POLITECHNIKA LUBELSKA

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Computer Aided Designing of Sanitary Installations

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Introduction

Environmental Engineers are often employed in design offices, developing solutions for sanitary systems in the branch of heating, ventilation, air conditioning, gas and water supply, sewage disposal, etc. This type of labor requires time consuming calculations which can be supported by Computer Aided Designing applications.

InstalSystem package offered by the InstalSoft Company is one of the popular tools for sanitary installations Computer Aided Designing. Applications in versions containing products of individual companies are intended for design, calculation and generation of complete drawings and lists of materials for central heating, water supply system and sewage systems. The subject of this study is combination of Instal-therm HCR and Instal-heat&energy, applications, that are used for designing heating systems, as well as Instal San, intended for water installations design. It should be underlined, that Instal-therm HCR and Instal-san T programs have a function to import drawings in *.dwg format, and generate created drawings to the above mentioned format.

Instal-therm HCR and Instal-heat&energy are compatible applications and enable editing of graphics elements and computational part of one project file at the same time. In practice this reduces the arduous calculations of energy demand for building, that the program carries out automatically after assignation of the building's architectural base with its location and construction. Creation of drawings is also shortened by the use of complete patterns of graphical equipment and pipes and creation the installation's schematic views in an automatic way. At the same time, the role of the designer is not only limited to drawing the installation, but it also covers selection of the heating medium supply temperature, selection of types and devices connections. These applications can therefore be extremely useful tools in designer's work, however, they require the necessary scope of knowledge to choose proper solutions.

1 Theoretical basics

1.1 Heating systems in single-family buildings

Heating is associated with the delivery of warmth to the premises of building in a quantity that will provide thermal comfort conditions for their users. If heating installation is designed to heat a room or several rooms located in some distance from the heat source, the solution is called central heating system. The basic elements of such a system include boiler, pipes and heaters. Considering the type of medium, water, air and steam central heating, together with electrical one can be distinguished (Brumbaugh, 2004; Krygier et al., 2007). Water heating systems constitute over 95% of all central heating systems in Poland, therefore the basic elements of such systems will be shortly described below.

Heat source in central heating system is boiler, which produces heat through fuel combustion. There are four main types of boilers depending on the type of fuel used: gaseous, oil, solid fuel or electric power.

Pipes distribute hot water to the heaters (radiators, convectors, etc.). In the case of higher buildings, water is distributed to the individual floors by the risers. Distribution pipes can be connected to the main duct in the following ways (Balcerowska, 2009):

- system of the tees: a few heaters – generally radiators – connected to supply pipe through the tees,
- system of the manifolds: a few heaters connected to supply pipe through the manifold.

Central heating pipes are made of steel, copper or plastic. Plastic pipes are made from peroxide cross-linked polyethylene, polypropylene or polybutylene.

Heaters are room heat emitters that transmit warmth to the room spaces. The choice of heater is influenced by heating installation solution in the designed object. Due to material type, steel, cast and aluminum radiators can be distinguished. Due to the way of heat transfer, heaters can be divided into surface (radiant) and convector devices.

Additional elements of heating systems are the fittings. Fittings like valves, thermostatic regulators, flow controllers, non-return valves etc. aim in regulation of flow, temperature and pressure of water. Among fittings assortment there are also air bleeders, filters and security equipment like safety valves, expansion vessels (Balcerowska, 2009).

Due to the fact that water heated in the boiler is distributed through the pipes to the heaters, cooled and returned to the boiler, several distinctions of systems can be made (Krygier et al., 1991; Nantka, 2010):

- according to the manner of water circulation in system: gravity and pumping,
- according to the manner of connection with atmosphere: open and closed,
- according to the manner of pipes arrangements: one-pipe and two-pipes systems.

Central water heating, as the most popular heating system for single family buildings – which was mentioned in the previous section – can be divided into radiant and convector heating. Radiators and convectors are standard solution in heating installations. The specific information about designing of such systems can be found in many literature positions (Albers et al., 2007; Krygier et al., 1991; Koczyk and Antoniewicz, 2004; Nantka, 2006, Nantka, 2010; Kwiatkowski and Cholewa, 1980). On the other hand, surface radiant heating is relatively modern and energy-saving solution for houses and dwellings (Causone, 2010; Nowicki and Chmielewski, 1995) and therefore most of the attention in this chapter will be paid to designing this kind of systems.

Heating systems using radiant heating are more and more popular, both among private investors, as well as in public buildings. This heating system type is widespread in the West European Countries, however, in Poland the beginning of its application is dated on 90's of 20th century, due to the availability of plastic pipes (Koczyk and Antoniewicz, 2004; Nowicki and Chmielewski, 1995).

Practically all partitions in the room can be used as heating surfaces, so wall, ceiling and floor heating can be distinguished. Currently, the most popular heating system in single-family buildings is floor heating, where a circuit powered by hot water is a heating element. There are also electric surface heating systems, which use, among others, heating foils, however, due to economic conditions and technical limits, they are much rarely used (Nantka, 2006; Kowalczyk, 2002).

The water floor heating system in single-family buildings usually requires the radiators, because there are some limitations of its use, which makes it impossible to ensure the required temperature in such rooms as bathrooms (usually small floor surfaces do not provide adequate amount of energy) and staircases (installation of heating circuits under stairs is impossible). Furthermore, in view of floor heating's investment cost (about 30% higher than in the radiator heating), standard radiators are used in technical and support rooms, fulfilling the secondary function in the building. Restriction of floor temperature up to 29°C also influences the need to use radiators, because this temperature condition affects the maximum heat efficiency from the square meter of the partition.

The radiator and surface heating systems are characterized by different temperature of heating source. In the radiant (surface) heating system, the temperature of medium amounts maximally 55/45°C, while radiator heating system requires higher temperatures like 75/65ºC, 70/55ºC or even 90/70ºC. In view of the above, there are two basic mixed heating systems (Nowicki and Chmielewski, 1995):

- two separate systems with different heating medium temperatures,
- one system with temperature adjusted for specific heating system.

These two types of connections between convection system and floor heating system are shown in Figures 1.1 A and 1.1 B.

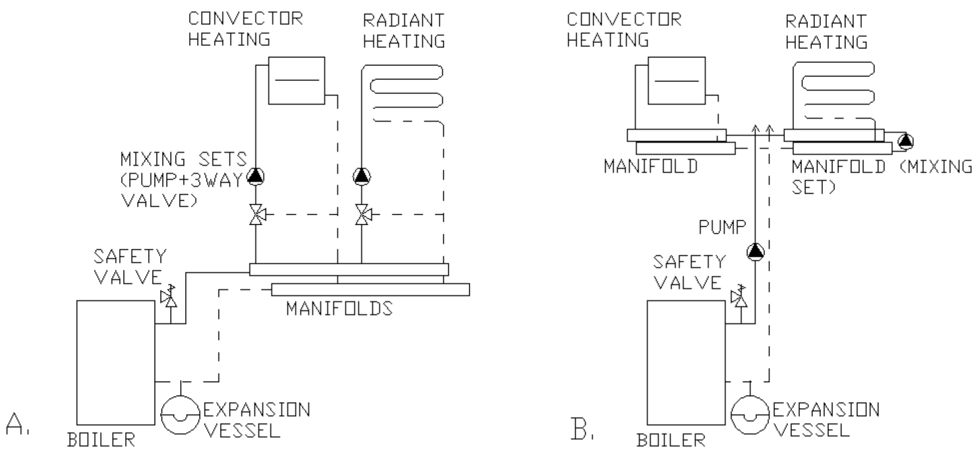


Fig. 1.1. Mixed system powered by medium: A) with different temperatures ensured by mixing sets, B) with temperature adjusted to the convection heating and local preparation of medium with radiant heating temperature (manifold with mixing set)

In the case presented in Figure 1.1 A, two separate circulations with the three–way valve temperature control are obeyed. In the case of 1.1 B, the heating medium distributed from boiler through the risers has a temperature specified for the radiator heating, however applying the compact manifold with the pump and mixing set ensures the parameters right for the floor heating system. This system is usually used in buildings, where the floor heating is designed only in particular, selected rooms (for example in the living room, kitchen and bathroom, while the other rooms are heated with radiators).

The mixed system can be powered both from solid fuel, gas and oil boilers. The surface heating system, due to relatively low temperature, can work together with condensate boilers, heat pumps and solar collectors (Kowalczyk, 2002; Oszczak, 2005).

1.1.1 Floor heating – basic theory

The Polish Standard PN-EN 1264-1, which introduces the guidelines of the European Standard, defines the components of floor heating system in the following way (PN-EN 1264-1):

- *"Floor heating system – installation consisting of floor heating, heating circuit distributors and control equipment.*
- *Floor heating – surface heating system, where pipes carrying water with or without additives as a heating medium are laid in the floor.*
- *Heating circuit – section of floor heating connected to a heating circuit distributor which can be independently switched and controlled.*
- *Heating circuit distributor – common connection point for several heating circuits.*
- *Heating floor area – area of the floor covered by the heating system between the outer pipes respectively the outer edges of the system with the addition of a strip whose width is equal to half the pipe spacing but not exceeding 0.15 m.*
- *Peripheral area – floor surface which is heated to a higher temperature and is generally an area of 1 m maximum in width along exterior walls. It is not an occupied area.*
- *Residence area – part of heating floor designed for longer stay."*

The basic feature of surface heating is the fact, that it delivers heat to the room mainly by radiation process (70% of the heat), therefore it is called radiant heating. This results in less intensity of convection currents, characteristic for the traditional radiator heating and moreover in very uniform temperature layout. Due to the limitation of supply temperature for surface heating system, temperature differences in heating room are smaller, so air movements are slighter. In comparison to the radiators as heating elements, it offers very hygienic conditions due to limitation of dust move and a lower air ionization (Kwiatkowski and Cholewa, 1980).

Typical floor heater is made as a heating circuit embedded in the screed. The Standard (PN-EN 1264-1) lists A, B and C floor heating types, differing location of heating pipes. The A-type refers to the floor heating with heating circuit embedded in the cement screed. The B-type refers to the system with heating pipes partially laid in the thermal insulation layer, while the C-type means heating circuit totally dipped in the leveling layer

The transfer of heat takes place initially by conduction between the heating medium and the pipe wall, across the screed and floor covering. Due to heating pipe spacing, floor temperature is not homogenous. Therefore, for the sake of calculations simplification, the term: *average heating floor surface temperature* was introduced, which is a resultant of temperatures in warmest (over pipes) and coolest (in the middle of pipe spacing) floor points (Figure 1.2) (Hepworth, 2009).

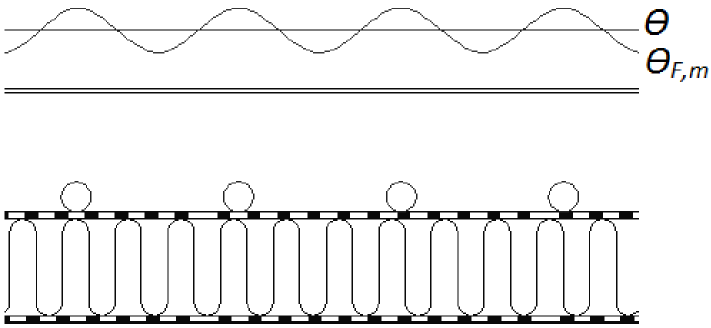


Fig. 1.2. Heating floor surface temperature layout

The heating floor temperature is specified by thermal comfort requirements (Maier and Tejchman, 2006) and it may amount between 25ºC and 35ºC (Kwiatkowski and Cholewa, 1978; Nantka, 2006; Rosiński and Spik, 2009). Vertical temperature distribution in a room heated by heating floor is highly similar to the perfect one, which provides thermal comfort conditions. This also results in the posibility of an average internal room temperature reduction for even about 2ºC, with thermal comfort requirements fulfilled. This relationship allows to reduce the costs of heating in winter season, due to the lower supply temperature required. Decrease of heating costs may even reach the amount of 10% during the heating season (Hepworth, 2009).

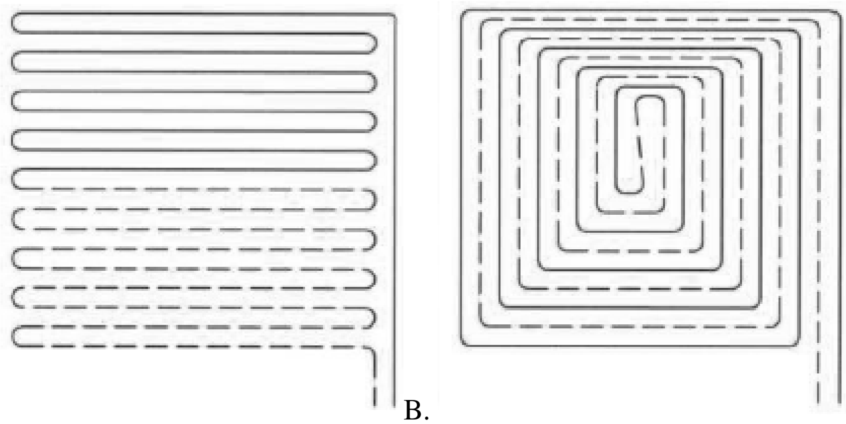
The stream of heat transfered into the room depends on (Hepworth, 2009):

- heating medium temperature,
- pipes embed depth,
- pipe spacing,
- indoor room temperature.

Due to slight differences between the heating floor temperature and indoor temperature, heating floor systems have a self-regulation ability. This process is connected with the decrease in the density of heat flow into the room as a result of rising room temperature and decreased temperature difference.

1.1.2 Structure of heating floor

Heating floor is an area of the floor, covered by the heating circuits, according to the definition contained in (PN-EN 1264-1). The main element is heating circuit, that delivers heating medium to the room. Due to pipe spacing in heating circuit, there are spiral systems (Figure 1.3 B) and meander systems (single or double) (Figure 1.3 A).



A. B.

Fig. 1.3. A) Pattern of the heating circuit in meander form with peripherial area, B) Pattern of the heating circuit in spiral form

The heating pipes spacing pattern has an effect on temperature layout in the room. Spiral system, more difficult in execution, causes more uniform temperature distribution, due to the fact that the supply and return pipes are parallel on the entire surface of the room. In case of meander system, heating floor temperature distribution is inhomogeneous. Characteristic for this system, irregular temperature distribution (temperature drop along the heating medium flow direction) can be used to compensate the increased loss in a specific parts of the room.

Aiming at compensation of the increased heat loss caused by the external windows, the peripheral area can be applied. The peripheral area is a part of the heating floor, or distinct heating circuit with pipe spacing smaller than the standard used in the room. Heating pipe spacing in the peripheral area is usually between 10 and 15 cm, while in residence zone it is 20 to 35 and even 40 cm. The peripheral area covers the surface of maximum 1 m in width along external wall with window.

Heating circuit can be laid in dry or wet systems (cement screed). The wet system types are specified in the Standard (PN-EN 1264-2). Illustrative diagram of the arrangement of the particular layers of the heating floor is presented in Figure 1.4.

The mentioned figure shows the basic elements of the floor heating system, and thus: the reinforced cement board, the thermal insulation layer (usually placed on a vapor-insulation barrier), sound insulation, system board for simplification of heat pipes installation, the layer of cement screed (4 – 7 cm) and floor covering layer.

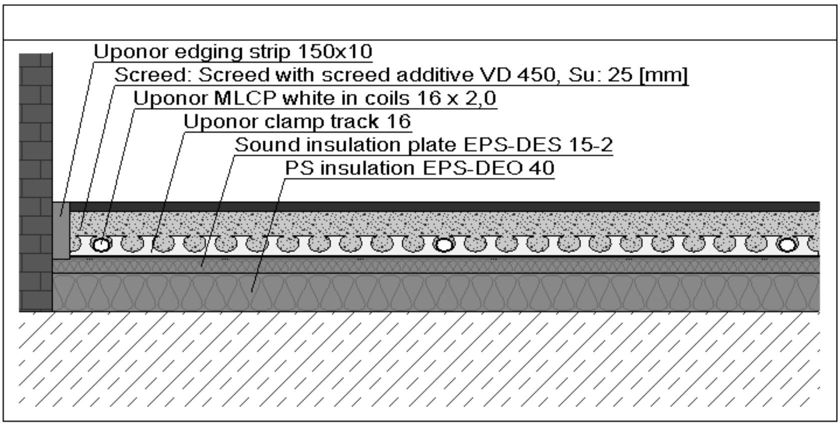


Fig. 1.4. Heating floor, wet system. The arrangement of the system layers with the clamp track 16 (Uponor system)

Suitable functioning of the heating floor depends mainly on the proper execution of thermal insulation. Thermal insulation should be designed to prevent the possiblity of dawnward heat flow exceeding 10% of the total heat flow. The whole heating floor is separated from the outer partitions using polyethylene tape, that fills the expansion joint. Pheripheral insulation, called the expansion joint tape, fulfills a protective function against heat loss and ensures the possibility of thermal compensation. The thickness of the expansion joint tape – pheripheral insulation – should be equal minimally 5 mm, while 8 mm thickness is recommended (www.uponor.com.pl).

Expansion joints in the heating floor are used in the case, when it is necessary to divide heating circuits and separate them from building partitions or building dilatations. The purpose of placing expansion layers between them is to allow for the transmission of thermal tensions caused by changes in the temperature of the heating floor, which prevents the occurrence of the cracks. By the use of the expansion joints, the heating circuits in the room with the irregular shape (L, Z, C) should be divided, in order to obtain a rectangle shape of the heating surface. The heating circuit should be divided into separate floors also in case when a maximum hydraulic resistance for a single loop or maximum length of the pipe (heating pipes must not be combined in a single heating circuit) are exceeded. Additionally, the division is necessary in the case of large, disproportionately long rooms, where the surface exceeds 40 m^2, the ratio of the sides is more than 2:1, or one of the sides is longer than 8 m (Kwiatkowski and Cholewa, 1980; PN-EN 1264-4). The transit pipes, passing through the dilatation should be protected by cover pipe.

The materials used to build the heating floor system should have certificates that allow for such use. As floor covering materials it is recommended to use the ceramics, terracotta, thin parquet and fitted carpet. There are also systems with smaller pipes diameters and low supply temperatures, which are allowed to be used under the panels.

1.1.3 Requirements for systems components

In accordance to the requirements set out in the standard (PN-EN 1264-3), there is a limitation of an average temperature of floor surface in heating floor systems. The most favorable temperature range is between 24 and 26°C, while it must not exceed 29°C. Due to the thermal comfort, the average floor surface temperature should not exceed (Nowicki and Chmielewski, 1995):

- 29°C – in residential area (residential rooms and offices),
- 35°C – in peripheral area (with the outer building walls),
- 33°C – in bathrooms,
- 27°C – in work rooms, where workers stand up.

Due to above presented rules, there is also a limitation for the maximum supply temperature. Allowable supply temperature is 55°C with the temperature difference between 5 and 10 K.

Because of the maximum allowed hydraulic resistance of the single heating circuit equal to 20 kPa, the value of water flow velocity in heating pipes should be in the range between 0.1 ÷ 0.6 m/s and the maximum length of a single loop equals 120 m (for multilayer pipes 16×2mm).

The efficiency of heat transfer to the room should not be less than 90%, while the downward heat transfer should not exceed 10%. Heat conduction resistance of the finishing layers should not exceed 0.15 m^2 K/W, and the resistance of the layers below the heating pipes should not be less than 1.5 m^2K/W. The average heat efficiency of 1 m^2 of the floor should be equal to about 80 W/m^2 (Nantka, 2006).

The peripheral areas constituting more than 20% of the room surface or exceeding 6 m^2 should be built as separate circuits, usually with the temperature difference 6 K. In the other case, a peripheral area, integrated with residence area can be designed with temperature difference 10K (Nowicki and Chmielewski, 1995; www.kisan.pl).

Manifolds used in the surface heating system should supply particular apartments at each floor. Each manifold is equipped with check valves and control valves for pressure equalization in the particular circuits. Control valves are installed on the return pipe. Manifolds set includes additionally shutoff valves and air bleeders. Floor heating manifold are installed in the central part of the apartment (e.g. hall, cleaning room) in concealed or on-wall cabinet (Nantka, 2006).

Heating floor effective surface should be estimated taking into account the floor area free of furniture, particularly kitchen furniture and bookcases. Anyhow, in some circumstances it is allowed to put pipes below the furniture and sanitary equipment on the request of the investor.

1.1.4 Designing of floor heating systems

Floor heating system should be taken into account at the design stage of the building investment, due to the special requirements for insulation properties of the partitions. The basics for the selection of heating floor are the calculations of the design heat load of rooms made according to the PN-EN 12831:2006 Standard, room dimensions and its shape. It is also necessary to establish the type of the floor covering at the design stage, due to the thermal resistance requirements.

The value of heat flow density can be calculated using below presented formula (www.kisan.pl):

$$q_{des} = \frac{Q_H}{F} \tag{1.1}$$

q_{des} – designed heat flow density [W/m^2],

Q_H – design thermal output of floor heated room [W],

F – heating floor surface [m^2].

Initial calculations ought to be conducted for the accommodation space with the greatest specific thermal output value. With the assumed supply and return temperatures and the internal room temperature, the average arithmetic temperature difference can be calculated (www.kisan.pl):

$$\Delta\theta_{av} = \frac{\theta_s + \theta_r}{2} - \theta_i \qquad (1.2.)$$

$\Delta\theta_{av}$ – average arithmetic temperature difference between heating medium and room temperature [K],

θ_s – supply medium temperature [°C],

θ_r – return medium temperature [°C],

θ_i – internal room temperature [°C].

Using producers guidelines it is possible to match pipelines spacing, when $q \cong q_{des}$ condition is fulfilled and the acceptable floor temperature is not exceeded. Basing on covering layer thermal resistance, the average arithmetic temperature difference and specific thermal output, it is possible to match pipelines spacing.

Thermal output per 1 m of a pipe can be calculated using the below equation (www.kisan.pl):

$$q_l = q \cdot a \qquad (1.3.)$$

q_l – thermal output per 1 m of a pipe of heating circuit [W/m^2],

q – specific thermal output, read from tables [W/m^2],

a – pipes spacing [m],

The required length of the heating circuit is then calculated as (www.kisan.pl):

$$l = \frac{Q_H}{q_l} \quad (1.4.)$$

l – heating circuit length [m],

Q_H – design thermal output of floor heated room [W],

q_l – thermal output per 1 m of a pipe of heating circuit [W/m^2].

If the length of the circuit exceeds 120 m (Ø16 mm), it should be divided into several circuits, for which separate heating and hydraulic calculations should be carried out. Supply temperature for heating circuit connected in parallel is the same.

After drawing the heating circuit in a room, the mass flow of the heating medium and the pressure drop caused by water flow through the circuit should be calculated, checking the condition of Δp < 20 kPa. In case of exceeded 20 kPa of pressure loss, the heating circuit should be divided and the calculations for each part should be repeated.

Specific guidelines concerning the heating and hydraulic calculations and dimensioning of heating floor pipes are included in the standards (PN-EN 1264-1, PN-EN 1264-2, PN-EN 1264-3, PN-EN 1264-4; www.kisan.pl).

1.2 Water supply systems in single-family buildings

1.2.1 Water supply systems – basic theory

Together with central heating, water supply systems are basic installations used in almost all buildings. Water supplying the internal systems is delivered from the water distribution networks or from individual water intakes. They are the complicated systems containing many elements like water intake, pump stations, water treatment plants, reservoirs, which are out of scope of this monograph and will not be discussed here.

This sub-chapter is devoted to indoor water supply systems and the regulations determining their designing, building and finally operation. According to (Chudzicki and Sosnowski, 2011) there are more than 20 documents (regulations and depositions) forming the rules of water supply systems designing and exploitation. Among them, there are the Acts of Parliament and Regulations of Polish Ministers. Morover, in designing practice there are commonly used Polish Standards, guidelines and technical literature.

The most important documents determining the methodology and rules of water supply systems designing are the following:

- Regulation of the Polish Minister of Infrastructure dated 12 April 2002 on technical requirements which have to be met by buildings and their situation (Journal of Laws - Dz. U. Nr 75, item 690 with subsequent amendments),

- Polish Standard PN-92/B-01706, Installations for water supply. Design (canceled without replacement).
- European Standard PN-EN 806-3:2006 – Specifications for installations inside buildings conveying water for human consumption – Part 3: Pipe sizing – Simplified method .

1.2.2 Structure of water supply systems

According to above mentioned Polish Standard PN-92/B-01706 the most important elements of water supply system are:

Water supply installation – system of elements providing water supply in building object and its surrounding, working as a whole system.

Hot water system – part of water supply installation used for hot water production and its delivery to the draw-off points.

Water connection – pipeline connecting water source (water distribution network or individual water intake) with indoor system.

Draw-off point (point of use)– point of water consumption.

Available pressure – hydraulic pressure at the point of water supply source in computational conditions.

Central domestic hot water system – hot water system where hot water is produced in boiler room.

Individual domestic hot water system – hot water system with hot water production for one or a few draw-off points set in common room.

The most important elements of water supply systems are:

- pipes of cold, hot and circulation systems,
- pumps or pumping stations,
- fittings (stop valves, non-return valves, backflow preventers, regulation valves, air bleeders, pressure meters, temperature meters, filters)
- water meters,
- water heaters, hot water storage tanks,
- mixers, taps and other types of draw-off points,
- manifolds,
- etc.

In general, each water supply system starts in bottom floor (basement or the groundfloor) after the building entrance, at main valve of the water meter set. It consists of the horizontal water pipelines and the vertical risers presented in Figure 1.5, delivering water to the particular floors by the branches, delivering medium to the particular draw-off points (Sosnowski, 2000).

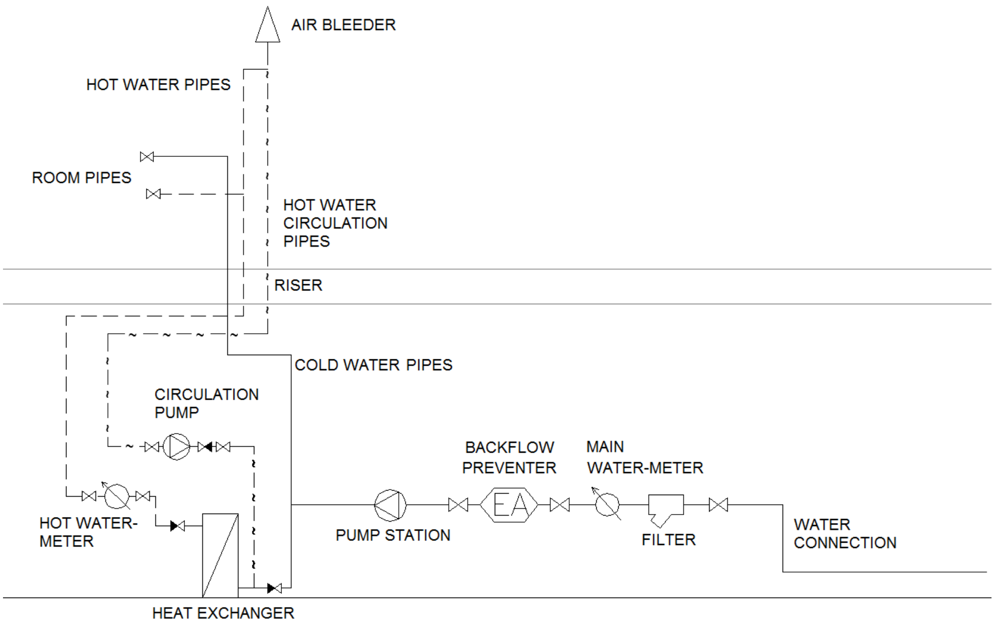


Fig. 1.5. Water supply system schematic view

In most cases water meter set at the system entrance should consist of stop valves, filter and main water meter. After water meter set, backflow preventers are used, which will be more extensively described in the next sub-chapter. In multi-family and public objects it is required (Regulation of the Polish Minister of Infrastructure dated 12 April 2002) to locate water meter sets in a separate, technical room, which is not obligatory for single family houses. If necessary, the next element of water supply system is pump station, which can be also set in water meter room.

Another important element of water supply system is the heat exchanger which produces hot water for the supply system. After water is heated, it is delivered by separate pipelines (hot water pipes) to the draw-off points. In case of the individual domestic hot water systems this element is not present, and whole cold and hot water is supplied using the same pipes. Hot water is produced locally in particular rooms with draw-off points. This solution will not be widely presented in this monograph. More advanced solution is a central domestic hot water system, where hot water is produced in boiler room together with hot water for central heating (Chudzicki, 2006). This approach requires application of extra pipes, parallel to cold water pipes. Together with hot water pipes it is suggested to apply hot water circulation system, which will enable constant circulation of hot water, even without hot water consumption. According to Polish regulations (Regulation of the

Polish Minister of Infrastructure dated 12 April 2002) it is allowed not to use hot water circulation in single family houses or in situations where total pipes capacity is lower than 3 dm3, anyhow it is strongly recommended to apply this solution due to bacteriological protection and hot water system efficiency (Chudzicki, 2012).

Depending on water distribution, the following systems are used (Antonowicz, 1976):

- bottom water distribution (most often applied in new systems, with water flow towards upwards direction; the advantage of this solution is good air prevention by draw-of points at highest floor),
- upper water distribution (with water reservoirs, not used in single family houses, with water flow downwards),
- ring water supply system (the most inevitable system, delivering water from many directions, anyhow not applied in single family houses).

Another important division of water supply topology is division into (Chudzicki and Sosnowski, 2011): one zone water supply system (in lower buildings), two- and more-zones water supply system (applied for higher buildings with available pressure not enough to provide water delivery to the higher floors, not applied in single family buildings).

To the particular floors of single-family or multi-family buildings water is delivered by vertical pipelines called risers (Figure 1.5) and there by tees or manifolds is delivered to the flats or particular rooms. In case of multifamily buildings there are also water meters applied for cold and hot water (Figure 1.5).

Similarly to central heating systems, water supply system pipes are made of galvanized steel, copper and plastic. The most important information about pipes and other materials are presented in the following monographs: (Gassner, 2008; Chudzicki, Sosnowski, 2011; Panas, 2011).

1.2.3 Designing of water supply systems

Designing of water supply system ought to be conducted basing on the requirements and regulations presented in the 1.2.1. sub-chapter of this monograph.

According to them, the maximum pressure in water supply system should not exceed 0.6 MPa (60 mH_2O) and should not be lower than 0.05 MPa (5 mH_2O) which means that in case of too high available pressure it is necessary to reduce it using the suitable fittings. On the other hand it may be necessary to apply pump stations to rise it, in case of too low pressure in the highest draw-off points.

According to (Chudzicki and Sosnowski, 2011) solution of water supply system depends on object type and investor requirements. From the point of view of this monograph, the most important are residential, single family buildings. Sanitary equipment for all buildings type is precisely determined in the following monograph (Chudzicki and Sosnowski, 2009).

In general, designing of water supply system is divided into the following parts (Chudzicki and Sosnowski, 2011):

- establishing water supply connection and positioning the main valve with water meter set,
- positioning of draw-off points, boilers, etc.,
- guiding the pipelines,
- hydraulic calculations (water flow in particular system sectors, hydraulic resistance and pipes dimensions) of cold water, hot water and, if necessary, hot water circulation,
- matching the necessary fittings: backflow preventers, pressure limiting valves, water meters etc.,
- calculating the minimal available pressure for the whole system and matching the suitable pump station if necessary.

For efficient system functioning it is required to calculate the suitable dimensions of pipes and calculate the minimal pressure available. According to the Polish Standard PN-92/B-01706 it is divided into the particular stages:

- division of the whole system into the particular calculation sectors,
- determination of computational flows for the particular sectors,
- matching the pipes dimension for the particular sectors,
- determination of hydraulic resistance,
- determination of minimal pressure available for the whole water supply system.

The most significant parameter for hydraulic calculations is computational water flow. While this monograph is elaborated, Polish Standard PN-92/B-01706, which is more than 20 years old and sometimes not adequate according to new living standards etc., is still applied and procedures presented in this regulation are still obeyed. In this document, the most significant parameters are: computational water flow and normative outflow from the draw-off points. Normative outflow (q_n) values are listed in the Table 1.1 of the discussed Polish Standard. They are expressed in dm^3/s and are characteristic for the particular types of draw-off points, which means that normative outflow values differ for taps, mixers, hose connections, shower heads, toilet flush tanks or urinal bowl flush pipes.

For hydraulic calculations computational flow is the most important and depends on the following factors:

- object type (residential, office, administrative, hotels etc.),
- the sum of normative outflows (Σq_n) [dm^3/s].

To calculate the computational flow, it is necessary to use one of the below presented formulas which are determined in Polish Standard PN-92/B-01706 and are set in (Chudzicki and Sosnowski, 2011) in the following table form.

Table 1.1. Formulas for determination of computational flows according to PN-92/B-01706 and Chudzicki and Sosnowski, 2011

Object type	Formula	Remarks
Residential buildings	$q = 0.682 \cdot (\Sigma q_n)^{0.45} - 0.14$	for $0.07 \le \Sigma q_n \le 20$ dm^3/s and fittings with $q_n < 0.5$ dm^3/s
	$q = 1.7 \cdot (\Sigma q_n)^{0.21} - 0.7$	for $\Sigma q_n > 20$ dm^3/s and fittings with $qn \ge 0.5$ dm^3/s
Office and administrative buildings	$q = 0.682 \cdot (\Sigma q_n)^{0.45} - 0.14$	for $\Sigma q_n \le 20$ dm^3/s
	$q = 0.4 \cdot (\Sigma q_n)^{0.54} + 0.48$	for $\Sigma q_n > 20$ dm^3/s
Hotels and markets	$q = (\Sigma q_n)^{0.366}$	for draw-off points with $q_n > 0.5$ dm^3/s and $1 < \Sigma q_n \le 20$ dm^3/s
	$q = 0.698 \cdot (\Sigma q_n)^{0.5} - 0.12$	for draw-off points with $q_n < 0.5$ dm^3/s and $0,1 < \Sigma q_n \le 20$ dm^3/s
	$q = 1.08 \cdot (\Sigma q_n)^{0.5} - 1.83$	for $\Sigma q_n > 20$ dm^3/s (for the hotels)
	$q = 4.3 \cdot (\Sigma q_n)^{0.27} - 6.65$	for $\Sigma q_n > 20$ dm^3/s (for the markets)
Hospitals	$q = 0.698 \cdot (\Sigma q_n)^{0.5} - 0.12$	for $\Sigma q_n \le 20$ dm^3/s
	$q = 0.25 \cdot (\Sigma q_n)^{0.65} + 1.25$	for $\Sigma q_n > 20$ dm^3/s
Schools	$q = 4.4 \cdot (\Sigma q_n)^{0.27} - 3.41$	for $1.5 < \Sigma q_n \le 20$ dm^3/s for $\Sigma q_n \le 1.5$ dm^3/s, $q = \Sigma q_n$
	$q = -22.5 \cdot (\Sigma q_n)^{-0.5} + 11.5$	for $\Sigma q_n > 20$ dm^3/s

From the point of view of this monograph, the first formula in Table 1.1 is the most important. This is caused by the fact, that single-family house is a residential house with small total normative outflow (Σq_n), not exceeding 20 dm^3/s. This formula will be applied in calculations presented in the practical part of this elaboration. Formulas presented above consider that water consumption is not an uniform phenomenon and it may vary depending on type of the building, thus computational water flow is a resultant of both parameters: object type and the sum of normative outflows.

It must be underlined here, that PN-92/B-01706 Polish Standard was cancelled in 2009 and no new regulations have been introduced. Even European Standard PN-

EN 806-3:2006 introduced in 2006 is not always applicable in designing of more complicable systems (Jeżowiecki and Nowakowski, 2011). According to its title, this regulation suggests to use a simplified method of pipes dimensions calculating, using load units (LU) depending on draw-off points types. Anyhow, the authors of this book decided to discuss PN-92/B-01706 Polish Standard, being still in common use. Also described in the third chapter CAD tool (Instal-San T) applies that standard for calculations.

One of the most important hydraulic parameters is water velocity in pipes, which, according to PN-92/B-01706, should not exceed:

- 1.5 m/s in sectors between the raisers and draw-off points,
- 1.5 m/s in the raisers,
- 1.0 m/s in the distribution pipelines,
- 1.0 m/s in the water source connections.

It must be explained, that above presented maximum velocities are suggested for steel pipes. In case of using of other pipelines types or materials it is suggested to follow the producers instructions. In general it can be assumed that for plastic pipes, maximum velocities can be increased for about 0.5 m/s comparing to steel ones, anyhow it is suggested to verify this in above mentioned instructions.

Hydraulic resistance is the resultant of the following flow parameters:

- computational water flow,
- water velocity,
- pipeline dimension.

Thus, with this parameters it is possible to determine pressure loss in particular sectors of the pipeline system.

In general, hydraulic pressure loses are divided into linear pressure drop and pressure drop in pipe fittings. Theory for fluid mechanics and hydraulics is out of the scope of this monograph, thus it will not be widely discussed in this place, anyhow it should be mentioned that linear pressure drop can be calculated using the following formula (PN-92/B-01706):

$$\Delta p_l = 0.5 \cdot \lambda \cdot \frac{1}{d_i} \cdot v^2 \tag{1.5}$$

λ – linear drop coefficient [-], depending on roughness coefficient "*k*",
l – length of the sector [m],
d_i – internal pipeline diameter [m],
v – average flow velocity [m/s],
ρ – water density [kg/m^3].

Pressure drop in pipe fittings can be determined using the following formula:

$$\Delta p_m = 0.5 \cdot \rho \cdot \zeta \cdot v^2 \tag{1.6}$$

ζ – coefficient of fitting pressure drop [-].

It must be underlined that for designing of water supply systems, hydraulic pressure drop is calculated using simplified methods, based on application of nomograms with visualized characteristics of pipelines. For typical pipes it is possible to use appendixes in Polish Standard PN-92/B-01706. Otherwise it is suggested to use the diagrams proposed by pipes producers, where hydraulic characteristics are presented for each pipe type and diameter depending on many factors, even temperature.

For designing process and the design execution, the most important task is assignation of the suitable pipe diameters to the particular sections. They depend on water flow and water velocity. Basing on those two, suitable pipeline diameter should be assigned and linear pressure drop checked.

Also it must be mentioned here, that Computer Aided Designing applications like Instal-therm HCR or Instal-San T are equipped with pipelines characteristics, that are assigned to the projects during designing, which acquits the designer from using the nomograms and makes work more efficient.

Considering pressure drop in pipe fittings, it should be mentioned that for simplified calculations it is possible to assume the approximate values of pressure loss. According to PN-92/B-01706, it can be assumed that fittings loss is about 30% of linear loss, anyhow new literature sources suggest to assign the following values (Brydak-Jeżowiecka et al., 1994; Sosnowski et al., 2000; Chudzicki and Sosnowski, 2011):

- 20 – 25% for steel pipes,
- 100 – 150% for plastic pipes.

This is mainly connected with improved hydraulic properties of modern pipes, their lower roughness and thus smaller linear pressure drop.

Next step in water supply designing is to design and calculate hot water system and hot water circulation system, if necessary. Designing procedure will depend on type of the assumed solution.

Hydraulic calculations of hot water system are the same as cold water system calculations, the only difference is connected to the smaller number of draw-off points (not all sanitary equipment requires hot water – toilet flush tank, urinal bowl, washing machine for example). Computational water flow of hot water influences hydraulic calculations (pipelines diameters, hydraulic resistance, etc.) and consequently it also influences total water flow of the whole system (at the building entrance).

According to Polish Standard PN-92/B-1706 and Chudzicki and Sosnowski, 2011, computational water flow in circulation pipelines is calculated using two formulas:

$$q_{mc} = \frac{Q_c}{\Delta t \cdot C_w} \tag{1.7}$$

q_{mc} – computational mass flow of circulation water [kg/s],

Q_c – heat loss along circulation pipelines [kW] calculated using instructions contained in (Chudzicki and Sosnowski, 2011),

Δt – computational temperature loss between the heat exchanger and the most inconvenient draw-off point [K], (5÷10 K),

C_w – water specific heat, [kJ/(kg·K)]

and

$$q_{vc} = \frac{V_p \cdot u}{3.6} \tag{1.8}$$

q_{vc} – computational volumetric flow of circulation water [dm^3/s],

u – number of circulation loops (between 3 and 5 per hour),

V_p – water volume in hot water and circulation pipelines [m^3].

Further calculations are based on the computational flow, which is greater from the one calculated using the above formulas. This flow is a base for hydraulic calculations:

- determination of hot water circulation pipes diameters,
- determination of hot water circulation pressure drop,
- determination of circulation pump,
- system regulation.

This procedure is not covered in this elaboration and is more precisely presented in (Chudzicki, 2006; Muszyński, 2009; Orłowska-Szostak and Orłowski 2011; Chudzicki and Sosnowski, 2011). Also, this monograph does not present the methodology of determination of hot water heat exchanger, which can be also found in the previously mentioned monograph and Polish Standard PN-92/B-1706.

Next step of water supply system designing is matching the suitable fittings like water meter, backflow preventer etc. An important part of each water supply system is a water meter which is used for water consumption determination and is the base for official reckonings between water provider and the consumer. Water meter topology is quite complicated and due to limitations of this monograph will not be presented here, anyhow it can be found in the following monographs (Gassner, 2008; Chudzicki and Sosnowski, 2011). Generally it should be underlined, that today's standard is to use one water meter in single family houses (at system entrance) and several water meters in multifamily houses – main water meter at system entrance and small, apartment water meters divided into cold water and hot water type.

Water meter determination is also standardized in PN-92/01706, which means that does not match current standards of water consumption (Gwoździej-Mazur and Tuz, 2002; Cholewa et al., 2009) and water meters selected with this method are often overestimated, which in turn, may result in wrong readouts of water consumption. Anyhow this Polish Standard has not been replaced by any official document yet and this methodology is still valid and will be presented in this monograph. Another attempts to the following task is presented in the following documents (Orłowska-Szostak, 2011)

To match the suitable water meter, the computational water flow for the building (or part of a building) should be determined and assumed water flow of water meter q_w should be calculated according to the equation:

$$q_w = 2 \cdot q \tag{1.9}$$

q_w – assumed water flow of water meter [m^3/h],
q – computational water flow [m^3/h].

After the assumed water flow is calculated, a suitable water meter device may be matched to this parameter, comparing q_w with maximal water flow of water meter q_{max}, established by the device producer.

After the suitable water meter is matched the following conditions must be checked:

$$q \le \frac{q_{\max}}{2} \text{ and } DN \le d \tag{1.10}$$

which means that the nominal diameter (DN) of matched water meter [mm] is not greater than the diameter of a pipe, where the discussed water meter is mounted on.

Final step of water meter matching is calculation of pressure drop, which can be done using data from the producers, comparing computational water flow with pressure drop on particular device.

Another elements of water supply system, which should be matched at this stage of installation designing are backflow preventers (system separators) which protect water distribution network or part of the installation from backflow and potential water contamination. Theory for backflow preventers is widely presented in following documents: PN-92/B-01706/Azl: 1999, replaced by PN-EN1717:2003; Gassner, 2008; Chudzicki and Sosnowski, 2011. From the point of view of the problems considered within this monograph it will be enough to underline that the following fittings may be used:

- EA check vale backflow preventer – for domestic systems,
- BA backflow preventers – for increased requirements,
- HA system separators for hose connectors,
- GA system separators for Water Treatment Stations.

Matching of the proper backflow preventer is important due to water quality protection, but it is also important for hydraulic calculations of minimal available pressure. This is caused by high pressure drop on backflow preventers (especially BA backflow preventers) which may strongly influence total pressure drop of the water supply system (Skiba 2011; Widomski et al., 2011).

After the above presented elements of water supply system are calculated and matched to the whole system it is possible to determine total pressure drop and calculation of available pressure for the system, which can be calculated using the below formula:

$$p_{\min} = h_g \cdot \rho \cdot g + p_w + \Delta p_l + \Delta p_m + \Delta p_{wm} + \Delta p_{exch} + \Delta p_{bp} \qquad (1.11)$$

p_{min} – total pressure drop in water supply system [m],

h_g – height difference between the highest draw-off point and main pipe [m],

ρ – water density [kg/m^3],

g – standard gravity (9.81 m/s^2) [m/s^2],

p_w – water pressure at draw-off point (5÷10 m) [m],

Δp_l – linear water pressure drop [m],

Δp_m – water pressure drop in fittings [m],

Δp_{wm} – water pressure drop in water meter [m],

Δp_{exch} – water pressure drop in heat exchanger (depending on boiler room technology) [m],

Δp_{bp} – water pressure drop in backflow preventer [m],

After the available pressure is calculated, it should be compared with pressure offered by water distributor. If the calculated available pressure exceeds pressure provided by water distribution network, pump station must be applied to the system, with the following parameters:

$$p_p = 1.2\left(p_{\min} - p_{dist}\right) \qquad (1.12)$$

$$q_p = 1.2 \cdot q \qquad (1.13)$$

p_p – pump station pressure [m],

p_{dist} – water pressure provided by distributor [m],

q_p – water flow of pump station [dm^3/s].

In case of single family buildings it hardly ever happens that minimal required pressure is exceeded, which is caused by small complicity of domestic systems and low geometric height of such a water supply system.

Another significant element of water supply system, which does not influence the hydraulic parameters of the system is insulation of pipelines. Insulation is mainly important for exploitation. Major tasks realized by pipelines insulation is prevention from water condensation on cold water pipelines and prevention of extraordinary heat loss on hot water and circulation systems. Regulations for pipelines insulation are contained in Regulation of the Polish Minister of Infrastructure dated 12 April 2002 and are stated in Table 1.2.

Table 1.2. Requirements for thermal insulation of pipes and elements connected to water supply systems (Regulation of the Polish Minister of Infrastructure dated 12 April 2002)

No	Type of pipe or type of element	Minimal thickness of thermal insulation (λ=0.035 W/(m·K))
1	Internal diameter up to 22 mm	20 mm
2	Internal diameter between 22 and 35 mm	30 mm
3	Internal diameter between 35 and 100 mm	equal to the internal diameter of pipe
4	Internal diameter over 100mm	100mm
5	Pipes and fittings from points 1-4, crossing the partitions, ceilings or pipelines crossing	½ of requirements from point 1-4

Above described information and procedures concerning water supply systems are basic and for professional application should be extended with other, more detailed literature. Anyhow they should be helpful for those who start designing sanitary installations and should be treated as necessary introduction for Computer Aided Designing techniques which will be presented in the further part of this monograph.

2 Description of the designing tool

2.1 InstalSystem 4.11 package

InstalSystem 4.11 package offered by the InstalSoft Company in full version includes the following applications: Instal-therm HCR, Instal-heat&energy, Instal-San T and Scan Combine. Information on the use of the Scan Combine application can be found in the textbook *Lessons* for Instal – therm HCR, Instal – heat&energy and Instal – San T software available via InstalSoft website.

The subject of this book is combination of Instal-therm HCR, Instal-heat&energy and Instal-San T. Program Instal-heat&energy is intended for calculation of heat load and seasonal energy demand for building within the current Polish-European Standard PN-EN 12831: 2006. Program Instal-therm HCR is intended for the graphical part of the design: drawing and selection of radiators, heating systems (double- and single-pipe systems) and radiant surface heating systems (floor and wall heating systems). Both of these applications, as it has been underlined in the introduction, are fully compatible and can work on a single file, which significantly simplifies the designing process. Instal-San T program is intended for the designing of water and sewage systems, which will be described in the second part of this study. It uses the same file type and is compatible with both above described applications.

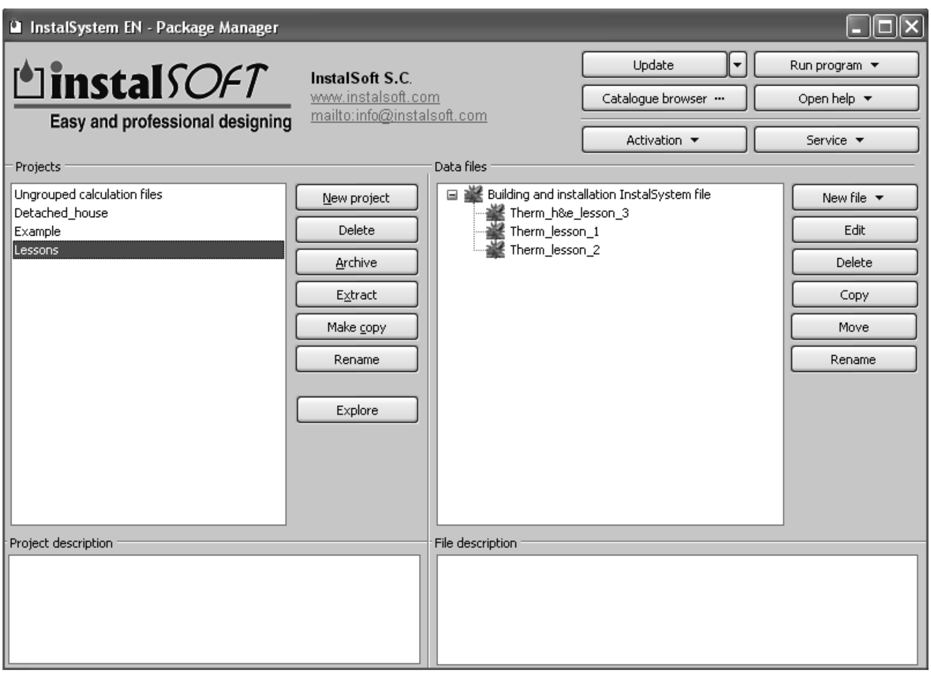


Figure 2.1. Package Manager for InstalSystem EN

The launch of InstalSystem package is executed by the Package Manager (Figure 2.1). The Manager enables program activation by entering the required license, update and view of the available catalogues and support of service. New projects are archived in the folder created in the Documents folder of user's computer (this location is selected automatically, but it can be changed during installation). Files editing requires the launch of one of the applications included in the package. Building and installation files of InstalSystem package have the extension *.isb, and backup files – *.~ ib.

2.2 Description of Instal-therm HCR and Instal-San T windows

Since both applications are intended for drawing of installation, the main windows of Instal-therm HCR and Instal-San T look the same. They differ only in the project edit scopes (Figure 2.2). In the Instal-therm HCR application it is possible to edit the following scopes: *Heating*, *RH loops drawings*, *Construction*, *Base*, *Printout*, while under Instal-San T only *San*, *Construction*, *Base and Printout* are active. That is why the more detailed description will be presented only for Instal-therm HCR, as this part of package is more complicated.

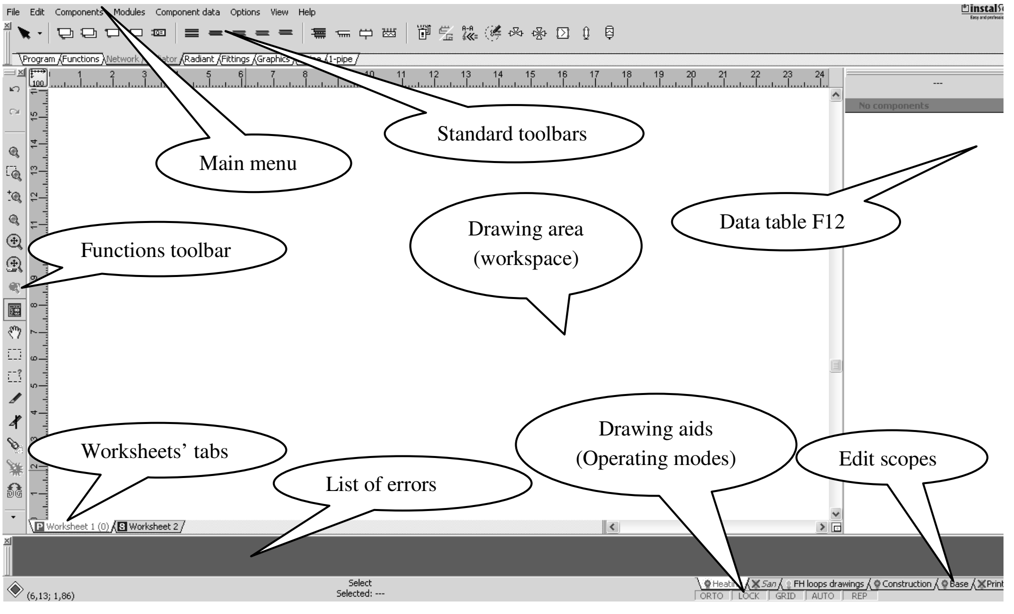


Figure 1.2. Instal-therm HCR main window

The main menu of Instal-therm HCR consists of the following fields: *File, Edit, Components, Modules, Component data, Options, View* and *Help*. It is suggested to check the functionality of each program feature by the user himself. Below, there are the main component functions described:

File: except of the standard functions as opening, closing and saving the file, it allows to start calculations, manage worksheets and import or export drawings.

Edit: it contains the basic Windows system functions like *Copy, Paste, Delete*, but also a useful selection tool, which allows to select components of the particular type (for example only radiators, walls or base, depending on the project edit scope).

Components: this tab contains functions useful for installation drawing, like automatic connection of elements, lock, flip, division, etc..

Modules: it is a useful option for installations drawing, where some recurrent group of components can be saved as module and pasted in the necessary localizations.

Component data: it includes functions which allow to add room numbers automatically, check connections between elements and create the pairs of primary and shadow elements.

Options: they contain *Project options* (F7) and catalogues database. *Project options* are the significant part of designing and they will be described in the practical part of the book.

View: it contains zoom scales, as well as the toolbar options and other elements visible in the window of program. Furthermore, it allows to show the critical hydraulic circuit.

Help: it contains the menu of help and connection with service website.

The next element that needs to be described is a *Standard toolbar*. This toolbar is consisted of several tabs. There are two constant tabs: *Program* and *Functions*, which are available under all the project scopes. *Functions toolbar* is visible all the time at the left side of the window as a separate tool (Figure 1.2). A rest of the tabs differ depending on the project scope. For example, in scope of *Heating*, there are additionally *Network / radiator*, *Radiant*, *Fittings, 2-pipe* and *1-pipe* tabs, including elements of heating installation to be added to created drawing. Under *RH loops drawing*, there is an additional tab called *Radiant*, where polylines for drawing the circuits (automatically or manually) are situated. Under *Construction* edit scope, *Standard toolbar* is additionally consisted of *Elements* tab, where the partitions of building and other elements connected with its structure can be found. It should also be mentioned, that the *Standard toolbar* can have different commands and icons in the worksheet of schematic view, which will be described below.

Worksheet tabs allow to move between different parts of the project of building. It is an important information because in Instal-therm HCR and Instal-San T every storey of building has to be located in separate worksheet. In standard option, we have two basic worksheets: *Worksheet 1* and *Worksheet 2*, representing plan view and schematic view of the installation respectively. Plan view aims in presentation of storey, while schematic view is intended to show the developed view of installation. Because of these differences, the editing of schematic view is possible within the scopes of: *Heating*, *San*, *Construction* and *Printout*. The meaning of commands included in the toolbars is also adjusted to this kind of drawing.

The workspace is enclosed on left–hand side and top by the rulers. These rulers (horizontal and vertical) are intended to control the position of components of the drawing. The button between the rulers enables changing the current scale. On the opposite side of the workspace, there are sliders, again vertical and horizontal. They are used to move the drawing area. In the corner between the sliders, there is the navigator, which assists moving within the workspace.

The *list of errors* is necessary for the appropriate hydraulic calculations of the installation. There are three types of basic statements:

errors – the most important messages, displayed in capital letters. All *errors* that occur in project must be corrected; if not it will be impossible to achieve all results of calculations,

warnings – the messages less important than errors. They do not block further calculations. *Warnings* are usually connected with data or results that should be checked,

hints – the messages aiming in reminding of some data or results. *Hints* do not block further calculations.

To check where exactly the element with error is situated, it is necessary to click on the chosen message. The wrong or suspicious element will be then underlined by yellow color.

Drawing aids called also operating mode fields are intended to facilitate the drawing functions. They include:

ORTO – allows to draw only in horizontal or vertical position.

LOCK – locks the elements on drawing so that they cannot be moved.

GRID – allows to draw only with some specified distance.

AUTO – an automatic search and connection of components to the closest one.

REP – repeating of the selected command.

2.3 Description of Instal-heat&energy window

Since the Instal-heat&energy application is intended for calculation of heat loss, it does not contain the worksheets with graphical presentation of building. However, as it was underlined in the introduction, it cooperates and is fully compatibile with Instal-therm HCR, which in practice means that all the dimensions of building partitions are imported from the graphical part of the project and do not have to be introduced manually, which is characteristic for the competitive programs.

The main window of Instal-heat&energy is presented in the Figure 2.3. It contains the program menu (*File, Edit, View, Tools, Window, Help*), editing categories / subcategories, clipboards, main toolbar and list of errors. Editing categories are the most important part of the program and therefore they will be described in detail.

The main editing categories include *General data*, *Partition definitions*, *Building structure* and *Calculation results*. All of these are divided into subcategories, which include one or more data tables accessible as tabs.

General data includes five subcategories:

Project description – this subcategory includes data table to fill in the description of the project, information about developer and designer, as well as info about the file.

Calculation standards and options – they are divided into *General*, *Name patterns* and *Results units*. *Name patterns* and *Results units* are intended for the predefinition of building elements' names and units of results expression, while *General* category includes the important settings for calculation methods and allows to choose the standards for heat loss and thermal bridges computation.

Building data – another important category divided into two tabs: *Climatic data* and *Heat loss calculation data*, where the choice of weather station and some characteristic of a building is possible. The data include type of building, sheltering class, tightness, ventilation type and characteristic dimensions.

Radiator sizing data – options for radiator selection in the case that the application is used only for heat losses calculation and radiator sizing, without the graphical presentation of project.

Expression variables – characteristic values of predefined storey height, floor thickness, etc.

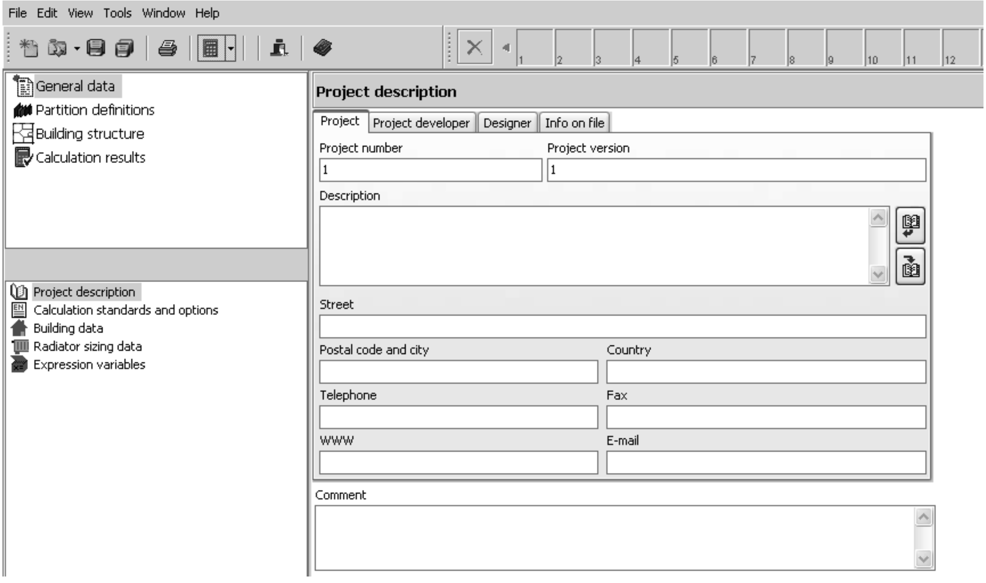


Figure 2.3. Fragment of the main window of Instal-heat&energy module

Partition definitions enable the calculation of heat transfer coefficient U [W/m^{2}K] by the use of building materials data library. Each partition of a building should be defined as consisted of individual materials, characterized by the density, specific heat, thermal conductivity (library data) and thickness of a layer (user data). The mode of definition creation will be described in detail in the practical part of this book.

Building structure includes the list of storeys, rooms and partitions and their characteristics of the calculated building. It is an useful tool to check the correctness of automatic computations (if the heat loss in the room is not calculated properly, it will be marked as "*???*" and the mistake is easy to be found in the list of partitions). In case when the project is only calculated in the Instal-heat&energy module, it enables to count heat loss by the creation of new rooms with partitions of specified dimensions and types defined in the *Partition definitions*.

Calculation results feature is intended to export the final results to the MS Excel file or to print them out directly from the program. The results are divided into several categories (*General data*, *Results for building*, *Room parameters*, *List of heat losses in rooms*, *Room data and results*, *Data and results for partitions*, *Partition list*, *List of heat losses through partitions*, *List of radiators in rooms*, *List of radiators*), which can be printed separately.

3 Examplary design of sanitary sysems

In this chapter, two complete examples of installations designing in InstalSystem package will be presented. The first case, described in section 3.1., concerns the heating installation designing, including design heat load calculation, hydraulic computations and graphical part of project. In the second case, the attention was paid on the water supply system in the designed single-family building.

3.1 Project of central heating installation for the detached house

3.1.1 Creation of a new file

The first step of the designing in InstalSystem package is the use of Package Manager. The main window of Package Manager is presented in Figure 3.1. It is consisted of two main areas with the list of folders (left side) and the list of files (right side of a window). Moreover, it includes the buttons for editing of the new file or project (folder), as well as the buttons for update, activation, catalogues database search and support. The installation and activation of the program is described in the producer's guidelines (www.instalsoft.com) and it will not be discussed here.

When the program is activated, it is necessary to start a new file. For the organization purposes, it should be preceded by the creation of a *New project*, which means the new folder with the new Instal Package file. By the use of *New file* button, it is possible to create new Word, Excel, text or *.isb files. It is necessary to enter a name of the file.

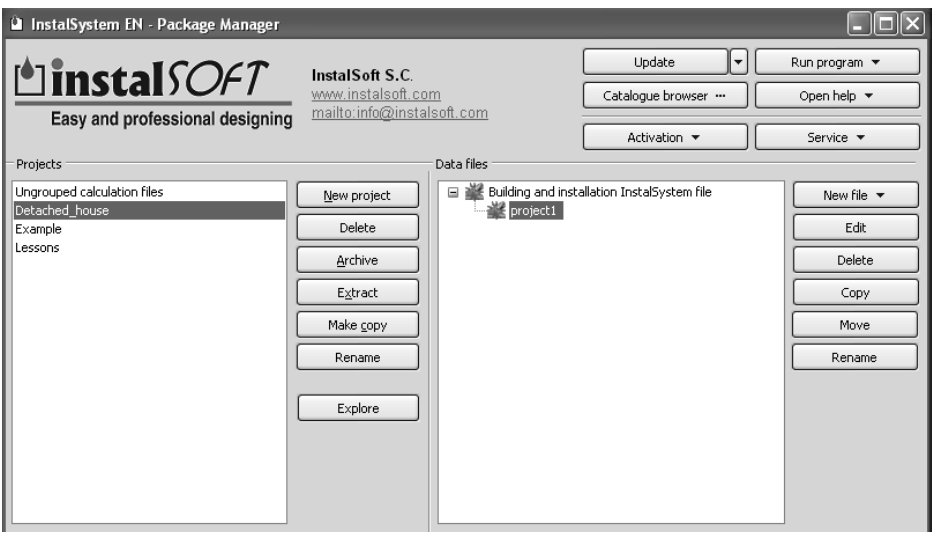


Figure 3.1. Fragment of the InstalSystem EN Package Manager window

For the purpose of this book, a new project Detached house and a new file *Project 1* were created. The file will be base for further calculations both for heating and water supply installations.

3.1.2 DWG base import to Instal-therm HCR

After opening the file *Project 1* in Instal-therm HCR (by the use of right button of a mouse) it is crucial to import AutoCAD base. There are two main ways of DWG files import. In the case of detached houses it is easy to prepare the base for automatic reading in the program, therefore the stage of base import in Instal-therm HCR is short. However, the file needs to be specially prepared in AutoCAD (Figure 3.2). Firstly, all the main elements of building structure like walls, windows, doors and other elements (ex. stairs) should be drawn in separate layers. Moreover, the building should be placed in 0,0 point in AutoCAD coordinates' system. Every separate storey of building has to be placed in separate file, in the same point with coordinates 0,0. The files should be saved as "ground_floor.dwg" and "first_floor.dwg" in AutoCAD 2000 format.

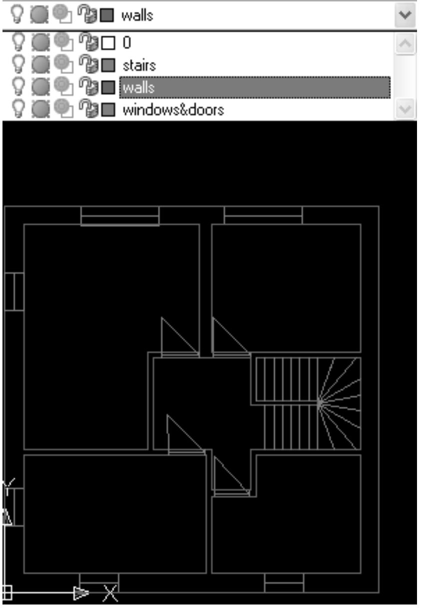


Figure 3.2. DWG base prepared for import

As it can be seen in the Figure 3.3, the import of a new base is done in the *Base* (or other) edit scope by the use of *Import base from DWG/DXF file* icon from *Program* main toolbar. The same command is available throughout the *File* field.

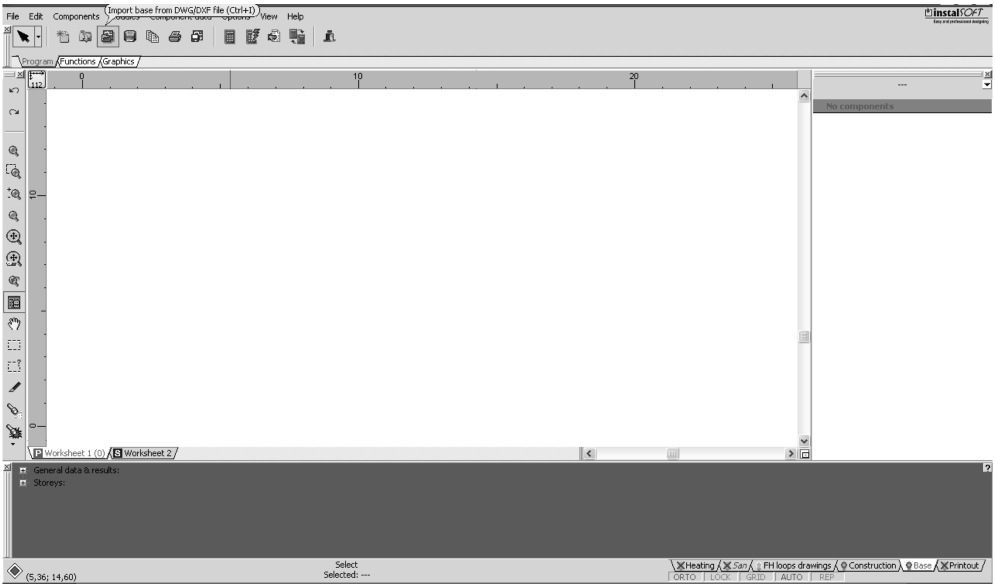


Figure 3.3. The DWG base import – edit scope *Base* and command icon in *Program* toolbar

After the selection of *Import base from DWG/DXF file* command, the new additional window with the access path to DWG file is open. It is necessary to find the right catalogue with DWG base (*prj. Detached_house* in this particular example, Figure 3.4) and cancel the fonts' files (Figure 3.5).

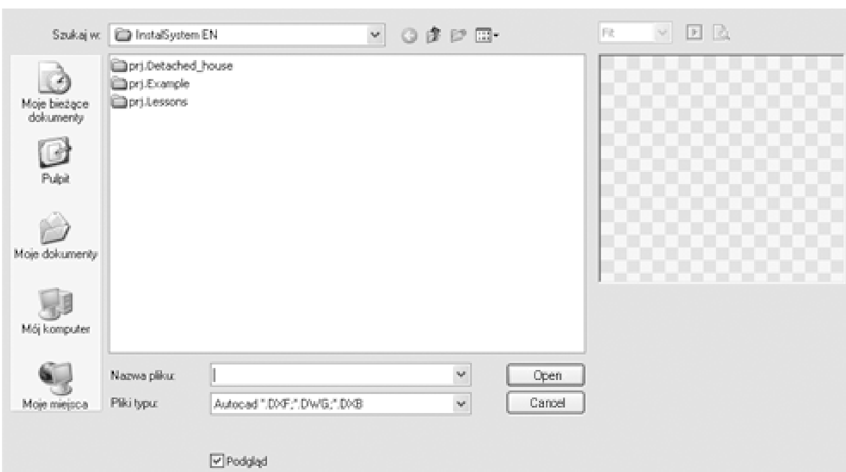


Figure 3.4. Access path to DWG base selection window

Figure 3.5. Fonts cancellation using *Cancel* Button

If the access path is already accepted, the new window of DWG base import appears. The file import process is divided into four main steps. First of all, the *Unit of measure in the drawing* is required to import the base in the right scale. This unit can be selected from the developed list as 1 mm, 1 cm, 1 m, etc., depending on the unit of drawing in DWG file. If the designer does not remember the unit of measure, it is possible to select the most probable unit (for example 1 cm) and measure some particular elements in the building, like doors, which are usually about 1 meter wide, to confirm the assigned unit. After verification of the selected unit, it is allowed to click *Continue* button in the top right corner (Figure 3.6).

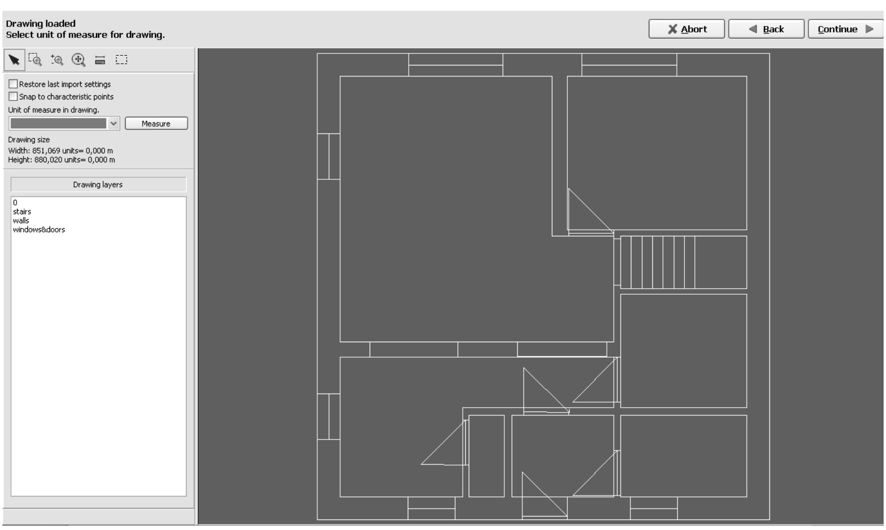


Figure 3.6. The unit of measure in the drawing selection window

In the case, when the imported file is prepared in the described previously manner, the selection of *drawing layers with walls* is the next step. Figure 3.7 presents the properly drawn walls (closed rooms without the brakes for doors and windows).

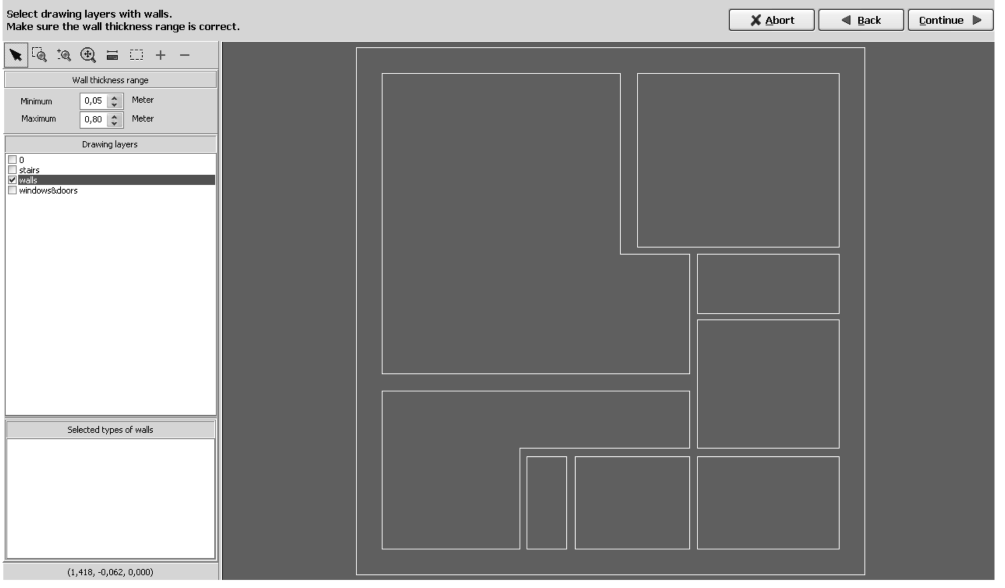


Figure 3.7. Walls layers selection window

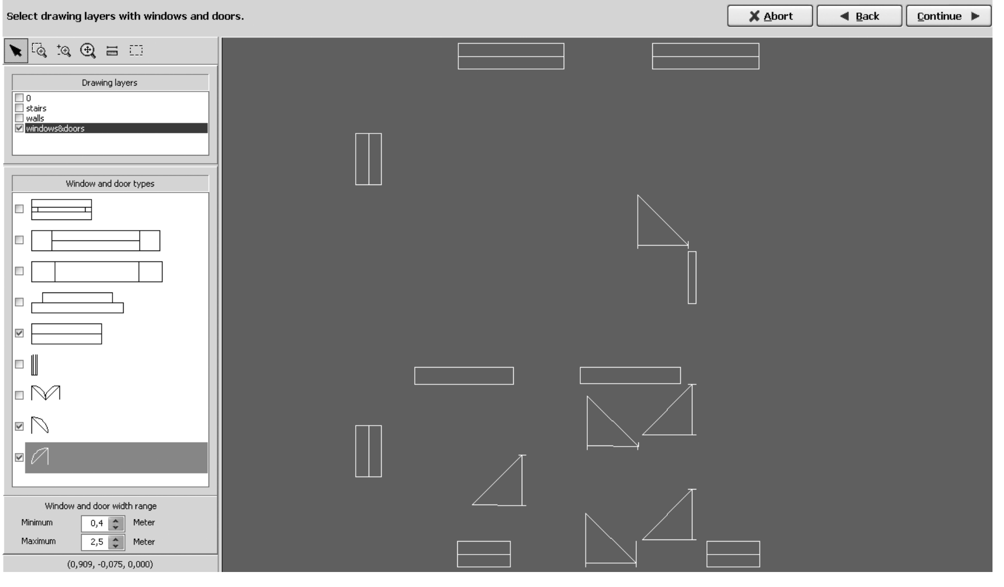


Figure 3.8. Doors and windows layers selection window

It is crucial to remember about the thickness range of the walls which means the distance between two lines that will be interpreted by the program as partition.

Continuation of import process means the selection of *drawing layers with windows and doors* as the next step. Figure 3.8 presents the examples of properly drawn windows and doors (recognized in program types). As well as the types selection, it is necessary to remember about the width range of windows and doors.

The final step of import is the selection of every AutoCAD layer that should be imported to Instal-therm HCR as a drawing. In the case of discussed example, these layers include stairs, walls and windows&doors (Figure 3.9). After completing the list of layers and clicking *Continue* button, the statement *Interpretation complete* (Figure 3.10) appears. After confirming by *OK*, the designer is moved back to the Instal-therm HCR window.

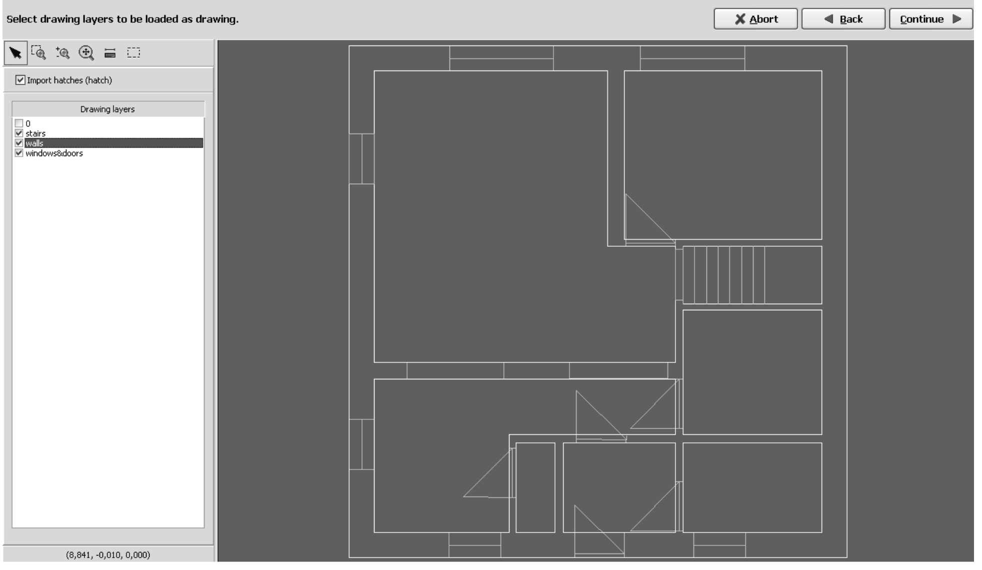


Figure 3.9. Drawing layers selection window

Figure 3.10. Final DWG import statement

Except of the described above, there is a second import manner. If the drawing is not prepared for the import, it can be simply read by the program as the base and edited under *Base* edit scope. The interpretation of partitions is not needed then, so the second (wall layers) and third (doors and windows layers) steps of import procedure should be neglected, which means continuation without the layers choice.

However, the user of InstalSystem package has to remember that without the interpretation of partitions, it is not possible to fulfill the design heat load calculations automatically. It means that the described alternative import manner is useful for Instal-San T users mostly. This manner can be also practical if the application user prefers to draw the building in Instal-therm HCR, using drawing functions available in *Components* toolbar in the *Construction* edit scope. Some of these functions are described in the next chapter of this book.

3.1.3 Building structure formation in Instal-therm HCR

After completing the DWG base import, the user continues work in Instal-therm HCR. The interpreted structure of building should be checked then in *Construction* edit scope. In Figure 3.11, there is the ground floor of the designed building, presented after the import of DWG base with interpretation. It is necessary to check if:

- all the walls have the connection point with adjoining partition closed (the shape of small square; if they are not connected properly, the connection point has a shape of larger, empty square and there is no room area hatched),
- all the windows and doors were interpreted properly (they are visible),
- other elements like openings in walls are marked in the drawing.

In the case of ground floor base imported as example, there are some openings in the wall between the kitchen and the living room which were not automatically interpreted. It means that these element should be drawn by the use of commands placed at *Elements* toolbar.

Before starting the edition, it is recommended to change the visibility of DWG base. This base is automatically shadowed because it may disturb the clearance of the drawing.

If it is needed to use the base, its visibility should be changed to simplify the localization of drawn elements (Figure 3.12). This change can be done in *Base* edit scope by simply clicking the area of building (the selection of base) and changing *Color highlighting* in *Data table*. The *Data table* related to base can also be used for changing: the visibility of selected layers, *Auto* mode settings and visibility of all the base drawing.

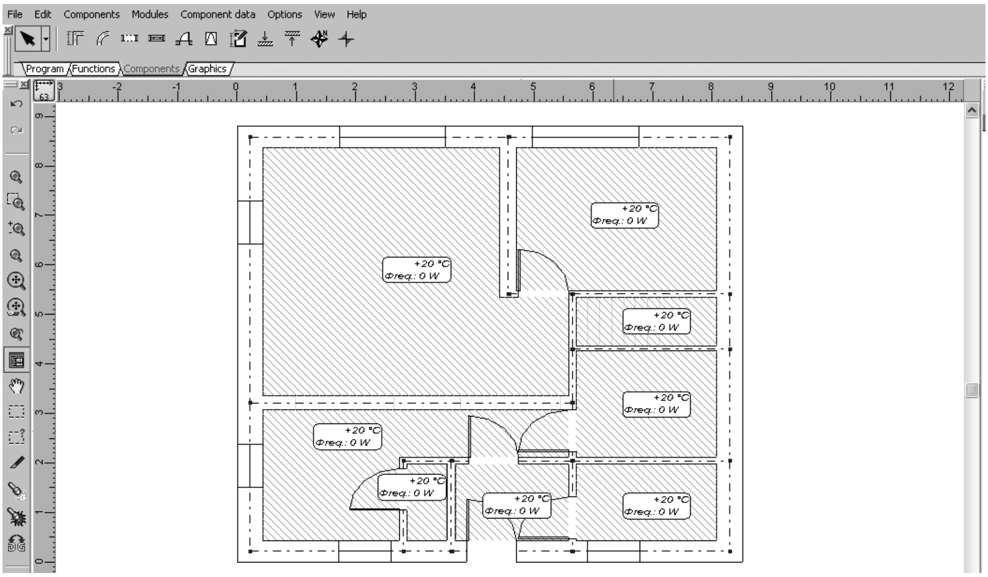


Figure 3.11. Interpreted construction of building

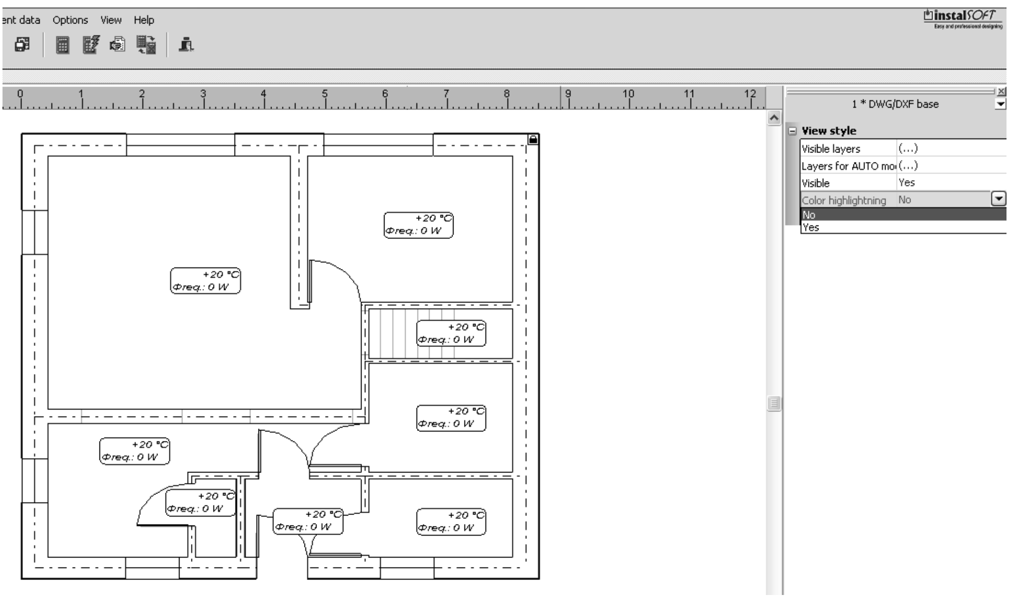


Figure 3.12. Base visibility change in data table

After the change of base visibility, the openings in the wall are easy to notice and measure. The measurement can be done by *Length measurement* command from *Functions* toolbar (Figure 3.13). Having the dimensions of openings measured, the user can move back to *Construction* edit scope.

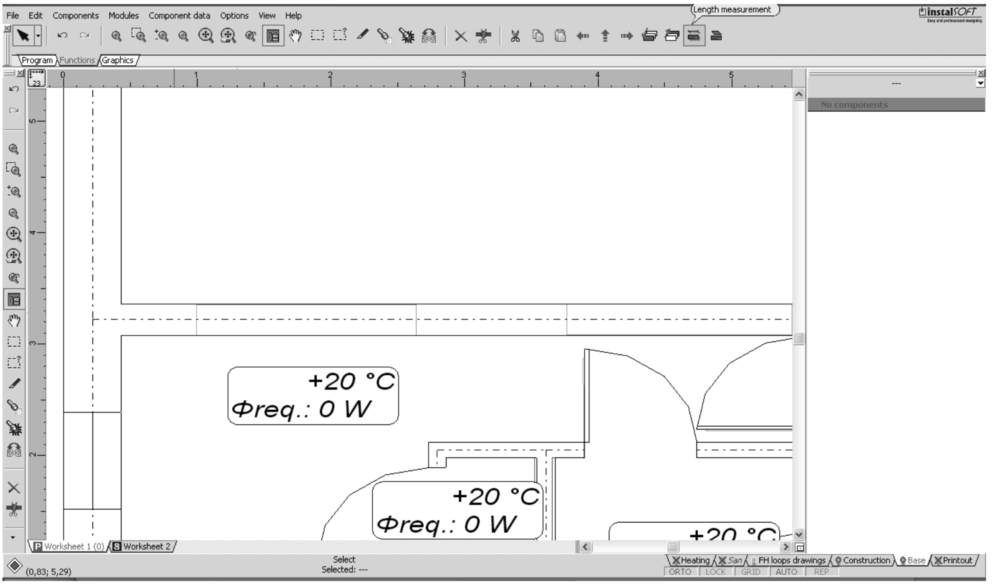


Figure 3.13. Length measurement of openings in wall

Every element of building structure like room, wall, window, etc. can be selected by simply click on its area (description of room, wall axis, middle of doorway).

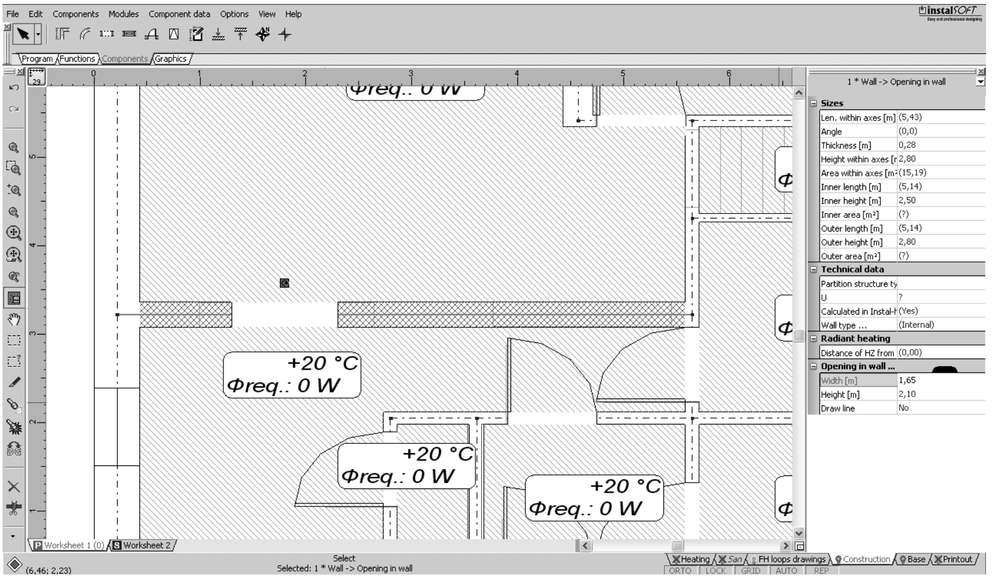


Figure 3.14. Insertion of *opening in wall*

The elements like doors and windows are not independent, they can be only treated as a part of a wall. That is why, it is not possible to insert the door anywhere in the drawing. The same situation takes place in the case of openings in the walls. To insert it in the right place, it is necessary to use the third icon from *Components* toolbar and click in the axis of wall. The inserted opening has the default width equal 1,65 m, which can be easily changed into the correct value by the use of *Data table* (Figure 3.14).

As it can be noticed, the *Data table* includes information about the wall (*Sizes*, *Technical data* and *Radiant heating*); it is characteristic for every dependent element like door and opening, that it is not possible to be selected separately and its data is located at the end of wall *Data table*.

The insertion of *opening in wall* was the only example of manually drawn vertical element in Instal-therm HCR. However, the same rules and procedures take effect in the case of other elements of building structure, like floor, ceiling, window, etc. The insertion of *Horizontal partition: floor* is presented in Figure 3.15.

NOTE: Floor should be added to every room on all storeys, while *Horizontal partition: ceiling* should be used only as a roof on the last storey.

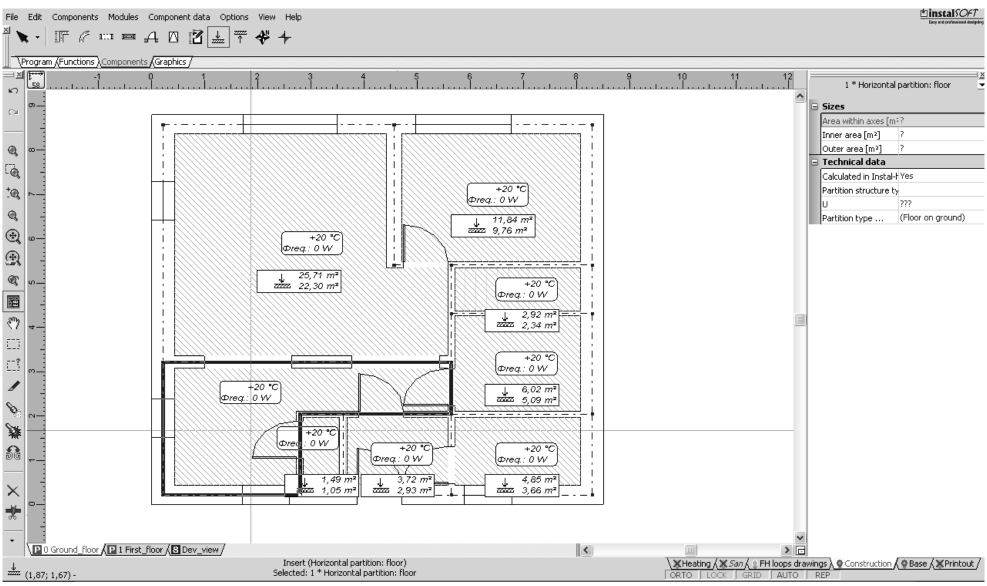


Figure 3.15. Insertion of floor

Because of the fact, that partitions and their dimensions are used to calculate the design heat loss for rooms, the floor can be divided into several pieces. It happens when the layout of rooms on ground floor differs from the one on first floor. Therefore, *Horizontal partition: floor* inserted on the second storey (sleeping room) may consist of two sections in the case when there is kitchen and the part of living room below this space.

The next step of building structure editing is the addition of new worksheets. As it has been described previously, the worksheet of *Plan view* represents one of building's floors, while *Schematic view* is designed for drawing of the schematic view of installation. Therefore it is necessary to add two new worksheets in the described project. The *Worksheet Management* window can be open by the use of deliberate icon from *Program* toolbar (Figure 3.16) or by clicking the name of worksheet with the right button of mouse.

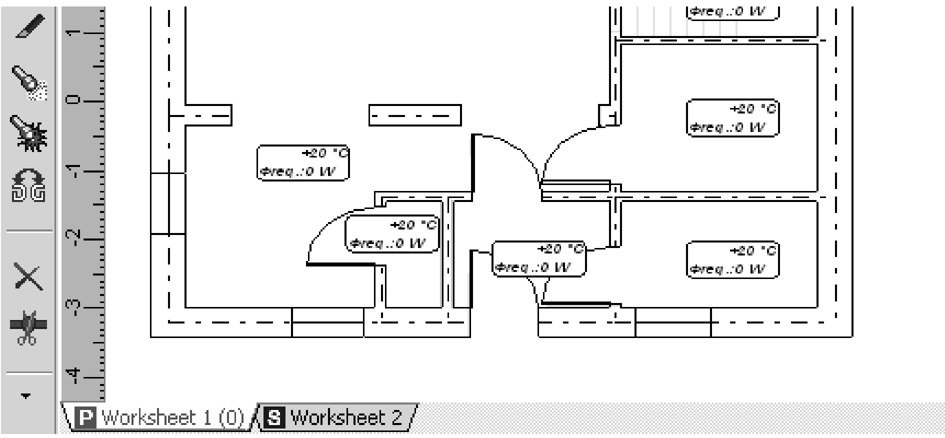


Figure 3.16. Worksheet management icon in *Program* toolbar

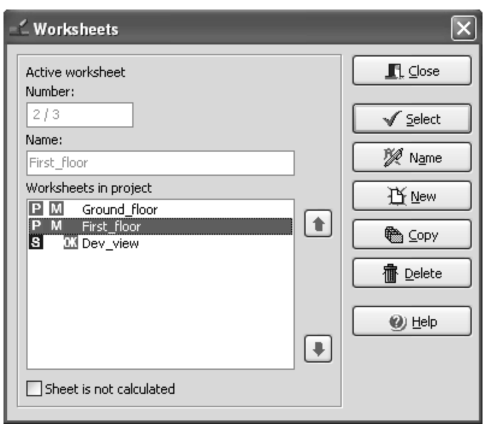


Figure 3.17. Window of *Worksheets*

By the use of *Worksheets* window (Figure 3.17), it is possible to select as presently edited, name, insert new, copy or delete worksheets. Moreover, this window enables to select worksheet as not calculated, which may sometimes be useful in the case the calculations should be run for chosen storeys only.

In the presented example, the new worksheet of *First_floor* was created. The procedure of DWG base import is parallel to the described previously and will be skipped in this part of the book. The plan view of second storey in *Heating* edit scope is presented in Figure 3.18. In the further part of project, additional storey of *Attic* will be created, to enable the proper calculation of design heat loss for the first floor. The attic will not be heated, it is assumed to have no usage function. It is used to simulate the heat transfer through the space between the last ceiling and final roof of building.

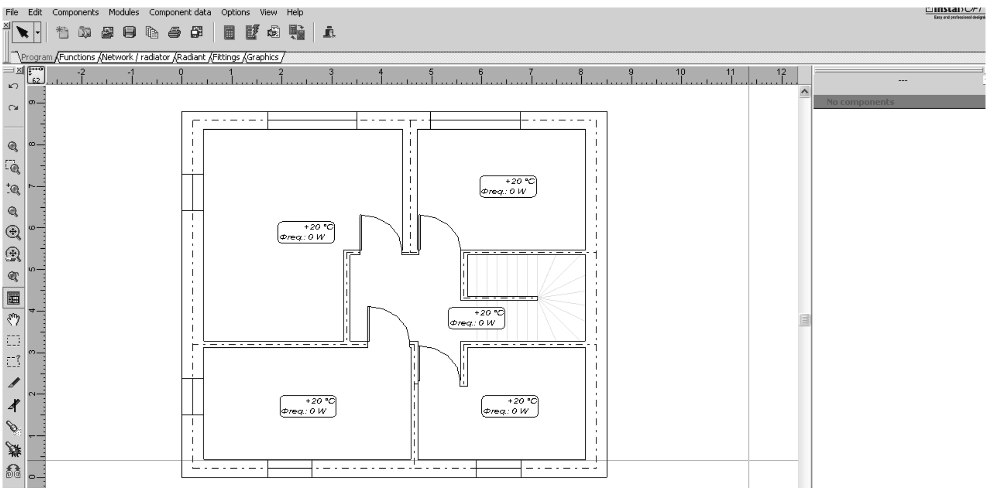


Figure 3.18. Plan view of second storey of building

To identify the particular rooms in the building, it is necessary to enumerate them. It can be done automatically by the use of *Assign numbers to rooms* command from *Component data* in *Program Menu* (Figure 3.19). This command works as simple click in the *Room label* area. Numbers consist of storey number and room number; storey numbers can be changed through *Options / Building Structure*. Numbers can be also assigned manually in *Data table* of every room.

It is also recommended to add the descriptions (kitchen, living room, hall, etc.) to all rooms. To make the descriptions visible in *Room label*, it is necessary to change its settings by the use of *Project options* (F7). Options are automatically started with the opening of new file in program and they can be changed in every stage of the project.

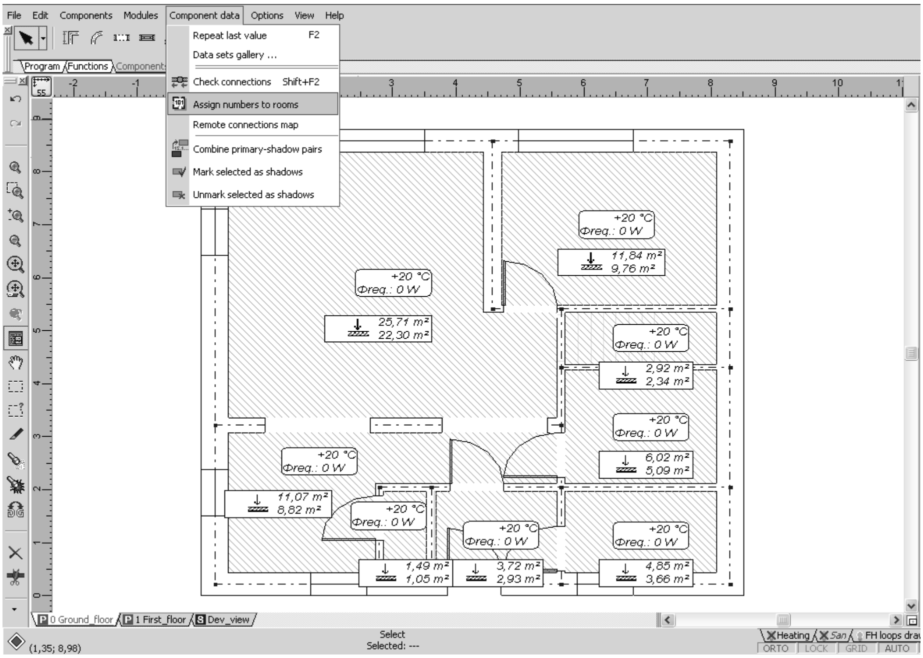


Figure 3.19. Numbering of rooms through automatic command

The main options window (Figure 3.20) consists of ten categories like: *Project info, Building data, General data, Catalogues, Default types, Radiant heating, Building structure, AUTO ORTO GRID, Edit, Components appearance*.

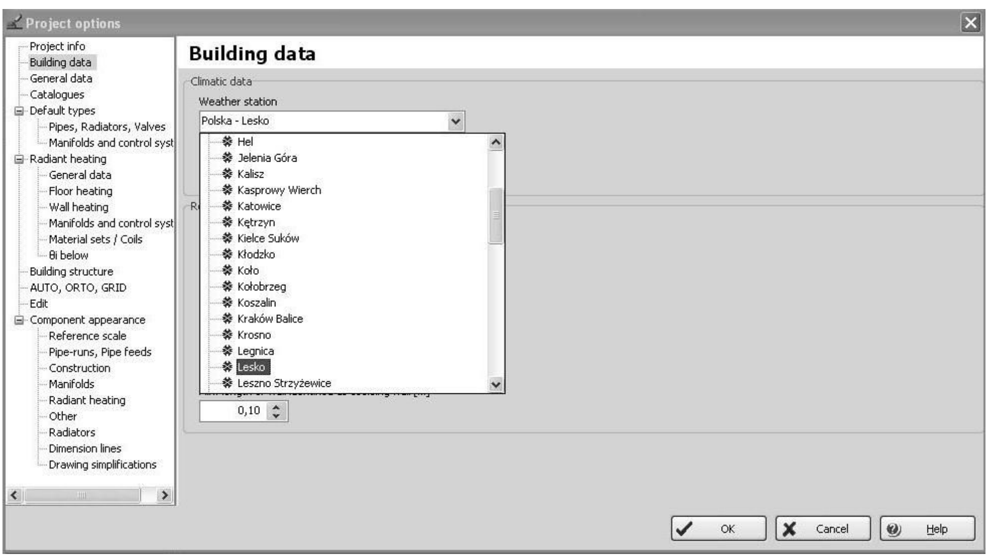


Figure 3.20 Project options and selection of the weather station

While opening the new project, it is recommended to start with *Catalogues / Climatic data*, choose the country and then select *Weather station* in *Building data*. In the presented example, designed building is located in Lesko, Poland.

The necessary change of *Room label* settings can be achieved by the use of *Component appearance / Construction*, as it is presented in Figure 3.21. In *Component styles, Room label* can be found. When it is selected, *Configure* button becomes active and it is possible to change the content of description according to the *Label* list. It is necessary to show the place of insertion for the selected label by the use of red cross in its middle part.

Except of the content, it is also feasible to change the size, lines, shape, background and font of the description upon the wish of the designer. After completing the changes, it is necessary to confirm them by clicking *OK* button.

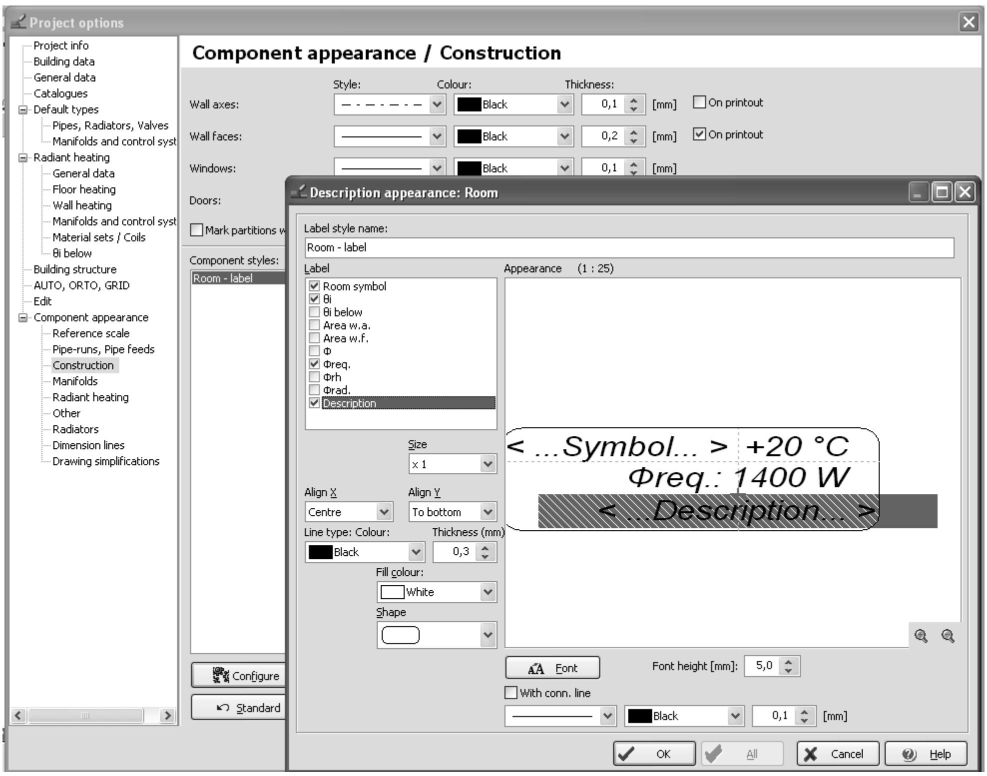


Figure 3.21. Management of *Room label* appearance

The performed change in appearance settings can be noticed as additional description in *Room label*. In fact, this is the end of construction editing stage. However, in the case of presented example, it is also necessary to change the setting for the Pantry, which will not be heated room. It is recommended to change this basic setting before the calculation of design heat load is done. The change can be achieved by the use of *Data table / Technical data* for room (Figure 3.22).

In the case when the default dimensions of partitions like the height of walls on attic are not correct, it is compulsory to change them. The change may be done by the use of *Data table*. Moreover, to fasten the work, it is recommended to use *Select in rectangle the components of type…* command from *Functions* toolbar, and as a type, *Walls / External* should be selected. It allows to select all the external walls on edited storey at the same time and change the height for all of them simultaneously.

The same command may be useful for selection of roof element to change its specific angle to horizon in *Data table*. In the described project, this angle equals 15˚.

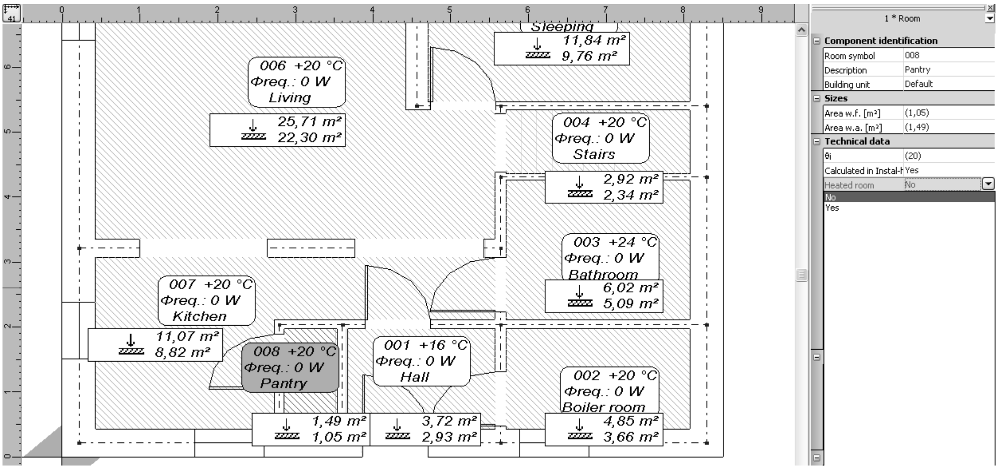


Figure 3.22. Technical data change for Pantry

After the described corrections, graphical part of the building structure interpretation is completed. To continue designing process, it is necessary to save project and move to Instal-heat&energy.

3.1.4 Defining partition structure in Instal-heat&energy

To open project in Instal-heat&energy it is necessary to use *Package Manager* and edit project file (Figure 3.23) or start program and select *Open file* command from the standard toolbar.

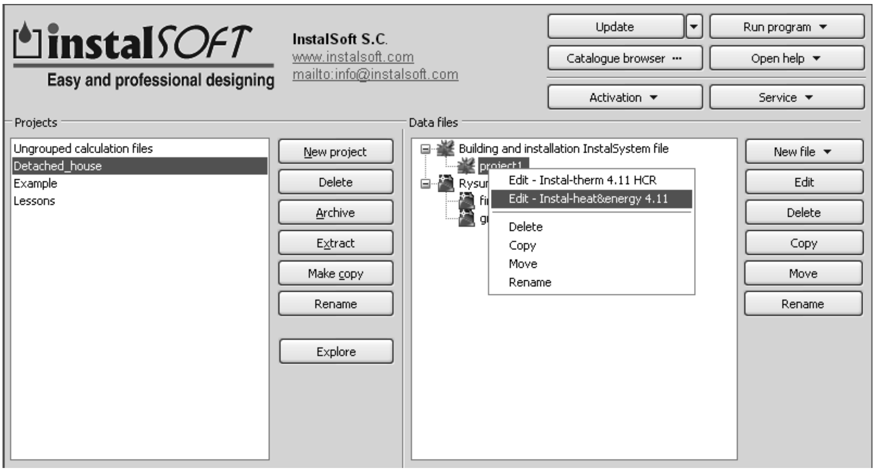


Figure 3.23. Opening the project file in Instal-heat&energy using Package Manager

Working in Instal-heat&energy requires selection of the basic settings in *General data* category and *Calculation standards and options* subcategory. The chosen standards package is European, which means that EN 12831 Standard is used for heat loss calculation and EN ISO 6946 for heat calculation of partitions (Figure 3.24).

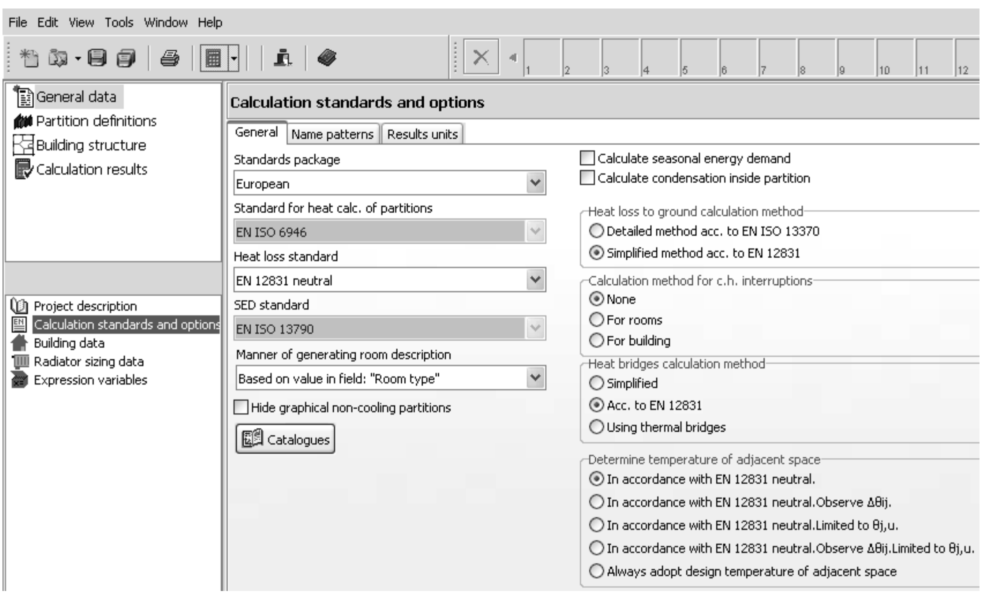


Figure 3.24. Selection of general *Calculation standards and options* for the project

Some of the important settings for heat calculations are placed in *Building data* subcategory (Figure 3.25). Except of the *Climatic data*, which in this case are imported from Instal-therm HCR (building localization in Lesko), *Heat loss* *calculation data* has to be checked. Most of this data is imported automatically (dimensions of floor on the ground), the rest as *Building structure type, Building tightness, Building sheltering class, Ventilation type* and level of ground h_{gr} have to be introduced manually.

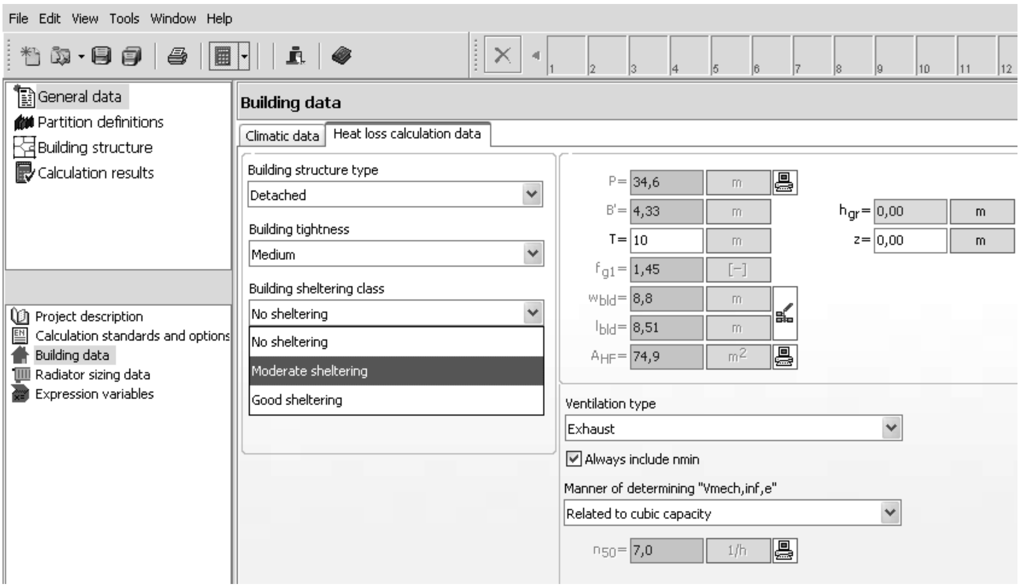


Figure 3.25. Selection of *Heat loss calculation data* for designed building

The next step, after completing the settings, is declaration of construction and properties of the partitions. At this stage of the design, the *List of errors* displays numerous information about the improper values of heat transfer coefficients for partitions. Since the definitions of partitions' structure are not prepared yet, this list should be currently passed over.

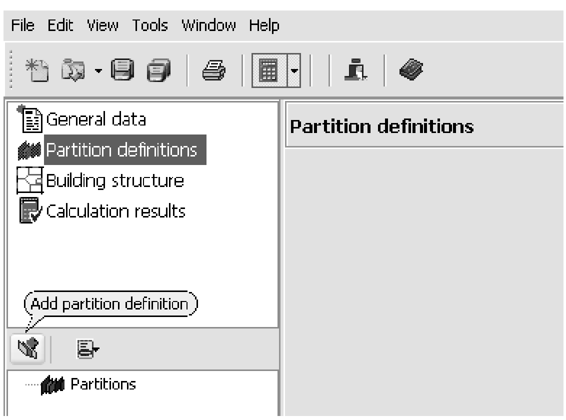


Figure 3.26. Creation of new partition definition

Declaration of partitions' structure is performed through the *Partition definitions* category. By the use of icon starting the command *Add partition definition* it is possible to create new partition structure (Figure 3.26).

In this example, the external wall will be the first partition defined. First of all, it is necessary to fill in the basic options like *Name, Description* (if needed), *Manner of partition definition, Partition type*. Heat flow direction is read automatically on the basis of partition type. In the case of external wall, it will be defined by layers (materials used for its construction). Therefore the manner of its definition should be chosen as *Partition with defined layers*. The table with materials and their properties is then displayed below the options. To switch to the list of materials contained in program database (Figure 3.27), it is necessary to click the small rectangle with three dots located on the right side of the *Material* column (Figure 3.28). Declaration of partition structure should be started with internal layer (plaster), which is shown as a symbol of two thermometers (warm and cold) in the first column.

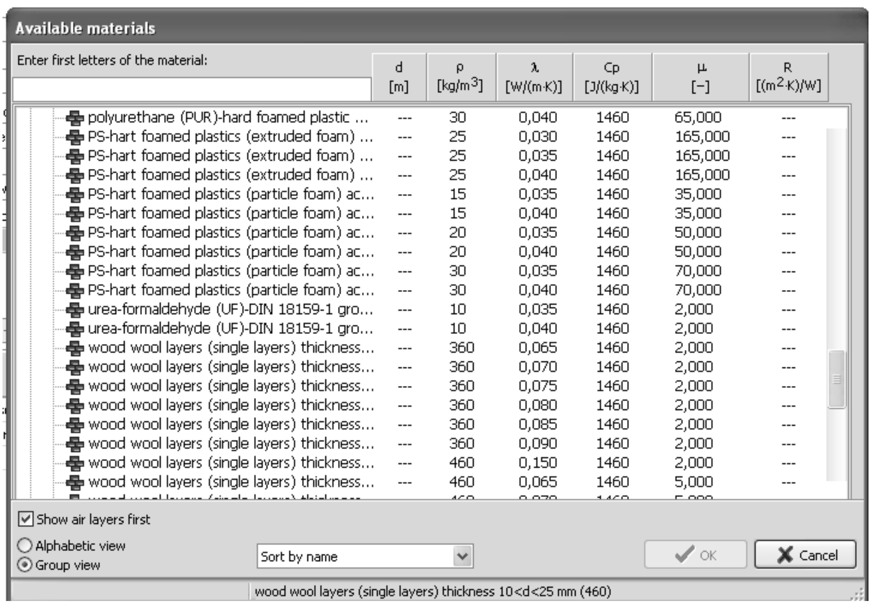


Figure 3.27. Selection of the external wall layers from project database

The structure of external wall defined in the example is declared as follows: gypsum plaster, full brick, PS insulation, external plaster. For all these layers it is necessary to fill the column *d* (thickness), the other information is read from database. On the basis of the completed structure, calculation of heat transfer coefficient is fulfilled. The additional value *ΔU* will be added to the specific partitions in building, depending on their location.

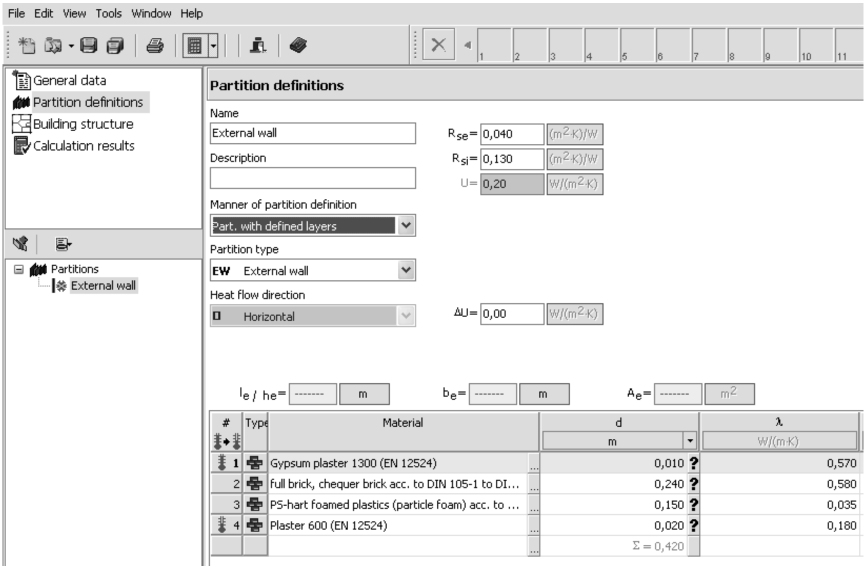


Figure 3.28. External wall defined by layers

The above described example of partition definition can be used for any type of wall, floor on ground, ceiling and even roof. Partitions like windows and doors should be defined according to the second available manner: *Partition with specified U*.

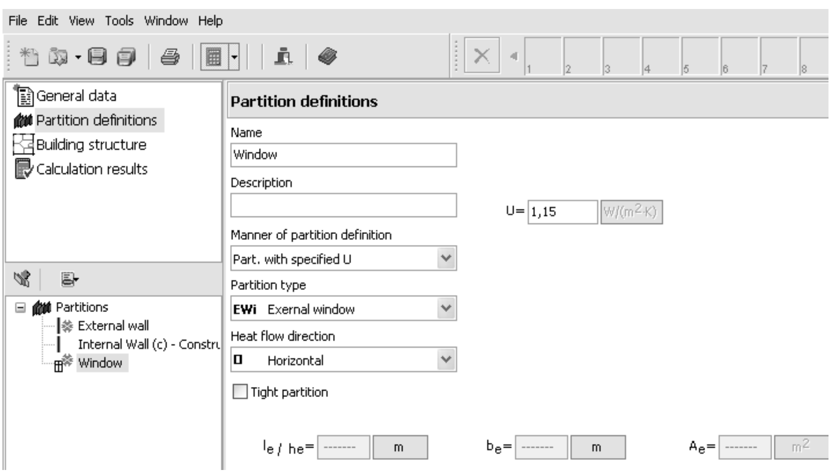


Figure 3.29. Window defined by the specified U coefficient

Usually the heat transfer coefficient *U* is given by producer and it ought to be written in an empty space in data table, as presented in Figure 3.29. It is crucial to remember about the *Partition type*, to be changed. If the computational part of the project is done using the graphical base, the dimensions of window should not be completed here, since they are read from the drawings.

The third manner of partition definition is called *Non-uniform partition*. It can be used in the cases, when the partition structure is not homogeneous. The example of a roof presented below can be treated as such partition, because it is consisted of the constructional elements (rafters) and insulation between them. Therefore, the declaration of roof structure needs to be carried out in three particular stages:

- definition of construction part (Figure 3.30. Definition of constructional part of roof by layers – constructional part (rafter)Figure 3.30),
- definition of insulated part (Figure 3.31),
- definition of the two structures' shares in roof area (Figure 3.32).

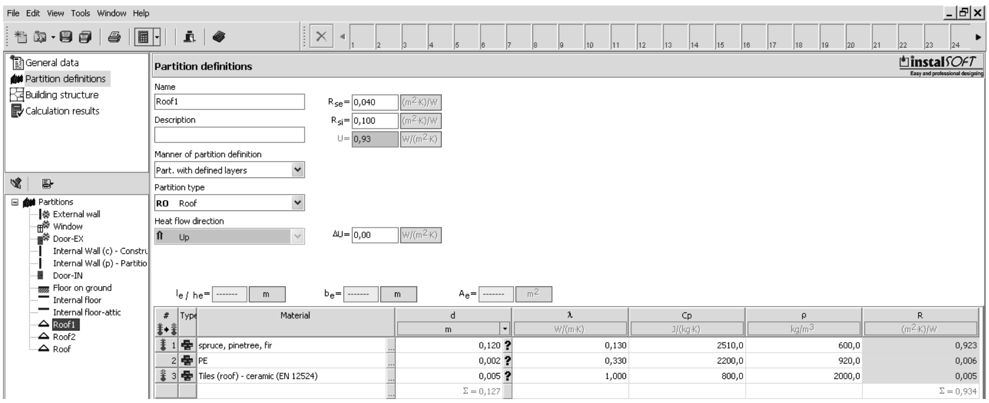


Figure 3.30. Definition of constructional part of roof by layers – constructional part (rafter)

Constructional part of the roof is built of the spruce rafters, vapor barrier and tiles, while in insulated part, the rafters are replaced by the foam glass. It is easy to create insulated part (Roof 2) as a copy of the constructional part (Roof 1) by changing only the selected material in the list.

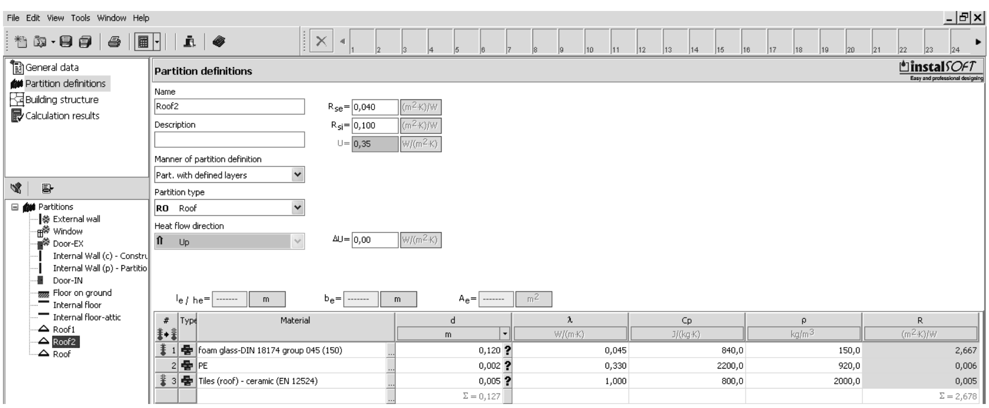


Figure 3.31. Definition of insulated part of the roof by layers – insulated part

Roof definition as non-uniform partition requires the declaration of predefined partitions' shares in total roof area. For the purpose of the presented example, it was assumed as 10% for constructional part and 90% for insulated part.

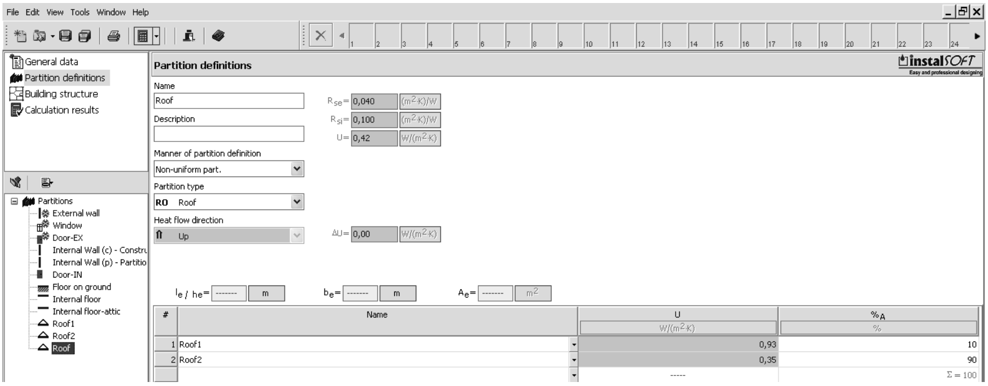


Figure 3.32. Roof definition as non-uniform partition

In the presented example of building, there are ten main types of partitions defined. The total list is consisted of:

- external wall,
- window,
- door (external),
- internal wall (constructional),
- internal wall (partition),
- door (internal),
- floor on ground,
- internal floor (between ground floor and first floor),
- internal floor (between first floor and attic, additionally insulated),
- roof.

All these partitions, with calculated heat transfer coefficients must, be then localized in the graphical part of the project. Therefore the continuation has to be carried out in Instal-therm HCR.

3.1.5 Partition type identification in Instal-therm HCR

Identification of partition types (combination of graphical elements and defined structures) is carried out under *Construction* edit scope in Instal-therm HCR. *Data table* for elements of building structure contains *Technical data*, including *Partition structure type*. Because the types were predefined in Instal-heat&energy, after selection of walls, only such types of partitions can be chosen from the developed list in *Data table*.

To facilitate the process of identification, it is recommended to use again the known command: *Select in rectangle the components of type…*, which at the beginning enables selection of the external walls only. When they are selected (Figure 3.33), it is possible to choose the *Partition structure type* for all of them simultaneously. It was selected as the “External wall” and therefore the value of heat transfer coefficient is automatically read as 0.2 (imported from Instal-heat&energy).

Since windows and doors are not autonomous elements, they are displayed as a part of the wall, so their data is located below *Technical data* and *Radiant heating* in the same *Data table* as wall data. Therefore, having walls selected, it is possible to identify the types of windows and doors at the same time.

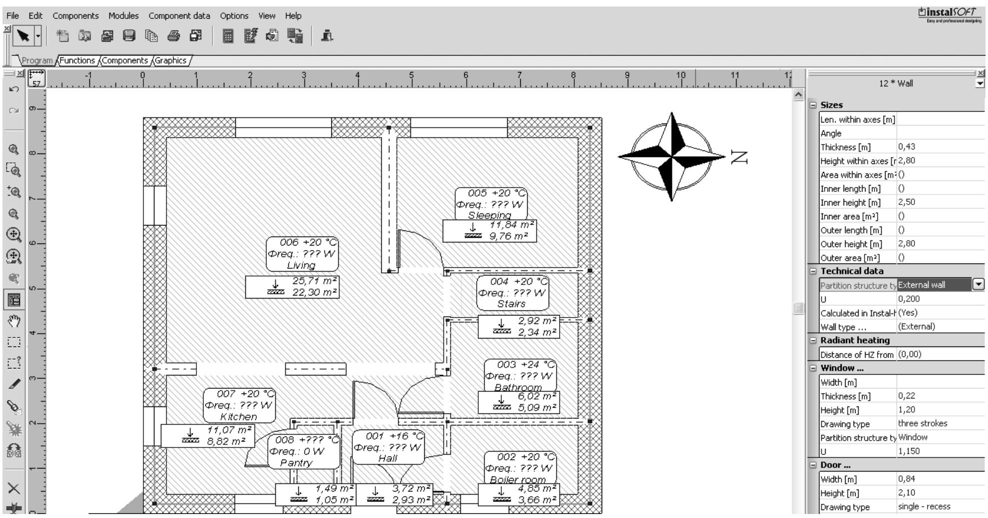


Figure 3.33. Identification of external wall, window and door type

The same procedure is not always opportune for the internal walls and doors. As presented in Figure 3.34, there are both constructional walls and partitions on this floor. Because of the diverse structure of these two walls, they have to be identified manually. Recommended procedure starts with the selection of all internal walls, which should have been given the type “Internal wall (p)”. The selection of all internal walls excludes the situation when any part of a wall is missed. Then, the doors should be identified as internal type, defined previously.

After this, the manual selection of constructional walls should be carried out. To keep once clicked element selected, Shift button is used, which allows to mark several elements simultaneously. Therefore it allows to change partition structure type for selected elements, as presented in Figure 3.34.

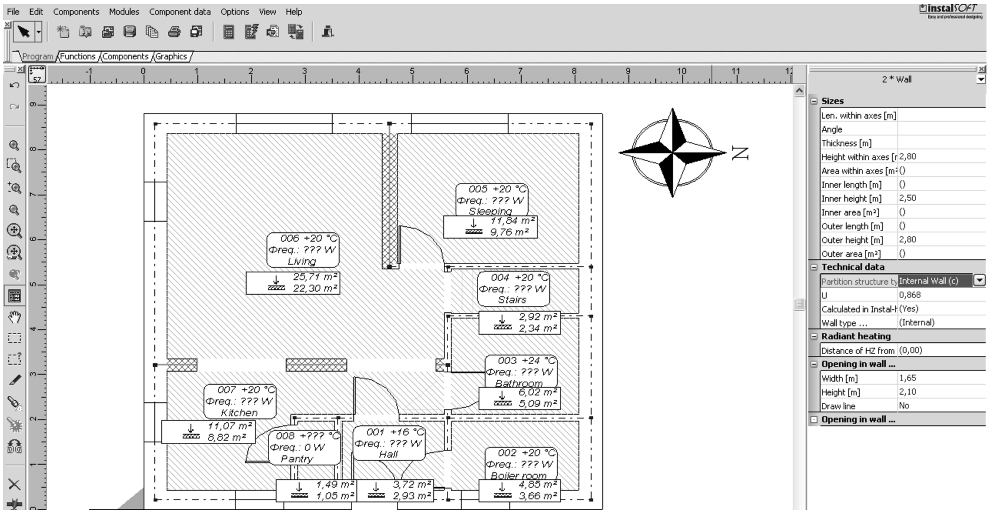


Figure 3.34. Identification of internal walls (construction type)

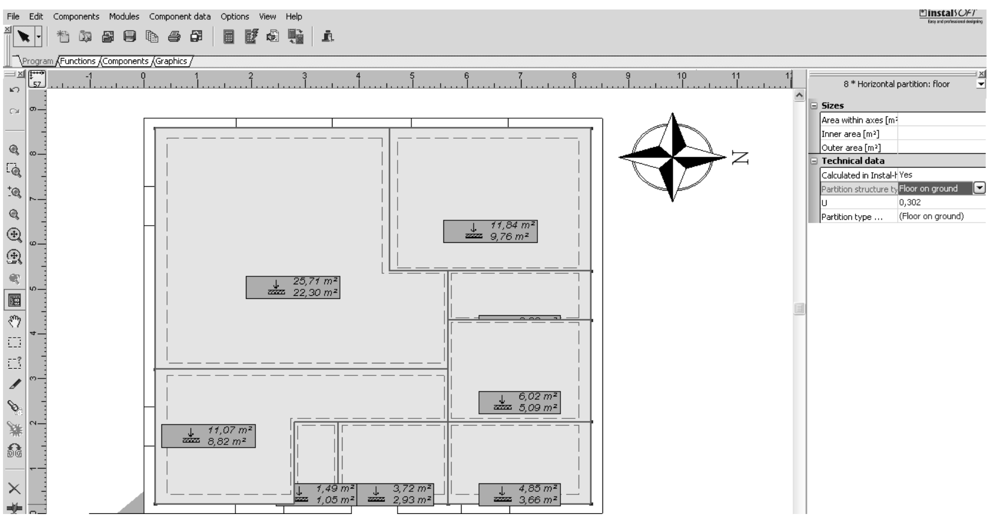


Figure 3.35. Identification of floor on ground type

On ground floor storey, there is also a floor on a ground to be selected and identified. The selection can be done by the same command as previously (*Select in rectangle the components of type / horizontal partition / floor*). In *Data table*, *Technical data* is located below information about floor size. *Partition structure type* should be selected as "Floor on ground", previously defined in Instal-heat&energy (Figure 3.35).

3.1.6 Heat loss calculation in Instal-heat&energy module

Heat loss calculation requires some corrections of the default settings in Instal-heat&energy module. First of all, the minimal ventilation rate for sanitary accommodations like bathroom, kitchen, shower, etc. should be changed. The reason is the fact that in such types of rooms there are ventilation grilles located, which are designed to ensure the exchange rate up to 1.5 1/h. The correction can be done in the right data table as highlighted in Figure 3.36.

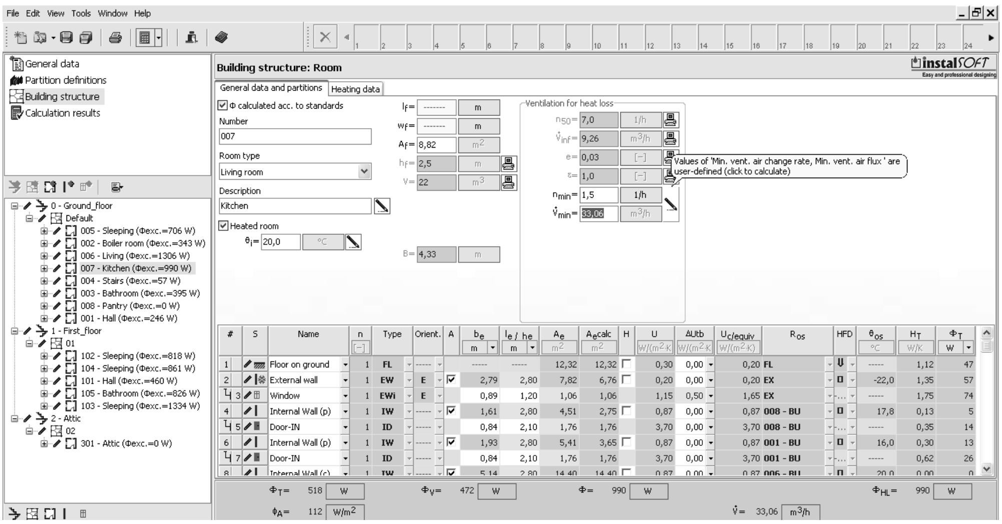


Figure 3.36. Correction of minimal ventilation rates for sanitary rooms

The second important change is halls combination. In the graphical part of program, there is no possibility to mark that the stairs are the constructional part of two storeys. That is why in the computational part intended for heat loss calculations, there is a possibility to change the dimensions of walls manually (required for those surrounding stairs) and to combine two rooms into one. It is important, because after combining it, it is more feasible to design heating element (stairs can be heated by the radiator located between the floors).

To combine two rooms, they have to be located in the same building unit. If not, it is recommended to combine the building unit firstly by selecting it (left button of a mouse + Shift) and using *Combine building units* command (right button of a mouse). Then, the same procedure can be carried out for the selected rooms by the use of *Combine rooms* command, as presented in Figure 3.37.

In buildings equipped with basement, partially recessed in the ground, there is also need to change the dimensions of external walls on the storey of cellar to the height above the ground. Then, it is necessary to add partitions to the rooms with the external walls. These partitions should have type: *Walls near ground*, and the length of external walls. The height of the wall near the ground is therefore equal the difference between the height of a storey and external wall above the ground.

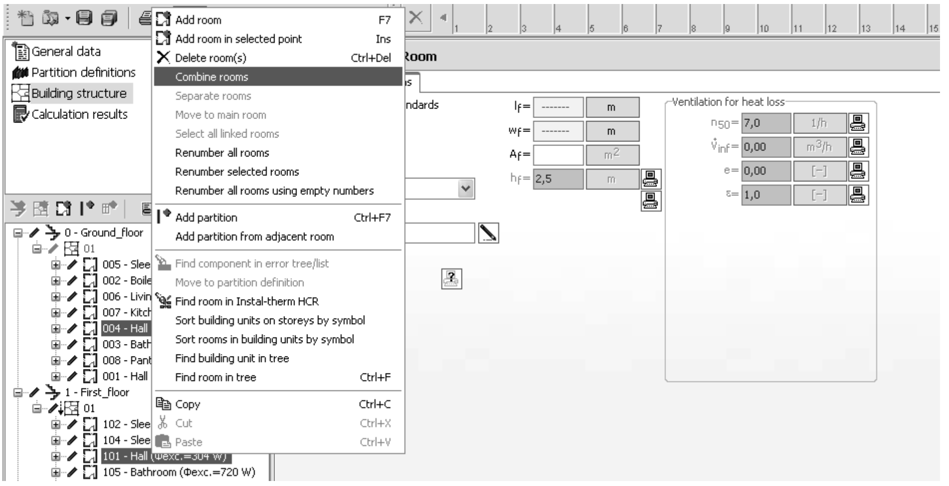
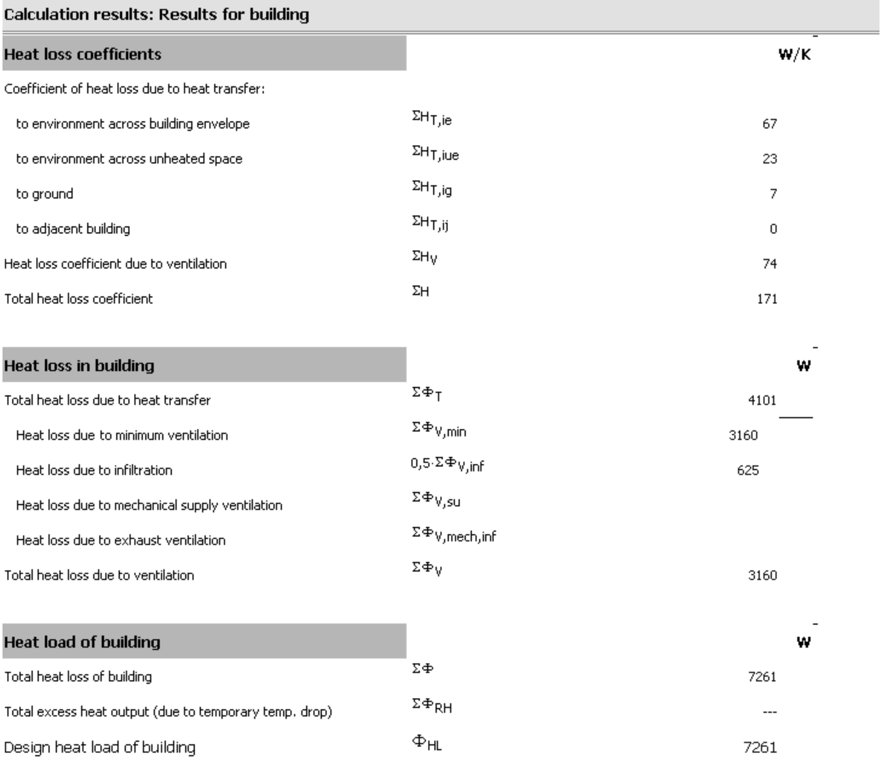


Figure 3.37. Combination of halls: 004 and 101 (stairs) into a single accommodation



Calculation results: Results for building		
Heat loss coefficients		W/K
Coefficient of heat loss due to heat transfer:		
to environment across building envelope	$\Sigma H_{T,ie}$	67
to environment across unheated space	$\Sigma H_{T,iue}$	23
to ground	$\Sigma H_{T,ig}$	7
to adjacent building	$\Sigma H_{T,ij}$	0
Heat loss coefficient due to ventilation	ΣH_V	74
Total heat loss coefficient	ΣH	171
Heat loss in building		W
Total heat loss due to heat transfer	$\Sigma \Phi_T$	4101
Heat loss due to minimum ventilation	$\Sigma \Phi_{V,min}$	3160
Heat loss due to infiltration	$0{,}5 \cdot \Sigma \Phi_{V,inf}$	625
Heat loss due to mechanical supply ventilation	$\Sigma \Phi_{V,su}$	
Heat loss due to exhaust ventilation	$\Sigma \Phi_{V,mech,inf}$	
Total heat loss due to ventilation	$\Sigma \Phi_V$	3160
Heat load of building		W
Total heat loss of building	$\Sigma \Phi$	7261
Total excess heat output (due to temporary temp. drop)	$\Sigma \Phi_{RH}$	---
Design heat load of building	Φ_{HL}	7261

Figure 3.38. Calculation results for building – heat loss and total heat load

After completed corrections, calculations of heat load for building are finished. As presented in Figure 3.38, total heat loss of building equals 7.26 kW and it is consisted of heat loss due heat transfer (4.1 kW) and heat loss due to ventilation (3.16 kW).

The detailed results of heat loss calculation for selected accommodation are presented in Figure 3.39. The table in the top of drawing contains the list of partitions with their dimensions, temperature differences, heat transfer coefficients and the final values of heat loss due to heat transfer. Below the table, there is information about ventilation fluxes and related heat loss.

Orient.	Type	n	b_e	l_e/h_e	A_e	$A_{e\ subtr}$	$A_{e\ des}$	e/u n/j	θ_{os}	e_k/b_u f_{ij}/f_{g2}	U	ΔUtb	U_c	H_T	Φ_T
---	FL	1	---	---	13,38	---	13,38	g	---	0,312	0,30	0,00	0,20	1,22	51,1
W	EW	1	3,95	2,80	11,05	2,15	8,90	e	-22,0	1	0,20	0,00	0,20	1,78	74,8
W	EWi	1	1,79	1,20	2,15	---	2,15	e	---	1	1,15	0,40	1,55	3,34	140,1
---	IW	1	2,96	2,80	8,28	---	8,28	j	20,0	0	0,87	0,00	0,87	0,00	0,0
---	IW	1	1,04	2,80	2,92	1,76	1,16	j	20,0	0	0,87	0,00	0,87	0,00	0,0
---	ID	1	0,84	2,10	1,76	---	1,76	j	---	0	3,70	0,00	3,70	0,00	0,0
N	EW	1	3,39	2,80	9,49	---	9,49	e	-22,0	1	0,20	0,00	0,20	1,90	79,8
---	IF	1	---	---	13,38	---	13,38	j	20,0	0	2,13	0,00	2,13	0,00	0,0
---	IW	1	2,40	2,80	6,73	---	6,73	j	20,0	0	0,87	0,00	0,87	0,00	0,0
Heat loss due to heat transfer						**H_T / Φ_T**								**8,2**	**346**

Min vent. air flux	$\dot{V}_{min}$	12,20	m^3/h		174
Infiltration air flux	$\dot{V}_{inf}$	6,83	m^3/h		98
Mechanically supplied air flux	$\dot{V}_{su} \cdot f_v$		m^3/h		
Excess exhausted air	$\dot{V}_{mech,inf}$		m^3/h		
Ventilation air flux	$\dot{V}$	12,20	m^3/h		
Heat loss due to ventilation	**H_V / Φ_V**			**4,1**	**17**[illegible]
Total design heat loss	**Φ**	**53,28 W/m²**	**21,31 W/m³**		**52**[illegible]

Figure 3.39. Detailed results for selected room

One of interesting functions available in Instal-heat&energy is graphical presentation of temperature distribution in the partition layers. In Figure 3.40, temperature distribution in external wall layers is presented. The layers include air layers adjacent to wall, as well as materials used for its construction. High temperature difference for the PS layer is connected with its thermal resistance. For the brick and plasters, temperature drop is relatively insignificant due to their low thermal resistance.

The subcategory *Data and results for partitions* encloses also information about their layers and heat transfer coefficients.

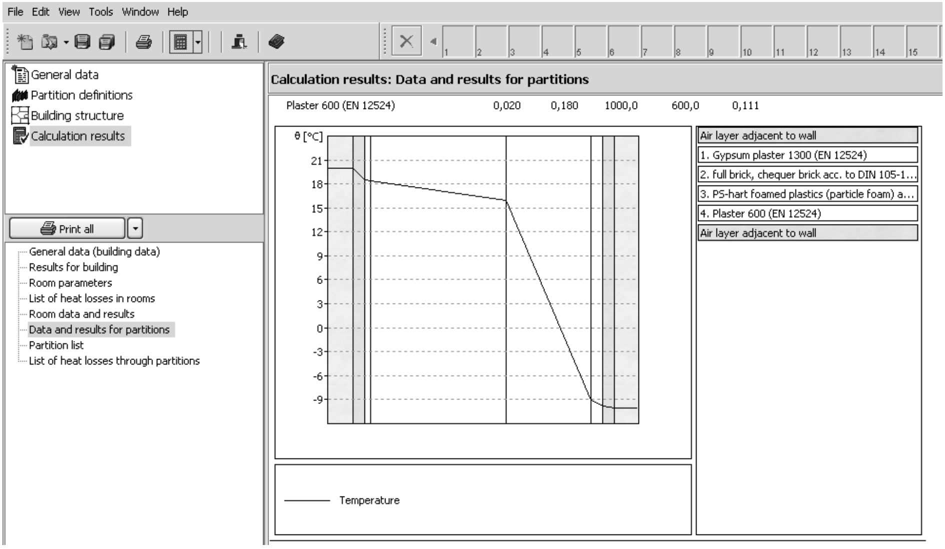


Figure 3.40. Temperature distribution in external wall layers

All results of calculations can be exported to MS Excel (for users owning the full version of the program) or only printed (available in educational version).

3.1.7 Installation designing – selection of project options in Instal-therm HCR

Continuation of installation designing requires introduction of the default settings in *Project Options* (F7 or *Options* in program *Main menu*). First of all, the *General data* of heating system has to be checked and corrected. The default supply temperature for installation (dependent on the source of hot water) as well as temperature drop can be changed in this part of options (Figure 3.41). There is also *Symbol set* available here to be edited, as well as default ambient temperatures for the pipes.

The next step of designing is selection of the devices and pipes for the project by the use of *Catalogues* (Figure 3.42). The window of *Catalogues* is consisted of six tabs: *Radiators, Pipes and pipe fittings, Valves and fittings, Radiant heating, Insulation* and *Climatic data*. In the left part of *Radiators* tab, there is white window of *Other catalogues*. There is the list of catalogues which can be chosen by designer. To be available in the program, the catalogues must be moved to the right window, called *Catalogues in the project* by the use of a single arrow. The double arrow allows to move all catalogues at the same time.

Catalogues with graphical information are marked by the icon of book. Selection of such catalogue by left button of mouse (single click) allows to watch the product by the use of F1 button. Unfortunately, this function is not available in new systems like Windows Vista or newer.

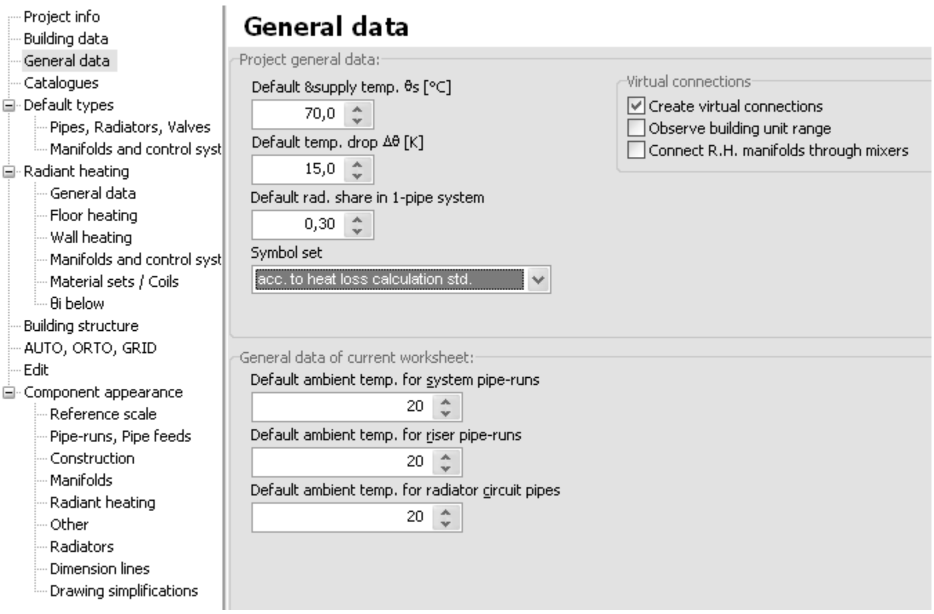


Figure 3.41. General data for heating installation designing

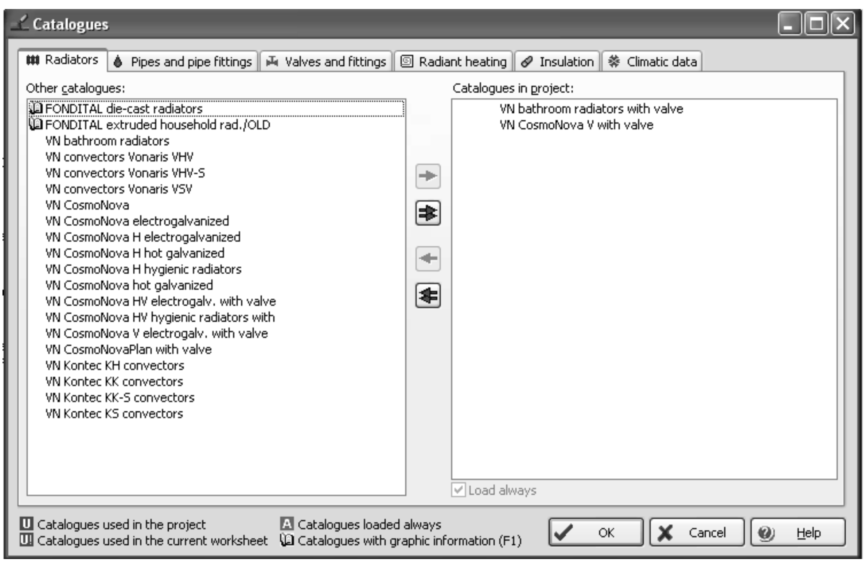


Figure 3.42. General options – catalogues used in project / *Radiators* selection

After selection of catalogues for all mentioned sections (tabs), it is recommended to fill in the *Default types*. Objects selected as the default types (pipes, radiators and other elements of installation) will be then used in the performed project without the need to select particular elements and choose their types manually.

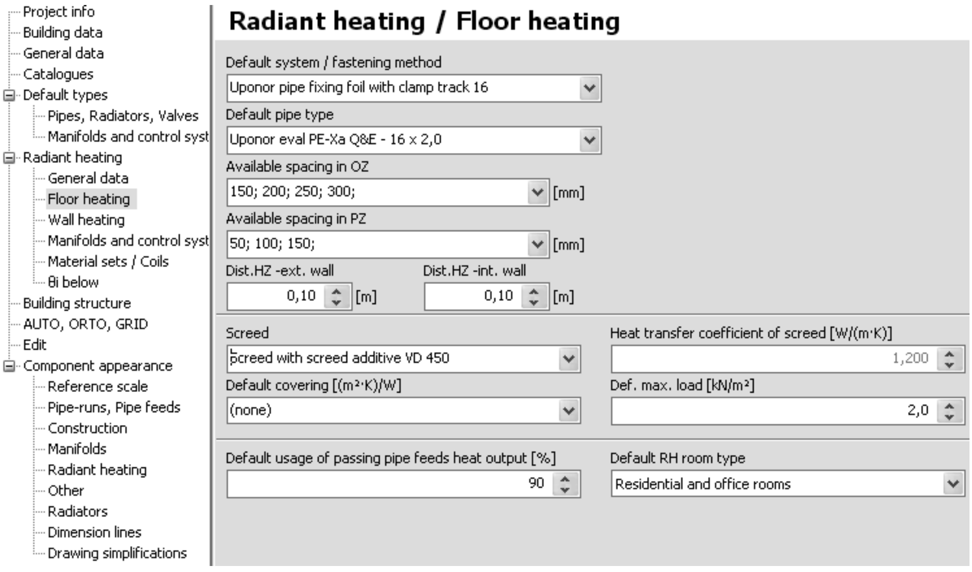


Figure 3.43. Radiant heating settings – floor heating properties

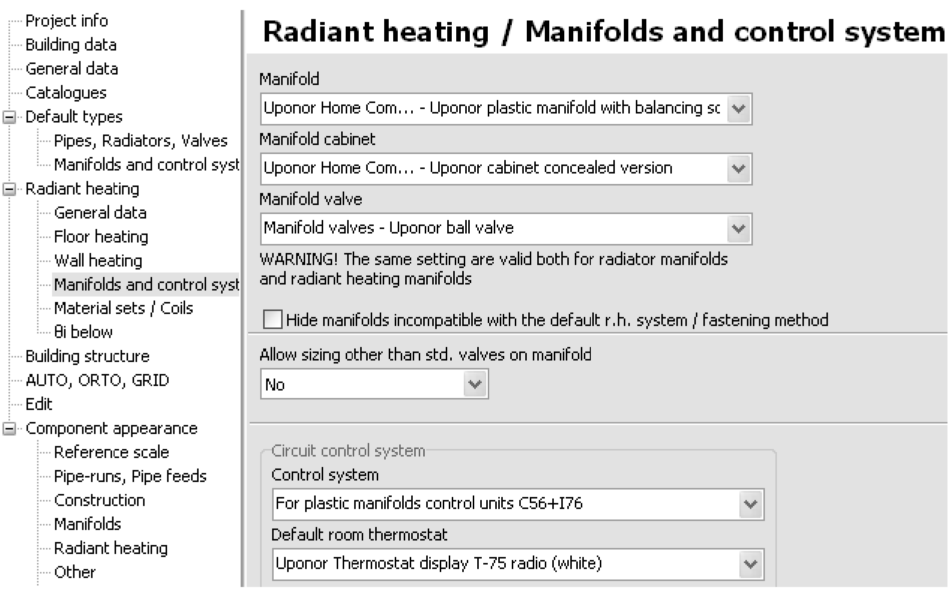


Figure 3.44. Radiant heating settings – *Manifolds and control system* selection

For radiant heating, it is suggested to check all the subcategories in options, to check the kind of a system, available pipe spacing, default floor covering etc., as presented in Figure 3.43. The important information is that the maximal length of heating circuit is limited by the technical issues (production lengths and designing settings – maximal pressure drop, described in theoretical part) and it can be edited in *Materials sets/Coils* section.

In Figure 3.44, the manifolds selection for floor heating is presented. It is possible to choose the type of manifold, its cabinet and valves, as well as the control system for temperature regulations.

In the presented example, Uponor concealed cabinet equipped with plastic manifolds was selected. Moreover, control system was chosen as specific for the manifolds.

3.1.8 Installation designing – drawing and calculation of the system

The manner of designing that will be presented in this chapter is one of examples of simple project. The sequence of elements' insertion used in that example is not the only right, however, as authors stated on the basis of own experience, it is one of the simpliest.

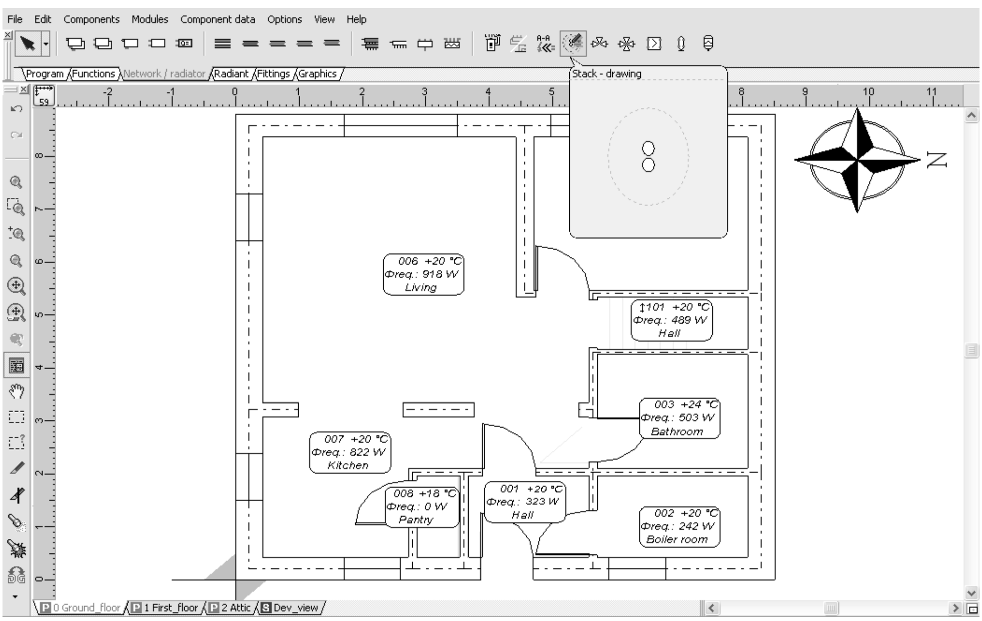


Figure 3.45. Insertion of *Stack – drawing*; an icon

The first step of the drawing part of heating installation design will be, in this example, the insertion of stacks (vertical elements, Figure 3.45) in Heating edit scope. The source of energy is intentionally skipped in this stage, because of the construction of building (technical room is located on the ground floor, therefore source will be drawn in the end of designing, in order to not to disturb during radiators localization).

Localization of stacks is not an easy issue because of different room distribution on particular storeys. To be sure, the vertical pipes are drawn exactly one above another, it is suggested to add the symbol to the stack. After its selection, *Component identification* in *Data table* can be changed.

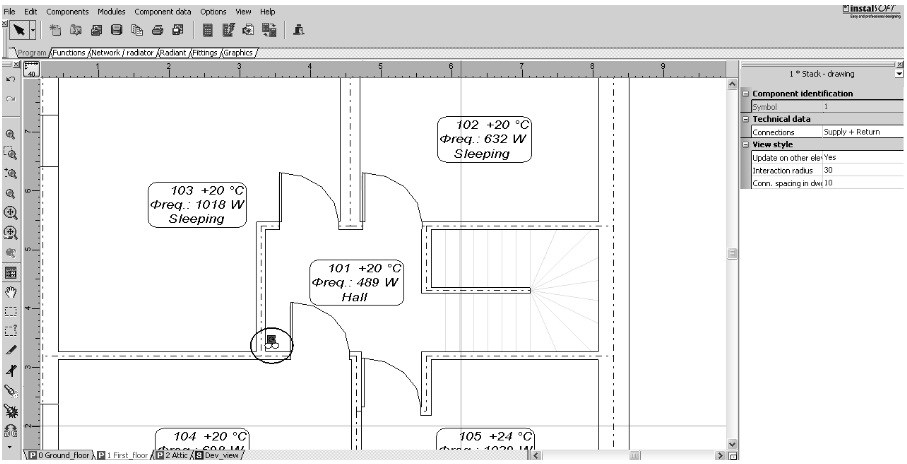


Figure 3.46. Stack inserted on ground floor storey

In the example, the given symbol is “1” (Figure 3.46). If it is added to a stack on ground floor, the same stack on the first floor will be applied automatically to the matching coordinates. It is a very useful function in the case of high buildings with many floors.

In the case of presented example, the above mentioned issue is not so important because the main distributing pipes will be conducted under the ceiling of the ground floor, so vertical pipes can be separate for ground and first floors. By the use of *Data table*, it is also possible to change connections in riser (the supply and the return).

The inserted stack is only a drawing symbol, to make it a part of the installation, it is necessary to attach *Remote connection* (Figure 3.47). Without this element, it is not possible to connect any pipes to the stack. The *Interaction radius*, which can be seen in *Data table* of stack, designates the area of automatic connection creation between the *Stack-drawing* and *Remote connection*. In this area, virtual pipes are inserted automatically between these two elements, and their beginning in *Remote connection* means the joining point between installation on particular floor and stack.

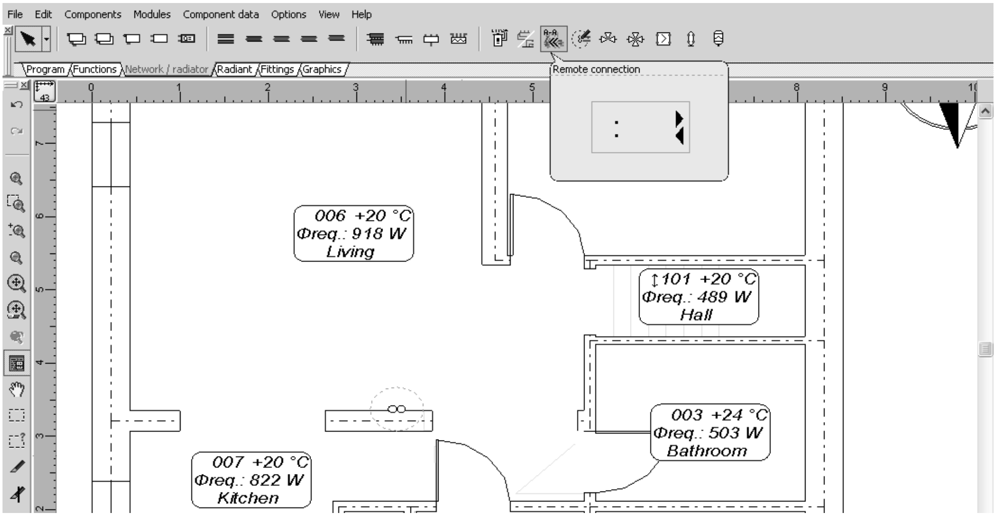


Figure 3.47. *Remote connection* insertion; an icon

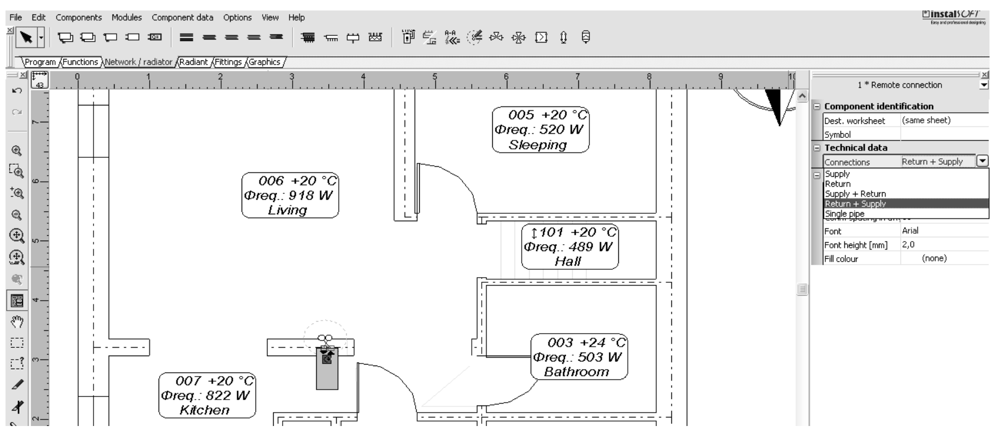


Figure 3.48. Remote connection inserted on ground floor storey

Remote connection is a virtual element, aiming in creation of links between parts of installation separated by different worksheets. It allows to connect the installation on ground floor to the first floor system and schematic view. Creation of links will be presented after the designing of installation on storeys and source insertion. At this stage of designing, remote connection should be inserted close to the stack as presented in Figure 3.48.

The further insertion of installation elements will cause the appearance of errors and warnings in *List of errors*; they should be skipped until all the elements of installation on the storey are connected in the right manner.

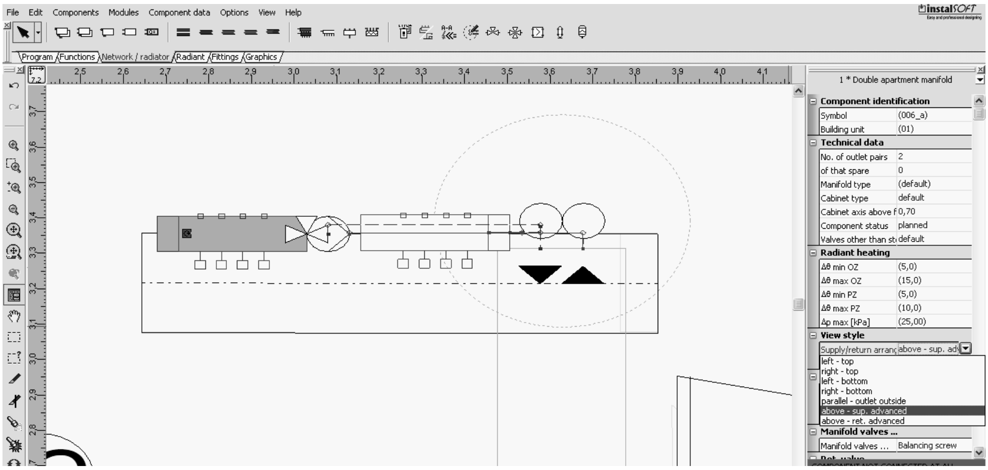


Figure 3.49. Double manifolds for radiant (left) and radiator (right) heating

Designed installation will be based on manifolds. Every heating circuit and radiator have to be connected to the separate output. It is necessary to design two diverse manifolds, because the supply temperatures for radiant and radiator heating are not identical. For radiators, supply temperature will be the same as for the source. In the case of radiant heating, the maximal temperature is 55°C, and therefore it is necessary to use manifold with mixing set (three-way valve and the pump) to ensure relevant temperature (Figure 3.49). The manifolds for radiant heating are available in *Radiant* toolbar, while the simple manifold for convector heating can be found in the *Netork/radiator* toolbar.

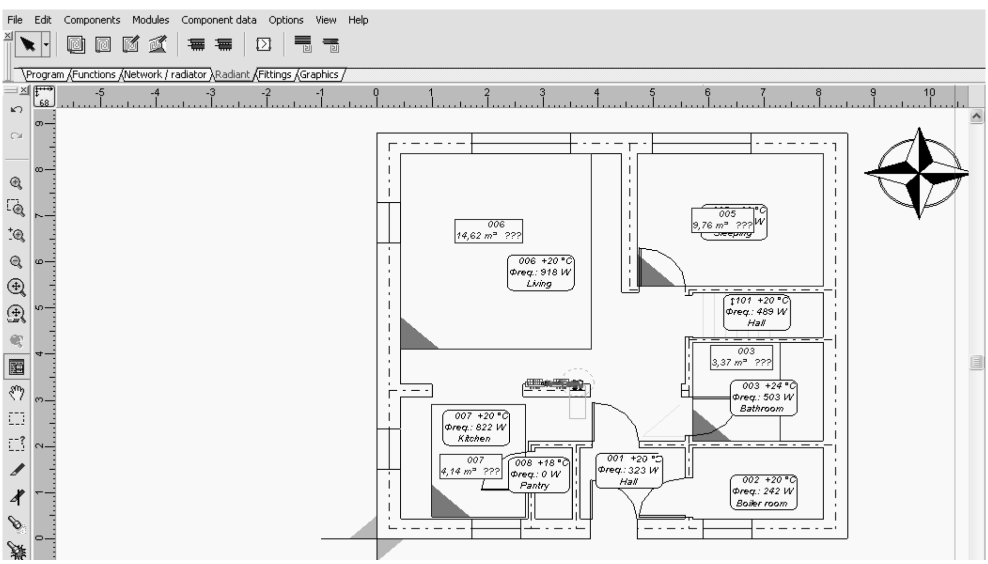


Figure 3.50. Heating floors drawn in the selected rooms

In fact, the supply temperature for floor radiant heating will be assumed after the first calculation on the basis of the current needs. At this stage, *Remote connection*, together with manifolds create supply point for ground floor storey. The receivers of heat will be the radiators and heating circuits.

Heating surfaces can be inserted into the rooms automatically or manually (drawn). The command of their insertion is available in *Radiant* toolbar as the first four icons. In the example, heating floors were drawn manually by clicking into their corners and ending with right mouse button (third icon from left side, see Figure 3.50). Heating floors were designed for kitchen, living room, sleeping room and the bathroom. Other accommodations will be heated by the radiators.

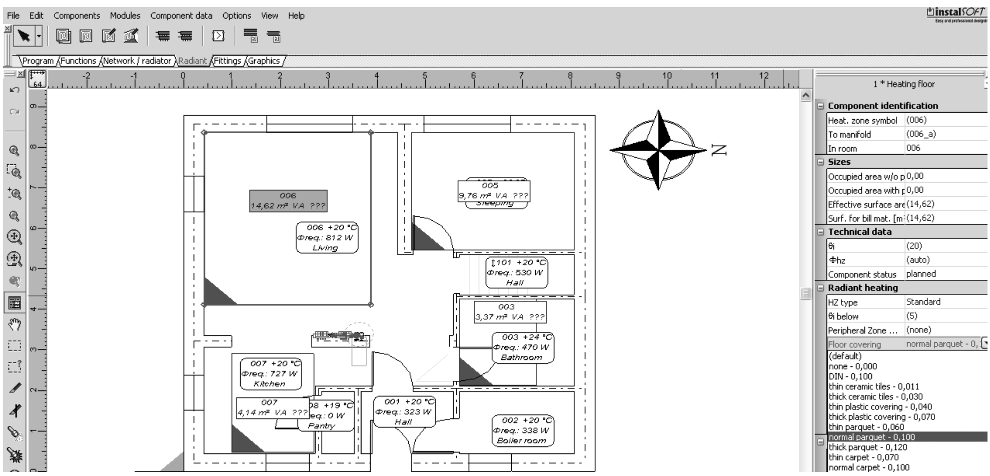


Figure 3.51. Selection of radiant heating specific settings for the chosen floor

After insertion, it is necessary to change to specific settings for the floors (Figure 3.51). Options available in *Data table* include the peripheral zone selection and floor covering, as well as other issues like floor construction, etc. Generally, the floor construction should be chosen automatically on the basis of temperatures below the given room. Peripheral zone will be added after the first calculations.

Floors should be connected to the manifold outcomes by the use of *Pipe feeds pairs* (Figure 3.52) from the *Radiant* toolbar. It is suggested to run pipes through the open space, not passing through the walls, if possible. Pipes should not collide in the floor and they should be conducted in possibly the shortest way.

In the rest of rooms, radiators are designed as heating elements. Radiators can be inserted automatically or manually, and there are two basic types: integrated and non-integrated with valve (Figure 3.53).

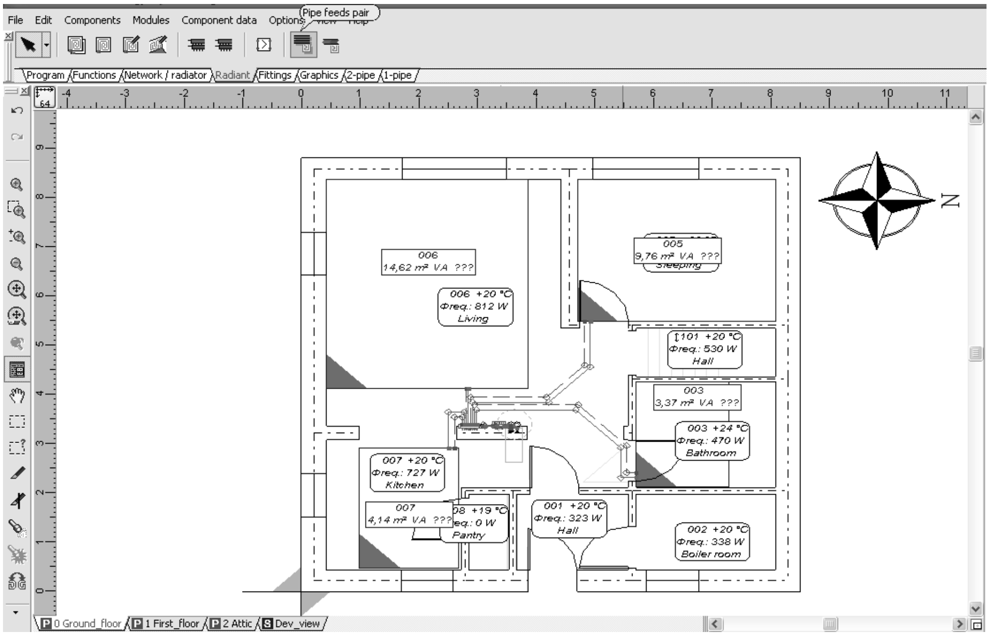


Figure 3.52. Heating floors connected to the manifold by *Pipe feeds pair*

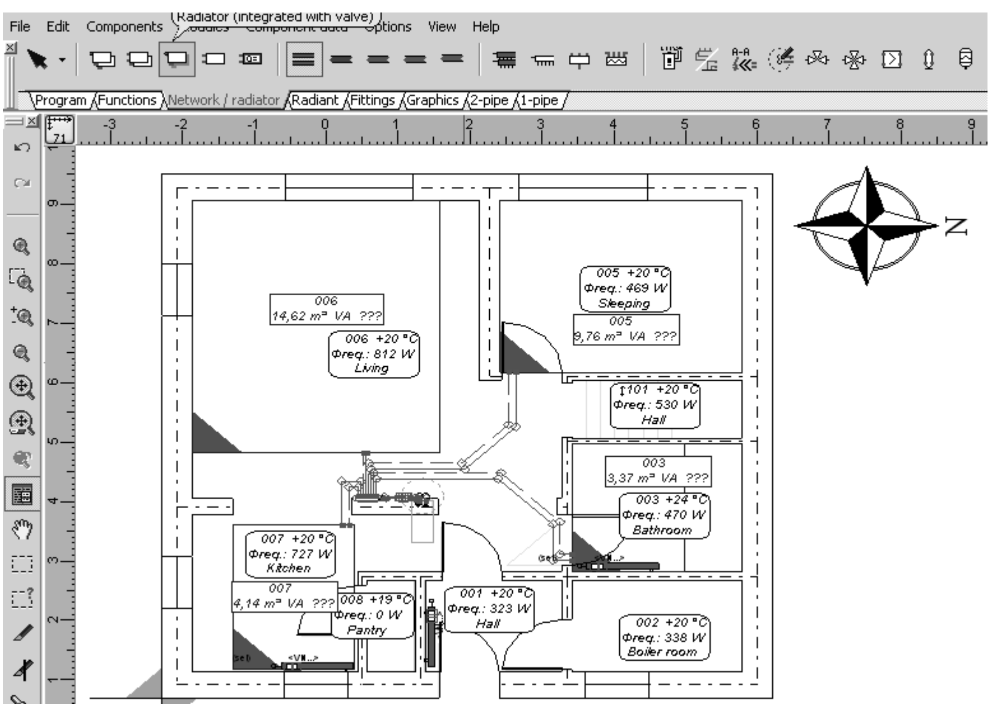


Figure 3.53. Insertion of radiators

Integrated ones will be used in the rooms like kitchen and hall, while non-integrated are intended to be used in bathrooms (ladder type). At this stage of the project example, the boiler room is intentionally neglected, to present the specific kind of an error describing uncovered heating demands for the room.

Radiators should be connected to the manifold by Pipe-runs pair on the same principles as heating circuits. Again, it is recommended not to cross the pipes of surface heating (Figure 3.54).

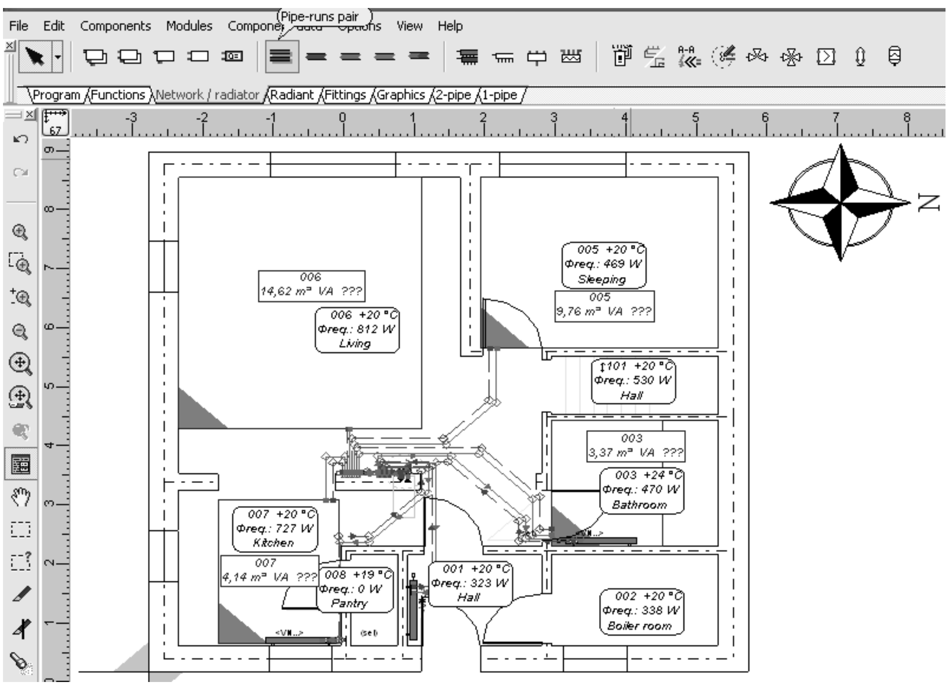


Figure 3.54. Radiators connected to manifold by *Pipe-runs pair*

When the part of installation from the manifolds to the heat receivers on the ground floor is drawn and all elements are connected, it is possible to start the first calculations. Calculations can be started by the use of F10 button or icon of calculator from the *Program* toolbar.

The first element of calculations is a window of *Diagnostic run results*. The aim of this information is to prevent starting calculations with errors like unconnected elements, wrong types of devices used, etc. Presented in Figure 3.55 examples of hints simply inform about the default types of pipes, radiators and manifolds. The default types are correct, so the calculations can be continued by clicking the *Continue* button.

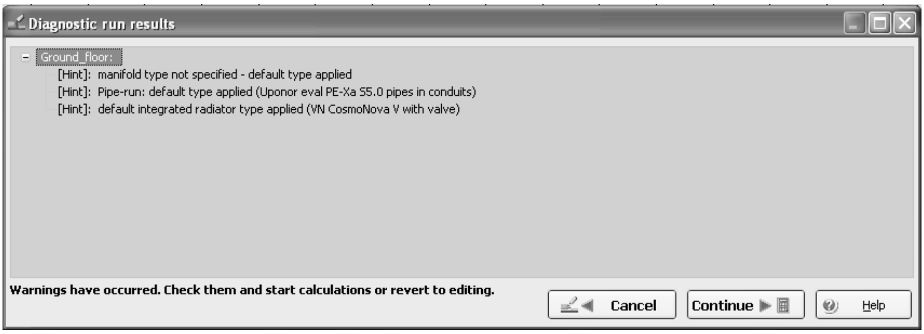


Figure 3.55. Window of *Diagnostic run results*

The next step of calculations is supply temperature selection for radiant heating (RH). The temperature can be optimized by 3 main methods: according to heat output and pressure drop, according to the investment cost or according to exploitation cost (Figure 3.56). It is possible to use *Opt.* θ_s button, however, to control the optimization process, *Graph* usage is recommended (Figure 3.57).

Figure 3.56. Calculations of installation – selection of RH supply temperatures

The graph is a simple temperature axis with the ranges acceptable for rooms, visible as horizontal lines. Supply temperature can be determined by the use of a button or manually by the change of vertical line localization.

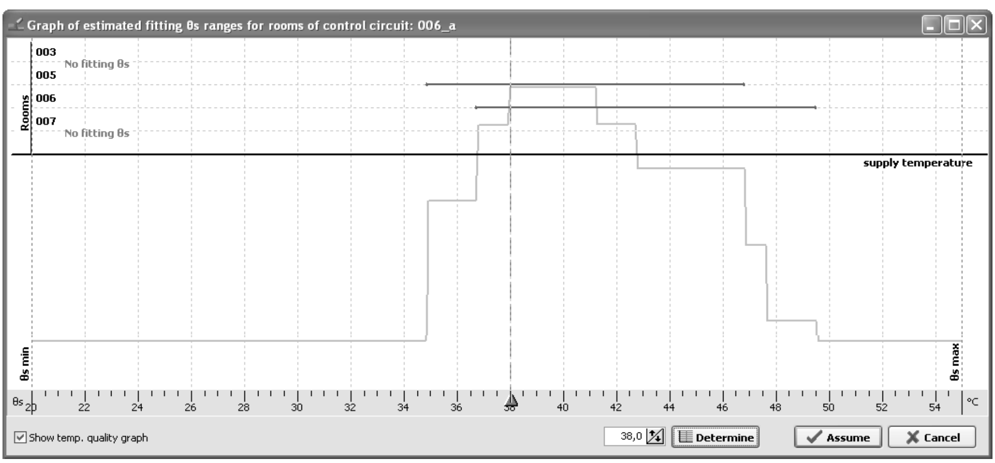
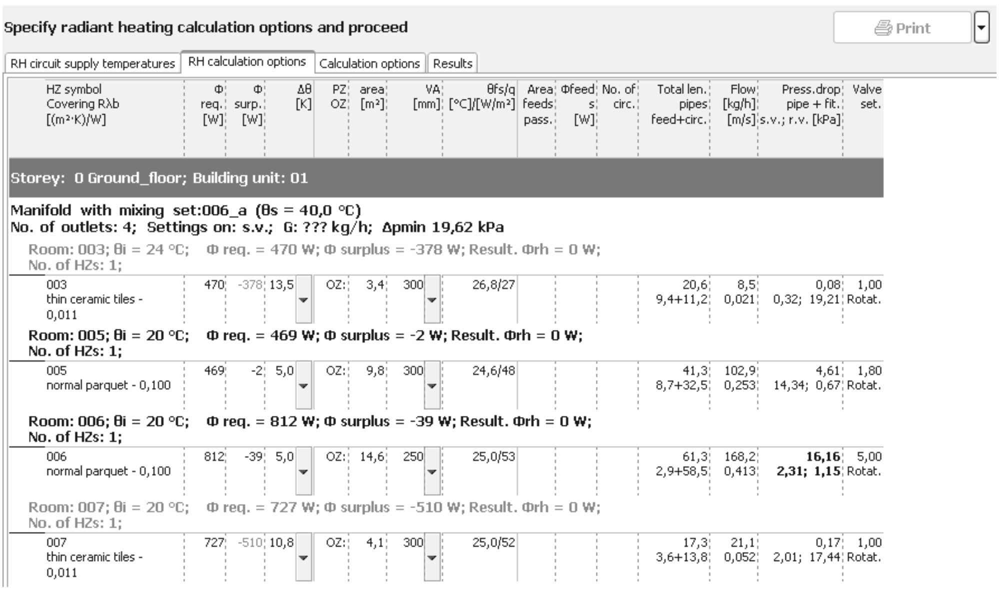


Figure 3.57. Calculations of installation – RH supply temperatures graph

When the line is located at left, in comparison to the temperature ranges, they are blue, which means that rooms are inadequately heated (supply temperature is too low). On the other hand, when located at right, the temperature range lines are red and the rooms are overheated (temperature is too high).

In the case when there is *No fitting* θ_s subscription instead of the range line, the radiant heating is not sufficient to heat the room and it cannot be changed by the increase of supply temperature. The situation has to be diagnosed when full calculations are done. *RH calculation options* include hydraulic calculations for heating circuits. Supply temperature was assumed as 40°C. As it was presented in the graph, only two from four rooms can be heated by RH. The rest of rooms (bathroom and kitchen) require additional radiator, as there is minus *Φ surplus* in these accommodations (Figure 3.58).


Specify radiant heating calculation options and proceed

Print

RH circuit supply temperatures | RH calculation options | Calculation options | Results

HZ symbol Covering Rλb [(m²·K)/W]	Φ req. [W]	Φ surp. [W]	Δθ [K]	PZ OZ	area [m²]	VA [mm]	θfs/q [°C]/[W/m²]	Area feeds pass.	Φfeeds [W]	No. of circ.	Total len. pipes feed+circ.	Flow [kg/h] [m/s]	Press.drop pipe + fit. s.v.; r.v. [kPa]	Valve set.
Storey: 0 Ground_floor; Building unit: 01														
Manifold with mixing set:006_a (θs = 40,0 °C) **No. of outlets: 4; Settings on: s.v.; G: ??? kg/h; Δpmin 19,62 kPa**														
Room: 003; θi = 24 °C; Φ req. = 470 W; Φ surplus = -378 W; Result. Φrh = 0 W; No. of HZs: 1;														
003 thin ceramic tiles - 0,011	470	-378	13,5	OZ:	3,4	300	26,8/27				20,6 9,4+11,2	8,5 0,021	0,08 0,32; 19,21	1,00 Rotat.
Room: 005; θi = 20 °C; Φ req. = 469 W; Φ surplus = -2 W; Result. Φrh = 0 W; No. of HZs: 1;														
005 normal parquet - 0,100	469	-2	5,0	OZ:	9,8	300	24,6/48				41,3 8,7+32,5	102,9 0,253	4,61 14,34; 0,67	1,80 Rotat.
Room: 006; θi = 20 °C; Φ req. = 812 W; Φ surplus = -39 W; Result. Φrh = 0 W; No. of HZs: 1;														
006 normal parquet - 0,100	812	-39	5,0	OZ:	14,6	250	25,0/53				61,3 2,9+58,5	168,2 0,413	**16,16** **2,31; 1,15**	5,00 Rotat.
Room: 007; θi = 20 °C; Φ req. = 727 W; Φ surplus = -510 W; Result. Φrh = 0 W; No. of HZs: 1;														
007 thin ceramic tiles - 0,011	727	-510	10,8	OZ:	4,1	300	25,0/52				17,3 3,6+13,8	21,1 0,052	0,17 2,01; 17,44	1,00 Rotat.

Figure 3.58. Calculations of installation – options for RH

The hydraulic calculation table for RH consists of 15 columns including room description, required *Φ*, surplus *Φ*, temperature drop, info about peripheral or occupied zone, area, pipes module, temperature to heat stream ratio, area of feeds passing and its *Φ*, circuit number, length of pipes, flow, pressure drop and regulation valve setting. Temperature drop and pipes module can be changed manually. The bolded value of pressure drop is the highest, characteristic for the most unfavorable circuit.

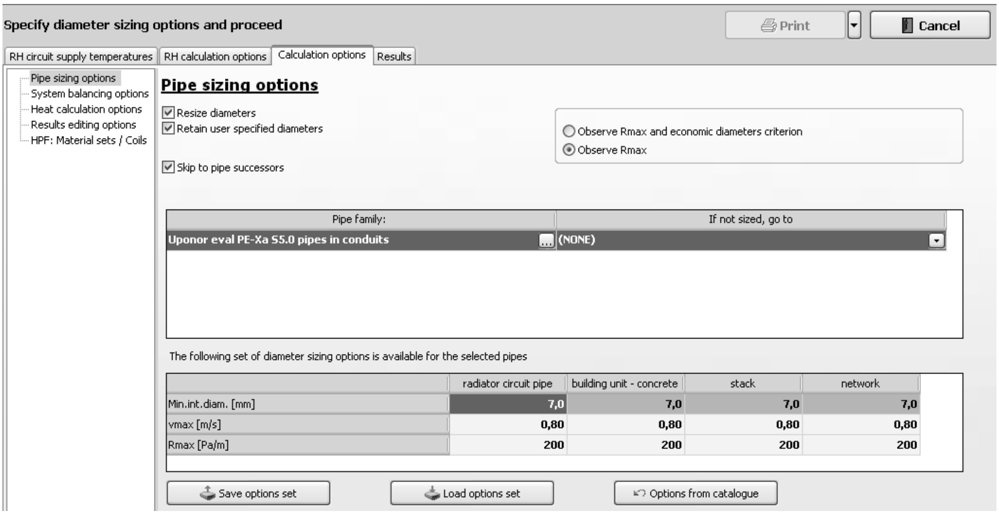


Figure 3.59. Calculations of installation – general options

The next step of calculations is general options window. It allows to change the usually used settings like maximal velocity of pipes, etc (Figure 3.59). In the example, standard options were left unchanged since they are compatible with catalogues used.

The last window of calculations includes results of the hydraulic calculations, grouped in the eight main categories plus bill of materials. General results for convector heating (C.H.) include information about supply and return temperatures, total outputs of radiant and convector radiators, pressure available, flow of medium in source, installation water capacity, etc. At this stage of design, they are not complete and cannot be used for any purposes. The results will be completed after the drawing the whole installation.

After first calculations are finished, it is necessary to make the corrections of types of heating systems in the kitchen and the bathroom. Generally, advanced designers do such corrections at the beginning of drawing, because they can predict the contributions of radiant and convector heating.

In the case of first project prepared in InstalSystem, it is easier to check the efficiency first (required Φ, surplus Φ). Required Φ is a sum of radiant and convector heating, while surplus should be covered by the radiators. Therefore it is easy to count the contribution of convector (surplus Φ / required Φ) and radiant (1 - surplus Φ / required Φ) heating.

It is also crucial at this stage of the project to remember about completing all the installation. In this particular case, it means the insertion of missing radiator in boiler room.

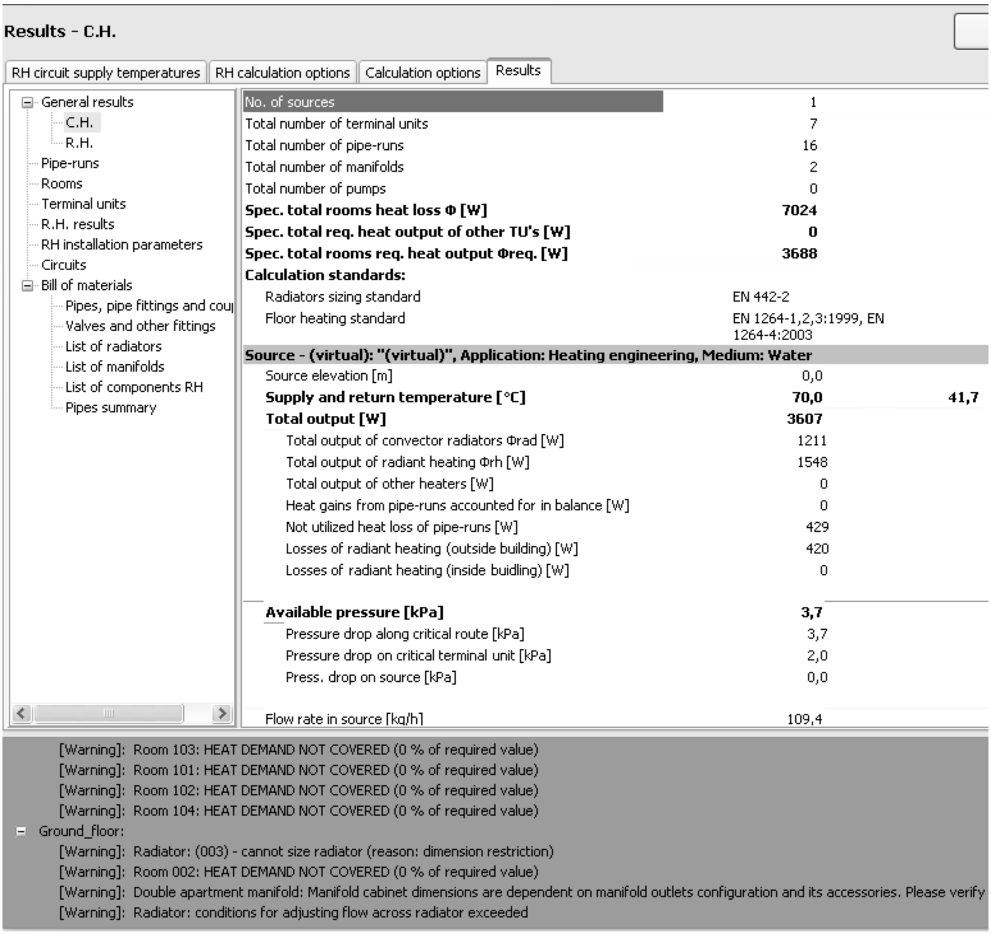


Figure 3.60. Hydraulic calculation results

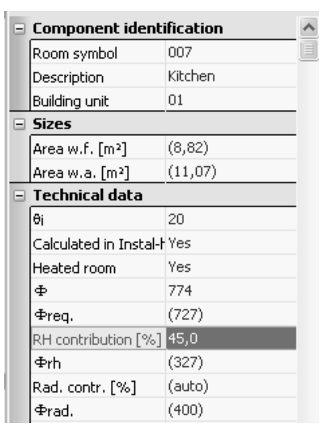


Figure 3.61. Correction of types of heating in *Data table*

To make the correction, it is necessary to select the room by clicking its label (Figure 3.61) and change *RH contribution [%]* and *Rad. Contr. [%]* (RH – radiant heating, Rad. – radiators). After changing the contributions, it is visible in RH calculation results that the heating floor will work properly in the selected conditions. In the graph for supply temperature selection, all the heating floors have similar temperature ranges (Figure 3.62) so they can be supplied from the same manifold. In the example, the assumed temperature equals 40°C.

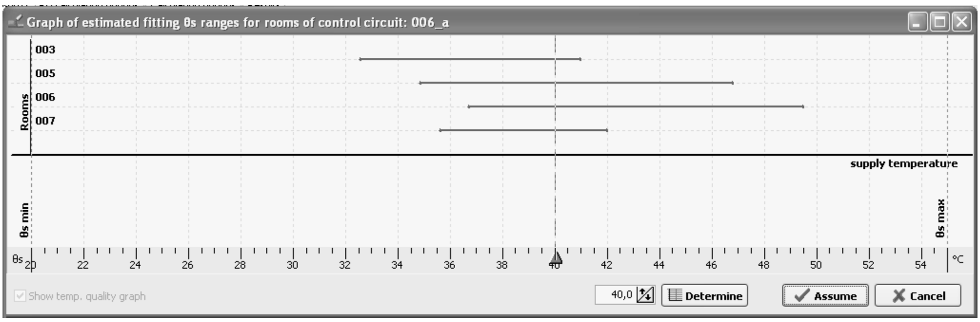


Figure 3.62. Selection of supply temperature for RH – second calculations

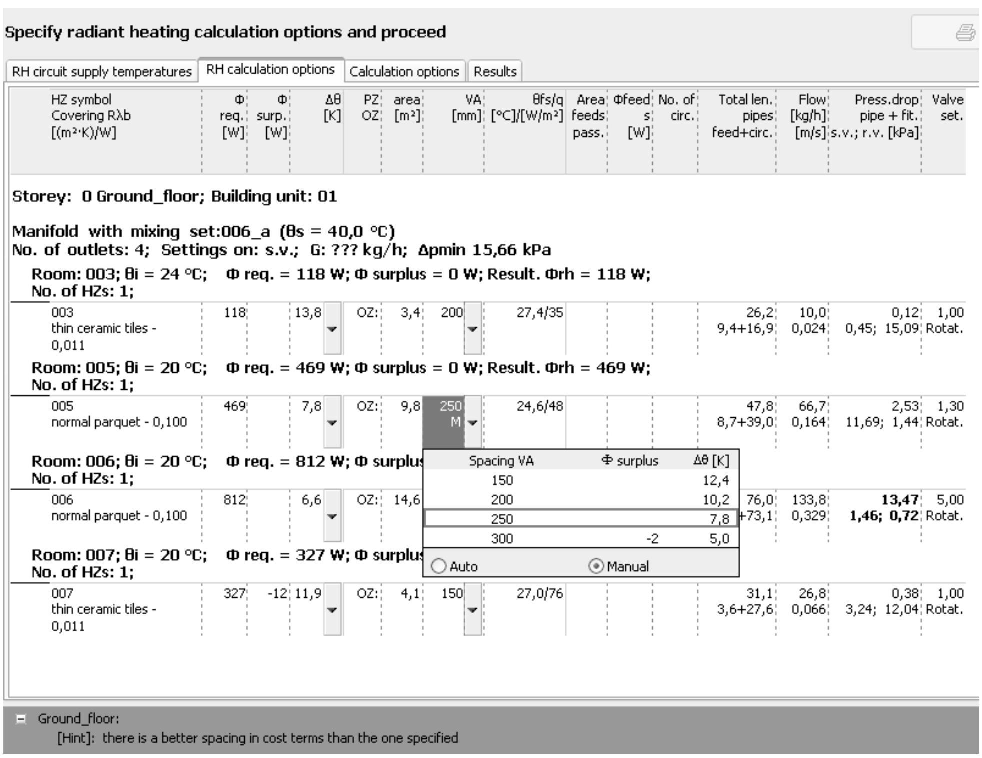


Figure 3.63. Manual change of RH circuit spacing

In some cases, it may be necessary to use manual selection of RH properties like temperature drop and pipes spacing. It may happen when there is a small, minus *Φ Surplus* and the selected way of system optimization does not allow to find the right solution. In such case, the manual selection of temperature drop and spacing is recommended (Figure 3.63).

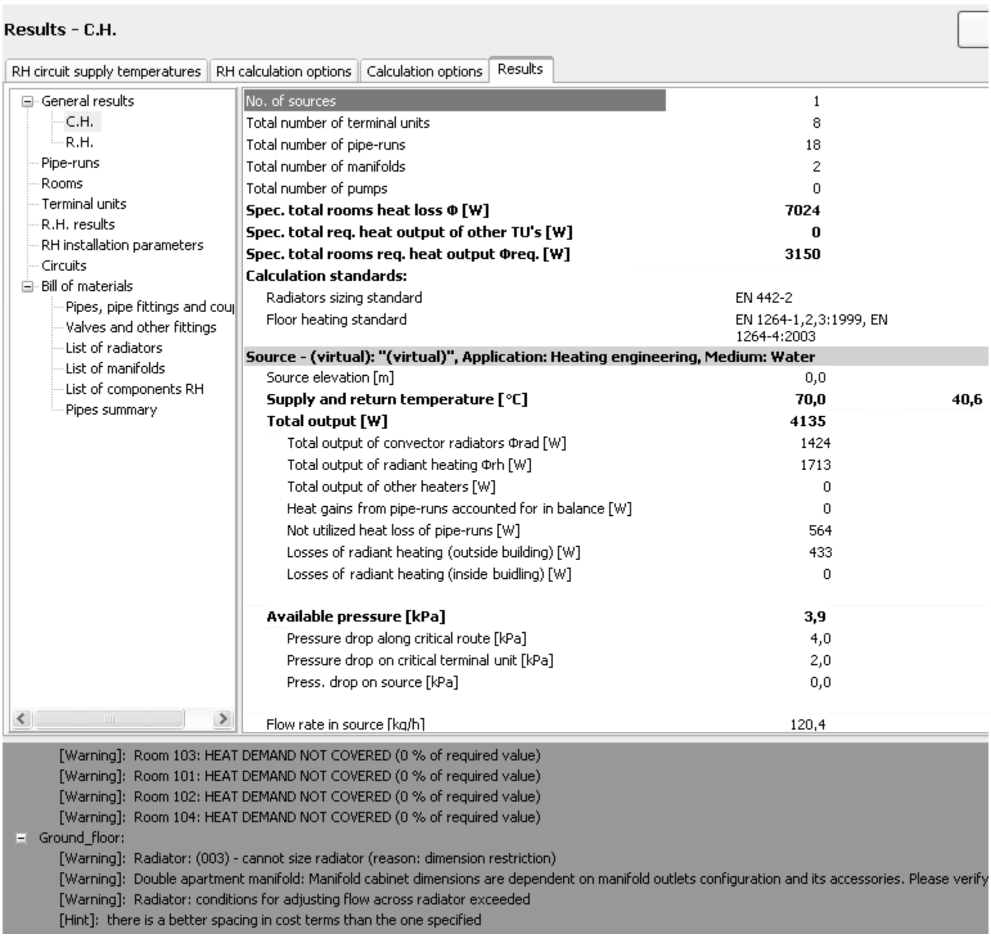


Figure 3.64. Results of calculations with Warnings and Hints

When calculations are finished, it is necessary to correct all the warnings for the ground floor storey. The list of warnings is available in the *List of errors* window and elements with warnings can be easily localized by simple clicking the particular one on the list. The first one – *cannot size radiator* – is active for bathroom radiator, which become selected after clicking in warning. The dimensions of bathroom radiators are not standard – they are usually higher, therefore it is necessary to change *Size limits* in *Data table* (Figure 3.65).

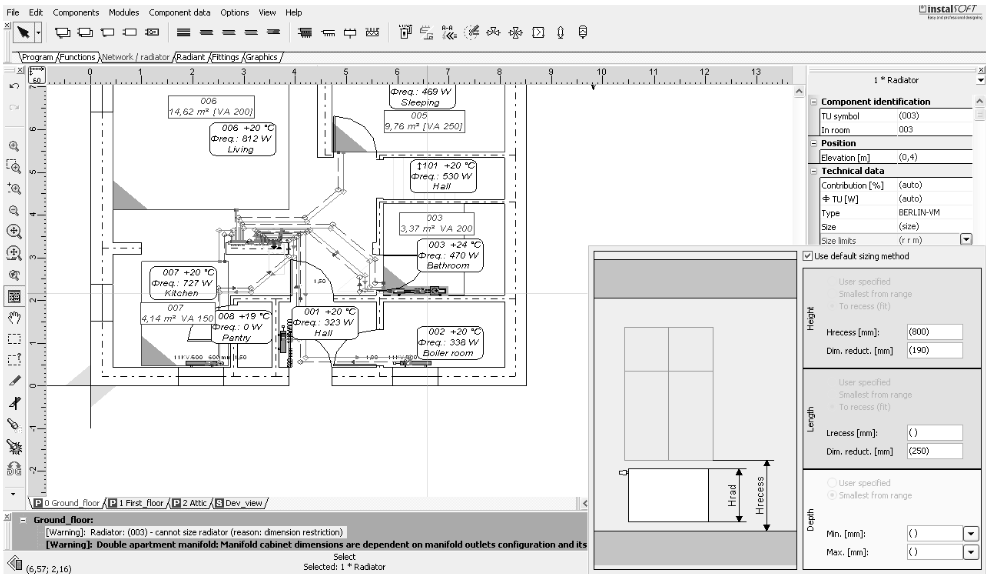


Figure 3.65. Correction of dimension restrictions for radiator

Since the size of radiator was not set during the calculations, it is recommended to choose the type and size of the radiator manually by the use of *Data table* (Figure 3.66).

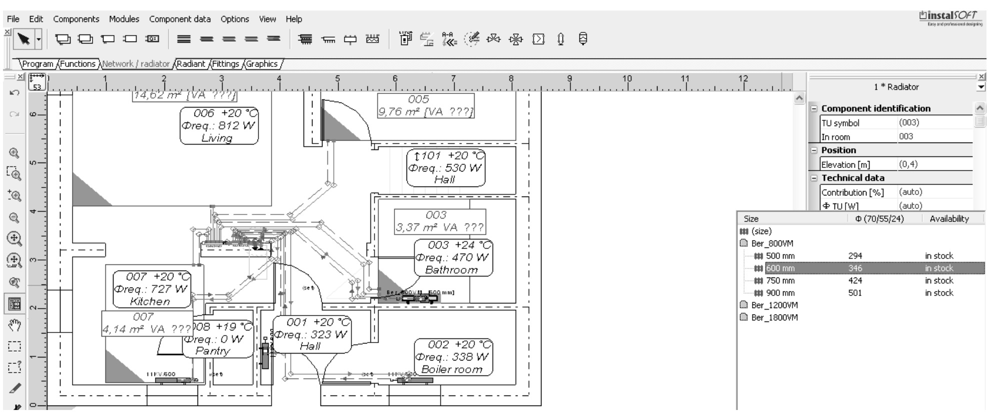


Figure 3.66. Manual selection of radiator

Firstly, it is necessary to select the type of radiator (VN bathroom radiators catalogue). Secondly, the list of available sizes with corresponding values of *Φ* is used to find the right radiator and select it by double clicking or Enter.

In the case of heating floors situated in rooms as the only source of energy, it is suggested to set the peripheral zone nearby the external walls with windows. In the example, living room and sleeping room will be equipped with such zone (Figure

3.67). Since it is built from the pipes with smaller spacing, heat stream from 1m^2 of such floor is higher. Therefore it allows to increase the efficiency of RH. After the change, calculations should be run once again, in this case in the shorter version (Shift + F10).

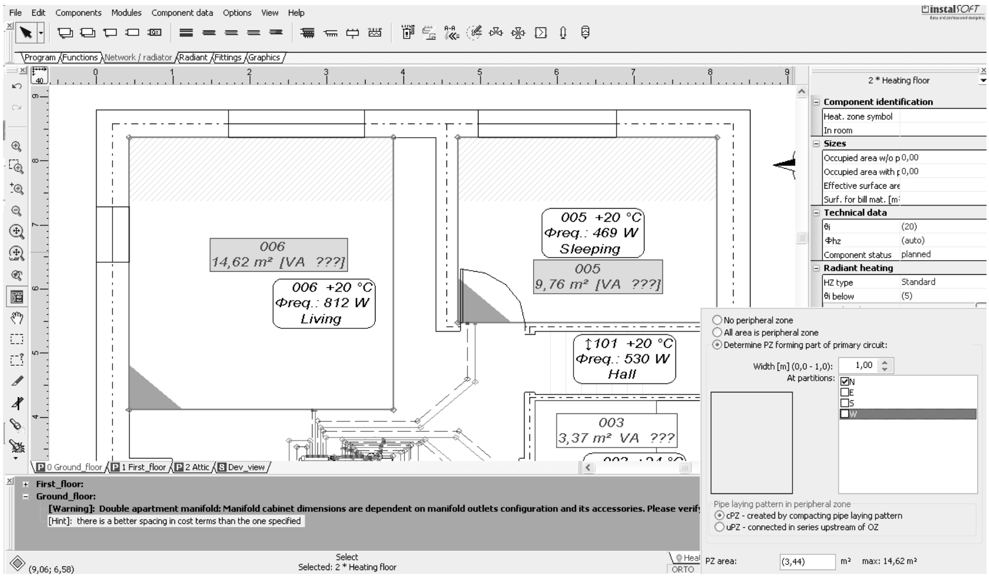


Figure 3.67. Insertion of the peripheral zone

After the final calculation, there are only two messages on the list for the ground floor storey: warning about the default type of manifold cabinet and hint about manually chosen spacing in one of accommodations. As the two messages are not significant for project calculations (they are simple information), they may be skipped in the future calculations. To exclude the selected type of hints and warnings from the list, it is necessary to use right mouse button on the selected message and select *Never show this message again* command (Figure 3.68).

Figure 3.68. Hiding of insignificant hints and warnings

Since the calculation for ground floor is finished, the designer should move to the *First floor* worksheet. The only element of installation already drawn / inserted on this storey is *Stack* (riser) with *Remote connection*. This storey will be heated by the use of convector heating only, therefore the first action will be insertion of radiators. It can be done automatically by the use of *Insert radiators under all external windows* command (first and second icon in *Network / radiator* toolbar). The first icon is used to insert radiators integrated with valves (bottom-fed radiators), while the second for non-integrated (side-fed) ones (Figure 3.69). Since Hall has no window, it is skipped in automatic insertion and the radiator has to be inserted manually by the use of third icon of the *Network / radiator* toolbar.

Moreover, radiator in Bathroom is located under the window. In the case of bathroom radiators of ladder type, this localization should be changed as they are usually hanged directly on the wall. Therefore the radiator will be moved. Moreover, it will be doubled since a single bathroom radiator rarely can provide more than 1 kW.

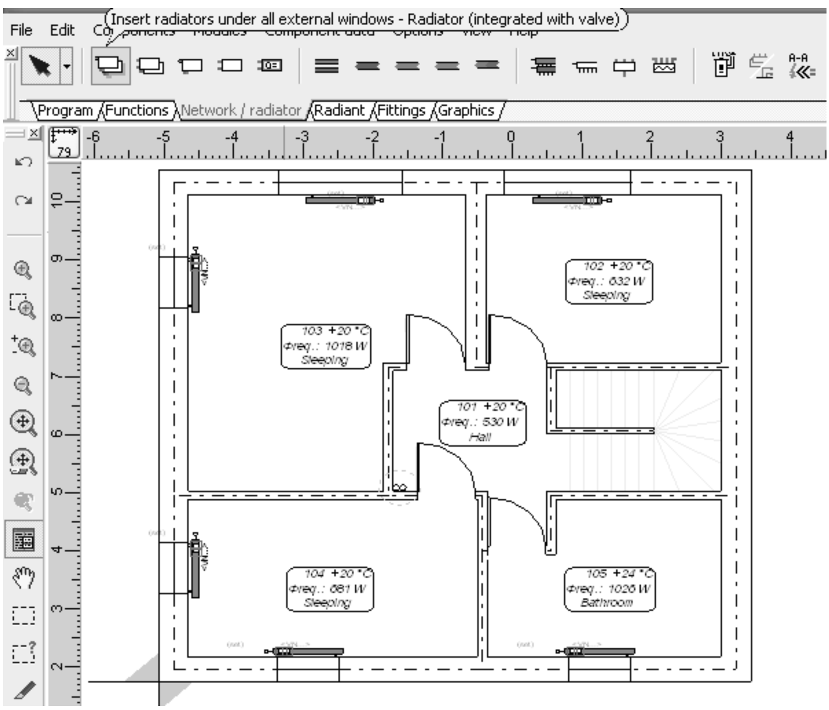


Figure 3.69. Insertion of radiators on the first floor

The next step is the insertion of manifold in a Hall (Figure 3.70). As it will be used for the convector heating installation, it should be selected from the *Network / radiator* toolbar as double manifold. After that, it is necessary to change the number of outlet pairs in *Data table* (Figure 3.70). Manifold should be connected with *Remote connection* by the use of *Pipe-run pair*.

The same tool is used for connection of the radiators with manifold. Single *Pipe-run pair* can be started in manifold outlet and run to the radiator on the basis of the same rules as in radiant heating, using possibly the shortest way through the openings in walls and trying not to criss-cross the pipes. In the end, it can be connected to the radiator (manual connection) or left near to it (right mouse button will finish the command).

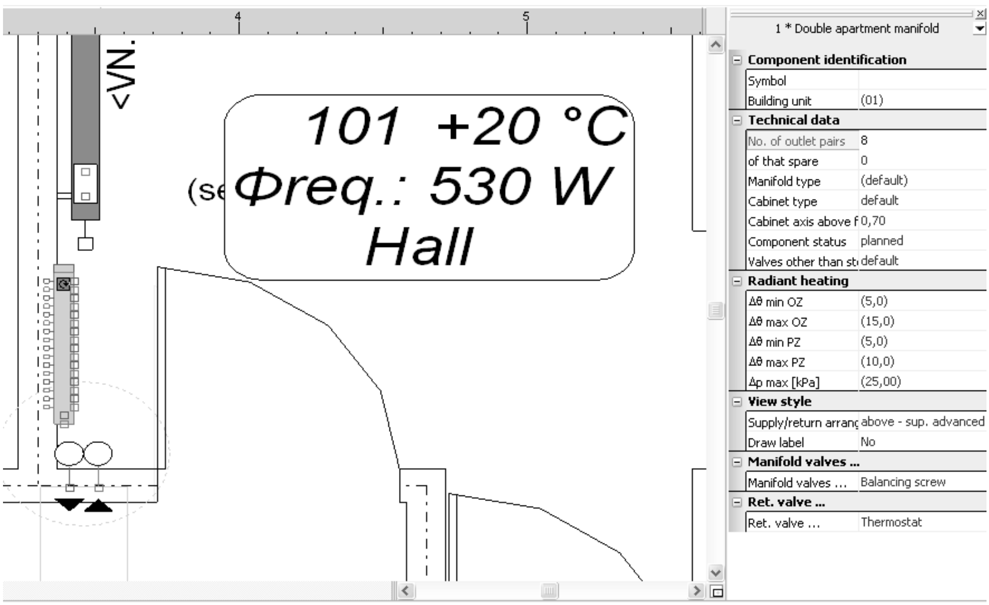


Figure 3.70. Insertion of manifold on first floor

In the case, when pipes were left close to the radiators, as presented in Figure 3.71, it is possible to use automatic connection command from *Components* menu (Shift + Ctrl + A). It allows to create connection between nearby elements of the installation.

After connection of all radiators, the installation on the first floor is completed. In the case of presented example, it consists of eight radiators, manifold, stock, remote connection and the pipes. Since the radiators are integrated with valves, there is no need to insert additional fittings. Thermostatic and return valves should be used only in the case of non-integrated radiators on supply and return pipe respectively.

To check the correctness of connections, it is necessary to save the file. If the installation is drawn properly, arrows with flow direction will appear on pipes (Figure 3.72).

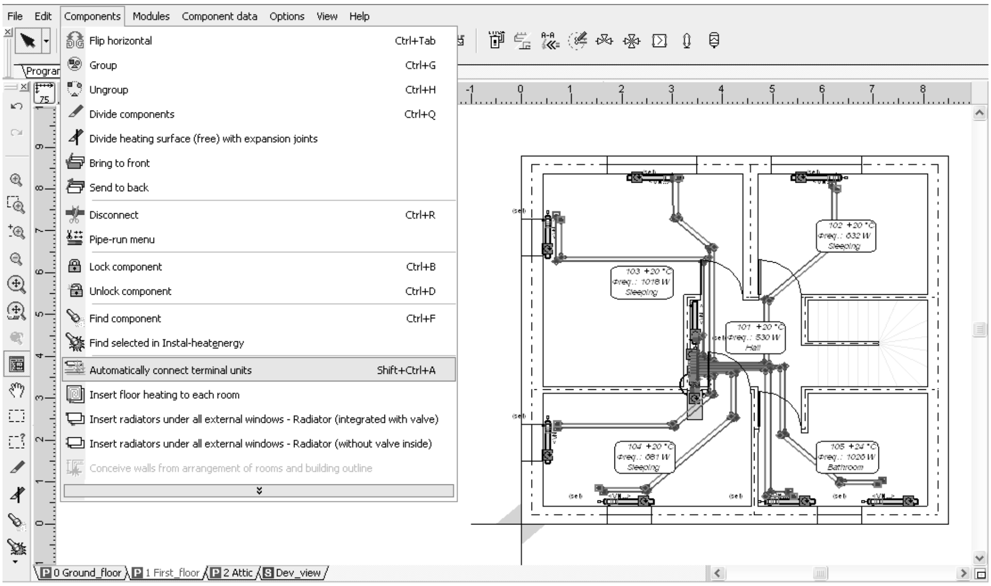


Figure 3.71. Automatic connection of radiators to manifold

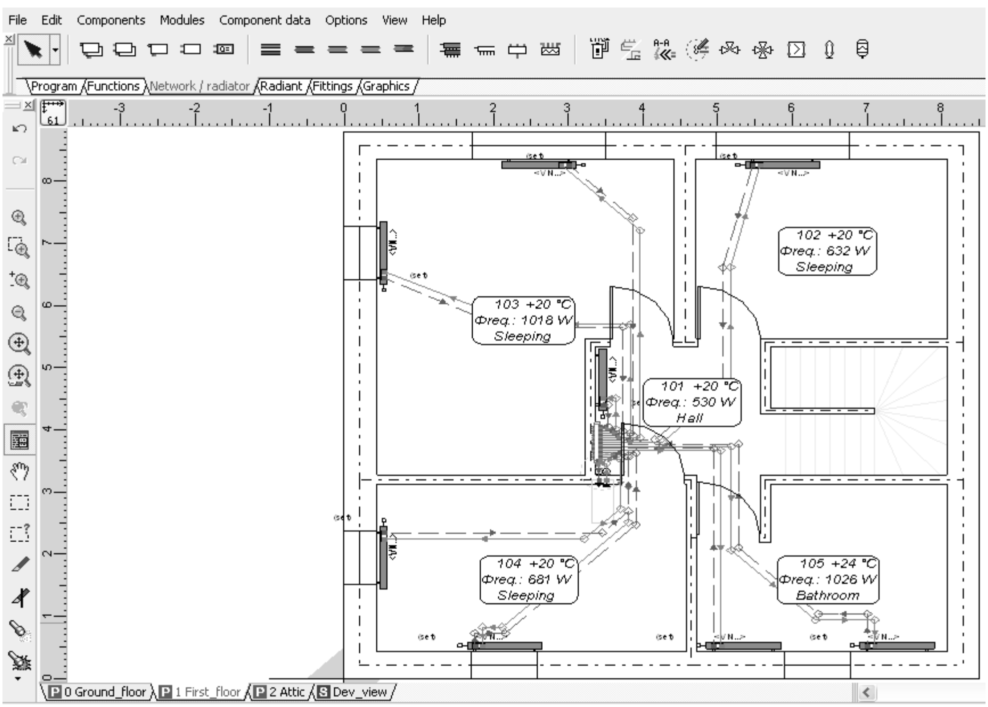


Figure 3.72. Convector heating installation on first floor

After completing installation on first floor, calculations should be run once more. Some warnings or hints may happen, which should be checked and corrected. In the case of presented example, there was one warning active for the boiler room: *Significant medium temperature drop in pipe-run*. This means the extended length of pipes and / or too low velocity of medium flow. It can be corrected by the addition of insulation (*Data table*) or selection of smaller radiator size, which causes increase of medium velocity.

The total output is equal 9.1 kW and covers heat load of building calculated previously in Instal-heat&energy module. However, calculations do not include source (visible as virtual in results) and distribution pipes from the source to the manifolds, therefore this part of installation should be drawn in the next step.

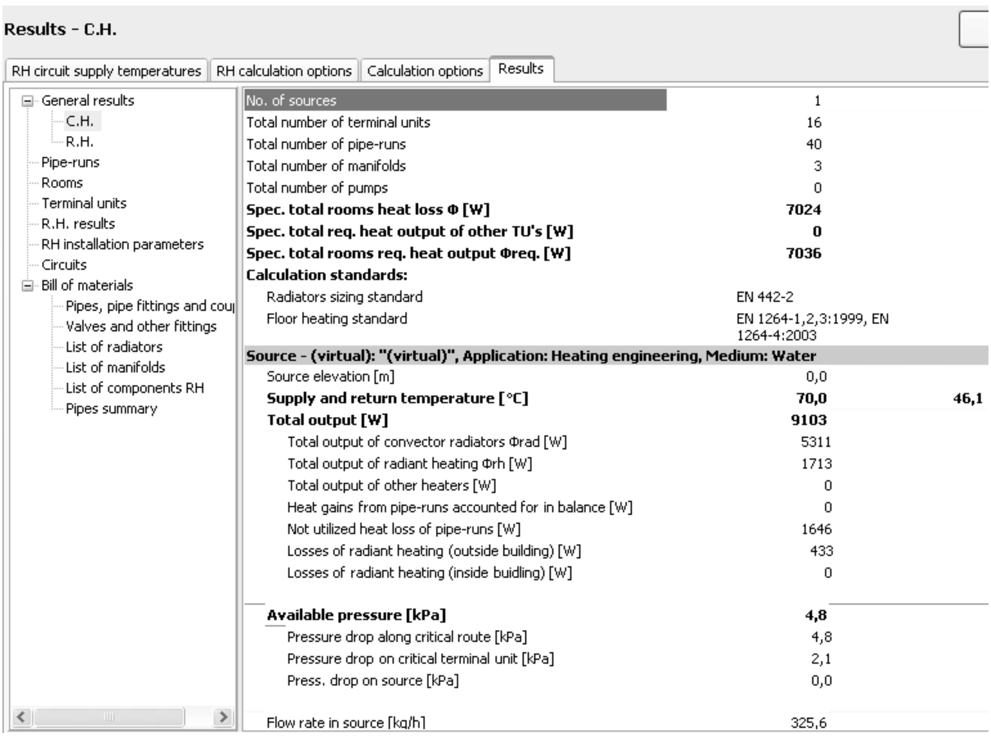


Figure 3.73. Results of calculations for both storeys

3.1.9 Creation and calculation of the schematic view

To draw the distribution pipes, stacks and boiler, it is necessary to create the schematic view of the installation. In the case of presented example, it will be created in worksheet of Dev_view. The type of worksheet is schematic view, in opposite to plan views used for storeys' drawings.

Floor elevation label is available to be inserted from the *Components* toolbar and represents cross-section of building storeys. It will be a base for further drawing of installation and should be inserted in 0,0 coordinates because of the automatic labeling of storeys elevations. The length and height of construction can be changed by the use of black rectangles in its corners and center of sides (Figure 3.74). Since the horizontal scale in the schematic view will not be kept, to present all the installation, the length of construction was assumed as more than 20 meters.

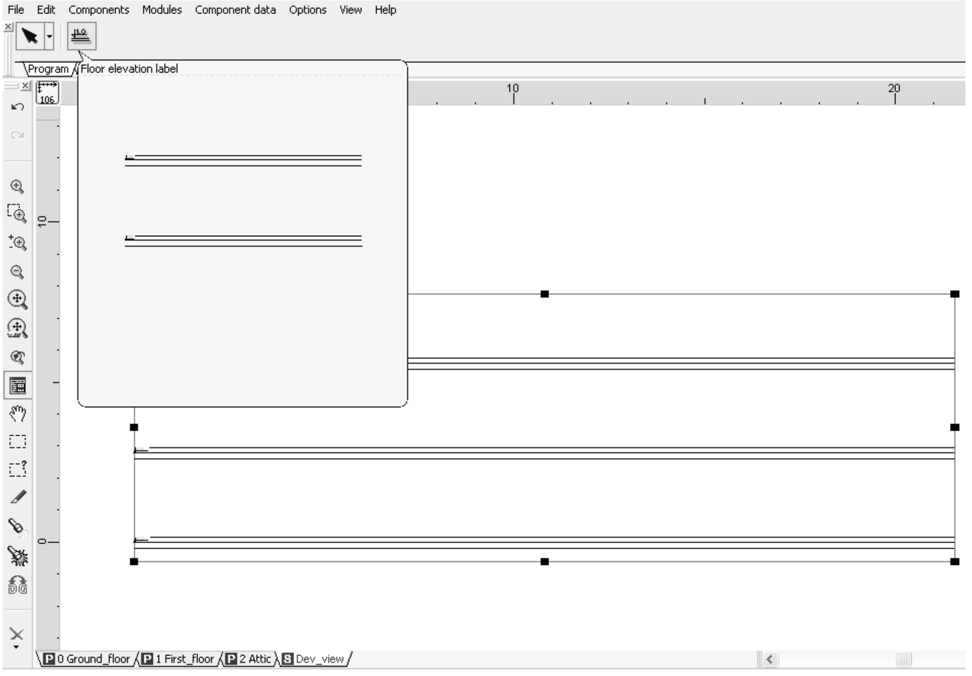


Figure 3.74. Insertion of *floor elevation label* on schematic view of installation

The next step is insertion of source of heat: *Boiler*. As one of the elements of installation, its icon is located in the *Network / radiators* toolbar (Figure 3.75). Data table for boiler includes *Component identification*, *Position*, *Technical data*, *Radiant heating* and *View style*. If the type of boiler is already selected, its technical data like pressure drop, water capacity and outlet diameter should be changed into the real values.

View style includes presentation options like *Connection type*, *Drawing type* and *Label type*. *Connection type* can be chosen as bottom, side or top, with wide and narrow distance between inlet and outlet pipe. Drawing style means hanging or standing boiler, depending on its type. *Label type* includes options for description presentation – in the example it is heat load, available pressure and flow of medium.

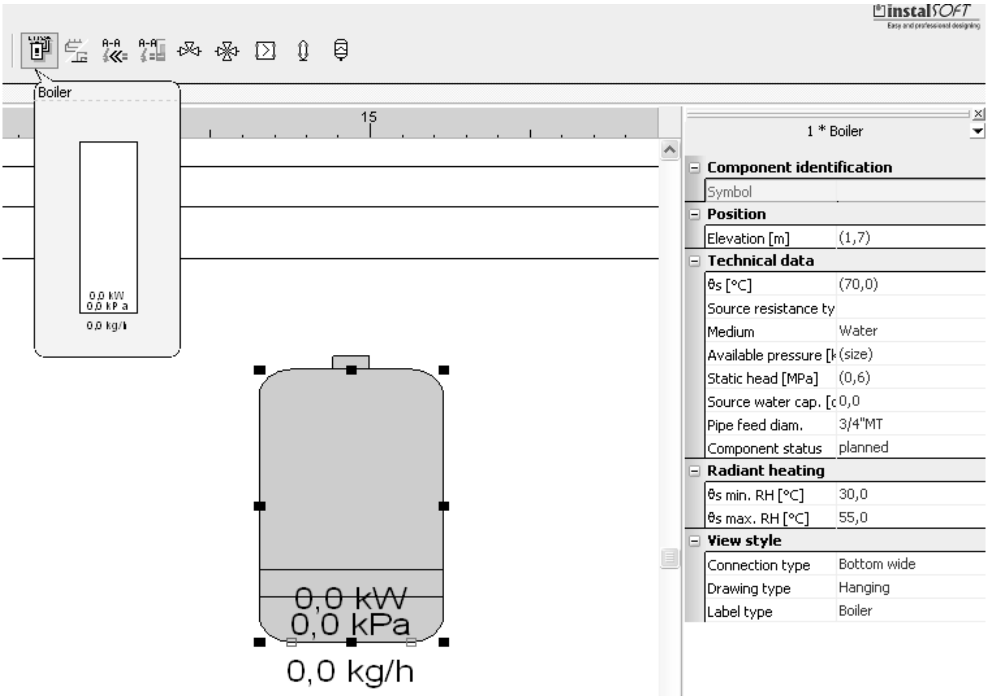


Figure 3.75. Insertion of boiler on schematic view

The inserted boiler will be used to supply the installation consisting of the distribution pipes (horizontal and vertical), manifolds and heat receivers. To connect all the installation into one system, *Remote connections* are used in plan views and the corresponding components of *Automatic schematic view of system* are used in schematic views. These two types of elements are virtual and are used to create connection between the particular parts of the system like for example two storeys (separate worksheets), first floor and schematic view, the extensions at the schematic view, etc.

Automatic schematic view can be inserted using an icon from the *Network / radiator* toolbar. It should be placed on the level of floor on every heated storey (corresponding to the two *Remote connections* from plan views), as in Figure 3.76.

Automatic schematic view should be connected with boiler by the use of pipe run pair, as presented in Figure 3.76. The length of these pipes should be inserted manually in *Data table*, since horizontal scale is not held.

To create connections between the separated parts of installation, it is necessary to identify virtual elements. *Component identification* of selected element is available in *Data table* and includes *Destination worksheet* and *Symbol*. Destination of bottom automatic schematic view is the ground floor worksheet, while the top one is corresponding to the first floor.

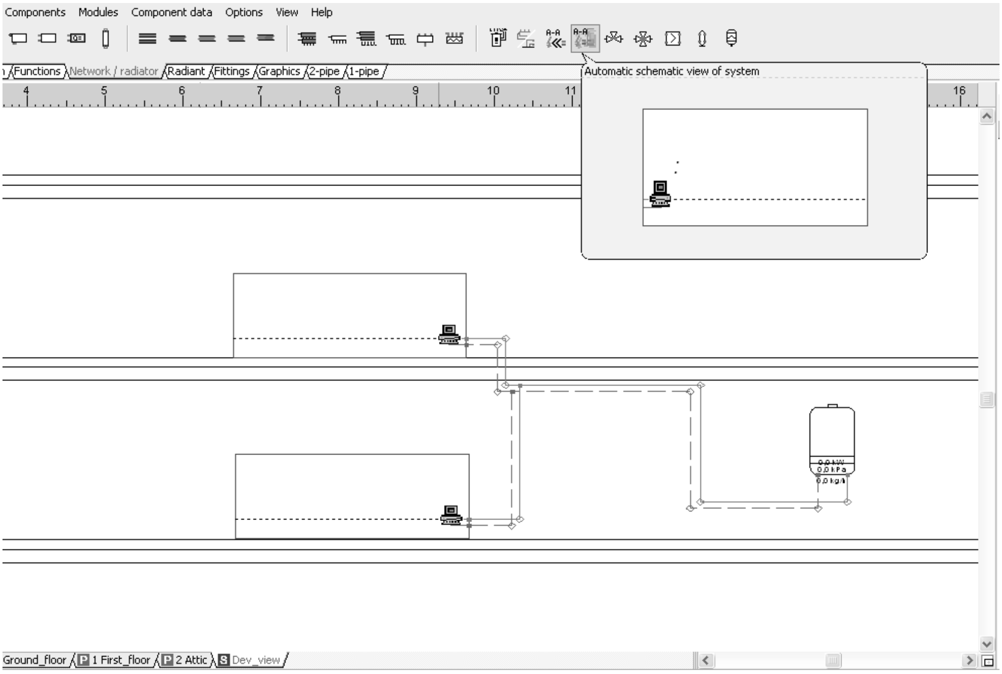


Figure 3.76. Insertion of automatic schematic views and distribution pipes

Every component of automatic schematic view located in the shematic view worksheet should have a unique symbol, specified for one pair of the virtual elements.

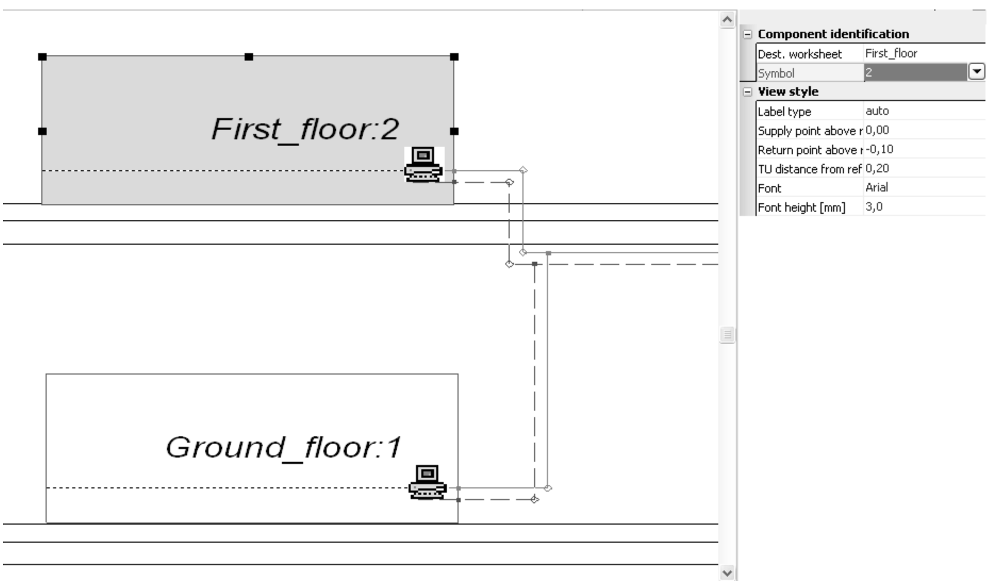


Figure 3.77. Identification of automatic schematic views in schematic view worksheet

As presented installation consists of only two such components, they will be assigned with simple symbols 1 (ground floor) and 2 (first floor) as presented in Figure 2.80. However, in the case of larger systems, it is recommended to use the following format: number of storey and number of stack, for example 32 means third storey and second stack. This manner of numbering allows to localize the virtual elements with higher precision and prevents errors.

The next step of connections creation is identification of the *Remote connections* on plan views worksheets. It is necessary to move to the ground floor worksheet and select the *Remote connection* localized nearby the stack. Identification includes the same elements as in schematic view, therefore it is needed to choose *Destination worksheet* as Dev_view and *Symbol* as 1 (Figure 3.78).

On the first floor storey, *Destination worksheet* is also Dev_view, however *Symbol* should be written as 2. After the identification is finished, the project should be saved. If the identification is done properly, arrows with flow direction will appear on the pipes in schematic view.

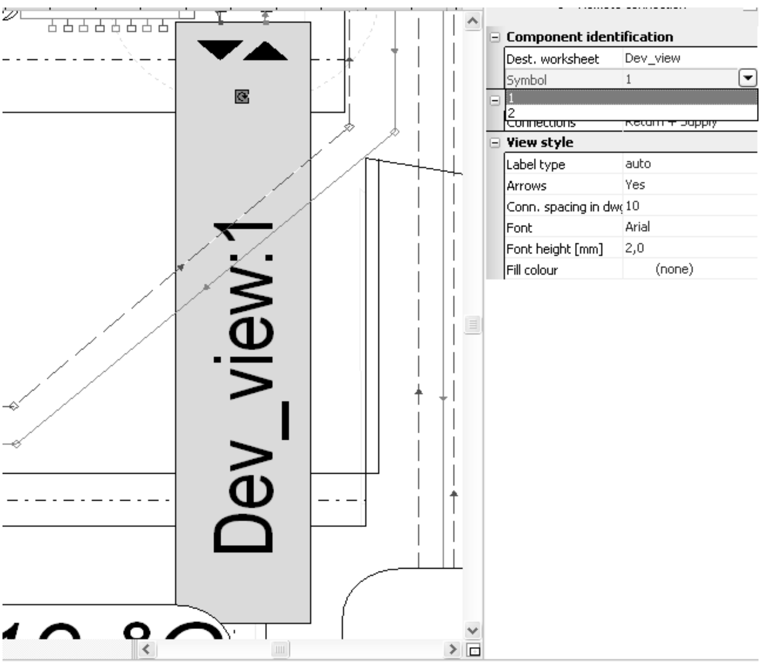


Figure 3.78. Identification of *Remote connection* in ground floor

To complete the design of heating installation, it is necessary to insert the required fittings (Figure 3.79). They are located in *Fittings* toolbar available in the same *Heating* edit scope, which is used in this chapter. The designed installation is equipped with safety valve, shutoff valves, non-return valve, pump, filter, pressure gauges, thermometer, expansion vessel and air bleeders. Expansion vessel should be connected with system by the use of *No-flow pipe-run*. Moreover, in the points of direction change not visible in schematic view (horizontal direction change), elements like 90^{o} elbows, other angles direction changes and offsets are inserted.

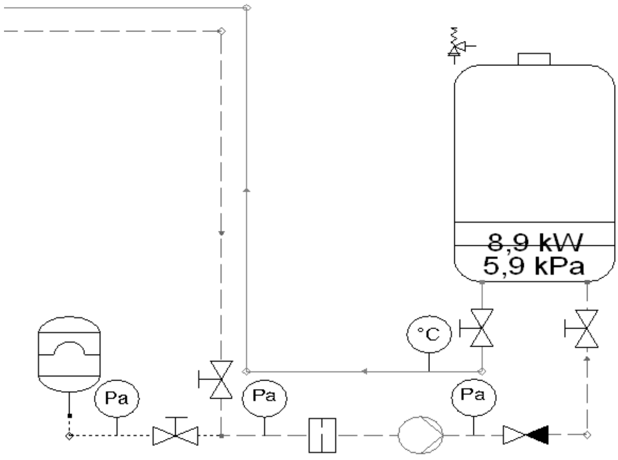


Figure 3.79. Insertion of fittings

All the components of fittings must have the type chosen from catalogues or manually introduced hydraulic specification. For example, inserted valve should be found in catalogues (*Data table / Valve*). If there is no required element type in catalogues, it is possible to enter its pressure drop as *Δp* (kPa) or *ζ* (-).

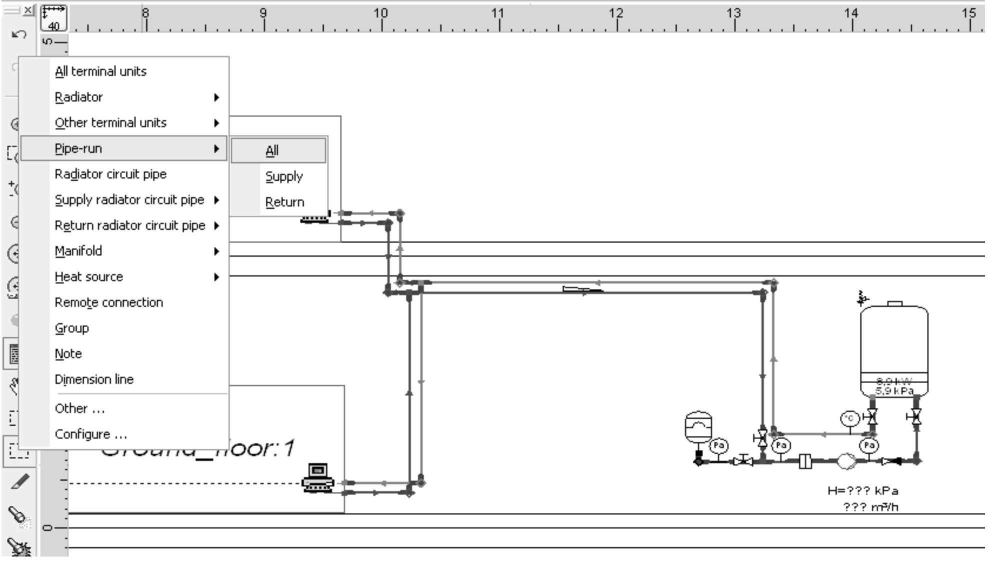


Figure 3.80. Selection of pipe-runs for material change

After completing the installation equipment, the change of pipes material was done in presented example. The part of installation located in boiler room, together with stacks will be designed as copper, and plastic pipes will be used only from manifolds to the receivers. For the material change, *Data table* is used. It is suggested to use the previously mentioned command *Select in rectangle the components of type…* (Figure 3.80) and change *Pipe type* from the default into copper one.

At this stage of the design, hydraulic calculations can be done in their final shape. Installation is completed from the hydraulic point of view, therefore the flows and pressures regulation can be done in an appropriate way.

As presented in Figure 3.81, final calculations' results include flow rate and pressure for pump selection, total output for boiler selection and water capacity and temperatures in installation for expansion vessel calculation. The mentioned elements have to be assigned manually, as there are no catalogues or calculation manners for their selection applied in program.

Results of final calculations can be printed out or exported to MS-Excel, and therefore included in paper version of the project. The mentioned functions are available under *Print* button, as presented in Figure 3.81.

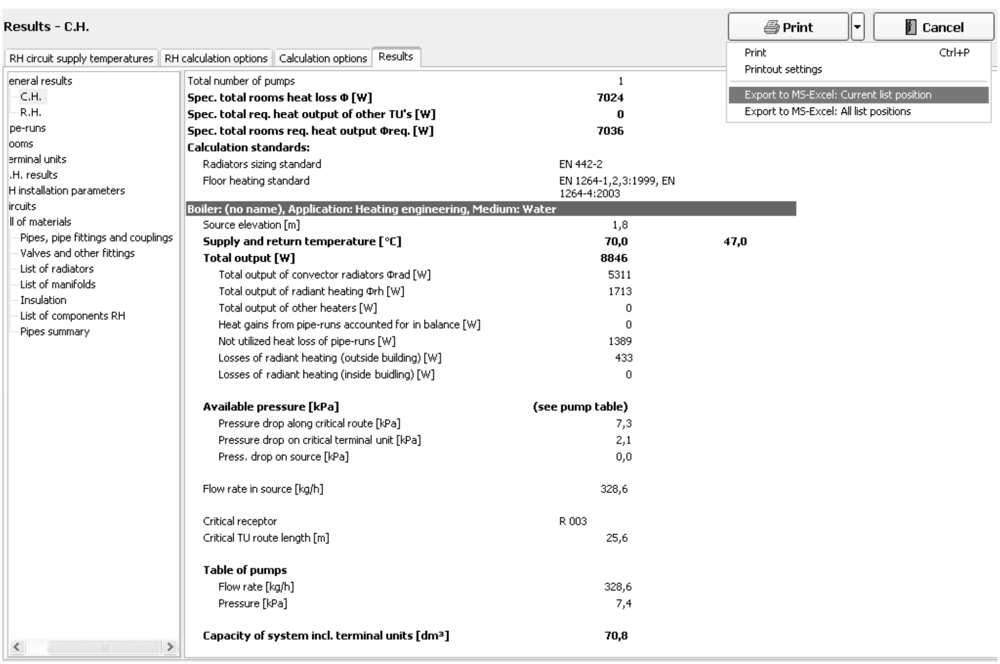


Figure 3.81. Final calculations' results printout

The last part of the project completing is connected directly to the drawings. It is possible to prepare and print the comprehensive drawings with drawing chart and description (legend). Therefore, the missing elements like plan view of boiler room, pipe-runs labeling, radiant heating loops drawing and developed views of installation on storeys should be completed.

If the boiler and distribution pipes are drawn in schematic view, they cannot be doubled on the ground floor because it will cause the calculation errors. Therefore, after drawing the missing elements, the combination of primary-shadows pairs is recommended. To start the combination, it is necessary to use *Combine primary-shadow pairs* from *Components data* menu (Figure 3.82).

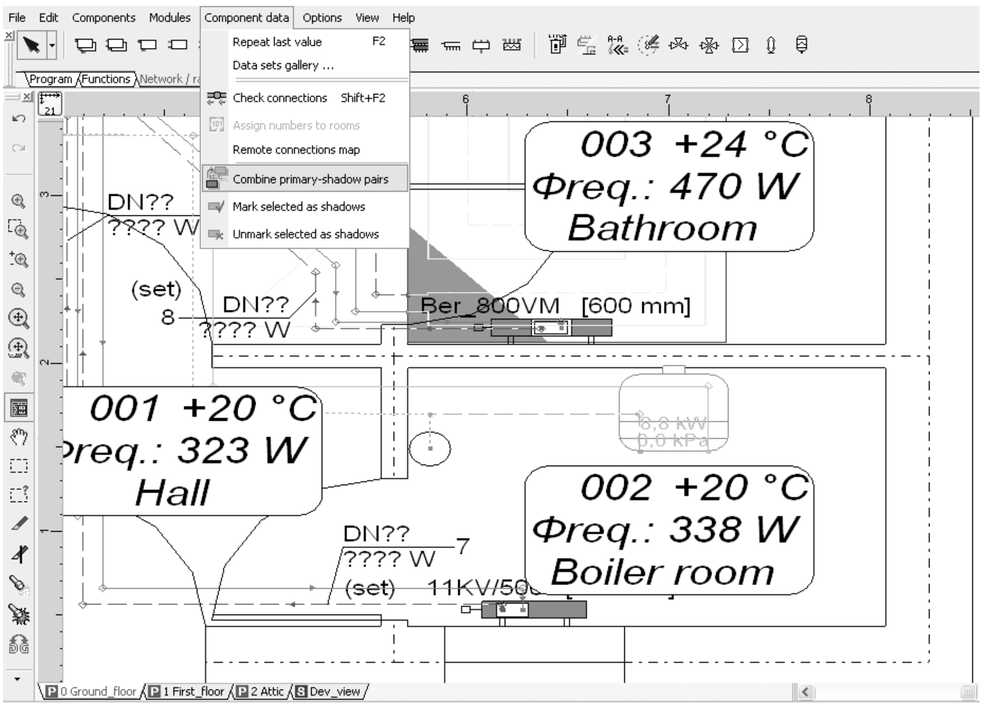


Figure 3.82. Primary-shadow pairs combination

Primary-shadow pairs are used to mark the corresponding elements of installation, which appear both in worksheets of plan and schematic view. It is important to draw the missing part of installation in exactly the same way as it was drawn in developed view (the same number of pipe-runs).

The window for pairs combination consists of the two main panels. The content of the left and the right panel can be chosen from the list of the worksheets. In the example, left panel includes ground floor and the right one – developed view worksheet. Elements in the left panel will be marked as shadows. It should be conducted individually for each pipe-run by the use of command shown in Figure 3.83. When the pipe-run in left panel is marked as shadow, it is necessary to select the corresponding pipe-run in the right panel and use *Combine* command. The procedure should be performed for every doubled pipe-run. In the presented example, the pipes between *Boiler* and *Remote connection* on ground floor are doubled (they are drawn on both ground floor and schematic view). Then, the window of primary-shadow pairs combination can be closed.

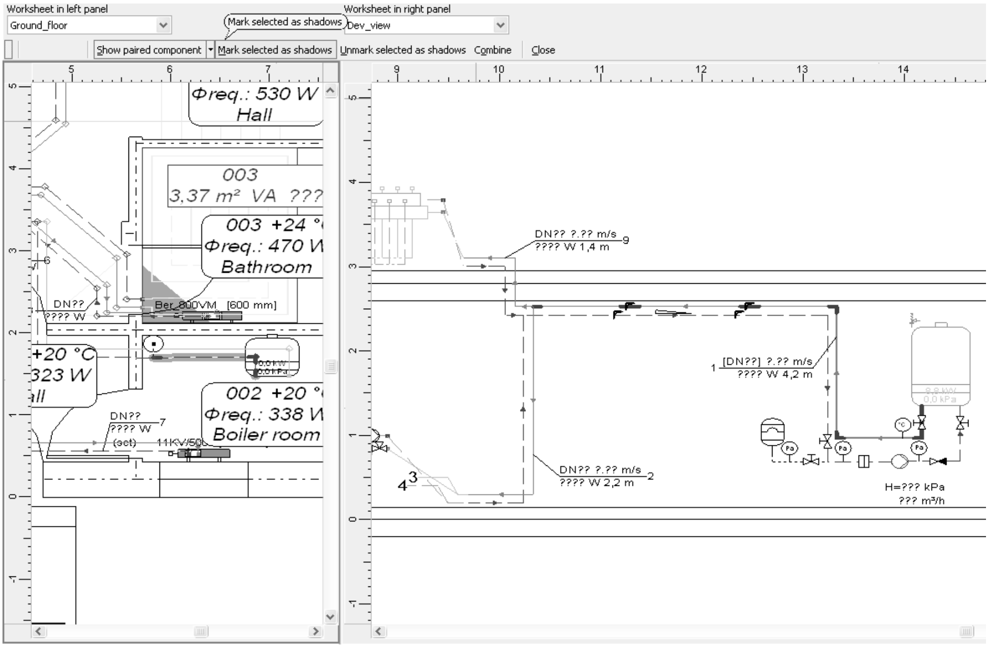


Figure 3.83. Selection of the shadow elements

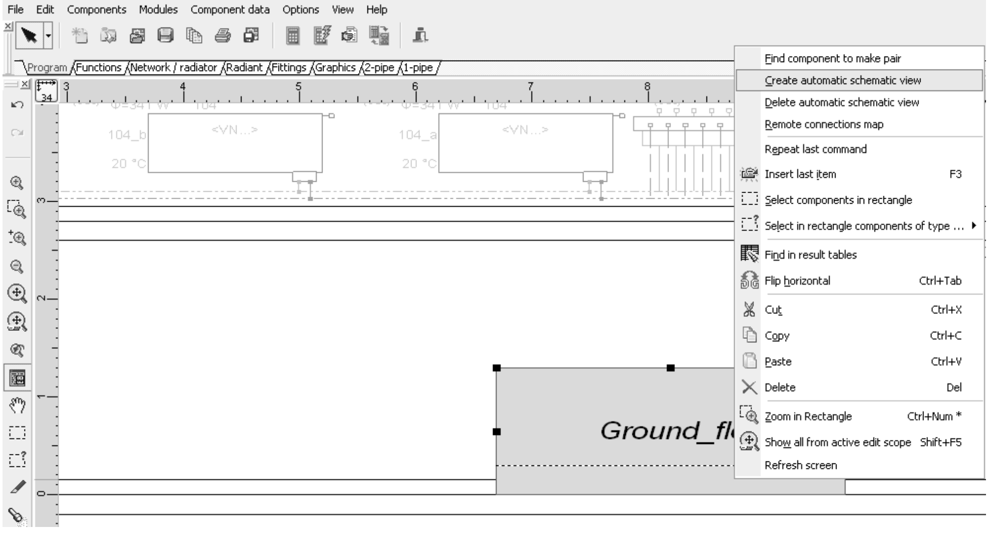


Figure 3.84. Creation of automatic schematic view of installation on storeys

Creation of automatic schematic view of the installation in worksheet Dev_view is a simple and easy procedure. It requires selection of *Automatic schematic view of system* by the use of the right mouse button. When the pop-up menu appears, it is possible to choose command *Create automatic schematic view* (Figure 3.84). The elements, which were not noticeable in the schematic view worksheet so far, become visible. On ground floor storey, there are two parts of the developed view because there are two separate manifolds for radiant and convector heating.

One of the final elements to be completed in drawings are the pipes description. *Pipe-run labels* can be inserted as slanting, straight or simplified from the *Graphics* toolbar (Figure 3.85). As far as it is used for the pipes supplying single radiator, the default type of slanting label will be used in the exemplary project.

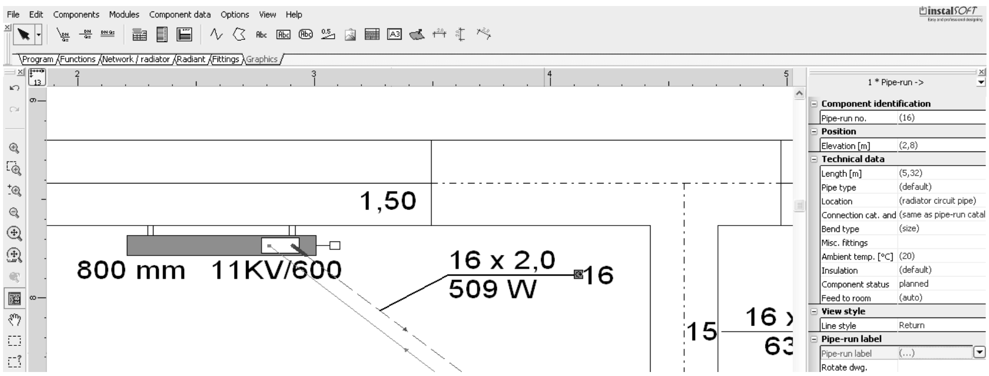


Figure 3.85. Labeling of pipe-runs

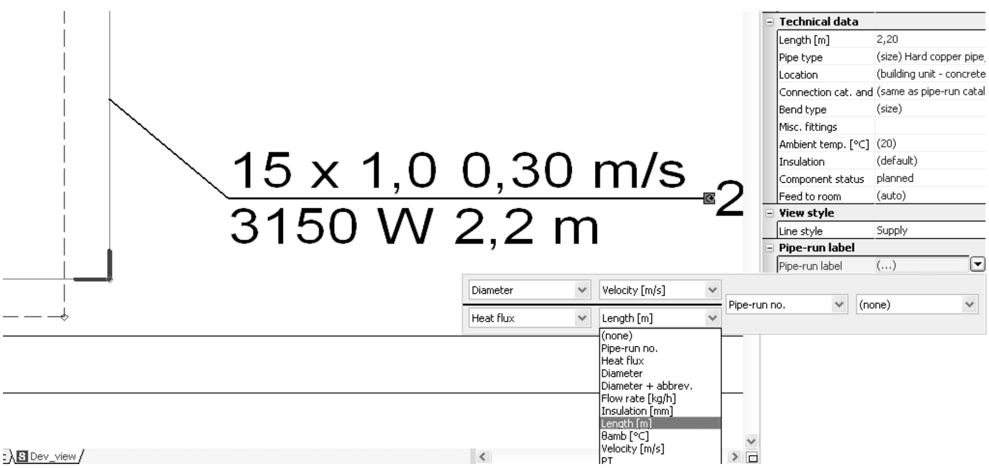


Figure 3.86. Pipe-run label edit table

When the more detailed description is needed, it is possible to choose other elements to be included in *Pipe-run label*. If the description is selected (by single click on its horizontal axis), the change of its content is feasible by the use of *Data table / Pipe run label*. The expanded list contains components like pipe-run number, heat flux, diameter, velocity etc. In the chosen labeling style, diameter, velocity, heat flux and pipe length are included (Figure 3.86).

The last missing element of the drawing is heating circuit. To start drawing such elements, it is necessary to change edit scope from *Heating* to *RH loops drawing*. It is possible then to choose the command *Polyline for drawing piping – auto* from the *Radiant* toolbar. By clicking in the area of heating floor, it is achievable to insert the missing pipes on heating floor area (Figure 3.87).

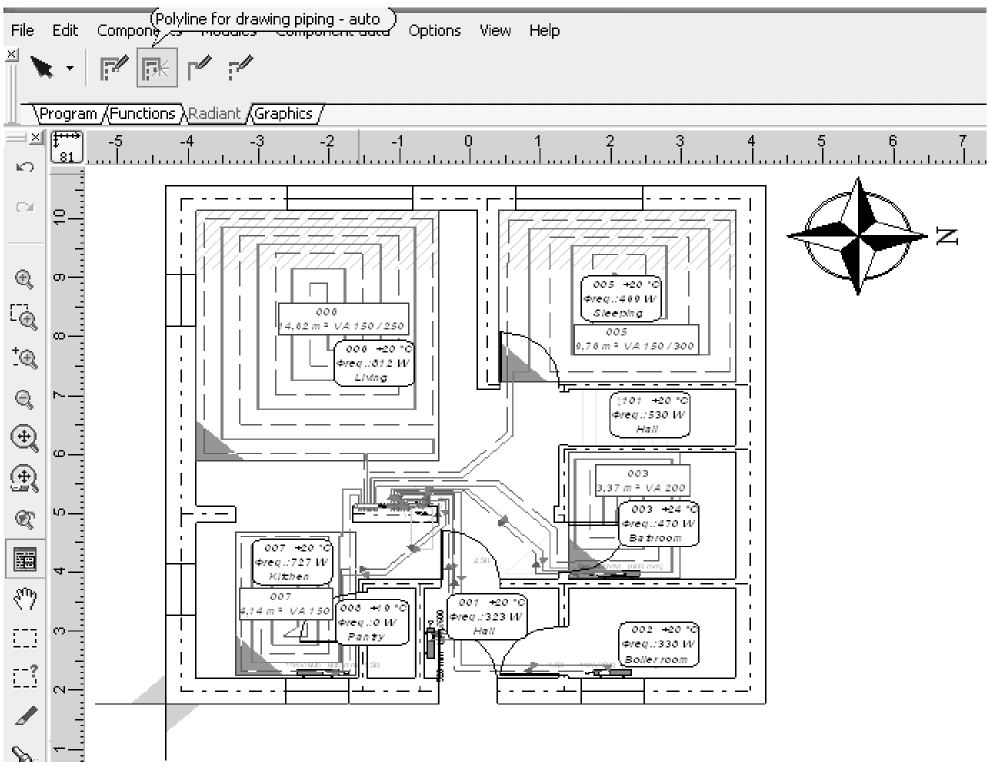


Figure 3.87. RH loops drawing

Radiant heating loops can be drawn as spiral or meander. In the case of presented drawing, the structure of meander was selected because of the favorable temperature layout.

3.1.10 Printout of drawings

Drawings prepared in Instal-therm HCR can be printed directly from this program or exported to AutoCAD. In both cases, it is recommended to insert the paper formats in worksheets which will be printed.

To finish the preparation of the drawings, *Graphics* toolbar can be used. It contains graphical elements as lines, shapes, text, slope icon, dimension lines, paper for printout and drawing chart. *Paper format* can only be inserted in the default size A3, which may be then changed (in *Data table*) into other upon the wish of the designer. *Paper format* insertion is presented in Figure 3.88.

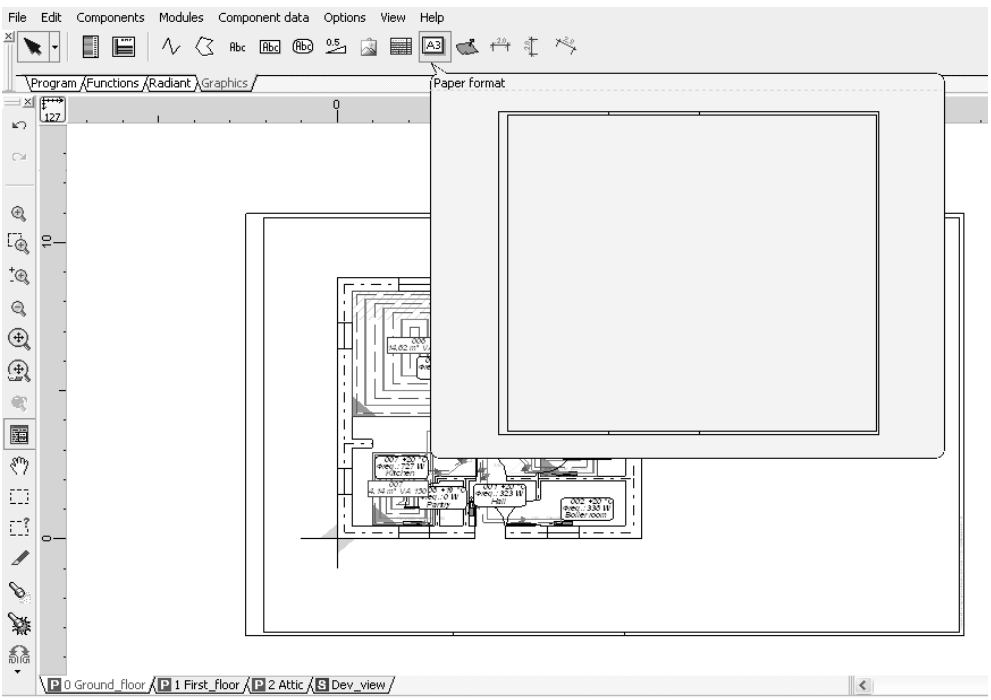


Figure 3.88. Insertion of *Paper format*

Another interesting function from *Graphics* toolbar in *Heating* edit scope is *Floor build-up drawing*. It allows to insert the cross-section of the heating floor, as presented in Figure 3.89.

Insertion of the floor drawing in the neighborhood of selected room will cause the correlation between the drawing of heating floor and its construction in this room. Room number is added at the top of the drawing.

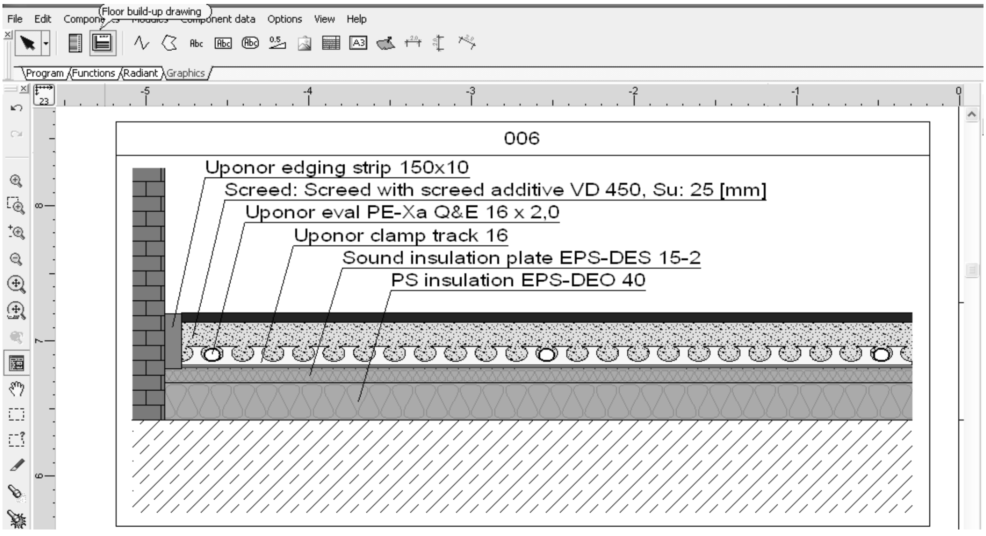


Figure 3.89. Insertion of *Floor build-up drawing*

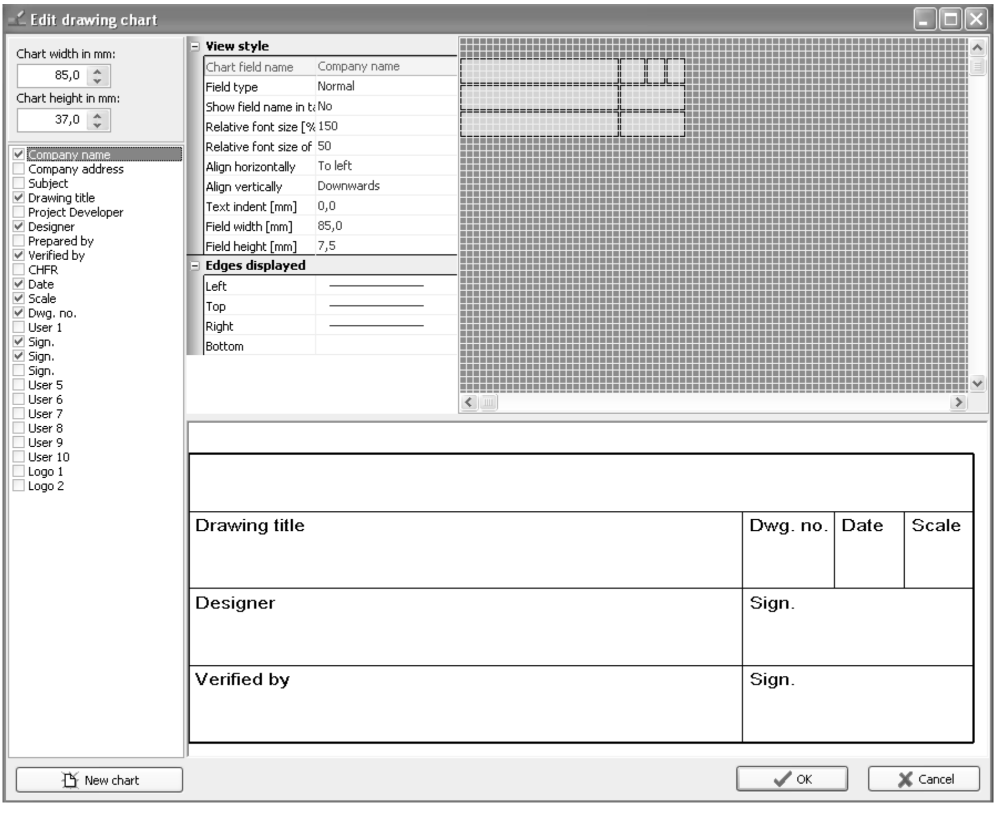


Figure 3.90. Window of the drawing chart edit

Having paper format and floor drawing inserted, it is necessary to add the drawing chart from the *Graphics* toolbar in the right bottom corner of paper. The chart can be edited by the use of *Edit drawing chart* window, accessible in *Data table* (Figure 3.90). The dimensions and content of a chart can be changed – only the area selected in the right panel of a window is a part of drawing chart. Having selected *Company name*, it is necessary to choose the area of its insertion, etc. The content of table (drawing title, designer, etc.) will be completed in *Data table* of the drawing chart.

After completing the drawings, it is recommended to move to the *Printout* edit scope (Figure 3.91). Then it is possible to choose the suitable printer and its settings, scale of printout and the border of the drawing. This option is recommended for users who dispose plotters as they can choose many options for paper format.

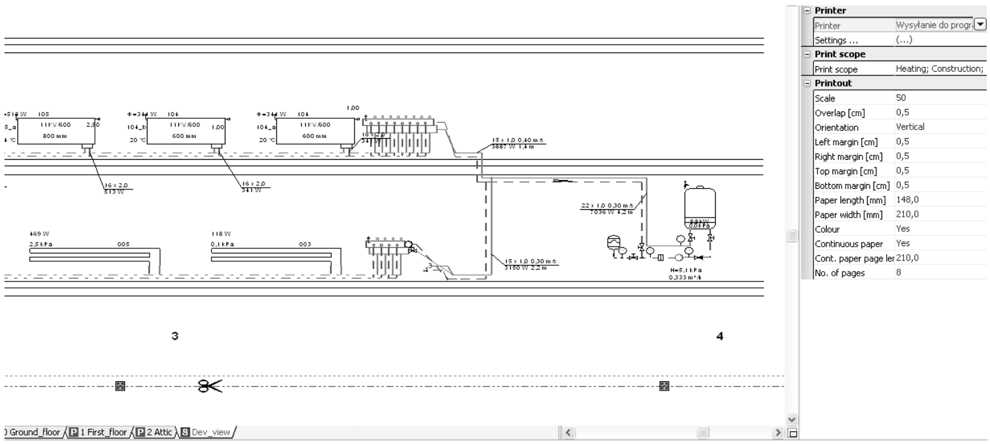


Figure 3.91. Printout from Instal-therm HCR

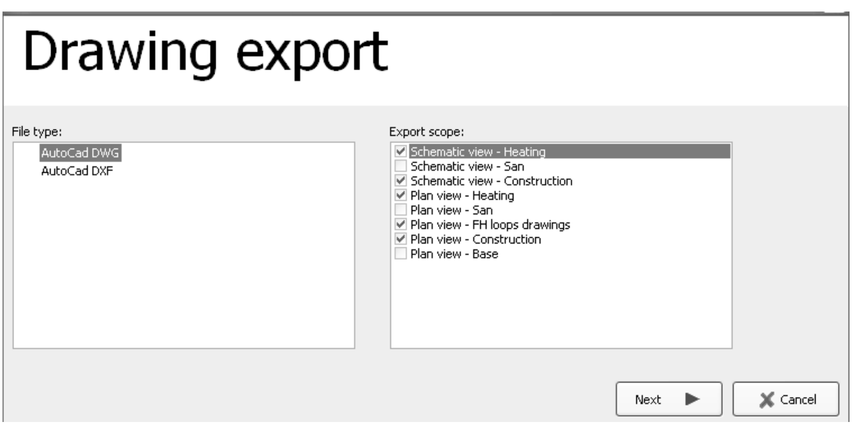


Figure 3.92. Drawing export – window 1

For the users of AutoCAD program, it is recommended to export drawings into *.dwg format. The function of exporting is available in main menu *File* and as an icon in the *Program* toolbar. The export of drawing runs in three stages. In the first (Figure 3.92), file type and export scope should be chosen. In the example, *Plan view-base* will be skipped, not to double the drawing.

The second stage needs the specification of the files exported. In the example, Attic worksheet will be skipped as it was created only for the proper calculation and it will not be heated (Figure 3.93).

After the selection of the exported worksheets, it is necessary to set up the file version, unit, type of lines in AutoCAD and option of lines thickness export. The exemplary set of options is presented in Figure 3.94.

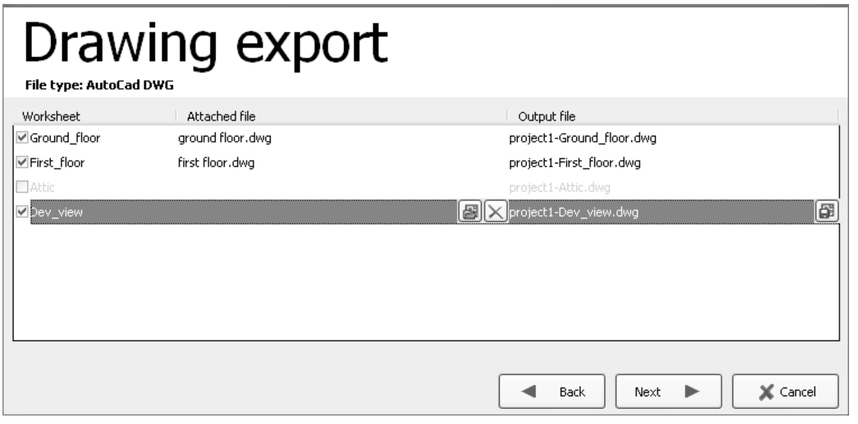


Figure 3.93. Drawing export – window 2

Figure 3.94. Drawing export – window 3

Confirmation of an export will cause the creation of new files (project 1-ground_floor, project 1-first_floor, project 1-dev_view). The exported file can be edited in AutoCAD program. The example of drawing (ground floor) is shown in Figure 3.95.

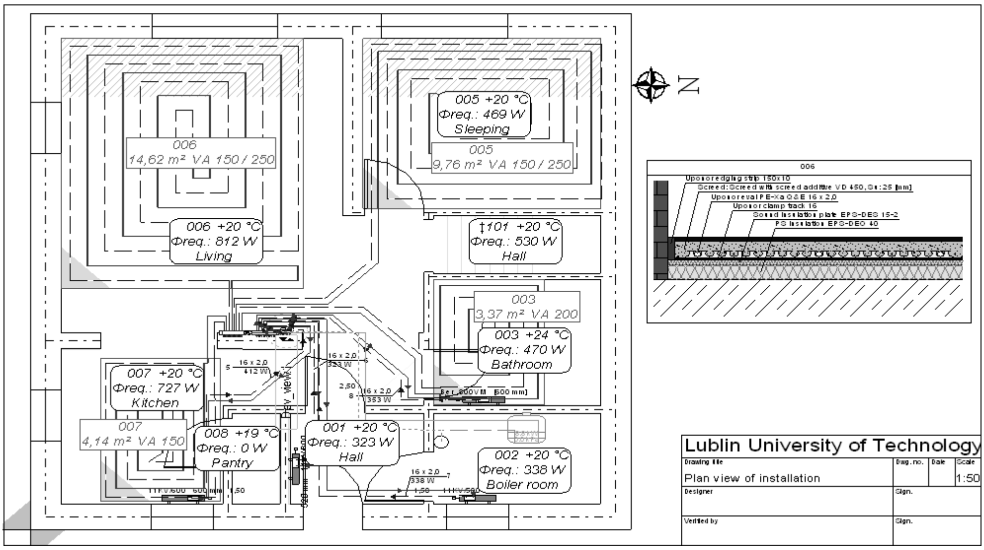


Figure 3.95. Drawing exported to AutoCAD

3.2 *Project of water supply installation*

Designing of water supply installations in Instal-San T module requires the use of the architectural base, generally imported from the AutoCAD program. The manner of DWG base import was explained in 3.1.1. and 3.1.2. chapters, therefore it will be skipped in this part of the book. However, it is important to mention that in the case of water installations, it is not necessary to read the base as structure recognized in program. Import of the base as a block from the *.dwg file is enough to do water installation calculations since the construction of partitions is not required in this type of the design. Therefore, no layers with walls, doors and windows should be chosen during the import. In result, the base will be read as the block of elements which cannot be edited, but it can be used for drawing of the water installation.

In the presented example, the base imported in previous chapter will be used, therefore it is enough to open the last saved file with heating installation in the Instal-San T module. Heating installation can be seen under *Heating* edit scope, however the further design of water installation will be executed in *San* edit scope.

3.2.1 Settings for water installation designing

Settings for design of cold and hot water installations can be edited after opening the *Project options* window (Figure 3.96) by the use of F7 button or main menu *Options*. In the case of water supply installation design, it is necessary to exclude drainage system from the *Calculations scope*, as presented in Figure 3.96.

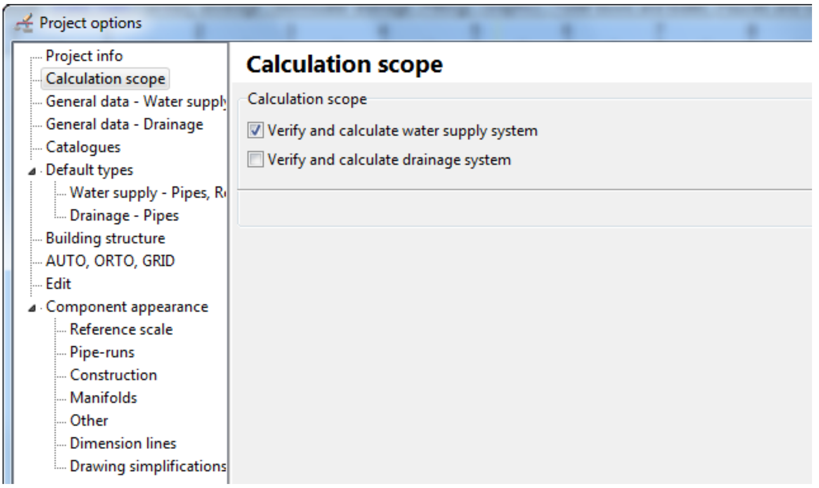


Figure 3.96. Window of *Project options* / *Calculation scope*

General data for water supply installations contains information about the default temperatures of hot and cold water, default ambient temperatures for specific parts of installation and measure units. It is also necessary to select the type of building (residential in the case of presented example) to ensure using the suitable formulas for hydraulic calculations (Figure 3.97).

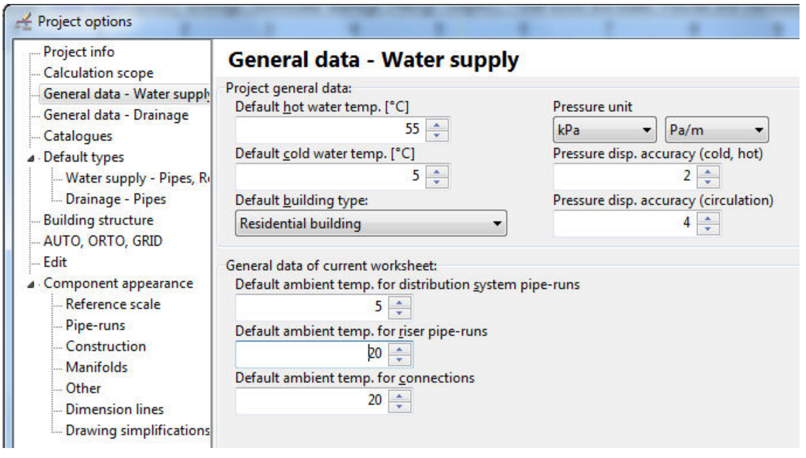


Figure 3.97. Window of Project options / General data – water supply

The next step of options' editing is the choice of the catalogues of applied devices or pipes. In the case of water supply systems, catalogues can be used in *Pipes and pipe fittings, Valves and fittings, Insulation, Faucets, taps and sanitary whiteware installation* categories. Selection of catalogues has already been described in chapter 3.1.7. and therefore it will be skipped here.

When the selection of catalogues is already done, it is necessary to assume default types for water supply system (Figure 3.98). The pipes and fittings from chosen catalogues are available in developed lists to be chosen as default for described component of installation.

For the presented water supply system there are applied the following solutions:

- PE-Xa S3.2 pipes in coils by Uponor,
- Pipes standard insulation – PU foam,
- Pipes connection system – surface brass for UPONOR PE-Xa,
- Other elements according to Figure 3.98.

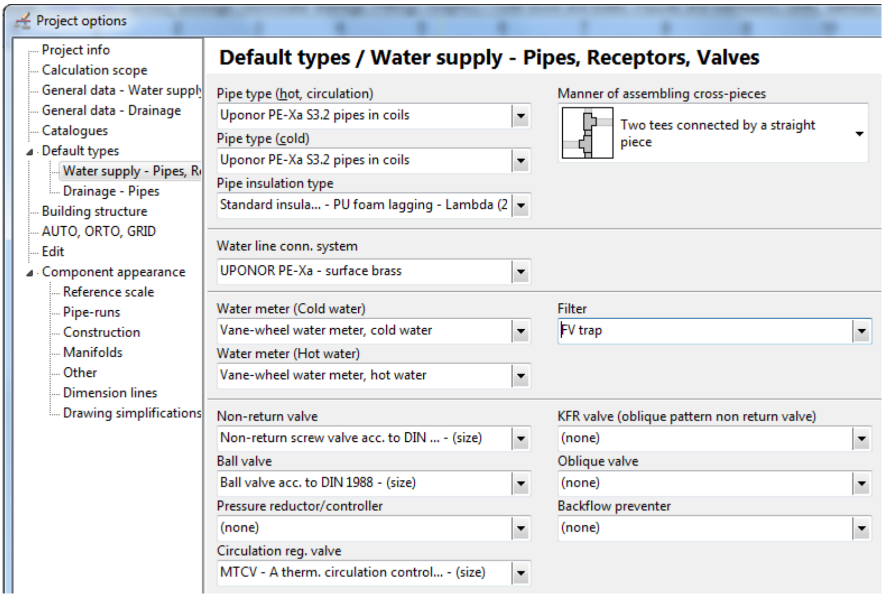


Figure 3.98. Window of *Project options / Default types*

3.2.2 Installation designing – drawing and calculation of the water supply system

Designing of water supply systems should be started from the insertion of its components. Therefore, the *Fixtures, Toilet bowls and bidets, Faucets and washbasins, Sinks, bathtubs and showers* toolbars ought to be used.

In the case of presented single-family house, it will be equipped with the basic sanitary receptors and equipment. The insertion of a bath is presented in Figure 3.99. It is recommended to use *Sinks, bathtubs and showers* toolbar for insertion. Bathtubs can be also found in *Sanitary sewerage* toolbar, however, they do not contain faucets in this case and therefore, this toolbar is intended for sewage system designing.

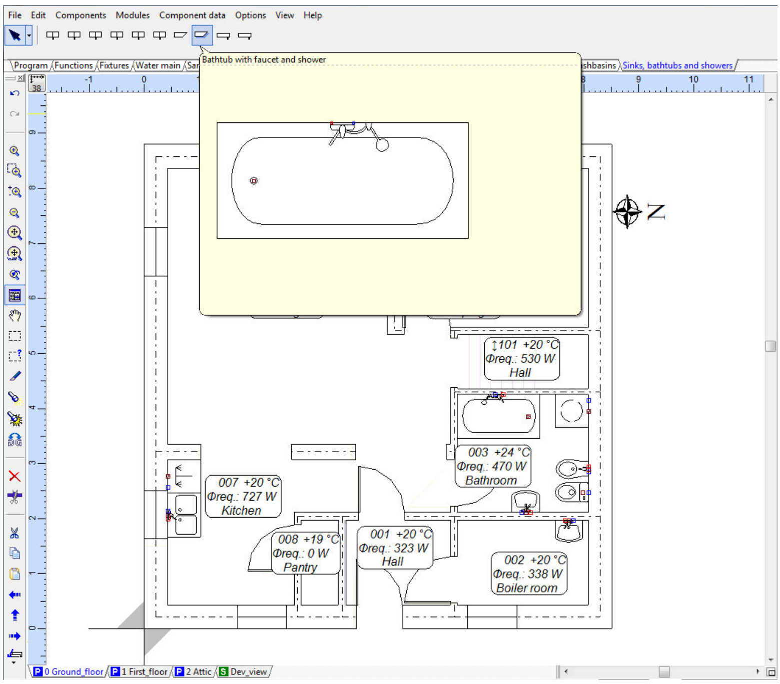


Figure 3.99. *Bathtube* insertion from *Sinks, bathtubs and showers* toolbar

Washbasins (Figure 3.100) can be found in *Faucets and washbasins* toolbar. After the insertion in the suitable location, their dimensions can be easily changed by the use of the *Data table*. In fact, it is also possible to change the type of the given element. For example, the change into double washbasin can be done.

Figures 3.100 and 3.101 show the process of insertion of different sanitary equipment applied in households in kitchen and bathrooms. All presented elements should be treated as the examples and application of them should depend on the investors and designers decisions.

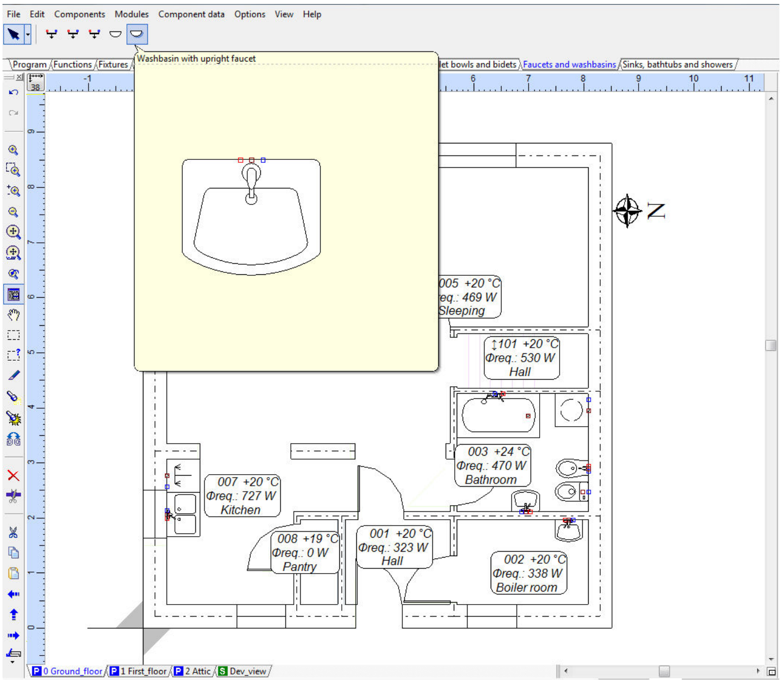


Figure 3.100. *Washbasin* insertion from *Faucets and washbasins* toolbar

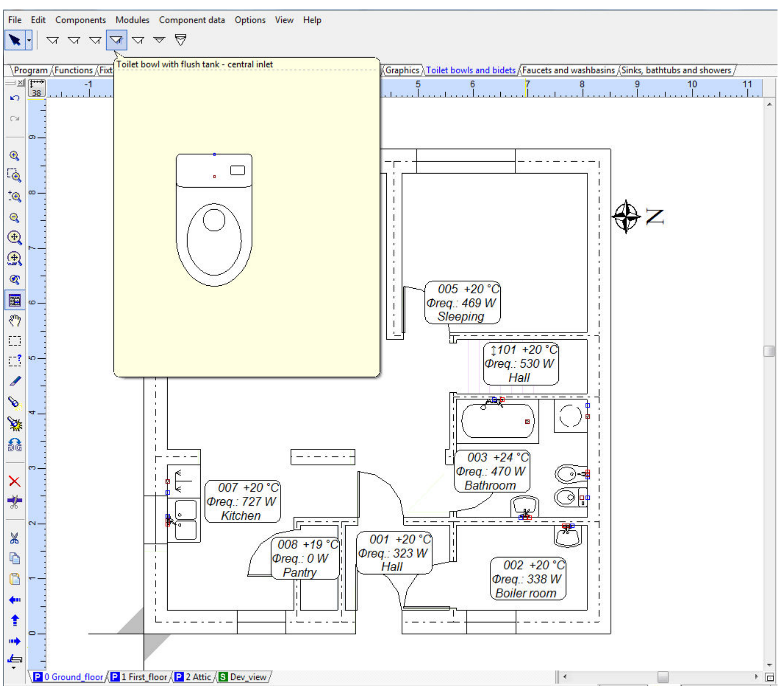


Figure 3.101. *Toilet bowl* insertion from *Toilet bowls and bidets* toolbar

Toilet bowls can be found in *Toilet bowls and bidets* toolbar. In the case of toilet bowl, it is possible to choose several types of flush tanks (standard or concealed with water inlets located centrally or in a side). In the presented example, standard flush tank with central inlet was chosen (Figure 3.101).

The other equipment like washing machines and dishwashers can be found in the *Fixtures* toolbar. Some unusual elements, applied for technological systems like air conditioners, etc., can be also found in the same place (Figure 3.102).

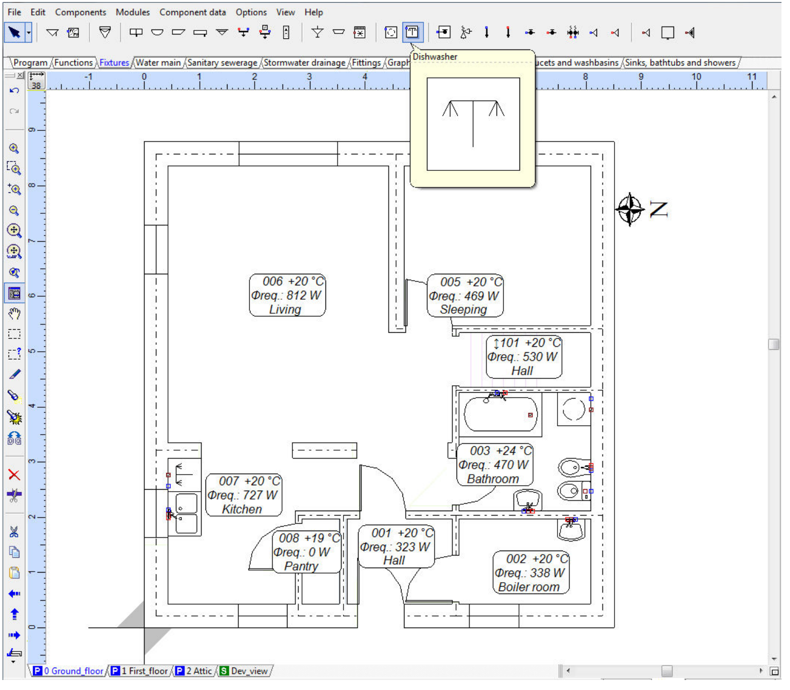


Figure 3.102. *Dishwasher* insertion from the *Fixtures* toolbar

The bathroom on the first floor is planned to be equipped with corner bathtub. To insert the corner bathtub, it is necessary to select the standard one and change its type in the *Data table*, as presented in Figure 3.103.

The dimensions of the bathtub can be easily modified by the use of *Sizes* in *Data table*. It is also possible to change the position of the faucet by the use of the mouse. For that aim it is necessary to select the given draw-off point by clicking it and then to move it to the suitable position, constantly pressing the left button of the mouse.

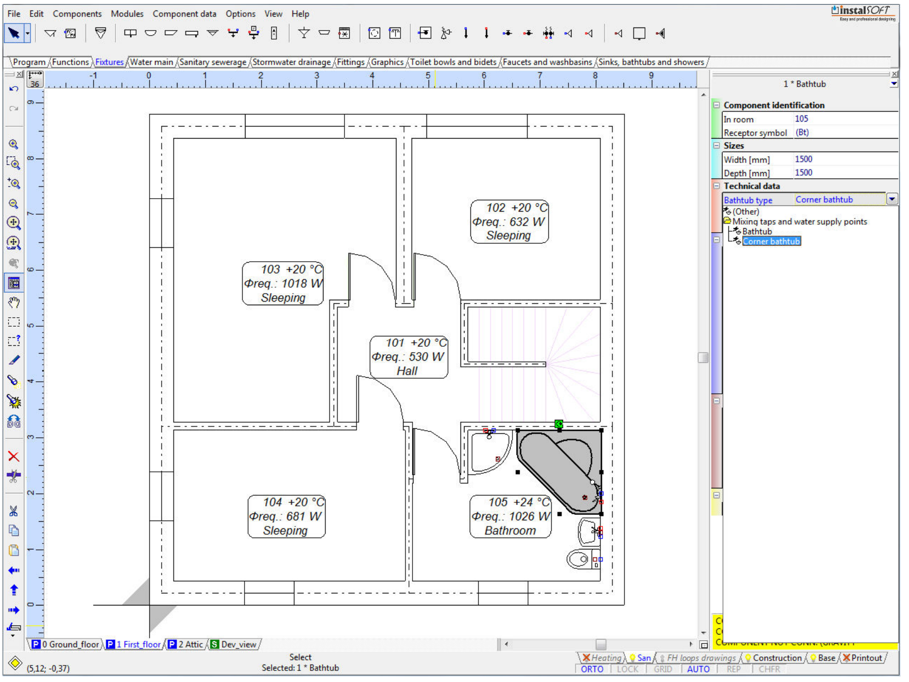


Figure 3.103. *Bathtube* type editing in *Data table*

The next step, after the insertion of all receivers with faucets and washing equipment, is an addition of the source elements of the system. *Water main* toolbar will be therefore used to insert the heater and source of water. In heater's *Data table*, hot water circulation connection should be added (Figure 3.104). Hot water circulation system is assumed to be made of the same pipes as cold and hot water system. The idea of hot water circulation designing is presented in the 1.2.2. and 1.2.3. sub-chapters. In this particular building it will provide water circulation between the heater and the kitchen draw-off points placed on the ground floor (horizontal pipe) but also it will support circulation for the above floor using the extra riser.

Other element to be inserted is a source of cold water. Source can be found in the *Water main* toolbar, as a symbol of cold and hot water starting points. After its insertion, it is necessary to change the type of source into cold water only (Figure 3.105).

Cold water source should be connected with the heater by the use of pipe-run icon from the *Water main* toolbar. Blue one means cold water and the red one – hot water. There is also pink line of circulation pipe, available for drawing. Using *AUTO* and *ORTO* function simplifies drawing of pipes routes.

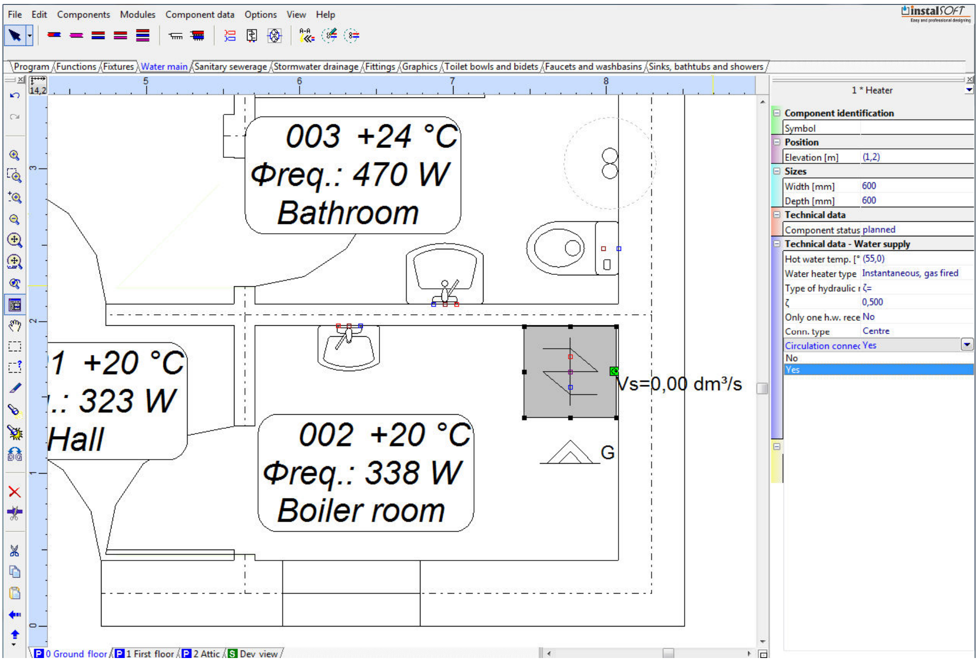


Figure 3.104. *Heater* insertion from *Water main* toolbar

At the beginning of the water supply system, the measure set should be designed. Therefore, insertion of ball valves, filter, water meter and backflow preventer is crucial. If the types of inserted components were not selected in project options (Figure 3.98), they should be chosen from catalogues in *Data table* (Figure 3.105).

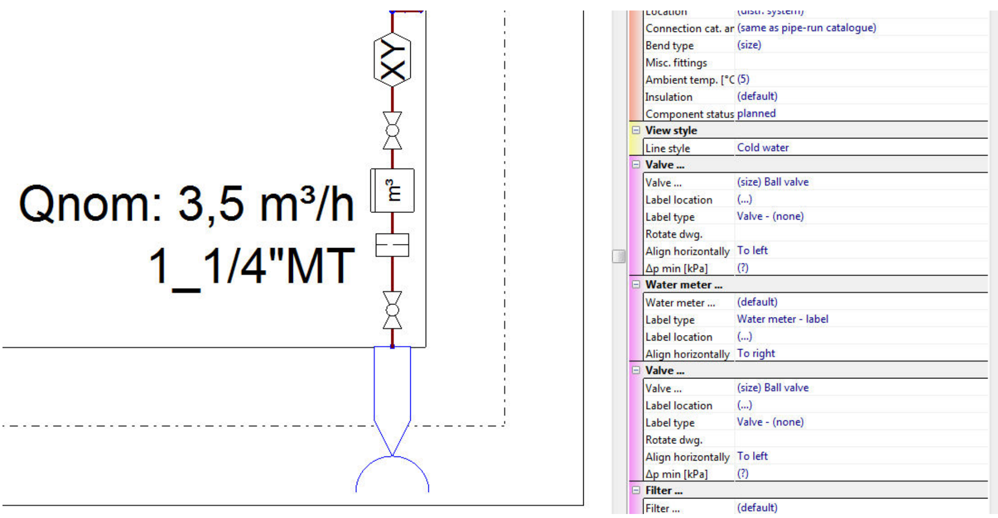


Figure 3.105. Measuring set with ball valves, water meter, filter and the backflow preventer

In the case when catalogues do not contain the suitable component, it is possible to use the other manner of its identification. In the described example, the backflow preventer was designed in this way. Instead of choosing its type from the catalogue, total pressure drop was entered in *Data table* (Figure 3.105). Pressure drop can be also described by hydraulic parameters like ζ or k_v, given by the valve producer.

After insertion of water source and the heater, the rest of installation components should be connected with sources of cold (installation) and hot (heater) water. For connection of the elements, pipe runs of chosen type from *Water Main* toolbar should be used.

The important element of installation is stack – its localization is crucial for the pipe runs drawing, especially between the particular storeys. Therefore, stacks of cold and hot water, as well as hot water circulation, should be inserted into the drawing. Unlike in the case of heating installation, here the stack should be inserted as stack object, not a drawing. The same idea of identification by symbol (number) works in the case of Instal-San T.

In the case of stack component application, it is important to change the default options from *Data table* into the real values. Therefore, *Elevation* and *Connection*s categories should be selected separately.

After the water meter set, the pipes vertically go below the ceiling of the ground floor and deliver water to the particular rooms of that storey. Cold water is delivered to the washbasin in the boiler room. All pipes ale directed towards bathoom (Room 003) and from there they are conducted towards stack described in Figure 3.106 as "1". From there water is supplied upwards to the first storey and downwards to draw-off points of the bathroom. Also three pipes (cold, hot and circulation) are directed towards kitchen (Room 007) in the space of the suspended ceiling.

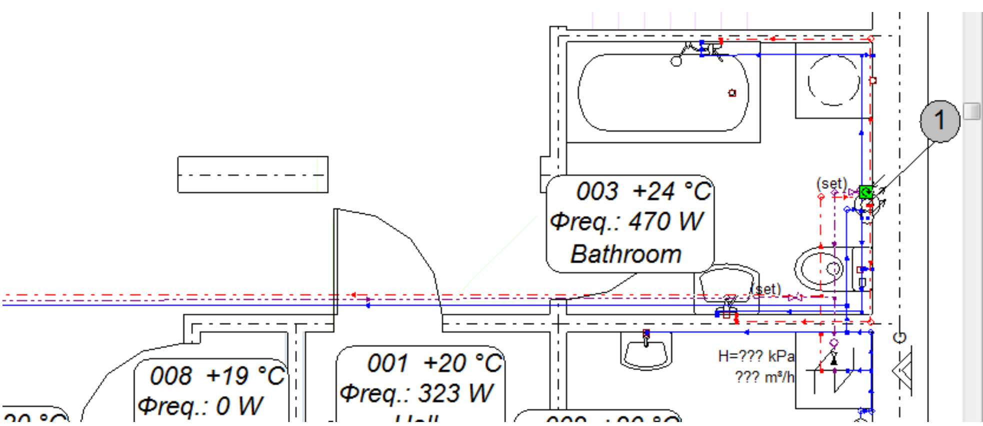


Figure 3.106. *Stack* insertion from the *Water main* toolbar and its identification on the ground floor

On the first floor, installation of cold and hot water is simple because it covers only one bathrom with bath, shower, washbasin and toilet. The circulation pipe should be connected with hot water on this exact storey. Stack, localized by the insertion of its number, is a source of water. All the components should be connected with the stack by the use of the pipe runs. Automatic connection of selected elements can be done by the use of method described in 3.1.8. chapter (Ctrl+Shift+A).

After all connections are finished, the first calculations can be done. In the case of water supply systems, calculation options can be imported from the producers' catalgues or inserted manually. Options for system calculation are presented in Figure 3.108.

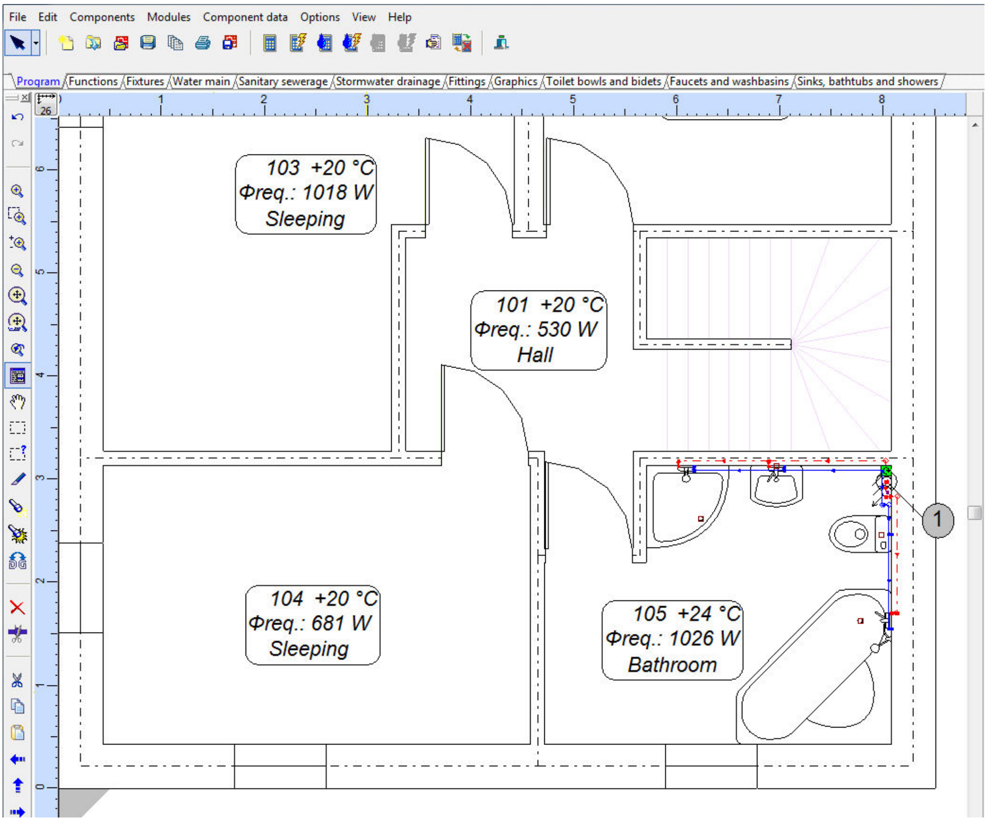


Figure 3.107. *Stack* insertion and identification on first floor

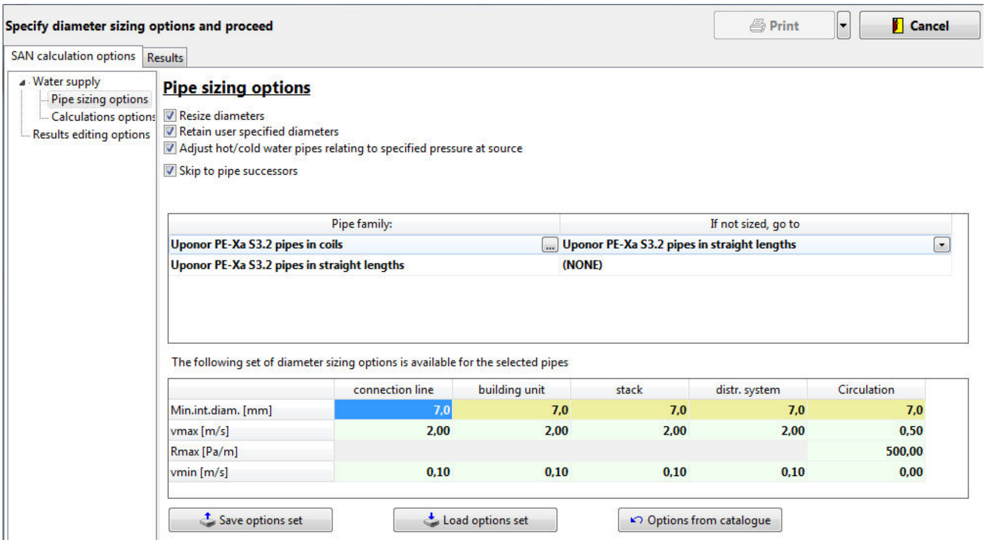


Figure 3.108. *Pipes sizing options* in calculations window

Results of calculations include *Title, General results – water system, Calculation options, Critical hydraulic routes, Receptor, Flow pats & circuits, Heaters, Pipe-runs* and *Bill of materials*.

General results containing calculated information about length of the particualr pipes, system capacity, available pressure etc. are presented in Figure 3.109.

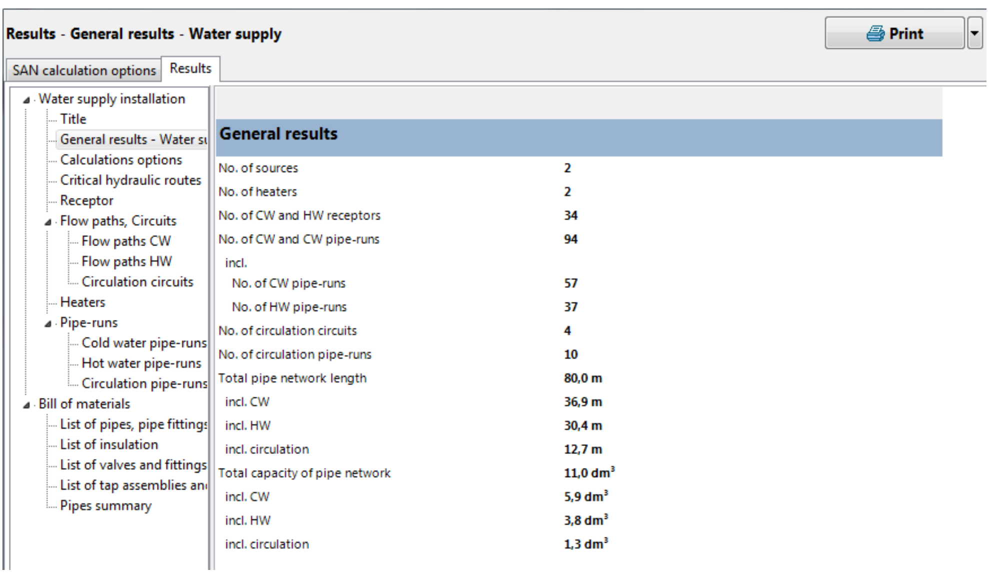


Figure 3.109. *General results* of calculations

Flow paths window (Figure 3.110) include information about path between draw-off points and system source together with types of the assigned pipes, dimensions of particular pipe-runs and other hydraulic parameters. Flow paths can be checked for all circuits: cold, hot and circulation water.

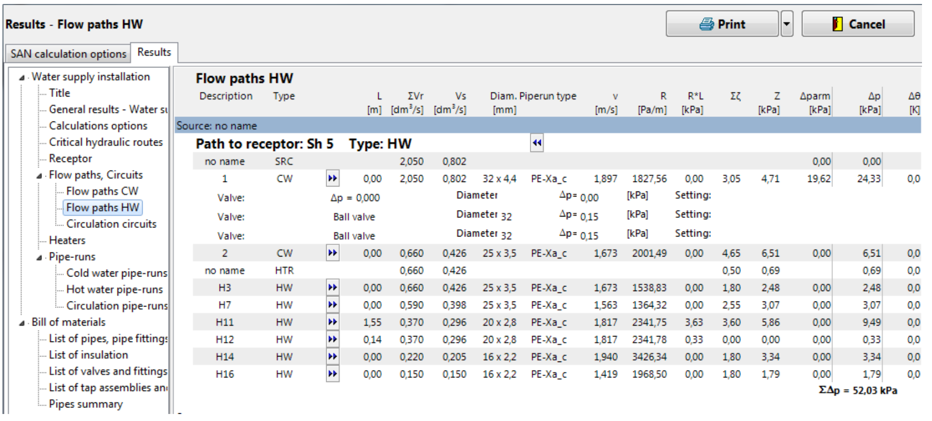


Figure 3.110. *Flow path* of hot water in results of hydraulic calculations

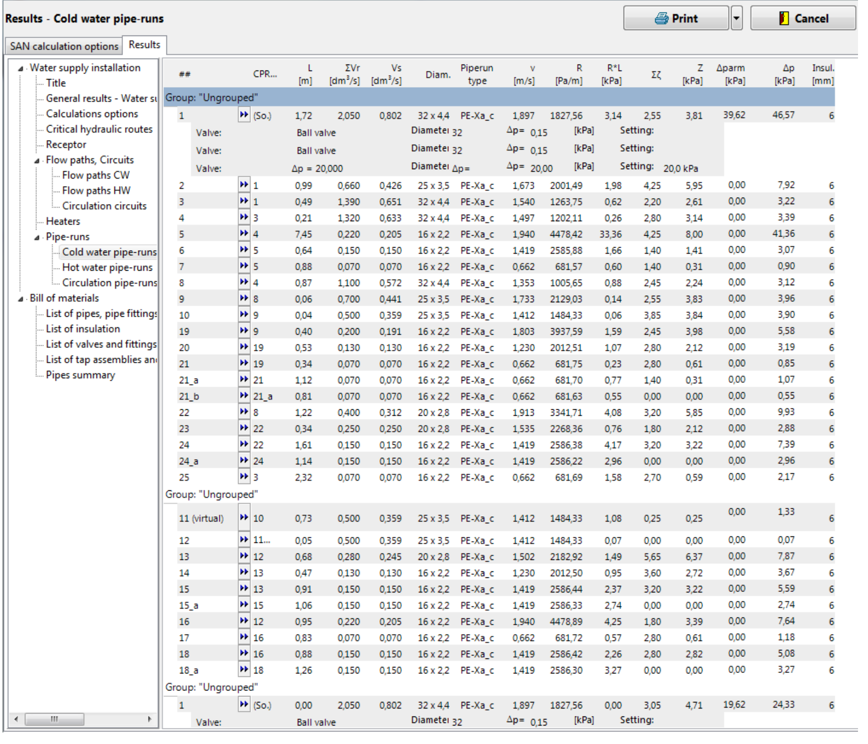


Figure 3.111. *Cold water pipe-runs* in results of hydraulic calculations

Pipe-runs include shown in Figure 3.111 presentation of the hydraulic calculation results of all instalation pats, with specification of the pipes types, dimensions, hydraulic pressure drop and width of insulation.

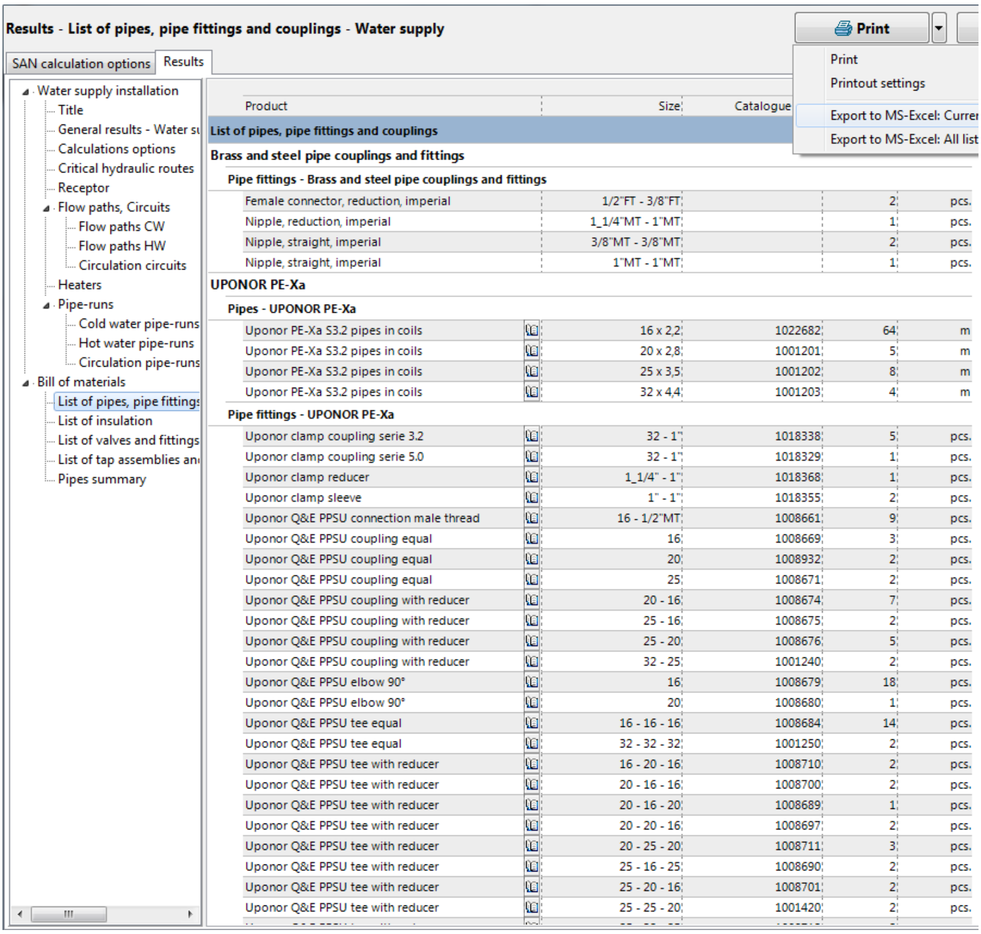


Figure 3.112. List of pipes, pipe fittings and couplings in List of materials used in project

List of pipes … window presented in Figure 3.112 includes all applied pipes together with their exact dimensions and catalogue numbers.

It must be also mentioned here, that all the calculation results can be exported to MS-Excel or printed from the program which can be executed using *Print* button (Figure 3.112).

3.2.3 Drawing of schematic view as a shadow of the plan views

The last drawing of installation will be the schematic view of the system. Creation of the schematic view requires insertion of new worksheet (Figure 3.113). As it was already described, it can be executed in *Worksheet management* window.

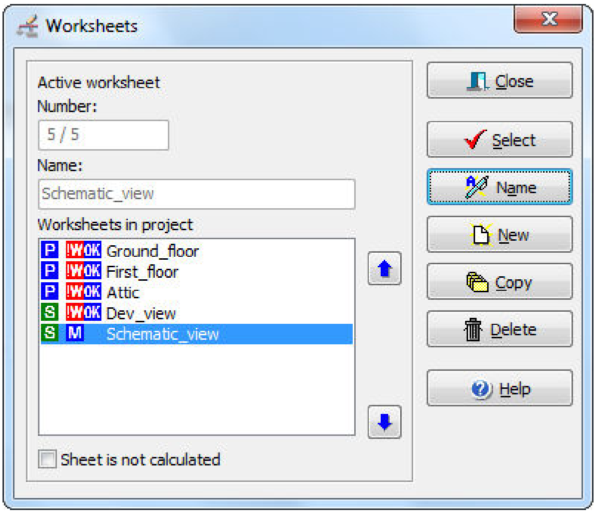


Figure 3.113. Creation of new *Schematic view* worksheet

The first element to be inserted is the construction of the builing in the form of schematically drawn storeys ceilings (Figure 3.114). Access to this function is available using suitable icon in *Components* toolbar under *Construction* edit scope.

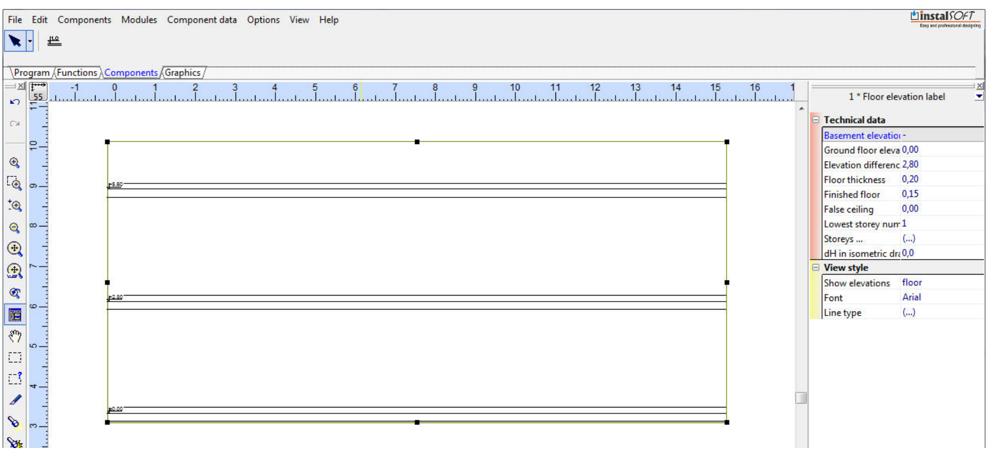


Figure 3.114. Insertion of building construction as cross-section view

All the elements of the designed installation should be inserted to the schematic view in the specific order. It is important to use the same manner of connection as in the plan views, because the installation drawn in planar and the schematic view will be combined as primary-shadow pairs. The schematic view of the exemplary installation is presented in Figure 3.115.

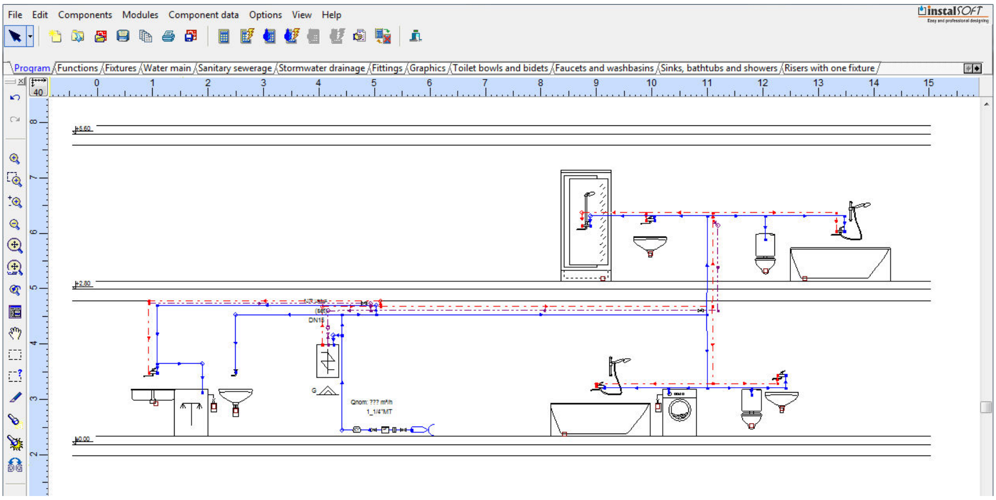


Figure 3.115. Insertion of the components of the installation in the schematic view

After drawing all the installation elements in the schematic view, it is recommended to use the function of primary-shadow pairs combination available in *Component data* main menu. Combination of primary-shadow pairs requires careful work with selection of the specific element in the right window (schematic view), its designation as shadows (*Mark selected as shadows*), selection of the relevant element in left window and combination (*Combine*).

All the sources, pipes, receivers should be marked in the following way (Figure 3.116).

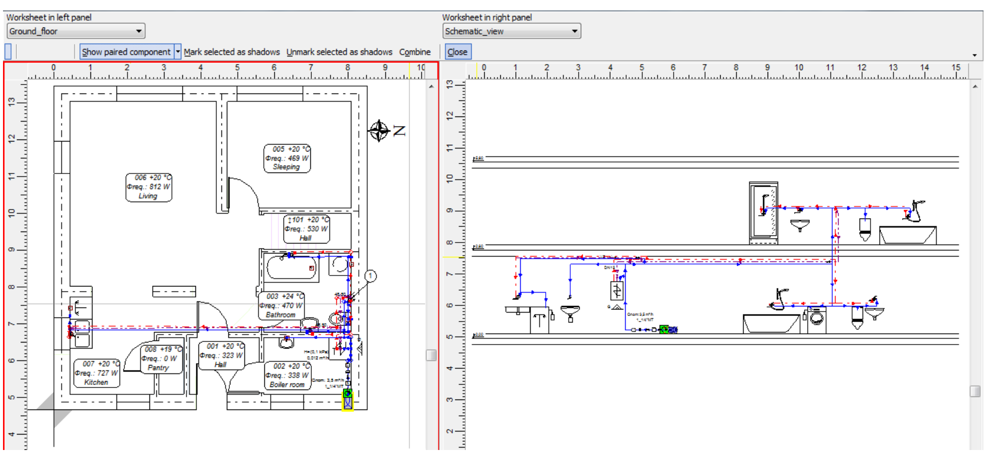


Figure 3.116. Combination of primary-shadow pairs

After the description of primary-shadow pairs, it is necessary to choose the window of combination and to save the project. Shift and F10 buttons can be then used to refresh the calculations. If the combination was performed properly, there will be no new errors and therefore the graphical part of the drawing, described in the next chapter, can be continued.

3.2.4 Printout of the drawings

To prepare the drawings for printout, it is necessary to insert some missing graphical elements like pipe-runs labels, paper format, drawing chart, etc. Since the most of these actions were already described in previous sub-chapter, they will not be discussed here.

Legend can be inserted as a *Rectangle* from the *Graphics* toolbar. However, it can contain text only, therefore it is recommended to finish the legend in AutoCAD after the drawing is exported, since no icons and symbols can be added to this text field.

Figures 3.117 – 3.119 contain drawings prepared for printout or export. Such drawings can be then finished in AutoCAD after exporting the file or printed directly from the current application.

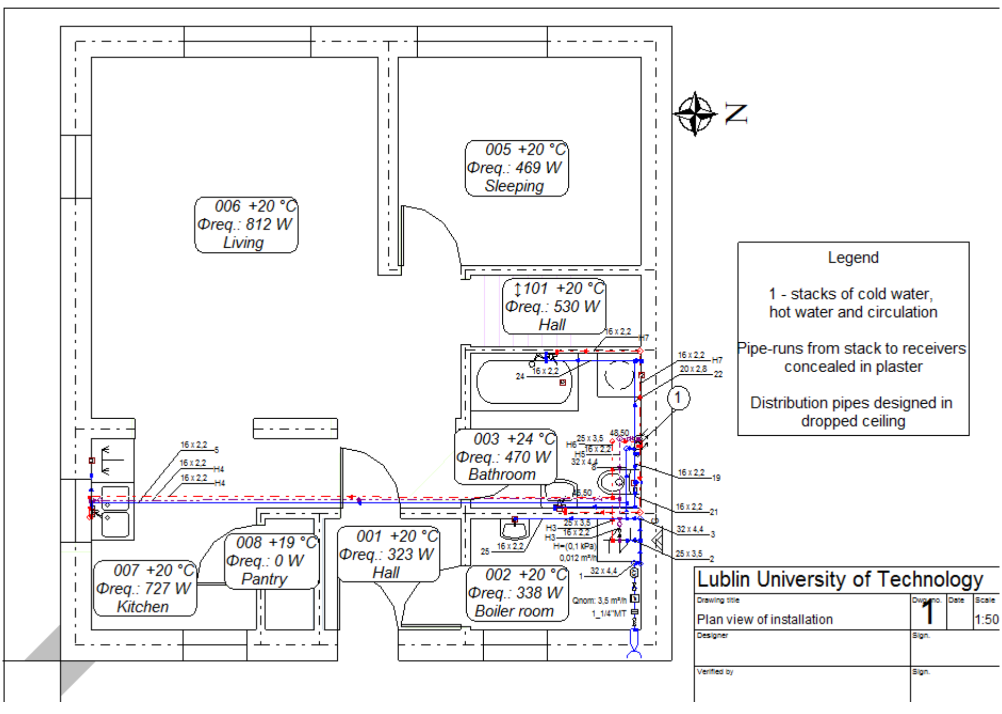


Figure 3.117. Final plan view drawing of water supply system on ground floor

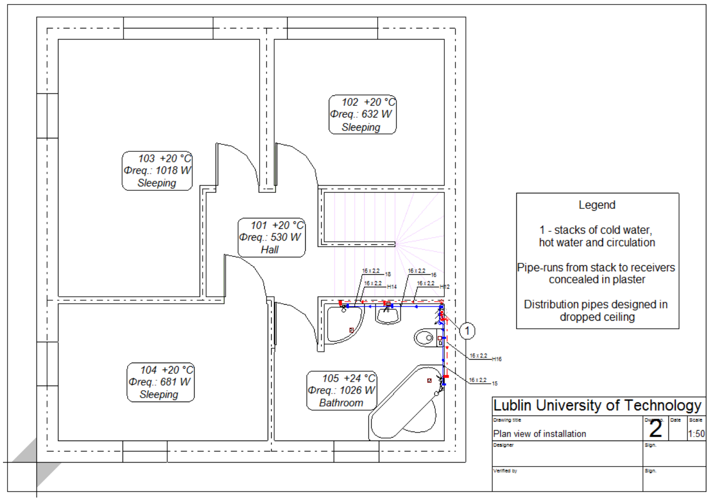


Figure 3.118. Final plan view drawing of water supply system on the first floor

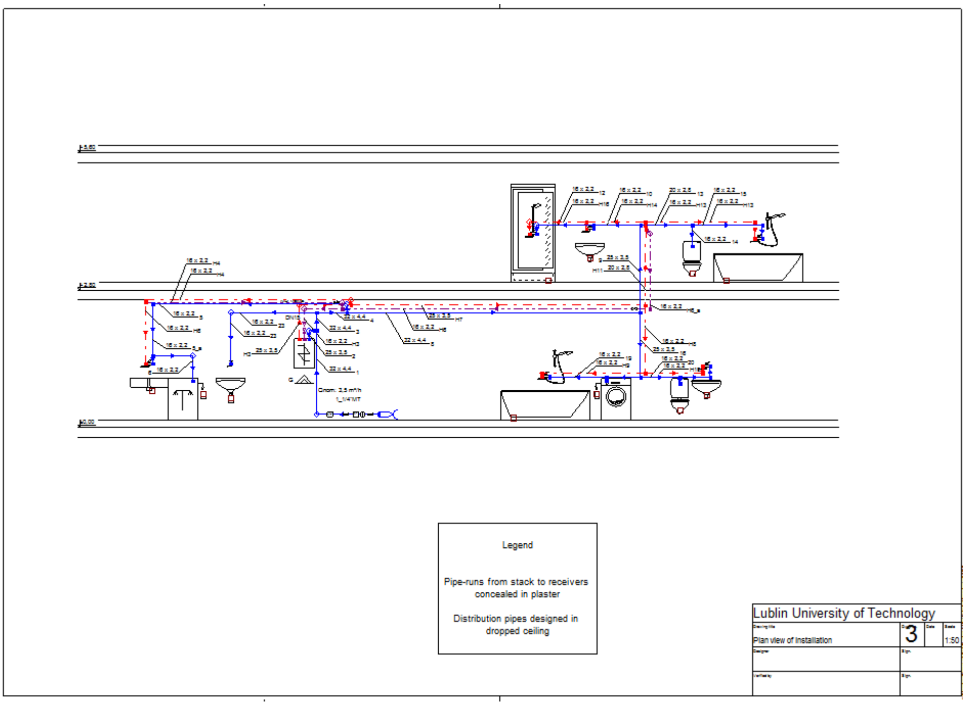


Figure 3.119. Final schematic view of water supply system

Export of the drawings to AutoCAD program can be executed in the same way as described previously in the sub-chapter sacrificed to the heating installations, thus it will not be described in this part of the book.

4 Summary

Designing of sanitary installations requires a broad scope of knowledge, connected with both physical basics of environmental processes and current regulations in the engineering branch. The basic information about radiant heating systems and water supply installations for single-family houses presented in the theoretical part of this book can be treated as brief foreword for Computer Aided Designing. Described in the first chapter theoretical basics are therefore intended for engineers who got the knowledge about designing of heating installations and water supply systems. For the beginners in Environmental Engineering, it is recommended to start with theoretical literature positions concerning traditional designing methods before using Computer Aided Desinging on the basis of this book.

InstalSystem package described in the second chapter of the monograph is one of the alternatives for Computer Aided Designing of sanitary installations. It discriminates among the corresponding applications by the simplicity of usage and abundance of automatic functions like creation of schematic view. The examples of Computer Aided Designing presented in third chapter are therefore deliberated as short (based on single-family house solutions), but full of additional options. They aim in presentation of possibilities offered by InstalSystem, and partially they are the source of knowledge about the solutions used in the engineers' practice. The authors wanted to encourage the possible users of the mentioned applications for development of abilities, which can be achieved mostly by practice.

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