TREES **Training for Renovated Energy Efficient Social housing**

Intelligent Energy Europe

Intelligent Energy -Europe programme, contract n° EIE/05/110/SI2.420021

Section 1 Techniques

1.6 Heating equipment

Author : Tamas CSOKNYAI (BUTE)
Reviewer : Uli NEUMANN (CESR)

Workpackage 4 Adaptation of the material
Deliverable D3: Final version of Educational material

Partners

Armines/Ecole Nationale Superieure des Mines de Paris – CEP, France
Budapest University of Technology and Economics (BUTE), Hungary
EnerMa, Sweden
DHV, The Netherlands
SINTEF, Norway
University of Kassel, Center for Environmental Systems Research (CESR), Germany

Contents

1. Introduction

Heating installations consist of heat producing systems (heat sources), transporting networks and heat emitters.

The most common system is central heating that supplies heat for numerous rooms produced in a common unit. The heat-carrying agent can be warm water, steam or warm air. According to the type of agent central heating systems are classify to: warm water, vapour and warm air heating systems.

1.1 Warm water heating systems

Advantages:

- Heat-carrying agent is available in unlimited quantity,
- Heat-carrying agent operation temperature is in respectable limits,
- Heat capacity of water is high, thus small amount of transported medium is enough,
- Great operational reliability,
- Good contolability (central equithermic, by thermostatic valves on heating units)

Disadvantages:

- High thermal persistence (long period of heating up and cooling down),
- Relatively high capital cost.

Water heating systems depend on the water temperature. They are classified to: warm water systems with temperature up to 110 °C (water temperature obviously does not exceed 95 °C) and hot water heating systems with temperature over 110 °C.

Warm water heating systems are the most spread used for residential, public, and administrative buildings. Hot water systems are applied especially for industrial halls heating.

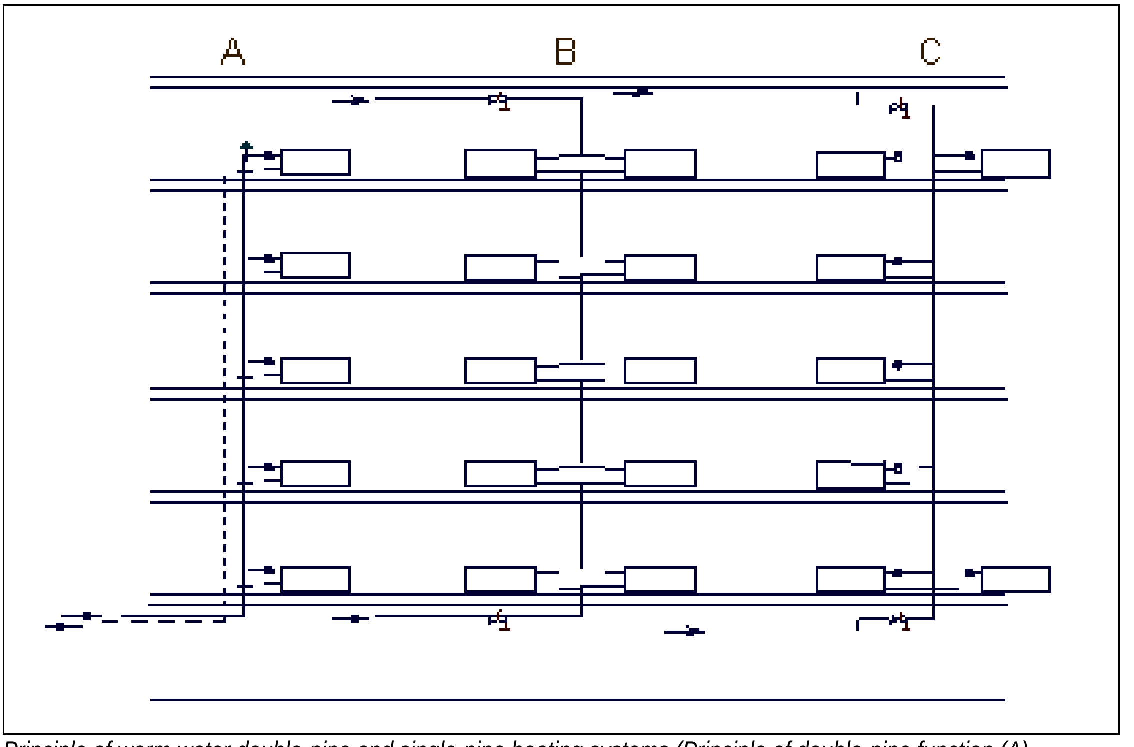
Heating water circulation according to manner heating systems we can classify to:

- Gravity water circulation heating systems and
- Forced water circulation heating systems (so called pumped recycle systems).

Gravity warm water circulation heating systems were used for smaller buildings. Today they are used only exceptionally.

Water heating systems according to dependence from heat-carrying agent distribution systems are classified to:

- Double-pipe heating systems
- Single-pipe heating systems

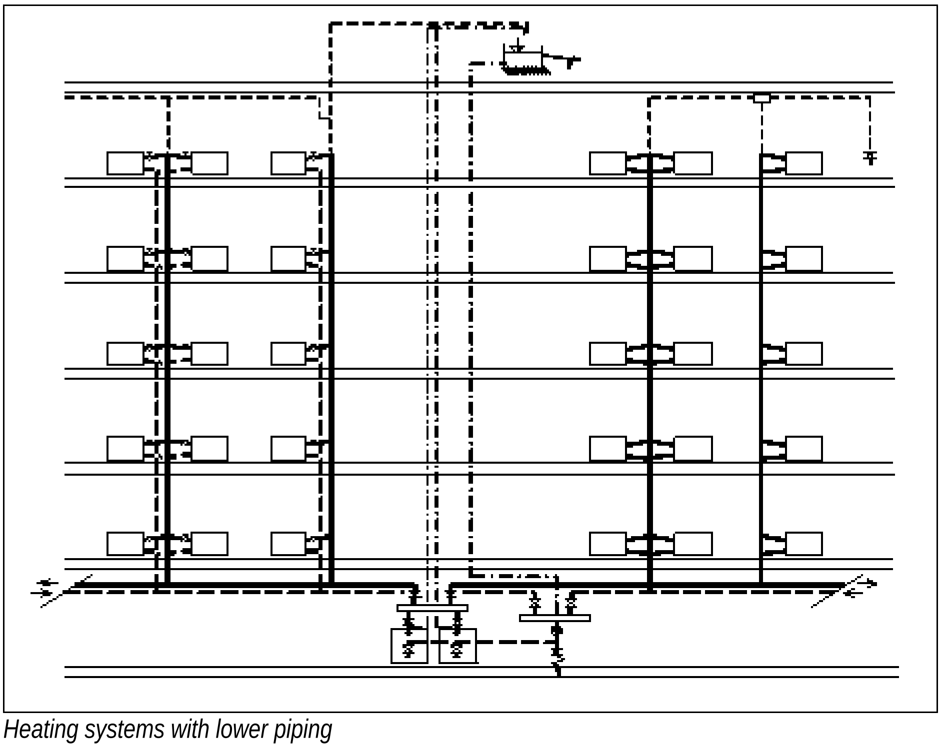


Principle of warm water double-pipe and single-pipe heating systems (Principle of double-pipe function (A) and single-pipe overflow (B) and by-pass (C) heating systems)

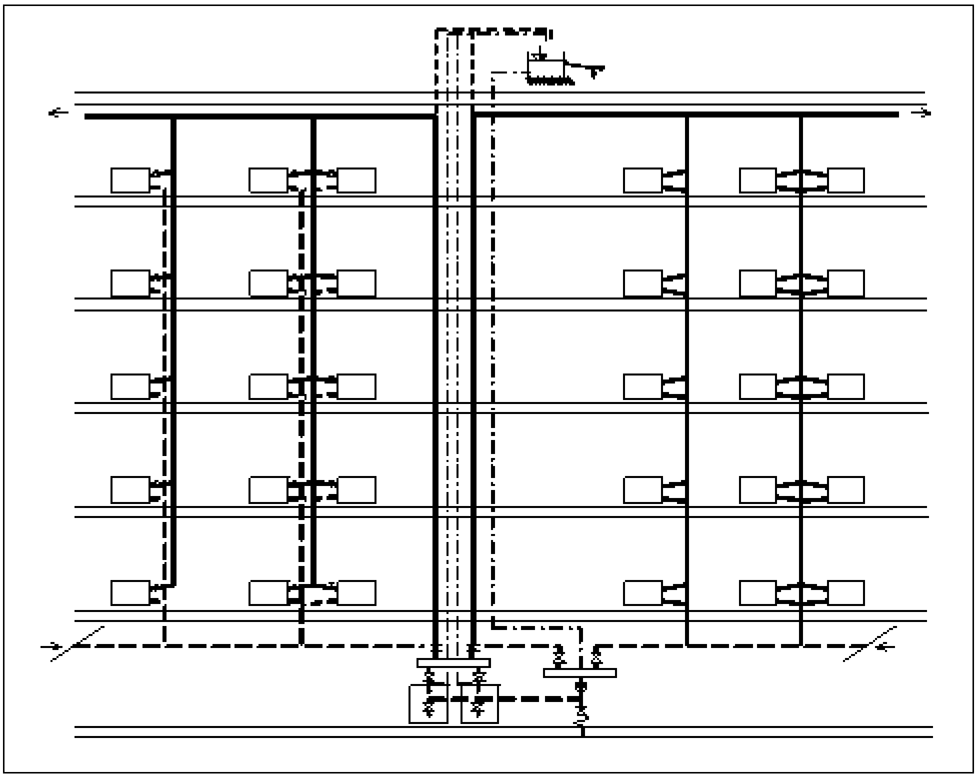
Heating systems according to horizontal water supply piping can be classified to:

- Heating systems with lower distribution piping
- Heating systems with upper distribution piping

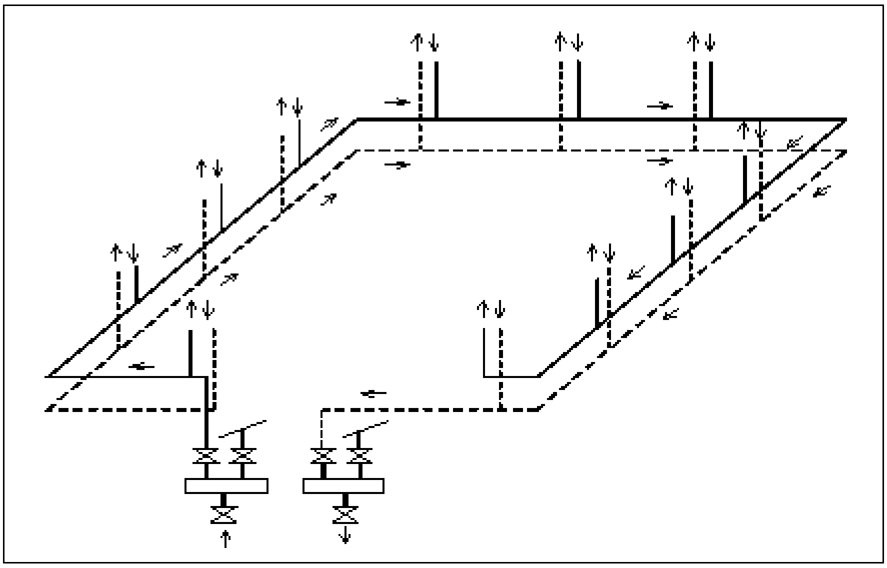
An optimal solution for a balanced double pipe systems is the so called Tichelmann´s two-piping horizontal distribution system.



Heating systems with lower piping



Heating systems with upper piping



Heating systems with Tichelmann piping

1.2 Steam heating systems

Steam heating systems have following advantages and disadvantages:

Advantages:

- Small thermal persistence, short period of heating up,
- Negligible danger of freezing,

- Capital costs are lower than that of warm water heating.

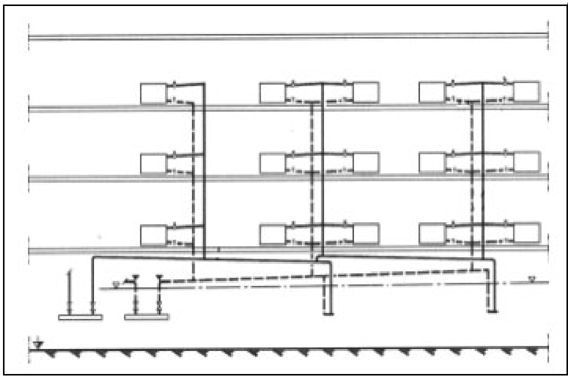
Disadvantages:
- Central control difficult, from this reason uneconomical operation,
- High surface temperature,
- Danger of corrosion.

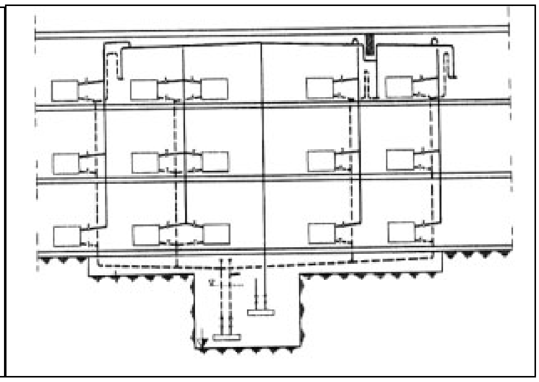
Steam (vapour) as calorific medium applies today mainly in industrial buildings. Vapour heating systems can be classified according to operation vapour pressure as follows:

- Low-pressure (steam overpressure < $0{,}5.10^5$ Pa)
- High-pressure (steam overpressure > $0{,}5.10^5$ Pa),
- Under pressured (vacuum) steam heating systems (steam absolute pressure < $1{,}0.10^5$ Pa).

Low-pressure heating systems are the most commonly used. Steam heating systems can be classified according to the position of horizontal steam supply piping as follows:

- Heating systems with lower distribution piping
- Heating systems with upper distribution piping


Heating systems with lower piping


Heating systems with upper piping

1.3 Air heating

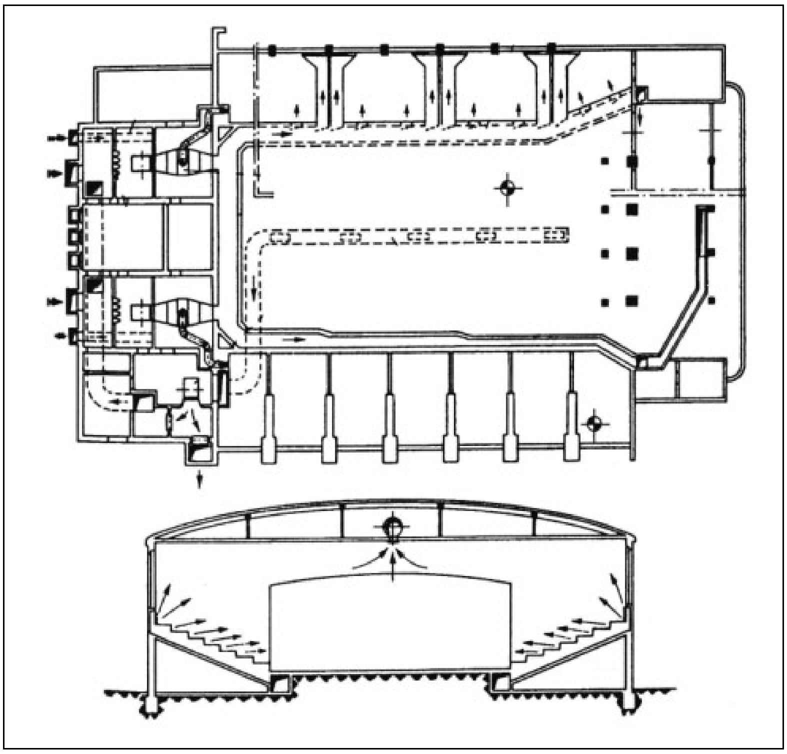
In an air heating system warm air is conveyed into the room. The air is heated up to the required temperature in an air heating unit. This unit can be located in central room (room for ventilation and air conditionning) or eventually in the heated room itself.

Advantages of air heating systems:
- Operational reliability,
- Low thermal persistence,
- Low capital cost,
- They can be used also for room ventilation.

Disadvantages of air heating systems:
- Dust turbulence owing to the air flow,
- Radiation component of heat exchange missing,
- Uneven temperature distribution, high vertical temperature gradient.

Air heating systems can work with:

- Recirculated air
- Mixture of fresh and recirculated air
- Fresh air.



Air heating systems are the most frequently used for heating of halls. Because of their small thermal persistence they are suitable for industrial halls, storage houses, parking houses, sport halls, exhibition halls and similar large rooms with intermittent heating.

However in the recent years air heating has become popular in a new function: in passive houses the ultra-low energy level can only be reached by using balanced ventilation with heat recovery. These systems make it possible to leave away conventional heating system. The necessary heat input can be provided by air heating connected to the heat recovery unit.

In many cases air heating is combined with conventional heating, influencing both the radiating and the air temperature at the same time. In periods when the room is unoccupied the air heating can be turned off and the conventional heating temperates the room. It is an energy saving solution.

Energy efficiency of air heating can be improved the following ways:

- recirculated air
- balanced ventilation with heat recovery
- efficient control

For more details see section *1.3 Ventilation*.

2. Transfer of heat into the heated space

Heat transfer into the heated rooms is performed by:

- Convection,
- Radiation.

In case of air heating the heat is transferred by convection, but in the case of some other type of heat emitters (convectors, some types of radiators and heating registers) the share of convection is dominant.

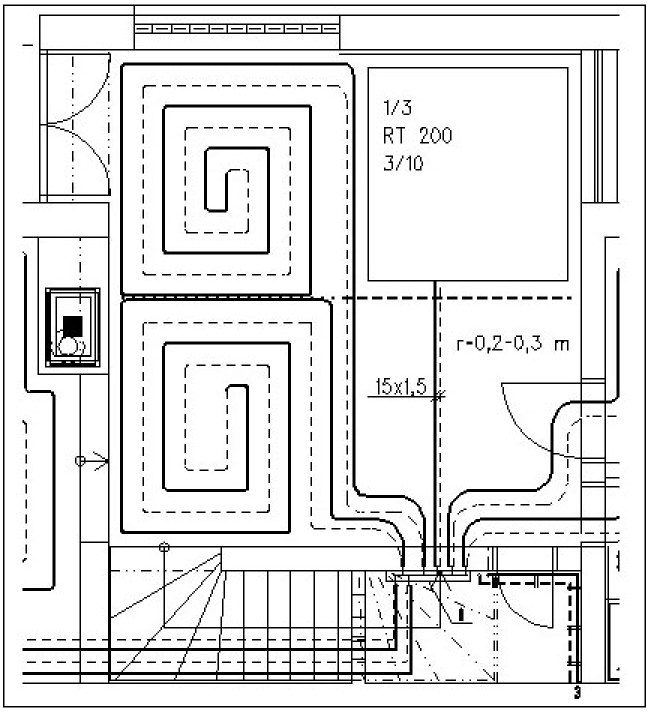
Heat transfer by radiation, or mainly by radiation is performed at the following heating systems:

- Large panel heating, thermo active heating systems
  - Floor heating
  - Ceiling heating
  - Wall heating
- Overall heating by hanged radiant panels,
- Local heating by hanged radiant panels,
- Heating by dark and light infrared irradiators.

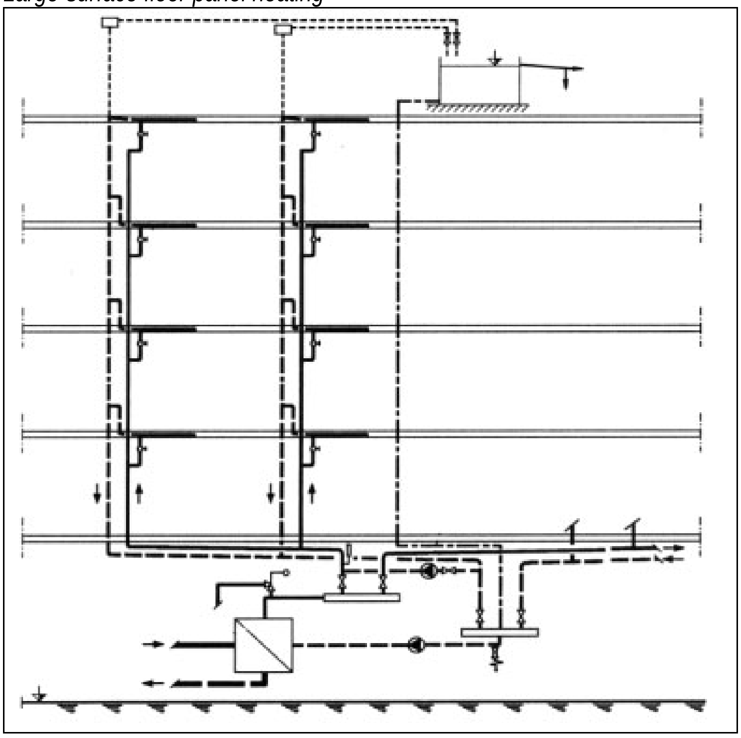
The above classification shows that the heat emitter can be an integrated part of the building construction or it can be a structurally independent part.
Essential difference between individual systems of radiant heating is not only the different structural design but also the surface temperature, the specific output and the used heat-carrying agent.

Used area:		Area surface temperature θ_p (°C)							
		25	30	35	40	45	50	55	60
Ceiling	q (W/m^2)			126	165	208			
Flooring	q (W/m^2)	64	120						
Wall	q (W/m^2)						352	422	491

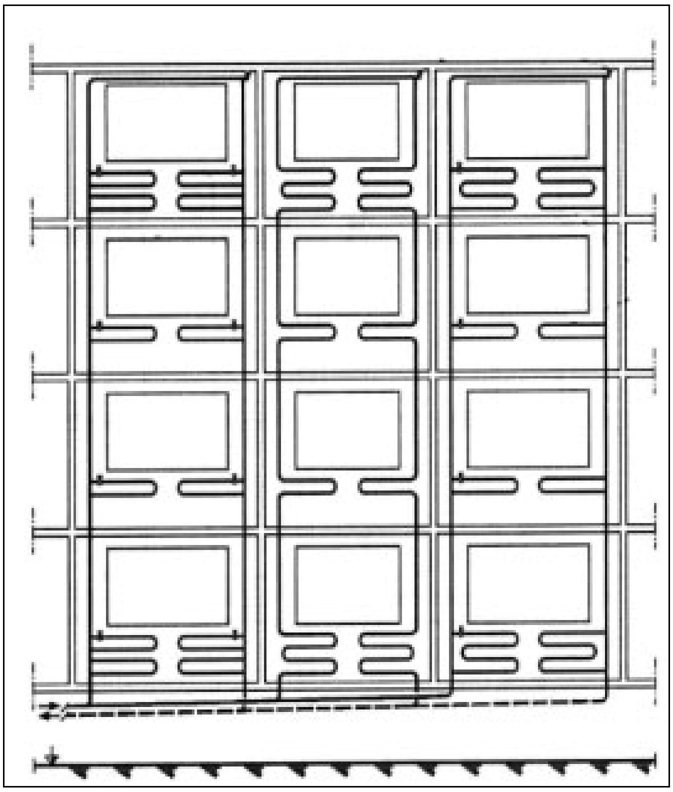
Table - Specific heat outputs q of large panel heating systems



Large-surface floor panel heating



Large-surface ceiling panel heating



Large-surface wall panel heating

Heating emitters using mainly convection:

- Convectors
- Heating pipes in floor channels

Conventional radiators use radiation and convection at the same tyme, the proportion depends on the shape of the heat emitter.

3. Heat production

3.1 Conventional boilers and boiler rooms

A boiler room can be in an independent building or a separate room in the heated building. The heat produced by the one or more boilers in the room is supplied for the heating system, domestic hot water production, air-conditionning system and eventually for technology purposes (e.g. cooking, sterilization, dehydrating). Beside boilers additional equipments are located in the boiler rooms in order to ensure the optimal operation. The geometry and the architectural requirements depend on the fuel used, the installed heating power, the used boiler type and the heating agent.

Classification of the boiler rooms according to the used fuel:

- Solid fuel,
- Gas fuel,
- Liquid fuel.

According to heat carrier boilers can be classified as:

- Warm water – with water temperature up to 115 °C
- Hot water – with water temperature above 115 °C

- Steam – low-pressure, medium-pressure

Boiler rooms according to operating pressure can be classified as:
- Low pressure: warm water to 115 °C,
  Steam to 0,07 MPa
- Medium pressure: hot water > 115 °C,
  Steam with an overpressure > 0,07 MPa

Boiler rooms should be equipped with safety, measurement and control instruments. Every boiler or hot water heater should be equipped with:
- Safety devices according to national standards.
- Operating control units of water temperature or steam pressure.

The economy of boiler operation depends on different actors, e.g. combustion fuel type quality and the quality of the combustion process. Physical properties of dfferent fuel types are listed in the following table. The main requirement of an efficient combustion process is the availability of air. Another important indicator of the combustion process efficiency is the CO_{2max} concentration in the flue gas (see below table).

Basic parameters of fuels:

Fuel Characteristics	Natural Gas	Propane Butane	Heating Oil EP	Coke	Black Coal	Brown Coal
Density/specific gravity (kg/m^3,)	0,72	2,02	860	650	850	600
Specific thermal capacity-c_p (J/kg.K)	2497	1584		1100	1260	980
Calorific value **(MJ/m^3, MJ/kg*)	35,8	92,0	42,01*	27,0*	28,1*	16,0*
Required combustion air (m^3/m^3), (m^3/kg)*	9,53	28,3	10,5	13,0*	12,1*	14,0*

* EP – low sulphur oil
** Informative calorific values

Informative values of CO_{2max} for different fuels

Fuel Characteristics	Natural gas	Propane Butane	Heating Oil EP	Coke	Black Coal	Brown Coal
CO_{2max}	12,0-12,5	13,8-14,1	15,5-15,9	20,0-20,3	18,5-19,5	18,5-20,5

Informative values of air abundance in function of combustion type

Combustion type	Grill (Solid fuel)	Oil pressure burner	Gas burner	
			Atmospheric	Pressure
Excessive air	1,3-1,5	1,01-1,15	1,10-1,20	1,01-1,10

3.2 Gas boilers

Gas fuel boilers are the most common for heating and hot water heating because of their high efficiency, good adjustability and relative low environmental impacts. In gas boiler rooms appliances must fulfill requirements of technical standards, codes and notices. The local gas supplier determines how to connect the building to the public gas distribution system, the main requirements of the location of the gas appliances, the type and location of the gas meter.

The requirements of the location, geometry and the the safety equipment of boiler rooms depend on the size and the regulations of the country. Smaller boilers don't require a separate room, but there are restrictions on the positionning and the installation. Rooms with larger heating power are recommended to be located on the highest floor, if the boiler room is in the building. Prescribed safety precautions should be performed if the boiler room is located elsewhere. Very large boiler rooms should be located in a separate building, except restricted cases of renovations. The concrete requirements depend on the categories prescribed by the national regulations.

Prescriptions on the air supply and the removal of flue gas (chimneys) are also specified in the national regulations. Dispositional solution of a gas boiler house is on the figure.

The efficiency of a boiler is influenced by the losses relating to the combustion process and to the heat distribution. New boiler constructions make it possible to decrease the temperature of the outgoing flue gas significantly resulting in a significant decrease of heat losses.

3.2.1 Classification of gas boilers

Flue temperatures of gas boiler different types:
- Classical gas boilers: > 200 °C
- Advanced gas boilers: 160 – 180 °C
- Low-temperature boilers: 110 – 130 °C
- Condensing boilers: < 60 °C

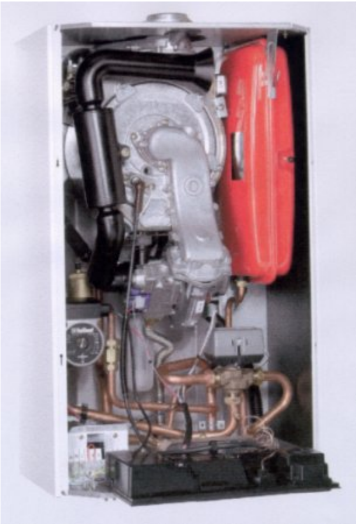
3.2.2 Ventilation of boiler rooms

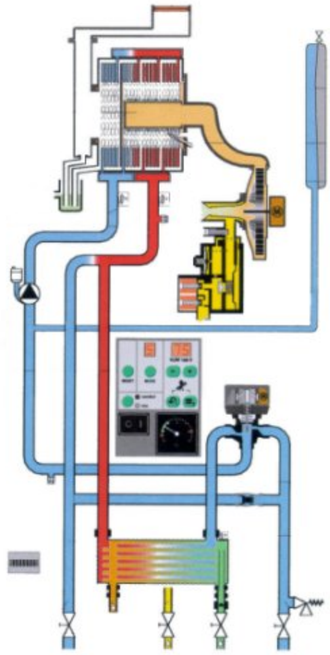
The combustion process produces heat and flue gas. Oxygen O_2 (respectively air) presence is a requirement of the oxidation process. During operation boiler rooms should be ventilated by an appropriate ventilation device for a continuous assurance of combustion air and the elimination of harmful particles. This device should fulfill the following requirements:

- To ensure the prescribed air change rate in all operational regimes to remove harmful components,
- To supply sufficient air required for the proper fuel combustion in boilers.

Boiler room ventilation can be natural, forced, or combined. Ventilation manner depends on the heating power of the boilers and local conditions. In smaller solid fuel boiler rooms natural ventilation is recommended, while in larger refined fuel boiler rooms forced or combined ventilation is preferred.

3.2.3 Condensing boilers





The scheme of a condensing boiler. It is a complete unit, consisting of a heat exchanger (below), pump, control unit, fan, combustion chamber and flue in closed system (marked with yellow), closed expansion tank (up, to the right, in blue and grey).

In the case of traditional appliances, together with other combustion products vapour departs to the environment, through the chimney. The presence of vapour is harmful from several points of view:

- vapour transfers latent heat energy out of the system;
- if condenses in the chimney (in the case of cooling down of the combustion product) vapour reacts with carbon dioxide and sulphur dioxide, to form acid whereby chimney corrosion is caused;
- in order to avoid condensing of the vapour - and to provide enough buoyancy - the combustion products have to leave the chimney at a high temperature, carrying out sensible heat.

Boiler efficiency can considerably improved (using formal equation over 100 % can be calculated) by cooling down the combustion gases below the dew point temperature. In such a way further sensible, and the latent, heat can be utilised.

In this case the material of the boiler must be corrosion free. Due to the lack of enough temperature difference (between the air and the outgoing combustion gases) the buoyancy is very small, thus air supply must be provided by a fan. Boilers that fulfil these criteria are the so called condensing boilers.

Above the better energy efficiency the condensing boilers are much less harmful to the environment than conventional boilers because of the much less pollution content of the flue gas.

3.3 Heating with biomass, wooden-chip boilers

Nowadays a new generation of solid fuel boilers are becoming popular again, namely the biomass/wooden fired boilers. The popularity can be explained by two reasons. First, new wood-combustion boilers had been developed with efficiency and low pollution emission. Second, wood/biomass is a renewable energy source, because the emission of CO_2 during firing is equal to the quantity of CO_2 decomposed during the lifetime of the original plant. Modern biomass boilers are applied in different sizes: from small units used in single family houses to large industrial boilers used in power plants.

From the point of view of heating biomass can be divided into three subgroups:

- firewood,
- pellets, wooden chips,
- grain and agricultural by-products.

3.3.1 Firewood

Heating with firewood is a traditional way of heating, in rural areas it is still in use in ordinary stoves. However, traditional stoves don't meet the present technical and environmental requirements, because the origin of most of the firewood is questionable and the efficiency of the stoves is usually poor. In order to fulfil the requirement of sustainability firewood has to be harvested from a forest managed in a sustainable way.

Wood has to be dried before burning. Therefore soft wood has to be stored for at least one year, hard wood for two years in a dry, ventilated space. It is certainly a disadvantage of wood compared to agricultural by-products, pellet and bio-briquette. Wood has to be burned under 25% moisture content. The lower the moisture content is, the efficiency will be higher. If the wood is wet pitch can be expected that may stick to the chimney wall. Pitch is a flammable material and can be dangerous. Furthermore it decreases the expected lifetime of the appliances.

In domestic boilers the length of fire logs should be less than 15 cm, because larger pieces have lower surface-to-volume ratio resulting in longer burning process and higher pollution emission.

3.3.2 Gasification process

Biomass materials depending on their type have significant volatile oil content. During the burning process at 250-300 ^{o}C the volatile oils are released. Therefore, the modern biomass boilers contain two burning chambers: in the first chamber the gasification process takes place. This is called primary burning. In the second chamber (afterburner) the released gases are burned. The most difficultly flammable components are burned at 1100 ^{o}C. The leaving blue flame reminds to gas-flame. This process ensures the burning of all components, high efficiency and low pollution emission. The remaining by-products of the perfect burning process are fine ashes.

3.3.3Control of boilers with wood firing

The main disadvantage of traditional stoves with wood firing is the lack of control: the heat output cannot be controlled; the stoves always work on high power. It can make difficult to maintain the requested indoor air temperature especially in mid-season and it decreases the efficiency significantly.
In modern wood gasifying boilers the control can be established in two ways:

- by control of the air volume entering into the burning chamber,
- by application of buffer tanks.

The latter can provide the most effective control, because the boiler can always work at high power and the required forward temperature can be established by setting the exact mixture of the hot water from the tank and cold water.

For safety reasons a water-cooling system has to be installed, because in case of power supply failure the circulation of water stops and the water gets boiled and the boiler can go bankrupt. In the water-cooling loop a thermostatic valve controls the volume of the cooling water: if the water gets too hot in the heating loop the valve lets more cooling water into the burning chamber.

3.3.4Pellets and bio-briquettes

In the recent years pellets and bio-briquette became very popular due to the strong demand on automatized firing. Pellets and bio-briquettes an be produced from any combustible wastes suitable for firing, such as wastes from the wood processing industry, agriculture, sewage. In the wood processing industry waste occurs mainly in the form of sawdust. In the case of agriculture the wastes are also of woody, fibrous material.

Sawdust or the wastes are mixed with a combustible binding material then compressed at a high pressure to form „pellets” or „bio-briquette”. If the diameter of the compressed item is above 50 mm it is called bio-briquette. Pellets are smaller (diameter 5-25 mm), their density is higher (1-1,3 g/cm³) and are produced at higher pressure (above 800 bar).

Special loading devices enable an automatic operation of the pellet-boilers. Due to the compression the calorific value of the pellets and bio-briquette is higher than that of the normal wood. Another advantage is that during the pressurization process the moisture content of the sawdust and waste significantly decreases (to below 10-12%), so pellets don’t need any drying period and the lower moisture content further increases the calorific value (See main parameters in the below table).

Phases of pellet production

The quantity of the remaining after the firing is negligible, an easily handled dust. It is rich is mineral salts and can be utilised in agriculture for fertilising purposes.

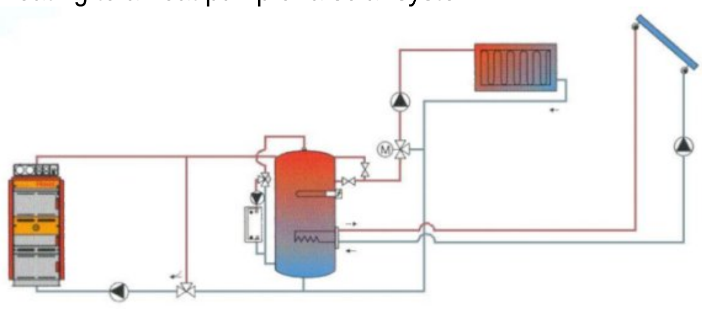
Certainly it must not be forgotten that an additional space of adequate size for boiler and fuel and ash storage is needed, as well and chimney of sufficient dimensions (cross section and height) are to be provided.

Main parameters of bio-briquette

Raw material	Density of briquette g/cm³	Moisture content %	Calorific value MJ/kg	Ashes content %
Straw of wheat	1,13-1,37	6,3	15,42	8
Straw of soya	1,31-1,35	8,7	14,87	6,5
Corn-stalk	1,29-1,31	6,2	15,49	6
Sunflower-seed skin	1,01-1,3	7,1	17,22	3,6
Waste wood, sawdust	0,92-1,11	6,1	16,84	1,4

3.3.5 Combination of wooden-chip boilers with other renewables

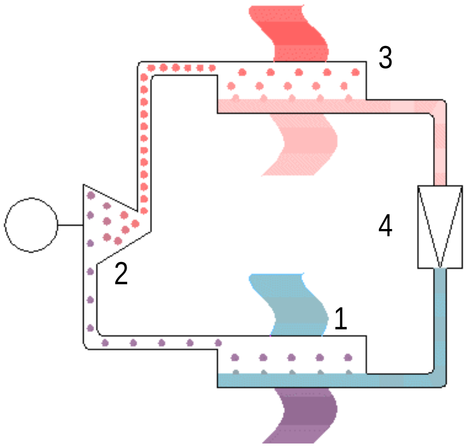
Wooden chip boilers and even traditional ovens or fireplaces can be taken into account as an auxiliary or boost heating to a heat pump or a solar system.



3.4 Heat pumps

The concept of heat pump is based on the followings:

- when a medium evaporates, it absorbs heat, when it condenses, it releases heat,
- the phase change temperature (boiling/condensation) depends on the pressure: the higher the pressure, the higher is the phase change temperature.



The figure shows the schematic model of a heat pump. The thermal process consists of the following steps:

1. First heat exchanger - called as **evaporator**: the medium evaporates at a lower temperature, absorbing heat from its environment. Here the pressure is low.
2. After that the vapour of this medium is compressed - the **compressor** is driven by an electric or Diesel engine - thus energy input is required.
3. The pressurised medium enters the second heat exchanger, - called as **condenser** -, where it condenses at a higher temperature, releasing heat to its environment.
4. The medium returns to the evaporator through a **pressure release** (choke) **valve**.

With regard to the end result a heat pump can be used for heating, cooling or both at the same time.

- Refrigerator in the households work on this basis: the source is the food and drink inside of it, while the condenser on the backside releases heat into the room.
- Heating:
  - **evaporator source** is in the environment: external air, soil, water
  - **condenser** is a heat emitter: radiator, coil, floor heating.
- Cooling:
  - **evaporator** is in the room
  - **condenser** is in the environment.

A heat pump can produce 4 kW heating performance whilst using only 1 kW for driving the compressor. It seems to be magic and contrary to the second law of thermo-dynamics. In fact this 1 kW is used only for removing the heat from a low grade source to a higher temperature. However, it must not be forgotten that the 1 kW electric energy is produced in a power station and distributed through a grid with an efficiency of 25 - 30 %. It means that a heat pump uses renewable (geothermal) and usually electric energy in a combined way.

In the best case the source is a big natural water reservoir: sea, lake, river with a relatively stable and high temperature. Evaporator in form of a long coil can be embedded in mud, too. Typical depths of buried coil are between 2 - 6 m. Regarding the soil - 30 W/m^2

peak load and 30 - 60 kWh/m^2,a consumption can be taken into account. The capacity of the dry soil is lower, that of soils with high moisture content or with filtrating underground water, is higher. If the coil is near to the surface, freezing of a thick layer of the soil can occur by the end of the heating season, which must be regenerated during the next summer. Therefore the terrain surface over the buried coil cannot be planted without limitation.

The source can also be the external air, in this case the evaporator can be an "energy roof" or an "energy wall" (roof or wall serve as heat exchanger). If they are irradiated by the Sun, the source temperature is higher. Unfortunately in case of air heat pumps the source temperature is not stable and the higher is the demand, the lower will be the coefficient of performance, due to the low external air (source) temperature. If the air temperature is lower than + 5 °C frost protection is needed in evaporator.

Heat pumps are applicable only for low temperature heating systems, thus they are ideal for floor heating, wall heating or any thermo active building elements. They can be used for traditional radiators, too, but they must be designed for low forward temperature. Heat pumps are not applicable for air heating.

3.5 District heating

In case of district heating the heat is supplied from the heating plant or from the power plant by piping networks to the heating system of the building in the transfer stations. Co-generation power plants, heating plants or eventually district boiler stations are the primary heat source. In the transfer stations the heat of the primary medium is transferred to the secondary medium. It is necessary because the two media have different phisical parameters (temperature/pressure/state of matter). Heat transfer between primary and secondary medium is realized through a heat exchanger.

4. Control of heating systems

In order to create the optimal thermal comfort in the heated rooms and the energy efficient it is necessary to assure:

- Good quality of fuel used, efficient heat production
- Energy distribution from the source to consumer’s places with minimal losses
- The energy supplied to the room must be adjusted to the needs by suitable control.

Heating medium control general classification:

- Qualitative control: A qualitative parameter of the heat carrying agent is controled. In heating system it means control of the temperature of the agent. In certain cases the return temperature entering to the boiler must be controled.
- Quantitative control: The quantity of the heat carrying agent is controled. It means the mass flow of the water or steam. Higher mass flow results in higher heating power. Quantitative control has an important influence to the system hydraulics.

Aspects for selecting the right control mode:

- Building size and type
- Building function and operation mode
- Time constant, thermal mass of building constructions
- Heating system type and inertia

- Capital costs on control
- User claims and demands on indoors climate comfort and quality.

5. District heating networks

District heating networks are complex systems for heat transport from central source to heat consumers, independent of their output, character and heat using manner. Heating networks are classified to primary and secondary networks. The primary network is the district heating network, whilst secondary network belong to the building. They are connected by the heat exchanger in the heat transfer station that is usually located in the building.

5.1 Heat network classification

According to location to the heat source and exchanger plant:

- Primary
- Secondary.

According to heat piping amount:

- Single-pipe
- Multi-pipe.

According to heat-carrying agent:

- Water
- Steam.

According to their position:

- Above ground
- Under ground.

Above ground heating networks can be fixed the following ways:

- Pillars or holding platforms
- Over ground supports
- Brackets fixed to building's walls.

Primary heating networks transport heat carrier agent from primary source to secondary source (delivery room). Heat carrier agent can be hot water with temperature over 110 °C or vapour with overpressure over 0,05 MPa. Primary heating network types are described above.

Secondary heat networks transport heat carrier (in required amount and quality) from secondary source (heat transfer station) to the heated room (e.g. radiators). Secondary heat network types are described in chapter 1.1.

Water in heating networks

Water as heat carrier in comparison with steam has the following advantages:

- Higher possibility of central control
- Possibility of higher heat accumulation in the system
- Higher specific production of electricity in thermal systems

Classification according to forward temperature:

- Warm water with water temperature up to 110 °C
- Hot water with water temperature over 110 °C.

In both types water temperature should not exceed 70 °C in return pipe.

Steam in heating networks are mainly used for heat supply of buildings with higher heat demand for industrial and technological purposes. Steam has generally the following advantages in comparison with water:

- It is transported by own pressure
- Negligible pressure loss in pipes
- Steam networks are cheaper because the diameter of condensate pipes are smaller
- Simpler localisation of breakdowns.

Steam networks were typical in the era of the large district heating systems mainly in the seventies. Nowadays they are outdated and steam is used only for technological purposes.

5.2 Optimising heating networks

In order to design optimal heating networks these main rules and conditions should be followed:

- Choice of the most effective heating network type according to the concrete conditions;
- Precise hydraulic calculation (optimisation for minimal capital and running cost);
- Optimal thickness and type of thermal insulation;
- Right design for ensuring optimal pressure conditions in different operation mode;

Heating network construction systems

The choice of heating network construction system is affected by following factors:

- Architectural point of view (aboveground, underground)
- Underground network level
- Heating networks cross connections with communication or other type of networks
    - Aboveground
    - Underground:
        - Channel
        - Ductless
- Capital and running cost.

Hydraulic calculation of heating networks

- Heat carrier flow rate can be calculated from the transported amount of heat
- The optimal diameter of heating pipes can be calculated from the flow rate and the equation of continuity. Admissible maxima of heat carrier speed:
    - Water ($w_v = 0,5 \div 2$ m/s)
    - Steam ($w_p = 10 \div 60$ m/s)
- The optimal pipe diameter comes from available pressure for the network.
- The total pressure loss of the network includes the pressure loss of the pipes and other system elements.

A hydraulic control is a part of the hydraulic calculation to assure stabile hydraulic system conditions.

Type and thickness of thermal insulation of heating networks

Thermal insulation of heating networks should meet the following requirements:

- Temperature of thermal insulated pipes surface should not exceed 50 °C (a security criterion),
- Minimizing thermal losses.

Thermal insulation should be selected considering the following requirements:

- Low thermal conductivity
- Temperature resistance in the range of the heat carrier temperatures
- Mechanical resistance against vibrations
- Resistance against chemical influences
- It must be not aggressive to pipe material
- Hygienic
- Resistance against microorganisms
- Sufficient technical lifetime.

Thermal insulation should be protected by suitable material against mechanical damage, permanent deformations and permanent impact of moisture.

Security appliances in order to stabilise pressure conditions in heating networks

The purpose of security appliances is to maintain stabile pressure conditions in the heating network in every operation mode, particularly in critical regimes at maximum thermal output or sudden interruption of heat carrier flow.

Design of these equipments comes from pressure diagrams:

- Expansion tanks
- Filling pumps.

Expansion of pipe materials

Expansion calculation aimes at the design of structural elements to eliminate the thermal expansion of piping caused by thermal changes. Thermal expansion should be compensated with:

- Compensator elements integrated in the pipeline (L-, Z-, U-elements),
- Elements designed for this purpose (axial, hinged).