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DETERMINING THE MOST SUITABLE MATERIAL FOR WATER PIPES

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DESCRIPTION

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Determining the most suitable material for water pipes

Abstract

The main purpose of the thesis is to compare different materials for hot and cold water. And after that, to determine the most favourable material for a specific building.

The first part of the diploma is the theoretical background of the different types of pipes. After that I will discuss in detail the most commonly used pipe. These are tubes like copper pipes, multilayer pipes and PEX-pipe. Will identify positive and negative aspects of each type of pipe.

Next, according to the plan of a business centre will be made water project of the commonly used pipes. This allows us to compare the prices of water supply business centre with different materials and make further conclusions.

As the result we got, that design of water supply with multilayer pipes has the lowest price. The draft of copper pipes is the most expensive. A water supply project with PEX pipe was in the middle. If we compare the pipe in terms of price / performance ratio, it can be concluded that the multi-layer pipes are the best material for the business center.

Subject headings, (keywords)

Pipes, copper, multilayer, PEX pipes.

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Remarks, notes on appendices

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CONTENTS

1 INTRODUCTION

If we think about the need to build any building, we can identify several key stages. Some of them are determine the cost-effectiveness of such a construction of the building, choice of a suitable location for the construction of the building, planning of the construction site, structural design of the building, architectural design of the building component, building services systems.

In this diploma, I would like to concentrate on the building services, especially on the design of water supply and on the choice of the pipe materials. Water supply of the building can be made of different materials. For example, there are pipes, as PEX – pipes, copper pipes, steel pipes, multilayer pipes and PVC – pipes.

Each of these pipes has advantages and disadvantages. Not all pipes can be used in any situation. In each case, people choose a certain type of pipe. Due to the fact that progress moves forward, there are new materials. However, one of the key parameters in selecting pipes is purchasing costs. But not all the new materials have low cost. That's why we have such a large selection of pipes of different materials.

Pipe material for water supply is selected depending on the required strength of the material and the quality of water. Also important is the temperature of the water and its pressure and of course, the economic feasibility of the material is important. /1./

Of course the customer can choose the material to the water supply for the building. Every customer wants to save time and money on its project. But on the other hand, the performers want to get more money for their work. Accordingly, if the customer is poorly versed in this matter it is easy to persuade and invite him to version of the draft which will be more expensive, arguing that the high quality of services, materials, compared with what the customer has chosen.

I want to identify the most important aspects that should be paid attention to when choosing a water supply pipe. The most important of them, in my opinion, are the weight of the material, the ability to keep the water clean and safe for consumers, the cost of materials, ability to maintain the desired temperature and pressure.

As the research object, I chose a draft of business center. Water supply system with different materials will be designed for a business center. After that we will get the amount of pipes of a certain size, the length of pipes, the amount of additional devices. These data will allow us to define costs for materials.

Also, one of the points of the study will determine what kind of material is easiest to use in the design. After that the durability of the material will be examined. One goal is to identify the material that is the easiest to install and requires minimal amount of time.

2 AIMS AND METODS

In this thesis there is information about pipe materials for water systems. One of the aims is to determine which pipe materials can be used in water systems. After that exclude materials, which are not used nowadays, and explain why is it so.

So, further we have to find advantages and disadvantages of each pipe material. I want to inform readers about parts design of water supply works. We need to find answers for questions like which material easy to install, or what pipes can serve longer than others. It is also very important to know what material is harmless for human health. In this thesis will be explained, which tools we have to have to work with different materials. We need to compare complexity of designing and installing pipes of different materials. One of the important points when comparing the price of materials and installation cost of pipes of a particular material.

The main aim of this thesis is to determine the most suitable material for water pipes. Aim is to help people who want to provide the water supply. For those who are not familiar with the water supply of buildings is hard to understand what kind of material to choose. This thesis will help them to understand what the main criteria in choosing the material are. With this thesis people will understand to what points they should pay attention.

To achieve the objectives of this thesis will use methods, which are described below. There are two main parts of this diploma. They are literature review and analysis of the design of water supply for a business center.

First part of thesis is dedicated to the analysis of literature. Many of people think that the main point of water supply is a cost of the work. But this is misleading. It is only one reason to choose one or another material. Literature review will help to find all points on which customers should look, when choosing material.

We will go through guidelines of designing water systems. It will help to find restrictions on use of materials in some cases. It is very important to find all advantages and disadvantages of each pipe material to provide an objective assessment of the pipe material selection.

In the second part of this thesis we will go through design of water supply for a building. By means of this part the reader will be able to understand the main points of choosing the most suitable pipes material by looking at the example. Water supply will be designed for a business center. A business center draft which was designed before will be taken for this designing. During this part of diploma we can find answers for aims about the complexity of the implementation of the design work. Conclusions about costs with the use of one or another material will be drawn after the analysis of design work.

After that, I will be able to make a conclusion about choosing pipe materials. All information will be analyzed. Further will be formed a general conclusion. I hope that the results will assist the reader does not miss important things which need to be addressed.

3 THEORETICAL BACKGROUND

3.1 Different types of materials

There are many different types of materials for water systems all over the world as shown Figure 1. First we need to analyze all of them. Also it is necessary to determine which of them are often used nowadays.

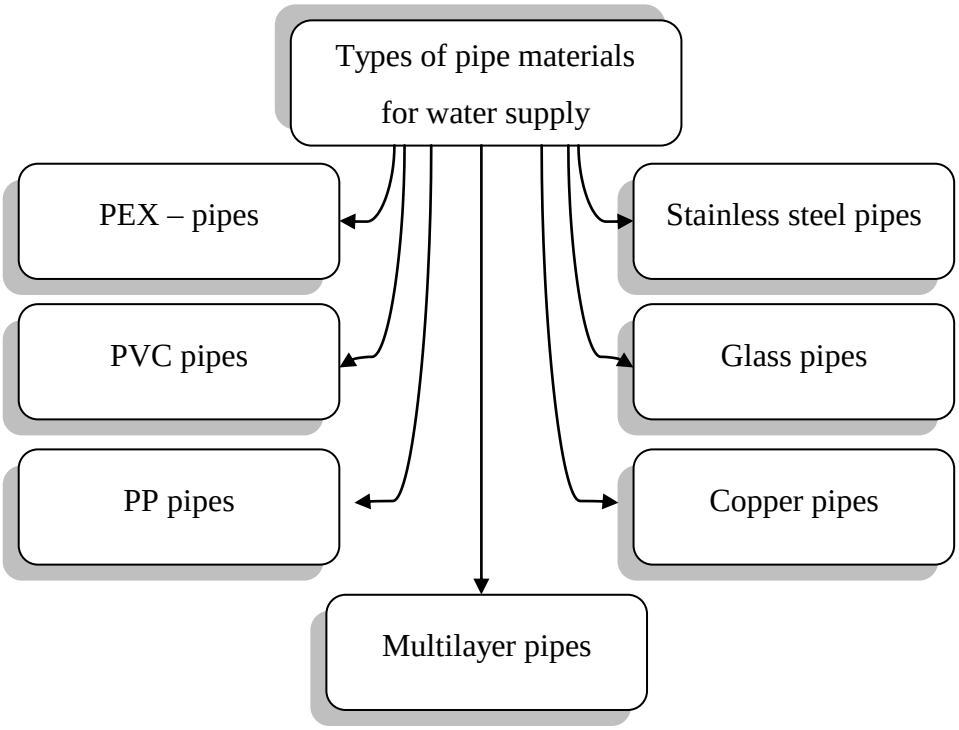

FIGURE 1. Types of pipe materials for water supply

3.1.1 Rarely used materials

Plumbers use different tubes in certain cases. Some materials are only used for hot water. Or vice versa some pipes are used only for cold water or gas. Other materials are obsolete. The use of certain materials for the production of pipes terminated because of technological backwardness.

3.1.1.1 Pipes from PVC

PVC is colorless and transparent plastic, thermoplastic polymer of vinyl chloride. PVC pipes has relatively low price. Mostly this material is applied for electrical insulation of wires and cables. But it can be also used as water supply pipe. PVC pipes glue for installation, making their installation is quite simple. One of the advantages is good ultraviolet radiation protection; this allows us to mount the pipes «open way». PVC pipe cannot corrode. PVC pipes are shown on the Figure 2.

FIGURE 2. PVC pipes /2/

This material does not burn. But PVC has very big disadvantage. PVC consists of chlorine, which one is very harmful for people. And also PVC pipes at 100 °C can begin to melt and allocate chlorine. That’s why it is impossible to use this material for domestic hot water systems. /3./

3.1.1.2 Glass pipes

Glass pipes are hollow transparent products for constructing pressure, non-pressure and vacuum pipelines for corrosive liquids and gases (except hydrofluoric acid), food products, water and other materials at temperatures from minus 50 °C to plus 120 °C. In accordance with GOST 8894-77 manufactures produce glass pipes with nominal sizes from 40 to 200 mm, an outer diameter of 45 to 221 mm and a length of 1500 to 3000 mm with intervals that are multiples of 250 mm. /4./ Glass pipes are shown on the Figure 3.

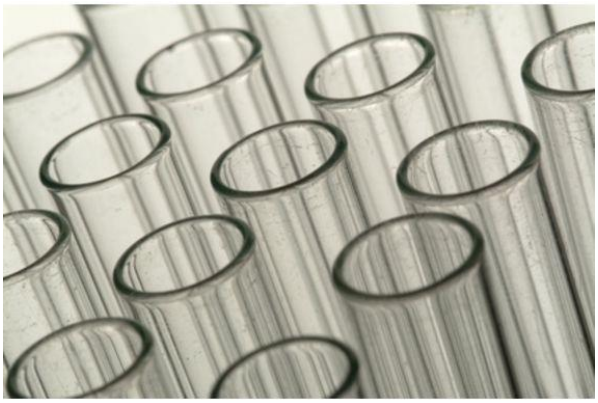

FIGURE 3. Glass pipes /5/

Glass pipes can be used in building without big heat losses and subject to vibration. So, in Russia and in Finland also, we have very big temperature range during the year, and quite big heat losses in winter. That’s why this kind of material is not good to use. Also pipes of this material are widely used in laboratories in order to see the change of water flow in different situations.

3.1.1.3 Stainless steel pipes

Stainless pipes are designed for outdoor installation for laying pipelines and internal plumbing. Stainless steel pipe is used in heating, hot and cold domestic water, because stainless steel does not have a negative impact on water quality. This type of material has a quite big cost. /6./

Steel pipes are covered with zinc, because they are highly susceptible to corrosion, especially under the influence of water. Zinc is more active metal that oxidizes rapidly, thus protecting steel pipes from corrosion.

Steel mark AISI 316 is an enhanced version of 304, with the addition of molybdenum and higher nickel content. This brand has become significantly improves corrosion resistance in most hostile environments. Molybdenum makes the steel more resistant to corrosion in chloride media, sea water and acetic acid vapors. Lower rate of general corrosion in mildly corrosive environments gives good corrosion resistance in polluted atmosphere and the marine atmosphere.

This brand of steel has higher strength and better creep resistance at higher temperatures. AISI 316 has excellent mechanical and corrosion properties at temperatures close to 0 °C.

FIGURE 4. Stainless steel pipes /6/

3.1.1.4 PP pipes

Polypropylene (PP) has corrosion resistance similar to PVC. Polypropylene pipes are able to keep their form in boiling water. PP pipes can tolerate temperatures of 95 °C and 110 °C for a short time. Also this material is able to retain strength at temperatures up to -50 °C, and the inner surface of the pipe does not appear any raids. Polypropylene is a material which can be recycled.

PP pipes are shown on the Figure 5.

FIGURE 5. PP pipes /7/

The melting point of polypropylene pipes is about 170 °C. Accordingly tubes of this material have a very small fire resistance. According to standard curve of the figure 7 it is enough 3 minutes to pipe of this material began to melt.

3.1.2 The most commonly used pipe materials in Russian Federation and in Finland

Some pipe materials are described above, but not all of them are now widely used. And probably their use is rapidly decreasing. Copper pipes, multilayer pipes and PEX – pipes are widely used today. Compared with stainless steel pipes, glass pipes and PVC pipes, they have much more advantages.

To achieve the research questions in the thesis, we need to compare the materials in many ways and select the most appropriate material for domestic water pipes. The selection criteria for the internal pipes of water supply are:

- ✓ inertness of flow medium, safety carried away by the flow erosion products for human health;
- ✓ resistance to atmospheric corrosion in wet conditions;
- ✓ abrasion resistance and minimal roughness of the inner surface;
- ✓ the ability to withstand excess of internal pressure of the transported medium without permanent deformation;

- ✓ the flexibility and elasticity, which reduces the complexity of installation and eliminate the use of compensating devices;
- ✓ low complexity of the assembly line;
- ✓ electrochemical compatibility with piping sections of other materials.

Also the most important key is the cost of the material and cost of the tools, which we need to install our water supply system.

3.1.2.1 PEX – pipes

PEX is cross – linked polyethylene. This type of pipes looks like the easiest tube material to work with. PEX – pipes can be delivered to the construction place in flexible canes with a length of 10 feet or in coils with different lengths. It is depending on the manufacturer. Manufacturers paint PEX – pipes in different colors. So you can use a pipe of a certain color for the cold – water and select a different color for the hot – water pipe. In order to avoid a large number of connecting nodes, use rolls. However, more often use sticks because they are easier to work with. Single stick is not as heavy as a full coil. /9, p.50./

FIGURE 6. PEX – pipes in coils with different colors

PEX – pipes are not protected from UV exposure. So you cannot install using the "open method". Pipes of this material should be hidden from the sunlight. Most often, the pipes of this material are laid into the space between the floor and the surface of the overlap. This leads to an increase in the time and cost of pipe – laying project.

Typically, PEX – pipes hidden in the casing. This allows you to change the pipe to the new very fast. It also does not require much effort.

There are many different manufacturers which produce PEX – pipes and fittings. Among all the positive qualities of these pipes is one important drawback. After choosing manufacturer of PEX – pipes we must work only with this manufacturer. We must have pipes of one producer on the same place. Also we need to buy tools and fittings from the same manufacturer. It because PEX – pipes, tools and fittings are not interchangeable with different manufacturer, unfortunately. /9, p.50./

The material melts at 400 °C. This means that in case of fire, the pipes will quickly melt and burn. If we consider the standard curve of increasing volume average temperature of the fire, plastic pipe will melt after five minutes of the fire. This curve is shown in figure 7.

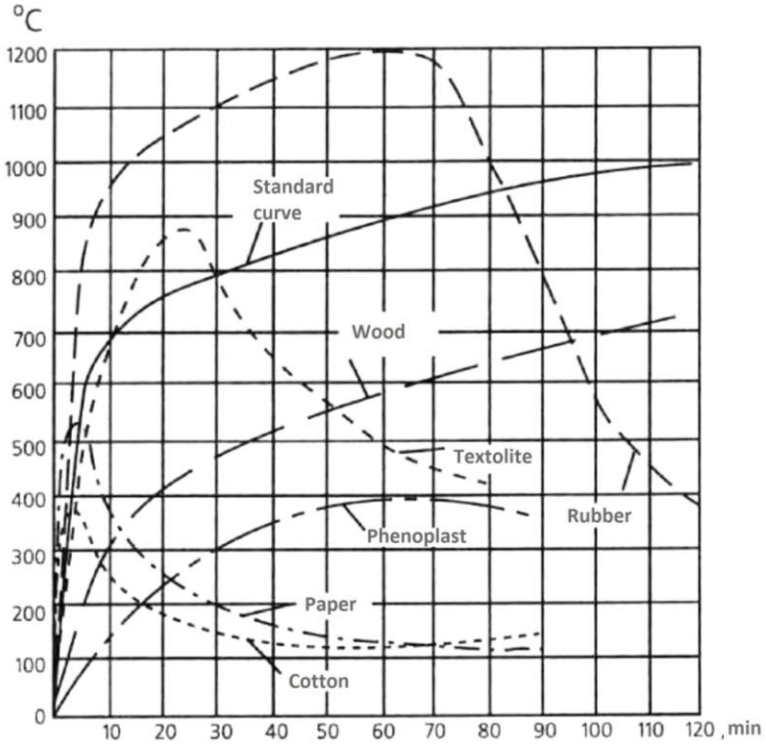

FIGURE 7. Volume average temperature curves of the change in the fire, depending on the fuel load /12/

3.1.2.2 Copper pipes

Copper pipes are divided into several types. The main indicator of the class it is a wall thickness of the pipe. So, the thickest type is the copper pipes with grade K. Pipes of this type have marks on the pipe with green color. Grade L is the copper pipe with medium thickness. This type has blue marks on the pipe. And the last one is grade M. This is the thinnest type of pipe. It is denote by red markings. /9, p.29./

There are two ways how copper pipes can be delivered on the construction site. One of them is in rolls. In this case copper pipes are called like soft copper. Another way of delivery is in sticks. Those pipes are called like hard copper or rigid copper. On the construction site soft copper is usually called tubing. But hard copper is usually referred to as pipe. Both of these types are quite good. But hard copper is better one, because soft copper is more expensive that rigid copper. And also it can kink when we unroll it. That's why hard copper is the most common. /9, p.29./

FIGURE 8. Copper pipes in sticks (left) and in roll (right) /8/

Copper pipes can be installed under a concrete slab. In this case the main idea is to reduce numbers of joints, because joints are the first reason for leak. And it will be difficult to find leakage and to eliminate it under a concrete slab. That's why it would be better to use soft copper, because soft copper can be unrolled and put on a long section without any connections. Also, if the pipes are laid in the concrete slab, they should be protected from exposure to corrosive substances such as lime.

The melting point of copper pipe about 1000 °C. According to standard curve in figure 7 pipes start to melt after two hours.

3.1.2.3 Multilayer pipes

Multilayer composite tubes consist of two polymer layers, one of them inside the pipe, the other outside. These layers are made of polyethylene with a high heat resistance. The two layers are separated by a central polymer layer made of aluminum. This gives greater strength pipe and provides an oxygen barrier. Aluminum layer on the outside and the inside is covered with adhesive layers.

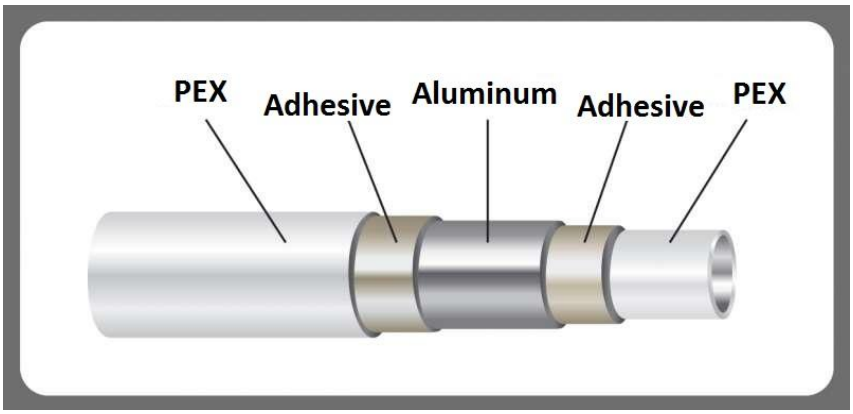

FIGURE 9. Principal scheme of the multilayer pipe

Multilayer pipe produced using TIG-welding (Tungsten Inert Gas). In TIG welding method uses inert argon gas. With it welded aluminum layer. Multilayer pipe can be used for hot and cold water and under floor heating.

Multilayer pipes can operate at temperatures ranging from 0 °C to 70 °C. Pipes can withstand a maximum pressure of 10 bars. For 100 hours for all the life cycle of the pipe it is capable of operating at a temperature of 95 °C /14./

Multilayer pipes have good UV protection. This allows you to install from the open way. As with PEX – pipe must adhere to the same manufacturer. You have to buy the pipe, fittings, and tools with a single manufacturer. This is a pretty big drawback.

As well as PEX tubing and copper pipes, multilayer pipes can be in rolls or individual pieces of straight pipes. This gives us a choice. For laying long lines would be better to use pipes in the coil to reduce the number of connecting nodes. Coil length may reach 500 meters /14./

4 COMPARISON OF THE MOST COMMONLY USED PIPE MATERIALS

4.1 Methods to join pipes and tools required for it

Different tools are needed to install the pipes. It depends on the pipe material. Just the tools depend on the installation and connection of pipes.

TABLE 1. Connection methods according to pipe material /13/

Pipe material	Connection methods
PEX – pipes	Crimp
Copper pipes	Solder
	Squeeze
	Crimp
	Flange
Multilayer pipes	Crimp

Plumbers need appropriate tools for connecting pipes to each other by crimping method. Uponor Company offers a range of tools, including a device for pressing (figure 10). The instrument can operate on battery power; it is very convenient in construction. However, you must take the time to charge the device. On the other hand you can buy an extra battery and then the work can be carried out continuously. The company also offers several jaws for different pipe sizes.

FIGURE 10. Uponor press toolkit battery with different jaws /14/

These instruments are used to crimping multilayer pipes. To connect PEX – pipes used by another device. This device extends one of the ends of the tube, and then the tube is put on the fitting. Due to the property PEX – pipes to maintain their original state, the tube again becomes the original, smaller diameter, and therefore clamps fitting. The expander can be manual or electric. Uponor Company offers a set that includes an expander and tool bits of different diameter, which are called expander heads.

FIGURE 11. Uponor expander toolkit manual (left) and electric (right) with different expander heads /14/

Other tool which we need to work with plastic pipe is cutter. For multilayer and PEX – pipes it is the same tool. Cutters are divided into the cutters of large diameter pipes and pipes of small diameter. For example, Uponor Company have pipe cutter up to 32, cutting tool 25-63, cutting tool 50-75.

FIGURE 12. Uponor cutters, cutter up to 32(left), from 25 to 63 (middle) and from 50 to 75 outer diameter (right) /14/

Soldering is the most commonly used for copper pipes is most commonly used. This requires only a paring tool to clean the pipe surface from dirt and also we need burner. The idea is to warm up a bit fitting, and then heat the tube to a temperature at which the pipe will be slightly melted. At this point, connect the elements. After that, the two elements are soldered to each other and become one. The obvious advantage of this method is that, for different diameter copper tubes used one burner. And no matter what a manufacturer we acquired pipes and fittings.

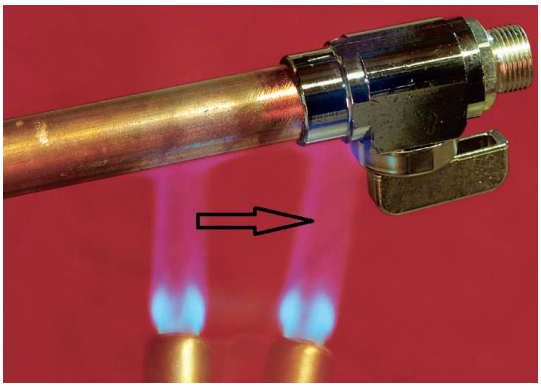

FIGURE 13. Soldering the copper pipe and fitting /9/

Solid blade cut-off is used to cut copper pipes. It is the most widely used tool for this purpose.

FIGURE 14. Solid blade cut – off /9/

4.2 Advantages and disadvantages of different materials

For comparison pipe materials is necessary to determine the positive and negative aspects of each type of pipe. Determine which of the deficiency is significant, and which may not be considered.

4.2.1 PEX – pipes

Below are the positive aspects of PEX – pipes, after that will be considered negative aspects. This will draw objective conclusions about PEX – pipes. In this section, will not be affected parameters such as price and features of the design. These points will be discussed later.

4.2.1.1 Advantages of the PEX – pipes

No need to run at an angle of 90 degrees. Pipe can be installed directly from point to point. Requires fewer fittings. Coil can be of varying lengths. This allows you to cover large areas without the use of connecting nodes. Requires no soldering pipes in pipe installations. This helps to avoid getting into the pipes to harmful substances such as lead or acid. PEX – pipes are not on some scale, as is often the case with copper pipes. PEX – pipes do not corrode. PEX – pipes are resistant to low temperatures. Chance of damage due to freezing is extremely small. PEX – pipe thermal conductivity is much lower than copper pipe. This reduces the loss of energy along the length of pipes. Transport of water through the PEX – pipes is quieter than through the metal pipes. Therefore the concept of «water hammer» can be excluded. The cost of PEX tubing is much lower than the cost of copper pipes. To install PEX – pipes need less time than for copper. Since there is no need to install fixtures at every turn, the pipes can be installed on the shortest distance. A smaller number of connecting nodes reduces the chances of the formation of leakage. Accordingly, it will save money in the future. PEX – pipes are flexible. Aggressive water does not have a bad influence on the pipe. However, the metal fittings can be damaged. Long coils can be laid in concrete floor from one end of the house to the other without the use of additional fittings to connect the pipes. /10./

There are many positive aspects of PEX – piping as we can see. But below are defects of pipes made of this material.

4.2.1.2 Disadvantages of the PEX – pipes

It is impossible to use PEX – pipes outside. PEX – pipes cannot be recycled. PEX – pipes exposure to ultraviolet radiation. Therefore, if the pipes are to be stored for a long time in the open sun, they will be unusable. Have a quite low melting temperature. May release hazardous emissions during combustion. /11./

4.2.2 Copper pipes

Below are the positive aspects of copper pipes, after that will be considered negative aspects. This will draw objective conclusions about copper pipes. In this section, will not be affected parameters such as price and features of the design. These points will be discussed later.

4.2.2.1 Advantages of the copper pipes

Copper pipes have a good resistance by ultraviolet radiation. That's why it is possible to install pipes in «open way». Also these pipes can be installed outside. It is difficult to damage copper pipes physically. Copper pipes do not corrode, unlike other metals. Pipes from this material have big melting point. It is triple bigger than melting point of PEX – pipes. Copper does not emit any hazardous substance into the water or air during use, also in case of fire. Copper pipes are not exposed to weather or bacteria. Soft copper can bend around obstacles (such as bolt, elevator shaft) if necessary. You do not need to cut the pipe and install additional fittings. Copper pipes can be recycled. We can use coils with big pipe length to put it under a concrete slab. In the event of an earthquake pipes may slightly change shape due to the fact that copper is a flexible material. Flexible and durable material makes it easy to change the shape of the pipe directly on the site.

4.2.2.2 Disadvantages of the copper pipes

Outer diameter can be changed when pipe is frozen. Copper as a metal quite expensive. Copper pipes are afraid aggressive water. Metal pipes have bigger weight than plastic pipes, that's why it is heavier to install it. Metals are good conductors of electricity. Therefore, the copper pipes must be grounded. Metals have a high thermal conductivity. Therefore, the copper pipes can lose a lot of heat through the walls if the pipe not insulated. Water can acquire a metallic taste in the use of pipes. /9./

4.2.3 Multilayer pipes

Below are the positive aspects of multilayer pipes, after that will be considered negative aspects. This will draw objective conclusions about multilayer pipes. In this section, will not be affected parameters such as price and features of the design. These points will be discussed later.

4.2.3.1 Advantages of the multilayer pipes

Multilayer pipes have a good resistance by ultraviolet radiation. That's why it is possible to install pipes in «open way». Pipes can be installed outside. With the addition of the aluminum layer, the strength of the pipe is much higher. However, the weight of the pipe is much less than the weight of the copper pipe. Multilayer pipe cannot corrode. Pipes are resistant to low temperatures. Chance of damage due to freezing is extremely small. The pipe has an aluminum layer, which prevents the ingress of oxygen into the pipe. Aggressive water does not have a bad influence on the pipe. However, the metal fittings can be damaged. Thermal conductivity of the multilayer pipe is much lower than copper pipe. This reduces the loss of energy along the length of pipes. The smooth inner surface of the pipe. We can use coils with big pipe length to put it from one point to another without cutting. Flexible and durable material makes it easy to change the shape of the pipe directly on the site. Multilayer pipes (PEX – Al – PEX) provide the necessary grip strength in the joints, even at very high temperatures.

Since the multilayer pipe consists of a cross – linked polyethylene and metal layer, the pipe has much less negative points. Disadvantages of these pipes are presented in the table below.

4.2.3.2 Disadvantages of the multilayer pipes

Multilayer pipes cannot be recycled. Have a quite low melting temperature. May release hazardous emissions during combustion.

5 CASE STUDY

The building has 5 floors, as well as the basement where the standpipes are connected to hot and cold water from centralized water supply. Floor height in the building is 3.9m. On each floor there are 3 toilets. There are two wash basins per each toilet. Floor includes 12 offices, each of which has a wash basin.

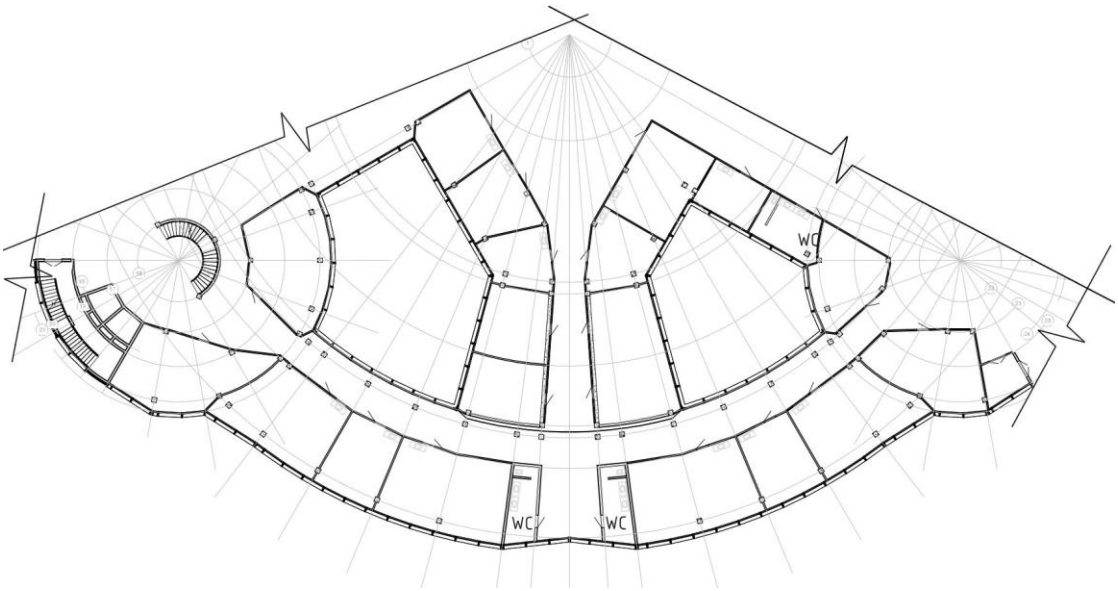

FIGURE 15. Typical floor of a business center

5.1 The object of investigation

A very important parameter when comparing tubes is their price. It would seem that you can compare the price of one meter of each type of pipe and to conclude what kind of material would be advantageous to use. However, to obtain accurate results, design the water supply of the three types of materials for a particular building.

When designing the water supply of different materials, we will get the pipes of different lengths and different diameters, as each material its settings when selecting pipes. The cost of toilets and wash basins are not included in the calculation. Tubes are fed to a wash basin and a toilet bowl to a height of 500 mm. Then they are connected through their own connection pipes and fittings.

There are restrictions on the speed of the water in the pipes. For connecting pipes water velocity should be less than 3 m/s. And for the distribution pipes adopted water velocity is less than 2 m/s. /13/.

5.2 Analysis of the water supply design of different pipe materials

5.2.1 Copper piping

When designing the water supply from copper pipes it is assumed that pipes are laid under the ceiling at a distance of 200 mm from the concrete floor, then fall down in a corner at a distance of 100 mm from the floor, and then routed to washbasin or toilet. Hot and cold water pipes run parallel to each other for the entire site.

The first step in the selection of pipes was to determine the standard flows of water to each faucet. According to National building code of Finland standard flow to wash basin and WC is 0,1 l/s for cold and warm water /13/. After that, the plan was drawn pipes on the floor. Than connection and distribution pipes were defined.

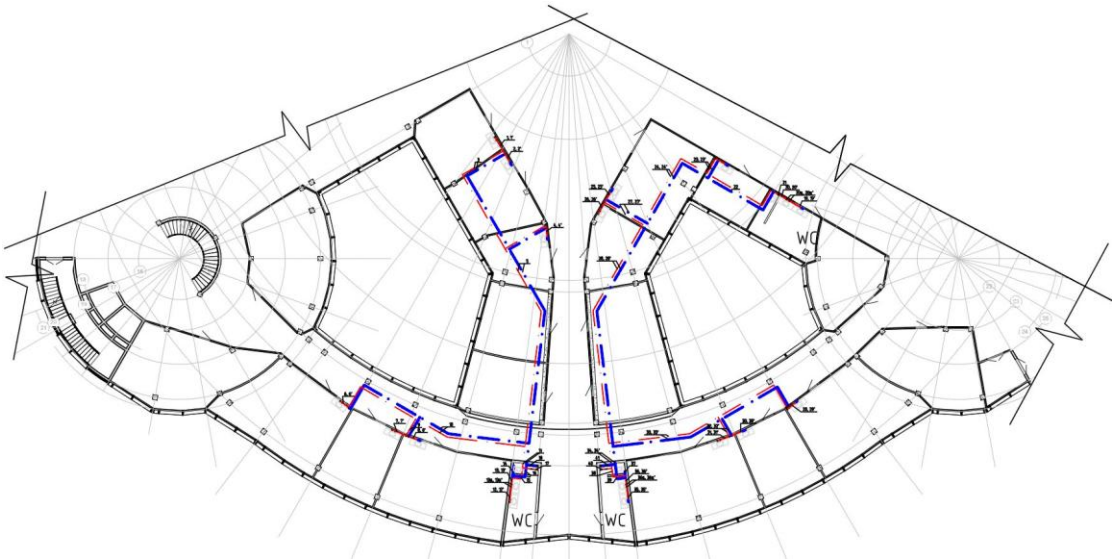

FIGURE 16. Design of water supply with copper pipes

After that, the total flow was calculated for each pipe. Using the nomogram for copper pipes, which based on the Colebrook formula, were chosen sizes of connecting copper pipes /13./ After that, the sum of flows was calculated for each distribution pipe. Refer

to the table (Table 2) was defined design flow /13/. Using the design flow have been defined dimensions of distribution pipes. In the selection of pipes used two terms – the maximum flow rate and the design flow. Two of these settings are superimposed on a nomogram for copper pipes and pipe sizes obtained.

In some cases, the diameter of pipes has been replaced by a bigger one. This was done because the connection pipes do not meet the requirements on the maximum length. In order to prevent the possibility of water hammer, the tubes are limited in length. If the tube which obtained is longer than indicated in the table, the larger diameter pipe should be selected. /13/. Thus all the pipes were selected for the floor.

TABLE 8. Total length of copper pipes for floor

Size, mm	Cost per m, €	Total needed length, m	Total cost, €
10×0,8	6,13	3,5	21
12×1,0	7,15	137	980
15×1,0	8,48	240	2035
18×1,0	10,78	1	11

Table 8 shows us different pipe sizes on the floor, total needed length and total cost for these pipes.

TABLE 9. Total length of vertical copper pipes between floors

Size, mm	Cost per m, €	Total needed length, m	Total cost, €
15×1,0	8,48	12	102
18×1,0	10,78	23	248
22×1,0	13,45	55	740

Table 9 shows us different pipe sizes between floors, total needed length and total cost for these pipes.

TABLE 10. Total length of copper pipes in the basement

Size, mm	Cost per m, €	Total needed length, m	Total cost, €
22×1,0	13,45	11,00	148
28×1,2	17,43	5,00	87

Table 10 shows us different pipe sizes which are in the basement, total needed length and total cost for these pipes.

The total number of fittings was also calculated. The number of fasteners was determined. To count the number of fasteners used condition. If the diameter is less than 15, you must install the clips every 0.6 m. And with a diameter less than 28, the tube is attached to the ceiling with a clamp at a distance 1.25 m. For larger diameters, the distance increases to 2.5 m.

After all the calculations of pipes, the results of the calculations are summarized in the table below. Since the pipes must be cleaned, melting, it will reduce the overall length of the pipe. Therefore, when calculating the cost of pipes, was taken in a 10% margin.

TABLE 11. Total cost of copper pipes for a building

Size, mm	Total needed length, m	Total cost, €	Final cost (+10%), €
10×0,8	17,5	107	117,7
12×1,0	685	4898	5387,8
15×1,0	1212	10278	11305,8
18×1,0	28	302	332,2
22×1,0	66	888	4231,7
28×1,2	5	87	95,7
		Total	21471

Even count the cost of the work has been included for installation of pipes made of this material. Prices of labor gave the Russian company "Granit" /15/. According to the rates of the construction company the cost of installing a meter of copper pipe is about 4.2 euro in December 2012.

TABLE 12. Total cost of copper pipes, labor, fittings and clamps

Name	Final cost, €
Pipes	21471
Elbow	134
T-branch	119
Clamps	675
Labor	8457
Total	30840

5.2.2 Multilayer piping

When designing the water supply from multilayer pipes assumed that pipes are laid under the ceiling at a distance of 200 mm from the concrete floor, then fall down in a corner at a distance of 100 mm from the floor, and then routed to washbasin or toilet. Hot and cold water pipes run parallel to each other for the entire site.

Since the design uses the same building, all the design flows are the same as in the design using copper pipes. The principle of selection of multilayer pipes is no different from copper, other than for use nomogram. Therefore, the total length of the pipes is given the same when using these two materials. But pipe diameters will vary.

With the same design flow, we need less different tube diameters than if designing with copper pipes. According to the table 13 we need only 2 different pipe sizes to floor.

TABLE 13. Total length of MLP pipes for floor

Size, mm	Cost per m, €	Total needed length, m	Total cost, €
16×2,0	1,82	341	621
20×2,25	2,81	32	90

Also need 2 different pipe diameters to vertical pipes.

TABLE 14. Total length of vertical MLP pipes between floors

Size, mm	Cost per m, €	Total needed length, m	Total cost, €
20×2,25	2,81	27	76
25×2,5	4,88	63	307

After all the calculations of pipes, the results were summarized in the table below. When calculating the cost of pipes, was taken in a 10% margin.

TABLE 15. Total cost of MLP pipes for a building

Size, mm	Total needed length, m	Total cost, €	Final cost (+10%), €
16×2,0	1705	3103	3413,3
20×2,25	187	526	578,6
25×2,5	74	361	397,1
32×3,0	5	37	40,7
		Total	4430

Last two diameters, which are shown in the table, are required for laying distribution pipes in the basement.

Even count the cost of the work has been included for installation of pipes made of this material. Prices of labor gave the Russian company "Granit" /15/. According to the rates of the construction company the cost of installing a meter of multilayer pipe is about 3.88 euro.

TABLE 16. Total cost of MLP pipes, labor, fittings and clamps

Name	Final cost, €
Pipes	4430
Elbow	2452
T-branch	1839
Clamps	248
Labor	7638
Total	16610

5.2.3 PEX – piping

When designing the water supply of PEX – pipe is assumed that the pipes are laid under the floor. Then pipes routed to the wash basin or toilet in tap box elbow, which is built into the wall. These connecting pipes are connected to the manifold. Then the manifold is connected to a vertical tube with the multilayer pipe. The vertical pipes and pipes in the basement also made of multilayer tubes.

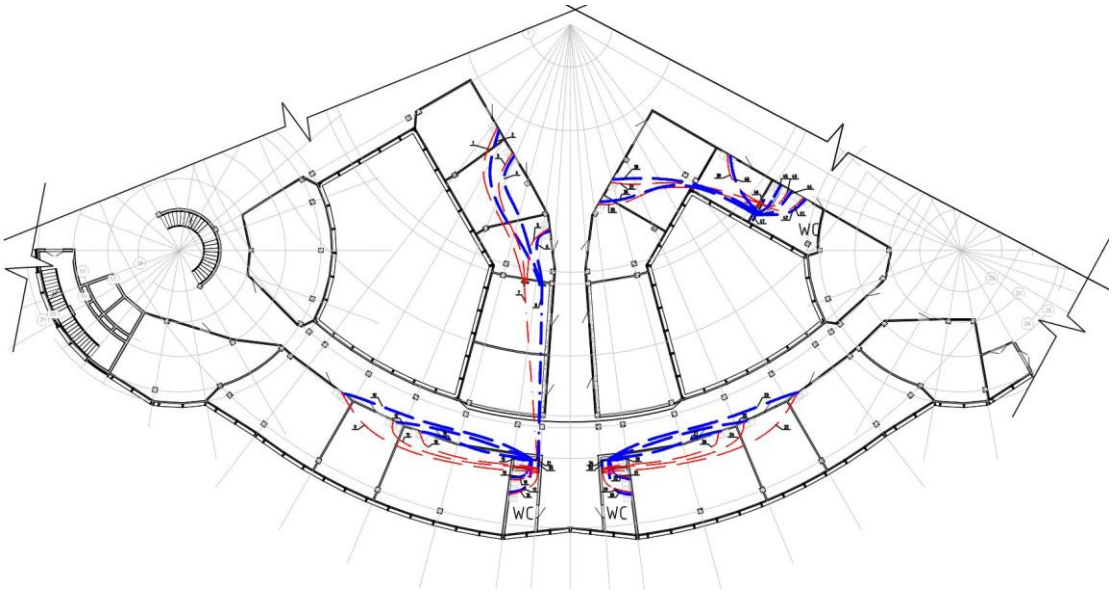

FIGURE 17. Design of water supply with PEX pipes

When using PEX – pipe, manifold and faucet are connected by the shortest distance with smooth curves.

TABLE 17. Total length of PEX – pipes and MLP for floor

Type of the pipe	Size, mm	Cost per m, €	Total needed length, m	Total cost, €
PEX	15×2,5	2,04	334,00	681
MLP	16×2,0	1,82	43,00	78
MLP	20×2,25	2,81	2,00	6
Casing pipe	25/20	0,94	334,00	314

Another difference from previous plans is that for a design with PEX – pipes customer must also purchase casing pipe.

TABLE 18. Total length of vertical MLP between floors

Type of the pipe	Size, mm	Cost per m, €	Total needed length, m	Total cost, €
MLP	20×2,25	2,81	70,00	197
MLP	25×2,5	4,88	44,00	215

Total cost of pipes is shown in the table below.

TABLE 19. Total cost of PEX – pipes for a building

Type	Size, mm	Total needed length, m	Total cost, €	Final cost (+10%), €
PEX	15×2,5	1670	3406,8	3747,48
MLP	16×2,0	215	391,3	430,43
MLP	20×2,25	80	224,8	247,28
MLP	25×2,5	126	615,00	676,5
MLP	32×3,0	5	37,00	40,7
Casing pipe	25/20	1670	1570	1727
			Total	6869

According to the number of faucets on the floor, we need to buy 39 tap box elbows to the floor, and 14 manifolds.

Even count the cost of the work has been included for installation of pipes made of this material. Prices of labor gave the Russian company "Granit" /15/. According to the rates of the construction company the cost of installing a meter of PEX – pipe is about 4.375 euro.

TABLE 20. Total cost of copper pipes, labor, fittings and clamps

Name	Final cost, €
Pipes	6869
Manyfold	3345
TBE	3687
Elbow	377,70
T-branch	381,67
Clamps	196,00
Labor	8957
Total	23810

In the table above we can see total cost of the water supply for whole building with PEX – pipes.

6 CONCLUSION

Analyzing the results obtained it can be concluded that the most cost-effective option is multilayer pipes. In second place are the PEX – pipes together with MLP. A copper pipe closes the top three most-used tubes. The study found that at Russian prices, more profitable to design water supply to a business center with using multi-layer pipes.

Also in the thesis examined other aspects of the selection of pipes. PEX – pipes are comparatively lighter than copper and multilayer pipes. This makes it easier to work with. The same ease of installation PEX – pipes that need not be fixed to the ceiling. PEX – pipes are laid under the floor. Old PEX – pipes are easily exchanged for new ones, if necessary, because PEX – pipes stacked in casing pipes.

In the modern world are increasingly looking to re-use materials. Among the three types of tubes only copper can be recycled. In operation, there were no certain design features of various types of pipes. Basically, all based on the same principle. However, the design of water using PEX – pipe takes less time because we have a smaller number of distribution pipes. This allows us to not spend time deciding the design flow of the distribution pipes.

Comparing all positive and negative features of all three types of pipes, it can be concluded that multilayer pipe is the best choice for supply of a particular building. Long service life of water pipes can omit such defects as the inability to re-use.

All three materials have many advantages, but the pricing is very often the deciding factor.

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APPENDIX 1.

Tables for designs of different pipe materials

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
1	Copper	C		0,1		≤3	10×0,8	1,80	**12×1,0**
1’		H				≤3	10×0,8	1,80	**12×1,0**
2		C				≤3	10×0,8	1,60	**12×1,0**
2’		H				≤3	10×0,8	1,60	**12×1,0**
3		C	0,2		0,16	≤2	**12×1,0**	14,60	
3’		H	0,2		0,16	≤2	**12×1,0**	14,60	
4		C				≤3	10×0,8	8,50	**15×1,0**
4’		H				≤3	10×0,8	8,50	**15×1,0**
5		C	0,3		0,18	≤2	**15×1,0**	17,30	
5’		H	0,3		0,18	≤2	**15×1,0**	17,70	
6		C				≤3	10×0,8	12,20	**15×1,0**
6’		H				≤3	10×0,8	12,20	**15×1,0**
7		C				≤3	10×0,8	1,80	**12×1,0**
7’		H				≤3	10×0,8	1,80	**12×1,0**
8		C				≤3	10×0,8	1,60	**12×1,0**
8’		H				≤3	10×0,8	1,50	**12×1,0**
9		C	0,2		0,16	≤2	**12×1,0**	5,30	
9’		H	0,2		0,16	≤2	**12×1,0**	5,00	
10		C	0,3		0,18	≤2	**15×1,0**	9,80	
10’		H	0,3		0,18	≤2	**15×1,0**	9,80	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
11		C	0,6		0,23	≤2	**15×1,0**	1,80	
11’		H	0,6		0,23	≤2	**15×1,0**	1,80	
12		C				≤3	10×0,8	1,80	**12×1,0**
12’		H				≤3	10×0,8	1,80	**12×1,0**
13		C	0,2		0,16	≤2	**12×1,0**	0,80	
13’		H	0,2		0,16	≤2	**12×1,0**	0,80	
13a		C				≤3	**10×0,8**	0,50	
13a’		H				≤3	**10×0,8**	0,50	
14	Copper	C		0,1		≤3	10×0,8	1,40	**12×1,0**
15		H	0,2		0,16	≤2	**12×1,0**	5,10	
16		C	0,3		0,18	≤2	**15×1,0**	5,50	
17		H	0,8		0,25	≤2	**15×1,0**	1,30	
18		C	0,9		0,26	≤2	**15×1,0**	1,00	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
19		C				≤3	10×0,8	1,90	**12×1,0**
19’		H				≤3	10×0,8	1,90	**12×1,0**
20a		C				≤3	**10×0,8**	0,50	
20a’	Copper	H		0,1		≤3	**10×0,8**	0,50	
20		C	0,2		0,16	≤2	**12×1,0**	1,00	
20’		H	0,2		0,16	≤2	**12×1,0**	11,90	
21		C				≤3	**10×0,8**	0,50	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
22		C	0,3		0,18	≤2	**15×1,0**	11,10	
23		C				≤3	10×0,8	6,70	**15×1,0**
23’		H				≤3	10×0,8	6,60	**15×1,0**
24		C	0,4		0,20	≤2	**15×1,0**	8,60	
24’		H	0,3		0,18	≤2	**15×1,0**	9,10	
25		C				≤3	10×0,8	1,60	**12×1,0**
25’		H				≤3	10×0,8	1,60	**12×1,0**
26		C				≤3	10×0,8	1,60	**12×1,0**
26’		H				≤3	10×0,8	1,60	**12×1,0**
27		C	0,2		0,16	≤2	**12×1,0**	7,50	
27’		H	0,2		0,16	≤2	**12×1,0**	7,20	
28		C	0,6		0,23	≤2	**15×1,0**	20,30	
28’		H	0,5		0,21	≤2	**15×1,0**	19,90	
29		C				≤3	10×0,8	12,20	**15×1,0**
29’		H				≤3	10×0,8	12,20	**15×1,0**
30		C				≤3	10×0,8	1,80	**12×1,0**
30’		H				≤3	10×0,8	1,80	**12×1,0**
31	Copper	C		0,1		≤3	10×0,8	1,60	**12×1,0**
31’		H				≤3	10×0,8	1,50	**12×1,0**
32		C	0,2		0,16	≤2	**12×1,0**	5,30	
32’		H	0,2		0,16	≤2	**12×1,0**	5,00	
33		C	0,3		0,18	≤2	**15×1,0**	9,80	
33’		H	0,3		0,18	≤2	**15×1,0**	9,80	
34		C	0,9		0,26	≤2	**15×1,0**	1,80	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
34’		H	0,8		0,25	≤2	**15×1,0**	1,80	
35		C				≤3	10×0,8	1,80	**12×1,0**
35’		H				≤3	10×0,8	1,80	**12×1,0**
36		C	0,2		0,16	≤2	**12×1,0**	0,80	
36’		H	0,2		0,16	≤2	**12×1,0**	0,80	
36a		C				≤3	**10×0,8**	0,50	
36a’		H				≤3	**10×0,8**	0,50	
37		C				≤3	10×0,8	1,10	**12×1,0**
38		H	0,2		0,16	≤2	**12×1,0**	1,80	
39		C	0,3		0,18	≤2	**15×1,0**	2,00	
40		H	1,0		0,27	≤2	**15×1,0**	1,00	
41		C	1,2		0,29	≤2	**18×1,0**	1,30	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
1	MLP	C		0,1		≤3	**16×2,0**	1,80
1’		H				≤3	**16×2,0**	1,80
2		C				≤3	**16×2,0**	1,60
2’		H				≤3	**16×2,0**	1,60
3		C	0,2		0,16	≤2	**16×2,0**	14,60
3’		H	0,2		0,16	≤2	**16×2,0**	14,60
4		C				≤3	**16×2,0**	8,50
4’		H				≤3	**16×2,0**	8,50
5		C	0,3		0,18	≤2	**16×2,0**	17,30
5’		H	0,3		0,18	≤2	**16×2,0**	17,70
6		C				≤3	**16×2,0**	12,20
6’		H				≤3	**16×2,0**	12,20
7		C				≤3	**16×2,0**	1,80
7’		H				≤3	**16×2,0**	1,80
8		C				≤3	**16×2,0**	1,60
8’		H				≤3	**16×2,0**	1,50
9		C	0,2		0,16	≤2	**16×2,0**	5,30
9’		H	0,2		0,16	≤2	**16×2,0**	5,00
10		C	0,3		0,18	≤2	**16×2,0**	9,80
10’		H	0,3		0,18	≤2	**16×2,0**	9,80
11		C	0,6		0,23	≤2	**20×2,0**	1,80
11’		H	0,6		0,23	≤2	**20×2,0**	1,80
12		C				≤3	**16×2,0**	1,80

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
12’		H				≤3	**16×2,0**	1,80
13		C	0,2		0,16	≤2	**16×2,0**	0,80
13’		H	0,2		0,16	≤2	**16×2,0**	0,80
13a		C				≤3	**16×2,0**	0,50
13a’		H				≤3	**16×2,0**	0,50
14	MLP	C		0,1		≤3	**16×2,0**	1,40
15		H	0,2		0,16	≤2	**16×2,0**	5,10
16		C	0,3		0,18	≤2	**16×2,0**	5,50
17		H	0,8		0,25	≤2	**20×2,0**	1,30
18		C	0,9		0,26	≤2	**20×2,0**	1,00

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
19		C				≤3	**16×2,0**	1,90
19’		H				≤3	**16×2,0**	1,90
20a		C				≤3	**16×2,0**	0,50
20a’		H				≤3	**16×2,0**	0,50
20		C	0,2		0,16	≤2	**16×2,0**	1,00
20’	MLP	H	0,2	0,1	0,16	≤2	**16×2,0**	11,90
21		C				≤3	**16×2,0**	0,50
22		C	0,3		0,18	≤2	**16×2,0**	11,10
23		C				≤3	**16×2,0**	6,70
23’		H				≤3	**16×2,0**	6,60

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
24		C	0,4		0,20	≤2	**16×2,0**	8,60
24’		H	0,3		0,18	≤2	**16×2,0**	9,10
25		C				≤3	**16×2,0**	1,60
25’		H				≤3	**16×2,0**	1,60
26		C				≤3	**16×2,0**	1,60
26’		H				≤3	**16×2,0**	1,60
27		C	0,2		0,16	≤2	**16×2,0**	7,50
27’		H	0,2		0,16	≤2	**16×2,0**	7,20
28		C	0,6		0,23	≤2	**20×2,0**	20,30
28’		H	0,5		0,21	≤2	**16×2,0**	19,90
29		C				≤3	**16×2,0**	12,20
29’		H				≤3	**16×2,0**	12,20
30		C				≤3	**16×2,0**	1,80
30’		H				≤3	**16×2,0**	1,80
31	MLP	C		0,1		≤3	**16×2,0**	1,60
31’		H				≤3	**16×2,0**	1,50
32		C	0,2		0,16	≤2	**16×2,0**	5,30
32’		H	0,2		0,16	≤2	**16×2,0**	5,00
33		C	0,3		0,18	≤2	**16×2,0**	9,80
33’		H	0,3		0,18	≤2	**16×2,0**	9,80
34		C	0,9		0,26	≤2	**20×2,0**	1,80
34’		H	0,8		0,25	≤2	**20×2,0**	1,80
35		C				≤3	**16×2,0**	1,80
35’		H				≤3	**16×2,0**	1,80

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
36		C	0,2		0,16	≤2	**16×2,0**	0,80
36’		H	0,2		0,16	≤2	**16×2,0**	0,80
36a		C				≤3	**16×2,0**	0,50
36a’		H				≤3	**16×2,0**	0,50
37		C				≤3	**16×2,0**	1,10
38		H	0,2		0,16	≤2	**16×2,0**	1,80
39		C	0,3		0,18	≤2	**16×2,0**	2,00
40		H	1,0		0,27	≤2	**20×2,0**	1,00
41		C	1,2		0,29	≤2	**20×2,0**	1,30

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
1	PEX	H		0,1		≤3	**15×2,5**	14,40	
2		C				≤3	**15×2,5**	14,60	
3		H				≤3	**15×2,5**	12,00	
4		C				≤3	**15×2,5**	12,10	
5		H				≤3	**15×2,5**	5,80	
6		C				≤3	**15×2,5**	5,60	
7	MLP	H	0,3		0,18	≤2	**16×2,0**	21,75	
8		C	0,3		0,18	≤2	**16×2,0**	21,55	
9	PEX	H				≤3	15×2,5	19,30	**18×2,5**
10		C				≤3	15×2,5	17,40	**18×2,5**
11		H				≤3	**15×2,5**	14,40	
12		C				≤3	**15×2,5**	12,30	
13		H				≤3	**15×2,5**	11,60	
14		C				≤3	**15×2,5**	9,90	
15		C				≤3	**15×2,5**	1,70	
16		H				≤3	**15×2,5**	3,80	
17		C				≤3	**15×2,5**	4,30	
18		H				≤3	**15×2,5**	2,90	
19		C				≤3	**15×2,5**	3,00	
20	MLP	H	0,5		0,21	≤2	**20×2,25**	0,30	
21		C	0,6		0,23	≤2	**20×2,25**	0,30	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
22	PEX	H		0,1		≤3	15×2,5	19,10	**18×2,5**
23		C				≤3	15×2,5	17,60	**18×2,5**
24		H				≤3	**15×2,5**	13,90	
25		C				≤3	**15×2,5**	12,50	
26		H				≤3	**15×2,5**	11,40	
27		C				≤3	**15×2,5**	10,10	
28		C				≤3	**15×2,5**	1,70	
29		H				≤3	**15×2,5**	3,60	
30		C				≤3	**15×2,5**	4,50	
31		H				≤3	**15×2,5**	2,70	
32		C				≤3	**15×2,5**	3,00	
33	MLP	H	0,5		0,21	≤2	**20×2,25**	0,20	
34		C	0,6		0,23	≤2	**20×2,25**	0,30	
35	PEX	H				≤3	**15×2,5**	14,60	
36		C				≤3	**15×2,5**	14,40	
37		H				≤3	**15×2,5**	13,50	
38		C				≤3	**15×2,5**	13,20	
39		H				≤3	**15×2,5**	5,90	
40		C				≤3	**15×2,5**	5,80	
41		H				≤3	**15×2,5**	4,40	
42		C				≤3	**15×2,5**	5,00	
43		H				≤3	**15×2,5**	3,40	
44		C				≤3	**15×2,5**	4,20	

Serial number of pipe	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m	Adjusted pipe size
			Q, l/s	q_N, l/s	q, l/s				
45		C				≤3	**15×2,5**	3,50	
46	MLP	H	0,5		0,21	≤2	**20×2,25**	0,25	
47		C	0,6		0,23	≤2	**20×2,25**	0,25	

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
Between 5 and 4 floor	Copper	C	0,9	0,1	0,26	≤2	15×1,0	3,90
Between 5 and 4 floor		H	0,8		0,25	≤2	15×1,0	3,90
Between 4 and 3 floor		C	1,8		0,35	≤2	18×1,0	3,90
Between 4 and 3 floor		H	1,6		0,33	≤2	18×1,0	3,90
Between 3 and 2 floor		C	2,7		0,41	≤2	22×1,0	3,90
Between 3 and 2 floor		H	2,4		0,39	≤2	18×1,0	3,90
Between 2 and 1 floor		C	3,6		0,47	≤2	22×1,0	3,90
Between 2 and 1 floor		H	3,2		0,45	≤2	22×1,0	3,90
Between 1 and basement		C	4,5		0,52	≤2	22×1,0	6,90
Between 1 and basement		H	4		0,49	≤2	22×1,0	6,90

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
Between 5 and 4 floor	Copper	C	1,2	0,1	0,29	≤2	18×1,0	3,90
Between 5 and 4 floor		H	1		0,27	≤2	15×1,0	3,90
Between 4 and 3 floor		C	2,4		0,39	≤2	18×1,0	3,90
Between 4 and 3 floor		H	2		0,36	≤2	18×1,0	3,90
Between 3 and 2 floor		C	3,6		0,47	≤2	22×1,0	3,90
Between 3 and 2 floor		H	3		0,43	≤2	22×1,0	3,90
Between 2 and 1 floor		C	4,8		0,54	≤2	22×1,0	3,90
Between 2 and 1 floor		H	4		0,49	≤2	22×1,0	3,90
Between 1 and basement		C	6		0,6	≤2	22×1,0	6,90
Between 1 and basement		H	5		0,55	≤2	22×1,0	6,90

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
Between 5 and 4 floor	MLP	C	0,9	0,1	0,26	≤2	20×2,0	3,90
Between 5 and 4 floor		H	0,8		0,25	≤2	20×2,0	3,90
Between 4 and 3 floor		C	1,8		0,35	≤2	20×2,0	3,90
Between 4 and 3 floor		H	1,6		0,33	≤2	20×2,0	3,90
Between 3 and 2 floor		C	2,7		0,41	≤2	25×2,5	3,90
Between 3 and 2 floor		H	2,4		0,39	≤2	25×2,5	3,90
Between 2 and 1 floor		C	3,6		0,47	≤2	25×2,5	3,90
Between 2 and 1 floor		H	3,2		0,45	≤2	25×2,5	3,90
Between 1 and basement		C	4,5		0,52	≤2	25×2,5	6,90
Between 1 and basement		H	4		0,49	≤2	25×2,5	6,90

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, mm
			Q, l/s	q_N, l/s	q, l/s			
Between 5 and 4 floor	MLP	C	1,2	0,1	0,29	≤2	20×2,0	3,90
Between 5 and 4 floor		H	1		0,27	≤2	20×2,0	3,90
Between 4 and 3 floor		C	2,4		0,39	≤2	25×2,5	3,90
Between 4 and 3 floor		H	2		0,36	≤2	20×2,0	3,90
Between 3 and 2 floor		C	3,6		0,47	≤2	25×2,5	3,90
Between 3 and 2 floor		H	3		0,43	≤2	25×2,5	3,90
Between 2 and 1 floor		C	4,8		0,54	≤2	25×2,5	3,90
Between 2 and 1 floor		H	4		0,49	≤2	25×2,5	3,90
Between 1 and basement		C	6		0,6	≤2	25×2,5	6,90
Between 1 and basement		H	5		0,55	≤2	25×2,5	6,90

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, mm
			Q, l/s	q_N, l/s	q, l/s			
Between 5 and 4 floor	MLP	C	0,9	0,1	0,26	≤2	20×2,0	3,90
Between 5 and 4 floor		H	0,8		0,25	≤2	20×2,0	3,90
Between 4 and 3 floor		C	1,8		0,35	≤2	20×2,0	3,90
Between 4 and 3 floor		H	1,6		0,33	≤2	20×2,0	3,90
Between 3 and 2 floor		C	2,7		0,41	≤2	25×2,5	3,90
Between 3 and 2 floor		H	2,4		0,39	≤2	25×2,5	3,90
Between 2 and 1 floor		C	3,6		0,47	≤2	25×2,5	3,90
Between 2 and 1 floor		H	3,2		0,45	≤2	25×2,5	3,90
Between 1 and basement		C	4,5		0,52	≤2	25×2,5	3,50
Between 1 and basement		H	4		0,49	≤2	25×2,5	3,50

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, mm
			Q, l/s	q_N, l/s	q, l/s			
Between 5 and 4 floor	MLP	C	0,6	0,1	0,23	≤2	20×2,0	7,80
Between 5 and 4 floor		H	0,5		0,21	≤2	20×2,0	7,80
Between 4 and 3 floor		C	1,2		0,29	≤2	20×2,0	7,80
Between 4 and 3 floor		H	1		0,27	≤2	20×2,0	7,80
Between 3 and 2 floor		C	1,8		0,35	≤2	20×2,0	7,80
Between 3 and 2 floor		H	1,5		0,32	≤2	20×2,0	7,80
Between 2 and 1 floor		C	2,4		0,39	≤2	25×2,5	7,80
Between 2 and 1 floor		H	2		0,36	≤2	20×2,0	7,80
Between 1 and basement		C	3		0,43	≤2	25×2,5	7,00
Between 1 and basement		H	2,5		0,4	≤2	25×2,5	7,00

Pipe name	Pipe	CW/HW	Flow			Velocity,	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
B CW 1	Copper	C	4,5	0,1	0,53	≤2	22×1,0	2,85
B CW 2		C	6		0,6	≤2	22×1,0	2,45
B CW TOTAL		C	10,5		0,8	≤2	28×1,2	2,70
B HW 1		H	4		0,49	≤2	22×1,0	2,45
B HW 2		H	5		0,55	≤2	22×1,0	2,85
B HW TOTAL		H	9		0,74	≤2	28×1,2	2,40

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
B CW 1	MLP	C	4,5	0,1	0,53	≤2	25×2,5	2,85
B CW 2		C	6		0,6	≤2	25×2,5	2,45
B CW TOTAL		C	10,5		0,8	≤2	32×3,0	2,70
B HW 1		H	4		0,49	≤2	25×2,5	2,45
B HW 2		H	5		0,55	≤2	25×2,5	2,85
B HW TOTAL		H	9		0,74	≤2	32×3,0	2,40

Pipe name	Pipe material	CW/HW	Flow			Velocity, m/s	Size, mm	Pipe length, m
			Q, l/s	q_N, l/s	q, l/s			
B CW 1	MLP	C	3	0,1	0,43	≤2	25×2,5	34,55
B CW 2		C	3		0,43	≤2	25×2,5	2,45
B CW 3		C	4,5		0,52	≤2	25×2,5	2,85
B CW TOTAL		C	10,5		0,8	≤2	32×3,0	2,60
B HW 1		H	2,5		0,4	≤2	25×2,5	37,15
B HW 2		H	2,5		0,4	≤2	25×2,5	2,85
B HW 3		H	4		0,49	≤2	25×2,5	2,45
B HW TOTAL		H	9		0,74	≤2	32×3,0	2,40