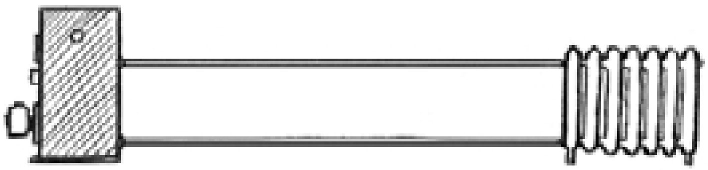
Secondary systems used in Europe.



Preface

Secondary systems are the parts of the heating systems with a lower pressure and temperature level, installed in buildings. A lower pressure and a lower temperature can be obtained with a shunt connection and a differential pressure control, (direct connected systems). The most commonly used system is, however, the connection through a heat exchanger, completely separating the two systems from each other, (indirect connected systems).

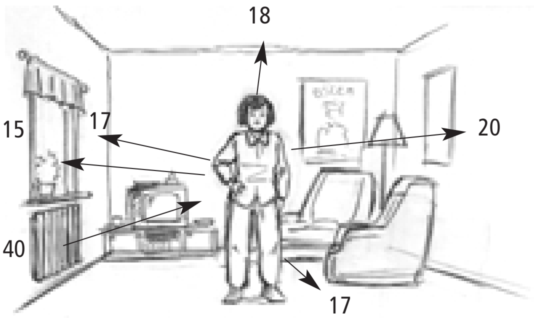
The secondary systems consist of three parts:

• production, boiler or heat exchanger

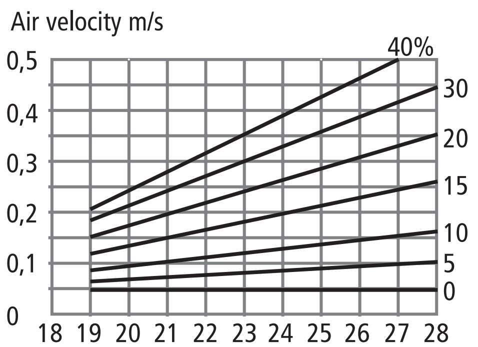
• distribution

• consumption

When speaking of district heating, the production unit is in fact only a transformation from one temperature- and pressure level to another, but regarding function, it is a production unit.



Heat radiates to surfaces with lower temperatures.
Fig. 3:1



Percent of unsatisfied persons as result of air temperature and air velocity.
Fig. 3:2


Different people react differently at the same temperature depending on age, activity, clothing etc.
Fig. 3:3

Comfort

The purpose of the heating system is to create environmental conditions in the building, comfortable for people to live in.

Generally an air temperature of 20-23 °C is considered acceptable, but there are also other factors influencing the comfort:

- the temperature of surrounding surfaces
- air movements, convection
- activity level
- clothing

The heat transfers which we can influence, towards and from a person in a room, are from radiation, convection and/or conduction. A minor share comes from breathing.

Heat transfer by radiation has the biggest influence. We are receiving heat from surfaces with a higher temperature than our skin, and we are emitting heat to surfaces with a lower temperature. The greater difference the larger the heat transfer.

Air with a lower temperature that flows over a surface removes heat from the surface. The higher velocity of the air-flow the more heat is removed. The greater the temperature difference the larger the heat flow.

Heat conduction requires direct contact, for instance when you are sitting on a cold chair, but it is normally short-lived as the chair is quickly warmed up by your body heat.

The result of the factors mentioned above and the temperature of the room air at a given point in a room, can be calculated. It is thus possible to determine in advance if a heating system will provide an acceptable comfort in a given room. Surface temperatures close to 20 °C on all surfaces in a room and air-flow velocities lower than 20 cm/s provides very good comfort.

Our activity level is also of great importance for how we are experiencing comfort. The temperature can be kept several degrees lower in a sports centre than in a living room.

We adapt to present conditions with our clothing.

Heat requirements.

The heat requirements in a building consist of:

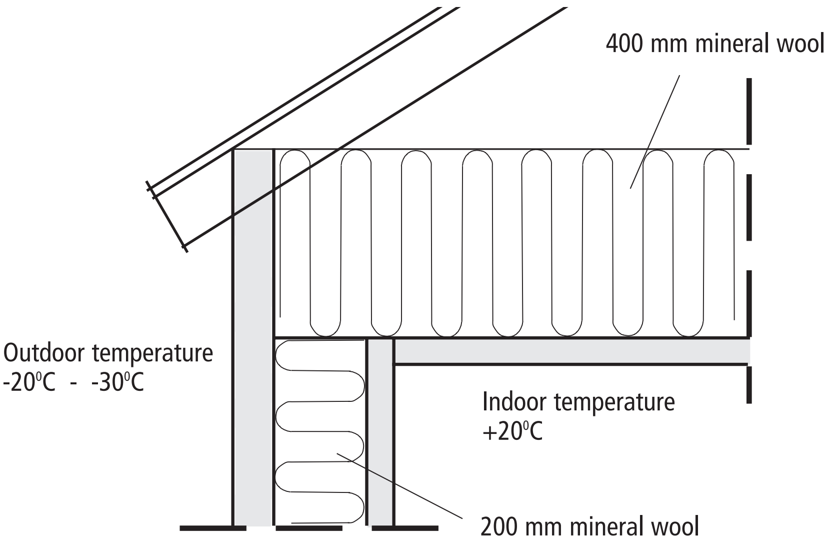
- transmission requirements
- ventilation
- domestic water

Transmission requirements.

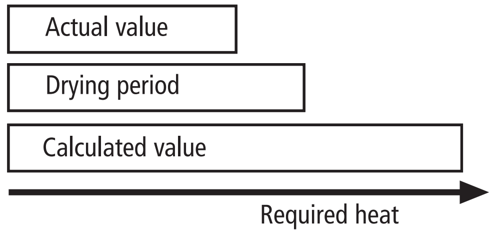
When designing a house, we can influence the transmission requirements, heat loss through walls, floors, roofs, windows and doors, based on differences between the outdoor and the indoor temperature.

In northern Europe, with long and cold winters, the standard requires 20-30 cm of high-quality insulation in the external walls and sealed triple glazing in the window units. Transmission requirements of 20 W/m^2 floor area are normal.

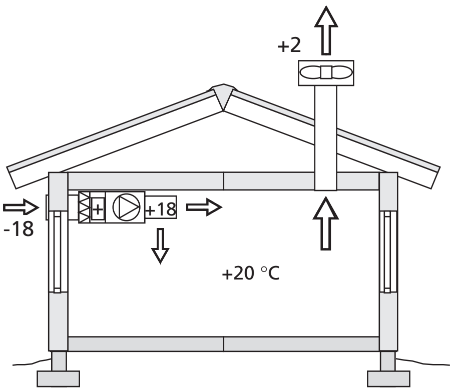
The calculations made to determine the transmisison requirements are based on data containing large safety margins. The real requirements therefore are far below the theoretically calculated ones. This is very obvious when you look at the flow temperature required and the temperature difference obtained when the heating plant is taken into operation. During the first year, the heat requirements will be about 30% more due to the drying out of the dampness of the building. Here therefore, part of the surplus will be needed.



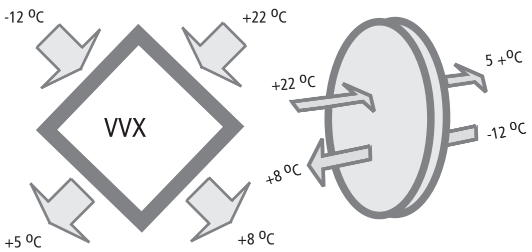
Standard insulation thicknesses in northern Europe.
Fig. 3:5



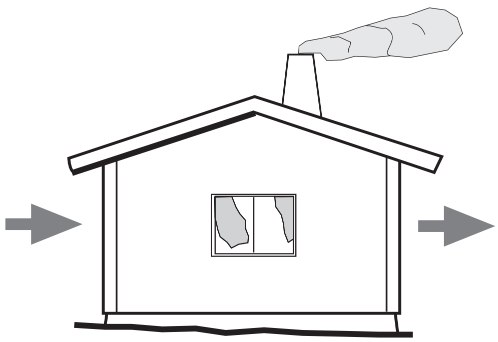
There are big differences between calculated and required heat.
Fig. 3:4



Ventilation system
Fig. 3:6



Systems for recovering heat
Fig. 3:7



Wind has a big influence on the air change in houses
Fig. 3:8

Ventilation.

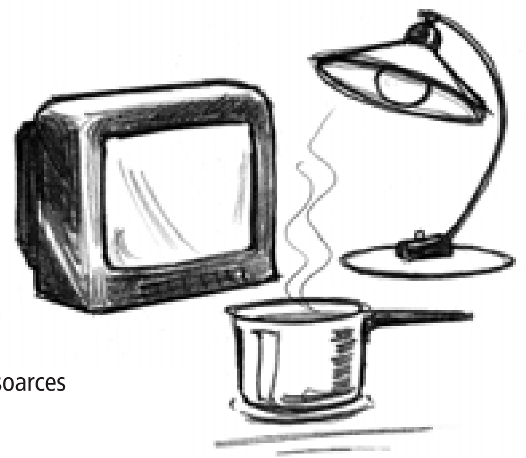
The purpose of ventilation is to remove pollutants (water vapour, odour, dust etc.). The air removed from a building must be replaced by cold outdoor air, heated to room temperature. Ventilation also requires heat and the colder the outdoor temperature, the more heat is required. In order to lower the heat consumption, the buildings are constructed as tightly sealed as possible in cold areas, and the ventilation is carried out so that the lowest air change is maintained, 0,5 change per hour. The warm air which is exhausted from a building contains much heat. Different devices are used to recover this heat, for example heat pumps and heat exchangers. It has turned out that a too few air change and too tightly sealed houses are causing problems with damp, condensation and mould.

Wind influence.

The wind has a great influence on the air changes and thus the heat consumption, in very tightly sealed houses. In many parts of Europe the wind is blowing more and stronger in the temperature range around 0 °C than at other temperatures when heat is required. Even moderate wind velocities of 10 m/s can double or treble the air changes, depending on how tightly sealed the house is built. As regards the heating system, the flow temperature must be raised considerably in order to keep the room temperature at the desired level.

Incidental heat gain from heat sources other than the heating system.

The irregular incidental heat gain from, people, the sun, cooking and electrical appliances is so great that ,it will cause over temperatures if no measures are taken. This is to much so that it is definitely profitable to equip, for example radiators with thermostatic valves in order to adjust the heat supply to present requirements. Furthermore the comfort level will increase owing to the more even temperature from the thermostatic valves.



There are lot of heat soarces in an apartment.
Fig. 3:9

	New buildings kWh/m² year	Old buildings kWh/m² year
Heating and ventilation	40 - 80	100 - 200*
Hot water	20 - 30	20 - 30
Common electricity	5 - 10	5
Electricity in dwelling	20 - 40	20 - 40

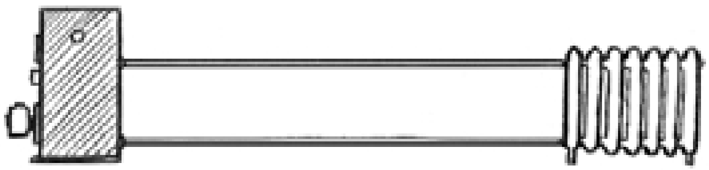
Energy consumption in dwellings.
* The lower values are for single houses and the higher for multi-story buildings.

Domestic hot water.

It was evident early on that it was not enough to just supply heat to the radiators. When in addition hot water could be offered to each apartment, the leakage was reduced and corrosion damage ceased in the heating system.

The consumption of domestic hot water forms a rather substantial part of the total heat requirements in a building, and that part becomes more substantial the better the house is insulated. After the discovery of the legionella bacteria and legionairés Desease, the control of domestic hot water temperature has become important. Stationary hot potable water should hold a temperature of at least 60 °C.

The pipes for domestic hot water are made of copper or of heat resistant plastic, for example PEX. The domestic water system in large buildings is equipped with a circulation pipe and a circulation pump so that domestic hot water always is available at all taps, without long delay s in delivery.



Production.

The production unit is the part of the system in which energy is transformed into heat (separate houses), or in which heat is transferred to the system (buildings connected to district heating)

There exist a lot of heat sources, for example:

• oil

• gas

• coal

• biodynamic fuels, wood, straw etc.

• solar heat

• heat pumps

• district heating

The three first-mentioned are the prevailing sources, while biodynamic fuels and heat pumps are continually increasing. Solar heat is marginal. From now on we are going to deal only with systems connected to district heating, in which the four first mentioned heat sources are prevailing.

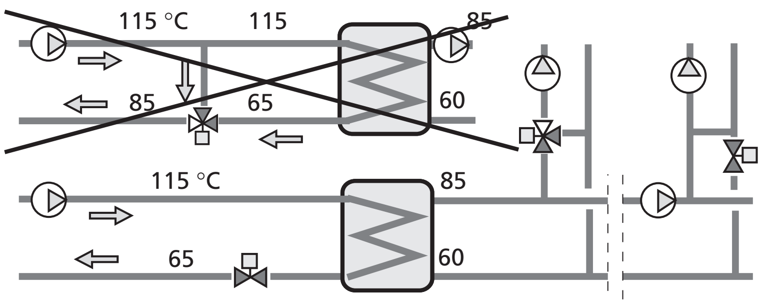
1. Control

The control is to guarantee that the required heat volume is available in the building and that the return temperature does not become too high.

2. Control valves

Only two-way valves are used on the primary side, and this generally applies to the secondary side as well. Three-way valves may be used if they are connected in a way that the flow towards the exchanger varies.

Control valves are sized according to the current flow and to the available pressure, independent of the pipe dimension in question.



Use two-way valves in district heating systems. In secondary systems use three-way valves only when there is no pump in the circuit from the heat exchanger.
Fig 3:10

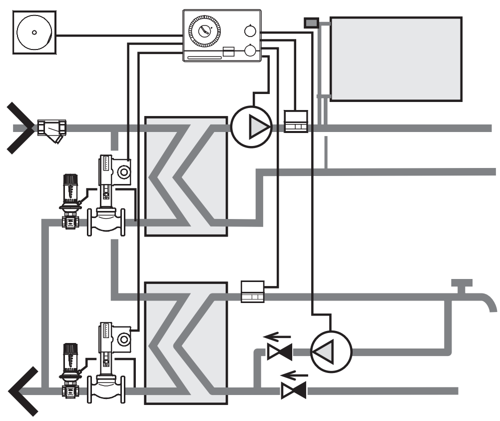
3. Temperature controller

The flow temperature to the radiators is controlled by a temperature controller according to the outdoor temperature. There is also a control possibility in the return temperature of the domestic hot water in most of the weather compensators.

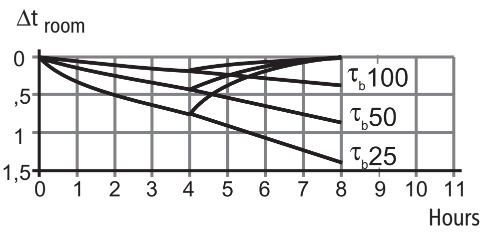
Should the domestic hot water be produced in a secondary connected water heater, the control of the temperature coming from the main heat exchanger will be made at the secondary connected water heater, at least when domestic hot water is produced.

Self-acting controls.

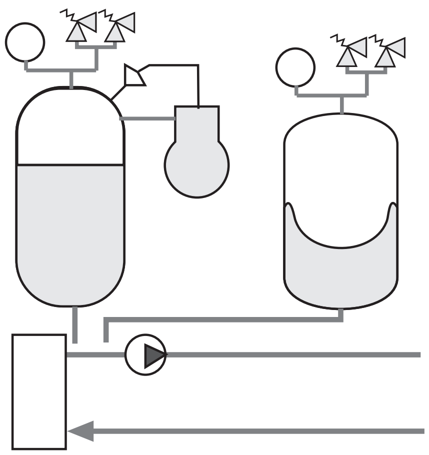
There are also self-acting controls for the control of the domestic water temperature.



Weather compensator controlling flow and return temperature according to outdoor temperature and domestic hot water temperature and return temperature.
Fig 3:11



Night set back does not pay.
Time constant, τ_b,100 = good apartment building.
Fig. 3:12



Closed expansion system
Fig. 3:13

4. Periodic set back of the flow temperature

Setting back the flow temperature during the night is to a great extent applied in order to reduce the heat consumption through a lowering of the room temperature. This despite the fact that it has been proved that on the whole there is no actual saving. Much longer set back periods are required than the normal 8 hours, minimum 3-4 days. After a temperature set back period, a great available effect is required in the production unit of the heating plant to raise the temperature to a normal level again. In a system with thermostatic valves, a reduced room temperature means that the heat authority disappears, the thermostatic valves open completely and the hydraulic balance disappears. To prevent this, the flow to each heater, radiator, is roughly pre-set so that a fair hydraulic balance is maintained even during these circumstances.

5. Expansion systems

Secondary systems, directly connected to a district heating network, do not need to be equipped with their own expansion system, if there is one in the network.

Other secondary systems are equipped with expansion systems. The conditions are the same as for the primary circuit.

6. Closed systems

Closed systems are for practical reasons the most commonly used. The pump is mounted in the flow pipe, and the static pressure has to correspond to the height of the pipe system.

7. Open systems

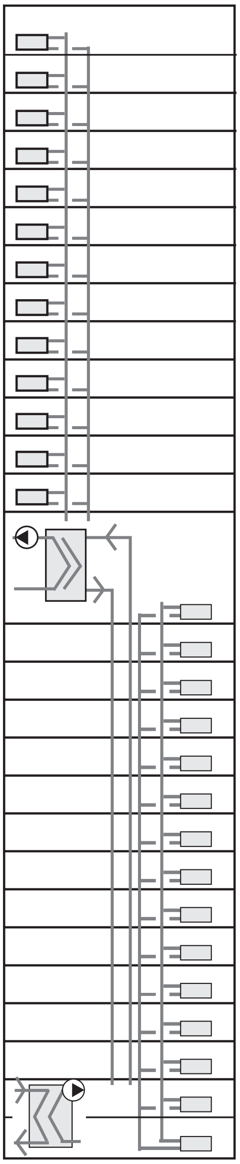
Open systems are less and less used even in smaller systems. The reason for this is problems with corrosion at the connection to the expansion tank, and to some extent the risk of freezing.

8. High-rise buildings

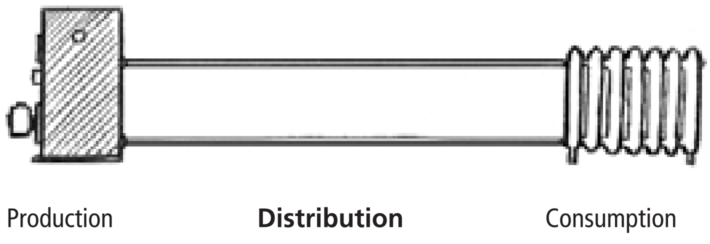
The heating system is divided vertically in high-rise buildings in order to prevent the static pressure from becoming higher than the maximum working pressure of any of the components, usually of the radiators. Note that this is working pressure, not test pressure.

In order to avoid the exposure of heat exchangers, expansion tanks, pumps, control valves etc. to high static pressures, a sub-station is placed on ground level for, let us say, the first 15 floors.

The sub-station for the floors 16-30 is placed on the 16th floor.



In high-rise buildings the heating system will be separated into high and low systems depending on the actual work load for the used components.
Fig. 3:14



Distribution

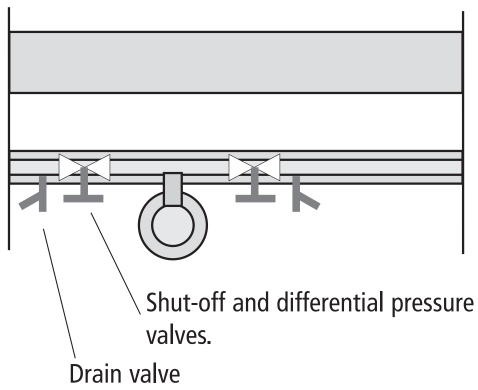
The distribution unit consists of circulation pumps, horizontal distribution pipes and risers.

1. Definitions

Horizontal distribution pipes distribute the water from the sub-station to other buildings and/or risers. Distribution pipes can be pre-insulated pipes or steel pipes lying in a passage in the cellar of the building.

The risers are vertical distribution pipes, distributing the water to the radiators on each floor.

A radiator circuit consists of pipes distributing the water from the riser to each radiator. The radiator circuit can be made for one or two-pipe systems.



Horizontal distribution pipe from ceiling in passage and branchings with valves.
Fig. 3:15

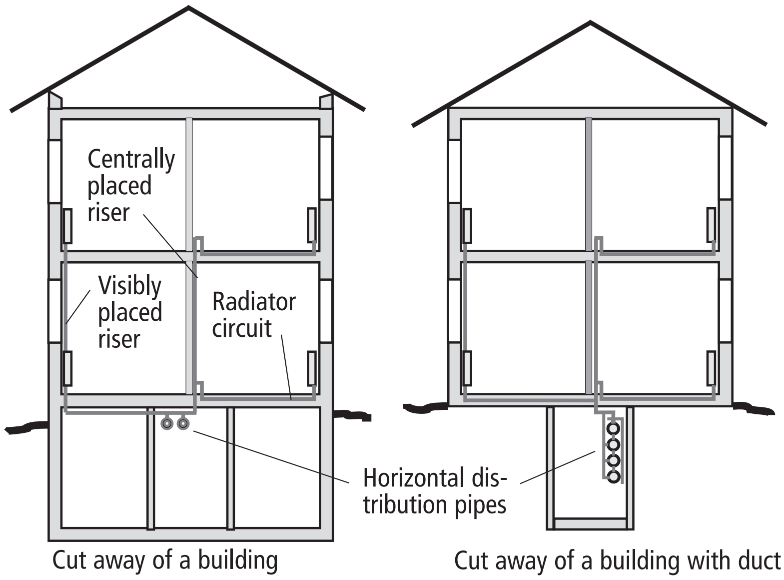


Fig. 3:15

2. Pipe material

Standard steel pipes are used for larger pipe dimensions, joined together through welding.

The connection to bigger valves and devices are made with flanges.

Smaller pipes are of threaded steel pipes with its dimensions adapted to standardized pipe threads.

Soft pipes delivered in coils of steel, copper or heat resisting plastic with a diffusion barrier, are used for the connection between riser and radiators. The joint is made with compression fittings of various types.

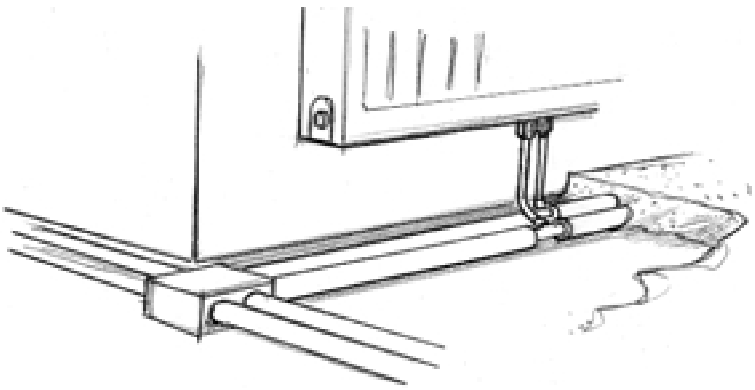
3. Piping

The distribution pipes can be laid as pre-insulated pipes, in the ground or under a building, or be hung from the ceiling in the cellar of the building.

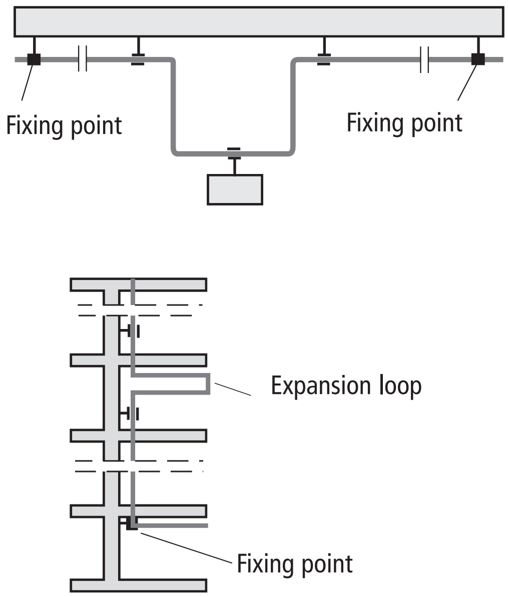
The risers are placed centrally, in shafts in the building, or at an outer wall, exposed or in shafts.

Soft pipes are laid insulated on the load-bearing system of joists and are covered with a layer of concrete.

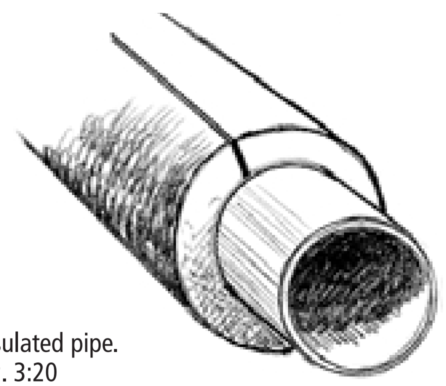
Soft pipes of steel, copper or plastic are, of smaller dimensions, used in heating systems.
Fig. 3:17



Insulated pipes which will be embedded in concrete.
Fig. 3:18



Expansion of pipes can easily be picked up by intelligent mounting of the pipes.
Fig. 3:19



Insulated pipe.
Fig. 3:20

4. Compensation for the linear expansion due to temperature variations

The linear expansion for steel pipes is about 0,12 mm/m pipe at 10 °C temperature change. Measures should be taken when it is a question of long exposed piping of steel or copper pipes.

The linear expansion is absorbed in special compensators, for example bellows which can expand or contract. An easier way would be to make an expansion loop on the pipeline or to move the pipeline sideways to obtain an expansion loop. It is important that the pipes can move towards the expansion unit, and that the branches are not blocked.

The pipes must be fastened so that they will not touch walls or other parts of the building, otherwise, any pipe movement may cause disturbing noises.

5. Insulation

All the pipes including those within a building are insulated to make the heat losses to the consumers radiators as small as possible. The radiators are to emit heat and the emitted heat volume is controlled by the thermostatic valves.

6. Flow

The flow in the distribution unit is going to vary in systems with thermostatic valves, in spite of the fact that the flow temperature is adjusted to the outdoor temperature. The reason for this is that the conditions vary from room to room in the building and the flow temperature must be adjusted to be able to hold the room temperature in the room which doesn´t receive any incidental heat. Less heat is required in rooms with incidental heat gain from various sources. In those cases the radiator thermostats reduce the heat transfer, i.e. the flow.

Incidental heat gain comes from people, the sun, cooking and electrical appliances and it is very unevenly spread throughout the building. Furthermore, the thermal mass in the building has to be considered.

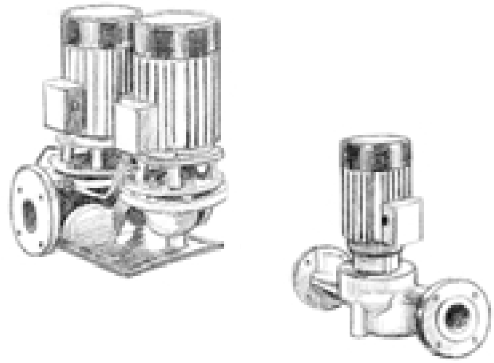
7. Pumps

The pumps on the secondary side are of two kinds:

- pumps with a dry motor
- pumps with a wet motor

In a pump with a dry motor, the motor and pump housing situated some distance from each other. The shaft connecting the motor and impeller is visible, and there is a sealing joint where the shaft enters the pump housing. The sealings, mechanical flat sealings, are nowadays very safe and tight, requiring practically no maintenance.

In a pump with a wet motor, the pump housing and motor are built together as one unit. The rotor of the motor is located in the system water, and a thin wall made of non metallic material separates the stator from the system water.



Pumps with dry motors.
Fig. 3:21

8. Pump control

The varying flow in the secondary system makes it beneficial to control the pump according to its pressure and varying flows.

The control can be made in accordance to several principles of function:

- constant pressure at the pump
- constant pressure at the last valve at the end of the system
- proportional pressure
- pressure control parallel to the pipe resistance

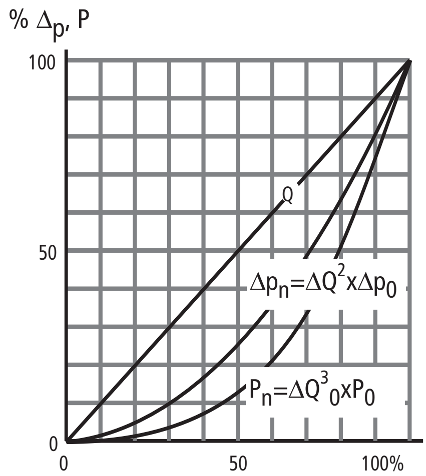
Constant pressure means that the pressure is not increasing when the flow is decreasing.

Proportional pressure means that the pressure decreases at decreasing flow along a straight line which, at the flow 0, is equal to half of the pressure at calculated flow.

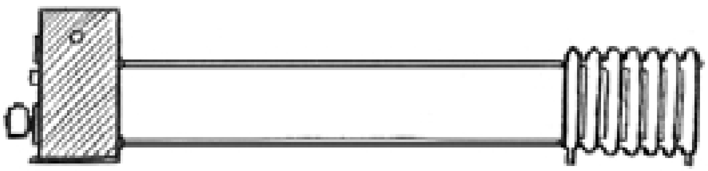
Pressure control parallel to the pipe resistance means that the pump pressure follows in accordance with the graph for the pipe resistance at decreasing flow, but only down to half of the calculated pressure.

The differential pressure controls can be integrated in to the wet pumps, and it is the pressure increase across the pump that is controlled. Frequency converters and separate pressure sensors can be used for all sizes of pumps.

Pump with wet motor
Fig. 3:22



The resistance varies by the square and the effect for the pump by the cubic of the flow change
Fig. 3:23



Consumption

The units emitting heat to the rooms are the heat consumers. They may be called heaters from the aspect of the rooms.

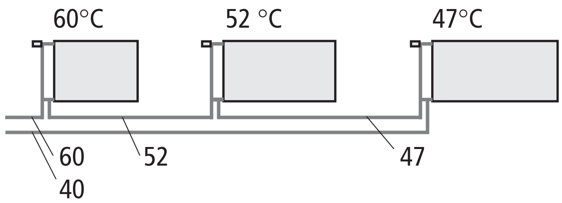
The most commonly used type of heaters are the radiators of pressed and welded steel. There are also radiators of cast iron, but they are seldom used, and finally there are convectors and convection radiators in different models.

Floor heating based on heat resistant plastic pipes has been used to a great extent during the past twenty years.

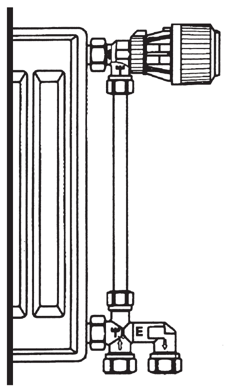
1. Radiator and convector systems

The connection of heaters can be made according to two principles:

- one-pipe systems
- two-pipe systems

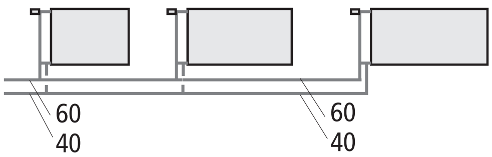


One-pipe system with temperature drop.
Fig. 3:25



Unit with thermostatic valve for connecting radiator to a one-pipe system.
Fig. 3:24

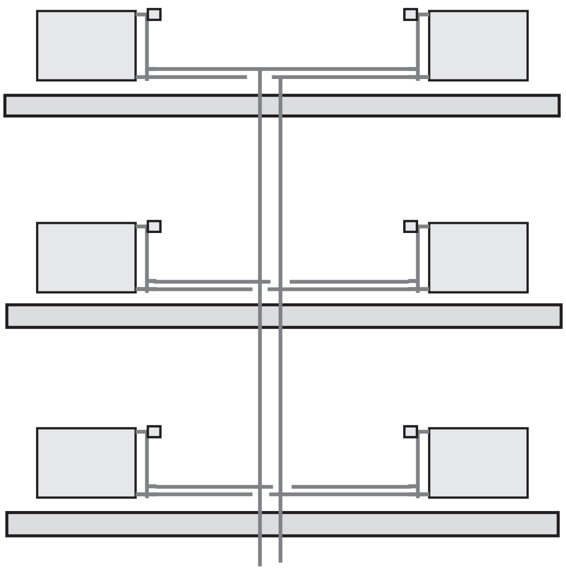
The one-pipe systems can for instance comprise one apartment. The heaters are equipped with special valves in which the distribution of the flow between heater and heating coil takes place. According to the requirement the flow to the heater is controlled with a thermostatic valve. The flow in the circuit is always constant and the circuit must be thoroughly insulated to prevent heat from being supplied to the room when there is no need. Soft copper pipes are the most commonly used pipe material, but soft thin-walled steel pipes and pipes of heat resisting plastic with a diffusion barrier are also being used. As a rule the pipes are fixed directly onto the insulation and embedded in concrete. The requirements for controlled reduced heat consumption have resulted in a reduced use of one-pipe systems, from about 15% five years ago to about 12% today.



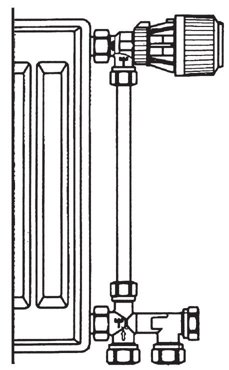
Two-pipe system with temperature drop.
Fig. 3:26

Two-pipe systems offer greater flexibility and more options regarding piping layout and efficient control of the room temperature. The heaters are equipped with special valves for the connection to flow and return with a thermostatic valve in the flow. From a centrally placed riser, the pipes can be laid parallel with T-branchings to each radiator or as a Tichelmann-coil (very seldom used in Europe), in order to provide the same available pressure for each heater.

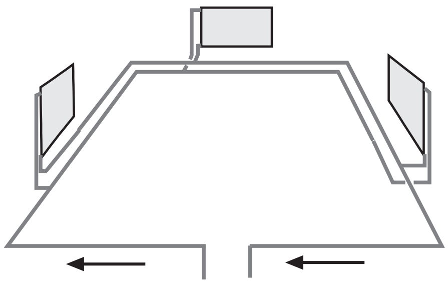
The piping can also be made with a separate flow and return pipe to each heater. The riser can be laid exposed on a wall with visible connecting pipes to a heater on each side of the riser, but this solution can cause disturbing noises between the floors.



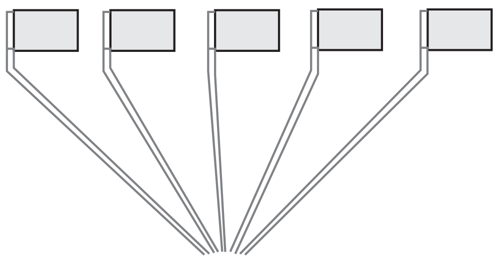
Risers on the outside walls.
Fig. 3:30



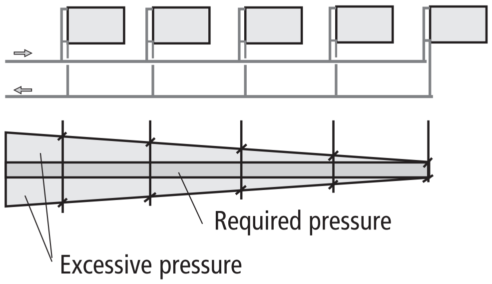
Unit with thermostatic valve for connecting radiator to a two-pipe system.
Fig.3:27



Tichelmann-coil.
Fig. 3:28



Separate flow and return pipe to each radiator.
Fig. 3:29



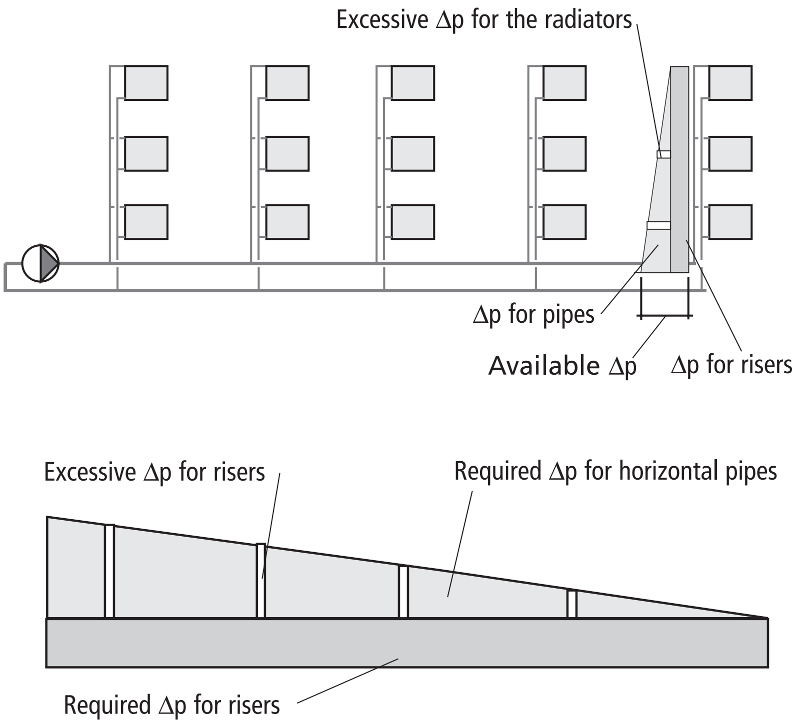
Pressure distribution in a two-pipe radiator circuit.
Fig. 3:31

2. Pressure distribution

Two-pipe systems cause different available pressures in various units of the system. The risers and the distribution pipes to which horizontal one-pipe systems are connected are also two-pipe systems and each one-pipe circuit has its own available pressure.

One-pipe systems have a constant flow, and a distribution of pressure and flow can therefore be made with manually adjustable valves, and a hydraulic balance can be obtained.

In two-pipe systems, with a control of the temperature in each room, the flow will vary and thereby also the available pressure, which in turn means that a pre-set adjustment will only function at full flow. At a decreasing flow the resistance reduces by the square of the flow change across the adjustment, and the exceeding differential pressure must be handled by the thermostatic valve or by the floor heating valve. Imbalance and disturbing noises may arise. Thermostatic valves should not have a higher differential pressure than 25 kPa.

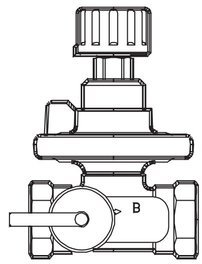


Pressure distribution in a two-pipe system.
Fig. 3:32

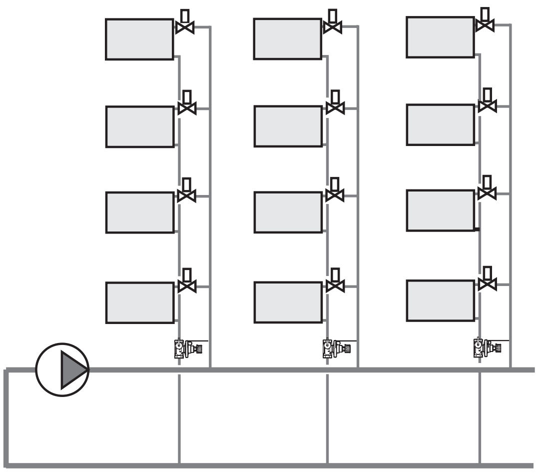
3. Differential pressure controls

In order to accommedate varying flows and pressures in a heating system, there are automatic adjusting valves differential pressure controls. Via impulse tubes they sense the pressure in the flow and return of the riser, and possible pressure changes are transferred via a diaphragm to a cone in the valve housing, and thus the differential pressure remains constant.

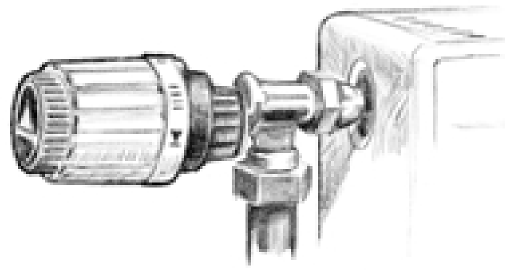
Thermostatic valves connected to a riser with differential pressure control will be exposed to virtually insignificant changes of the differential pressure, and above all they will never be exposed to a higher differential pressure than the one set on the differential pressure control.



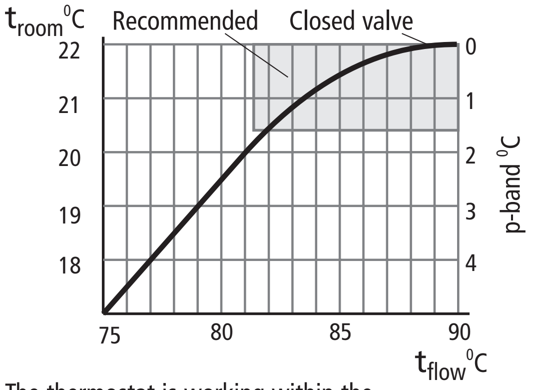
Differential pressure control.
Fig. 3:33



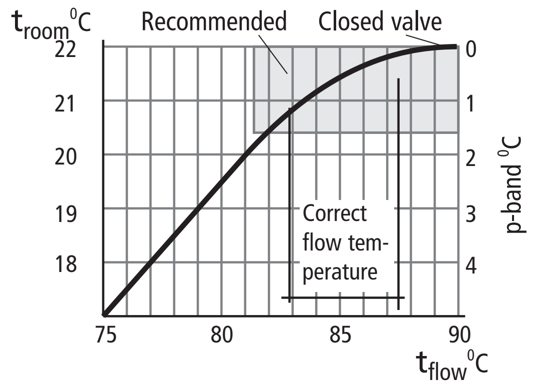
Differential pressure control on every riser.
Fig. 3:35



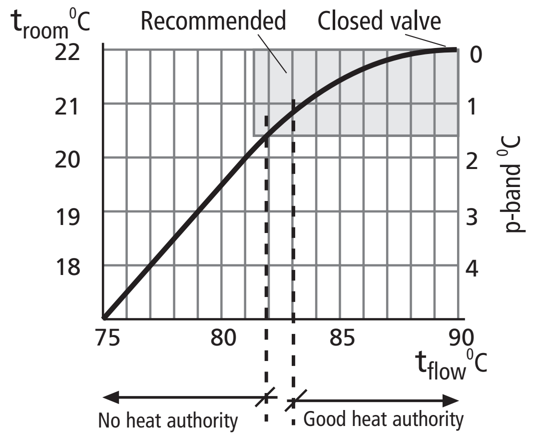
Thermostatic valves are generally used in most installations.
Fig. 3:34



The thermostat is working within the recommended area.
Fig. 3:36



The flow temperature is important for the functioning of the thermostat
Fig. 3:37



Good heat authority gives a small p-band and good use of the incidential heat gain.
Fig. 3:38

4. Control of the room temperature

In order to reduce the heat consumption, but nevertheless offer comfort, there are requirements or recommendations in most countries to use thermostatic valves on radiators and convectors as well as the corresponding control equipment for floor heating.

Thermostatic valves have to be mounted on each heater to give a good result. They are to have a heat authority larger than 1,0, which means that they are to have at least that heat amount available at the valve which is required to keep the temperature set on the thermostat. The thermostatic valves must also be able to sense the present room temperature.

5. Correct flow temperature

It is important that the room control has the right pre-conditions in order to work with a control of the temperature in each room:

- available pressure should be equal to or higher than required
- available heat amount should be equal to or larger than required

The mounting of differential pressure controls at the bottom of each riser and a control, if necessary an adjustment, of the available pressure at the riser located farthest away can manage the first item.

The available heat volume is adjusted by the flow temperature. If the flow temperature is raised, more heat is emitted from the heater, the room temperature increases a little, the thermostat reduces the flow and there will be a larger temperature difference and a larger amount of heat is available. The room control should have heat authority.

A higher flow temperature reduces the p-band for a thermostatic valve. The p-band is the temperature increase by the sensor, required to make the thermostatic valve pass from a nominal position to a closed valve. Thermostatic valves are tested at 2^{o}C p-band, but in practice the p-band is less than 1^{o}C and the thermostatic valve therefore reacts efficiently even to small temperature changes in the room.

At a too low flow temperature, the heater does not emit sufficient amount of heat. In these cases the thermostat opens the valve completely and the whole system gets unbalanced, unless a rough pre setting of the flow has been made.

6. Floor heating systems

Floor heating provides a very high comfort level. The whole floor area is warm and all the surrounding surfaces will obtain radiant heat which increases their temperature.

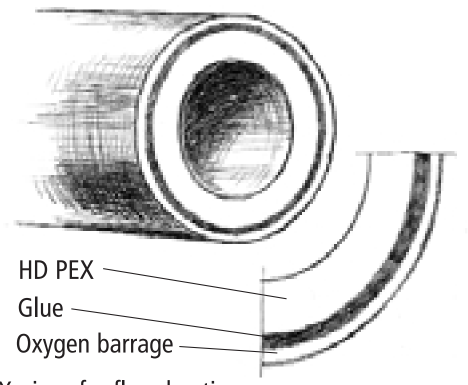
Modern floor heating systems are based upon light pipes of plastic, which can be manufactured and handled in substantial lengths. The most common pipe material is cross linked polyethylene, PEX, with an external diffusional barrier, which on the whole eliminates any penetration of oxygen through the pipe wall.

The coils emanate from centrally placed distributors. They can be laid according to three different methods:

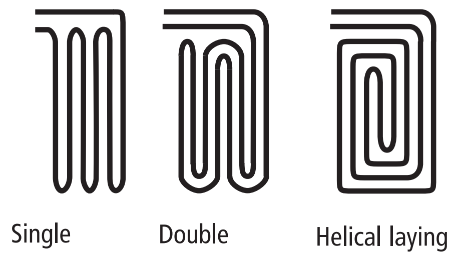
- single laying, which is the easiest way of laying
- double laying
- helical laying

The coils are cast into concrete, and there must always be an insulation under the coils in order to reduce the heat emission downwards. Each room should have its own coil to make it possible to control the heat supply to the room.

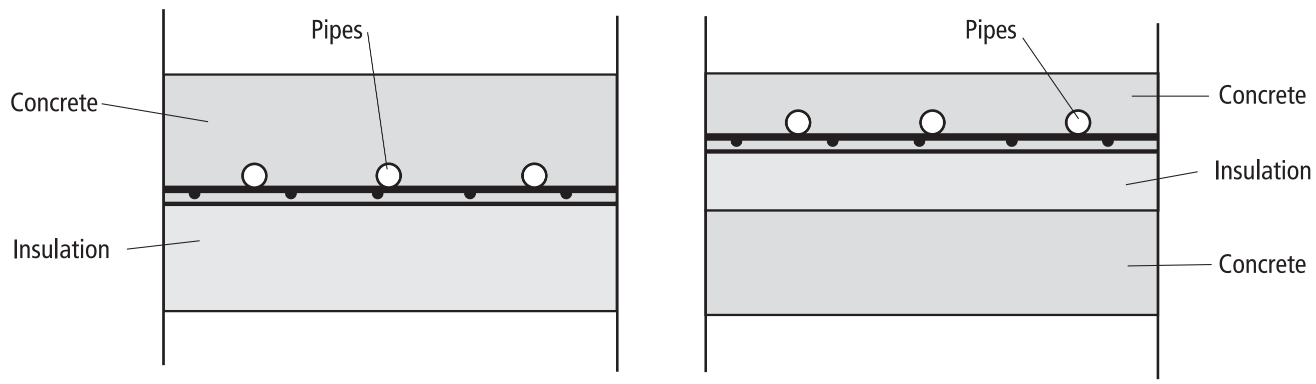
Floor heating emits, at a room temperature of 20°C, about 11 W/m² floor area and per °C temperature difference between the floor surface and the room air. The temperature of the floor surface should not exceed 27°C if you are going to stay on the floor for a long time. The required flow temperature is low, often not more than 40°C, and the temperature drop across the coils is calculated to be between 5 and 10°C.



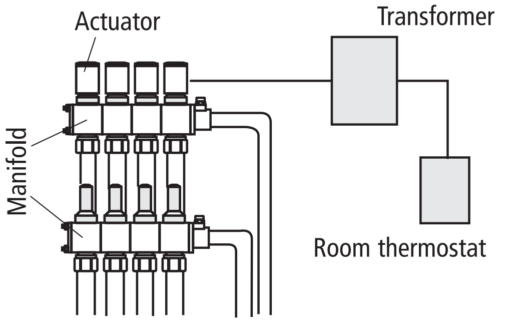
PEX-pipes for floor heating.
Fig. 3:39



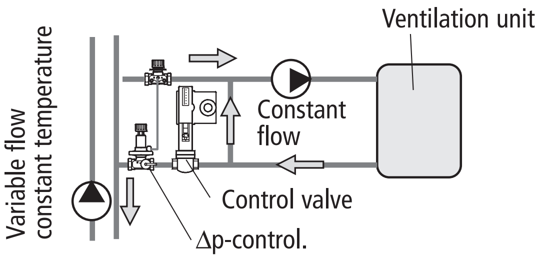
Different kinds of laying.
Fig. 3:40



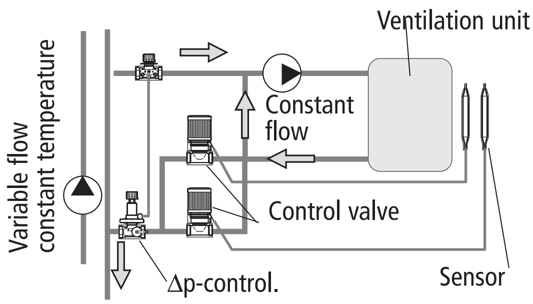
Floor heating in different floor constructions.
Fig. 3:41



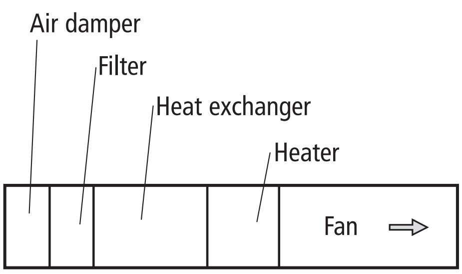
Room temperature will be controlled for every room.
Fig. 3:42



Shunt for ventilation unit with Δp-control.
Fig 3:43



Shunt for ventilation unit with Δp-control and self-acting control valves
Fig. 3:44



Principle for supply air unit.
Fig. 3:45

7. Control

The control of the room temperature is made with an electric thermostat, opening and closing a control valve via a thermo-hydraulic motor. The electric thermostat contains an electric resistance, which is activated when the thermostat opens the control valve. The resistance emits heat in the thermostat, which after a while, believes that the room temperature has increased and closes the control valve. This type of on-off control has proved to be very efficient in the use with floor heating. The type of circuit layout chosen is of little or no significance.

8. Ventilation

In the colder parts of Europe, mechanical exhaust air systems (a fan exhausting air out of the building), is the most common in dwellings. In the southern parts, natural ventilation is applied. Offices and industrial buildings have other requirements, and in these buildings both supply and exhaust air are mechanized. The supply air volumes in these systems are also considerably larger and require a pre-heating of the supply air to obtain an acceptable comfort.

The supply air is treated in special units before being distributed to the different rooms through a ducted system. Special inlet terminal devices are used to diffuse the supply air into the rooms without creating draught or noise.

The supply air devices consist of a filter unit for cleaning the air. Thereafter the air is heated to a little below the room air temperature and then it passes the exhaust fan of the unit. Beside these functions, the devices can be used to cool or humidify the air.

The control of the temperature of the supply air is made by a shunt circuit, containing a control valve and a circulation pump. The control valve supplies the required heat and a control station with a sensor in the supply air duct ensures that the correct temperature is obtained. The control can also be made by self-acting controls.

Air has a low heat capacity. You can change its temperature rapidly, and that is why the control must be stable. Oscillations in the control systems are devastating. The distance between battery and shunt circuit should be the shortest possible. A change of the temperature in the air supply duct must result in a changed temperature of the radiator as quickly as possible. For the same reasons, differential pressure controls are mounted to keep a constant pressure across the control valves.

The flow in the battery circuit should be constant, which can be accomplished by adjustment of a valve or with a pressure controlled circulation pump.