Nadezhda Romanova

Heat distribution losses in ventilation heating systems

Bachelor's thesis
Building Services Engineering

May 2016

MAMK
University of Applied Sciences

DESCRIPTION

MAMK University of Applied Sciences

Date of the bachelor's thesis

18.05.2016

Author

Romanova Nadezhda

Degree programme and option

Double Degree Programme in Building Services Engineering

Name of the bachelor's thesis

Heat distribution losses in ventilation heating systems

Abstract

Nowadays heat losses from hot water heating pipelines in ventilation systems are taken as zero in energy calculations in Finnish National Building Codes D3 and D5. The main aim of this bachelor thesis was to define the necessity to take those losses into account.

In order to achieve this aim two cases were examined: theoretical and practical. For both cases energy need of air handling unit (AHU) and the heat energy of heating coil were found. Then calculating of heat losses from hot water heating delivery pipelines was made. The relative amount of heat losses into the building space during heat distribution was calculated as two ratios. The first was the ratio between heat losses and heat energy of heating coil and the second ratio was between heat losses and the total energy need of AHU.

After finding the total energy need and heat delivery losses the ratio between them was found. For the theoretical case the ratio between heat losses and heat energy of heating coil is 2,5 % and the ratio was between heat losses and the total energy need of AHU equals 0,5 %. For the practical case the same ratios respectively equal 4,5 % and 2,1 %. According to the results of both cases it was concluded that the heat distribution losses from delivery pipelines of hot water heating system in energy calculations can be ignored in energy calculations.

Subject headings, (keywords)

Distribution losses, rotating wheel, annual energy efficiency

Pages	Language	URN
30	English	

Remarks, notes on appendices

Tutor	Employer of the bachelor's thesis
Martti Veuro	

CONTENTS

NOMENCLATURE

c_p – the specific heat capacity of air, kJ/kgK

h_{in} – the heat transfer coefficient in the pipe, W/m^2·K

h_{out} – the heat transfer coefficient at the outside insulation surface, W/m^2·K

k – thermal conductivity, W/m·K

k_{PIPE} – the thermal conductivity of pipe, W/m·K

$k_{INSULATION}$ - the thermal conductivity of insulation, W/m·K

L - combined length of supply and return pipes in a non-heated space, m

L – length of pipe

$q_{distribution\ losses,out}$ – heat loss into a non-heated room during heat distribution, kWh/m,a

q_{sHR} – supply air flow rate after HR, m^3/s

q_{exhHR} - exhaust air flow rate after HR, m^3/s

q_{exh} – the exhaust air flow rate of ventilation, m^3/s

q_r – the heat transfer rate

Q_{AHU} – the heat energy used for ventilation heating, kWh

$Q_{distribution,out}$ – heat loss into a non-heated room during heat distribution, kWh/a

$Q_{heating,\ spaces}$ – energy consumption for heating spaces from heat delivery to heat production, kWh/a

$Q_{heating,space,net}$ – net energy need for space heating, kWh/a

r_1 – inner radius

r_2 – outer radius

t_{ext} – extract air temperature after HR, °C

t_{exh} – indoor=exhaust air temperature, °C

t_{out} – outdoor air temperature, °C

$T_{s,1}$ – inner surface temperature

$T_{s,2}$ – outer surface temperature

$\Delta\tau$ – the time period when that temperature difference (t_{exh}- t_{out}) occurs, h

$\eta_{heating,spaces}$ – heating system efficiency in heating spaces,

η_s – temperature ratio for supply air

η_{ext} – temperature ratio for exhaust air

ρ – the density of air, kg/m^3

1 INTRODUCTION

The issue of energy saving is very important in conservation of natural resources. When taking care of energy saving we care about the future, because uncontrolled consumption will lead to shortages of natural resources, most of which are not renewable. Energy conservation and energy efficiency have become one of the global issues. The reasons for that are the limited natural energy resources, the slow recovery period, the excessive demands of modern life, wasteful consumption and high wastage rates. People all over the world are trying to find ways to reduce energy consumption. Different measures must be developed and adopted in order to ensure preserving these resources and their effective use.

Energy efficiency of a building can be improved in different ways. One of them is the reduction of heat losses. Talking about heating, ventilation and air conditioning systems, designers should choose such equipment and distribution systems insulation so that the losses would be as low as possible. So duct and pipe insulation is necessary almost always for all HVAC ductwork and pipes.

Nowadays heat losses from hot water heating pipelines in ventilation systems are taken as zero in energy calculation in Finnish National Building Codes D3 and D5. The main topic of this bachelor thesis is to calculate the real amount of those losses and to compare it with the total amount of energy needed in ventilation heating system.

2 AIM AND METHODS

2.1 Aim

The most important aim of this bachelor’s thesis is to find out if there is a necessity to take into account the heat losses from delivery pipelines of hot water heating system in energy calculations. In order to achieve this aim it is necessary to calculate the total energy need of ventilation and heat delivery losses and then to define what is the value of the actual heat demand of a ventilation system.

2.2 Methods

The initial data will be obtained from the measuring devices of air handling units of the system chosen for analyzing. The data that should be collected: supply air temperature after heat recovery unit, supply air flow, exhaust air flow, annual temperature efficiency of the heat recovery unit. Some values such as the extract air minimum temperature and indoor air temperature will be taken from Finnish National Building Code.

After collecting all the initial data the calculations will be made. The energy demand for ventilation, the heat recovery energy from exhaust air, the heat energy of the heating coil and the annual heat recovery efficiency of ventilation will be calculated first. The calculation of the total energy need will be made as the sum of energy demand for all periods during which all the possible outdoor temperatures. Supply and return water flow temperatures in the heating ventilation system will be correspond to the outdoor temperatures. Microsoft Excel program will be used for making all the calculations.

Then calculation of heat losses from hot water heating delivery pipelines will be made. The method used for defining the sum of the losses will be analogical to the method used for defining the total energy demand of the system. The total length of pipes from the heat source to the Air Handling Unit (AHU) will be found. Some other information such as the heat transfer coefficient in the pipe, nominal pipe diameter or thickness insulation will be taken from the books on specialized subjects and Euro Norms. The calculations will also be made in Microsoft Excel.

After these calculations two ratios will be found: the first one between pipelines losses and total energy need of ventilation system and the second one between pipelines losses and the heat energy of the heating coil. The theoretical case calculations will be compared with the study case calculations. As a result of calculations the conclusion about the necessity to consider heat distribution losses in heating ventilation system will be made.

3 ENERGY DEMAND CALCULATIONS OF VENTILATION SYSTEM

3.1 Energy Certification of buildings in Finland

The Ministry of the Environment of Finland provides legislation and guidelines for energy performance certificates of buildings. Part D3 of National Building Code of Finland gives the regulations on the energy efficiency of the buildings to be applied in construction. /1./

In order to determine the class of the building the total energy consumption of the building, the E-value ($kWh/m^2 \cdot a$) must be found. This value describes the total energy demand of the building per m^2 of its net floor area during the whole year. There are several energy classes of the building from A to G- class: A class corresponds to the most energy efficient building type and G is the most energy consuming one.

The energy audit calculation procedure is made in accordance with the values that correspond to every certain type of the building. There are 9 different classes of buildings which have different kind of requirements and the initial values such as supply air rate from outside (dm^3/sm^2) and heating and cooling limits (C°).

The certification of all new buildings in Finland began in 2008. Usually new buildings that meet the requirements of the Building Regulations are assigned to energy class C. The existing building must be certificated in case it will be sold or rented. The energy certificate is valid for 10 years and if it is new apartment blocks and commercial buildings then 4 years only. /2./ The certificate is not necessary at all in for several types of buildings such as: buildings which have floor area of less than 50 m^2; buildings which have seasonally operating heating system; non - occupied buildings which have small energy consumption; etc.

The calculation methodology is described in the building regulations. For Finland it is in Part D5 of NBC. To calculate the E-value it is necessary to define the overall energy use of the building. It includes the total space heating and space cooling consumption, ventilation system total energy need, water consumption and electric energy consumption. First of all, initial data about the building and building structures must be found. It includes information about the type, location, construction year and the number of rooms of the building, the area and the volume of the building, U-value, heat losses through building envelope and so on.

The required information for E-value in heating system part needs the data about the use of existing heating system. Data involved to heat distribution have to be known. In ventilation part there must be information about outgoing and incoming air flow rates of ventilation (m^3/s) and annual energy efficiency of the heat recovery of the ventilation system. /3./ But there is no any information about heat delivery in this system.

3.2 Ventilation system types

The main purpose of the ventilation system in the building is to supply the clean air into the room and to remove unclean air from the indoor space. In a very simplified classification there are two main types of ventilation systems. They are natural ventilation and mechanical ventilation systems.

Natural ventilation is the simplest and the most reliable ventilation system type. It is based on the temperature difference principle which causes air density difference. Air flow rates vary in accordance with weather conditions and depend on the wind speed and direction. Wind and thermal buoyancy drive outdoor air through purpose-built, building envelope openings. As building openings windows, doors, solar chimneys, wind towers, etc. are used. The main disadvantages of this ventilation system are climate- and weather-dependent air flows, the difficulty to dimension it accurately, the fact that air can flow in the wrong direction and that it requires a centralized location of air ducts. /4./

The second type is mechanical ventilation. It is divided into three subtypes: mechanical air supply with natural air exhaust, natural air supply with mechanical air exhaust and mechanical supply and exhaust ventilation system.

In case of mechanical air supply with natural air exhaust ventilation the supply air is delivered mechanically and the exhaust naturally with the help of openings. That creates an overpressure in the building. The prevention of draught is provided by the highest possible location of supply air device in the room and by preheating of the incoming air. The cleaning of the incoming air is made with filters. The main advantage of this system in comparison with natural ventilation is that mechanically produced overpressure makes the system much less dependent on the weather conditions.

Natural air supply with mechanical air exhaust ventilation type is usually used in residential and office buildings. In this system underpressure is created. In the system the same precautions against draught are used as in the previous one. The exhaust air ducts may be drawn separately to the attic where collector chamber combines them with the fan. /4./ If this system is used in residential buildings then mechanical suction most commonly goes from at least kitchen, the bathroom and the toilet by suction ducts. In case of non-residential buildings it most often goes from corridor./4./

There are several advantages of this system compared to natural ventilation: air flows can be boosted as required; this system gives possibility to combine exhaust air flows from different dwelling rooms in case residential buildings). Also it gives possibility to combine a cooker hood with the system. As to the disadvantages: this system has some operating costs, as there is no heat recovery system and it has some maintenance costs. It also has such problems as transfer of noise, lack of routes for transfer air and so on.

Mechanical supply and exhaust ventilation system can be combined with all types of heating and cooling systems. The draught decreasing is implemented also by high displacement of the supply air devices and by preheating of the incoming air. The main advantage of this system is the possibility to use the air heat recovery system. This system also decreases the allergy risk as the supply air is filtered. And the building envelope can be made more air-tight and thus more energy efficient. The disadvantages of this system are only quiet high acquisition and operation costs and the space requirement.

3.3 The heat recovery system

The heat recovery system is based on the principle of reuse of the exhaust air's heat content. Energy recovery ventilation is one the most widely used measures for saving energy. The exhaust air is used to precool and dehumidify the outdoor air during the cooling season and to preheat and humidify it in the heating season. Taking energy from the exhaust air flow helps to reduce cooling or heating loads and to decrease energy use. It gives possibility to downsize the equipment and to reduce the peak load on designed conditions. /5./

The main parameter of heat recovery unit (HRU) is the temperature ratio. This value shows the ratio between the realized temperature rise of supply air and with the theoretical maximum. The theoretical maximum can be achieved in case the temperature of supply air is the same as the temperature of exhaust air. The most frequently used types of heat exchangers are described below.

3.3.1 Plate heat exchanger

In plate heat exchanger the heat is transferred from the extract to the outdoor air through plates which are separating the air flows. The plates can be made of steel, copper, graphite or titanium. Those plates are arranged alternately and form channels through which hot and cold air flow. The hot air flows on one side of the plate while the cold fluid flows on the other. Effect of this type of heat exchanger depends on the surface area of the plates. The approximate temperature ratio is 70 – 80 % /6/. The supply and exhaust air flows are not mixed so there is almost no risk to move bacteria and odours to the supply air. On the plate heat exchanger plates some amount of condensate can appear, therefore such exchangers must be equipped with outlets for condensate. Because of the condensation there is a serious risk of ice formation, so the melting system is necessary. An example of the air-handling unit with a cross-flow heat exchanger is shown in the Figure 1.

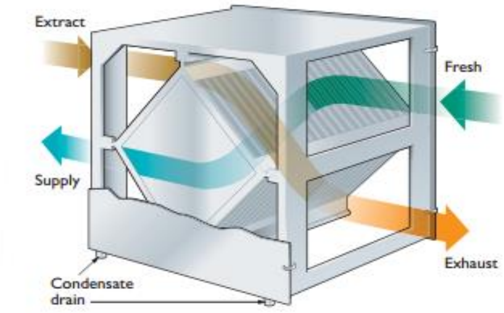

FIGURE 1. A cross-flow plate heat exchanger /7/

3.3.2 Liquid-coupled heat recovery system

In this system water or water-glycol mixture is circulating between two heat exchangers, one is located in the exhaust duct and the other one in supply. The medium takes heat from exhaust air and transfers it to the supply air. /8./ The temperature ratio of this heat recovery system is lower than the value of plate heat exchanger and equals to 50 – 60 % /6/. There is no need to put supply and exhaust units to the same place so they can be separated. The anti-frost protection can be easily put into practice with a three port valve.

3.3.3 Rotary heat exchanger

The main part of this exchanger is a rotating wheel which accumulates heat. This type of heat exchangers is regenerative. Not only heat but humidity can also be transferred. In the rotary type heat exchangers there is a heat and mass transfer with a desiccant coating. At first the core absorbs heat and moisture from the warmer and more humid air flow and then it extracts it to the cooler and drier flow. All this process goes while the wheel rotates. Core material stores heat and moisture when the core passes from one air flow to the other. /5./ The temperature ratio of this exchanger is about 70 % /6/. And the equipment requires not too much space. But the main disadvantage is that small amount of impurities can be moved to the supply air so this system can’t be used in buildings with high demands of hygiene such as health care centers. The picture of the rotating wheel is shown in the Figure 2.

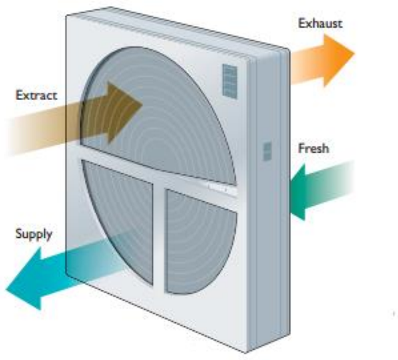

FIGURE 2. Schematic of a thermal wheel /7/

3.4 Calculation of heating ventilation efficiency

The calculation of the total energy need of ventilation can be made in much the same principle as for the heating system of the building. According to the equation /9, p.35/, energy consumption for space heating is calculated so that heat losses during distribution are taken into account. Equations which should be used:

$$Q_{heating,spaces} = \frac{Q_{heating.space,net}}{\eta_{heating,spaces}} + Q_{distribution,out} \tag{1}$$

$$Q_{distribution,out} = q_{distribution\ losses,out} \cdot L \tag{2}$$

For every heating system type /9/ gives certain guideline values for annual efficiencies for heat distribution and delivery systems. Description of heating solutions takes into account the availability or lack of insulation, temperature requirements (in case of water radiator solution), etc. The guideline value for annual efficiency value varies from 0,75 for hot-water floor heating system with 40/30 °C temperature conditions in case building butts against outdoor air to 0,94 for electric heater heating system solution.

Specific heat loss $q_{distribution\ losses,out}$ can also be found from a table in NDC D5. It depends on the size of a building and also on the location of pipes and the availability of insulation.

When adopting those equations for ventilation heating system instead of the energy consumption for heating spaces the total energy need of ventilation system should be used. The ventilation system efficiency coefficient will be found in this bachelor thesis. So the equation for the total energy consumption of ventilation will be:

$$Q_{ventilation,spaces} = \frac{Q_{AHU}}{\eta_{ventilation,spaces}} + Q_{distribution,out} \quad (3)$$

3.5 Calculation of total energy need of ventilation

In order to estimate how large the heat losses are the total energy need of ventilation must be found. The temperature of the transfer medium inside the ventilation or heating system depends on the temperature of the air outside the building. The duration curve of outdoor air temperature shows for how long time period the certain outdoor temperature is below or exceeds a certain value.

In Finland in the heating energy calculations the weather data and the duration of time of a certain outdoor temperature for η_a calculations is usually taken for the weather zone 1. In Figure 3 the duration curve is shown.

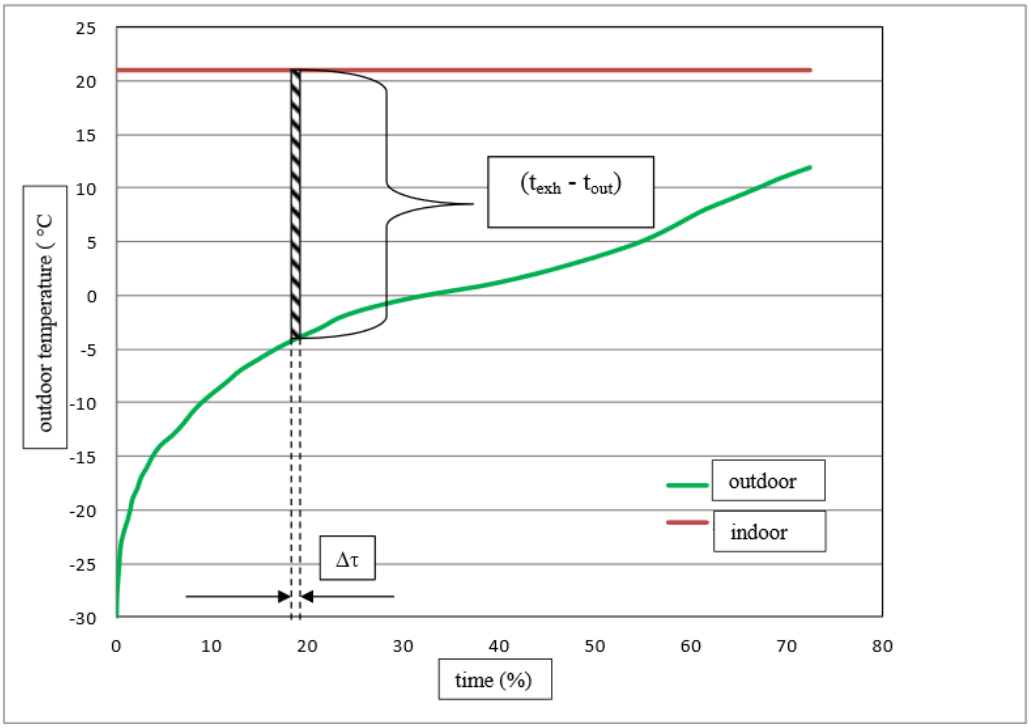

FIGURE 3. The duration curve of outdoor air temperature (Weather zone 1) /10/

Within the short time period the outdoor temperature change is so small that this temperature is assumed to be constant. Therefore, the energy need for the ventilation system during that time period is also constant. To calculate this period of time the duration in percentage is multiplied by 0,01 and by the amount of hours in the whole year. Such calculations are made for two temperatures with 1 °C step and then the difference between those two periods is taken as unit interval. For this interval the temperature difference is taken as the difference between mean outdoor temperature for those two temperature values and the indoor air temperature which according to NBC D2 /11, p.8/ is taken as 21 °C for room temperature in the occupied zone.

For example, for the t_{out}= - 30 °C:

$0{,}011\ \% \cdot 0{,}01 \cdot 365 \cdot 24 \approx 1$ hour

t_{out}= - 29 °C:

$0{,}034\ \% \cdot 0{,}01 \cdot 365 \cdot 24 \approx 3$ hour

$\Delta\tau$=3-2=1 hour

The extract temperature is found using the formula:

$$t_{ext} = t_{exh} + \eta_{exh} \cdot (t_{exh} - t_{out}) \tag{4}$$

To prevent freezing limitation of the extract air temperature after HR is used. The minimum values for those temperatures are given in NBC D5. They correspond to the type of HR and to the functional purpose of the building. Those temperatures are given in Table 1.

TABLE 1. The minimum values of the extract air temperature after the heat recovery unit for different heat exchanger types /3/

Heat exchanger type	Temperature
plate heat exchanger in residential buildings	+5 °C
thermal wheel in residential buildings	0 °C
plate heat exchanger in other buildings	0 °C
thermal wheel in other buildings	-5 °C

In case the extract temperature is taken as minimum value then the temperature ratio for exhaust air might be lower than the one given by manufacturer and must be calculated with formula:

$$\eta_{ext} = \frac{t_{exh} - t_{ext}}{t_{exh} - t_{out}} \quad (5)$$

The temperature ratio for supply air is

$$\eta_s = \frac{t_{sHR} - t_{out}}{t_{exh} - t_{out}} \quad (6)$$

If the manufacturers' data about η_s is not given then the values from NBC D5 should be used. Those values are given in accordance with the heat exchanger type and are shown in Table 2.

TABLE 2. Values for heat exchangers for ventilation heat recovery temperature ratio η_s to be used for calculating the annual efficiency of heat recovery on the supply air side /3/

Heat exchanger type	Temperature ratio η_s
Coil-coil with liquid circulation	0,40
Cross flow plate heat exchanger	0,50
Counter flow plate heat exchanger	0,60
Regenerative heat exchanger	0,65

If the specific heat capacity and the density are equal for both exhaust and supply air parts in the heat balance equation then the relationship between temperature ratios is

$$\eta_{exh} = \eta_s \cdot R_{HR} \quad (7)$$

In the equation given above the relation between supply and exhaust air flow rates R_{HR} was found with the ratio:

$$R_{HR} = \frac{q_{sHR}}{q_{exhHR}} \quad (8)$$

The supply air temperature after HR is:

$$t_{sHR} = t_{out} + \eta_s \cdot (t_{exh} - t_{out}) \quad (9)$$

The total energy need of ventilation system will be found by summarizing of all the heat energy used for ventilation heating in every short time period. The energy need in one unit time period can be found with the following equation:

$$Q_{AHU} = \rho \cdot c_p \cdot q_{exh} \cdot (t_{exh} - t_{out}) \cdot \Delta\tau \quad (10)$$

To find out the annual energy efficiency of ventilation heat recovery the heat recovered by HR Q_{HR}, kWh must be found:

$$Q_{HR} = \rho \cdot c_p \cdot q_{sHR} \cdot \Sigma(t_{sHR} - t_{out}) \cdot \Delta\tau \quad (11)$$

The formula for the annual energy efficiency is

$$\eta_{a,AHU} = \frac{Q_{HR}}{Q_{AHU}} \quad (12)$$

3.6 Heat transfer

Heat transfer is a physical process of transferring heat energy from a more heated object to a less one either directly (through contact) or through separating with a barrier made of some material. When the physical objects of one system are at different temperatures there is heat transfer from one body to another until the thermodynamic equilibrium will be achieved. According to the second law of thermodynamics spontaneous heat transfer always goes from a warmer object to a cooler one. There are three types of transferring the heat, they are: conduction, convection, radiation.

Conduction is the process of the transfer of energy (heat) from the more heated parts to less heated parts of the object by randomly moving of the particles of this object (atoms, molecules, electrons, etc.). It can occur in all parts of the body with nonuniform temperature distribution but the mechanism of heat transfer depends on the state of aggregation of matter.

Convection is a type of heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it. Natural convection above a hot surface occurs because hot air expands, becomes less dense, and rises. Hot water is likewise less dense than cold water and rises, causing convection currents which transport energy. Forced convection appears when the fluid is forced by external means like pump or fan. /12./

Radiation is the process of broadcasting the energy in the form of waves or particles through space or through a material medium. It includes electromagnetic radiation, particle radiation such as α -, β -, and neutron radiation and acoustic radiation.

In this case there is conduction which goes from the water inside the pipes to the pipes and from the pipes to the air.

3.7 Heat losses of pipes

The pipes which deliver the heat from the heat source to the consumer always have some amount of heat delivery losses. Those delivery losses can be reduced with additional layer that covers these pipes along the whole length of them. That’s why the insulation layer is needed and should be chosen properly so that the system would be efficient and would have reasonable investment costs.

The values of heat losses through thermal system insulation in general depend on:
— type of insulation structure and the applied insulation material;
— types of installation (aerial, underground duct, etc.) and their ratios for a given heat network;
— the temperature and the duration of the operation of the heat network during the year;
— environmental parameters: outside air temperature, soil and the nature of its changes during the year, and in some cases, from wind velocity (above ground routing);

— the material characteristics of the heat network and its structure depending on diameter and length of pipelines according to type gasket and insulating structures;
— period and operation conditions of heat networks;
— local characteristics (hydrologic conditions, and schematic planning, the intensity and character of adjacent lines, etc.). /13./

In case of hot water heating pipelines there are only several factors from all those mentioned above that are worth of considering. They are: insulation material and insulation thickness, material of pipe and outside air temperature.

Nowadays there is a huge range of different insulating materials. There are several parameters that vary depending on which insulation was chosen. The main parameter which describes insulation properties is its thermal conductivity. It shows how much heat the insulation conducts per one unit of length when there is a 1 K increase of the temperature of the heat transfer medium. So in calculations the insulation material is taken into account in the thermal conductivity of insulation. The thickness of the insulation affects the diameter of pipe. And the temperature of heat transfer medium inside the pipe is influenced by the outdoor air temperature.

Almost all pipes of hot water heating ventilation system are covered with insulation but there are some uninsulated parts. Generally radial conduction through a cylindrical uninsulated pipe /14, p. 137/ can be defined using the formula for the heat transfer rate:

$$q_r = \frac{2 \cdot \pi \cdot L \cdot k \cdot (T_{S,1} - T_{S,2})}{\ln({}^{r_2}/_{r_1})} \tag{13}$$

According to the following equation /15/ heat loss per one meter of insulated pipe is:

$$\frac{Q}{L} = \pi \cdot D_3 \cdot U \cdot (T_{in} - T_{out}) \tag{14}$$

In Figure 4 cross section of insulated pipe with designation of diameters is shown.

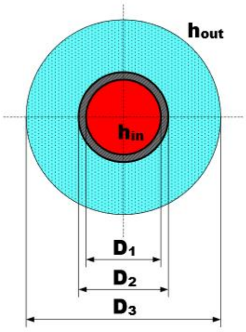

FIGURE 4. Cross section of Insulated Pipe /7/

The overall heat transfer coefficient of insulated pipe:

$$U = \frac{1}{\frac{D_3}{D_1 \cdot h_{in}} + \frac{D_3 \cdot \ln(\frac{D_2}{D_1})}{2 \cdot k_{PIPE}} + \frac{D_3 \cdot \ln(\frac{D_3}{D_2})}{2 \cdot k_{INSULATION}} + \frac{1}{h_{out}}} \quad (15)$$

The first two additive components of the denominator in Equation are much smaller than the next two. Their influence on the result of the final calculation of overall heat transfer coefficient is very small. A similar situation appears in the great majority of cases in practice. So the following simplification can be used:

$$U = \frac{1}{\frac{D_3 \cdot \ln(\frac{D_3}{D_2})}{2 \cdot k_{INSULATION}} + \frac{1}{h_{out}}} \quad (16)$$

The most frequently used pipe diametres in ventilation systems are over the range of 32 - 65 mm for nominal diameter. In these systems steel pipes almost always are used. Steel pipe data chart includes information about wall thickness, inner and outer diameter according to nominal diameter of pipe. For the diameter less than 50 mm the pipes with threaded connection will be used. The information about corresponding diameters and thicknesses is given in Table 3.

TABLE 3. The steel pipe data chart for threaded connection of pipes /16/

Diameter nominal		Outer diameter	Wall thickness	
			medium-heavy	heavy
DN	R	Da	d	d
mm	inches	(mm)	mm	mm
10	3/8	17,2	2,35	2,9
15	1/2	21,3	2,65	3,25
20	3/4	26,9	2,65	3,25
25	1	33,7	3,25	3,25
32	11/4	42,4	3,25	4,05
40	11/2	48,3	3,25	4,05

If the diameter of pipes is 50 mm and more then welded pipes are used. Table for this pipe connection is taken from international Standard /17/.

TABLE 4. The steel pipe data chart for welded pipes /17/

Diameter nominal		Inner diameter	Outer diameter	Wall thickness
DN	R	Di	Da	d
mm	inches	mm	(mm)	mm
50	2	54,5	60,3	2,9
65	21/2	70,3	76,1	2,9
80	3	82,5	88,9	3,2
100	4	107,1	114,3	3,6

The thickness of insulation for pipes is taken in accordance with pipe diameter. The values are taken for Series 22 from General Quality Requirements for HVAC systems in Buildings /18/.

TABLE 5. The thickness of insulation of pipes /18/

Pipe diameter	Insulation thickness
Du, mm	mm
10 - 49	30
50 - 89	40
89 - 169	50

The temperature of the water inside the hot water heating pipelines depends on the outdoor weather conditions. The information about the outside temperature is taken with help of temperature sensor which measures the outdoor temperature. For every outdoor temperature there is a certain temperature of supply water and return water. In this study case it was decided to take the following temperature rate: for outdoor temperature -30 °C the supply water temperature +70 °C and return water temperature +40 °C are taken. For +15 °C outside supply temperature of water is +22 °C and return +21 °C are taken. All the intermediate values are calculated as the linear dependence which was found with the help of values given above. For example, if the weather outside the is – 10 °C then the temperature of the flow water is +48,7° and the return water temperature is +31,6°.

Heat losses out of pipelines were calculated with the same method which was used for determination of the total heat demand – with help of the duration curve. The whole year was divided in several periods of time. Within the same period medium temperature outside is assumed to be constant. The total amount of losses is calculated as the sum of all the losses in those periods for both supply and return pipelines. The same linear dependence with the same boundary conditions is used to define the temperatures. This linear dependence is shown on the temperature curves in the Figure 5.

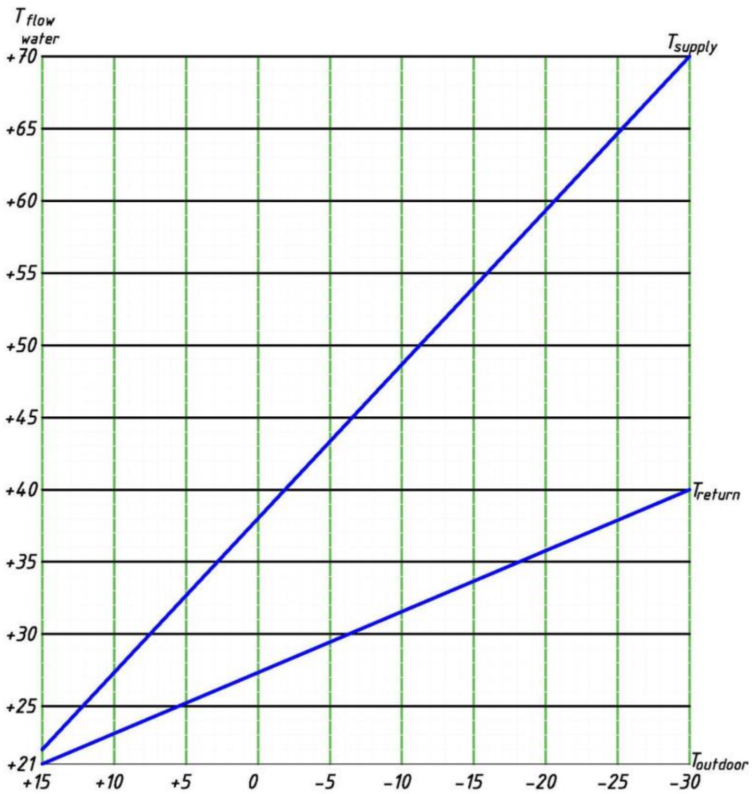

FIGURE 5. The temperature curve

4 THEORETICAL CASE

For the theoretical case it was decided to make calculations for the rotary heat exchanger. This type of heat exchangers is usually installed in public buildings where not high hygiene demands are made. In MAMK building there are three kinds of heat exchangers used but the heat recovery unit with rotating wheel is the most often used type.

4.1 Calculating the total heat demand

For theoretical case the air flow rates were taken as an example of average value for this building. The values of temperatures were taken from the NBC of Finland. Temperature values and also such parameters as density of air and specific heat capacity of air will be the same for the practical case. All the initial data used for theoretical case is shown in the Table 6.

TABLE 6. The initial data

Time weighted supply air flow rate	$q_{v,s}$	4	m^3/s
Time weighted exhaust air flow rate	$q_{v,exh}$	4	m^3/s
Relationship between supply and exhaust air flow rate	R_{HR}	1	
Temperature ratio of supply air according to the D5	η_s	65	%
Density of air	ρ	1,2	kg/m^3
Specific heat capacity of air	c_p	1	kJ/kgK
Indoor=exhaust temperature	$t_{ext}(= t_{exh})$	21	°C
Supply air temperature	t_s	18	°C
The extract(exit) air minimum temperature	$t_{ext, min}$	-5	°C
Max. temperature of supply air after HR	$t_{sHR,max}$	18	°C

To calculate heat energy of the heating coil, the total energy need of AHU and the other necessary parameters equations (4-12) were used. All the calculations and the final result are shown below in the Table 7.

TABLE 7. Calculating the total heat demand.

t_{out}	duration	Δτ	$t_{out,mean}$	t_{ext}	$η_{exh}$	$η_s$	t_{sHR}	Q_{vent}	Q_{HR}	Q_{HC}
	%	h	°C	°C	%	%	°C	kWh	kWh	kWh
-30	0,011	2	-29,5	-5,0	51,5	51,5	-3,5	488	251	208
-29	0,034	2	-28,5	-5,0	52,5	52,5	-2,5	479	251	198
-28	0,057	7	-27,5	-5,0	53,6	53,6	-1,5	1631	875	656
-27	0,137	7	-26,5	-5,0	54,7	54,7	-0,5	1598	875	622
-26	0,217	7	-25,5	-5,0	55,9	55,9	0,5	1564	875	589
-25	0,297	6	-24,5	-5,0	57,1	57,1	1,5	1301	743	472
-24	0,365	13	-23,5	-5,0	58,4	58,4	2,5	2788	1629	971
-23	0,514	25	-22,5	-5,0	59,8	59,8	3,5	5213	3116	1738
-22	0,799	32	-21,5	-5,0	61,2	61,2	4,5	6523	3990	2072
-21	1,164	26	-20,5	-5,0	62,7	62,7	5,5	5183	3247	1561
-20	1,461	19	-19,5	-5,0	64,2	64,2	6,5	3695	2372	1049
-19	1,678	46	-18,5	-4,7	65,0	65,0	7,2	8720	5668	2390
-18	2,203	32	-17,5	-4,0	65,0	65,0	7,5	5909	3841	1608
-17	2,568	57	-16,5	-3,4	65,0	65,0	7,9	10265	6672	2772
-16	3,219	50	-15,5	-2,7	65,0	65,0	8,2	8763	5696	2347
-15	3,790	71	-14,5	-2,1	65,0	65,0	8,6	12091	7859	3210
-14	4,600	115	-13,5	-1,4	65,0	65,0	8,9	19047	12381	5010
-13	5,913	92	-12,5	-0,8	65,0	65,0	9,3	14790	9614	3852
-12	6,963	76	-11,5	-0,1	65,0	65,0	9,6	11862	7710	3057
-11	7,831	93	-10,5	0,5	65,0	65,0	10,0	14066	9143	3584
-10	8,893	116	-9,5	1,2	65,0	65,0	10,3	17018	11062	4282
-9	10,220	124	-8,5	1,8	65,0	65,0	10,7	17490	11368	4343
-8	11,630	112	-7,5	2,5	65,0	65,0	11,0	15339	9970	3754
-7	12,910	160	-6,5	3,1	65,0	65,0	11,4	21161	13754	5098
-6	14,740	165	-5,5	3,8	65,0	65,0	11,7	20948	13616	4960
-5	16,620	193	-4,5	4,4	65,0	65,0	12,1	23589	15333	5481
-4	18,820	222	-3,5	5,1	65,0	65,0	12,4	26063	16941	5931
-3	21,350	183	-2,5	5,7	65,0	65,0	12,8	20652	13424	4592
-2	23,440	314	-1,5	6,4	65,0	65,0	13,1	33870	22015	7338
-1	27,020	440	-0,5	7,0	65,0	65,0	13,5	45382	29499	9551
0	32,040	578	0,5	7,7	65,0	65,0	13,8	56891	36979	11586
1	38,640	434	1,5	8,3	65,0	65,0	14,2	40669	26435	7977
2	43,600	362	2,5	9,0	65,0	65,0	14,5	32127	20882	6035
3	47,730	324	3,5	9,6	65,0	65,0	14,9	27226	17697	4862
4	51,430	283	4,5	10,3	65,0	65,0	15,2	22409	14566	3769
5	54,660	219	5,5	10,9	65,0	65,0	15,6	16294	10591	2549
6	57,160	184	6,5	11,6	65,0	65,0	15,9	12804	8322	1832
7	59,260	185	7,5	12,2	65,0	65,0	16,3	11977	7785	1530
8	61,370	238	8,5	12,9	65,0	65,0	16,6	14296	9293	1573
9	64,090	241	9,5	13,5	65,0	65,0	17,0	13298	8643	1185
10	66,840	227	10,5	14,2	65,0	65,0	17,3	11435	7433	735
11	69,430	268	11,5	14,8	65,0	65,0	17,7	12223	7945	418
12	72,490									
								649138	**420363**	**137347**

$η_{a,AHU}$	0,648

The needed diameter of pipe should be found with the help of calculated heat energy at the coldest period of time, because the highest temperature inside the pipe corresponds to this case. The heat flow can be found according to formula:

$$\phi = \frac{Q_{HC}}{\Delta\tau} \quad (17)$$

The water flow:

$$q_v = \frac{\phi}{\rho \cdot c_p \cdot \Delta T} \quad (18)$$

For the instant case the lowest temperature outside - 30 °C. According to the Figure 3 the supply temperature will be -So the flow will be:

$$\phi = \frac{208}{2} = 104 \text{ kW}$$

$$q_v = \frac{104}{1 \cdot 4{,}2 \cdot (70-40)} = 0{,}83 \text{ l/s}$$

According to the diagram which is shown in the Appendix 1 /16/ the pipe diameter for the flow 0,83 l/s is DN 50. According to the Table 5 the thickness of insulation must be 40 mm.

The calculations are made for supply and return pipes. The approximate length of pipeline in one direction for theoretical case is assumed 70 m which approximately equals to the distance from the technical room on the ground floor to the technical room on the roof for 3-storey university building. Technical rooms are located in different parts of the building.

4.2 Calculating the total amount of losses through pipelines

The heat loss amount per one meter was found with the formula (14) The data which was taken to find out the overall heat transfer coefficient of insulated pipe: h_{out}=12 W/m^2·K and $k_{INSULATION}$=0,046 W/m·K /6/. The diameters were taken from the Table 4 for the found nominal diameter. To define the total energy losses through the pipelines the sum of the losses per each meter of pipe should be multiplied by the total length of pipe. All the calculations are shown below in the Table 8.

TABLE 8. Calculating the total amount of losses through pipelines.

SUPPLY				DN50		RETURN			DN50	
T_{out}	Δτ	T_{flow}	ΔT	Q/L	Q·h/L·a	T_{out}	T_{flow}	ΔT	Q/L	Q·h/L·a
°C	h	°C	°C	W/m	kW·h/m a	°C	°C	°C	W/m	kW·h/m a
-30	2	70,0	49,0	15,74	0,03	-30	40,0	19,0	6,10	0,01
-29	2	68,9	47,9	15,40	0,03	-29	39,6	18,6	5,97	0,01
-28	7	67,9	46,9	15,06	0,11	-28	39,2	18,2	5,83	0,04
-27	7	66,8	45,8	14,72	0,10	-27	38,7	17,7	5,70	0,04
-26	7	65,7	44,7	14,37	0,10	-26	38,3	17,3	5,56	0,04
-25	6	64,7	43,7	14,03	0,08	-25	37,9	16,9	5,43	0,03
-24	13	63,6	42,6	13,69	0,18	-24	37,5	16,5	5,29	0,07
-23	25	62,5	41,5	13,34	0,33	-23	37,0	16,0	5,15	0,13
-22	32	61,5	40,5	13,00	0,42	-22	36,6	15,6	5,02	0,16
-21	26	60,4	39,4	12,66	0,33	-21	36,2	15,2	4,88	0,13
-20	19	59,3	38,3	12,32	0,23	-20	35,8	14,8	4,75	0,09
-19	46	58,3	37,3	11,97	0,55	-19	35,4	14,4	4,61	0,21
-18	32	57,2	36,2	11,63	0,37	-18	34,9	13,9	4,48	0,14
-17	57	56,1	35,1	11,29	0,64	-17	34,5	13,5	4,34	0,25
-16	50	55,1	34,1	10,95	0,55	-16	34,1	13,1	4,21	0,21
-15	71	54,0	33,0	10,60	0,75	-15	33,7	12,7	4,07	0,29
-14	115	52,9	31,9	10,26	1,18	-14	33,2	12,2	3,93	0,45
-13	92	51,9	30,9	9,92	0,91	-13	32,8	11,8	3,80	0,35
-12	76	50,8	29,8	9,57	0,73	-12	32,4	11,4	3,66	0,28
-11	93	49,7	28,7	9,23	0,86	-11	32,0	11,0	3,53	0,33
-10	116	48,7	27,7	8,89	1,03	-10	31,6	10,6	3,39	0,39
-9	124	47,6	26,6	8,55	1,06	-9	31,1	10,1	3,26	0,40
-8	112	46,5	25,5	8,20	0,92	-8	30,7	9,7	3,12	0,35
-7	160	45,5	24,5	7,86	1,26	-7	30,3	9,3	2,98	0,48
-6	165	44,4	23,4	7,52	1,24	-6	29,9	8,9	2,85	0,47
-5	193	43,3	22,3	7,18	1,38	-5	29,4	8,4	2,71	0,52
-4	222	42,3	21,3	6,83	1,51	-4	29,0	8,0	2,58	0,57
-3	183	41,2	20,2	6,49	1,19	-3	28,6	7,6	2,44	0,45
-2	314	40,1	19,1	6,15	1,93	-2	28,2	7,2	2,31	0,72
-1	440	39,1	18,1	5,80	2,55	-1	27,8	6,8	2,17	0,95
0	578	38,0	17,0	5,46	3,16	0	27,3	6,3	2,03	1,18
1	434	36,9	15,9	5,12	2,22	1	26,9	5,9	1,90	0,83
2	362	35,9	14,9	4,78	1,73	2	26,5	5,5	1,76	0,64
3	324	34,8	13,8	4,43	1,44	3	26,1	5,1	1,63	0,53
4	283	33,7	12,7	4,09	1,16	4	25,6	4,6	1,49	0,42
5	219	32,7	11,7	3,75	0,82	5	25,2	4,2	1,36	0,30
6	184	31,6	10,6	3,41	0,63	6	24,8	3,8	1,22	0,22
7	185	30,5	9,5	3,06	0,57	7	24,4	3,4	1,09	0,20
8	238	29,5	8,5	2,72	0,65	8	24,0	3,0	0,95	0,23
9	241	28,4	7,4	2,38	0,57	9	23,5	2,5	0,81	0,20
10	227	27,3	6,3	2,03	0,46	10	23,1	2,1	0,68	0,15
11	268	26,3	5,3	1,69	0,45	11	22,7	1,7	0,54	0,15

The total amount of losses:

- for supply pipe equals 36,42 kW·h/m·a;
- for return pipe – 13,61 kW·h/m·a.

For both pipes with 70 m length the total amount of losses is 3,5 MW·h/a.

5 STUDY CASE

In this chapter the heating ventilation system that was taken for calculations will be described. The calculations of the heat losses will be made and the total energy need of ventilation systems will be found.

The calculations will be made for one of the systems located in the building of Mikkeli University of Applied Sciences campus area. The type of ventilation system in those buildings is mechanical supply and exhaust. The handling unit which will be used for calculations is located in technical room on the roof of the D building. The connection to the district heating is located in a technical room on the ground floor of the D building. There are three stories in that building. The delivery pipes that produce heating losses go from the heating source to the AHU heating coil. The connection point to the heat source is located in the technical room on the ground floor and the heating coil is located on the last floor of the building. The type of a heat recovery unit is a rotating wheel.

To find out the weighted supply and exhaust air flow rate the operation time of the AHU should be taken into account:

$$q_{v,s} = 3{,}5 \cdot \frac{13{,}17}{24} \cdot \frac{5}{7} = 1{,}37\ {m^3}/{s},$$

$$q_{v,exh} = 2{,}7 \cdot \frac{13{,}17}{24} \cdot \frac{5}{7} = 1{,}06\ {m^3}/{s},$$

Relationship between supply and exhaust air flow rate is found according to formula (8):

$$R_{HR} = \frac{1{,}37}{1{,}05} = 1{,}3$$

The calculations were made according to equations (4 – 12). The result is shown in the Table 9.

TABLE 9. Calculating the total heat demand.

t_{out}	duration	$\Delta\tau$	$t_{out,mean}$	t_{ext}	η_{exh}	η_s	t_{sHR}	Q_{vent}	Q_{HR}	Q_{HC}
	%	h	°C	°C	%	%	°C	kWh	kWh	kWh
-30	0,011	2	-29,5	-5,0	51,5	39,7	-9,4	129	67	91
-29	0,034	2	-28,5	-5,0	52,5	40,5	-8,4	127	67	88
-28	0,057	7	-27,5	-5,0	53,6	41,4	-7,4	432	231	294
-27	0,137	7	-26,5	-5,0	54,7	42,2	-6,4	423	231	282
-26	0,217	7	-25,5	-5,0	55,9	43,1	-5,4	414	231	270
-25	0,297	6	-24,5	-5,0	57,1	44,1	-4,4	344	197	220
-24	0,365	13	-23,5	-5,0	58,4	45,1	-3,4	738	431	461
-23	0,514	25	-22,5	-5,0	59,8	46,1	-2,4	1379	824	840
-22	0,799	32	-21,5	-5,0	61,2	47,2	-1,4	1726	1056	1023
-21	1,164	26	-20,5	-5,0	62,7	48,3	-0,4	1371	859	790
-20	1,461	19	-19,5	-5,0	64,2	49,5	0,6	978	628	546
-19	1,678	46	-18,5	-4,7	65,0	50,1	1,3	2307	1500	1264
-18	2,203	32	-17,5	-4,0	65,0	50,1	1,8	1563	1016	852
-17	2,568	57	-16,5	-3,4	65,0	50,1	2,3	2716	1765	1474
-16	3,219	50	-15,5	-2,7	65,0	50,1	2,8	2319	1507	1251
-15	3,790	71	-14,5	-2,1	65,0	50,1	3,3	3199	2079	1717
-14	4,600	115	-13,5	-1,4	65,0	50,1	3,8	5039	3276	2689
-13	5,913	92	-12,5	-0,8	65,0	50,1	4,3	3913	2544	2075
-12	6,963	76	-11,5	-0,1	65,0	50,1	4,8	3138	2040	1653
-11	7,831	93	-10,5	0,5	65,0	50,1	5,3	3722	2419	1946
-10	8,893	116	-9,5	1,2	65,0	50,1	5,8	4503	2927	2336
-9	10,220	124	-8,5	1,8	65,0	50,1	6,3	4627	3008	2381
-8	11,630	112	-7,5	2,5	65,0	50,1	6,8	4058	2638	2069
-7	12,910	160	-6,5	3,1	65,0	50,1	7,3	5599	3639	2827
-6	14,740	165	-5,5	3,8	65,0	50,1	7,8	5542	3603	2769
-5	16,620	193	-4,5	4,4	65,0	50,1	8,3	6241	4057	3082
-4	18,820	222	-3,5	5,1	65,0	50,1	8,8	6896	4482	3362
-3	21,350	183	-2,5	5,7	65,0	50,1	9,3	5464	3552	2627
-2	23,440	314	-1,5	6,4	65,0	50,1	9,8	8961	5825	4243
-1	27,020	440	-0,5	7,0	65,0	50,1	10,3	12007	7805	5588
0	32,040	578	0,5	7,7	65,0	50,1	10,8	15052	9784	6873
1	38,640	434	1,5	8,3	65,0	50,1	11,3	10760	6994	4808
2	43,600	362	2,5	9,0	65,0	50,1	11,8	8500	5525	3707
3	47,730	324	3,5	9,6	65,0	50,1	12,3	7203	4682	3055
4	51,430	283	4,5	10,3	65,0	50,1	12,8	5929	3854	2434
5	54,660	219	5,5	10,9	65,0	50,1	13,3	4311	2802	1705
6	57,160	184	6,5	11,6	65,0	50,1	13,8	3388	2202	1281
7	59,260	185	7,5	12,2	65,0	50,1	14,3	3169	2060	1135
8	61,370	238	8,5	12,9	65,0	50,1	14,8	3782	2459	1268
9	64,090	241	9,5	13,5	65,0	50,1	15,3	3518	2287	1084
10	66,840	227	10,5	14,2	65,0	50,1	15,8	3025	1967	835
11	69,430	268	11,5	14,8	65,0	50,1	16,3	3234	2102	766
12	72,490									
								171746	**111218**	**80059**

$\boldsymbol{\eta_{a,AHU}}$	0,648

According to formula (17):

$\phi = \frac{91}{2} = 45{,}5$ kW

$q_v = \frac{45{,}5}{1 \cdot 4{,}2 \cdot (70-40)} = 0{,}36$ l/s

From the diagram in Appendix 1 it can be seen that the he most appropriate pipe diameter for the found flow is DN 40 /16/. The insulation thickness according to the Table 5 is 30 mm.

To calculate the overall heat transfer coefficient (16) the steel pipe data from Table 3 is used. The values for the insulation thermal conductivity and for the heat transfer coefficient are the same that were taken in the theoretical case - h_{out}=12 W/m^2·K and $k_{INSULATION}$=0,046 W/m·K. /6/:

$$U = \frac{1}{\frac{0{,}1083 \cdot \ln(\frac{0{,}1083}{0{,}0483})}{2 \cdot 0{,}046} + \frac{1}{12}} = 0{,}9673 \frac{\mathrm{W}}{\mathrm{m2}} \cdot \mathrm{K}$$

Heat loss per one meter of insulated pipe is defined with the formula (14). For example, for the outside temperature t_{out}= - 30 °C and for supply pipeline:

$$\frac{Q}{L} = 3{,}14 \cdot 0{,}1083 \cdot 0{,}97 \cdot (70 - 21) = 16{,}12\ \mathrm{W/m}$$

$$16{,}12 \cdot 0{,}001 \cdot 2 = 0{,}03\ \mathrm{kW \cdot h/m}$$

The total energy losses through the pipelines are the sum of the losses per each meter of both supply and return pipelines. The total losses should be multiplied by the total length of pipelines. All the calculations are shown below in the Table 10.

TABLE 10. Calculating the total amount of losses through pipelines.

SUPPLY				DN40		RETURN			DN40	
T_{out}	Δτ	T_{flow}	ΔT	Q/L	Q·h/L·a	T_{out}	T_{flow}	ΔT	Q/L	Q·h/L·a
°C	h	°C	°C	W/m	kW·h/m a	°C	°C	°C	W/m	kW·h/m a
-30	2	70,0	49,0	16,12	0,03	-30	40,0	19,0	6,25	0,01
-29	2	68,9	47,9	15,77	0,03	-29	39,6	18,6	6,11	0,01
-28	7	67,9	46,9	15,42	0,11	-28	39,2	18,2	5,97	0,04
-27	7	66,8	45,8	15,06	0,11	-27	38,7	17,7	5,83	0,04
-26	7	65,7	44,7	14,71	0,10	-26	38,3	17,3	5,69	0,04
-25	6	64,7	43,7	14,36	0,09	-25	37,9	16,9	5,55	0,03
-24	13	63,6	42,6	14,01	0,18	-24	37,5	16,5	5,42	0,07
-23	25	62,5	41,5	13,66	0,34	-23	37,0	16,0	5,28	0,13
-22	32	61,5	40,5	13,31	0,43	-22	36,6	15,6	5,14	0,16
-21	26	60,4	39,4	12,96	0,34	-21	36,2	15,2	5,00	0,13
-20	19	59,3	38,3	12,61	0,24	-20	35,8	14,8	4,86	0,09
-19	46	58,3	37,3	12,26	0,56	-19	35,4	14,4	4,72	0,22
-18	32	57,2	36,2	11,91	0,38	-18	34,9	13,9	4,58	0,15
-17	57	56,1	35,1	11,56	0,66	-17	34,5	13,5	4,44	0,25
-16	50	55,1	34,1	11,21	0,56	-16	34,1	13,1	4,31	0,22
-15	71	54,0	33,0	10,85	0,77	-15	33,7	12,7	4,17	0,30
-14	115	52,9	31,9	10,50	1,21	-14	33,2	12,2	4,03	0,46
-13	92	51,9	30,9	10,15	0,93	-13	32,8	11,8	3,89	0,36
-12	76	50,8	29,8	9,80	0,75	-12	32,4	11,4	3,75	0,29
-11	93	49,7	28,7	9,45	0,88	-11	32,0	11,0	3,61	0,34
-10	116	48,7	27,7	9,10	1,06	-10	31,6	10,6	3,47	0,40
-9	124	47,6	26,6	8,75	1,08	-9	31,1	10,1	3,33	0,41
-8	112	46,5	25,5	8,40	0,94	-8	30,7	9,7	3,19	0,36
-7	160	45,5	24,5	8,05	1,29	-7	30,3	9,3	3,06	0,49
-6	165	44,4	23,4	7,70	1,27	-6	29,9	8,9	2,92	0,48
-5	193	43,3	22,3	7,35	1,42	-5	29,4	8,4	2,78	0,54
-4	222	42,3	21,3	7,00	1,55	-4	29,0	8,0	2,64	0,58
-3	183	41,2	20,2	6,64	1,22	-3	28,6	7,6	2,50	0,46
-2	314	40,1	19,1	6,29	1,97	-2	28,2	7,2	2,36	0,74
-1	440	39,1	18,1	5,94	2,61	-1	27,8	6,8	2,22	0,98
0	578	38,0	17,0	5,59	3,23	0	27,3	6,3	2,08	1,20
1	434	36,9	15,9	5,24	2,28	1	26,9	5,9	1,94	0,84
2	362	35,9	14,9	4,89	1,77	2	26,5	5,5	1,81	0,65
3	324	34,8	13,8	4,54	1,47	3	26,1	5,1	1,67	0,54
4	283	33,7	12,7	4,19	1,19	4	25,6	4,6	1,53	0,43
5	219	32,7	11,7	3,84	0,84	5	25,2	4,2	1,39	0,30
6	184	31,6	10,6	3,49	0,64	6	24,8	3,8	1,25	0,23
7	185	30,5	9,5	3,14	0,58	7	24,4	3,4	1,11	0,21
8	238	29,5	8,5	2,78	0,66	8	24,0	3,0	0,97	0,23
9	241	28,4	7,4	2,43	0,59	9	23,5	2,5	0,83	0,20
10	227	27,3	6,3	2,08	0,47	10	23,1	2,1	0,69	0,16
11	268	26,3	5,3	1,73	0,46	11	22,7	1,7	0,56	0,15
					37,28					13,93

The total amount of losses:

$(37{,}28 + 13{,}93) \cdot 0{,}001 \cdot 70 = 3{,}58$ MW·h/a.

6 ANALYSIS OF THE RESULTS

In this chapter the relative amount of losses for both theoretical and practical cases will be calculated. The result will be shown as the total sum of the energy need and the losses and as the annual efficiency of the system. The difference between the results will be found and the conclusion will be made.

6.1 Calculating the theoretical case

The relative amount of heat losses into the building space during heat distribution was calculated as two ratios. The first was the ratio between heat losses and heat energy of heating coil:

$$Q_{distribution,out} = \frac{3{,}5}{137{,}35} \cdot 100\% = 2{,}5\ \%$$

The second ratio was between heat losses and the total energy need of AHU:

$$Q_{distribution,out} = \frac{3{,}5}{649{,}14} \cdot 100\% = 0{,}5\ \%$$

So the actual value of the total energy need of AHU is:

649,14+3,5=652,64 MW·h.

The annual efficiency of this systems equals 99,5 %.

6.2 The study case

The same ratios were found for the study case:

$$Q_{distribution,out} = \frac{3,59}{80,06} \cdot 100\% = 4,5\ \%$$

$$Q_{distribution,out} = \frac{3,59}{171,75} \cdot 100\% = 2,1\ \%$$

The total energy need of AHU with the losses is:

171,75+3,59=175,34 MW·h.

The annual efficiency of the system for the practical case is 97,9 %.

In both cases the total efficiency is very high but the practical case it is lower in comparison with the theoretical case. The reason for that is the big difference in the values of the air flow rates for both supply and exhaust air.

7 DISCUSSION

The aim of this bachelor was to define the necessity of calculating the heat losses through pipelines which deliver the heat from the heat source to the AHU heating coal. To achieve the aim two cases were analyzed.

The first one was the theoretical. The values for this case were taken mostly from NBC and the relation between supply and exhaust air flow rates R_{HR} was taken as 1. The second case was calculated for the existing AHU located in the D building of the MAMK campus area. Such information as volume flow and operation time of the AHU was taken from the measuring devices of the handling unit.

For both cases the total energy need of AHU and the heat delivery losses were found. The duration curve of outdoor air temperature was used to calculate case by case all the temperature differences when defining the total energy need of AHU. The total value was found as the sum of all cases. The temperature curve method was used for calculating the heat delivery losses. For both cases the same total length of pipes was taken.

After finding the total energy need and heat delivery losses the ratio between them was found. For the theoretical case the ratio between heat losses and heat energy of heating coil is 2,5 % and the ratio was between heat losses and the total energy need of AHU equals 0,5 %. For the practical case the same ratios respectively equal 4,5 % and 2,1 %. The main reason of such dissemblance in values can be caused by the big difference in both supply and exhaust air flow rates.

According to the results of both cases it can be concluded that the heat distribution losses from delivery pipelines of hot water heating system in energy calculations can be ignored in energy calculations. The influence of losses in the heat distribution and delivery systems for different heating solutions is several times bigger than the achieved result for the ventilation system.

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APPENDIX 1.

Diagram for determination of the pipe sizes