

# Improving the quality of installation of preinsulated pipelines of heat supply systems

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**Abstract.** One of the most important directions of Russia's economic and energy strategy is to increase the efficiency in the field of heat supply. One of the options for solving this issue is using preinsulated pipelines, such as steel pipes in polyurethane foam polyethylene insulation. The experience of their application indicates several disadvantages associated with defects in pipes in polyurethane foam insulation and installed pipelines. The studies carried out made it possible to identify the main defects and inconsistencies in the manufacture and installation of preinsulated pipelines and the reasons for their occurrence. Following this, the authors have developed a set of operations and control tools during the installation of pipes in polyurethane foam PE insulation, clarifying the requirements of the input, operational and acceptance types of control, which contribute to improving the quality of the finished product, which was the purpose of this work.

## 1 Introduction

Increased energy saving and energy efficiency requirements contribute to the introduction of new materials and technologies into construction practice, which can significantly reduce the consumption of energy and material resources during the operation of permanent and linear construction facilities and improve their quality [1-3]. An analysis of the implementation of Russia's energy strategy for the period up to 2020 shows that the use of low-quality thermal insulation materials in the process of central heating networks building is one of the main problems of energy conservation. Up to the date, the implementation of the energy strategy for the period up to 2020 cannot be considered satisfactory, since the heat losses of the central heating system have not been reduced by 60%, the production of heat energy has been increased for 34% [4]. This is confirmed by statistics [4], indicating an increase in the depreciation of the centralized heat supply fund from 65% to 70% since 2010 and the need for major repairs or complete replacement of 82% of heating networks. Moreover, their actual heat loss is 30% for the present moment. In this regard, one of the most important areas of economic and energy policy in Russia is to improve efficiency in the field of heat supply.

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Analysis of literature data indicates an active study of the issues of improving the production, installation and operation [12, 13] of pipelines in polyurethane foam PE insulation [14–16]. The positive experience of pipelines maintenance in polyurethane foam PE insulation in Germany and Denmark should be noted [17]. The works [18–21] show the discrepancy between the standard and calculated heat energy losses for different types of pipe insulation. Studying the quality control system during the construction of external water supply and sewerage systems is studied in the present work [22]. The issues of optimization of the thickness of polyurethane foam insulation of pipelines in heat supply systems were studied by the authors in the works [9, 23].

The production process of pipes in polyurethane foam PE insulation includes the following technological operations: primary control of raw materials and materials; the processing of steel pipes and fittings; installation of centering rings made of low-pressure polyethylene (HDPE) and copper wire ORMS; installation of a steel pipe into a PE pipe; installation of filling plugs on the ends of pipes; preliminary thermostatic treatment of the assembled pipe structure to improve the adhesion of polyurethane foam to the steel pipe; dosing and feeding of PPU components through the plug hole; quality control of manufactured products; marking of finished products with accompanying documentation; transfer of finished products to the warehouse.

The presence of quality control in the manufacture of pipes in polyurethane foam PE insulation does not exclude the occurrence of defects, which indicates the need to analyze and systematize them to improve production efficiency, which is one of the tasks of this work.

Installation of pipes with polyurethane foam PE insulation includes the following stages: pipes surface conditioning from insulation at a distance of up to 300 mm from each edge, making a welded joint of pipes, completing with a heat shrink sleeve, filling the cavity under the sleeve with polymer, followed by heating and settling the sleeve in place, ensuring the tightness of the outer sheath. Pipes with polyurethane foam PE insulation are welded following GOST 30732-2001( Russian National State Standard).

Failure to comply with the installation technology, namely the sealing and insulation of joints when installing pipes with polyurethane foam PE insulation, leads to a violation of insulation in the most vulnerable places of any pipelines - the joints of the pipe and the shaped element. The result of this will be the occurrence of premature external corrosion of the pipe [24], a decrease in durability [25], followed by the failure of the pipeline or carrying out constant expensive repair work [26, 27].

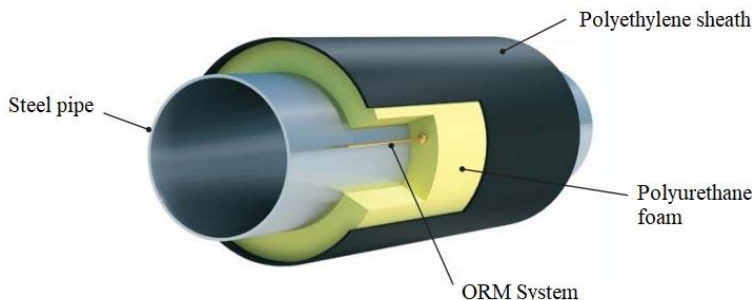
The performed analysis indicates the need to carry out research to identify pipe defects in polyurethane foam PE insulation formed during the manufacturing and installation process, and the reasons for their occurrence, with the subsequent development of the composition of operations and control means during their installation, which is the purpose of this work.

One of the options for solving this issue is the use of preinsulated pipelines in the central heating system, such as steel pipes in polyurethane foam (PPU) polyethylene (PE) insulation [5, 6], including the use of resource-saving polymer compositions [7]. Their use will significantly reduce the time and specific damage of pipelines and increase the efficiency of construction of linear facilities compared to the traditionally used channel pipelines using mineral wool [8–10].

The advantage of steel pipes in polyurethane foam PE insulation is the presence of an operational remote monitoring system (ORMS), which ensures timely identification of facts and places of defects occurrence, which makes it possible to reduce heat carrier losses, increase its energy potential and, as a result, reduce heat energy costs. However, it should be noted that this system has disadvantages due to inaccurate determination of the place of depressurization of the PUF cover layer and the area of distribution of this process [11].

## 2 Methods

The object of the present research are pipelines in polyurethane foam PE insulation, manufactured in the factory and having a multilayer structure "pipe in pipe" [28, 29] (Figure 1).



**Fig. 1.** Elements of the pipeline in polyurethane foam insulation

As internal pipes, we used hot-deformed round steel pipes for general purposes following Russian National Standard 8732-78, longitudinal electric-welded pipes following Russian National Standard 10705-80, longitudinal welded steel pipes following Russian National Standard 20295-85. As outer pipes, protective shells made of HDPE are used following Russian National Standard 18599-2001, Russian National Standard 16338-85.

Polyurethane foam insulation is a two-component system consisting of polyol and polyisocyanate, applied by pouring a liquid substance into the tube space of steel and polyethylene pipes.

The subject of the research is the quality control system for manufacturing and installation of pipelines in polyurethane foam PE insulation. At the first stage of the research, the analysis of the technical condition and energy efficiency of the existing central heating networks was carried out; the technologies for the manufacturing and installation of pipes in polyurethane foam insulation, the issues of improving the production of pipelines, improving the quality of their installation and operation, the relationship between defects and thermal characteristics of buildings were studied. Analysis and generalization as the research methods were applied.

At the second stage, by the method of visual and instrumental control, the study of pipes in polyurethane foam PE insulation at the manufacturing plant and at the construction site during installation was carried out. By the method of systematization, their main defects and damages revealed in the process of manufacturing and installation were classified.

At the third stage, using the obtained quantitative data on the defects types and the reasons for their occurrence, the authors systematized the quality control requirements for the manufacturing process and installation of pipes in polyurethane foam PE insulation.

To determine the geometric deviations, a set for visual and measuring control was used [22, 30], which included a steel ruler, caliper with a depth gauge, a testing square, etc.

## 3 Results and Discussion

The most typical defects and the reasons for their occurrence, which occur during the production of pipes in polyurethane foam PE insulation, are shown in Table 1 and Figure 2.

**Table 1.** Defects and the causes of their occurrence revealed during the manufacturing of pipes in polyurethane foam PE insulation.

Defect title	Possible causes
Inconsistency of the wall thickness of steel pipes in polyurethane foam PE insulation (108 × 5 mm - fact 108 × 4 mm)	Violation of incoming quality control
Peeling of polyurethane foam from the steel pipe and/or from the shell	Violation of the technology: the polyethylene shell did not go through the coronation process; mechanical stress during transportation
Remote monitoring system does not work	Internal break in copper wire; Touching the copper wire against the wall of the steel pipe inside the polyurethane foam; copper wire does not meet the requirements of Russian National State Standard
The thickness of the polyurethane foam layer does not comply with Russian National State Standard 30732-2006	Technology violation: the diameter of the PE shell-pipe is not accepted correctly
Misalignment of steel and polyethylene pipes	Technological violation: the use of centering supports of the wrong size
Increased porosity, brittleness of polyurethane foam at the ends of pipes	Violation of technology, inadequacy of the quality of the materials used
The length of non-cast ends of steel pipes exceeds the permissible values	Error when choosing the length of the polyethylene sheath

The analysis of the results given in Table 1 indicates the need to supplement the operations and controls scope during the installation of the pipes under study, shown by the authors in Table 3.



**Fig. 2.** Peeling of polyurethane foam from the polyethylene shell

Systematization of pipes defects and damages in polyurethane foam PE insulation during their installation is shown in Table 2.

**Table 2.** Defects and damages revealed during the installation of pipes in polyurethane foam PE insulation

Defect title	Cause of occurrence
Lack of product labeling	Violation of the technological process in the production of pipes; deliberate removal of markings
Scratches, roughness of the polyethylene shell of pipes in polyurethane foam insulation	Violation of the rules of transportation, loading and unloading operations
Cracking on the surface of polyethylene pipes	Violation of storage rules; violation of the rules of loading and unloading operations; the use of polyethylene of an inappropriate grade (Russian National State Standard 30732-2006)
The thickness of the thermal insulation of fittings does not correspond to the thickness of the thermal insulation of pipes	Error when choosing the diameter of the polyethylene shell of pipes and fittings
Soaking of polyurethane foam at open ends of pipes	Violation of storage rules
Lack of tightness of the pipeline	Defects of welded seals of steel pipes
Difficulty mounting the heat-shrinkable sleeve on the pipe	Non-conformity of the sleeve diameter, violation of storage rules
Remote monitoring system does not work	Violation of installation rules: incorrect connection or broken wires

The analysis of Table 2 shows that the cause of the above-mentioned defects and damages are violations of production and installation technology and violations of quality control during construction and installation works. On this basis, the authors have systematized the requirements for quality control of the manufacture and installation of pipes in polyurethane foam PE insulation (Table 3), ensuring compliance with the production technology and improving the quality of finished products.

**Table 3.** Scope of operations and means of control during the installation of pipes in polyurethane foam PE insulation

Stages of work	Controlled operations	Control (method, scope)	Documentation
Preparatory work	Check: availability of a quality document for materials, tags, labels, markings on pipes;	Visual	Passports, certificates, general work log
	quality control of supplied pipes: wall thickness, ORMS wires, pipe integrity, polyurethane foam, etc.	Measuring, technical inspection	
	availability of a quality document for materials, tags, labels, markings on pipes;	Visual	
	quality control of supplied pipes: wall thickness, ORMS wires, pipe integrity, polyurethane foam, etc.	Measuring, technical inspection	
Installation of pipelines from PPU pipes	Control: quality and sequence of installation of PPU pipes;	Technical inspection	General work log
	quality of welded joints of steel pipes;	Measuring	
	coincidence of the thickness of thermal insulation of fittings and pipes	Visual	
	working condition of remote monitoring system	Measuring	
Acceptance of work performed	Check: the quality of the work performed;	Measuring, technical inspection	General work log, act of acceptance of work performed, executive scheme, test report of pipelines
	testing of pipelines;	Measuring, technical inspection	
Control and measuring tool: level; density meter, thickness meter, flaw detector			
Input and operational control is carried out by foreman			
Acceptance control is carried out by quality service workers, foreman (foreman), representatives of the customer's technical supervision			

Control tools have been developed to install pipes in polyurethane foam PE insulation, clarifying the requirements of the input, operational and acceptance types of control, contributing to the improvement of the quality of the finished product [31].

The performed studies can be useful in carrying out studies to improve the quality of pipelines in polyurethane foam PE insulation as part of the implementation of a strategy for increasing energy efficiency and reliability of central heating networks.

## 4 Conclusions

1. The performed analysis of literature data indicate the need to improve the efficiency of central heating systems, to carry out research to identify defects in the manufacture and installation of pipes in polyurethane foam PE insulation, the reasons for their occurrence, followed by the development of the composition of operations and controls during their installation.

2. The technology of production and installation of pipes in polyurethane foam PE insulation has been studied, the main technological processes of production and installation of pipes are given. The decline in the quality of manufacture and installation of pipes in

polyurethane foam PE insulation is revealed. It is shown that the causes and damages of the defects are violations during the execution of technological processes of manufacturing, transportation, storage and installation of preinsulated pipes.

3. The composition of operations and control means for the installation of pipes in polyurethane foam PE insulation based on the identified defects formed during the manufacture and installation of pipes, and the determination of the causes of their occurrence, which will improve the quality of installation of preinsulated pipelines and the efficiency of heat supply systems has been developed.

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