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7. MODERN SOLUTIONS IN HEATING SYSTEMS

7.1. Heating systems

A heating system is a complex system which is used to generate and transfer heat to all heating devices within a building.

The heating system components (Fig. 7.1) (Lapinskienė & Laukys, 2011; Bilinskienė et al., 2012) are:

- boiler room of the building,
- heating devices (to transfer heat to the room areas),
- pipelines (the pipes which transfer heat from the boiler room to heating devices),
- other equipment.

Heating systems should be designed in accordance with the requirements of the technological process intended for the building (STR1, 2005). The desired level of comfort and specific requirements of customers must be assessed. All components of the heating system (heating devices, piping materials, control and regulating equipment) must be chosen according to the requirements of fire safety and hygiene standards (STR1, 2005).

The heating system needs to be designed so that the boiler room of a building provides technical means to ensure heat transfer to all devices (STR1, 2005; Bilinskienė & Graudinytė, 2012). The heating systems of apartment buildings are designed in such a way that it is possible to estimate the heat consumption in each apartment, without entering them. The systems must be tested and approved for use in accordance with (STR1, 2005) Technical Construction Regulation requirements.

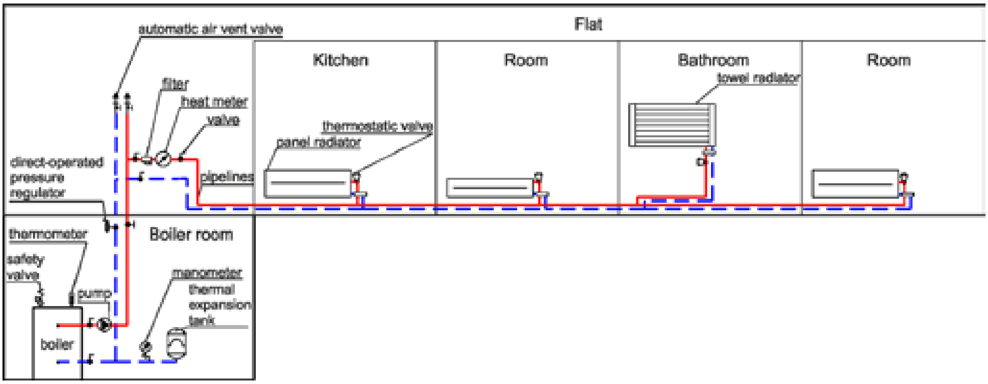
When designing the most energy efficient building engineering systems (STR2, 2016; STR3, 2017), priority should be given to the systems which report the lowest non-renewable primary energy factor and the highest value of the renewable primary energy factor, as well as the maximum efficiency of the installations in these systems (STR2, 2016).

Energy performance design requirements for a building heating system (STR2, 2016) are as follows:

- in heating system design decisions, the priority should be given to heat sources with the highest efficiency;

- in heating system design solutions, the priority must be given to control devices to comply with the regulation of heating in the whole building with thermostatic valves and indoor or outdoor thermostats;
- the projected annual thermal energy consumption for heating in the building energy performance class in Lithuania should comply with (STR2, 2016) Technical Construction Regulation requirements.

A



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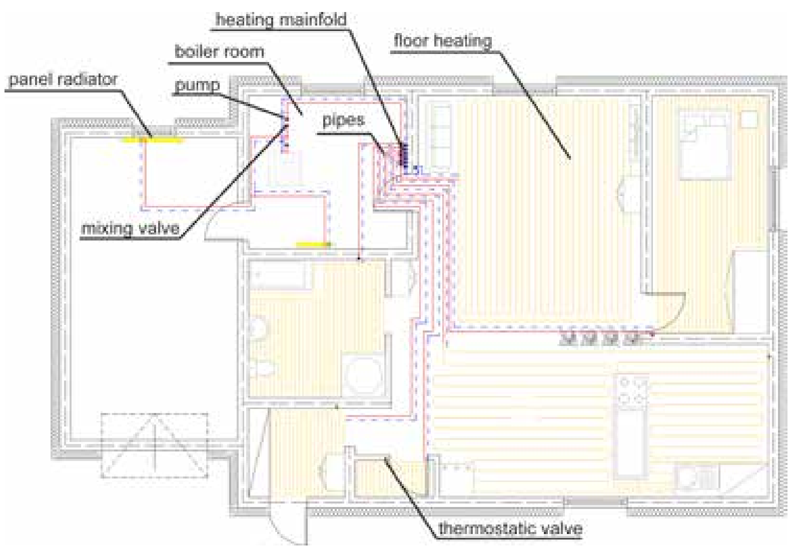


Fig. 7.1. Main components of a heating system. A) Schema, B) Example of heating system in a house (Source: own elaboration)

Classification of heating systems:

- Water heating systems. The heat in these systems is carried by water or, when there is a danger of frost, by ethylenglycol. The heat in these systems is carried by

water or, when there is a danger of frost, by ethylenglycol. These system are the most popular in Lithuania.
- Steam heating systems. They were used in industrial objects with steam boiler-rooms.
- Electric heating systems. These systems are used for heating of separate properties or small buildings, or for the buildings that are far away from another heat source. These systems disadvantage is a high cost of maintenance.
- Gas heating systems. They are used for heating of industrial or non-residential buildings where heating can be turned on periodically.

The infrared-heating system can be used for heating of non-residential and public buildings as well as for spaces with heavy thermal losses, for example: covered terraces, exhibition halls, airports, etc.

- Air-heating systems are being used more and more often since the heating and cooling spaces, places where required fresh air flow rate.

Water-heating systems have the advantage that the thermal energy is transported more efficiently by water than by air, which means that water has a lower energy requirement to provide the same heating capacity.

In panel surface heating systems, with heating elements installed in building structures (floor, ceiling), the surface temperature requirements are as follows (STR1, 2005; Juodis, 2009):
1) for the bathroom floor, as well as heated swimming pool tracks and benches – 33˚C;
2) for rooms, where people are temporarily on the floor – 35˚C;
3) for rooms, where people are constantly on the floor – 29˚C;
4) for the ceiling, in case the height of the building is 4-6 m, – 38˚C;
5) for the ceiling, in case the height of the building is 3.5-4 m, – 36˚C;
6) for the ceiling, in case the height of the building is 3-3.5 m, – 33˚C;
7) for the ceiling, in case the height of the building is 2.8-3 m, – 30˚C;
8) for the ceiling, in case the height of the building is 2.5-2.8 m, – 28˚C.

The surface temperature of the special-purpose buildings, like kindergarten and hospital wards, in the underfloor heating, must not exceed 35˚C (STR1, 2005).

The radiating heating devices with a surface temperature of more than 150˚C must be installed above the working area so that the radiation intensity in the work area does not exceed the permitted value (STR1, 2005).

Heating systems classification (Šarupičius, 2012; Lapinskienė & Laukys, 2011). Depending on heat generation mode, heating systems can be divided into:
1) the renewable energy sources (geothermal or solar energy),
2) the central heating systems (the heat is supplied from the city heating networks),

3) the electrical sources for heating system,
4) the gas, solid or liquid fuel systems.

Heating systems can also be classified depending on the type of users (STR1, 2005; Lapinskienė & Laukys, 2011):
1) local (direct) heating systems – when all the main elements of the system (boiler, pipes, heating device) are for a single user;
2) central (indirect) heating systems – when this equipment is separated, the heat is generated in a boiler and then is distributed to several users.

Heating system schemes classification depends on the mode of the heating flow through a heating device (STR1, 2005; Pieńkowski et al., 1999):
1) double-pipe heating systems,
2) single-pipe heating systems.

We may also classify the heating systems depending on the position of stands, vertical or horizontal system schemes (Šarupičius, 2012; Bilinskienė et al., 2012; Siemiończyk & Krawczyk, 2013).

In the case of horizontal distribution of heating installations, the following systems are most popular:
1) pipes distributed in a single-pipe loop,
2) pipes distributed in a two-pipe loop on the floor's perimeter,
3) heating system pipe tees set,
4) distribution system in which radiators are connected individually to the central heating manifold.

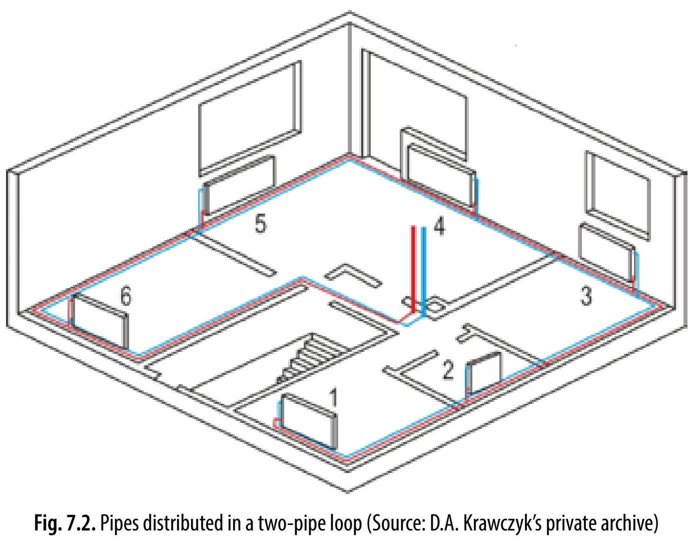


Fig. 7.2. Pipes distributed in a two-pipe loop (Source: D.A. Krawczyk's private archive)

Fig. 7.2 shows a system with pipes distributed in a double loop around the floor, while Fig. 7.3 presents a system with radiant heat manifolds. In Fig. 7.4 radiant heat manifolds can be seen. Figures 7.4A-B show the connection of the central heating installation in a two-pipe loop and the connection to the central heating manifold respectively.

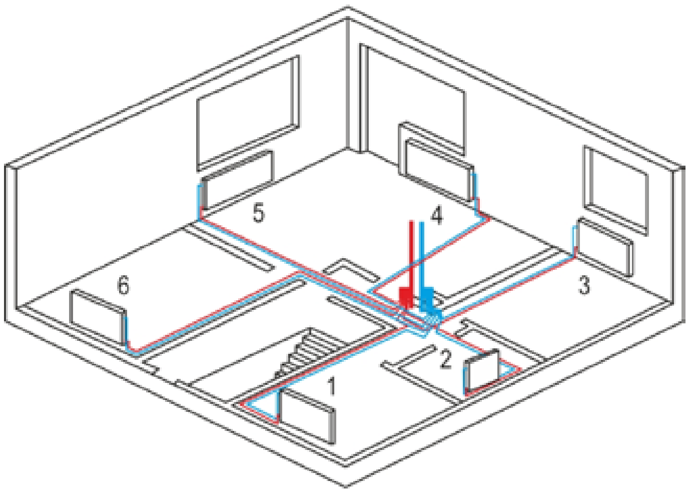


Fig. 7.3. Heating system with radiant heat manifolds (Source: D.A. Krawczyk's private archive)

A B

Fig. 7.4. The connection of the central heating installation: A) pipes distributed in a two-pipe loop B) the radiant heat manifolds (Source: T.J. Teleszewski's private archive)

7.2. Heating devices

The heating device type, its performance, external appearance, temperature of the heating surface must comply with the requirements of hygiene norms, fire safety rules and the purpose of the room (STR1, 2005). The amount of heat from the heating device placed in the room must be sufficient to maintain the designed temperature of the room (STR1, 2005). The power of the heating device must compensate for the heat loss from the room. For each heating device or a group of devices, the heat transfer must be regulated by the variable heat output in the heated room or by the needs of the room users.

Fig. 7.5. Examples of heating devices. Radiators: A) panel radiator, B) column cast iron radiator C-D) different surfaces of panel radiators (Source: A) Bilinskienė at al., 2012, B) Bilinskienė, 2017, C) photo by D.A. Krawczyk, D) photo by E. Szatyłowicz)

Heating devices must be available for cleaning, maintenance and repair. Heating appliances should have the heating surface easily accessible for cleaning (STR1, 2005; Bilinskienė & Graudinytė, 2012).

There are a lot of forms and colors of heating devices (Andruszkiewicz & Krawczyk, 2015). Radiators are most often manufactured as sectional (mostly from metal elements that can be assembled to the desired size) and panel (two welded and stamped steel panels). Examples of heating devices are given in Fig. 7.5.

Due to their construction, we can divide radiators into:
1) panel radiators (Fig. 7.5A),
2) column radiators (Fig. 7.5A, 7.7A-B),
3) towel radiators (Fig. 7.8A-D),
4) finned tube radiators (Fig. 7.9A-B).

Plate radiators, depending on the model, heat the room by emitting heat with the whole surface (radiation) or – when they have the ribbing – by radiation combined with convection. They can have one, two or three plates connected to one another (with or without ribs). The number of panels affects the thickness of the device and its performance – in this case, more does not mean better. In single panel radiators, a single plate optimally transfers heat to the room through radiation. In addition, these radiators can be equipped with convection fins. Double panel radiators are used in rooms with large surfaces, where there is not enough space on the wall to fit a very wide single panel radiator. Their efficiency in relation to single boards is lower, because the heat radiating through the second panel does not go entirely into the room and is partially reflected by the first one. Therefore, they are designed in such a way that the power of the internal board is about 30% smaller than the external one. Triple panel radiators are used mainly where technical conditions (limited length of the wall in relation to the surface of the heated room) do not allow the installation of a longer double panel radiator. Fig. 7.6 shows the view of a single panel radiator (Fig. 7.6A), a double plate radiator (Fig. 7.6B) and a triple panel radiator (Fig. 7.6C).

In order to determine the type of heater, numerical digits are used:
- type 10 – single panel, without ribs,
- type 11 – single panel with convection fins,
- type 20 – double panel without ribbing,
- type 2l – double panel with single convection fins,
- type 22 – double panel with double fins,
- type 30 – triple panel without ribbing,
- type 33 – triple panel with triple convectional fins.

Fig. 7.6. View of the ribs in different types of flat heaters: A) 11, B) 22, C) 33 – radiator with the top cover removed (Source: T.J. Teleszewski's private archive)

The advantage of a radiator is the possibility of determining precisely its power – by attaching the appropriate number of ribs. We can make minor corrections to their number even after the entire installation. Column heaters are most often produced as cast iron radiators, aluminium radiators and steel radiators.

A cast iron radiator is most often characterized by large water capacity, and hence large thermal inertia. This type of heater heats up slowly, but also slowly releases heat. Cast iron radiators work well in gravity installations because they generate small hydraulic losses. The parameters of a cast iron radiator make it work well with solid fuel boilers. The advantage of cast iron radiators is their high resistance to corrosion, and thus high durability of the installation. Another asset of the radiators is a large share of heat exchange by radiation, which increases the comfort of living in the room.

Aluminium radiators are made of aluminium alloys containing, among others, silicon and copper. They have many advantages over cast iron radiators. They are light and have lower water capacity – and hence lower thermal inertia. The aluminium radiator will heat up faster than the cast iron one and after turning off the power supply it will stay warm for a short time. The smoothness of the surface of the aluminium radiator makes cleaning easier. Aluminium radiators cannot be installed in installations made of copper due to the formation of electrochemical corrosion cells (Pieńkowski at al., 1999).

There is also a steel variant of segment heaters. They are made of steel pipes and profiled sheets. The individual elements are joined by welding. Other parts are also welded, and the heater is ordered to size, given the number of ribs.

Fig. 7.7A-B shows an example of a column cast iron radiator from the eighties of the twentieth century (Fig. 7.7A) and a contemporary column chromed steel radiator (Fig. 7.7B).

A B

Fig. 7.7. Examples of radiator heaters: A) column cast iron radiator from the 1980s, B) contemporary column chromed steel radiator (Source: A) photo by T.J. Teleszewski, B) photo by D.A. Krawczyk)

A B C

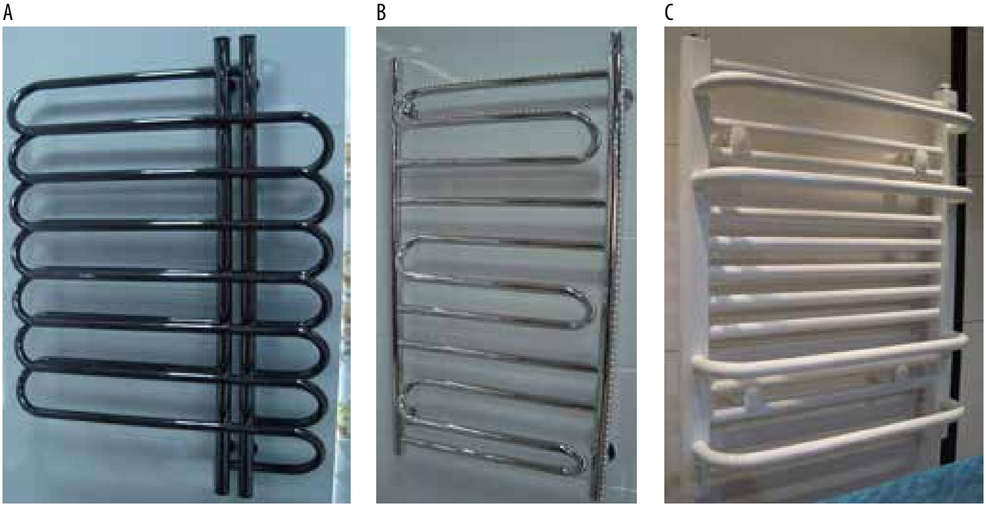
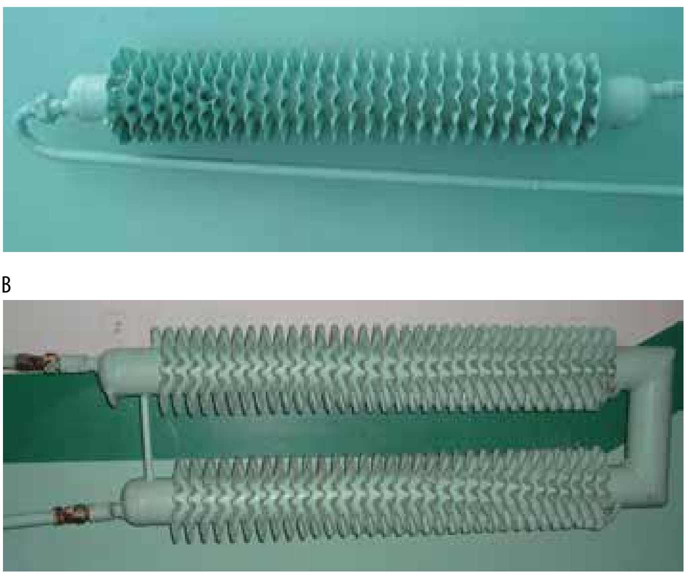


Fig. 7.8. Examples of shapes of towel radiators (Source: T.J. Teleszewski's private archive)

Towel radiators are usually made of two vertical pipes connected by horizontal tubes of smaller diameter and round, rectangular or oval cross-section. Ladder radiators are one of the most popular heating systems found in bathrooms. The special impregnation of the ladder radiator makes it resistant to moisture. In addition, it can also act as a hanger or towel dryer. Increasingly, bathroom radiators are available in various shapes and colours fulfilling at the same time decorative functions. Depending on the type of connection, bottom, side and central heaters are available. They are also characterized by different heating power and the possibility of connecting electric heaters to them. Figure 7.8 shows various shapes of ladder radiators.

A finned tube radiator (Fig. 7.9A) consists of a tube and a sheet metal ribbon attached to it; this ribbon is shaped in such a way that it forms a helical spring which is tightly placed on the pipe (adhering to the pipe not with its plane, but with the edge) acting as a heat sink (heat dissipater). Finned tube radiators are used mainly in industrial, storage and high temperature installations that use steam or water as a heating medium with working pressure of up to 1.6 MPa. Typically, ribbed pipe radiators are placed horizontally, about a meter above the floor. Sometimes, when there is a need to dissipate significant power (and when space conditions prevent the installation of a single long pipe), two or more finned tube radiators are installed one under another (Fig. 7.9B).

A



B

Fig. 7.9. An example of a configuration of finned tube heaters: A) a single-row single radiator, B) a single-row double radiator (Source: T.J. Teleszewski's private archive)

The thermal efficiency of installed radiators can be reduced as a result of all kinds of obstacles. The proper air circulation around the radiator, which determines the quality of heat transfer to the surrounding air, is limited even by curtains and lace curtains. If a valve with a thermostatic head is covered, then it will not react correctly to changes in temperature in the heated room. As a result, the hot water supply to the radiator will be cut off whenever the temperature behind the cover reaches the set value. In this way, only the space behind the cover will be well heated, and the room will remain unheated. All kinds of covers also limit the radiator's efficiency by up to several percent. Fig. 7.10 shows exemplary radiator covers that contribute to reducing the thermal efficiency of radiators. Opened radiators under normal conditions guarantee that heat can spread freely in rooms, and the radiator reaches the heating power planned by the installation designer. The rules for selecting radiators, including covers, can be found in PN-B-02401:1975.

Fig. 7.10. Examples of radiator covers (Source: T.J. Teleszewski's private archive)

Convectors are mostly installed in commercial office buildings (STR1, 2017) which have large glass facades. Convectors are made of finned tubes connected in parallel, which the heated air passes through (Lapinskienė & Laukys, 2011; Bilinskienė &

Graudinytė, 2012). Floor convection heaters are mounted into the floor, especially in places where it is not possible to install high radiators (Lapinskienė & Laukys, 2011; Bilinskienė & Graudinytė, 2012). If the floor convection heater is not enough, more powerful heat source is selected. For this purpose, floor convection heater with a fan is developed (Fig. 7.11). Convection heaters can be installed in rooms with high heat loss. The fan rotation speed can be easily adjusted depending on the heat demand for the premises.

A B C

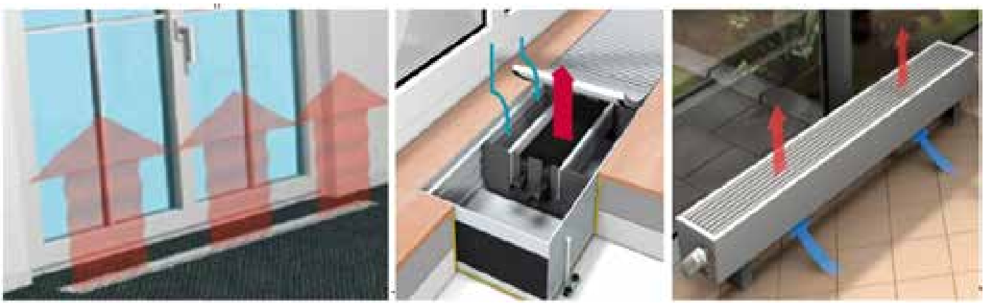


Fig. 7.11. Examples of heating devices. Convectors (Source: Bilinskienė at al., 2012; Bilinskienė, 2017; R. Bilinskienė's private archive)

Freestanding convection heaters (Fig. 7.11) are adapted in low spaces with large area windows. Heating registers are the most popular of all the convection heaters, so that their usability is significantly higher. They are suitable for individual use in the interiors, which is important for the compactness and the materials used (Lapinskienė & Laukys, 2011; Bilinskienė & Graudinytė, 2012).

Main steps in heating device selection can be listed (Lapinskienė & Laukys, 2011; Bilinskienė & Graudinytė, 2012; Pieńkowski et al., 1999):

- Selecting a device in a manufacturer's catalogue (considering aesthetical and hygiene requirements, shape, width, height); this device must be accompanied by heat emission tables.
- Determining heat emission of the selected type the radiator for proper water supply and return temperature (for example, 80/60°C, 70/55°C) and design indoor temperature (for instance 20°C).
- Finding enlargement coefficients to increase the nominal emission in case the device is hidden in the floor or covered with grills, because then the heat emission is smaller.

Heating devices are installed under the windows in a room. In special heating buildings, kindergartens and hospitals, the heating devices must be not less than 75% of the window length. When a heating device is located below the windows, the heat output must cover heat losses through partitions up to 4 m high from the floor (STR1, 2005; Bilinskienė & Graudinytė, 2012). Heating devices must be installed on the lowest floors of the staircase of a building (STR1, 2005; Bilinskienė & Graudinytė, 2012).

At present, there is a tendency to create custom-made heating devices by designers. These are usually tubular radiators in which the heating medium can circulate through square pipes (Šarupičius, 2012). Manufacturers of these devices, as well as in standard cases, present the tables where there are indications of the device heat power having concrete temperature values (Šarupičius, 2012).

7.3. Space heating systems

There are different forms of space heating – floor, ceiling, wall, water heating systems, infrared heating, air heating, etc. (Fig. 7.12).

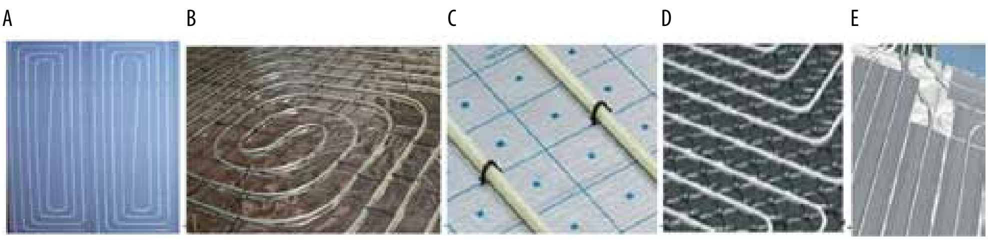


Fig. 7.12. Examples of space heating systems (Source: R. Bilinskienė's private archive)

The most popular of these systems are (Bilinskienė et al., 2012):

- the profiled panel,
- insulating plates,
- dry system plates.

The profiled panel system: it can be used in residential and public spaces; for high-loads and for the outer layer of ready-mix and cement mixture, the upper surface has a compacted structure of loops; the loops help capture the heating pipes tightly.

Insulating plates adapted for fastening with pins: the rolls of insulating coating adapted for fastening with pins are laid in parallel lanes all over the entire length of the room. To install the pipes easier, surface markings should be the same. Niches and corners of the room should be lined with coating residues. Dry system plates: the minimum plate height (25 or 30 mm) seems to work well particularly in old buildings or renovation projects.

The surface of a building structure with mounted plastic pipes is used for floor or ceiling heating. Flowing via pipes, the heat carrier warms up the building structure, which reflects heat into the premises. This is a highly-efficient, economical and hygienic heating method.

It must be noted that the temperature of the heat medium supplied to the floor heating system is two times lower than that of a radiator. The disadvantage of such installation is that this is an inertial heating system (Šarupičius, 2012a).

7.4. Heating system equipment

The following pipelines are used in the heating systems (Lapinskienė & Laukys, 2011; Bilinskienė & Graudinytė, 2012; Bilinskienė et al., 2012):

- the main supply/return pipeline – for supplying, return and distributing hot water from/into the heating source into/from the stands (Fig. 7.13);
- the main stand – designed to supply hot water to the main pipelines;
- supply/return stands – for supplying or collecting hot water to/from the heating devices (Fig. 7.13);
- transit pipelines, where the heat released from them is not used for heating the working (or service) area (STR1, 2005).

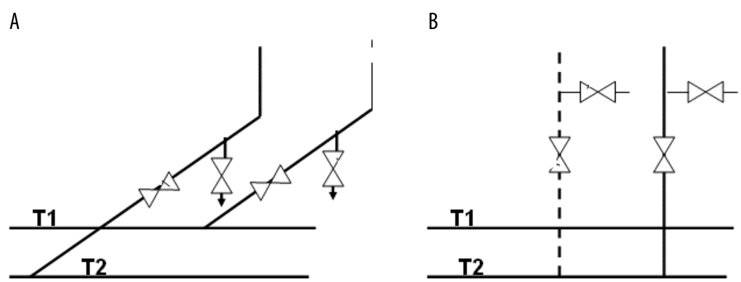


Fig. 7.13. Heating system pipelines plan and scheme (Source: R. Bilinskienė's private archive)

Materials for producing heating system pipes are: plastic, plastic composite, copper and steel (STR1, 2005; Bilinskienė et al., 2012). The pipes used in heating systems shall, under normal operating conditions, be resistant to the chemical and mechanical effects of temperature and pressure (STR1, 2005). Heating and heat supply pipes in a building can be installed open or hidden – in closed channels, niches, engineering communications tunnels or building constructions. When pipelines are installed hidden in building constructions, they must have no connections (STR1, 2005; Bilinskienė et al., 2012).

The pipes of the collector heating systems must be installed in the floor construction, but in such a way that they can be replaced without touching the floor.

The configuration, fittings and heating devices of the heat supply systems must be reliable in all possible operating conditions. The heat user needs to be capable of controlling the thermal energy of the devices by adjusting the system's hydraulic and thermal settings and by switching the appliances on or off.

Part of the heating system pipelines and stands must have closing, hydraulic balancing and regulating fittings (Fig. 7.14) as far as they are needed for the system to be started, controlled, and comfortably operated (STR1, 2005; Bilinskienė et al., 2012).

A B

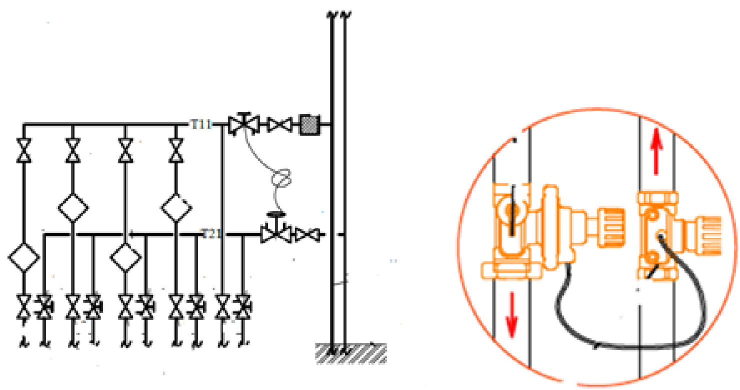


Fig. 7.14. Heating system pipelines plan and scheme (Source: R. Bilinskienė's private archive)

For regulating the temperature and pressure, direct-operated regulators are most commonly used. An example of a direct-operated pressure regulator is shown in Fig. 7.15. Fig. 7.16 shows an example of a direct-operated temperature regulator.

Fig. 7.15. An example of a direct-operated pressure regulator installed on a central heating system (Source: T.J.Teleszewski's private archive)

A thermostatic heating device valve (Fig. 7.16) together with a thermostat form the automatic regulation equipment. The thermostatic valve has 6 steps from * (freezing protection) to 5.

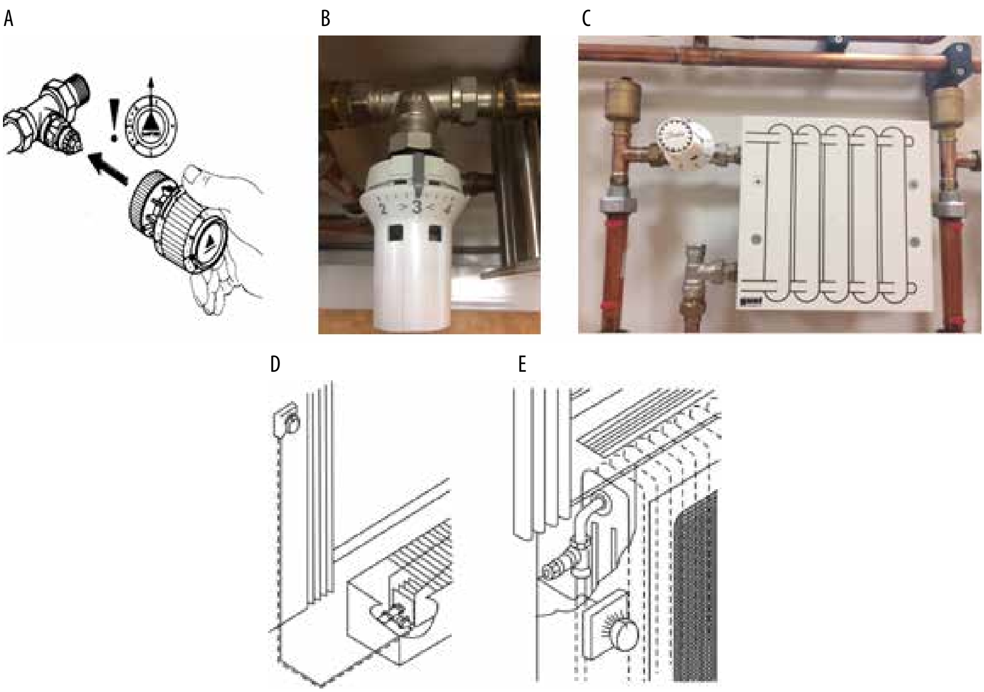


Fig. 7.16. A thermostatic valve (Source: A-C R. Bilinskienė's private archive, D-E D.A. Krawczyk's private archive)

The maximum velocity of water or steam in the heating system pipelines should be adjusted so that the noise in the pipelines does not exceed the permissible noise levels (STR1, 2005; Bilinskienė et al., 2012). The length of the steam heated system, when the condensate flows in front of the steam, must not be longer than 6 m (STR1, 2005; Bilinskienė et al., 2012).

Heating and heat supply pipes in buildings must be inclined as follows (STR1, 2005; Bilinskienė et al., 2012):

- water, steam and condensate pipes – not less than 0.2%;
- steam pipes, when moving the vapour – not less than 0.6%;
- it is permissible to lay pipes without sloping, when the water flows with the velocity of not less than 0.25 m/s.

Heating and heat supply pipelines must be accompanied by the equipment for the air discharge and for emptying the pipelines, as well as by the equipment for compensating the thermal expansion (STR1, 2005; Bilinskienė et al., 2012).

The heat insulation of the heating and heat supply pipelines must be installed in accordance with the requirements for thermal insulation installation (STR1, 2005; Bilinskienė et al., 2012).

Thermal insulation is an insulation for heating pipes with a temperature higher than the environment, used to reduce heat loss. The shells of stone wool of different thickness or mats with aluminium foil are commonly used for thermal insulation (Bilinskienė et al., 2012; Šarupičius, 2012a).

Thermal insulation should have the following features:

- low heat transfer coefficient λ (W/(m·K);
- resistance to the maximum operating temperature of the installation and temperature differences;
- resistance to the working medium in the installation;
- resistance to the environment, including the action of microorganisms and rodents;
- resistance to static and dynamic loads during installation of insulation as well as subsequent installation work;
- non-flammability or very low flammability;
- chemical inertness towards the insulated material.

Standard insulation usually consists of two layers: a thermal insulation layer, which must have a low heat transfer coefficient and a protective coat that protects the insulation from mechanical damage and the impact of the environment.

The following materials are most commonly used in thermal insulation:

1) Foamed polyethylene (Fig. 7.17A-B) has the following characteristics: coefficient of thermal conductivity t=+40°C from 0.035 to 0.045 W/(m·K), operating temperature from -45°C to +105°C, high flexibility.
2) Foamed polyurethane (Fig. 7.17C-D) has the following characteristics: coefficient of thermal conductivity t =+40°C from 0.03 to 0.04 W/(m·K), working temperature from -45°C to +135°C, sound absorption, lower resistance to dampness.
3) Foamed polystyrene is characterized by the following features: coefficient of thermal conductivity t=+40°C from 0.03 to 0.04 W/(m·K), operating temperature of up to +80°C, very low weight, mainly used for insulating fittings.
4) Mineral wool and glass wool (Fig. 7.17E) are intended primarily for use in thermal insulation of high temperature pipelines and ventilation ducts. Wools are characterized by very good fire resistance (rock wool up to 1000°C, glass wool up to 600°C), non-flammability and resistance to microorganisms and rodents. The thermal conductivity coefficient for mineral wool lagging, measured at + 200°C, is about 0.060 W/(m·K).
5) Elastomer insulations (Fig. 7.17F) are characterized by resistance to high temperature differences and variability of atmospheric conditions. They are also resistant to UV and water vapour. In addition, they prevent the spread of fire, even though they are combustible materials. Their main applications are air-conditioning, refrigeration systems and solar installations.

Protective coats, manufactured most often in the form of sheets, can be made of the following materials:

1) aluminium tape (Fig. 7.17E),
2) plastic film (Fig. 7.17B),
3) asphalt pavement on aluminium tape,
4) galvanized steel sheet.

Insulation thickness e_1 can be determined according to the following formula (PN-EN ISO 8497: 1999, PN-B-02421:2000):

$$e_1 = \frac{D\left(\frac{D+2e}{D}\right)^{\frac{\lambda_1}{0.035}-D}}{2}, \tag{7.1}$$

where:

D – outer diameter of the insulated pipe (mm),

e – the thickness of the specific insulation layer according to Tables 7.1, 7.2 or 7.3 (mm),

λ_1 – value of the heat transfer coefficient of the insulation material at 40°C (W/(m·K)).

A B C D E F

Fig. 7.17. Examples of insulation: A) foamed polyethylene without an outer coating, B) foamed polyethylene with an outer coating of polyethylene film, C-D) foamed polyurethane in a PVC housing, E) mineral wool with an aluminium foil coating, F) elastomer insulations (Source: A-C T.J. Teleszewski's private archive, D-E R. Bilinskienė's private archive)

Table 7.1. Minimum thicknesses of the insulation layer on the heating network lines in underground intransitive channels and in buildings as well as central heating and hot water installations in heated rooms with a design temperature greater than or equal to 12°C (Source: according to PN-82 / B-02402)

Nominal diameter of the pipe	Thickness of the insulation layer (mm) at the temperature of the medium being transferred				
	up to 60ºC	95ºC	135ºC	150ºC	200ºC
=<20	15	20	30	35	45
25	15	20	30	35	45
32	15	25	35	40	50
40	15	25	40	40	50
50	20	25	40	45	60
65	20	30	45	50	60
80	25	35	50	55	65
100	25	40	55	60	75

Table 7.2. Minimum thicknesses of the insulation layer on the lines of the central heating and hot water installations in heated rooms, with a design temperature equal to or less than 12°C (according to PN-82 / B-02402) and in unheated rooms with a design temperature greater than or equal to -2°C (Source: according to PN-82 / B-02403)

Nominal diameter of the pipe	Thickness of the insulation layer (mm) at the temperature of the medium being transferred				
	up to 60ºC	95ºC	135ºC	150ºC	200ºC
=<20	30	30	35	40	50
25	30	30	40	45	55
32	30	35	45	50	55
40	30	35	45	50	60
50	35	35	50	55	65
65	40	40	55	60	70
80	40	45	60	65	70
100	45	50	65	70	80

Table 7.3. Minimum thicknesses of the proper insulation layer on the overhead lines of district heating networks and central heating and hot water installations in unheated rooms with a design temperature equal to or less than -2ºC (Source: according to PN-82/B-02403)

Nominal diameter of the pipe	Thickness of the insulation layer (mm) at the temperature of the medium being transferred				
	up to 60ºC	95ºC	135ºC	150ºC	200ºC
=<20	50	45	45	50	55
25	50	45	50	55	60
32	50	45	55	60	65
40	50	45	60	60	65
50	55	50	60	65	70

Nominal diameter of the pipe	Thickness of the insulation layer (mm) at the temperature of the medium being transferred				
	up to 60°C	95°C	135°C	150°C	200°C
65	60	55	65	70	75
80	60	55	70	75	80
100	65	65	75	80	90

Figures 7.18A-B show the temperature field of non-insulated central heating pipes (Fig. 7.18A) and insulated central heating pipes (Fig. 7.18B) located in the external wall of a residential building determined by the boundary element method. In the case of a wall in which there is a pipe without insulation, the temperature field around the duct is clearly visible in comparison to the insulated duct. Examples of simulations of the impact of central heating installations and hot water installations on the creation of thermal bridges can be found in the literature (Teleszewski & Sorko, 2010, Teleszewski & Rynkowski, 2011).

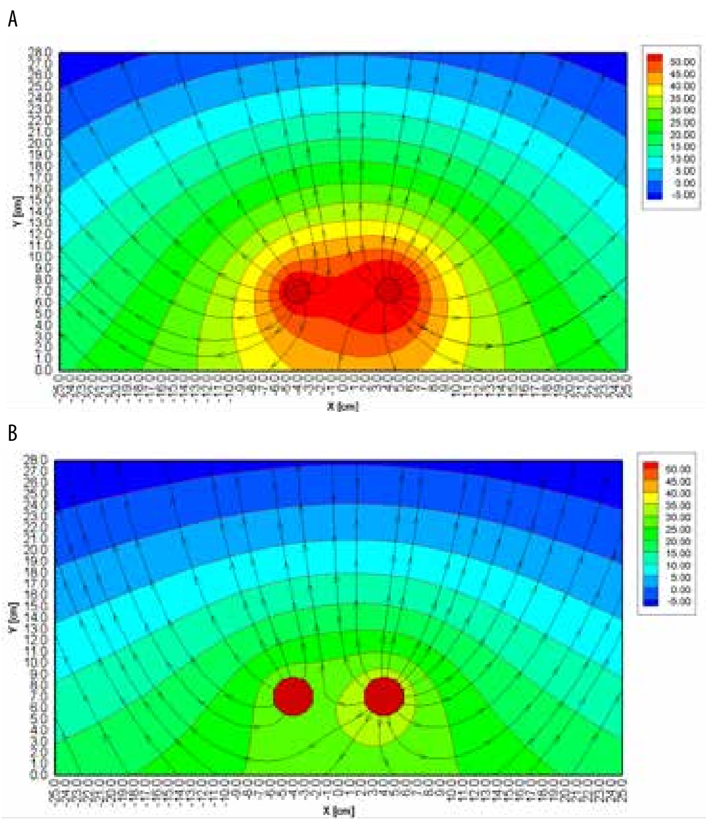


Fig. 7.18. Heat flow lines and temperature field in the wall section in the case of the central heating pipe line located in a furrow: A) without thermal insulation, B) with thermal insulation (Source: own elaboration)

Minimum insulation thickness of heating system pipes in Poland is regulated by law (Reg1, 2017) and depends on a diameter of pipes. For small pipes (20-35 mm) it is set at level 20 mm, for average diameters of pipes (35-50 mm) it is 30 mm, while for bigger pipes thickness of isolation should be at least equal to the inner diameter of the pipe.

Heating supply systems can be central (CHSS) and local (LHSS). The local heating supply systems are those in which heating energy is generated for several buildings or the local boiler-rooms are installed inside the buildings. If compared with central systems, local systems are more effective for smaller buildings, or for those that are situated further from the heating network (Bilinskienė et al., 2012; Šarupičius, 2012).

In central heating installations, in order to force the flow of the medium through the installations, glandless circulation pumps are most often used. In the design of a glandless pump, all rotating parts inside the motor are immersed in the medium to be pumped. It is not necessary to seal the shaft with a stuffing box or mechanical seal, which is needed for standard pump designs. The pumped liquid lubricates the shaft bearings and cools the engine components. Fig. 7.19 shows the view of installed circulation pumps in the boiler room, while Fig. 7.20 presents the construction of a glandless circulation pump. Pump selection is based on calculations of hydraulic central heating installations. The intersection of the system characteristic with the pump curve is the duty point (Fig. 7.21). The selected pump should be characterized by the highest efficiency. Examples of calculations of hydraulic central heating installations can be found in the literature (Pieńkowski et al., 1999 Part 1; Pieńkowski et al., 1999 Part 2).

A B

Fig. 7.19. Circulation pumps in a boiler room (Source: photos by T.J. Teleszewski)

Currently, in central heating installations, the most frequently used is the type of pump regulation which changes the rotational speed of the pump impeller. This is also the most effective form of regulation, because it adjusts the pump's power to the changing operating conditions of central heating installations. Most often, two control modes are used (Bidstrup, 2002):

1) proportional pressure (Fig. 7.22A),
2) constant pressure (Fig. 7.22B).

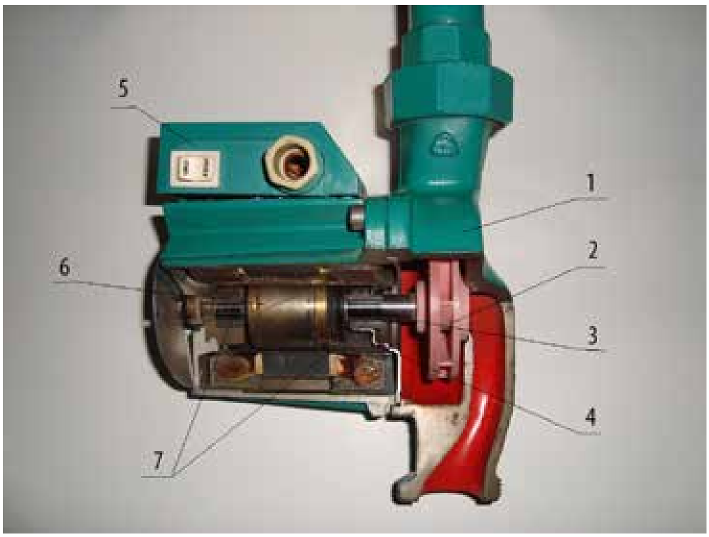


Fig. 7.20. The construction of a glandless pump: 1 – pump housing, 2 – impeller, 3 – shaft, 4 – stator housing, 5 – control box, 6 – rotor, 7 – thrust bearing (Source: T.J. Teleszewski's private archive)

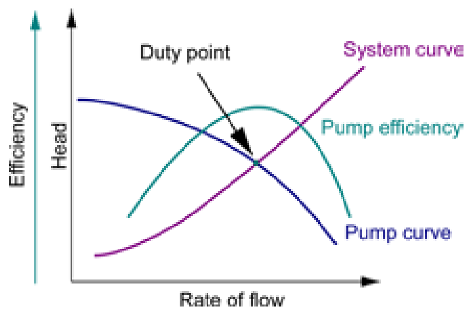


Fig. 7.21. Determination of the operating point for a given pump and central heating installation system (Source: own elaboration)

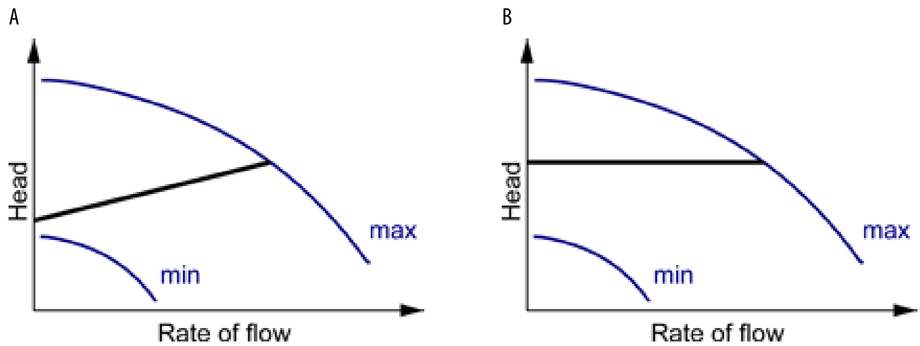


Fig. 7.22. Control modes: A) proportional pressure, B) constant pressure (Source: own elaboration)

Constant control of the pressure difference is the most optimal at high pressure losses on the heater/cooler in relation to head friction losses, while proportional pressure control is recommended when the supply pipes are relatively long and the head friction losses override head losses for local resistances in the receiver (Bidstrup, 2002).

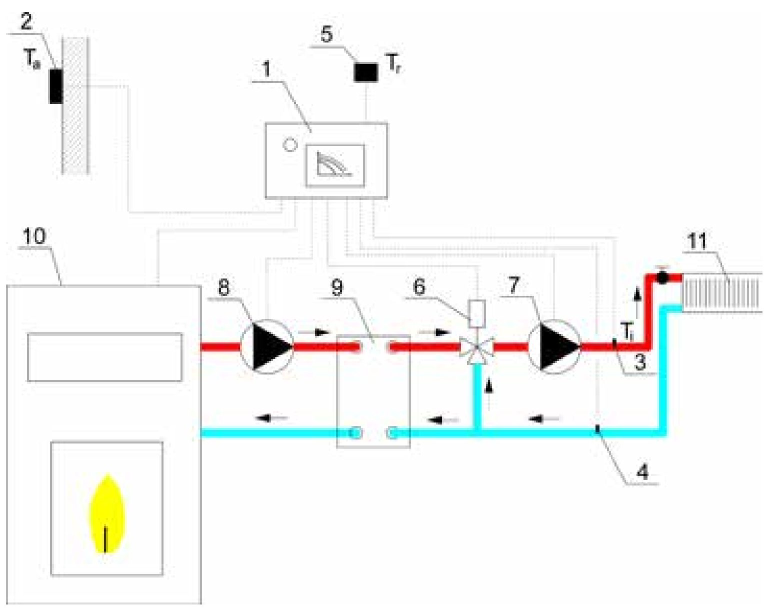


Fig. 7.23. An example of a schematic diagram of "weather regulation": 1 – controller, 2 – external temperature sensor, 3 – heat circuit temperature sensor, 4 – heat circuit temperature sensor, 5 – room temperature sensor, 6 – mixing valve (three-way valve with actuator), 7 – pump heating circuit, 8 – pump heating circuit, 9 – heat exchanger, 10 – heat source (boiler), 11 – radiators (Source: own elaboration)

Currently, central heating installations are equipped with so-called "weather regulators" or "climatic regulators" that regulate the temperature of the heating medium depending on the outside temperature T_a. Fig. 7.23 shows a typical weather regulation scheme. The outside air temperature T_a determines the building's heat demand. Adjusting the heating system according to the outside temperature of the building brings greater economic benefits than regulating it based on the internal temperature T_r. A weather-compensated heating system ensures that the room temperature is evenly maintained and the energy is properly used, as the supply water temperature is regulated depending on the outside temperature T_a. The weather regulation is based on the programmed heating characteristic called "the heating curve" or "the gradient of heating characteristic" (Fig. 7.24). This curve determines the relationship between the outside air temperature T_a and the water temperature T_i coming out of the boiler or heat exchanger. A heating medium with a temperature adjusted to the current outdoor temperature is supplied to the radiators. The supply water temperature is read from the temperature sensor (3) (Fig. 7.23), while the outside temperature is read from the temperature sensor (2). The actuator in the weather regulation can be a boiler (10), a mixing valve (6) or a circulating pump (7) The regulator can be additionally equipped with an internal room temperature sensor (5). This option enables automatic correction of the programmed heating characteristics.

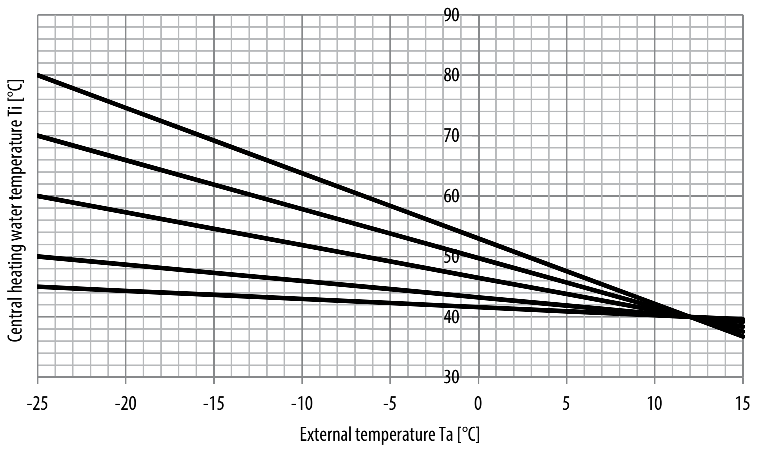


Fig. 7.24. Gradient of heating characteristic (Source: own elaboration)

7.5. The role of building planning for HVAC systems selection

The good operation of heating and ventilation systems is just a small part of the conditions for creating healthy and comfortable microclimate conditions in a building. In residential buildings the air quality is often determined by the construction materials, the maintenance of the building, etc. The most important projecting solutions for HVAC systems are made by the architect at the first sketch (possible location of technical rooms, energy source, comfort level requirement, etc.). Energy efficient building has to be designed to ensure proper indoor thermal comfort and air quality, and also less energy consumption. The main stages of the energy efficient building design are (STR2, 2016; WEB-1; WEB-2; Gluosnis, 2004):

1) the energy saving and heat retention requirements analysis,
2) the possible building HVAC systems analysis, which includes: building structure, hygiene requirements, energy demand, area and space demand, heat power for building services, etc.

It is the architect who projects solutions that determines the efficiency of a building by selecting its shape, fenestration, building construction thermal properties, building services installation and maintenance, etc. The building design solutions and the HVAC system selection depend on the building location. The local climate zone must be considered when selecting design solutions. There are different dominant systems and solutions for: cooling, air conditioning (in Spain) or heating, ventilation (in Lithuania, Poland). The climate zone has a major effect on HVAC system design solutions. The building construction solutions are very important, too. The better the building is insulated, the lower energy supply is needed for its heating (Poland, Lithuania) or cooling (Spain). The efficiency of a building may be understood in different ways. The most efficient "zero energy" buildings do not need external energy supply, heat losses are compensated by solar heat and internal gains. In a big project work, the architect, as the head of the enterprise, is responsible for the project completeness and quality. The thermal engineer is responsible for selecting and designing HVAC systems solutions. The project quality depends on the project manager, good communication between designers, architects, and engineers, and their design solutions (STR2, 2016; WEB-1; WEB-2; Gluosnis, 2004).

Apartment windows in residential buildings may be positioned in one or two opposite facades. Double-sided apartments are better ventilated due to the difference in pressure from the wind. On the upper floors of buildings, where the wind blows strongly, apartments may be cooled off (Juodis, 1998). Maintaining the projected temperature inside these apartments could be resulting in overheated apartments with one-sided window exposure on the lower floors. The one-sided apartments facing the south, south-east, or south-west, could be overheated or the air inside might be too hot during the summer season.

The right planning and designing of buildings, the properly selected materials for the walls and adequate maintenance can support the operation of heating, ventilation, air conditioning systems and create healthy microclimate in the building (STR1, 2005; STR2, 2016).

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