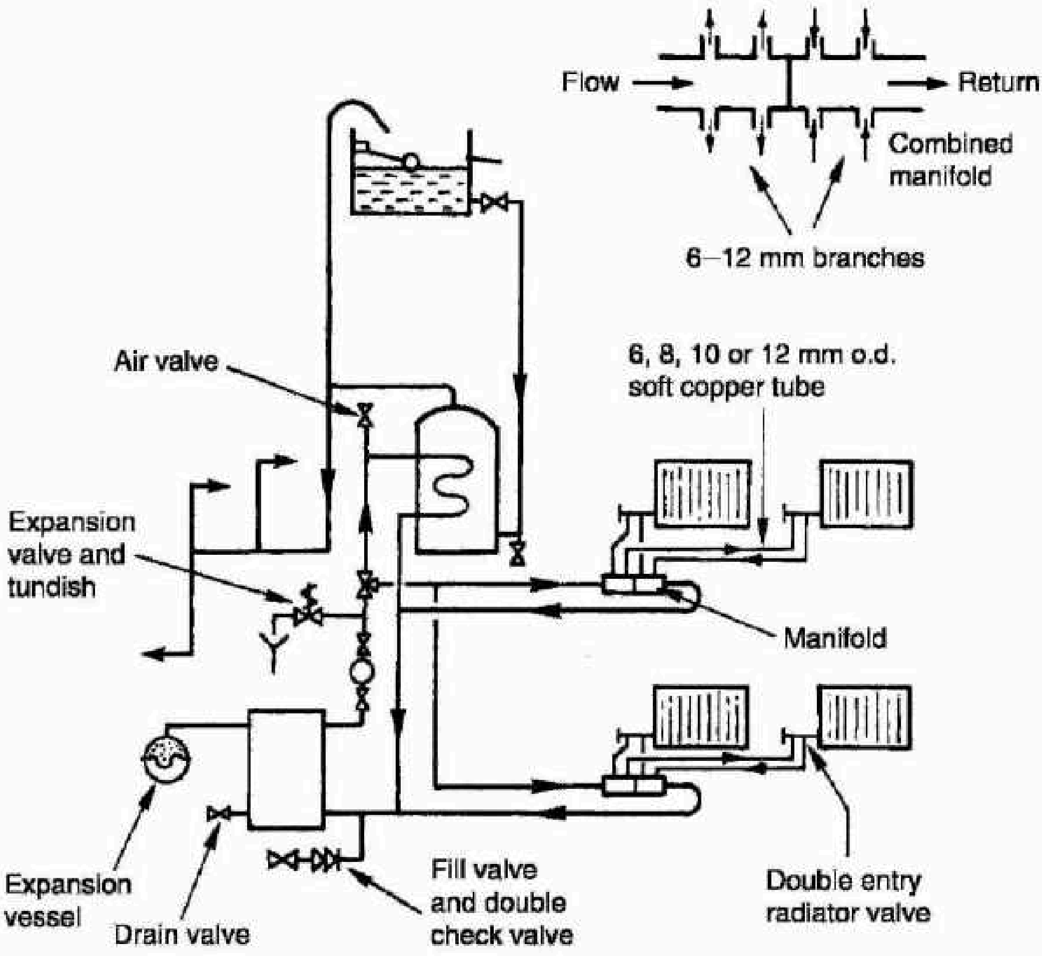
Small bore heating system

Notes:

1. 'Cyltrol' valve to be as close as possible to hwsc, to sense hot water return temperature and maintain stored water at about 55°C. Where used with a solid fuel boiler, an unvalved radiator or towel rail is connected across the primary pipes to dissipate excess heat when the 'cyltrol' closes.

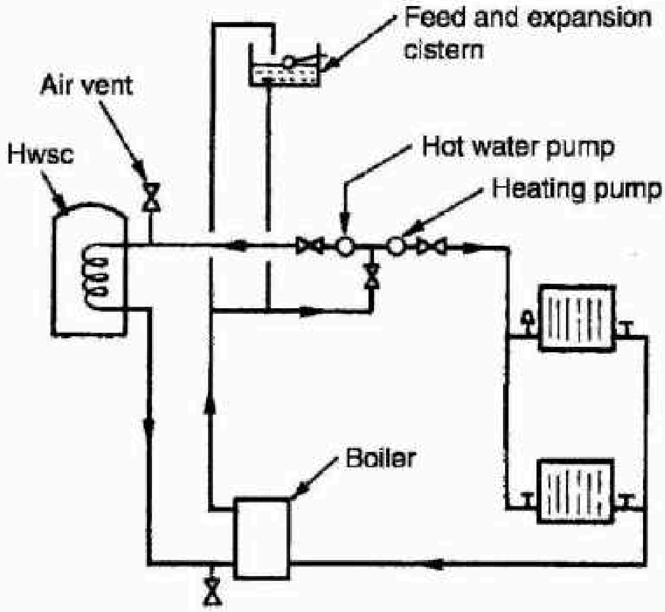
2. Min. height of expansion pipe above cistern water level (A) = (B) in metres × 40 mm + 150 mm. E.g. if (B), cistern water level to base of hwsc is 2·5 m, then (A) is 2·5 × 40 mm + 150 mm = 250 mm.

The microbore system also has pumped circulation through 28 or 22 mm o.d. copper tube main flow and return pipes to radiators. The diameter depending on the number and rating of emitters connected. The difference between this system and conventional small bore is the application of a centrally located manifold between boiler and emitters. Manifolds are produced with standard tube connections for the flow and return and several branches of 6, 8, 10 or 12 mm outside diameter. A combined manifold is also available. This is more compact, having a blank in the middle to separate flow from return. Manifolds are generally allocated at one per floor. Systems may be open vented or fitted with an expansion vessel. The advantage of microbore is ease and speed of installation, as long lengths of small diameter soft copper tubing are produced in coils. It is also unobtrusive where exposed, very easily concealed and is less damaging to the structure when holes are required. Water circulation noise may be noticeable as velocity is greater than in small bore systems. Pumped circulation is essential due to the high resistance to water flow in the small diameter pipes.

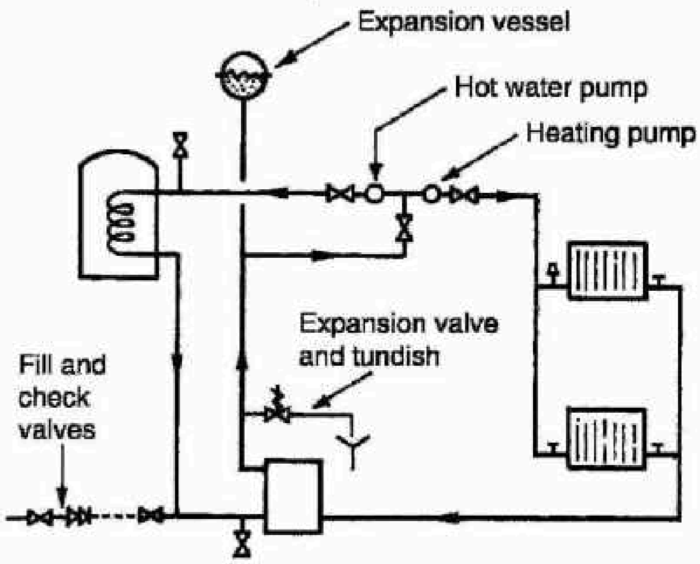


Microbore system

This is an alternative method for distributing hot water. It can be effected by using two separate pumps from the boiler flow: one to supply the hot water storage cylinder and the other the heating circuit. Grundfos Pumps Ltd. have developed a purpose-made dual pump for this purpose, which is integrated into one body. This system conveniently replaces the conventional single pump and associated two or three port motorised distribution valves. Each pump is dedicated to hot water or heating and individually controlled by cylinder or room thermostat. The correct flow and pressure can be regulated to the characteristics of the specific circuit.

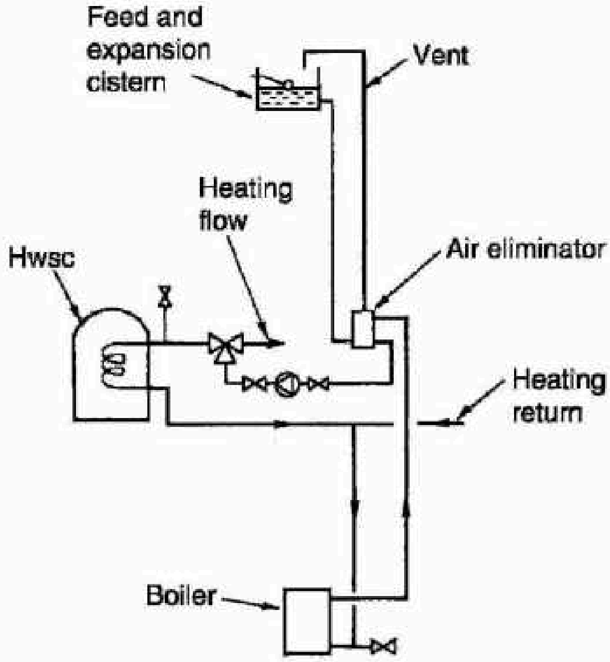


Conventional open vent system

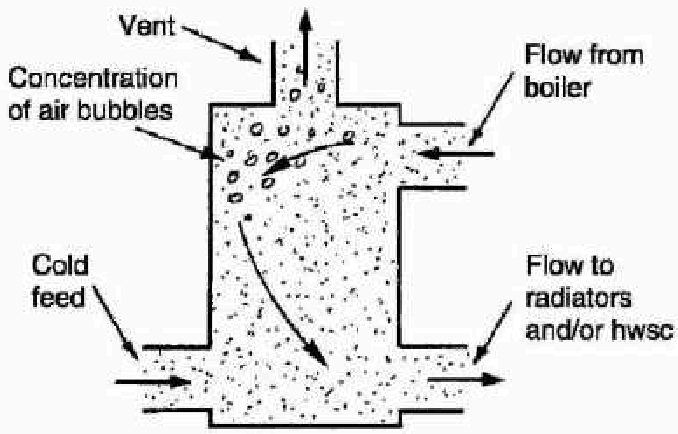


Typical sealed system

In conventional low pressure systems, air and other gases produced by heating water should escape through the vent and expansion pipe. Air must be removed to prevent the possibility of air locks, corrosion and noise. To assist air removal, a purpose-made device resembling a small canister may be used to concentrate the gases. This simple fitting is located on the boiler flow and vent pipe to contain the water velocity and ensure efficient concentration and release of air into the vent.



Application of air eliminator

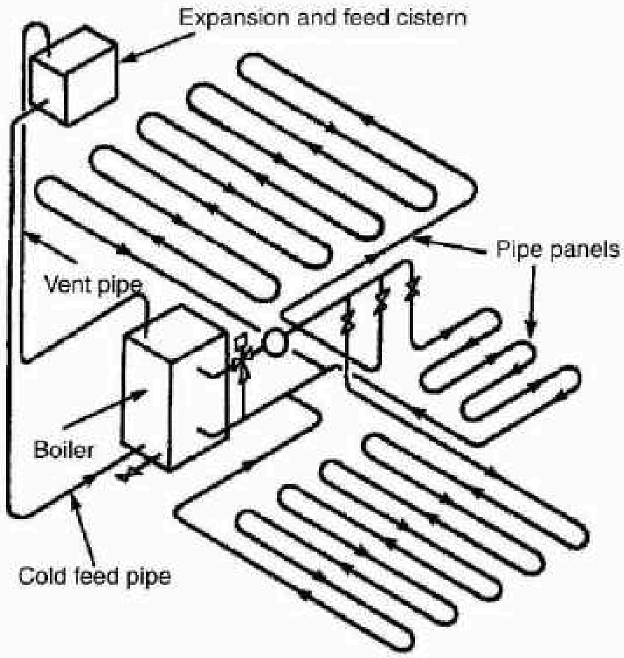


Air eliminator (approx. 100 mm high × 75 mm dia. with standard 22 mm o.d. copper tube connections)

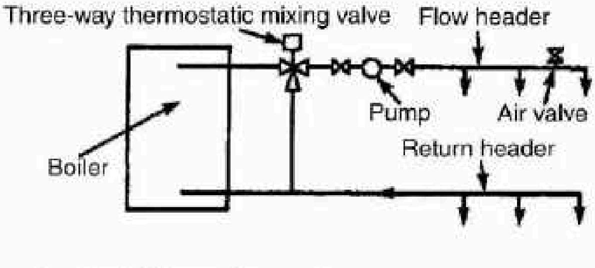
The system consists of 15 mm or 22 mm o.d. annealed copper pipes embedded in the floor, ceiling or walls. This has the benefit of avoiding unsightly pipes and radiators. Heat distribution is uniform, providing a high standard of thermal comfort as heat is emitted from the building fabric. However, thermal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

Floors - 27°C
Ceilings - 49°C
Walls - 43°C

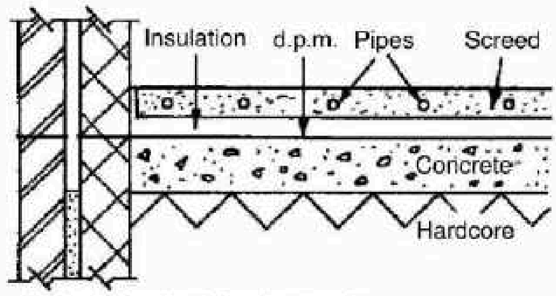
Joints on copper pipes must be made by capillary soldered fittings or by bronze welding. Unjointed purpose-made plastic pipes can also be used. Before embedding the pipes they should be hydraulically tested as described on page 133.



Installation of panel heating system



Detail of boiler and connections



Method of embedding the panels

Current practice is to use jointless plastic pipe in continuous coils. Pipes can be embedded in a 70 mm cement and sand screed (50 mm minimum cover to tube). In suspended timber floors the pipe may be elevated by clipping tracks or brackets with metallic reflective support trays, prior to fixing the chipboard decking. Materials include:

PEX: Cross linked polyethylene.

PP: Co-polymer of polypropylene.

PB: Polybutylene.

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

Boiler flow temperature for underfloor heating is about 50°C, whilst that for hot water storage and radiators is about 80°C. Therefore, where the same boiler supplies both hot water storage cylinder and/ or radiators and underfloor heating, a motorised thermostatic mixing valve is required to blend the boiler flow and underfloor heating return water to obtain the optimum flow temperature.

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

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

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

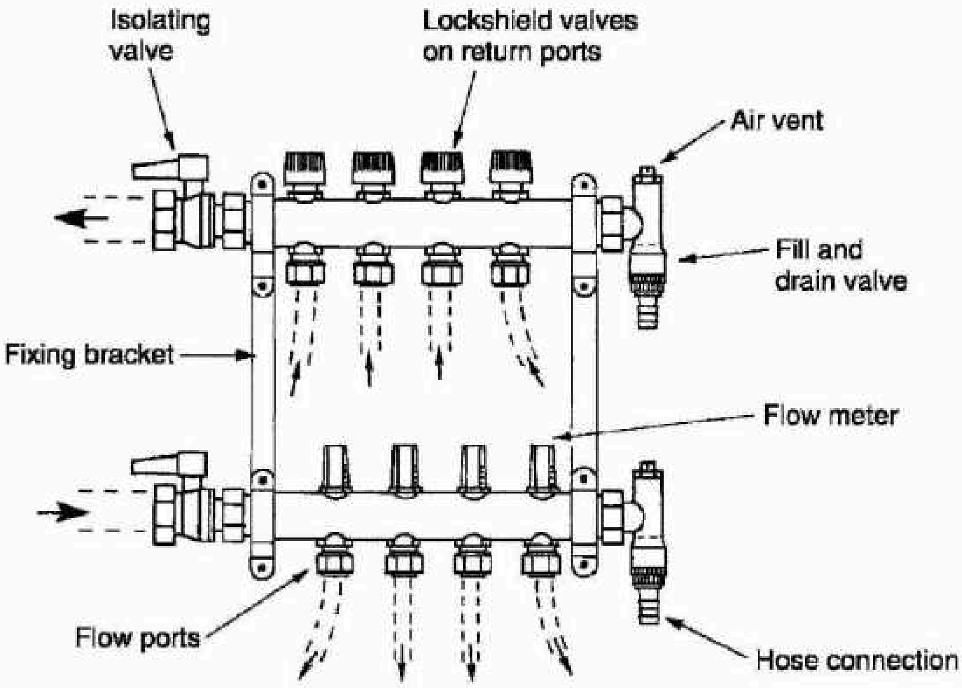
For a room with a solid floor area of 13·5 m^2 requiring a heating input of 779 watts (see page 125), the output required from the underfloor piping is:

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

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

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

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



Underfloor heating manifold

Installation notes –

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

Refs.

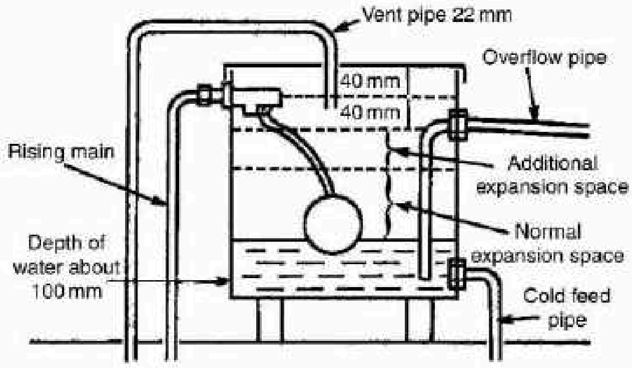
BS 5955-8: Plastics pipework.

BS 7291-1 and 2: Thermoplastic pipes.

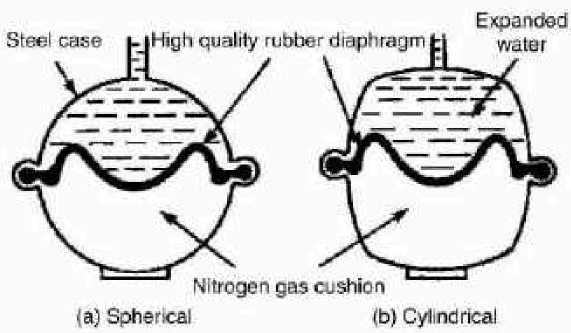
BS EN 1264-4: Floor heating. Systems and components. Installation.

In any water heating system, provision must be made for the expansion of water. A combined expansion and feed cistern is the traditional means. This will have normal expansion space under usual boiler firing conditions of about 4% of the total volume of water in the system, plus a further third as additional expansion space for high boiler firing. Although the expansion can be accommodated up to the overflow level, there should be at least 25 mm between overflow and the fully expanded water level.

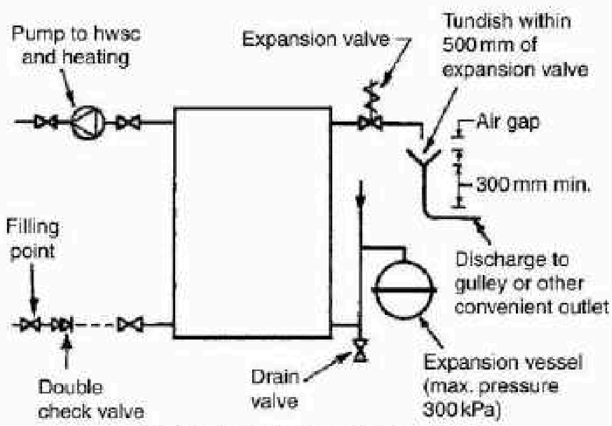
Contemporary sealed systems have an expansion vessel connected close to the boiler. It contains a diaphragm and a volume of air or nitrogen to absorb the expansion. To conserve wear on the diaphragm, location is preferred on the cooler return pipe and on the negative side of the pump. System installation is simpler and quicker than with an expansion cistern. The air or nitrogen is pressurised to produce a minimum water pressure at the highest point on the heating system of 10 kPa (approx. 1 m head of water). This is necessary, otherwise when filling the system, water would fill the vessel leaving no space for expansion.



Expansion and feed cistern



Diaphragm expansion vessels



Installation of expansion vessel

Expansion vessels are produced to BS 6144. They must be correctly sized to accommodate the expansion of heated water without the system safety/pressure relief valve operating. The capacity of an expansion vessel will depend on the static pressure (metres head from the top of the system to the expansion vessel), the system maximum working pressure (same setting as p.r.v.) obtained from manufacturer's details and the volume of water in the system (approx. 15 litres per kW of boiler power).

Capacity can be calculated from the following formula:

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

where: V = vessel size (litres)
e = expansion factor (see table)
C = capacity of system (litres)
P_i = static pressure (absolute)*
P_f = max. working pressure (absolute)*

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

E.g. C = 100 litres
P_i = 1·5 atm or 150 kPa (5 m head static pressure)
P_f = 1·9 atm or 190 kPa (9 m head static pressure)

Water temp. = 80°C

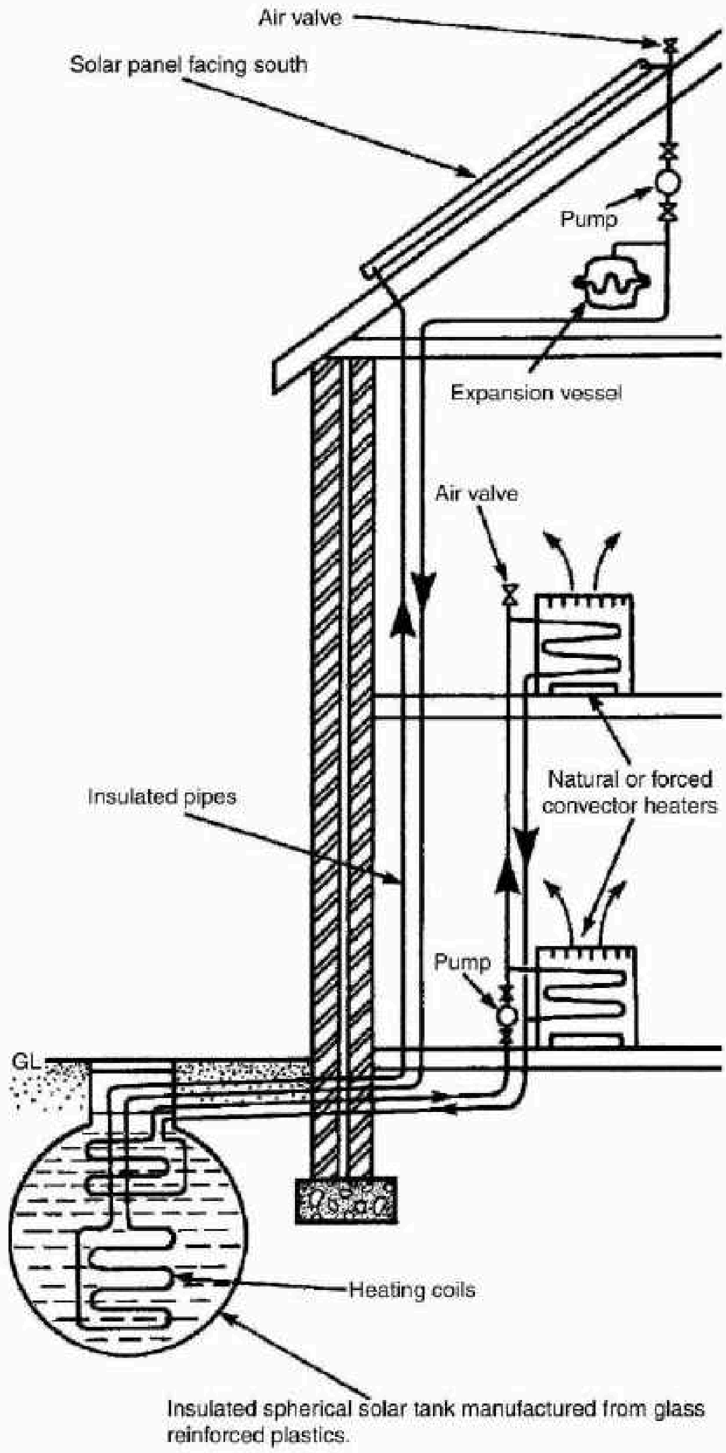
Temp. °C	Exp. factor
50	0·0121
60	0·0171
70	0·0227
80	0·0290
90	0·0359

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

Ref: BS 6144, Specification for expansion vessels using an internal diaphragm, for unvented hot water supply systems.

Solar space heating must be complemented with a very high standard of thermal insulation to the building fabric. The solar panel shown on page 64 for hot water provision will need a much larger area, typically 40 m^2 for a 3 to 4 bedroom detached estate house. A solar tank heat exchanger of about 40 m^3 water capacity is located in the ground. It is fitted with a pre-set safety type valve which opens to discharge water to waste if it should overheat. The solar panel and associated pipework are mains filled and supplemented with a glycol or anti-freeze additive.

With diminishing fossil fuel resources and inevitable rising fuel prices, solar heating is encouraged as a supplement or even an alternative to conventionally fuelled systems. For use as the sole energy for a heating system there is still considerable scope for research and development. Technological developments are improving, particularly with the 'heat bank' or storage facility shown. In time it may become viable even with the UK's limited solar energy in winter months.



See also page 65, Properties of Heat – Hot Water. The following additional data has particular application to design of hot water heating systems and components.

CHANGE OF STATE. Water has three basic characteristic states, solid (ice), liquid (fluid) or gas (steam). Water changes state at the specific temperatures of 0°C and 100°C.

LATENT HEAT is the heat energy absorbed or released at the point of change from ice to water and from water to steam, i.e. where there is no change in temperature. This is measured as specific latent heat, in units of joules per kilogram (J/kg).

Specific latent heat of ice = 335 kJ/kg

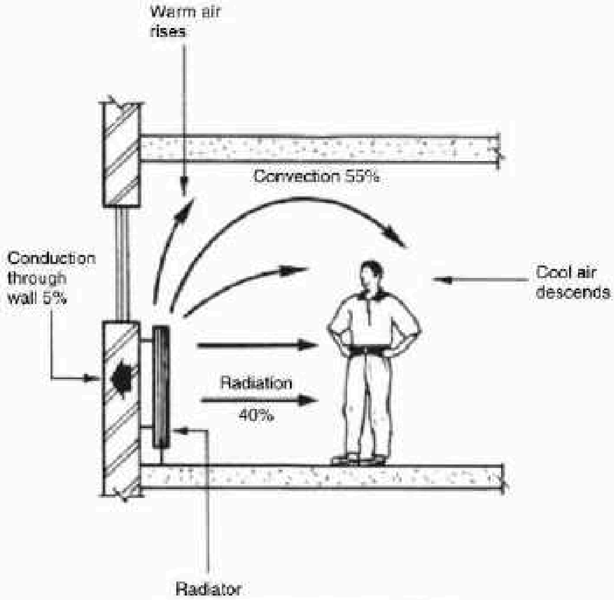
Specific latent heat of water = 2260 kJ/kg

SENSIBLE HEAT is the heat energy absorbed or released during change in temperature.

E.g. to convert 1 kg of ice at 0°C to steam at 100°C:
Ice at 0°C to water at 0°C = 1 kg × 335 kJ/kg = 335 kJ
Water at 0°C to water at 100°C = 1 kg × Shc of water (approx. 4·2 kJ/kg K) × 100 K = 420 kJ
Water at 100°C to steam at 100°C = 1 kg × 2260 kJ/kg = 2260 kJ
The total heat energy will be 335 + 420 + 2260 = 3015 kJ
Note: Total heat is also known as enthalpy.

HEAT ENERGY TRANSFER can be by:

Conduction – heat travelling along or through a material without appreciable change in position of the material particles.
Convection – heat travelling by movement of particles as they expand or contract.
Radiation – heat transfer by electromagnetic waves through space from one material body to another.

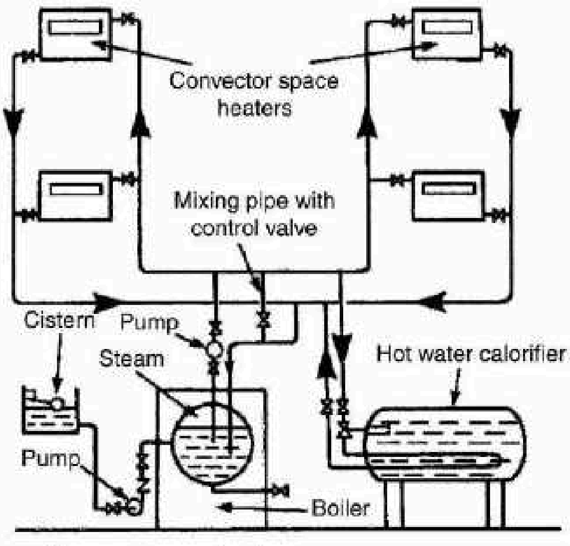


Heat energy transfer from a radiator

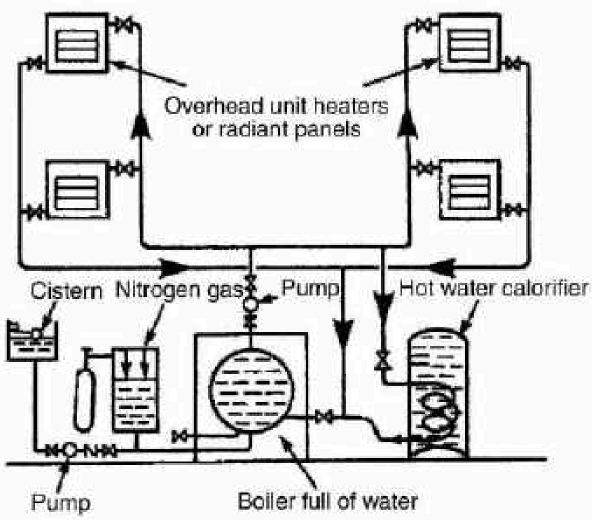
Note: Most heat energy is convected from a radiator, although the term radiator is preferred to differentiate from a convector, where about 90% of heat is convected

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

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



Steam pressurisation



Nitrogen pressurisation

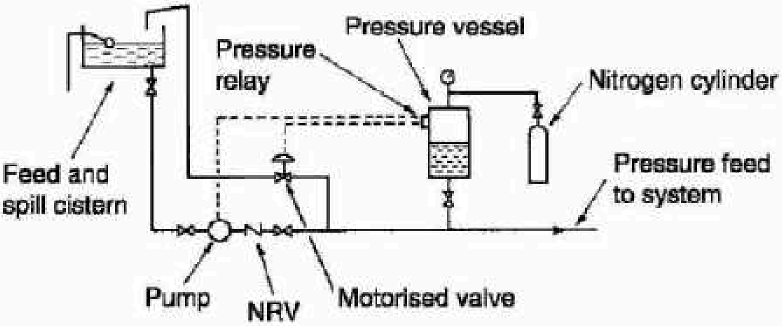
When pressurising with nitrogen it is important that the pressure increases in line with temperature. If it is allowed to deviate the water may 'flash', i.e. convert to steam, causing system malfunction and possible damage to equipment.

To commission the system:

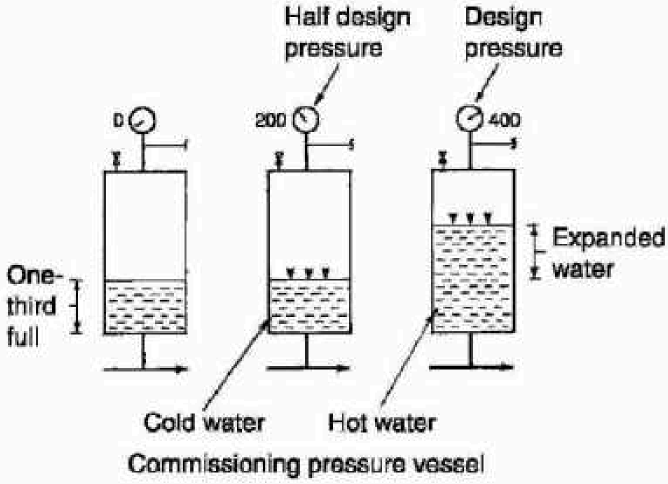
1. Water is pumped from the feed and spill cistern.
2. Air is bled from high levels and emitters.
3. Air is bled from the pressure vessel until the water level is at one-third capacity.
4. Nitrogen is charged into the pressure vessel at half design working pressure.
5. Boiler fired and expansion of hot water causes the water volume and nitrogen pressure in the vessel to double.

Note: Pressure vessel must be carefully designed to accommodate expanded water - approximately 4% of its original volume.

Safety features include a pressure control relay. This opens a motorised valve which lets excess water spill into the feed cistern if the boiler malfunctions and overheats. It also detects low pressure, possibly from system leakage and engages the feed pump to replenish the water and pressure.



System pressurisation



Commissioning pressure vessel

Steam was the energy source of the Victorian era. At this time electricity and associated equipment that we now take for granted were in the early stages of development. Steam was generated in solid fuel boilers to power engines, drive machines and for a variety of other applications, not least as a medium for heat emitters. In this latter capacity it functioned well, travelling over long distances at high velocity (24–36 m/s) without the need for a pump.

By contemporary standards it is uneconomic to produce steam solely for heating purposes. However, it can be used for heating where steam is available from other processes. These include laundering, sterilising, kitchen work, manufacturing and electricity generation. Most of these applications require very high pressure, therefore pressure reducing valves will be installed to regulate supply to heating circuits.

Steam systems maximise the latent heat properties of water when evaporating. This is approximately 2260 kJ/kg at boiling point, considerably more than the sensible heat property of water at this temperature of approximately 420 kJ/kg. Because of this high heat property, the size of heat emitters and associated pipework can be considerably less than that used for hot water systems.

Steam terminology:

Absolute pressure – gauge pressure + atmospheric pressure (101·325 kN/m^2 or kPa).

Latent heat – heat which produces a change of state without a change in temperature, i.e. heat which converts water to steam.

Sensible heat – heat which increases the temperature of a substance without changing its state.

Enthalpy – total heat of steam expressed as the sum of latent heat and sensible heat.

Dry steam – steam which has been completely evaporated, contains no droplets of liquid water.

Wet steam – steam with water droplets in suspension, present in the steam space, typically in pipes and emitters.

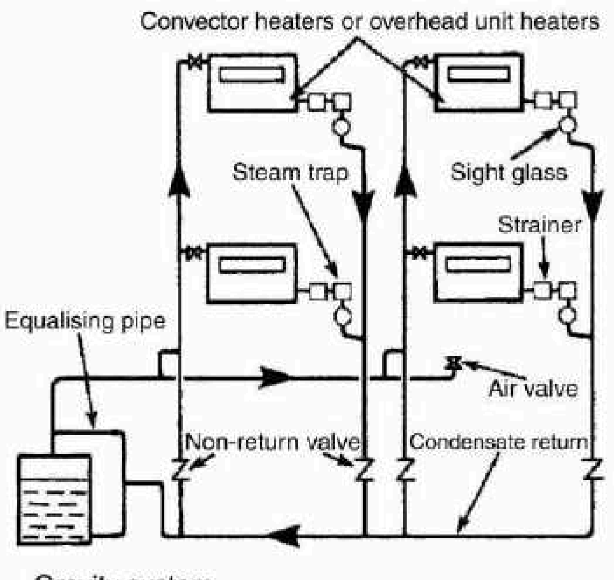
Flash steam – condensate re-evaporating into steam after passing through steam traps.

Saturated steam – steam associated with or in contact with the water in the boiler or steam drum over the boiler.

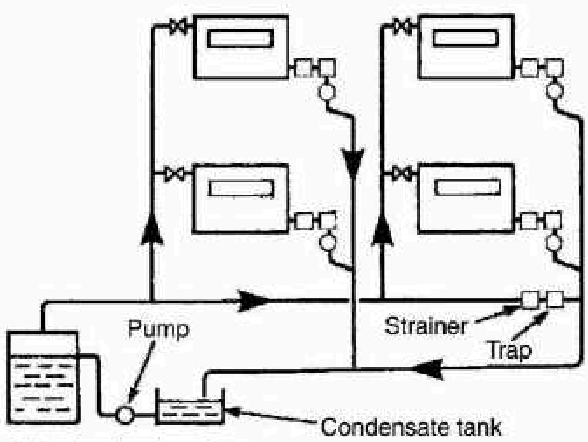
Superheated steam – steam which is reheated or has further heat added after it leaves the boiler.

Classification – low pressure, 35 kPa–170 kPa (108–130°C).
medium pressure, 170 kPa–550 kPa (130–160°C).
high pressure, over 550 kPa (160°C and above).
Note: Gauge pressures shown.

Systems can be categorised as gravity or mechanical. In both, the steam flows naturally from boiler to emitters without the need for a pump. In the mechanical system a positive displacement pump is used to lift condensed steam (condensate) into the boiler. Steam pressure should be as low as possible as this will increase the latent heat capacity. A steam trap prevents energy loss at each emitter. These are fitted with a strainer or filter to contain debris and will require regular cleaning. A sight glass after each trap gives visual indication that the trap is functioning correctly, i.e. only condensate is passing. On long pipe runs a 'drip relay' containing steam valve, strainer, trap, sight glass and a gate valve will be required to control condensing steam. This is represented by the strainer and trap in the mechanical system shown below. Expansion loops or bellows will also be required on long pipe runs to absorb thermal movement. All pipework and accessories must be insulated to a very high standard.



Gravity system



Mechanical system

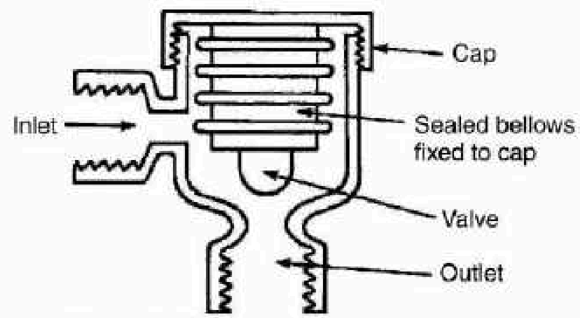
The purpose of a steam trap is to separate steam from condensate, retaining the energy efficient steam in distribution pipework and emitters. Traps are produced in various forms and sizes to suit all situations, some of which are shown below. The thermostatic and bi-metallic types are for relatively small applications such as radiators and unit heaters. The bucket and ball-float types are more suited to separating larger volumes of condensate and steam at the end of long pipe runs and in calorifiers.

Thermostatic – bellows expand or contract in response to steam or condensate repectively. Lower temperature condensate passes through.

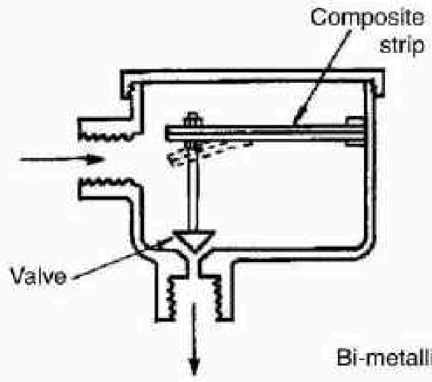
Bi-metallic – condensate flows through the trap until higher temperature steam bends the strip to close the valve.

Bucket – condensate sinks the bucket. This opens the valve allowing steam pressure to force water out until the valve closes.

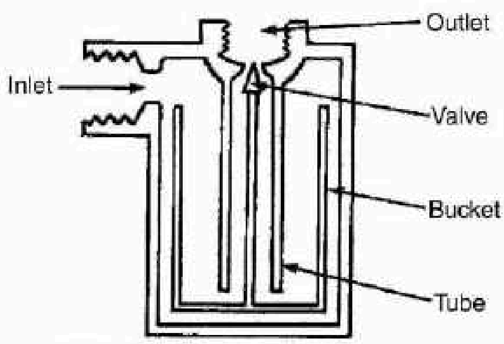
Ball-float – the copper ball rises in the presence of condensate opening the valve to discharge water until steam pressure closes the valve.



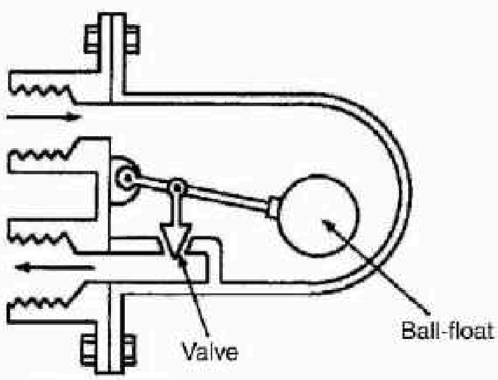
Thermostatic type



Bi-metallic type



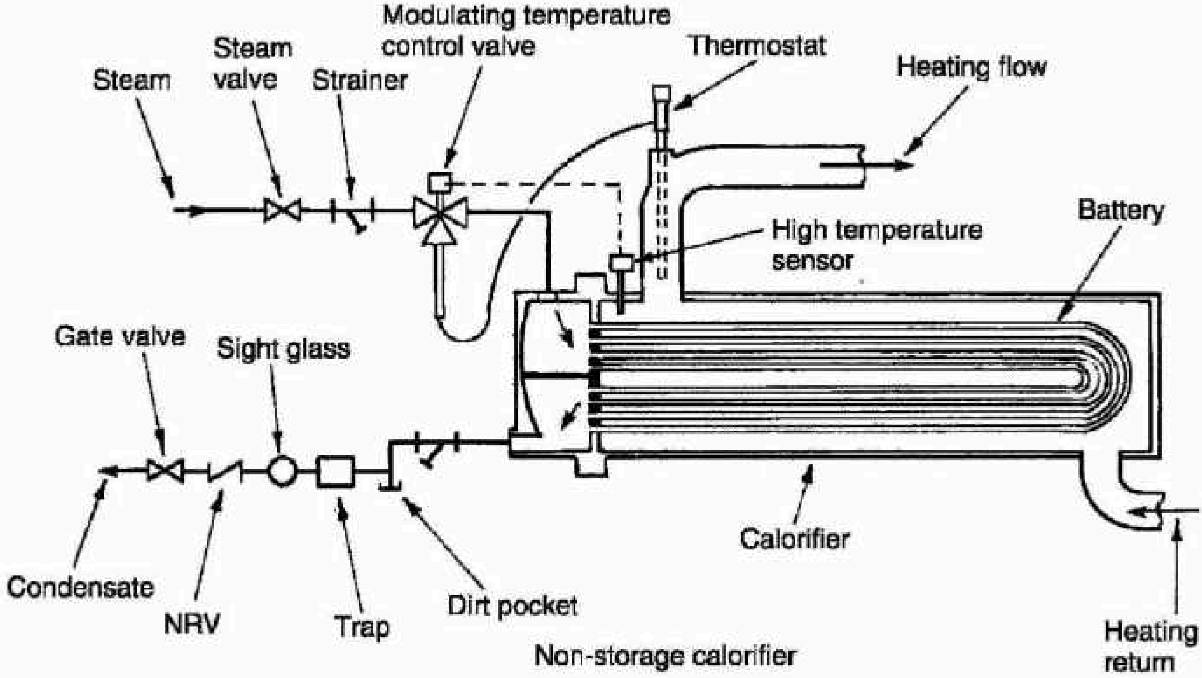
Bucket type



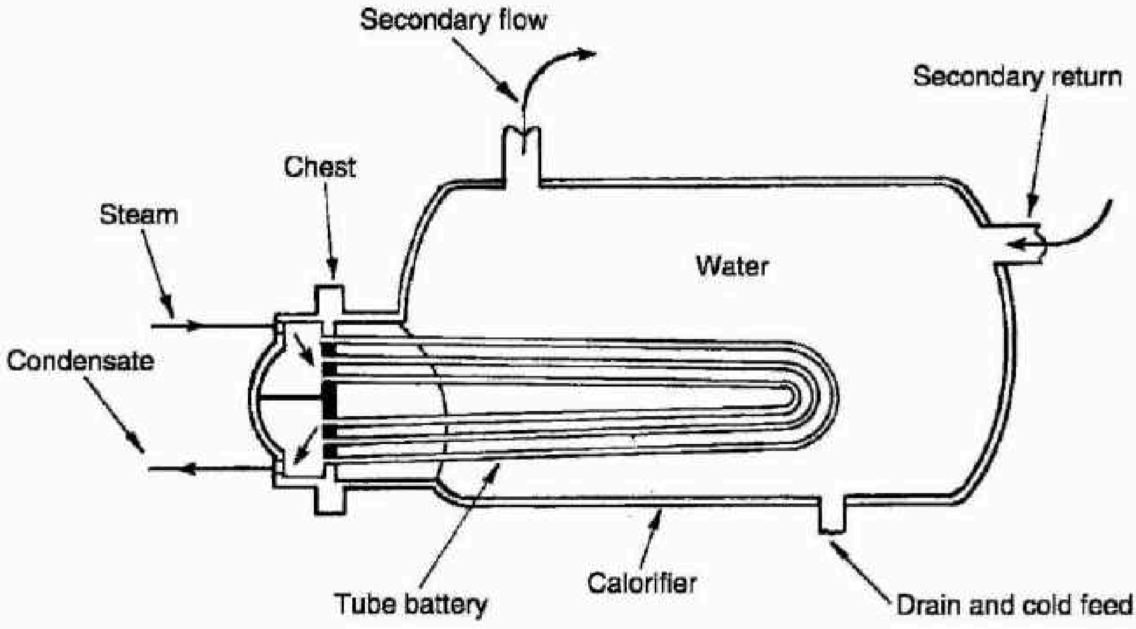
Ball-float type

Non-storage type – used for providing instantaneous hot water for space heating. The steam tube bundle or battery occupies a relatively large area compared to the surrounding amount of water. To avoid temperature override and to control the steam flow, a thermostat and modulating valve must be fitted.

Storage type – these are used to store hot water for manufacturing processes and/or washing demands. Unlike non-storage calorifiers, these have a low steam to water ratio, i.e. a relatively small battery of steam pipes surrounded by a large volume of water.

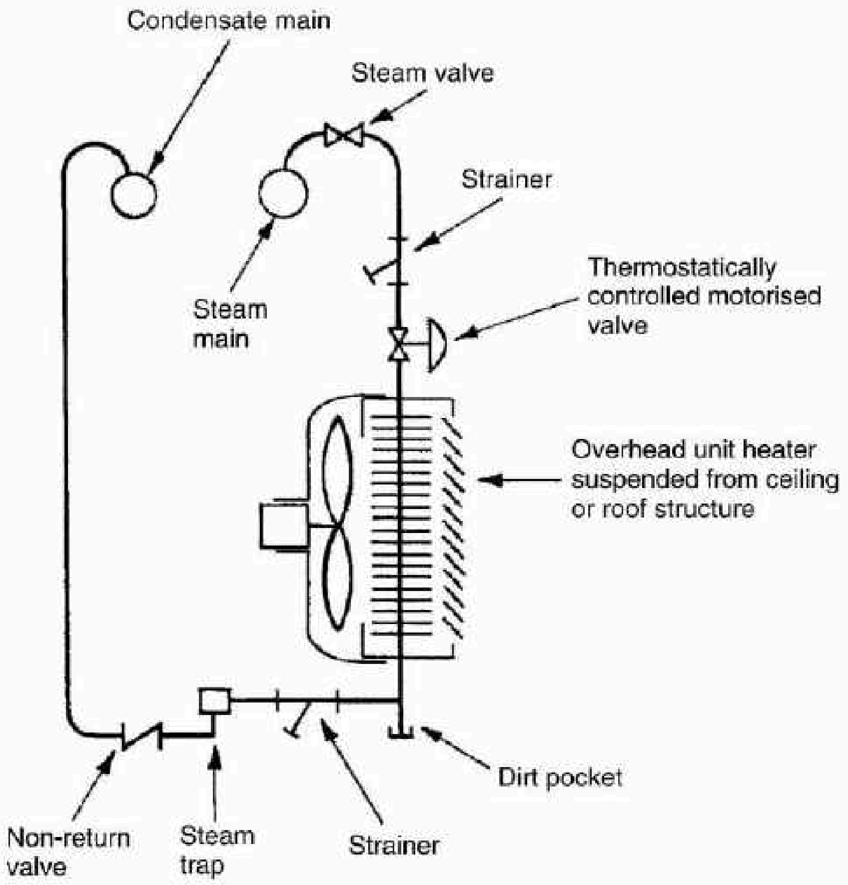


Non-storage calorifier

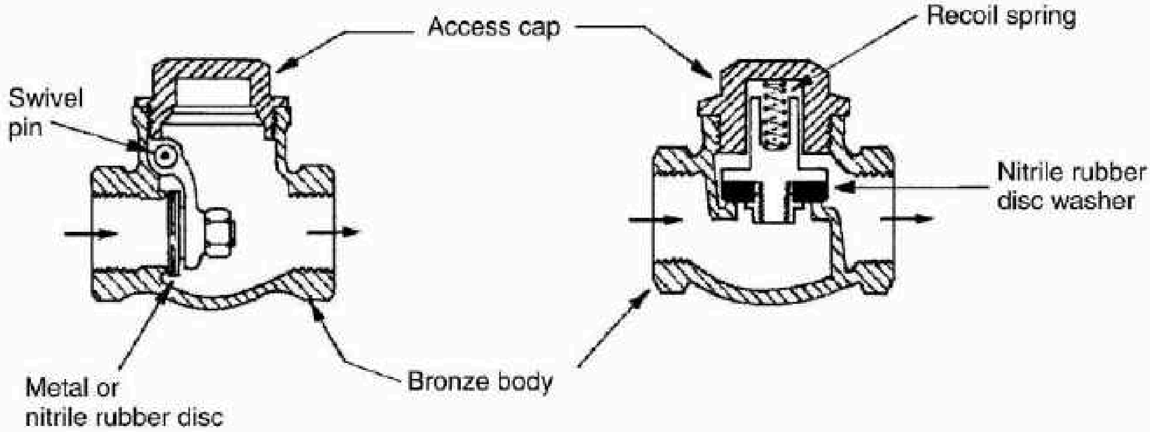


Storage calorifier (controls as above)

High level fan assisted unit heaters are often the preferred means of heat emission for use with steam heating systems. Unless housed, radiators and convectors can be dangerously hot to touch, and they take up useful floor space in industrial production and warehouse premises. A typical installation is shown below with a non-return type of check valve to control the flow of condensate.



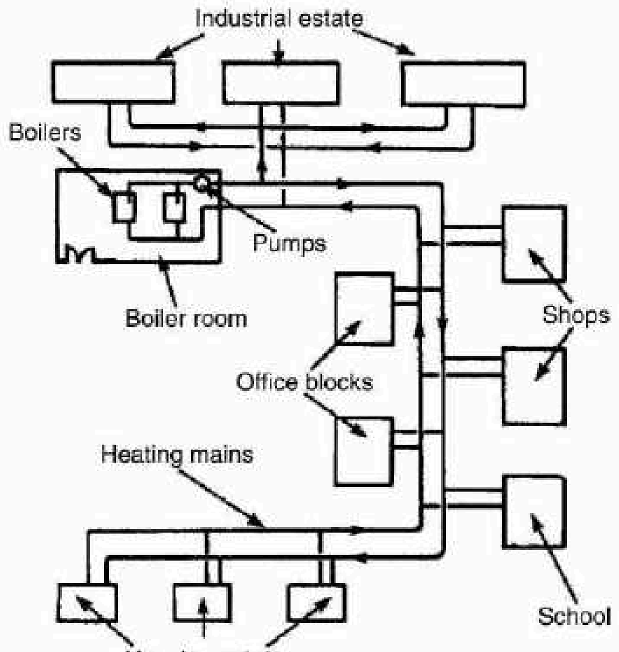
Overhead unit heater connections



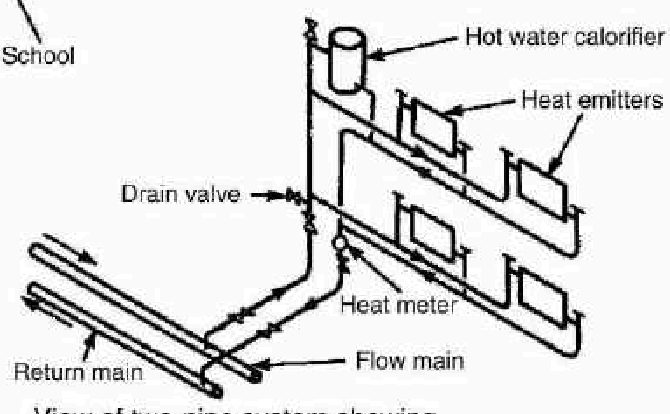
Swing pattern non-return valve

Horizontal lift non-return valve

A district heating system is in principle an enlarged system of heating one building, extended to heat several buildings. It can be sufficiently large enough to heat a whole community or even a small town from one centralised boiler plant. Centralising plant and controls saves space in individual buildings. An effective plant management service will ensure the equipment is functioning to peak efficiency. Each building owner is required to pay a standing charge for the maintenance of plant and to subscribe for heat consumed through an energy metered supply, similar to other utilities. An energy meter differs from a capacity or volume meter by monitoring the heat energy in the water flow, as this will vary in temperature depending on the location of buildings. The boiler and associated plant should be located in close proximity to buildings requiring a high heat load, e.g. an industrial estate. Long runs of heating pipes are required and these must be well insulated. They are normally located below ground but may be elevated around factories. Systems can incorporate industrial waste incinerators operating in parallel with conventional boilers and may also use surplus hot water from turbine cooling processes in power stations or electricity generators. This is known as Combined Heat and Power.



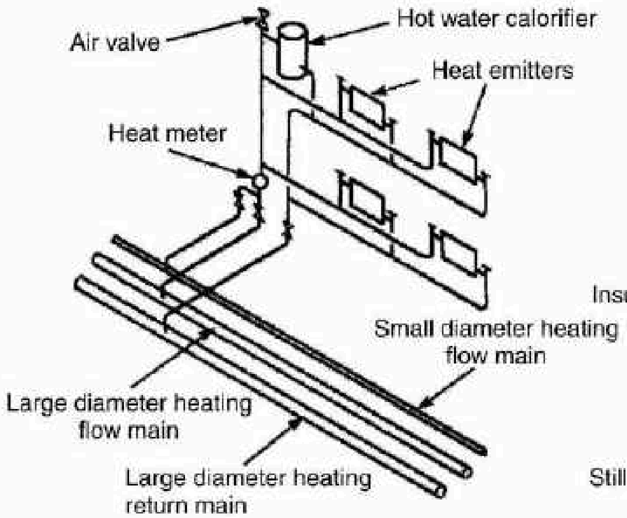
Plan of typical two-pipe scheme



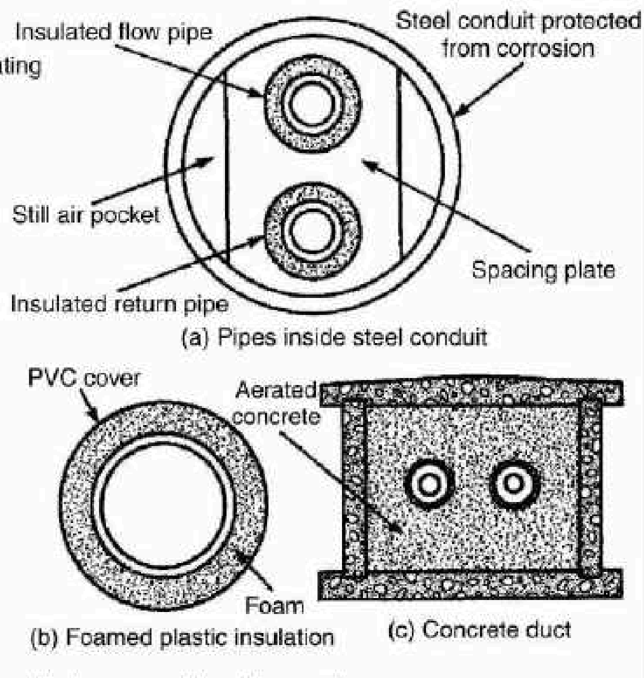
View of two-pipe system showing the internal distribution

The three-pipe system is similar to the two-pipe system except for an additional small diameter flow pipe connected to the boilers. This is laid alongside the larger diameter flow pipe and has a separate circulation pump. This smaller flow pipe is used during the summer months when space heating is not required, although in the intermediate seasons it could supply both with limited application to heating. It should have enough capacity to supply the heating coils in the hot water storage cylinders plus a small reserve. It can be seen as an economy measure to reduce hot water heating volume, energy loss from the larger diameter pipe and pump running costs. A common large diameter return pipe can be used.

Pipes must be at least 450 mm below the surface as protection from vehicle loads. They must also be well insulated against heat loss and frost damage if water is not circulating. Insulation must be waterproof and the pipes protected from corrosion. Inevitably there will be some heat losses from the mains pipework. This will approximate to 15% of the system heating load.

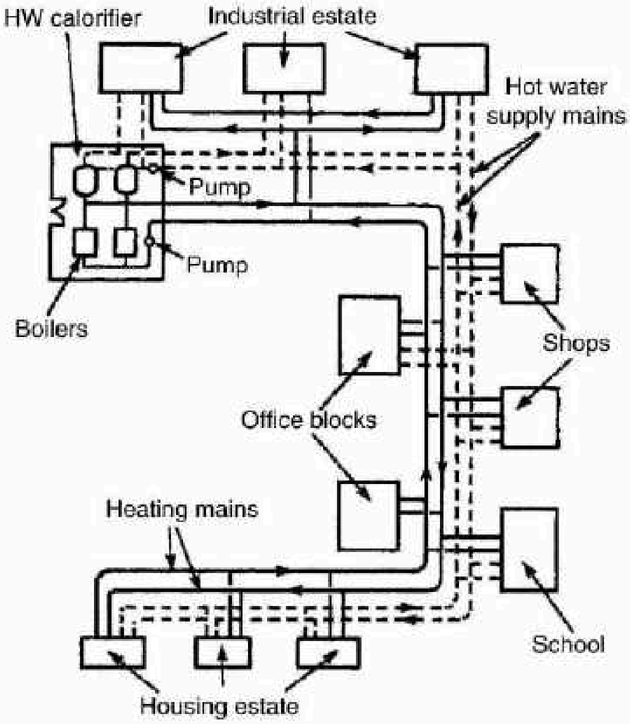


View of typical three-pipe system showing the internal distribution

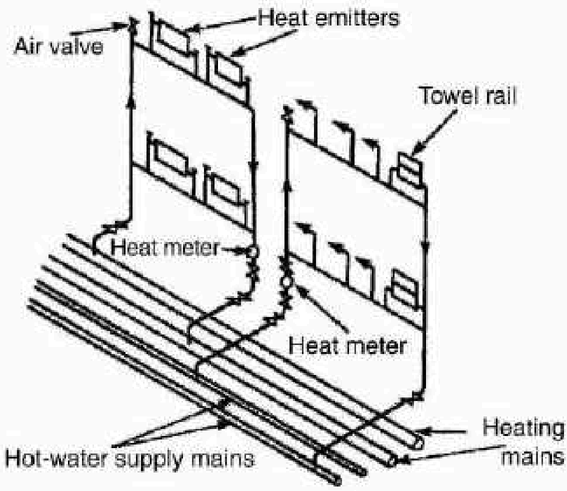


Underground heating mains

The four-pipe system supplies both hot water and space heating as two separate systems. Individual hot water storage cylinders are not required, as large capacity calorifiers are located in the boiler plant room and possibly at strategic locations around the district being served. This considerably simplifies the plumbing in each building as cold water storage cisterns are also unnecessary, provided all cold water outlets can be supplied direct from the main. However, the boiler plant room will be considerably larger to accommodate the additional components and controls. Excavation and installation costs will also be relatively expensive, but system flexibility and closure of the heating mains and associated boilers during the summer months should provide economies in use.



Plan of typical four-pipe system

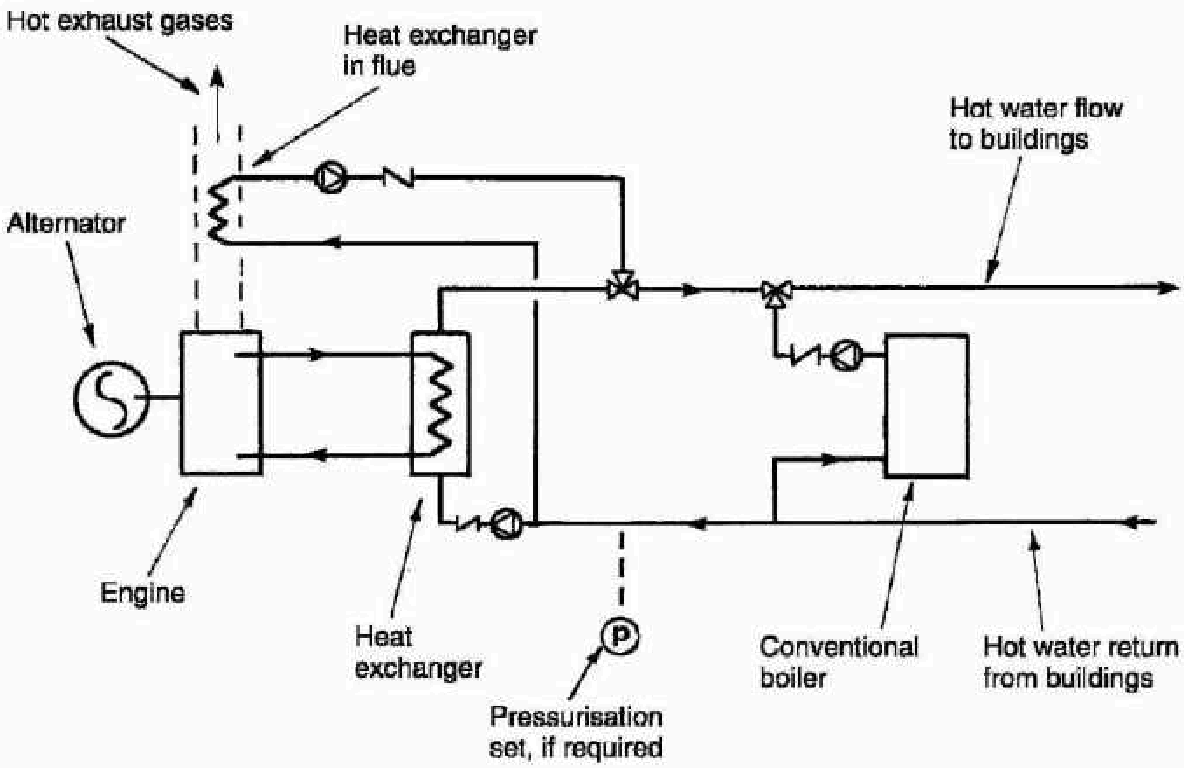


View of typical four-pipe system

Potential for more economic use of electricity generating plant can be appreciated by observing the energy waste in the large plumes of condensing water above power station cooling towers. Most power stations are only about 50% efficient, leaving a considerable margin for reprocessing the surplus hot water.

Combining electricity generation with a supply of hot water has become viable since the deregulation and privatisation of electricity supply. Prior to this, examples were limited to large factory complexes and remote buildings, e.g. prisons, which were independent of national power generation by special licence. Until the technology improves, it is still only practical for large buildings or expansive collections of buildings such as university campuses and hospitals.

Surplus energy from oil- or gas-fired engine driven alternators occurs in hot water from the engine cooling system and the hot exhaust gases. In a CHP system the rate of heat energy produced is directly related to the amount of electricity generated. There will be times when available hot water is insufficient. Therefore a supplementary energy source from a conventional boiler will be required.



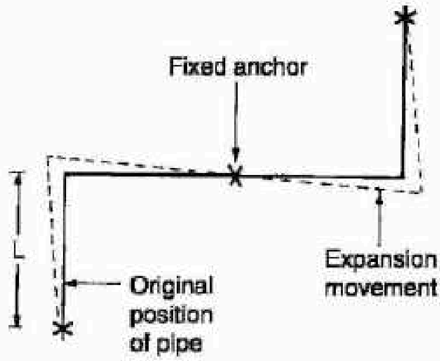
Principles of CHP

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

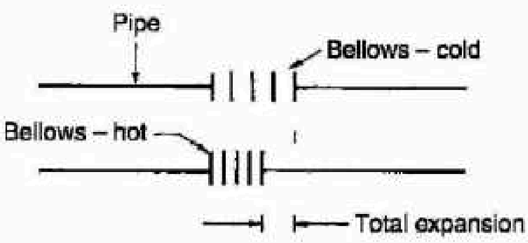
Expansion devices:

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

Bellows and loops are not normally associated with domestic installations.

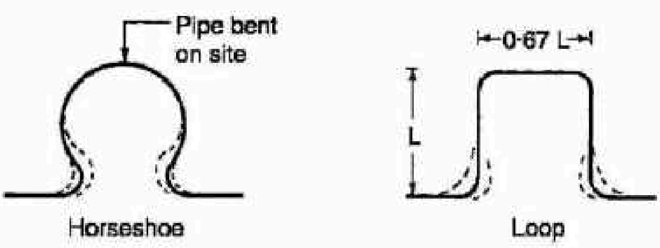


Natural changes in direction or offsets



Axial expansion bellows responding to hot water

Bellows are factory-made fittings normally installed 'cold-drawn' to the total calculated expansion for hot water and steam services. The bellows can then absorb all anticipated movement by contraction. Where the pipe content is cold or refrigerated fluids, the bellows are compressed during installation.



Site made loops or horseshoe

Coefficients of linear expansion for common pipework materials:

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

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

Formula:

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

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

$= 0{\cdot}0136$ m or 13·6 mm

Single offset:

$L = 100\sqrt{zd}$

L = see previous page

z = expansion (m)

d = pipe diameter (m)

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

Loops:

$L = 50\sqrt{zd}$

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

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

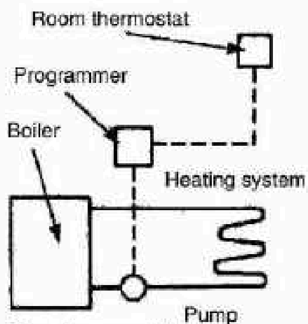
Notes:

- Provide access troughs or ducts for pipes in screeds (Part 14).
- Sleeve pipework through holes in walls, floors and ceilings (see pages 325 and 520 for fire sealing).
- Pipework support between fixed anchors to permit movement, i.e. loose fit brackets and rollers.
- Place felt or similar pads between pipework and notched joists.
- Branches to fixtures to be sufficient length and unconstrained to prevent dislocation of connections.
- Allow adequate space between pipework and structure.

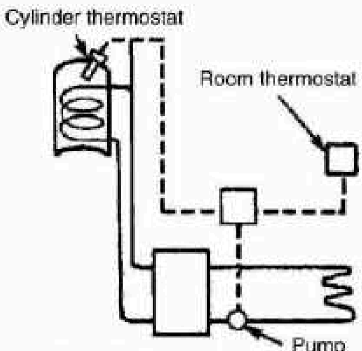
Thermostatic control of heating and hot water systems reduces consumers' fuel bills, regulates the thermal comfort of building occupants and improves the efficiency of heat producing appliances. Approved Document L to the Building Regulations effects these provisions. This has the additional objective of limiting noxious fuel gases in the atmosphere and conserving finite natural fuel resources.

A room thermostat should be sited away from draughts, direct sunlight and heat emitters, at between 1·2 and 1·5 m above floor level. Thermostatic radiator valves may also be fitted to each emitter to provide independent control in each room. A less expensive means of controlling the temperature in different areas is by use of thermostatically activated zone valves to regulate the temperature of individual circuits.

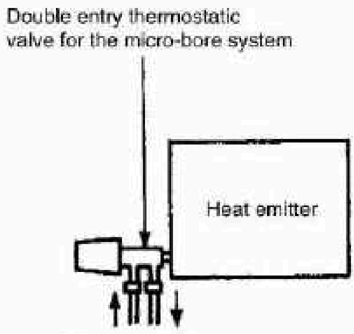
Three-port thermostatic valves may be either mixing or diverting. The mixing valve has two inlets and one outlet. The diverting valve has one inlet and two outlets. Selection will depend on the design criteria, as shown in the illustrations.



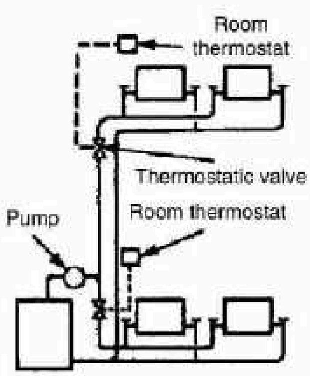
One thermostat controlling the pump



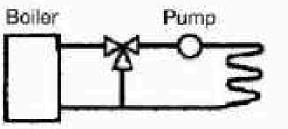
Two thermostats controlling the pump to give priority to hot water supply



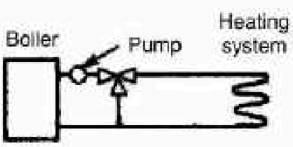
Thermostatic radiator valve



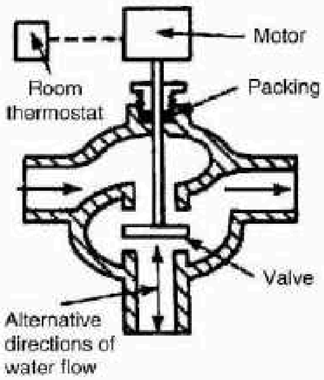
Thermostatic zoning valves



Mixing valve gives constant rate of flow and variable flow temperature



Diverting valve gives constant flow temperature and variable flow

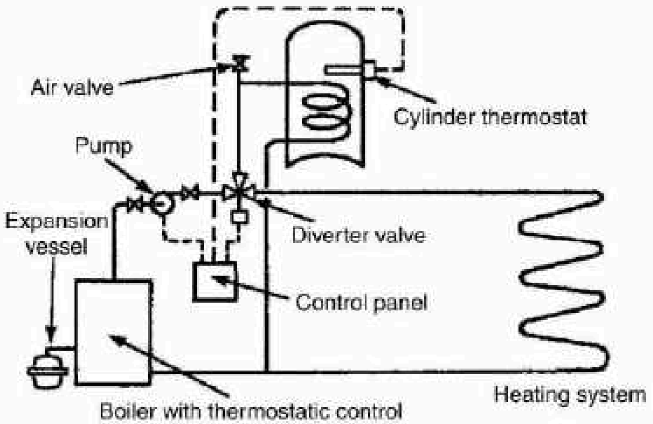


Section through a three-port valve operated by a room thermostat

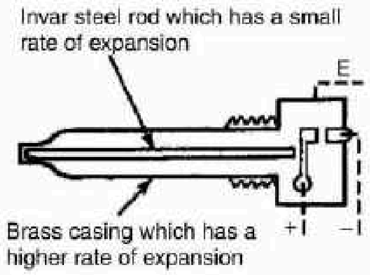
The diverter valve may be used to close the heating circuit to direct hot water from the boiler to the hot water cylinder. The reverse is also possible, depending on whether hot water or heating is considered a priority. With either, when the thermostat on the priority circuit is satisfied it effects a change in the motorised diverter valve to direct hot water to the other circuit.

A rod-type thermostat may be fitted into the hot water storage cylinder, or a surface contact thermostat applied below the insulation. At the pre-set temperature (about 60°C) a brass and invar steel strip expands to break contact with the electricity supply. A room thermostat also operates on the principle of differential expansion of brass and invar steel. Thermostatic radiator valves have a sensitive element which expands in response to a rise in air temperature to close the valve at a pre-set temperature, normally in range settings 5–27°C. Sensors are either a thermostatic coil or a wax or liquid charged compartment which is insulated from the valve body.

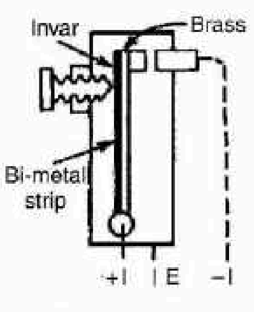
A clock controller sets the time at which the heating and hot water supply will operate. Programmers are generally more sophisticated, possibly incorporating 7 or 28-day settings, bypass facilities and numerous on/off functions throughout the days.



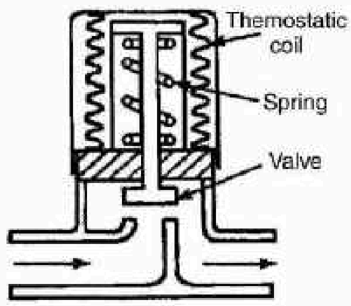
Use of diverter valve to give priority to hot water supply to a system having a pumped circuit to both the heating and the hot water cylinder



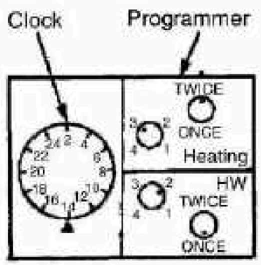
Rod type thermostat



Room thermostat



Thermostatic radiator valve



Clock control and programmer

Ref. Building Regulations. Approved Document L1: Conservation of fuel and power in dwellings -

From 2002 it has been mandatory in the UK to provide a higher standard of controls for hot water and heating installations. This is to limit consumption of finite fuel resources and to reduce the emission of atmospheric pollutants. All new installations and existing systems undergoing replacement components are affected.

Requirements for 'wet' systems -

- Only boilers of a minimum efficiency can be installed. See SEDBUK values on page 72 and 74.

- Hot water storage cylinders must be to a minimum acceptable standard, i.e. BSs 1566 and 3198: Copper indirect cylinders and hot water storage combination units for domestic purposes, respectively for vented systems. BS 7206: Specification for unvented hot water storage units and packages, for sealed systems. Vessels for unvented systems may also be approved by the BBA, the WRc or other accredited European standards authority. See pages 534 and 535.

- New systems to be fully pumped. If it is impractical to convert an existing gravity (convection) hot water circulation system, the heating system must still be pumped, i.e. it becomes a semi-gravity system, see pages 108 and 112. Existing system controls to be upgraded to include a cylinder thermostat and zone (motorised) valve to control the hot water circuit temperature and to provide a boiler interlock. Other controls are a programmer or clock controller, a room thermostat and thermostatic radiator valves (TRVs to BS EN 215) in the bedrooms.

Note: The boiler is said to be 'interlocked' when switched on or off by the room or cylinder thermostat (or boiler energy management system). The wiring circuit to and within the boiler and to the pump must ensure that both are switched off when there is no demand from the hot water or heating system, i.e. the boiler must not fire unnecessarily even though its working thermostat detects the water content temperature to be below its setting.

continued . . . .

Requirements for 'wet' systems (continued) –

- Independent/separate time controls for hot water and space heating. The exceptions are:

  (1) combination boilers which produce instantaneous hot water, and
  (2) solid fuel systems.

- Boiler interlock to be included to prevent the boiler firing when no demand for hot water or heating exists.

- Automatic by-pass valve to be fitted where the boiler manufacturer specifies a by-pass circuit.

  Note: A circuit by-pass and automatic control valve is specified by some boiler manufacturers to ensure a minimum flow rate whilst the boiler is firing. This is particularly useful where TRVs are used, as when these begin to close, a by-pass valve opens to maintain a steady flow of water through the boiler. An uncontrolled open by-pass or manually set by-pass valve is not acceptable as this would allow the boiler to operate at a higher temperature, with less efficient use of fuel.

- Independent temperature control in living and sleeping areas (TRVs could be used for bedroom radiators).

- Installations to be inspected and commissioned to ensure efficient use by the local authority Building Control Department or self-certified by a 'competent person', i.e. CORGI, OFTEC or HETAS approved (see page 73).

- System owners/users to be provided with equipment operating guides and maintenance instructions. This 'log-book' must be completed by a 'competent person'.

- Dwellings with over 150 m^2 living space/floor area to have the heating circuits divided into at least two zones. Each to have independent time and temperature control and to be included in the boiler interlock arrangement. A separate control system is also required for the hot water.

continued . . . .

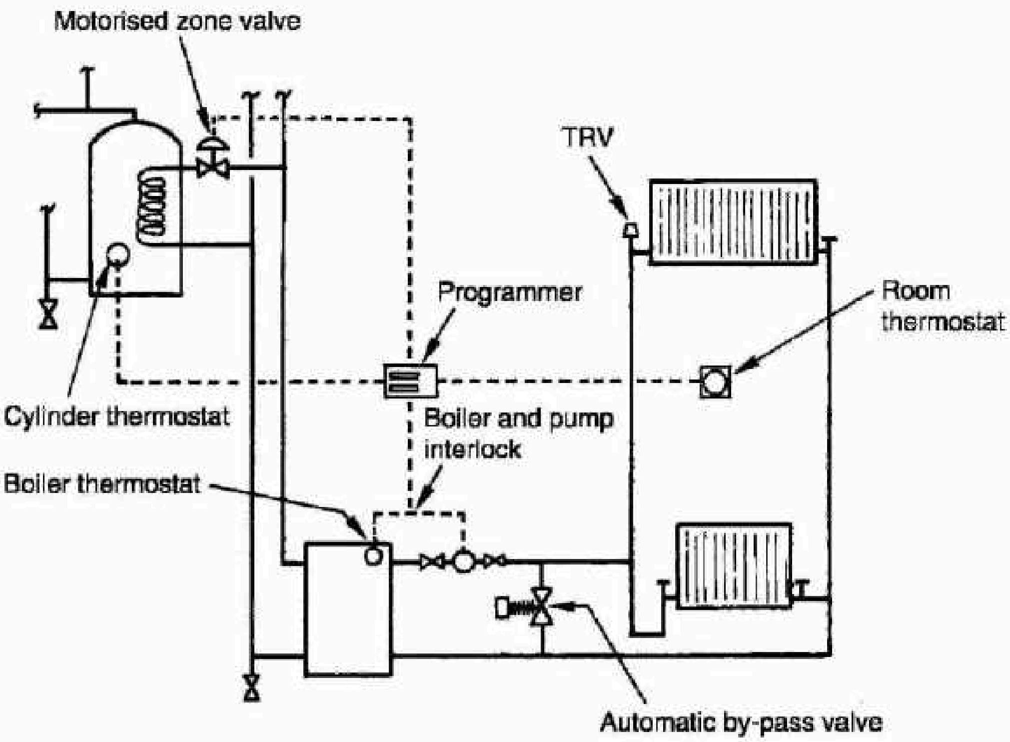
Requirements for 'dry' systems –

- Warm air or dry systems (see page 122) should also benefit fully from central heating controls. Although gas-fired air heaters are not covered by SEDBUK requirements, these units should satisfy the following standards:

  BS EN 778: Domestic gas-fired forced convection air heaters for space heating not exceeding a net heat input of 70 kW, without a fan to assist transportation of combustion air and/or combustion products, or

  BS EN 1319: Domestic gas-fired forced convection air heaters for space heating, with fan-assisted burners not exceeding a net heat input of 70 kW.

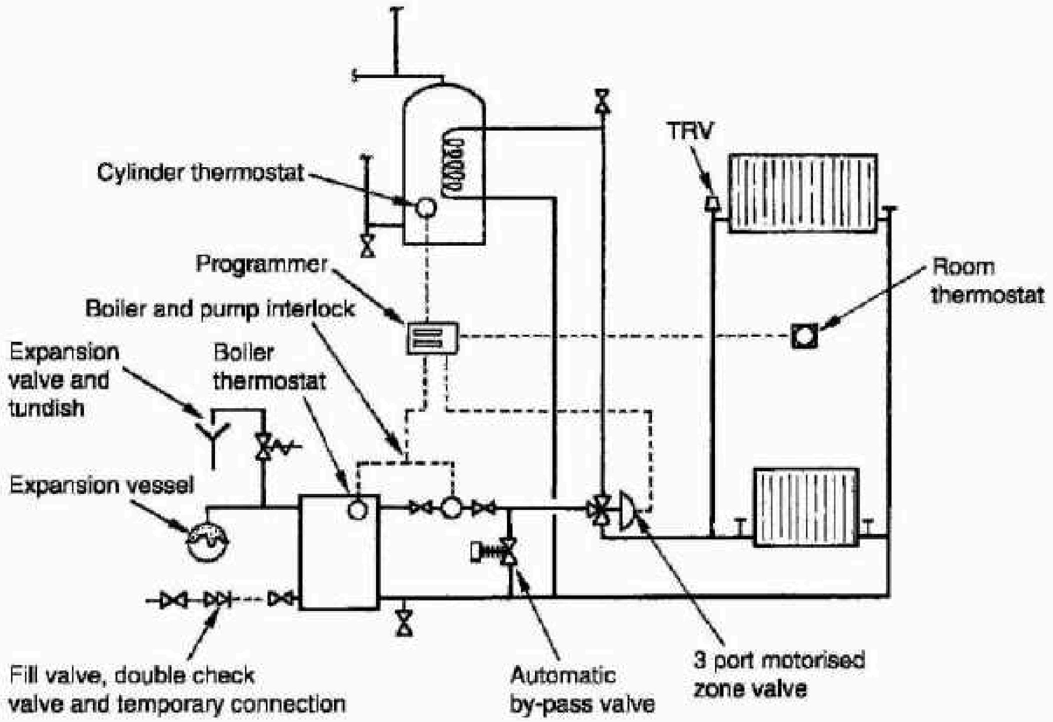
- Replacement warm air heat exchanger units can only be fitted by a 'competent person'. All newly installed ducting should be fully insulated.



Note: Boiler and pump interlock is the wiring configuration as explained on the previous two pages

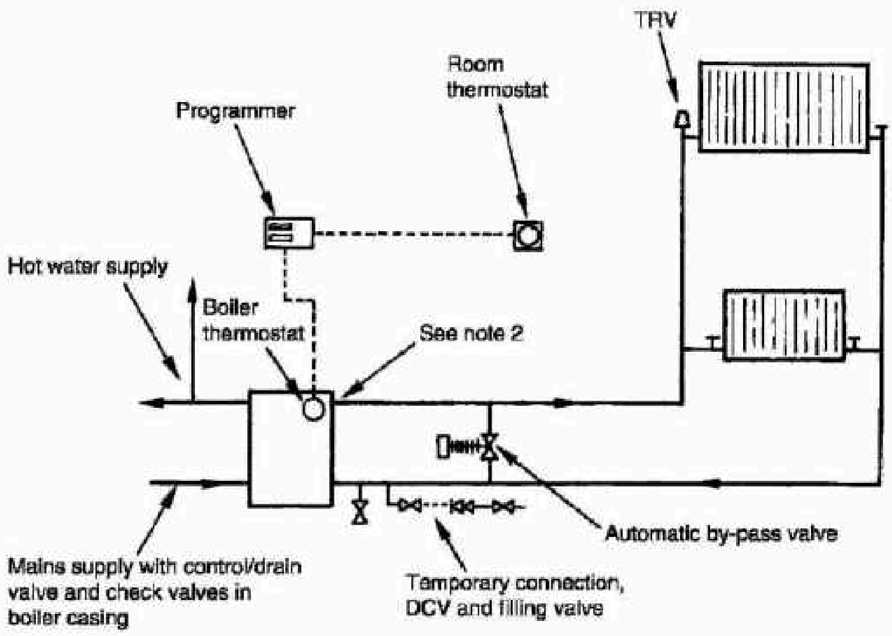
Typical semi-gravity system of hot water and heating controls

Schematic of control systems –



Note: Boiler and pump interlock is the wiring configuration as explained on pages 110 and 111

Typical fully pumped system of hot water and heating



Notes:
1. Hot water draw off taps supplied direct from mains, through instantaneous water heater
2. Heating water is sealed. Additional components include heating pump and expansion vessel in boiler casing, with expansion valve and tundish (see upper diagram)

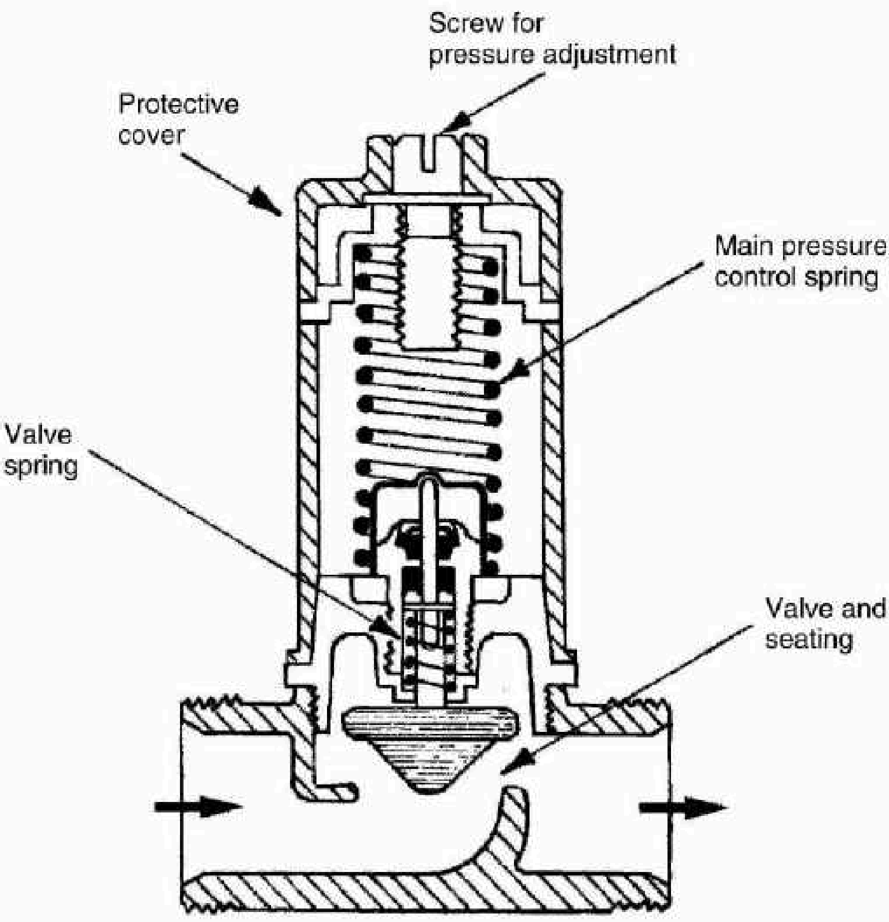
Typical combination boiler (see also page 54)

Modern boilers and heating systems are low water content to provide fuel efficiency and a rapid response. Therefore, to maintain a minimum flow through the boiler and to accommodate pump over-run, most boiler manufacturers will specify that a system by-pass be used with their products.

An open by-pass or by-pass with a valve set in a fixed open position will satisfy the basic objectives, but with the boiler flow pipe feeding the return pipe at all operating times, the boiler will need to function at a higher temperature than necessary to fulfil system requirements. Also, the heat energy transferred into the system will be limited, as a proportion of boiler flow water will be continually diverted through the by-pass pipe.

Thermostatically controlled radiator valves and motorised zone and circuit valves are now standard installation. With these controls parts of the system may be closed, leaving only a limited demand for heat. Selective demands will cause varying pump pressures, unless a by-pass valve is in place to automatically adjust, regulate and respond to pressure changes from the pump. Some applications are shown on the previous two pages.

Typical automatic by-pass valve –

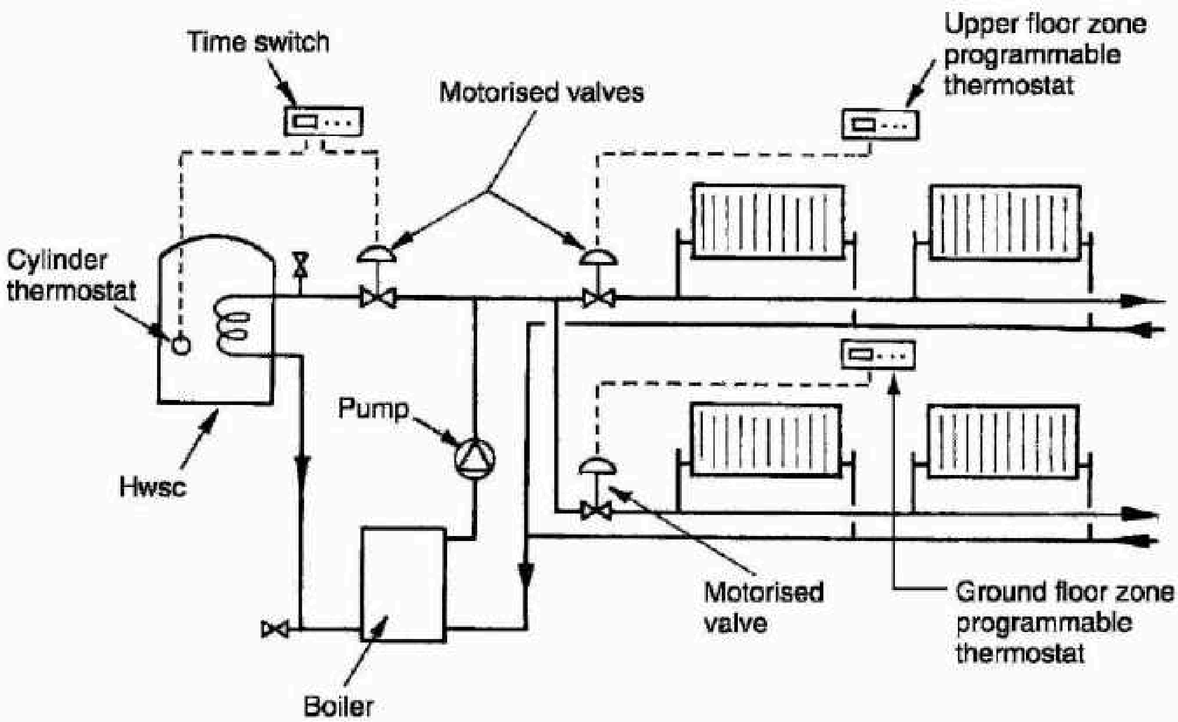


In addition to high efficiency boilers, optimiser controls, thermostatic radiator valves and other fuel-saving measures considered elsewhere in this chapter, further economies and user comforts can be achieved by installing programmable thermostats with motorised valves dedicated to heat only a specific part or zone within a building.

Zone control or zoning provides fuel saving and user convenience by regulating heat/energy distribution to particular locations in response to occupancy. This prevents wasteful distribution of heat in a building that is not fully utilised.

Examples where zoning has greatest benefit:

- Unused upper floor rooms, i.e. bedrooms, during daytime.
- Supplementary accommodation, bedsit or granny flat.
- Conservatories or other rooms with heating characteristics which are weather and seasonally variable.
- Office in the home, occupied whilst the remainder of the house is not.
- People with irregular working patterns, i.e. shift workers may require heating downstairs when others will not.
- Insomniacs and people who get up regularly in the night (the elderly?) may require heating in a specific room at unusual times.



Note: See page 91 for boiler feed/fill and expansion facilities

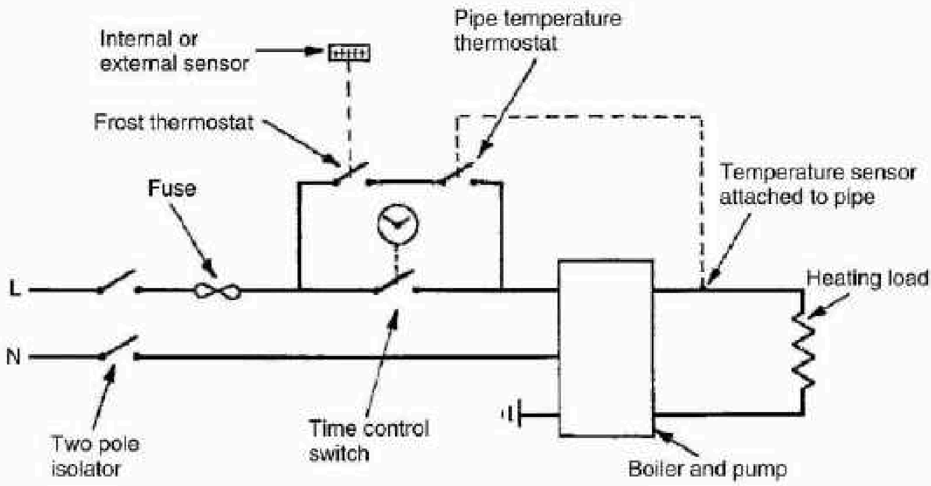
Example using zone control programmable thermostats with 'wireless' (radio frequency signals) regulation of the boiler

Piped water systems in modern highly insulated buildings are unlikely to be affected by modest sub-zero external temperatures. Nevertheless, an automatic 24-hour frost damage fail-safe facility may be specified as a client requirement or to satisfy insurer's standards. This is particularly appropriate for buildings located in very exposed parts of the country, and for buildings that are periodically unoccupied.

Frost thermostat – similar in appearance to a normal room thermostat but with a lower temperature range. Installed internally or externally on a north facing wall and set to about 5°C.

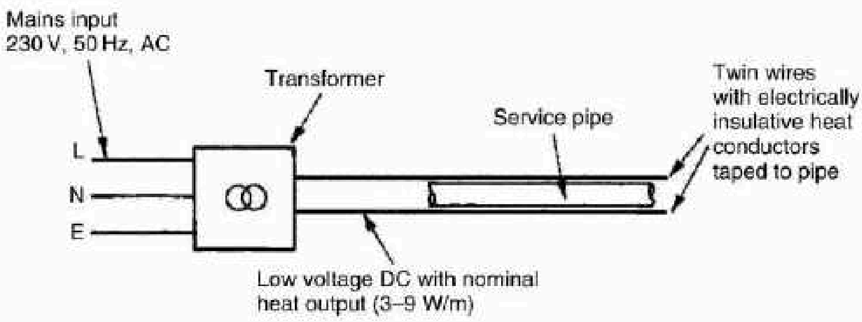
Pipe thermostat – strapped to an exposed section of pipe to detect the temperature of the contents.

Both types of thermostat can be used independently or wired in series to the same installation as shown below. Whether used in combination or individually, they are installed to by-pass the time control.



Thermostatic frost protection

Trace element frost protection – a low voltage electric heating element taped to the pipe surface. Used mainly for external piped services.



Trace element heating

Wireless or radio frequency (RF) band communications are in common use. For example, remote keyless entries, TV controls, portable telephones, burglar alarm systems, garage doors, estate gates and computer links. For heating system controls, this form of communications technology offers many benefits to both installer and property owner/end user. Not least a saving in installation time, as hard wiring between thermostatic controls, boiler controls, motorised valves and programmer is not required. There is also considerably less disruption to the structure and making good the superficial damage from channelling walls, lifting floorboards, drilling walls and holing joists. This is particularly beneficial where work is applied to existing buildings and refurbishment projects.

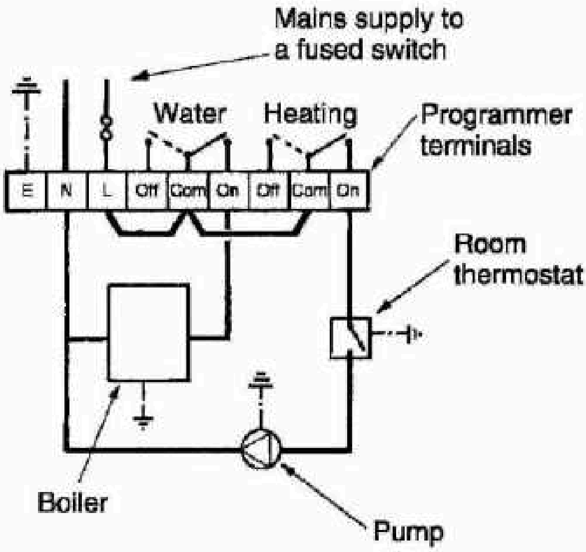
In principle, a battery cell power source is used to transmit a secure, unique radio signal from the hot water storage cylinder thermostat and each of the room thermostats. This signal is recognised by a receiver which is hard-wired to switching units placed next to the boiler, pump and motorised valves. Installation cabling is therefore reduced to an absolute minimum at localised receivers only. The appearance and location of thermostats is similar to conventional hard-wired units. The capital cost of components is significantly more, but the savings in installation time will justify this expenditure.

The use of radio frequencies for communications systems in modern society is strictly controlled and regulated by operator licensing regulations to prevent interference and cross communications. For wireless domestic heating controls this is not a problem as the unique low power signals function at around 430 MHz at a short range, typically up to 30 metres. At this specification, an operating license is not required as it satisfies the recommendations of the European Telecommunications Standards Institute, European Standard EN 300-220 for equipment in the 25 to 1000 Mhz frequency band at power levels up to 500 mW.

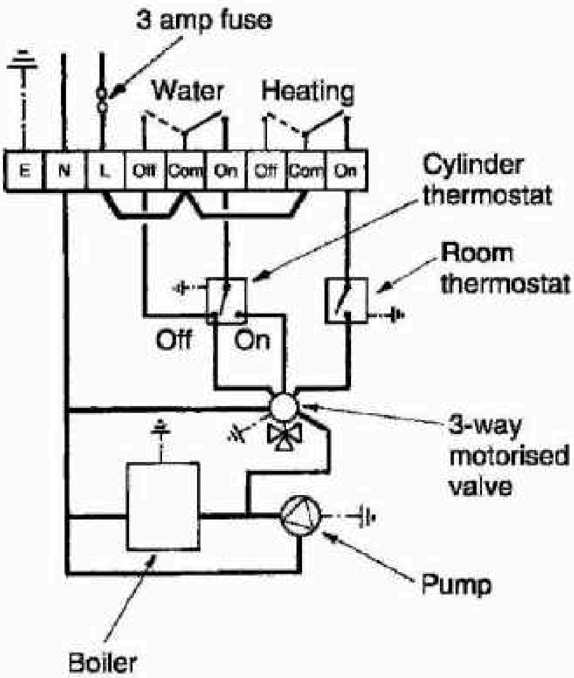
To commission RF controls, each thermostat is digitally coded and programmed to the associated signal receiver. Therefore, the controls in one building will not interfere with similar controls in adjacent buildings, and vice versa. Siting of controls will require some care, as large metal objects can inhibit the signalling function. Location of the boiler and hot water storage cylinder are obvious examples that will need consideration.

There are a variety of wiring schemes depending on the degree of sophistication required and the extent of controls, i.e. thermostats, motorised valves, etc. Boiler and control equipment manufacturers provide installation manuals to complement their products. From these the installer can select a control system and wiring diagram to suit their client's requirements.

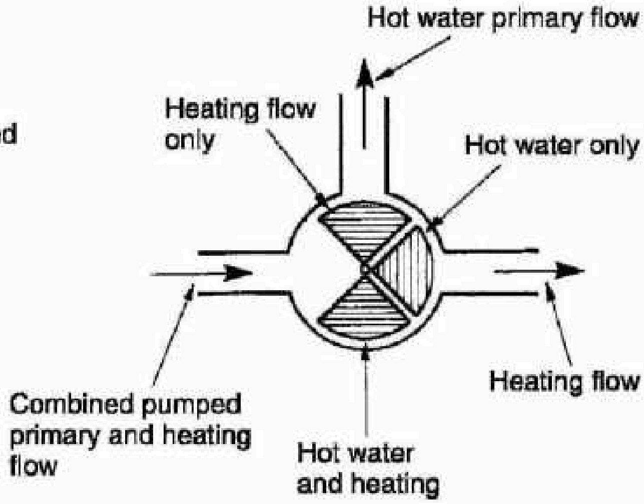
The schematic diagrams shown relate to a gravity or convected primary flow and return and pumped heating system (see page 84) and a fully pumped hot water and heating system using a three-way motorised valve (see page 109).



Gravity primary flow and return, pumped heating system



Fully pumped system

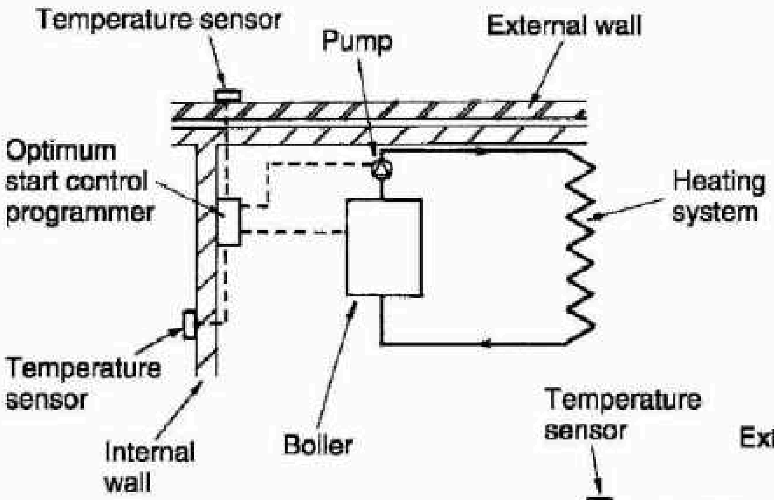


Theoretical operation of 3-port motorised valve. Note: may be installed to give hot water priority over heating.

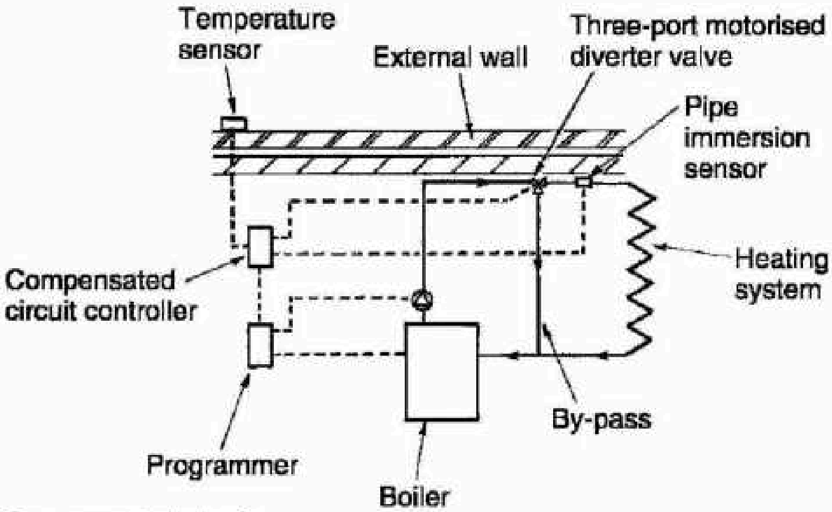
Optimum Start Controls - these have a control centre which computes the building internal temperature and the external air temperature. This is used to programme the most fuel efficient time for the boiler and associated plant to commence each morning and bring the building up to temperature ready for occupation. The system may also have the additional function of optimising the system shutdown time.

Compensated Circuit - this system also has a control centre to compute data. Information is processed from an external thermostat/sensor and a heating pipework immersion sensor. The principle is that the boiler water delivery temperature is varied relative to outside air temperature. The warmer the external air, the cooler the system water and vice versa.

The capital cost of equipment for these systems can only be justified by substantial fuel savings. For large commercial and industrial buildings of variable occupancy the expenditure is worthwhile, particularly in the intermediate seasons of autumn and spring, when temperatures can vary considerably from day to day.



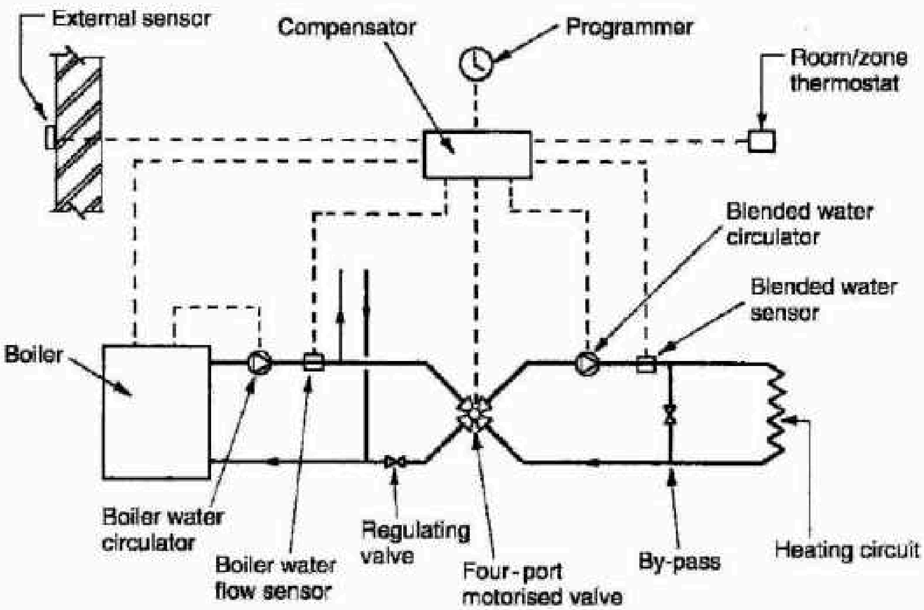
Optimum start controller



Compensated circuit

Weather compensated circuit – accurate control of indoor temperature depends on monitoring and modulating system heat input with the heat losses from a building. This differs considerably from the traditional heating system controlled solely by a thermostat. A thermostat functions relative to internal air temperature, switching on the boiler to supply water at a pre-set temperature.

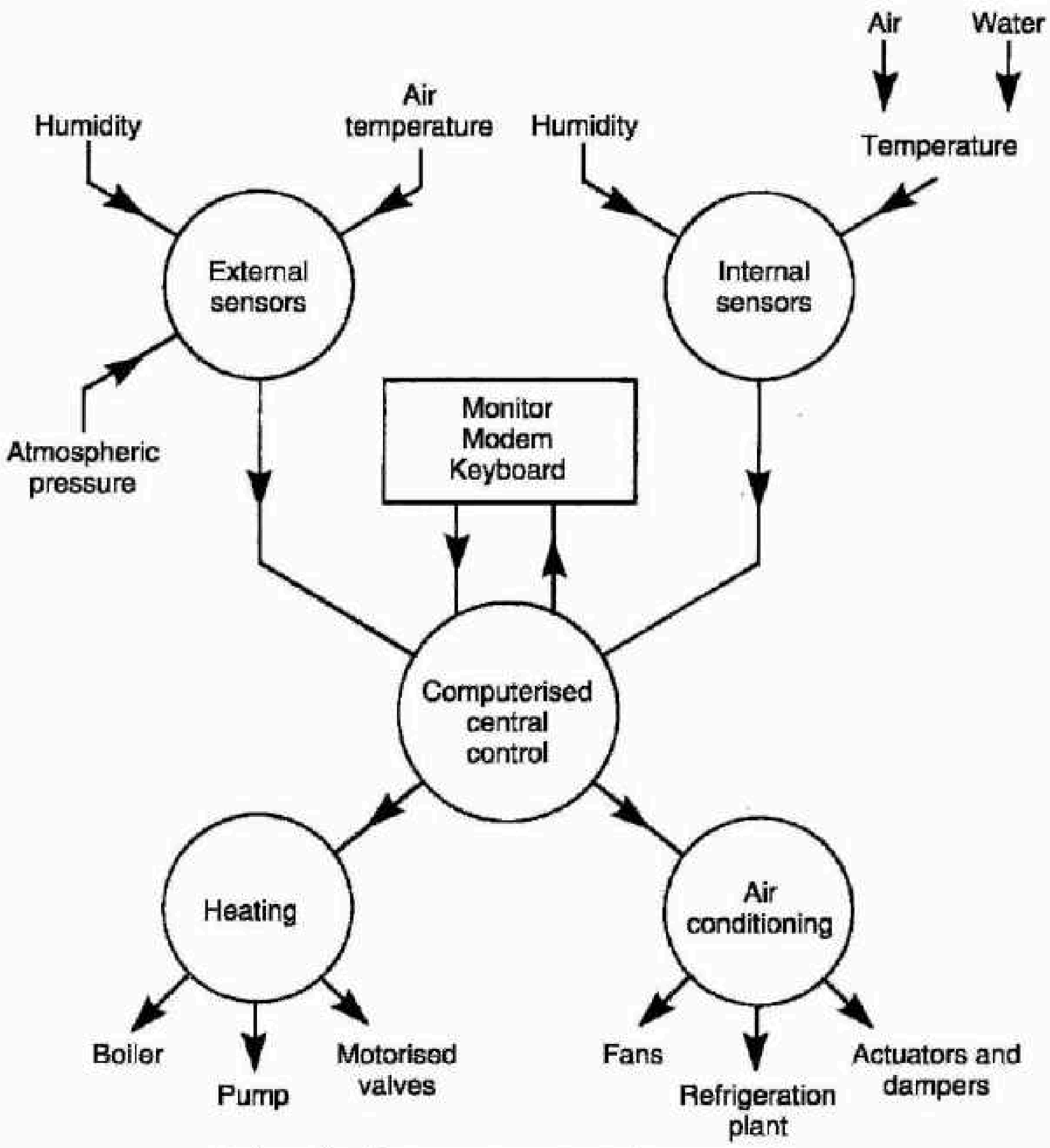
Optimum comfort and economy are achieved if the heating system water is constantly circulated with temperature varied to suit occupancy needs. A balance is achieved by incorporating into the heating programme, the external air temperature and internal heat gains from people, machinery, solar sources, etc. At the centre of the installation is a compensator-controlled 3- or 4-port motorised valve (3 port shown on previous page). This valve blends the required amount of cool system return water with hot water supplied from the boiler, to ensure a continuous supply of water at the required temperature to satisfy ambient conditions. The motorised valve setting varies depending on the boiler water temperature, the system supply water temperature, internal air temperature and outdoor air temperature. The latter is measured by a thermostatic sensor fitted to a north facing wall. Data from all four sources is computed in the compensator for positioning the motorised valve, activating the system circulator and to regulate the boiler functions.



Weather compensated control system

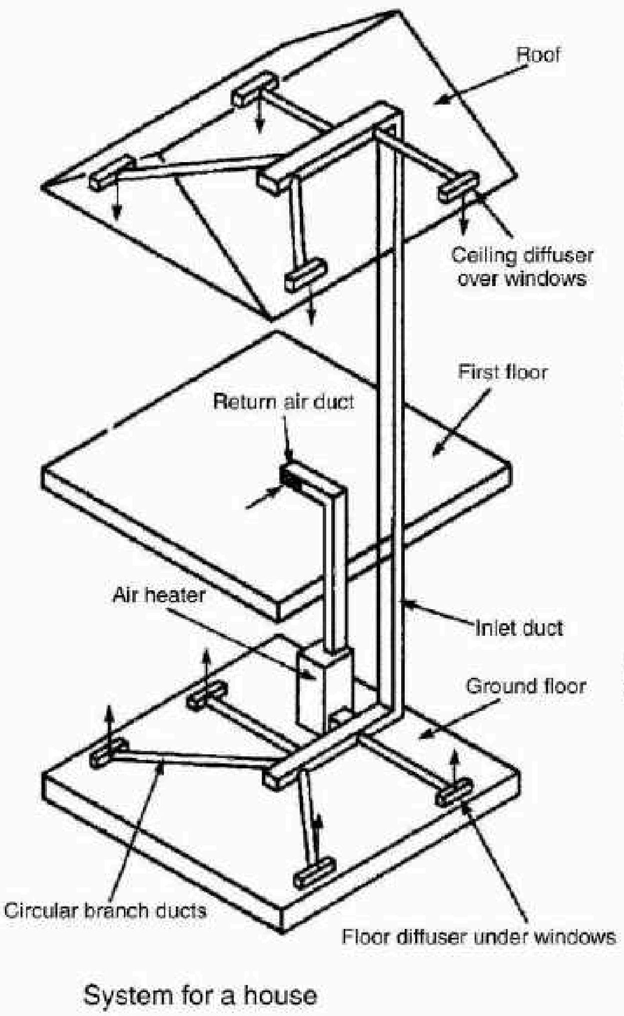
Note: Variable water temperature systems are particularly suited to underfloor heating. The heating demand is more evenly controlled through the 'thermal' floor than by on-off thermostatic switching.

Energy management systems can vary considerably in complexity and degree of sophistication. The simplest timing mechanism to switch systems on and off at pre-determined intervals on a routine basis could be considered as an energy management system. This progresses to include additional features such as programmers, thermostatic controls, motorised valves, zoning, optimum start controllers and compensated circuits. The most complex of energy management systems have a computerised central controller linked to numerous sensors and information sources. These could include the basic internal and external range shown schematically below, along with further processed data to include: the time, the day of the week, time of year, percentage occupancy of a building, meteorological data, system state feedback factors for plant efficiency at any one time and energy gain data from the sun, lighting, machinery and people.

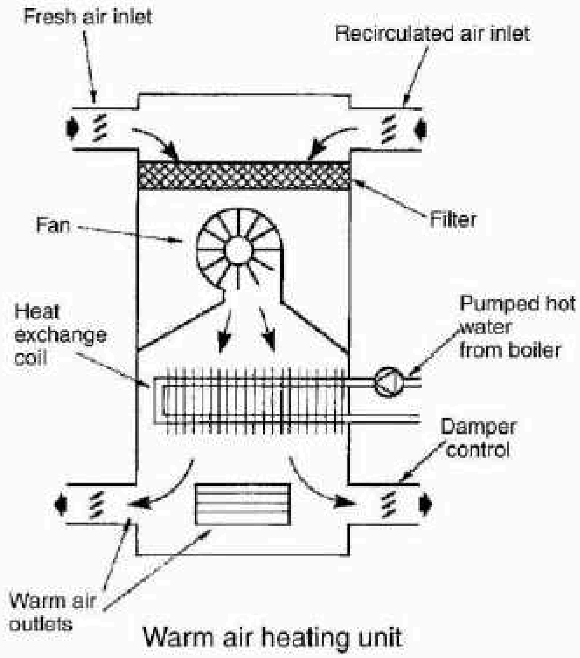


Schematic of energy management components

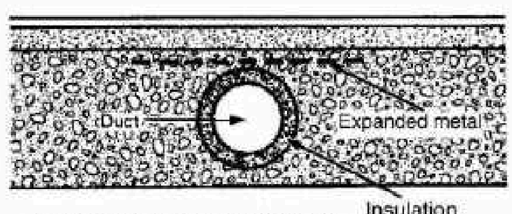
If there is sufficient space within floors and ceilings to accommodate ducting, warm air can be used as an alternative to hot water in pipes. There are no obtrusive emitters such as radiators. Air diffusers or grilles with adjustable louvres finish flush with the ceiling or floor. The heat source may be from a gas, oil or solid fuel boiler with a pumped supply of hot water to a heat exchanger within the air distribution unit. The same boiler can also be used for the domestic hot water supply. Alternatively, the unit may burn fuel directly, with air delivered around the burner casing. Control is simple, using a room thermostat to regulate heat exchanger and fan. The risk of water leakage or freezing is minimal, but air ducts should be well insulated to reduce heat losses. Positioning grilles in doors is an inexpensive means for returning air to the heater, but a return duct is preferred. Fresh air can be supplied to rooms through openable windows or trickle ventilators in the window frames. If rooms are completely sealed, fresh air should be drawn into the heating unit. The minimum ratio of fresh to recirculated air is 1:3.



System for a house



Warm air heating unit



Duct inside concrete floor

The thermal transmittance rate from the inside to the outside of a building, through the intermediate elements of construction, is known as the 'U' value. It is defined as the energy in watts per square metre of construction for each degree Kelvin temperature difference between inside and outside of the building, i.e. W/m^2 K. The maximum acceptable 'U' values vary with building type and can be found listed in Approved Documents L1 and L2 to the Building Regulations.

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

External walls. . . . . 0·35
Pitched roof. . . . . 0·16
Pitched roof containing a room. . . . . 0·20
Flat roof. . . . . 0·25
External floor. . . . . 0·25
Windows, doors and rooflights . . . . . 2·00 (ave.) Wood/uPVC
Windows, doors and rooflights . . . . . 2·20 (ave.) Metal

Note: Windows, doors and rooflights, maximum 25% of floor area.

Non-domestic buildings also have a maximum 'U' value of 1·5 for vehicle access doors, along with the following requirements for windows, doors and rooflights:

Residential buildings – maximum 30% of exposed wall internal area.

Industrial and storage buildings – max. 15% of exposed wall internal area.

Places of assembly, offices and shops – maximum 40% of exposed wall internal area.

Rooflights – maximum 20% of rooflight to roof area.

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

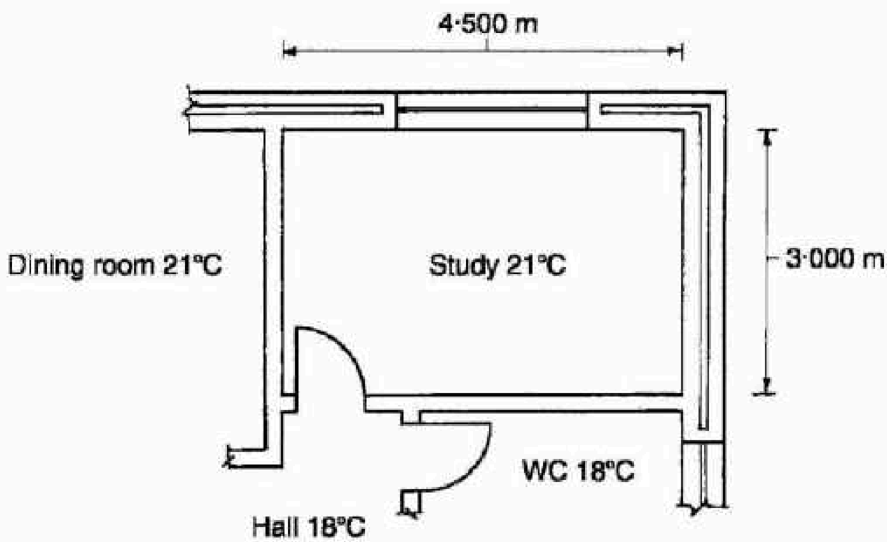
	Area × 'U' × temperature difference	
Wall:	27 × 0·35 × 24 =	226·80
Window:	3 × 2·00 × 24 =	144·00
		370·80 watts

*Note: Area weighted average allows for interruption in the construction, e.g. meter cupboard voids.

A heat emitter should be capable of providing sufficient warmth to maintain a room at a comfortable temperature. It would be uneconomical to specify radiators for the rare occasions when external temperatures are extremely low, therefore an acceptable design external temperature for most of the UK is −1°C. Regional variations will occur, with a figure as low as −4°C in the north. The following internal design temperatures and air infiltration rates are generally acceptable:

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

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



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

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

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

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

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

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

Note: The lower denomination 3, is derived from density of air (1·2 kg/m^3) × s.h.c. of air (1000 J/kg K) divided by 3600 seconds.

For the study shown on the previous page:

(4·5 × 3 × 2·3) × 1·5 × (21 − −1) divided by 3 = 341·55 watts

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

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

Total heat loss from the study = 341·55 + 436·88 = 778·43, i.e. 779 watts

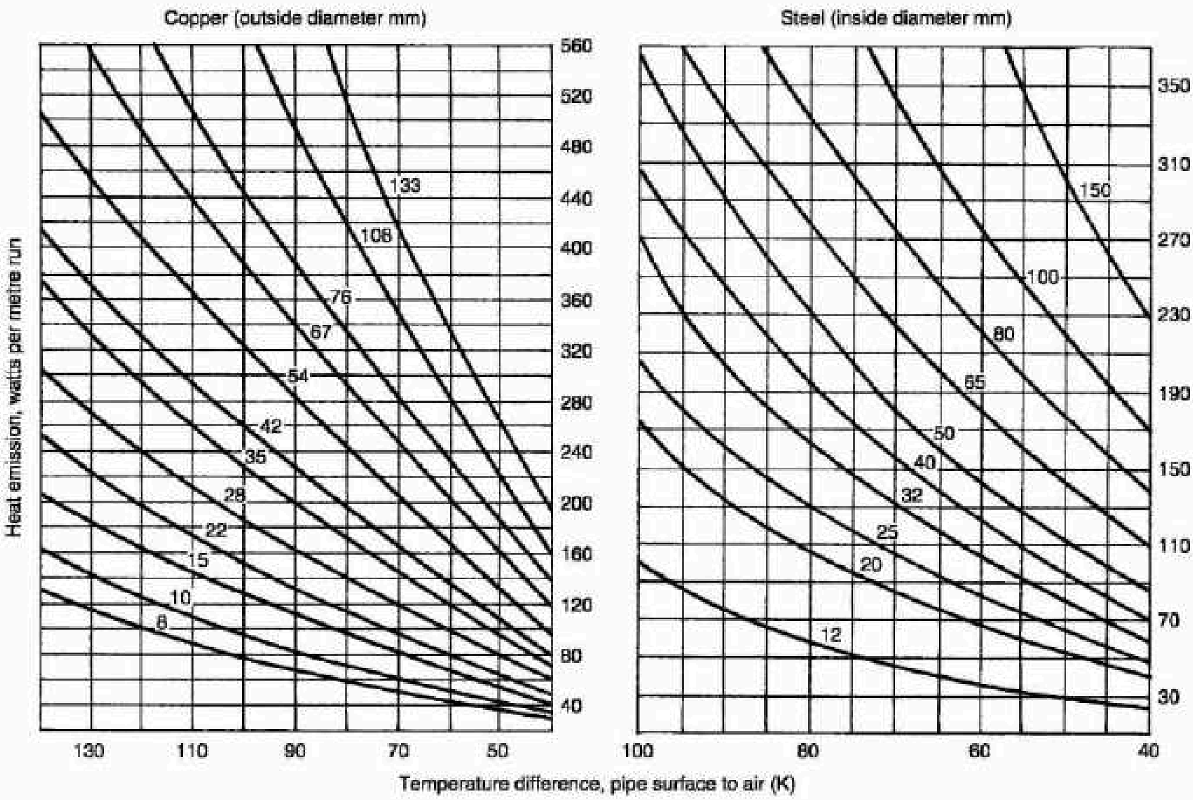
Radiators are specified by length and height, number of sections, output in watts and number of panels. Sections refer to the number of columns or verticals in cast iron radiators and the number of corrugations in steel panel radiators. Panels can be single, double or triple. Design of radiators and corresponding output will vary between manufacturers. Their catalogues should be consulted to determine exact requirements. The following extract shows that a suitable single panel radiator for the previous example of 779 watts, could be:

450 mm high × 1100 mm long × 33 sections (832 watts), or
600 mm high × 800 mm long × 24 sections (784 watts).

Selection will depend on space available. Over-rating is usual to allow for decrease in efficiency with age and effects of painting.

Height (mm)	Length (mm)	Sections	Watts (single)	Watts (double)
450	400	12	302	548
	500	15	378	686
	600	18	454	823
	700	21	529	960
	800	24	605	1097
	900	27	680	1234
	1000	30	756	1371
	1100	33	832	1508
	1200	36	907	1645
	1400	42	1058	1919
	1600	48	1210	2194
	1800	54	1361	2468
600	400	12	392	693
	500	15	490	866
	600	18	588	1039
	700	21	686	1212
	800	24	784	1386
	900	27	882	1559
	1000	30	980	1732
	1100	33	1078	1905
	1200	36	1176	2078
	1400	42	1372	2425
	1600	48	1568	2771
	1800	54	1764	3118

Note: Radiators are also manufactured in 300 and 700 mm standard heights.



Note: Emission figures will vary slightly, depending on pipe quality and extent of painting

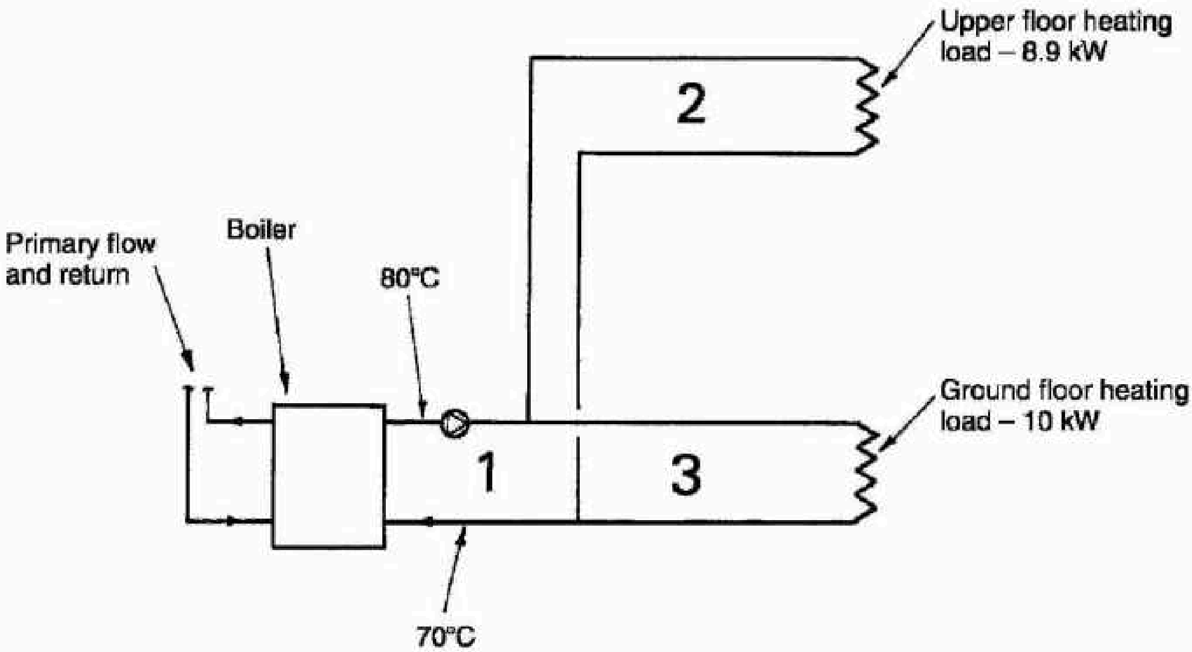
To determine the overall boiler rating, the requirement for hot water (see Part 2) is added to that necessary for heating. Heating requirements are established by summating the radiator specifications for each of the rooms. To this figure can be added a nominal percentage for pipework heat losses, the amount depending on the extent of insulation.

E.g. if the total radiator output in a house is 18 kW and an additional 5% is added for pipework losses, the total heating requirement is:

$$18 + (18 \times 5/100) = 18{\cdot}9 \text{ kW}.$$

Given the manufacturer's data of 80% boiler efficiency, the boiler gross heat input will be:

$$18{\cdot}9 \times 100/80 = 23{\cdot}63 \text{ kW}.$$



Pipes 1 – Heating flow and return at boiler

Pipes 2 – to upper floor

Pipes 3 – to ground floor

Schematic illustration, assuming a heating load of 8·9 kW on the upper floor and 10 kW on the ground floor, i.e. 18·9 kW total.

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

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

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

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

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

Therefore, the mass flow rate for:

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

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

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

Selecting a pumped water velocity of 0·8 m/s (see page 68) and copper tube, the design chart on page 132 indicates:

Pipes 1 = 35 mm o.d.
Pipes 2 = 22 mm o.d.
Pipes 3 = 22 mm o.d.

The specification for a pump is very much dependent on the total length of pipework, summated for each section within a system. In existing buildings this can be established by taking site measurements. For new buildings at design stage, estimates can be taken from the architects' working drawings. Actual pipe lengths plus an allowance for resistance due to bends, tees and other fittings (see page 29), provides an effective length of pipework for calculation purposes.

Using the previous example, given that pipes 1, 2 and 3 are 6 m, 10 m and 12 m effective lengths respectively, the design chart shown on page 132 can be used to determine resistance to water flow in each of the three sections shown:

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

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

Therefore:	Pipes 1 @ 6 m × 200 Pa =	1200
	Pipes 2 @ 10 m × 360 Pa =	3600
	Pipes 3 @ 12 m × 360 Pa =	4320
		9120 Pa or 9·12 kPa

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

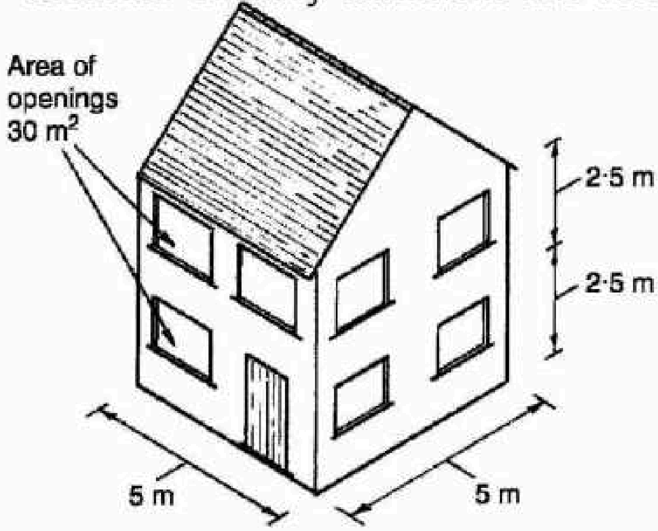
However, a higher figure for pump pressure will be necessary as the resistances in branch pipes to individual emitters will also need to be included. Pump selection is from manufacturer's pump performance charts similar to that shown on page 70.

Note: The smaller the pipe diameter, the greater the pressure drop or resistance to flow.

A simple and reasonably accurate estimate for determining boiler size.

Procedure –

- Establish dwelling dimensions and factor for location –



Detached house, location south east

UK location	Factor
North & Midlands	29
Scotland	28·5
South east	27
Wales	27
Northern Ireland	26·5
South west	25

- Approximate heat losses:

  Openings area (30 m^2) × Openings 'U' value (2·00 ave.)* = 60 (A).

  Gross wall area (100 m^2) – Openings area (30 m^2) × Wall 'U' value (0·35)* – 24·5 (B).

  Roof length (5 m) × Roof width (5 m) × Roof 'U' value (0·16)* = 4 (C).

  Floor length (5 m) × Floor width (5 m) × Standard correction factor (0·7) = 17·5 (D).

  (For ceiling and floors in a mid-position flat, use zero where not exposed.)

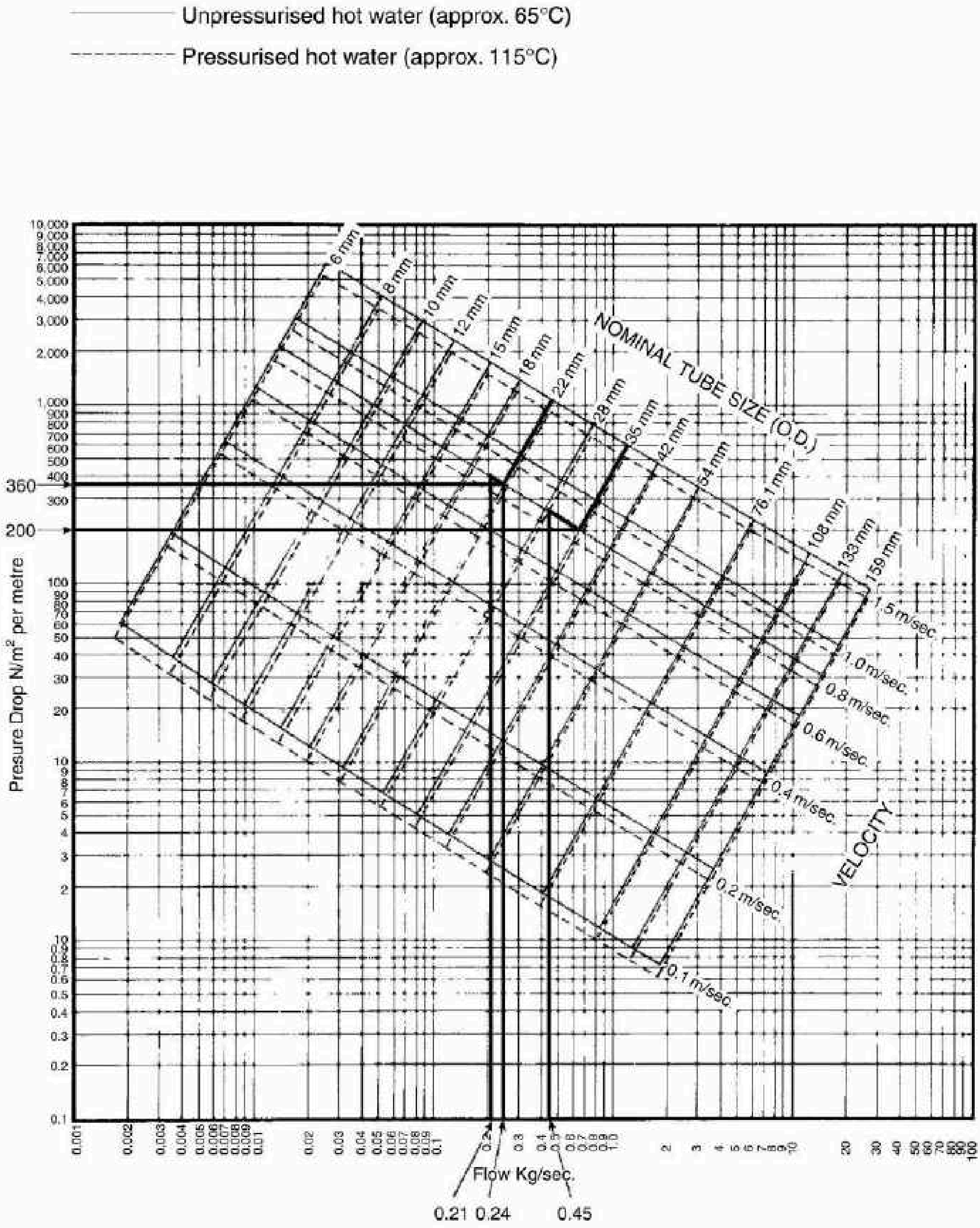
- Summate fabric losses: A + B + C + D = 106.
- Multiply by location factor: 106 × 27 = 2862 watts.
- Calculate ventilation losses:

  Floor area (25 m^2) × Room height (2·5 m) × No. of floors (2) = Volume (125 m^3 × Standard ventilation correction factor (0·25) × Location factor (27) = 843·75 watts.

- Boiler input (net) rating = 2862 + 843·75 + 2000 (watts for hot water) + calcs. for any extension to building = 5706 watts or 5·71 kW.

*See page 123 for 'U' values.

Water Flow Resistance Through Copper Tube



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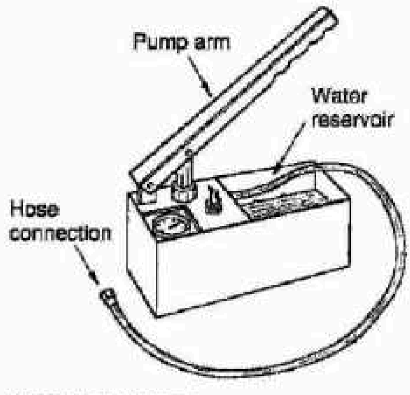
Testing medium – water is preferred to air, as water is virtually incompressible. Also, about 200 times more energy would be stored in compressed air at the same pressure and volume as for water. This could have a damaging effect on personnel and property if a component leaked or failed.
Where premises are particularly sensitive to water leakage, a low pressure air test can be undertaken before applying a hydraulic test.



Hydraulic test pump

Procedure

- Disconnect ancillary equipment that may not be designed to withstand test pressures, e.g. shower, boiler, etc. Manufacturer's data should be consulted.
- Check all system high points for location of air vents.
- Blank or plug any open ends including float valves. Close valves where sub-sections only are being tested.
- Open all valves in the enclosed section under test.
- Attach test pump to a convenient point.
- Start filling the system by pump priming and replenishing the pump water reservoir.
- Ventilate air from high points until water shows.
- When the system is full, raise the pressure as required.
- If pressure falls, check joints, valves, etc. for leakage.
- When the test is satisfied, ensure the appropriate documentation is signed.

Test requirements

- Rigid pipes – provide an internal water pressure at the lowest point in the system at 50% above normal operating pressure. This should hold for 1 hour. For example, 1 bar (10 m or 100 kPa) operating pressure requires a 1·5 bar (15 m or 150 kPa) test pressure.
- Plastic pipes – elastic by nature, will expand to some extent under pressure. Therefore the test procedure for rigid pipes is inappropriate. Either of the following tests, A or B is acceptable:

Test A – test pressure as for rigid pipes is applied and maintained for 30 minutes. After this time, pressure is reduced by one-third. For another 90 minutes the test is satisfied if there is no further reduction in pressure.
Test B – required test pressure is applied and maintained for 30 minutes. Test is satisfied if:

1. pressure drops <0·6 bar (60 kPa) after a further 30 minutes, and
2. pressure drops <0·2 bar (20 kPa) after a further 120 minutes, and
3. there is no visible leakage.

Application – underground and above ground systems of water pipework.
Ref. Water Supply (Water Fittings) Regulations, Schedule 2, Section 4, Paragraph 12.

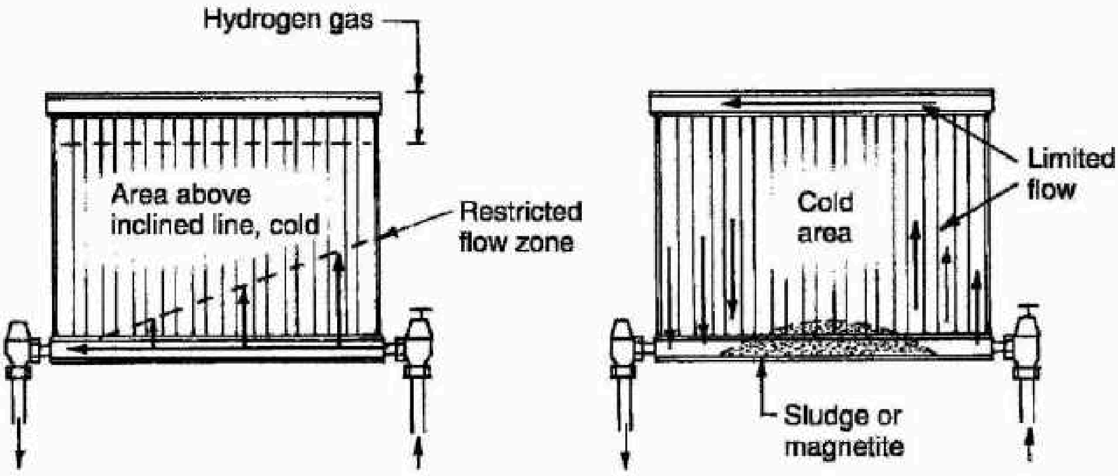
Boilers with a cast iron heat exchanger used with an indirect sealed system are unlikely to corrode. However, some electrolytic reaction between copper pipes and steel heat exchangers in boilers and pressed steel radiators is possible. Also, some corrosion of steel can occur where minute amounts of air enter the system. This may occur:

- Through undetected leakage at pipe joints
- From air present in solution
- From air dissolving into water contained in the feed and expansion cistern.

The initial indication of internal corrosion is one or more radiators failing to get hot and a need for frequent 'bleeding' through the air valve. Corrosion produces hydrogen gas. This may be detected by holding a lighted taper to the draught escaping at the air valve. Caution should be observed when effecting this test and if the taper is seen to burn with a blue flame, hydrogen is present. Air will not burn.

Another characteristic of corrosion is black sludge accumulating in the bottom of radiators. This is known as magnetite and it may also obstruct circulating pipes. Magnetite is the metallic breakdown of steel radiator walls. In addition to blockage and corrosion, magnetite is drawn to the magnetic field of the circulating pump where its abrasive presence may cause the impellor to fail.

Corrosion in heating systems can be prevented or at least considerably reduced, by introducing a proprietary inhibitor to the feed and expansion cistern as the system is filled. With sealed systems the inhibitor can be introduced with a funnel and hose temporarily connected to a high level radiator.



Internal corrosion of radiators

General Considerations and Rules for Natural Ventilation. The following considerations and rules should be followed for promoting the natural ventilation in buildings:

1. Inlet openings in the buildings should be well distributed and should be located on the wind-ward side at a low level. The outlet openings should be located on the leeward side near the ceiling in the side walls and in the roofs.

2. Inlet and outlet openings should preferably be of equal size for greatest air flow, but when outlet is in the form of a roof opening the inlet should be larger in size.

3. Where the wind direction is variable, openings should be provided in all walls with suitable means of closing them.

4. Inlet openings should not be obstructed by adj-oining buildings, trees, signboards, partitions or other obstructions in the path of air flow.

5. Increased height of the room gives better ventilation due to stack effect.
6. The long narrow rooms should be ventilated by providing suitable openings in short sides.
7. The rate of air-change in a room mainly depends on the design of opening location of inlet and outlet, and the difference in temperature between the inside and outside air. Generally, the outside air is cooler than the inside air. Hence, the cooler air enters from the bottom and after becoming hot during its stay in the room, it leaves from the top (as shown in Fig. 21.2). It would, therefore, be advantageous to provide ventilators as close to the ceilings as possible.
8. The efficiency of roof ventilation depends on their location, wind direction and the height of the building.
9. It is found that the ventilation through windows can be improved by using them in combination with a radiator, deflector and exhaust duct, as shown in Fig. 21.4.

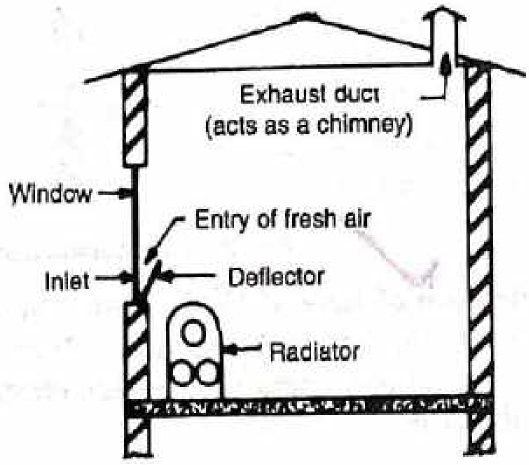


Fig. 21.4 Ventilation through windows in combination with radiator, deflector and exhaust duct.

10. For cross-ventilation, the position of outlets should be just opposite to inlets. The openings over the doors of back walls create good conditions for cross-ventilation.
11. Windows of living rooms should either open directly to an open space or open space created in buildings by providing adequate courtyards.
12. If the room is to be used for burning gas or fuel, enough quantity of air should be supplied by natural ventilation for meeting the demands of burning as well as ventilation of the room.

II. Mechanical or Artificial Ventilation. In this system of ventilation the outside air is supplied into a building either by positive ventilation, or by infilteration by reduction of pressure inside due to exhaust of air, or by a combination, of positive ventilation and exhaust of air. The supply of outside air by means of a mechanical device, such as a fan, is termed as '*positive ventilation*', whereas the removal of air and its disposal outside by such a device is termed as '*exhaust of air*'. For positive ventilation, centrally located supply fans of centrifugal type, whereas for exhaust of air, wall or roof located exhaust fans of propeller type, are normally used. So, this ventilation involves the use of some mechanical arrangement for providing enough ventilation of the room.

Mechanical ventilation is recommended in all the cases where a satisfactory standard of ventilation in respect of air quantity, quality or controllability cannot be obtained by natural means. A mechanical system is capable of meeting the requirements of air quantity and qualities (of air) regarding humidity, temperature, etc. and produces the comfortable conditions at all times during the year. Though this system is comparatively costly but it results in the considerable increase in the efficiency of the persons under the command of this system. This system is adopted for big offices, banks, assembly halls, auditoriums, theatres, large factories, work-shops, places of entertainment, etc. This system may be regarded as generally desirable in all rooms occupied by more than 50 persons, where the space per occupant is less than 3 cu.m.

The following methods of mechanical or artificial ventilation are in common use:

1. Extract or Exhaust Systems,
2. Supply or Plenum Systems,
3. Combination of Exhaust and Supply Systems or Balanced Systems, and
4. Air-conditioning.

1. Extract or Exhaust Systems. In this system, a partial vacuum is created in the inside of room by exhausting or removing the vitiated inside air by means of propeller type fans. The extraction of air from inside permits the fresh air to flow from outside to inside and, thus, it becomes possible to provide fresh air to the room through doors and windows.

These fans for exhaust are installed at suitable places in the outside walls or roofs and they are further connected to different rooms through a system of duct-work.

These exhaust systems are best confined to situations where it is essential to create an air-flow towards the ventilated rooms, such as in kitchens, lavatories, industrial plants, etc. This system is useful for removing smoke, odours, fumes, dust, etc. from the above mentioned rooms. In this system, the ducts are placed near the place of formation of smoke, fumes, odours, dust, etc.

2. Supply or Plenum Systems. As the name implies, in this system the space is filled with air by means of a fan, but no special provision is made to remove it. In plenum ventilation, the air inlet is selected in the side of the building where the air is purest. In this opening, screens or filters may be fixed, and a fine stream of water may be impugned in the path of the incoming air. The disinfection of incoming air is achieved by adding ozone at the point of inlet. Thus, by this system of mechanical ventilation, it is possible to control the quality, humidity and temperature of the incoming air.

Ventilation by plenum process may be downward or upward. In downward ventilation, the incoming air is allowed to enter at the ceiling height and is taken out through outlets situated at floor level. In upward ventilation, the fresh air is allowed to enter the floor level and the outlet is provided at the ceiling height.

These ventilation systems are costly and are used for factories, big offices, theatres, etc. and also for supplying air to the air-conditioned buildings.

3. Combination of Exhaust and Supply Systems or Balanced Systems. This balanced system in a combination of above two systems and makes use of fans to supply and to extract air (*i.e.*, input fans and exhaust fans). This system enables full control over the air movement and conditions to be obtained, and should be used where accurate performance is desired. In most buildings, it is desirable to extract only about 75% of the quantity of air supplied so that positive pressure is maintained within the rooms. This is essential to prevent the entry of hot air when doors are opened and also to prevent the infiltration of dust and air-borne contaminants. Moreover, the recirculation of air is possible in this system.

4. **Air-conditioning.** This is the most effective system of artificial ventilation, in which provision is kept for humidifying or dehumidifying, heating or cooling, filterations, etc. of the air to meet the possible requirements. The study of air-conditioning involves several aspects and hence will be dealt separately under subsequent Part II of this chapter.

13.3 ELEVATORS OR LIFTS

Elevators are used in buildings having more than four storeys. They are used for providing vertical transportation of passengers or freight. They can be either electric traction elevators or hydraulic elevators. Electric traction elevators are used exclusively in tall buildings. Hydraulic elevators are generally used for low-rise freight service which rise up to about six storeys. Hydraulic elevators may also be used for low-rise passenger service.

The different components of an electric traction elevator are the car or cab, hoist wire ropes, driving machine, control equipment, counterweight, hoistway rails, penthouse, and pit. The car is a cage of light metal supported on a structural frame, to the top of which the wire ropes are attached. The ropes raise and lower the car in the shaft. They pass over a grooved motor-driven sheave and are fastened to the counter weights. The paths of both the counterweights and the car are controlled by separate sets of T-shaped guide rails. The control and operating machinery may be located in a penthouse above the shaft or in the basement. Safety springs or buffers are placed in the pit, to bring car or counterweight to a safe stop. Elevators, serving more than three floors, should be provided with means for venting smoke and hot gases from the hoistways to the outer air in case of fire. Vents may be located in the enclosure just below the uppermost floor, with direct openings to the outside or with non–combustible duct connections to the outside. Vent area should be at least 3.5% of the hoistway cross sectional area.

A few important terms, generally, used in elevator description, are defined below:

1. Annunciator. This is an electrical device which indicates, usually by lights, the floors at which an elevator landing signal has been registered.

2. Buffer. This is a device for stopping a descending car or counterweight beyond its bottom terminal by absorbing and dissipating the kinetic energy of the car or counterweight. The absorbing medium may be oil, in which case the buffer may be called an oil buffer, or a spring, in which case the buffer may be referred to as a spring buffer.

3. Bumper. This is a device other than a buffer stopping a descending car or counterweight beyond its bottom terminal by absorbing the impact.

4. Car. This is the load carrying element of an elevator, including car platform, car frame, enclosure and car door or gate.

5. Car-door Electric Contact. This is an electrical device for preventing normal operation of the driving machine unless the car door or gate is closed.

6. Car Frame. This is the supporting frame to which the car platform guide shoes, car safety, hoisting ropes or hoisting rope sheaves, or the plunger of a hydraulic elevator are attached.

7. Car Switch. This is the manual operating device in a car by which an operator actuates the control.

8. Control. This is the system governing the starting, stopping, direction of motion, acceleration, speed and retardation of the car.

9. Generator Field Control. This employs individual generator for each elevator, with voltage applied to the driving machine motor adjusted by varying the strength and direction of the generator field.

10. Multivoltage Control. This impresses successively on the armature of the driving machine motor at various fixed voltages, such as those that might be obtained from multi-commutator generators common to a group of elevators.

11. Rheostatic Control. This varies the resistance or reactance of the armature or the field circuit of the driving machine motor.

12. Single Speed Alternating Current Control. This governs a two-speed driving machine induction motor that runs at a specified speed.

13. Dispatching Device. This is a device which operates a signal in a car to indicate when the car should leave a designated floor or to actuate the car's starting mechanism when the car is at a designated floor.

14. Emergency Stop Switch. This is a car-located device that, when operated manually causes the car to be stopped by disconnecting electric power from the driving machine motor.

15. Hoistway. This is a shaft for travel of one or more elevators. It extends from the bottom of the pit to the underside of the overhead machine room or the roof. A blind hoistway is the portion of the shaft that passes floors or other loadings without providing a normal entrance.

16. Hoistway Access Switch. This is a switch placed at a landing to permit car operation with both the hoistway door at the landing and the car door open.

17. Hoistway-door Electric Contact. This is an electrical device for preventing normal operation of the driving machine unless the hoistway door is closed.

18. Hoistway-door Locking Device. This is a device for preventing the hoistway door or gate from being opened from the landing side unless the car has stopped within the landing zone.

19. Levelling Device. This is a mechanism for moving a car that is within a short distance of a landing towards the landing and stopping the car there. An automatic maintaining two-way levelling device will keep the car floor level with the landing during loading and unloading.

20. Machine. This is the power unit for raising and lowering an elevator car.

21. Non-stop Switch. This is a device for preventing a car from making registered sanding stops.

22. Operating Device. This is the car switch, push button level, or other manual device used to actuate the control.

23. Operation. The method of actuating the control.

24. Car-Switch Operation. This starts and stops a car in response to a manually operated car switch or continuous pressure buttons in a car.

25. Pre-register Operation. This is one in which signals to stop are registered in advance by buttons in a car or loadings and then at the proper points as car, travel are given to an operator in the car who initiates the stop, which is complete automatic.

26. Signal Operation. This starts and stops a car automatically as landings are reached, in response to actuation of buttons in cars or at landings, irrespective of direction of car travel or sequence in which buttons are actuated, but the car can be started only by a button or starting switch in the car.

27. Parking Device. This is a device for opening from the landing side the hoistway door at any landing when the car is within the landing one.

28. Pit. This is a portion of a hoistway below the lowest landing.

29. Position Indicator. This is a device for showing the location of a car in the hoistway.

30. Rope Equalizer. This is a device installed on a car or counterweight to equalize automatically the tensions in the hoisting ropes.

31. Runby. This is the distance a car can travel beyond a terminal landing without striking a stop.

32. Safety. This is a mechanical device attached to the counterweight or to the car frame or an auxiliary frame to stop or hold the counterweight or the car, whichever undergoes a free fall, or if the hoisting ropes should slacken.

33. Safety Bulkhead. This is in a cylinder of a hydraulic elevator, a closure, at the bottom of the cylinder but above cylinder head, with an orifice for controlling fluid loss in case of cylinder-head failure.

34. Signal Registering Device. This is a button or other device in a car or at a landing that causes a stop signal to be registered in a car.

35. Signal Transfer Device. This is a manually operated switch for accomplishing the same function as a signal transfer device.

36. Slack Rope Switch. This is a device that automatically disconnects electric power from the driving machine when the hoisting ropes of a winding drum machine become slack.

37. Starter's Control Panel. This is an assembly of devices with which an elevator starter can control the way in which one or more elevators function.

38. Terminal Speed–Limiting Device (Emergency). This is a device for reducing automatically the speed of a car approaching a terminal landing, independently of the car operating device and the normal terminal stopping device if the latter fails to slow the car as intended.

39. Terminal Stopping Device. This is a device for slowing or stopping a car automatically at or near a terminal landing, independently or the car operating device. A final terminal stopping device after a car passes a terminal landing, disconnects power from the driving apparatus, independently of the operating device, normal terminal stopping device or emergency terminal speed limiting device. A stop motion switch, or machine final terminal stopping device, is a final terminal stopping device operated directly by the driving machine.

40. Transom. This comprises of one or more panels that close the opening above hoistway entrance.

41. Travel (Rise). This is the vertical distance between top and bottom terminal landings.

42. Travelling Cable. This is a cable containing electrical conductors for providing electrical connections between a car and a fixed outlet in a hoistway.

43. Truck Zone. This is a limited distance above a landing within which the truck zoning device permits movement of a freight elevator car with its door or the hoistway door open.

44. Truck Zoning Device. This is a device that permits a car operator on move, within a specified distance above a landing, a freight-elevator car with its door or the hoistway door open.

up to 17 m/min.

13.5 ESCALATORS

These are powered stairs. They are used when it is necessary to move large number of people from floor to floor. These stairs have continuous operation without the need for operators. They have large capacity with low power consumption. These escalators are in the form of an inclined bridge spanning between floors. The components of an escalator consist of a steel trussed framework, hand rails and an endless belt with steps. At the upper ends of an escalator there is a pair of motor-driven sprocket wheels and a worm-gear driving machine. At the lower end is a matching pair of sprocket wheels. Two precision made roller chains travel over the sprockets pulling the endless belt of steps around the steps which move on an accurately made set of tracks attached to the trusses with each step supported on four resilient rollers. Escalators are reversible in direction. They are generally operated at a speed of 30 or 40 m/min. Slope of stairs is standardized at 30°. For a given speed of travel width of step determinines the capacity of the powered stairs.

Escalators should be installed where traffic is heaviest and convenient for passengers. In the design of a new building, adequate space should be allotted for powered stairs. Structural framing should be made adequately to support them.

Escalators are generally installed in pair. One of them is used for carrying up-going traffic and the other for traffic moving down. The arrangement of escalators in each storey can be either parallel or criss-cross (*See* Figs. 13.15 and 13.16). Criss-cross arrangement is more compact. It reduces walking distance between stairs at various floors to a minimum. That is why a criss-cross arrangement is

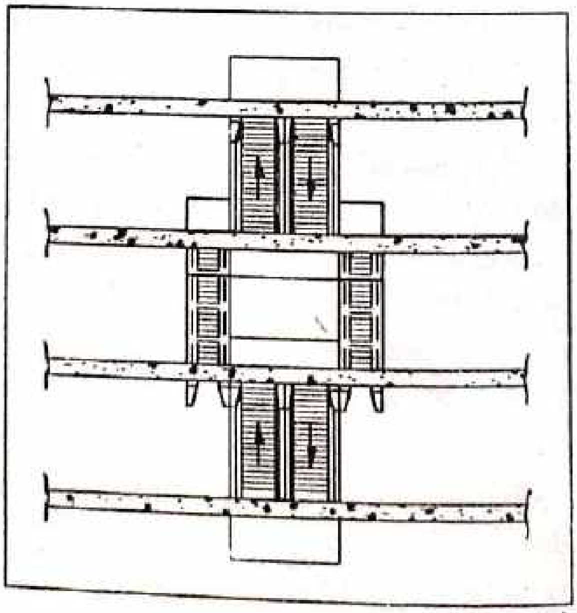


Fig. 13.15 Parallel arrangement of Escalators.

preferred over parallel arrangement. The floor openings of an escalator not serving as required if exist must be protected. The following protection methods are generally used in buildings completely protected by a standard supervised sprinkler system.

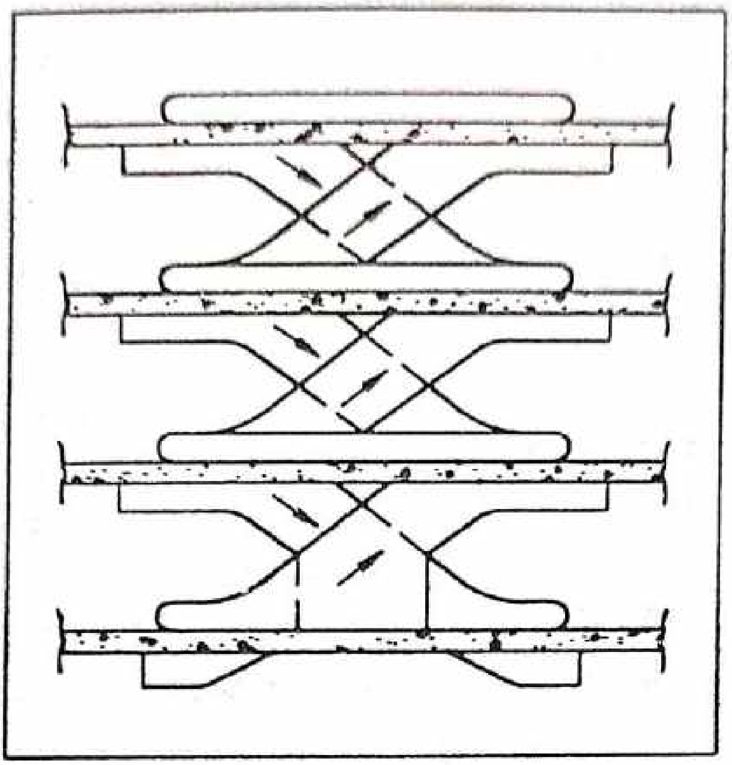


Fig. 13.16 Criss-cross Arrangement of Escalators.

Sprinkler-vent method. This is a combination of an automatic fire or smoke detection system, automatic air-exhaust system and an automatic water curtain.

Spray-nozzle method. This is a combination of an automatic fire or smoke detection system and a system of high velocity water-spray nozzles. 3

Rolling shutter method. In this an automatic, self-closing, rolling shutter is used to enclose completely the top of each escalator.

4

Partial enclosure method. In this kiosks, with self-closing, fire-doors, provide an effective barrier to the spread of smoke between floors.

CONSTRUCTION AND EARTH MOVING EQUIPMENTS :-

The infrastructure development is an importa- -nt aspect for the overall development of country. India is considered as the hub for service industry for which the infrastructure development plays an important role. The major problem frequently faced by contractor in the selection of most suitable equipment. Under given conditions, one of the largest elements of investigation of contractor would be own and operating cost of plant and equipment. The capital investment on purchase and/or rental/lease and operation of the plant and equipment being very high, it has to be managed so as to ensure maximum return on investment, productivity and minimum operating, maintenance and repair cost. Thus appro- -priate selection and planning is essential for successful completion of project and to secure max. profit out of it. The type of equipment selected usually depends upon the characteristics of material to be handled. Whether to use wheeled equipment or track equipment, whether to use dragline excavator or power shovel, are some of the eg.

PLANNING AND SELECTION OF CONSTRUCTION EQUIPMENT :-

Modern construction projects are complex in nature and success of a project depends greatly on proper and scientific planning. Before starting any project & its planning is done with great care as the effeciency of the whole project largely depends upon its planning. While planning each and every details should be worked out in anticipation and should be considered carefully. planning of a construction project involves deciding about the extent of mechanization, equipment planning and execution planning etc. while planning a highway project equipment manager should be carefully decide the extent of mechanization so as to minimize the cost of project.

Proper selection of equipment for a construction project is of vital importance for its speedy and economical completion. Problem of equipment selection has become more complicated because large variety of equipments are being manufactured now-a-days. for Selection of equipment a considerable experience in the operation and maintenance in the field is essential. Records kept for operation, maintenance and actual output obtained under comparable conditions of previous project with greatly help in taking decision for equipment selection with the undertaking of new project and the retirement of old machinery and equipment, it becomes necessary to acquire new construction equipment. in this stage, sufficient knowledge base of current brands and product is necessary. It is also important to determine what sort of equipment and capacity is needed.

In fact, Selection of equipment for the project is one of the key decisions in planning and executing a construction project, which affect how the work will be done, the time required to complete the work, and the cost that will be accured. Generally an equipment manager is responsible of selecting the equipment; where as it is the responsibility of the construction planning group to select equipment. Never-theless; both the inventory of equipment in hand and the standard equipment policy play an impor-tant role in equipment selection. Therefore final decision on the equipment required for the project is generally given by equipment manager, project mana-ger and construction planning group together. often the decision making process can create tensions in the firm. once the selection of equipment is made, a choice has to be made whether to buy, rent or lease it. These decisions are given based on the economic standing and stratergy of the firm and nature and frequency of equipment use.

DRAG LINE:-

It is a piece of heavy equipment used in civil engineering and surface mining. Dragline fall into two broad categories: those that are based on standard lifting cranes. and the heavy units which have to be built on-site. Most crawler cranes, with an added winch drum on front, can act as a dragline. These units are designed to be dismantled and transported over the road on flat bed trailers. Draglines used in civil Engineering are almost always of this smaller, crane type. These are used for road, port construct pond and canal dredging and as pile driving rigs. These types are built by crane manufacturers such as link belt and hysten.

A much larger type which is built on site is commonly used in strip-mining operations to remove overburden above ~~coa~~ coal and more recently for oil sands mining. The largest heavy draglines are among the largest mobile land machin ever built. The smallest and most common of the heavy type weigh around 8,000 tons while the largest built weighed around 13,000 tons.

A dragline bucket system consists of a large bucket which is suspended from a boom with wire ropes. The bucket is maneuvered by means of a ~~ra~~ number of ropes and chains. The hoist rope powered by large diesel or electric motors, supports the bucket and hoist - coupler assembly from the boom. The dragrope is used to draw the bucket assembly horizontally. By skillful maneuver of the hoist and the dragropes the bucket is controlled for various operations. A schematic of a large dragline bucket system

TRACTOR :-

A tractor is a versatile earth moving equipment that finds many uses at a construction site. While its primary purpose is to pull or push loads, it is also used as a mount for many types of accessories, such as front end shovels, bulldozers and others. There are types and sizes to fit almost any job for which they are usable.

BULLDOZER :-

The bulldozer is a very powerful crawler that is equipped with a blade. The term bulldozer is often used to mean any type of heavy machinery, although the term actually refers to a tractor that is fitted with a dozer blade. Often times, bulldozers are large and extremely powerful tracked vehicles. The tracks give them amazing ground mobility and hold through very rough terrain. Wide tracks on other hand, help to distribute the weight of the dozer over large areas, therefore preventing it from sinking into sandy or muddy ground.

bulldozer have great ground hold and a torque divider that is designed to convert the power of the engine into dragging ability, which allows it to use its own weight to push heavy objects and even remove things from the ground. ~~Take thane.~~

The blade on a bulldozer is the heavy piece of metal plate that is installed on the front. The blade pushes things around. Normally, the blade comes in 3 varieties :-

(1) A straight blade that is short and has no lateral curve, no side wings and can be used only for fine grading.

(2) A universal blade or U-blade, which is tall and very curved and features large side wings to carry more material around.

(3) A combination blade that is shorter, offers less curvature and smaller side wings.

POWER SHOVEL :-

A power shovel is a bucket equipped machine, usually electrically powered, used for digging and loading earth or fragmented rock and for mineral extraction. Power shovels are a type of rope/cable excavator, where the digging arm is controlled and powered by winches and steel ropes, rather than hydraulic like in the more common hydraulic excavators. Basic parts of a power shovel include the track system, cabin, cable rack, stick, boom foot pin, saddle block, boom, boom point shaves and bucket. The size of bucket varies from 0.73 to 0.53 cubic meters.

26.4 COMPACTION EQUIPMENT

1. **Rolling.** In this process heavy weights in the form of rollers are used to press the soil particles together. Smooth wheeled rollers are typical examples of compaction equipment which operate on this principle.

2. Kneading. In this process kneading of soil while at the same time applying pressure is allowed. Sheeps foot rollers are typical examples of compaction equipment which operate on this principle. The pneumatic tyred roller has a compaction action which is a compromise between that obtained with a smooth wheeled roller and a sheep's foot roller.

3. Vibrations. In this process the soil particles are shaken together in a compact mass. Vibrating rollers are typical examples of compaction equipment which operate on this principle.

4. Ramming. In this process the soil particles are forced to move closer together by pounding action. Hand-temping and mechanical tempers are typical examples of compaction equipment which operate on this principle.

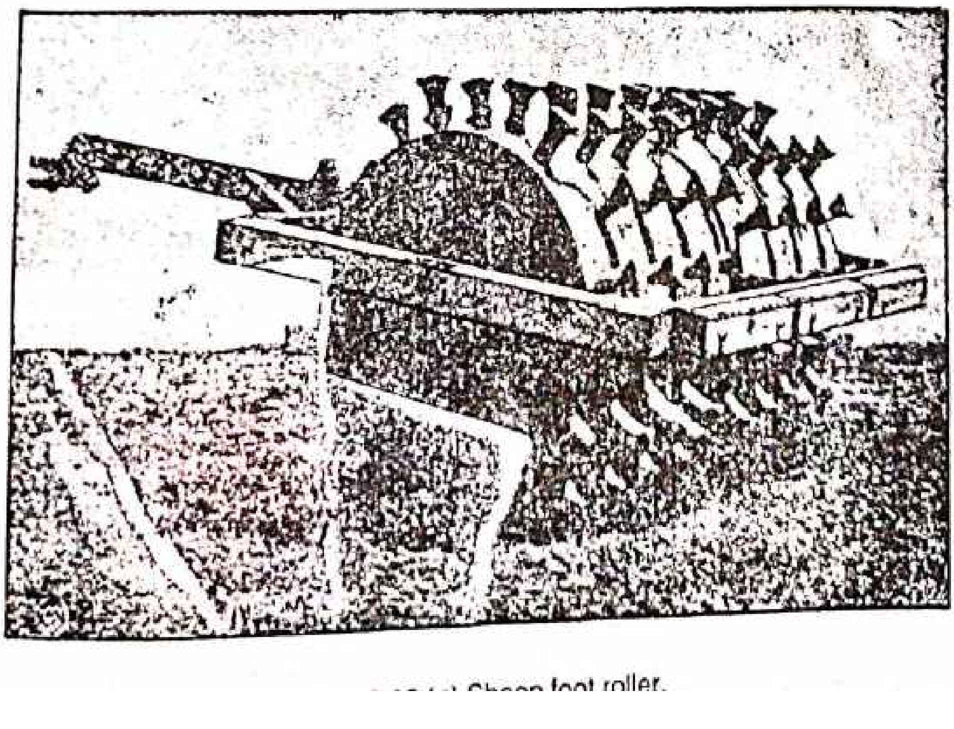
A brief description of each type of compaction equipment is given below:

(*i*) **Smooth Wheeled Roller.** Three wheeled or macadam rollers and tandem rollers are the typical examples of smooth wheeled rollers. These rollers have either two or three rolls in line behind each other. The rolls are actually hollow steel drums which can be filled with water or damp sand to obtain the desired pressures.

These rollers are most suitable for compacting gravels, sands and such materials where a crushing action is needed. The depth of the layer which can be satisfactorily compacted depends on the type of soil, the weight of the roller and the purpose of the work. In general compacted thickness varies from about 15 cms for subgrade and to about 15 cm for material used in embankments.

(*ii*) **Sheep's Foot Roller.** This type of roller consists of a cylindrical steel drum with steel projection extending in a radial direction outward from the surface of the cylinder [*See* Figs. 26.10 (*a*) and 26.10 (*b*)]. They may be self-propelled but more commonly they are towed by a tractor. Compaction is obtained by the feet penetrating and applying a high vertical pressure while at the same time providing lateral pressure. This type of roller is more suitable for silty and clayey sand, clayey silt and medium to heavy clays. The thickness of the layer to be compacted should not be more than the length of the feet plus 5 cm in order to get better performance. The modified AASHO compaction dry density can be achieved by approximate 24 passes of the roller. The use of sheep's foot roller leads to higher void contents in the soils. Thus, in construction jobs where the performance has to be based upon the minimum void content, this type of roller is not suitable.

(*iii*) **Pneumatic Tyred Roller.** This type of roller consists of a box mounted on two axles. The front axle has one wheel less than the rear axle. They are usually divided into three types—popularly known as medium, heavy and super heavy weight. The medium class includes both towed type and self-propelled units up to 13 tonnes rolling capacity. The roller gives kneading action as well as compression to the soil underneath. These rollers are suitable for



Sheep foot roller.

Fig. 26.10 (*b*) Sheep foot roller.

moderately cohesive silty soils, clayey, gravelly and clean sands of close gradation. The compaction should be done in layers less than 15 cm thickness.

(*iv*) **Vibratory Compactors.** They consist of a vibrating unit of either the out-of-balance weight type or a pulsating hydraulic type mounted on a screed, plate or roller in such a way that the net effect is an up and down vibratory movement of the compactor. These compactors are most effective for coarse-grained soils.

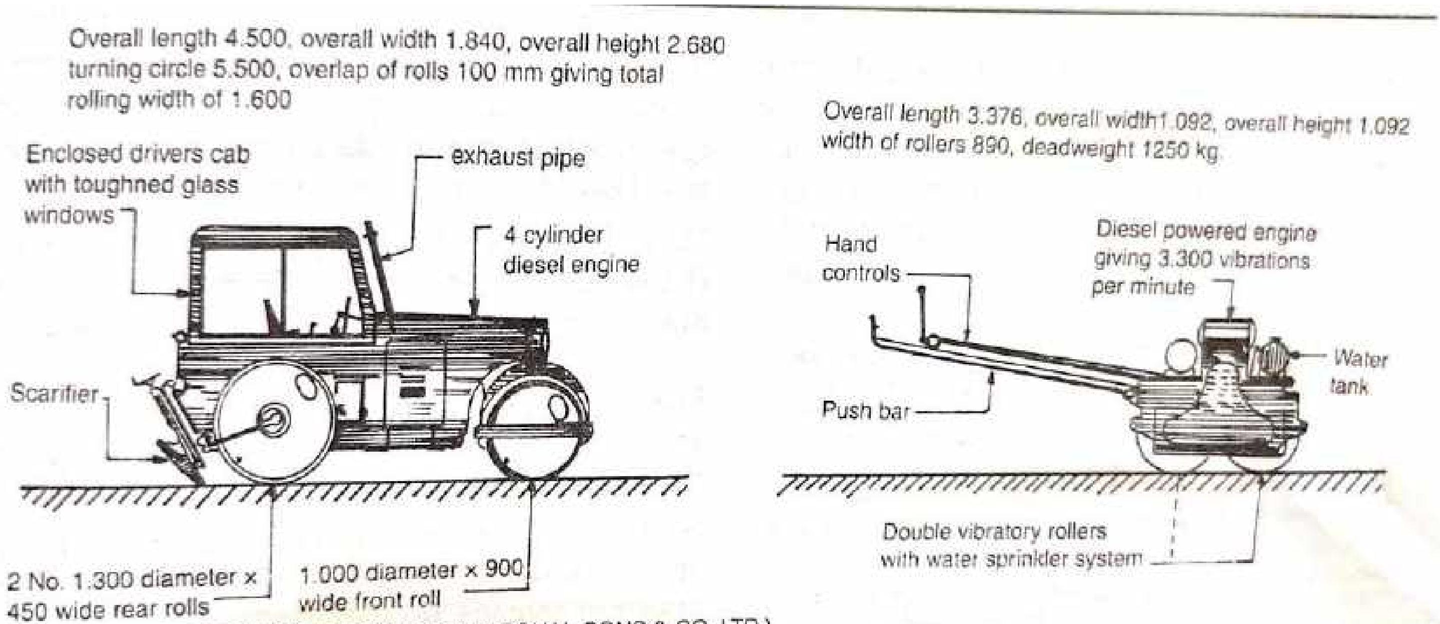
(*v*) **Rammers.** This type of compacting equipment consists of a relatively small area and is useful for compaction of trenches, foundations and slopes.

(*vi*) **Jetting and Ponding.** This technique is utilized for compacting cohesionless sand.

The roller equipment used for building purposes is basically a smaller version of the large rollers used for roadworks. These rollers consolidate filling materials and compact surface finishes. Rollers generally rely upon dead weight to carry out the consolidating operation or by vibration as in the case of lightweight rollers. Deadweight rollers are usually diesel powered and driven by a seated operator within a cab. They weigh from 1 to 16 tonnes which is distributed to the ground through two large diameter rear wheels and a wider but small front steering wheel. Many of these rollers carry water tanks to add to the dead load and to supply small spares or sprinkler pipes fixed over the wheels to dampen the surfaces thus preventing the adhesion of material when being rolled. These rollers are also available fitted with a sacrifier to the rear of the vehicle for ripping up the surfaces of beds or roads. [*See* Fig. 26.10 (*c*)].

Vibrating rollers have petrol or diesel-powered engine which is either hand guided or towed and are available with weights ranging from 500 kg to 5 tonnes [*See* Fig. 26.10 (*d*)]. These can be manoeuvered into buildings for consolidating small areas or similar bed material. Single or double rollers are available with or without water sprinkler attachments and with vibrations within the region of 3000 vibrations per minute. Vibrating rollers are particularly effective for the compaction and consolidation of granular soils in building works.

Compaction Control. During compaction in the field, it is density and moisture contents to affect proper control on the work. The *insitu* dry density of the soils may be checked by core cutter method, volumenometer method and rubber balloon method. The moisture content can be calculated on the spot with the help of a soil penetrometer. A soil penetrometer is a device which measures the penetration resistance of the soil at the given moisture content and for given compactive effort. The other devices for measuring the field moisture contents are B'ouyoucous, moisture meter and nuclear devices.



TYPICAL 6 TONNE DEADWEIGHT ROLLER (MARSHAL SONS & CO. LTD.)

Fig. 26.10 (*c* and *d*). Rollers for Building Work.

SOIL REINFORCING TECHNIQUE

Soil reinforcement is a technique which is used to improve the strength and stiffness of soil. Different engineering techniques are used to enhance the strength of soil, like geogrid and geotextile. It is a combina-tion of earthfill and reinforcing strips. They are capable of bearing large tensile strength. Soil reinfor-cement is a modern technique which is employed in various projects to prevent the failure of slopes of soil and it improves the bearing capacity of the soil.

NECESSITY OF SOIL REINFORCING :-

→ Reinforcement of soil is performed by placing tensile elements in the soil to enhance the stability and strength of the soil.

→ Soil reinforcement is a cost-effective technique which is used to improve tensile and bearing strength of the soil.

→ It is opted to improve the engineering and mechanical properties of soil.

→ Reinforced soil bed increase the bearing capacity of the soil and reduce the differential settlement of soil bed.

To reduce the quantity of earth fill. Steepen embankment slopes reduce the land take required.

USE OF WIRE MESH :-

Wire mesh fencing is one of the most
basic types of fencing. It can either be made
from galvanized steel or stainless steel. Wire mesh
fencing has a lot of uses from residential to
industrial purposes. Over the years, it has slowly
taken over chain link fences because users see it
to be more durable.

1. SECURITY FENCING :-

One of the main uses for wire mesh fencing
is for security purpose. This type of fencing is
often used as a security fence or perimeter wall.
It can be used for industrial, commercial or
residential installation. Most homes use this type
of fencing to secure their exterior fencing. The
type of wire mesh used for security fencing comes
in different sized holes from 5mm - 6mm. The typ
of wire mesh fencing you need depends on your pu-
-ference and requirement. There are also types of
wire mesh fences that have very small openings
preventing toe or finger holds. It also prevent tool
to cut through the fencing.

2. ANIMAL FENCING :-

Another common use of wire mesh fen
-cing is to fence in animals. Since this type of
fencing comes in different hole sizes, you can
choose to have a small holed or big holed
fencing to accommodate the type of animal you
would like to fence in. This type of fencing is

is often used in chicken coops, rabbit fencing and horse fencing to name a few. Since wire mesh fences do not have any sharp edges, it is also deemed as safe fencing for animals.

3. GARDEN FENCING :-

Wire mesh fencing is also best used for garden fencing. It can be used to surround the entire garden area or it can also be install-ed around certain area of the garden. Garden fencing can add a certain look into your garden since it can also come in several colors. This type of fencing is also used as an alternative to wires for climbing plants. They are more durable and can take the weight of these types of plants without having to make repairs regularly.

4. WINDOW SCREENS :-

This type of fencing can also be used as an alternative to window screens. Just like security fences wire mesh fencing provides a durable option for window screens. Wire mesh fencing is often used as an alternative to window screens on structures or buildings that require extra security. Window barns, storage facili-ties and stock rooms are often installed with wire mesh fencing. It prevents outsiders from entering the facility through the window.

5. HIGHWAY AND RAILWAY FENCING:-

Wire mesh fencing is also commonly used in industrial applications. One of the main industrial uses of this type of fencing is for highway and railway fencing. Wire mesh fencing is commonly used as sort of security fencing for highway and railways. It is used to prevent animal and people from trying to cross the rail tracks and highway roads. Wire mesh fencing for railway and highways are also often used to prevent and minimize damages on the tracks.

USE OF GEO-SYNTHETICS:-

- ⇒ For improving ground stabilization.
- ⇒ Pavement roads, parking bay, runways
- ⇒ Heavy duty pavements : ports and harbor
- ⇒ For railways
- ⇒ For erosion control
- ⇒ For retaining wall and bridge abutment
- ⇒ For building foundation improvements.