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COMMISSIONING

OF HEATING SYSTEMS

Bachelor's thesis

Building Services Engineering Double Degree

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DESCRIPTION

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Abstract

This thesis reviews the commissioning of heating systems. Each stage of the process is studied step by step. The following commissioning stages are reviewed: pre-commissioning, hydraulic-pressure test, flushing, start of operation, hydraulic balancing of systems and documentation.

This thesis also includes condition and general recommendations for commissioning and frequent installation mistakes. This thesis also addresses the problem of effective labor management upon which relies success of commissioning. In the last chapter two different structures of management during commissioning are explored.

Subject headings, (keywords)
pre-commissioning, hydraulic-pressure test, flushing, start of operation, hydraulic balancing of systems, commissioning management

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CONTENTS

1 INTRODUCTION

Nowadays every new building has heating, ventilation and air conditioning system (HVAC). HVAC systems in buildings are the synergy of technologies that ensure comfortable conditions for life and labor of people. There are different kinds of systems: systems of ventilation and air conditioning, water supply and sewage, heating, gas supply, artificial lighting, electrical equipment, automatics etc.

There exist severe requirements for HVAC systems in Russia and European countries. It is very important to follow operating quality standards for the design, installation and operation of HVAC systems. In this thesis I would like to talk about process of heating systems commissioning because it is one of the most important stages for the good functioning of heating systems

Commissioning is a complicated and long process of technical and organizational work. It is impossible to adjust heating system without education, skills and knowledge about commissioning process. In this thesis I would like to describe the process of heating systems commissioning step by step. The process includes installation, pre-commissioning, hydraulic-pressure test, flushing, balancing of system and documentation. I am going to explore all the available information to review commissioning stages. It is also important to know what kind of complications and problems which can appear during pre-commissioning and commissioning periods.

Also I would like to talk about commissioning management in Russia and Great Britain. One chapter of this thesis is devoted to the comparative analysis of commissioning management in Russia and Great Britain. During my studies I have got a chance to get acquainted with construction works processes in these two countries and therefore I have chosen the comparative analysis as a main topic of my thesis. To analysis these two Russian and Great Britain approaches I have used Chartered Institution of Building Services Engineers (CIBSE) Commissioning Code M : 2003 and Russian State Standard: 12-01-2004 Building process organization, Town planning Code of Federal law Russian Federation from 29.12.2004 № 190. Also I have used my personal work experience. The main value of this comparison is that it may potentially become a basis for improvement commissioning process in general by assembling best practices of both countries.

2 MAIN DESCRIPTION OF HEATING SYSTEMS

The first traces of HVAC systems in buildings were discovered 2200 years ago. Archaeologists find that heating systems were widely in use in the region of contemporary Italy, France, Switzerland, Germany and England. The invention of central heating appertains to the ancient Romans few centuries BCE. They installed a system of air ducts in walls and floors in public baths and private house /1. /

2.1 Heat transmission

The heat transfer requires are material medium as a necessary condition because the heat transfer is carried out by physical contact between high temperature molecules and low temperature molecules. Human being becomes a part of heating exchange system on the molecular level. Of course convection functions upon the same principles as other methods of heat transfer. According to these principles the temperature of the air (heated by convectors) has to be higher than temperature of the surrounding objects (heated by this air).

The energy can be transmitted by three methods: convection, conduction, electromagnetic wave. Convection means when the heat is transmitted by air. Conduction means when the heat transmitted by conductivity. Every day we can observe the third method of heat transmission - radiation. The sun transmits heating energy to the Earth by means of radiation. The heat transmission is performed by means of electromagnetic radiation by electromagnetic wave. The ways of heat transmission are represented in figure 2. /2. /

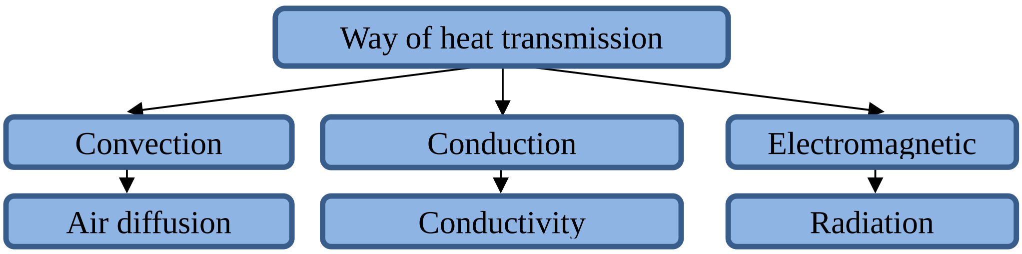


FIGURE 1. Way of heat transmission

Air heating use convection and conduction as energy transmission methods. Heat emitters of water heating systems use two physical processes – convection and radiation. /3. /

2.2 Specific requirements to engineering system

Heating systems are an integral part of building and they should satisfy four requirements. Figure 2 shows these requirements.

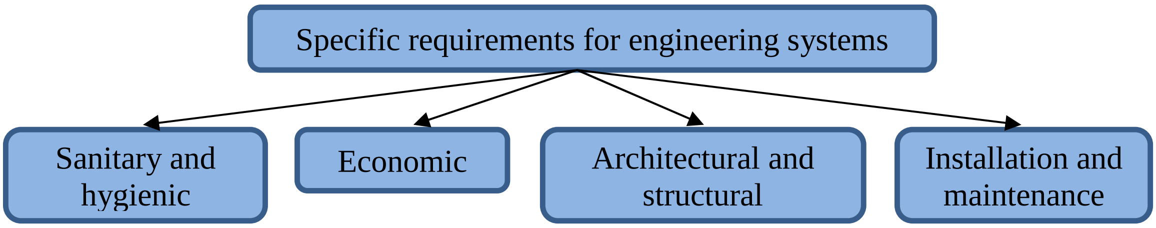


FIGURE 2. Specific requirements to engineering system

Sanitary and hygienic requirements regulate indoor temperature, and the temperature of radiator.

Architectural and structural requirements regulate location of heating systems location according to the room design plan, preserving construction of the building during all operational lifecycle.

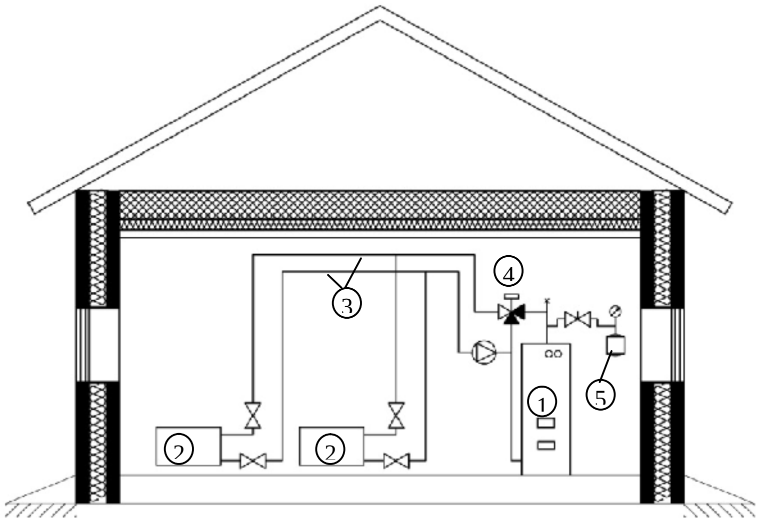
Installation and maintenance requirements ensure that heating systems correspond to the modern standards of mechanization, guarantee reliability during operation and easy service (maintenance) of heating systems.

The air heating is one of the safest types of heating. The heated air is carried out by calorifer. As the medium of heat transmission in the calorifer heated water or steam is used. But in some cases gas or electric energy is employed. Today it is used in electrical fireplaces, electric heating coils, floor heating and other electrified heaters.

The water and steam systems meet sanitary and hygienic requirements in the more effective way. But water and steam systems are used with some restrictions. These systems can't be installed inside the room where calcium carbide, potassium, sodium or lithium are stored. More often steam systems meet in hospitals.

Heating systems are classified as local or central systems. Local heating systems are used in low-rise buildings in small localities. Local heating systems produce heat at the location where it is needed (for example in flat). These systems are used in small spaces well. In these systems the heat carrier does not circulate throughout the total structure. /2. /

The central heating systems heat is generated in one place in a building. Heat is distributed to heat emitters (radiator or convector) with some fluid (water). In these systems water can be heated with the different ways: with heat pump, in a water tank, in a heat exchanger, in boiler room in the building, in boiler house. There are was list of the heat sources. Heat is transmitted by a pipeline from heat source to the heat emitters. Water circulates in central heating system. Central heating system can be divided into five main parts. In the figure 3 is shown the main part of central heating system. /4. /



Legend: 1 – Heating device/heat source
2 – Heat emitters
3 – Distribution pipelines
4 – Control device
5 – Expansion and safety device

FIGURE 3. Main parts of central heating system. /4. /

3 DESIGN AND INSTALLATION

In this thesis described the central water heating systems because they are more popular. Heating system should have good functionality. The stage of heating systems design consists of several steps which are represented in figure 3.

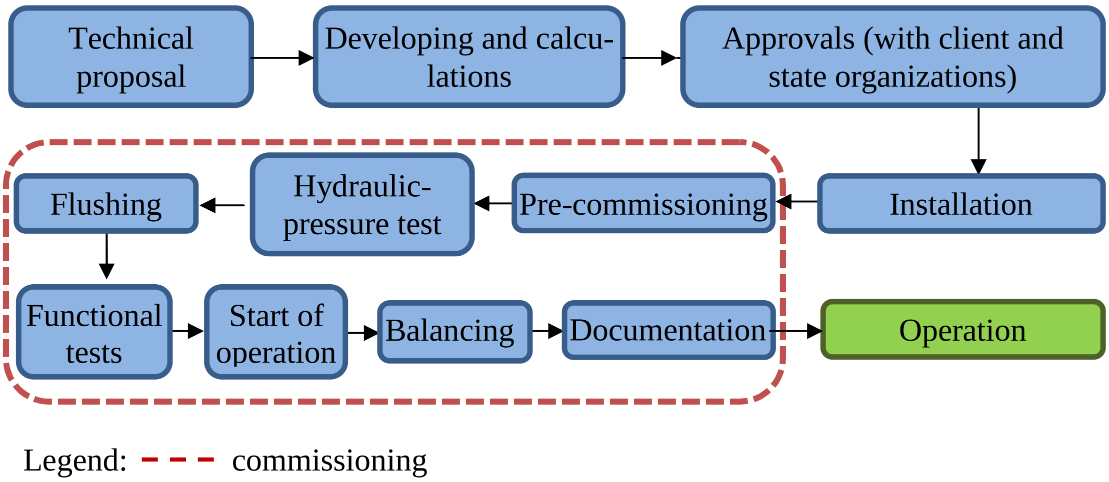


FIGURE 4. Stage of heating systems design

Technical proposal is the document for project design. It consists of demands for heating system, architectural drafts and other documents needed for design.

Contractor (HVAC-designer) is organization which performs design stage of project development, calculation of heating system or installation process.

Technical proposal is given to the contractor (HVAC-designer) by the client (customer) at the beginning of design process. Design stage consists of project development and calculation of heating parameters. Contractor makes calculation of heat loss (through building envelope, leakage air and ventilation air), choice of heating equipment (radiator, thermostatic valve, pipe, etc.). After these stages the client accords project with state organizations. If state organization finds some mistakes the project should be readjusted accordingly. If project are accepted then the installation process is started. Frequent installation mistakes are examined in the next chapter.

Commissioning has to be done after equipment installation. Commissioning consists of five stages: pre-commissioning, hydraulic-pressure test, flushing, balancing and documentation. The commissioning is shown by red dashed line in the figure 3. Every stage of commissioning is discussed in detail in the next chapters. Operation stage follows after commissioning stage. It means that heating system ready to work. /5. /

3.1 Frequent installation mistakes

Equipment installation has to be executed in accordance with installation manual. In this chapter we will take a look at frequent mistakes of heating system equipment installation demonstrated with comprehensive graphical illustrations.

3.1.1 Installation of the temperature elements to measure the temperature

Temperature elements (T.E.) are a piece of equipment for automatic temperature control. It is installed on the return pipe as shown in the figure 4. So that it is measuring the right value (the temperature of return water). In the figure 4 is shown installed T.E. after the coil. /6, p.143. /

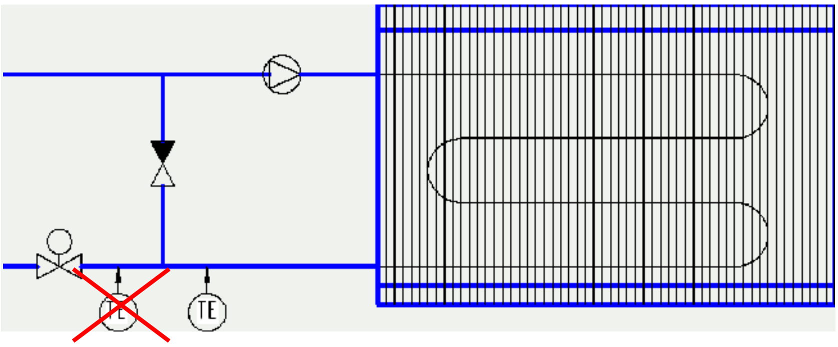


FIGURE 5. T.E. installation /7, p.51/

So the correct locations of temperature sensors are also very important. For instance the sensor is intended to measure outside or inside temperature. Temperature sensor should not be placed near to heating objects which may influence on elements correct functioning by generating the heat. In the figure 5 and 6 is shown examples of correct and uncorrect installation place.

In the figure 5 is shown installation of outside temperature sensor. This sensor should not be placed under or above window, on the duct and under ventilation pipe on the roof because these objects influence on the correct sensor function by generation heat. More possible place for installation T.E. is place between windows. /6, p.241. /

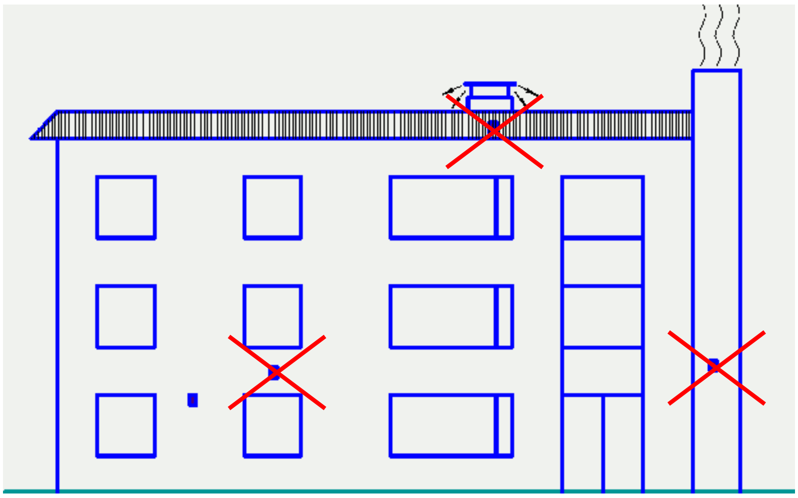


FIGURE 6. Temperature sensor installation outside the building. /7, p.52. /

In the figure 6 is shown installation of inside temperature sensor. This sensor should not be placed beside the kitchen range or air diffuser. It should not perceive the solar radiation from window. More possible place for installation T.E. is shown on the picture 6. /6, p.241./

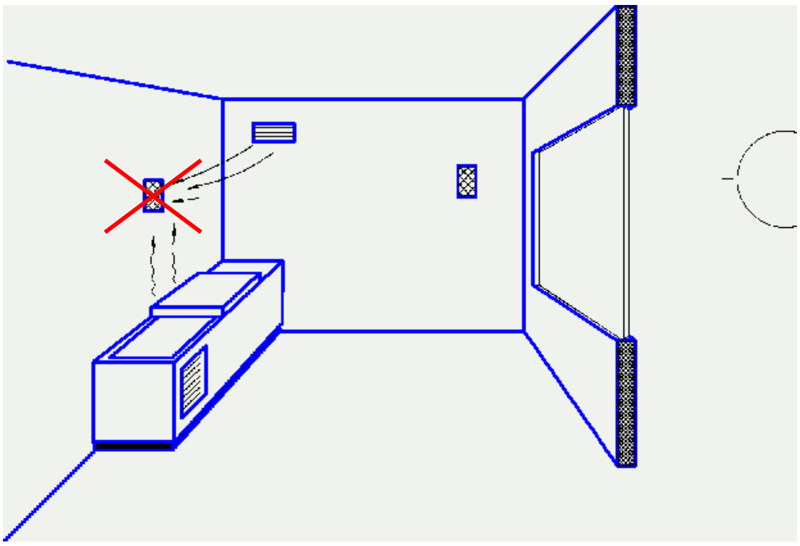


FIGURE 7. Temperature sensor installation inside the building. /7, p.51. /

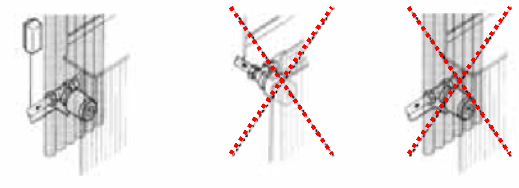
3.1.2 Radiator thermostat installation

“The radiator thermostat is a self-operated controller, which controls the room temperature by regulating water flow through the valve body.” /8./ The thermostat installation has to ensure correct work of its heat-sensitive elements. Room air should flow freely for the right functioning. This thermostat should not take ascending heat flow from pipeline (see figure 7a and 7b). In the figure 7c the radiator thermostat perceives convection current from pipeline.

a b c

FIGURE 8. Radiator thermostat installation /6, p.245./

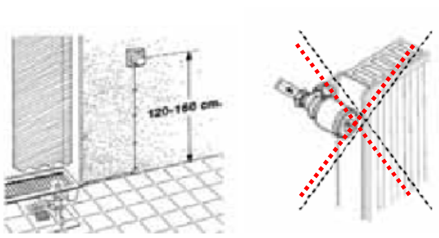
Heat-sensitive elements should not be covered by blind curtain (see figure 8c) or situated in draft zone (see figure 8b). If this situation the location of the sensor should be changed (see figure 8a). /6 p.244-245. /



a b c

FIGURE 9. Radiator thermostat installation /6, p.245. /

If heat-sensitive elements are hidden in the wall remote regulator with built-in temperature sensor should be used (see figure 9a, 8a). It is installed on the wall. The height of regulator installation is approximately 1.5 meters above floor level. In case when surface of radiator is large enough to influence the correct functioning of the temperature sensor the remove regulator should also be used (see figure 9b). /6, p.244-245. /



a b

FIGURE 10. Radiator thermostat installation /6, p.245. /

All these mistakes should be prevented during installation process or found and correction during pre-commissioning period. /6. /

4 COMMISSIONING OF HEATING SYSTEM

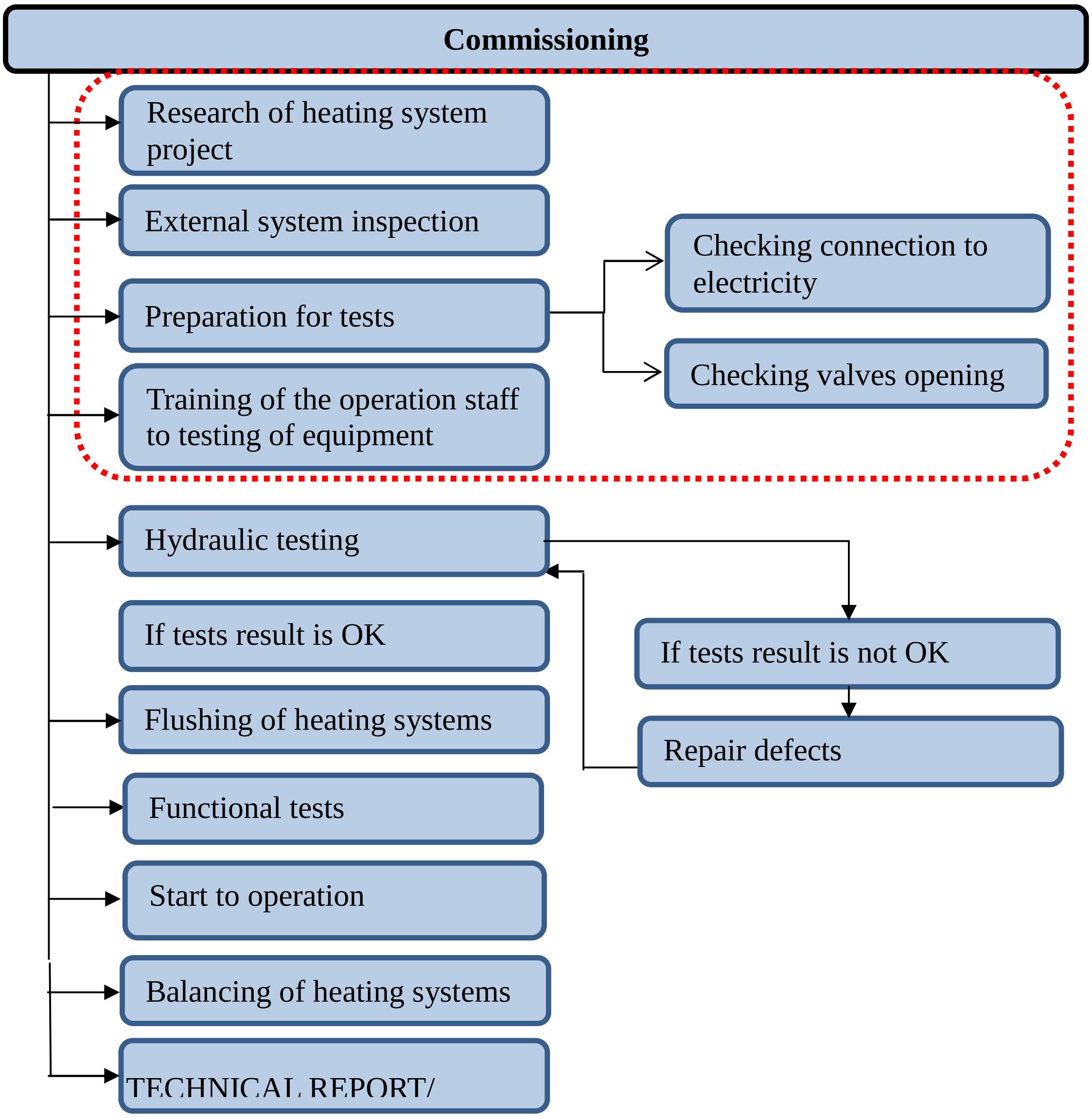
Commissioning has to be done after equipment installation. The main task of commissioning is to check reliability and safety of system and also project parameters (the temperature in room). As the result of complex tests all defects have to be discovered and removed because they prevent reliable and safe equipment exploitation.

In the final stage of commissioning the functioning of the system is determined by operation tests. The result of commissioning is issued as a technical report. Technical report is the main document which describes accomplished work and its effectiveness.

Based on experiences of different commissioning organizations we can say that expenses coming from well-done commissioning are compensated within months. Comparison test and calculations show that well-done commissioning improves in energy economy of 3—5%.

Commissioning has to be done by specialized organizations and employees in accordance with contract agreement. Balancing and commissioning should be implemented by a specially trained team supervised by an experienced engineer. The number of people in team depends on the amount of work but should not exceed five persons. Usually team consists of engineer employees.

The quality of installation should be detected during commissioning period. The number of tests to define the quality of equipment operation has to be minimal. The commissioning consists of several steps which are represented in figure 10. /9. /



Legend: ····· pre-commissioning

FIGURE 11. Commissioning

We will look into detail at the pre-commissioning stage in this chapter.

4.1 Pre-commissioning process

The pre-commissioning process is shown in the figure 3 by red dashed line. Pre-commissioning consists of external system inspection, preparation of heating system for tests, training of the operation staff. Visual external inspection of installed heating should guarantee that components of HVAC-plans are installed using good way. Location of heating equipment should correspond to the project design. All connections have to be hermetic.

The pre-commissioning also includes the training of the operation staff. It means they familiarization with commissioning documentation and preliminary instruction /9. /

4.2 Hydraulic-pressure test

Hydraulic pressure test can be done before electrical installation. All installed pipelines of heating system have to be tested for strength and tightness. This is hydraulic-pressure test. Hydraulic-pressure test is performed according to the main requirements and conditions represented in figure 11. /9. /

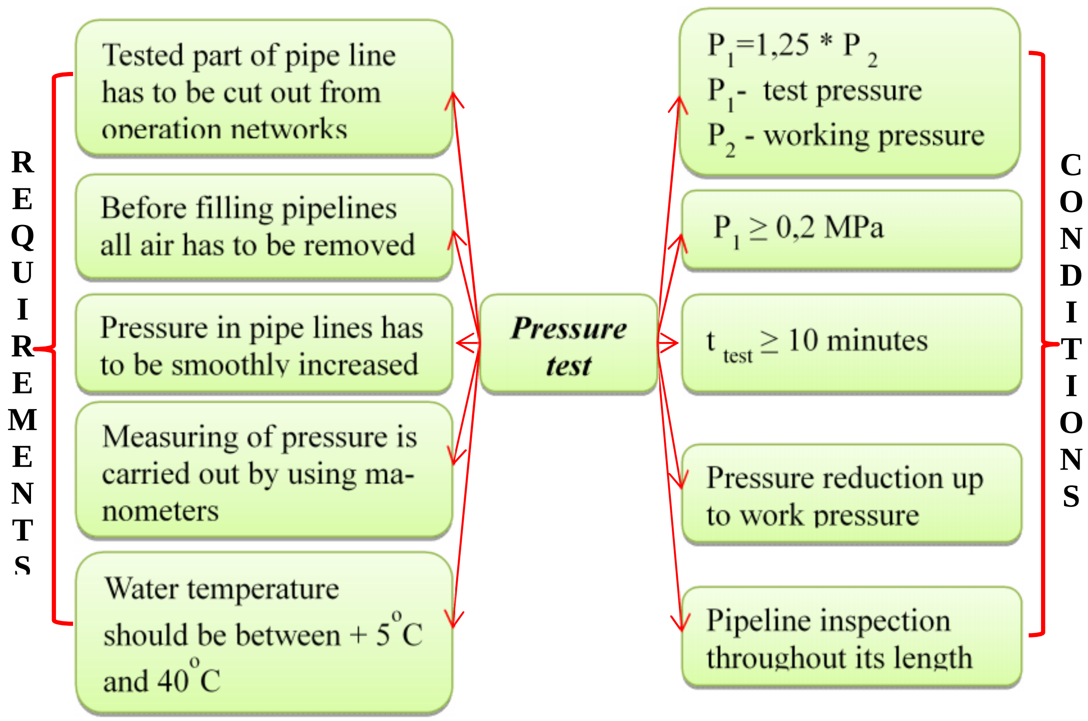


FIGURE 12. Pressure test (requirements and conditions)

4.2.1 Testing procedure

Firstly the system should be filled with water. Air should be removed through the air valve. Pressure should be adjusted to the test pressure (P_2) for the test time (t_{test}). The test time should not be less than 10 minutes. Work pressure is pressure during operation live (“use pressure”). The test pressure is pressure during test time. At least the test pressure has to be 0,2 MPa. Pipe connections, as well as their connection with valves and other equipment have to inspected during test time. Pipeline pressure test procedure is shown in figure 12.

Test result should be regarded as satisfactory if during the test we did not find the following problems: pressure drop, signs of blowout (during visual inspection), leakage in the main structure of pipeline, leakage in flange connections and others elements of pipelines. If some of these problems were found then operation staff should repair it and test system again. /9. /

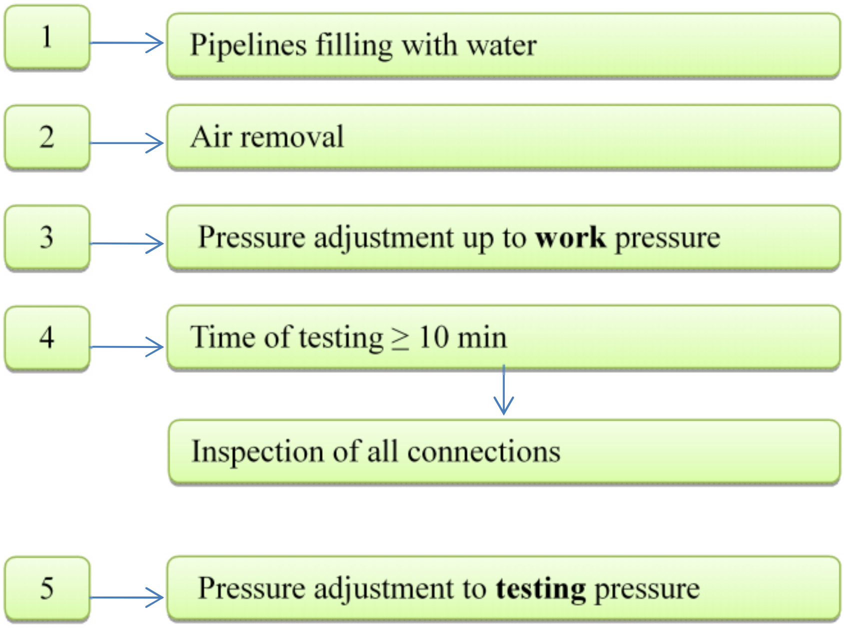


FIGURE 13. Testing procedure

The amount of test pressure for water heating system should be at least 0.2 MPa (2 bar) in the lowest point of system. /9. /

4.3 Flushing

The aim of flushing is to remove dust and some particles (ex. metal particles) from inside the pipe. Flushing is performed after the hydraulic test. All radiator thermostats and valve should be closed for prevent dust ingress to its. The heating system flushing is performed with water from domestic water system. The volume of water used during flushing should be equal to 5-7 times the volume of heating system. After the flushing the water has to be removed from the pipeline. The flushing water is removed from the system to floor drain.

Also the pipeline could be cleaned by using hydro-pneumatic flushing. Hydro-pneumatic flushing is performed by adding compressed air to the pipes filled with water. Hydro-pneumatic flushing is successively performed in different sections of the pipeline. Every 10-15 minutes air flow output should be decreased for 5 minutes (to achieve effective flushing). Flushing should continue till clear water starts to come from pipe line. After this air supply should be stopped and pipe line has to be flushed by water for 15-20 minutes.

Hydro-pneumatic flushing of heating pipeline and heat source should be performed separately. During pipeline flushing heat source has to be unconnected (in case the heat source is in use). Hydro-pneumatic pipeline flushing is performed by water with flushing temperature not more than 40 ^{o}C. The pipeline flushing pressure has to be equal work pressure but no more than 0,6MPa. After flushing the water is removed from the system to floor drain. Result of flushing should be properly documented. /10. /

4.4 The functional tests

The functional tests mean the checking correct work of heating system parts, connection to electricity and valve opening. For example, if heating system use the heat pump as the heat source it is necessary to make functional tests of heat pump. All functional tests of heating equipment have to performed according with instruction manual. The functional test considered on the example of heating pump.

The power supply to the heat pump must not be turn on until the heat pump is filled with water. The follows of filling is listed below.

1. Open all of the hot water taps in the house (don’t forget the shower).
2. Open the cold water isolation valve fully to the water heater.
3. Air will be forced out of the taps.
4. Close each tap as water flows freely from it.
5. Check the pipe work for leaks.
6. Switch on the electrical supply at the isolating switch to the water heater.

Also it is necessary to check the unit’s operating parameters (pressure and flow rate), correct direction of heat pump rotation. /11. /

4.5 Filling of heating systems

4.5.1 Filling of heating systems at the below zero air temperature

Before filling it is necessary to perform external system inspection to check handles easily rotate of air valves. Parts with heat insulations defect have to be absented. Filling of heating system with water is performed consequently section by section of the pipeline. First the water is supplied to the main pipe. Before this air valves have to be opened, drain valve and shut pipes (which divides supply and return pipelines and at the end of the pipe) have to be closed.

Foreman of the group of workers appoints the person responsible for monitoring of the air valve. Filling is performed by opening valves on return. Air valves should be closed as soon as the air is forced out from pipe. After finishing filling of return pipeline the shunt pipe should be opened. Filling of supply pipeline is performed in the same way as the filling of return pipeline. /10. /

4.5.2 Main conditions of the water filling

Pressure of water during the filling should not exceed the static pressure by 0.2 MPa. Water temperature during filling has to be no more than 70°C. Hourly water flow G [m3/h] depends on pipeline diameter D_y. For preventing water hammering and better air displacement from pipelines the hourly water flow G [m3/h] should not be more than values which are represented in table 1.

TABLE 1. Dependence of water flow from diameter /10. /

G [m^3/h]	100	150	250	300	350	400	450	500	600
D_y [mm]	10	15	25	35	50	65	85	100	150

4.5.3 Specifics of operation at the negative outside air temperature

Supply and return main pipes are filled with water at the same time. Water temperature during the filling should arrange from 50°C to 60 °C. Supply and return pipelines should be equipped additional drain valves. Water is drained across drain valves before the temperature of water achieve the 40°C (if in start of filling the system is filled with water with temperature less than 40°C). After this the drain valves are closed (when temperature of drain water is about 40°C). Directry after that heat source is powered on. Other steps of operation start are the same as during water filling at positive temperature.

If some troubles happen during the filling the pipeline of heating systems should be drained. Drainage is performed by opening all drain valves and air valves to discharge water in the lowest-lying point. /10. /

4.6 Hydraulic balancing of systems

4.6.1 General information

The main purpose of HVAC systems design is to create thermal comfort in a room with the minimal consumption of energy resources. Although modern equipment approaches ideal parameters, achieving optimal results is still a challenge. For almost 80% of systems the main problem is inadequacy of water flow distribution.

Inadequacy is provoked by many factors such as errors in calculation and system installation errors. As a result the water flows is redistributed incorrectly. And it leads to inaccurate indoor temperature due to the lack of flow in some flow circuits and surplus of flow in others. It also leads to noises and excessive consumption of energy resources. That is why it is necessary to adjust system for operation mode by valve balancing before commissioning of a facility.

Before system balancing it is necessary to execute pre-commissioning such as studying of project documentation, technical manuals for valves, devices etc. Further it is necessary to check operability of system elements, its working capacity and functioning, correctness of installation. Then the system balancing can be done.

All thermostatic valves should be open at maximum. Only in this way it is possible to detect overheating and underheating of rooms. Before system balancing it is necessary to analyze that thermostatic valves function correctly and to check that heating system maintains required room temperature. Otherwise there is a risk of overheating and underheating of floors, rooms located on different facades of a building, risers, etc.

The problem should be solved by adjusting pump capacity and the temperature of a heating water. The general recommendations are given in the table 2.

TABLE 2. The general recommendations for balancing. /6, p. 256. /

	Indoor temperature compared to design temperature (temperature on the floor)		**Way of problem removal**
	Lower floors	**Upper floors**	
1	higher	normal	The pump capacity should be increased
2	higher	normal	The pump capacity should be decreased
3	normal	higher	The temperature of heating water should be decreased
4	Too low	Too high	The temperature of heating water should be decreased
5	Normal	Too low	The temperature of heating water should be increased before normal temperature (design temperature) in the upper floors. The pump capacity should be decreased to achieve of normal temperature on the lower floors
6	Too high	Too low	The same as in previous point
7	Too high	Too high	The temperature of a heating water should be decreased

If problems persist the balancing of system should be done. In this case the process of system balancing should be cheap, quick and compliant with technical requirements. There are 5 different methods of system balancing. There are following methods: temperature drop, computer method, preparatory balancing of valves, proportional and compensation method. Let us briefly review these methods. /6, p.254-257./

4.6.2 The method of temperature difference

$Q = c_w V \Delta t / 3600 = c_w G \Delta t / 3600 = 1.16G \Delta t,$ **1 /6, p258/**

Here Q is heat flow, W

c_w is water thermal capacity (4,2 kJ/(kg·K)

V is water volume flow, m^3/h

Δt — difference of water temperature in heating system, K.

G — mass flow of heat carrier (water), kg/h;

1.16 is conversion factor. It takes into account water thermal capacity

The equation 1 means that in the balanced system the temperature difference t of heating water should be the same at input and at output of all heat exchange devices. If water flows are distributed incorrectly the temperature difference at input and output will not be the same. Insufficient heating water flow reduces thermal unit radiation and the excessive flow is not able to increase it significantly. The temperature difference of heating water is the temperature t in equation 1. Radiator capacity usually corresponds to heat loss. The radiator is chooses from radiators directory. Radiator capacity is taken the closest greater value from the directory. Usually the value of chosen radiator is different from calculated radiator to 1.15 (in general cases).

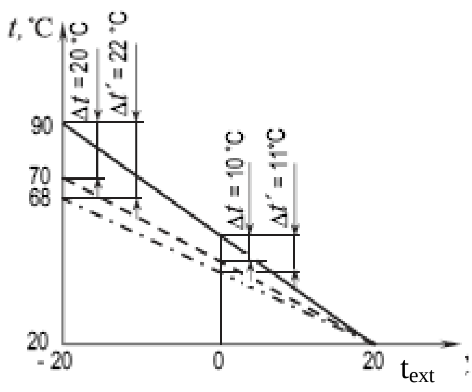


FIGURE 14. Determination of required temperature difference of a heating water in a thermal unit /6, p.258./

To find the temperature difference one should use the geometric construction shown in fig. 1.2. The solid line describes the temperature of heating water supplied to the thermal unit. Dotted line describes specified temperature of heating water at the output of the thermal unit. Chain line describes required temperature of heating water of radiator heat exchange surface with a factory capacity corresponding to the 1.15 times the heat loss of a room. Range of outdoor temperature is represented on the X-axis. The starting point of axis is outdoor temperature (which of course will vary for different geographical locations) e.g., –20 °C and the ending point corresponds to the required indoor temperature (e.g. 20°C). Y-axis shows the range of temperature of the heating water of the input and output. As a rule, heating water temperature at the input of heating thermal unit is accepted as equal to the temperature at the output of heat source (e.g. 90 °C at the output of a boiler). For an accurate calculation one should take into consideration the cooling of heating water in the pipes. Temperature in the return pipeline, for example, 68 °C could be estimated from the average temperature difference between the thermal unit (including 1.15 factor).

In this method the balancing is carried out by using a T.E. or a control valve. Radiator thermostat should be fully opened at this time (with the freely fasten cap). To achieve the equal temperature in all radiators, that is, the procedure of thermostatic valve regulation balance in the system could be repeated several times. Therefore adjusting of each thermal unit affects temperature characteristics of others, even regulated before. The method of balancing is not precise enough, especially in systems with low temperature variations, which are the floor heating systems. It is necessary to provide permanent temperature conditions both indoor and outdoor. The lower the outdoor temperature is the better for the balancing result. So the temperature difference method is used to balance small-size heating systems.

Despite all its disadvantages this method is the only possible method to balance the thermal unit within the risers or thermal unit branch. It means the balancing of risers or thermal unit branch is performed only by the method of temperature difference. /6, p.257-260./

4.6.3 Proportional method

The method is based on the flow deflection in parallel sections of system. It is expected that in a system with a large amount of branches the balancing of one valve inside a module does not lead to proportional change of parameters in other of another module. The regulation of a general control valve leads to proportional change in all the modules. A group of upraise pipes or thermal unit branches controlled by a general control valve (and for each upraise pipe or branch there should be a control valve) is considered a module of system. Then by this method of balancing it is possible to make equal unbalance of upraise pipes or branches inside a module and then to adjust a nominal flow by balancing of a general valve.

Thus, the proportional method of balancing is applied for system with several branches complicated configuration of modules. This method is implemented by one or two service engineers. One of the disadvantages of it is necessity of repeated measuring. The proportional method requires long time to adjust each of valves in several steps. /6, p.261-264./

4.6.4 Compensation method

The compensation method of balancing of heating systems represents of the proportional method. The main advantage of this method is the possibility of balancing of systems with several branches in one step. In this case there is no need in repeated measuring which considerably reduces timeframe of balancing. It is possible to reduce time required for balancing if pump is operating and separate branches of the system undergo balancing process while other part of the system is being installed. The disadvantage of the method is a necessity to involve 3 persons with radiophones and using of two devices for example PFM 3000 by Danfoss Company or other measuring devices (figure 14)

FIGURE 15. Device PFM 3000 /12. /

The compensation method is meant for systems with manual control valves. If the automatic control valves of pressure differential on upraise pipes are or radiators are used there is no need to balance a system are used there is no need to balance such system. The balancing will be done automatically. Thus the compensation method is an improvement of the proportional method. It is performed in one step and requires several devices for example FM 3000 by Danfoss Company and several service engineers. /6, p.264-266./

4.6.5 Preparatory balancing method of valves

The method is based on the balancing according to hydraulic calculation when we make a project of heating system before its mounting. Coordination of heating circuits is made by balancing of each control valve and thermostatic valve. Balancing is defined by the discharge capacity (k_v). However, this method does not consider operational discharge characteristics under the influence of authority. Therefore this method not completely conforms to the real characteristics of the system. Valve authority should be less than 0.5 to achieve good control of heating.

Valve authority is the ratio between pressure loss on the maximum opened radiator valve and the maximum possible pressure loss on the balancing part. Authority is defined by the formula 3:

$$a = \frac{\Delta P_1}{\Delta P} = \frac{\Delta P_{vs}}{\Delta P}$$ **2 /6, p.260. /**

Here $\Delta P1$ is the pressure loss on the radiator valve,

ΔP is the pressure loss on the balancing part of heating system

ΔP_{vs} is the pressure loss on the control valve

This method has a disadvantage. It does not consider deviations which appear during installation of heating system. Moreover, detection of pressure loss in system elements is a complicated process and it result closes not always correspond to the reality. This method suggests that coefficients of the local resistances (at the full range of water flow regulation) are constant and do not influence have reciprocal influence during the process of water flow regulation.

During balancing of the pressure at each selection is performed by control valve regulation. For this the difference between pressures exerted on the closed control valves should be measured.

Thus the influence of authority (when a $< 0,5$) on discharge characteristics of valves and possibility of balancing by means authority should be considered for the preparatory balancing method of valves. /6, p. 260./

4.6.6 Computer method

The computer method is based on application of microprocessors to diagnose valves and determine their adjustment when we perform system balancing. To implement this method PFM 3000 is used (fig. 14).

PFM 3000 has been designed for the adjustment and hydraulic balancing of most heating systems. It enables measuring of under-pressure and over-pressure as well as differential pressure within a given system. Furthermore, based on the differences, the flow through individual branches of the system can be measured, whole system to be balanced. It optimizes hydraulic ratio in a system with the minimal losses of energy. It uses complicated methods of calculation and parameters of system balancing. The device has a lot of other additional functions helping which reduce time required for balancing and simplify it. The device PFM can define not only over pressure or depression in a system but also differential pressure. By measuring pressure difference in a control valve or in a measuring unit PFM can determine the water flow. The minimization measurement errors give possibility for accurate determination of hydraulic parameters of a system.

Thus, the computer method helps to reduce time for system balancing. As only system engineer is required to perform balancing of the system. /6, p. 266-270./

4.6.7 Differences of methods

Main points of balancing method tabulated for easier understandable differences of balancing method.

TABLE 3. Differences of balancing methods.

The method of temperature difference	In this method the balancing is carried out by using a T.E. or a control valve. First of all the inside and outside temperature have to measured. The temperature differences between supply and return flow (using fug. 13) is installed by T.E
Proportional method	This method is carried out by using control valves of branches and common control valves. To make equal unbalance of risers or branches inside a module and then to adjust a nominal flow by balancing of a common (general) valve. In this method balansing is carried out by regulation every valses in consecutive order.
Compensation method	In this method used special devise for measuring pressure difference in control valve. In this method balansing is carried out by regulation conrol valves за every branches synchronous.
Computer method	By measuring pressure difference in a control valve or in a measuring unit PFM can determine the water flow.
Preparatory balancing method of valves	This method is carried out by using control valves and T.E. Balancing is defined by the discharge capacity (k_v).

4.7 Documentation

When the commissioning of heating system is ended the Technical Client (or Project Manager) has to inform client (customer) about acceptance of commissioning works. Heating system has to correspond to demands of project design, norms and contract. Acceptance inspection has to estimate correspondence of heating system to demands. Acceptance inspection consists of representative of client (customer), main contractor, design team, technical supervision and safety arrangement inspection. Client has to represent to acceptance inspection all documentations about object.

Results of commissioning should be properly documented. List of necessary documents in Russia is presented below. This list of documents is based on requirements of State Acceptance Commission in Russia.

1. Technical conditions for connection of heating system to district heating system;
2. Design of heating system (approved by State Expertise and other organizations);
3. Drawing of pipe lines and stop valves with its numbering and equipment specification;
4. Acts for flushing;
5. Testing acts;
6. Acts of installation of regulator devices in heating system;
7. Certificate of acceptance by working committee or acceptance certificate between installation companies and client;
8. System Operation permit certificate;
9. Appointing order of decision-maker for operational condition and safety operation of heating system;
10. List of operation and maintenance personnel (with contact information) or service contract;
11. List of available protective means, fire extinguishing equipment, safety posters;
12. Program of start to operation approved by organization’s management – customer and approved by energy-supplying organization. /13. /

5 COMPARATIVE ANALYSIS OF COMMISSIONING MANAGEMENTS

Conventional terms: Client, Technical client (TC), Commission management organization (CMO), Building services contractor (BSC), Main contractor (MC), Consultant engineer (CE); Technical supervision (TS), General designer (GD), Specialist suppliers, Mechanical installation organization. /14. /

5.1 Explanation

Technical Client (TC) - is a special organization which has direct contract agreement with client (investor). Its functions are: project managing, project expertise, total commission of building;

Technical Supervision (TS) – it is one of the department within the Technical client organization. Its main functions are: control of building process according to design documents and the supervision of commissioning.

General Designer (GD) – it is main project design organization which is responsible for all design solutions and approves with state organization and execution of designer supervision. Designer supervision controls on site all solutions of the general designer. General designer controls and checks others design subcontractors. For example if heating system part was developed by subcontract organization. /15. /

5.2 Organization structure and participants of heating system commissioning management

Organizational structure of commissioning management and its participants in Great Britain are represented in figure 15. This picture shows relationship between every participant of the process. /14. /

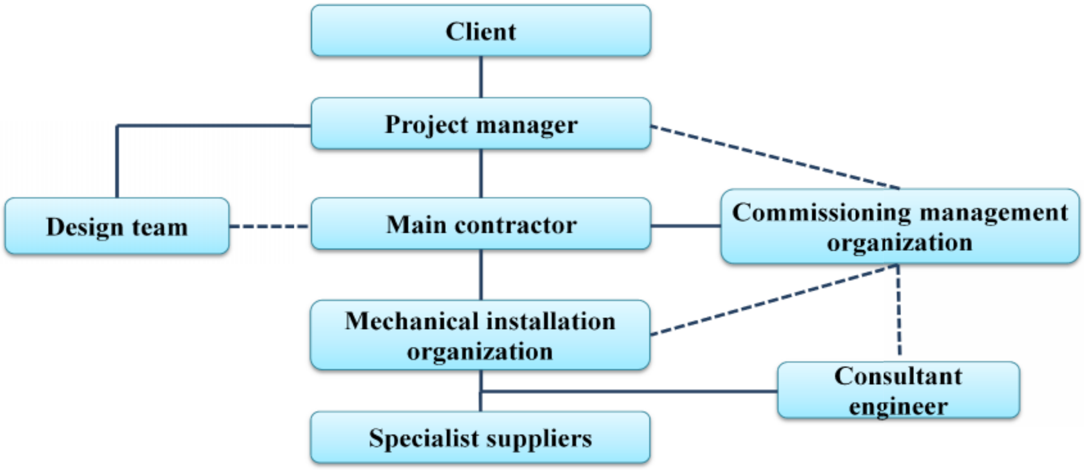


FIGURE 15. Organizational structure of commissioning management in Great Britain /14. /

In the figure 15 is shown the organizational structure of commissioning management in Great Britain. There are 2 different types of relations between companies which participate in commissioning. These are contractual connections and communication route. Project manager represent client's interests. Project Manager hires Design Team (which is responsible for project design) and Main Contractor (this is organization which employs Commissioning Management Organization and Mechanical Installation Organization). Mechanical Installation Organization makes a purchase contract of equipment with Specialist Supplier. The Specialist Supplier can also be engaged if there are difficulties with installation and commissioning.

This figure also shows Consultant engineer who appointed by MIO. He reviews, comments and accepts documentation.

Organizational structure of commissioning management and its participants in Russia are represented in figure 16. This picture also shows relationship between participants. /16,17. /

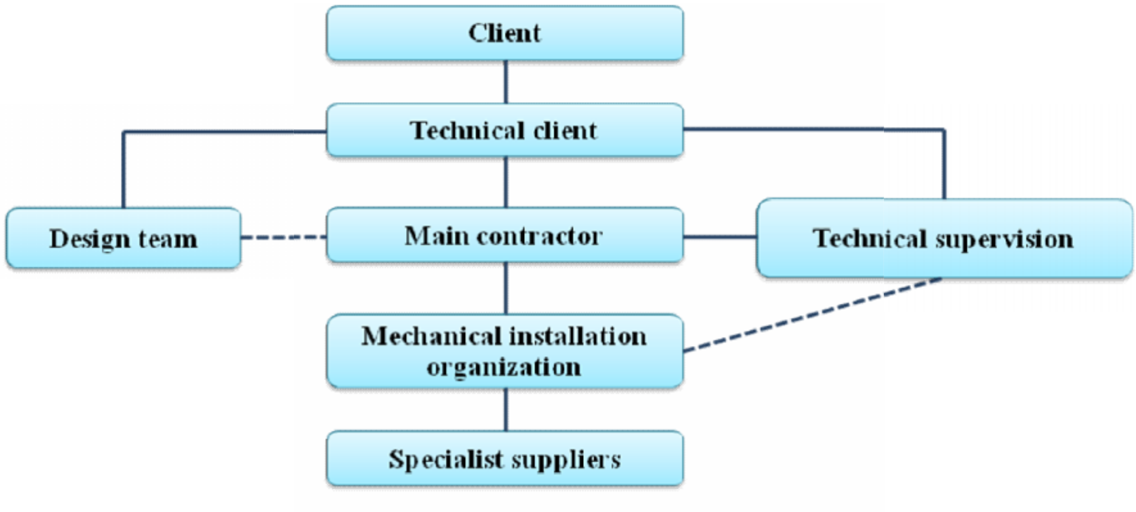


FIGURE 16. Organizational structure of commissioning management in Russia /14. /

The client exercises a function of investor. Technical client has a contract with Technical supervision, Main contractor and Design team. Technical supervision inspects the construction work. Other stages of commissioning management process in Russia are similar to commissioning management in Great Britain.

Upon competition of the comparative analysis of this chapter I can draw a conclusion that there is no big difference between Great Britain and Russia commissioning management. In some small differences are shown below:

1. In Russia technical client has functions of project manager.

2. In Russia there is no Commission management organization (CMO) and its functions are performed by TS. For the most difficult cases organizations having similar function are created.

3. In Russia functions of Consultant engineer are performed by group of people consisting of several specialists from every participant organization. There are representatives from main contractor, technical client, and general designer- Technical supervision.

In general I can say that these schemes almost are similar and there are no fundamental differences. In different cases organizational structure and relationship between participants can vary a little bit in accordance with client requirements.

5.3 Main stages of heating system commissioning management

Main stages of commissioning in Great Britain and the Russian Federation are very similar. These stages are represented in figure 16.

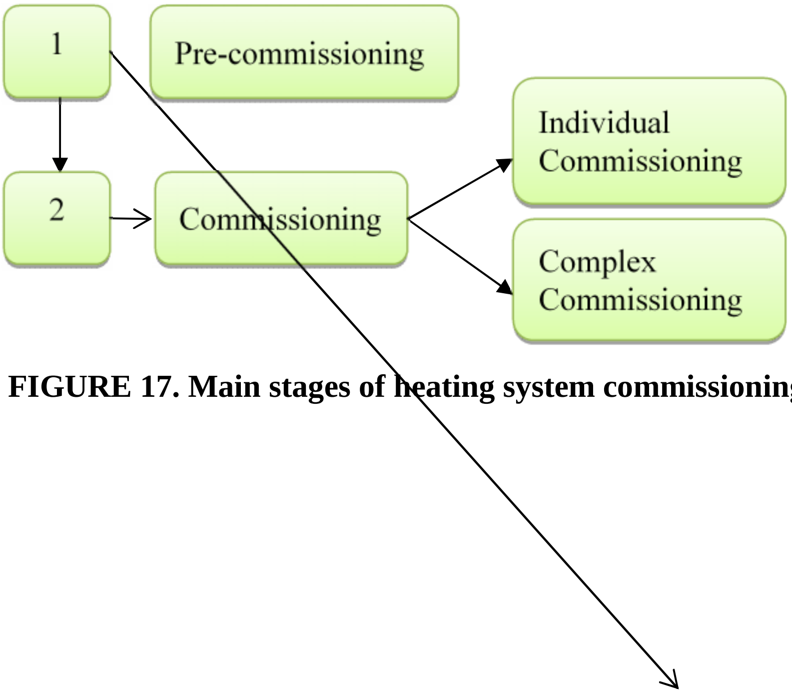


FIGURE 17. Main stages of heating system commissioning management /14. /

5.4 Comparative analyses of responsibility matrix

The responsibility matrix of commissioning process of the main participants is done based on the principle of the responsibility matrix of commissioning process of the main participants in Great Britain which is shown in CIBSE code M-Commissioning management. /12, appendix MA2, figure 14 and 15. / The responsibility matrix of commissioning process of the main participants in Russia was made by me. Moreover I made comparative analysis of these two responsible matrixes and as well the conclusion was drawn. Comparison of responsibility matrixes of commissioning in Great Britain and Russia is represented in the table in appendix.

For this purpose I take as an example the management of commissioning of a heating system. I have conducted a detailed comparative analysis of responsibilities of the main participants of commissioning procedure in Great Britain and the Russian Federation. The results of this analysis are given in the form of comparative table (responsibility matrix). Based on the performed research the following conclusions were made:

1. It is not usual to additionally involve a special company to manage commissioning in Russia. Some functions of Commissioning Management Organization are fulfilled by Technical Client.
2. The main works on preparation, performance and report on commissioning are done by Main Contractor (appendix 1, item 4 – 9, 12-14)
3. In Great Britain all stages of commissioning are supervised by Consultant Engineer and in Russia the same function has Technical supervisor. During commissioning the Technical supervisor performs and not just partial checking but full scope of supervision and control of commissioning process (appendix 1, item 10 and 11)
4. There is no difference in Building Services Contractor functions.
5. There is no difference at the final stage of commissioning process (appendix 1, item 15 - 17) in the responsibilities of the main participants of commissioning in Great Britain and Russia.

In conclusion I would recommend to use experience of our Great Britain colleagues in the Russian Federation to involve Commissioning Management Organization to arrange commissioning in order to facilitate the work of the suggest Main Contractor. Equally to Consultant Engineer in Great Britain might in some cases achieve fuller control over all commissioning stages by adopting some elements of Russian commissioning structure.

6 CONCLUSION

The main goal in this thesis was to find and research information about heating system commissioning procedure. Heating system commissioning is rather labor-consuming and complicated process. The procedure has several stages such as pre-commissioning, hydraulic test, flushing, starting of operation, system balancing and documentation. For heating system operation all mentioned stages should implement consecutive order. Conditions for each of the stages should be satisfied.

A special attention should be paid to frequent installation mistakes. If mistakes are not prevented then it will be impossible to balance a heating system properly. As the result of wrong balancing the water flows are redistributed incorrectly which leads to unreasonable energy consumption.

The main asset of my thesis is that the commissioning process is described not only from the engineering point of view but also from the management point of view. The management of the construction process is the important aspect during construction of different purpose buildings and facilities. Cooperation between all participants of construction process is reviewed in my thesis. This cooperation during all participants of construction process affects the quality and timeframe of facility construction. The commissioning also depends on it.

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APPENDIX (1).

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APPENDIX

TABLE. Responsibility matrix /10, 11/

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
1. Review design drawings and specification for commission requirements.	Action and advice CE. Coordinate any comments from BSC and MC.	Action and advice CE. Coordinate any comments from BSC and MC.	Advice MC of any comments.	Participate and making any comments as appropriate.	Liaise and assist all parties.	Liaise and assist all parties.	Review comments and action as appropriate.	Write to MC of any comments for commission requirements.
2. Review installation drawings and technical submissions from BSC for commissioning requirements.	Action and advice MC/CE. (in Russia MC/TS).		Prepare and submit for review. Action and any comments as instructed by MC.		Coordinate, supervise, and direct /instruct as appropriate.		Review, comment and issue directives to MC. If applicable.	

APPENDIX (2).

Appendix on 10 pages

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
3. Review installations with respect to compliance with specification and drawings intent for commissioning.	Supervise inspection of installations and issue reports to MC.	Supervise inspection of installations and issue reports with comments from BSC and TS to MC.	Receive CMO reports? And action as necessary.	Preparation reports with comments of installations .	Coordinate, supervise, and direct /instruct as appropriate.	Coordinate, supervise, and direct /instruct as appropriate.	Review, comment and issue directives to MC. If applicable.	Preparation reports with comments of installations.
4. Production of detailed coordinated commissioning programme, including revisions and updating.	Procure information from BSC. Prepare programme, discuss with MC, and issue to all parties for comment.	Review programme with regard to impact on construction process. Issue comments and approve.	Submit information, and liaise with CMO.	Submit information, and liaise with TC.	Review programme with regard to impact on construction process. Issue comments and approve.	Procure information from BSC. Prepare programme, discuss with MC, and issue to all parties for comment.	Review, comment and accept.	Review, comment and accept. Submit information, and liaise with TC.

APPENDIX (3).

Appendix on 10 pages

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
5. Production of detailed commissioning method statement, including pre-commissioning, setting to work, and interface tests.	Guide and assist in their production. Review and accept content. Liaise with MC/CE.	Control MC and TS production. Review and accept content. Liaise with MC/TS.	Discuss format and contend with CMO. Produce method statements.	Discuss format and contend with CMO. Produce method statements.	Receive, review and approve. Liaise with CE/CMO.	Preparation of detailed commissioning method statement, including pre-commissioning, setting to work, and interface tests.	Review, comment and accept.	Review, comment and accept.
6. Testing and pre-commissioning, including off-site works testing (as requested)	Procure procedure from BSC and suppliers for approval. Witness and validate tests and results.	Review, comment and approve. Carry out of sports checks.	Submit information and liaise with CMO. Complete outstanding works schedule.	Participate and control testing and pre-commissioning, including off-site works testing	Review, comment and approve. Carry out of sport checks.	Procure procedures from BSC and suppliers for approval. Witness and validate test and results. Complete outstanding works schedule.	Review, comment and accept. Spot check as required.	Review, comment and accept. Spot check as required.

APPENDIX (4).

Appendix on 10 pages

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
7. Production of project specific test sheets.	Prepare and issue pro forma sheets, including interface and performance tests.	Control works of BSC and TS. Receive review and approve.	Liaise with CMO.	Review, comment and accept.	Review, comment and approve.	Prepare and issue pro forma sheets, including interface and performance tests.	Review, comment and accept.	Review, comment and accept.
8. Monitor and report on commissioning progress.	Prepare spreadsheets to be used to monitor all progress. Issue and update at regular intervals.	Receive and review reports, and circulate.	Assist CMO during monitoring progress.	Assist MC during monitoring progress.	Receive and review reports, and circulate. Monitor progress, and mange any programme changes.	Prepare spreadsheets to be used to monitor all progress. Issue and update at regular intervals. Monitor progress, and mange any programme changes.	Review and comment.	Review and comment.

APPENDIX (5).

Appendix on 10 pages

Activity description	Commission manages organization (CMO)	Technical client (TC)	Building services contractor (BSC)		Main contractor (MC)		Consultant engineer (CE)	Technical supervision (TS)
	Great Britain	Russia	Great Britain	Russia	Great Britain	Russia	Great Britain	Russia
9. Progressive installation tests and pre-commission.	Monitor, witness, and ensure accurate recording of all results, in accordance with method statements.	Monitor progress.	Implement testing, prepare records, and demonstrate.	Review, comment and accept. Spot check as required.	Monitor progress. Carry out of sport checks.	Implement testing, prepare records, and demonstrate. Carry out of sport checks. Monitor, witness, and ensure accurate recording of all results, in accordance with method statements.	Review, comment and accept. Spot check as required	Review, comment and accept. Spot check as required.

APPENDIX (6).

Appendix on 10 pages

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
10. Pipework system flushing, cleaning and dosing	Monitor, witness, and ensure accurate recording of all results, in accordance with method statements.	Monitor and follow of progress	Implement activities, prepare records, and issue analysis reports.	Review, comment. Spot check as required	Monitor progress. Carry out of sport checks.	Implement activities, prepare records, and issue analysis reports. Carry out of sport checks. Monitor, witness, and ensure accurate recording of all results, in accordance with method statements.	Review, comment and accept. Spot check as required	Review, comment. Full check

APPENDIX (7).

Appendix on 10 pages

Activity description	Commission manages organization (CMO)	Technical client (TC)	Building services contractor (BSC)		Main contractor (MC)		Consultant engineer (CE)	Technical supervision (TS)
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
11. Setting to work of plant and systems, commissioning and performance testing in accordance with programme.	Direct BSC, giving guidance as necessary. Witness activities? And ensure accurate recording of results.	Monitor and follow of progress	Execute all planned activities. Demonstrate selected items to MC/CE as directed.	Witness activities. Spot check as required	Monitor progress. Witness as required.	Execute all planned activities, demonstrate selected items to TS and BSC and TC as required. Ensure accurate recording of results.	Carry out of sport checks and witness activities on a selected basis.	Witness activities. Full check.

APPENDIX (8).

Appendix on 10 pages

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
12. Prepare testing and commissioning reports incorporating all plant and system result.	Action and submit to MC.	Monitor progress	Liaise with MC and supply all relevant documentation. Action adjustment to system performance as advised or instructed by MC.	Review, comment and accept. Issue directives to MC as appropriate.	Monitoring progress. Issue directives/instructions to BSC as appropriate.	Action and submit to TC. Issue directives/instructions to BSC as appropriate.	Review, comment and accept. Issue directives to MC as appropriate.	Liaise with MC and supply all relevant documentation. Action adjustment to system performance as advised or instructed by MC.

APPENDIX (9).

Appendix on 10 pages

Activity description	Commission manages organization (CMO)	Technical client (TC)	Building services contractor (BSC)		Main contractor (MC)		Consultant engineer (CE)	Technical supervision (TS)
	Great Britain	Russia	Great Britain	Russia	Great Britain	Russia	Great Britain	Russia
13. Prepare models for record documentation/drawings and O&M manual format.	Monitor preparation and comment on submissions via MC.	Monitor preparation and comments and control of relationship MC and BSC.	Submit information and liaise with CMO.	Submit information and liaise with MC.	Monitoring progress. Issue directives/instructions to BSC as appropriate.	Preparation of models for record documentation/drawings and O&M manual format. Liaise with BSC.	Review, comment and accept.	Review, comment and accept.
14. Statutory demonstration	Manage and coordinate the demonstration of all life safety systems as required, to the Statutory	Monitor progress. Attend demonstrations	Execute all planned activities in conjunction with MC	Manage and coordinate the demonstration of all life safety systems as required, to the Statutory	Monitor progress. Attend demonstrations	Execute all planned activities in conjunction with BSC	Review, comment and attend demonstration	Review, comment and attend demonstration

APPENDIX (10).

Appendix on 10 pages

Activity description	**Commission manages organization (CMO)**	**Technical client (TC)**	**Building services contractor (BSC)**		**Main contractor (MC)**		**Consultant engineer (CE)**	**Technical supervision (TS)**
	Great Britain	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**	**Great Britain**	**Russia**
15. Prepare final record documents	Receive, collate, and comment on submissions by BSC. Advise on CDM issues.		Submit record documents for approval, and liaise with MC. Update to suit comments.		Issue to client, and coordinate all comments with BSC.		Review, comment and accept.	
16. Client /end user awareness and liaison	Coordinate activities and advise the client of all potential operation implications		Liaise with MC and be responsive to the client /end user's needs.		Liaise with client /end user		Monitor status	
17. Client /end user training	Coordinate and manage BSC contractual obligations. Prepare programme		Liaise with CMO (TC). Coordinate the activities of specialist suppliers		Monitor progress and participate. Liaise with client /end user		Review, comment and accept. Participate as required	