LIFE CYCLE MANAGEMENT OF CONSTRUCTION FACILITIES
УПРАВЛЕНИЕ ЖИЗНЕННЫМ ЦИКЛОМ ОБЪЕКТОВ СТРОИТЕЛЬСТВА

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Development of the Structure of the Life Cycle of the Heating System of a Construction Facility

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Abstract

Introduction. The heating system is an integral part of the construction site. In the article, the author explores the life cycle of a heating system, a complex system of engineering and technical support for buildings and structures, the elements of which must function stably, efficiently and fully throughout the heating period during the entire service life. The productive operation of the heating system is laid at the stage of its design, installation, adjusted and maintained at the stages of operation and modernization. Therefore, studying the life cycle of a heating system is an important scientific and practical task, and managing the stages of the life cycle becomes important, as it allows for efficiency, adaptability, cost-effectiveness and reliability.

Materials and methods. The authors have developed the structure of the life cycle of a building heating system using methods of analogy, comparative analysis and synthesis based on scientific and practical research results. The study focuses on the water heating system of residential and public buildings. The purpose of the work is to create a model of the life cycle for effective management of its stages and stages.

Results. The study of the heating system helped to identify five stages of its operation (pre-design, design, operation, modernization and disposal) and to create a life cycle structure. In the future, this will make it possible to create an energy-efficient, reliable and economical system that meets modern operational requirements, improve the quality of its maintenance, and simplify the management process.

Discussion and conclusion. The life cycle of a heating system includes all stages from design to modernization. Proper management of these stages ensures efficient operation of the system, increasing comfort and reducing costs. An integrated management approach makes it possible to maximize the heating potential. A systematic study of each stage helps to choose the optimal system that meets the criteria of efficiency, safety and cost-effectiveness. The structure of the life cycle allows one to create a single digital model for intelligent management of an object at all stages.

Keywords: life cycle, heating system, life cycle management, construction site

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Оригинальное эмпирическое исследование

Разработка структуры жизненного цикла системы отопления строительного объекта

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Аннотация

Введение. Система отопления является неотъемлемой частью строительного объекта. В статье авторы исследуют жизненный цикл системы отопления — сложной системы инженерно-технического обеспечения зданий и сооружений, элементы которой должны стабильно, эффективно и полноценно функционировать на протяжении отопительного периода в течение всего срока эксплуатации. Продуктивная работа системы отопления закладывается на этапе ее проектирования, монтажа, корректируется и поддерживается на этапах эксплуатации и модернизации. Следовательно, изучение жизненного цикла системы отопления представляет собой важную научную и практическую задачу, а управление этапами жизненного цикла становится важным, т.к. позволяет обеспечить эффективность, технологичность, экономичность и надежность. Цель работы — создать модель жизненного цикла для эффективного управления его этапами и стадиями.

Материалы и методы. Авторы разработали структуру жизненного цикла системы отопления зданий, используя методы аналогии, сравнительного анализа и синтеза на основе научных и практических результатов исследований. Исследование сфокусировано на системе водяного отопления жилых и общественных зданий.

Результаты исследования. Исследование системы отопления помогло выделить пять этапов ее функционирования (предпроектная подготовка, проектирование, эксплуатация, модернизация и утилизация) и создать структуру жизненного цикла. В дальнейшем это дает возможность создать энергоэффективную, надежную и экономичную систему, отвечающую современным требованиям эксплуатации, повысить качество ее обслуживания, а также упростить процесс управления ею.

Обсуждение и заключение. Жизненный цикл системы отопления включает все этапы от проектирования до модернизации. Грамотное управление этими этапами обеспечивает эффективную работу системы, повышая комфорт и снижая расходы. Комплексный подход к управлению позволяет максимально использовать потенциал отопления. Системное исследование каждого этапа помогает выбрать оптимальную систему, соответствующую критериям эффективности, безопасности и экономичности. Структура жизненного цикла позволяет создать единую цифровую модель для интеллектуального управления объектом на всех стадиях.

Ключевые слова: жизненный цикл, система отопления, управление жизненным циклом, строительный объект

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Introduction. The concept of system management of the stages of the life cycle is commonly used in lots of areas of human economic activity in order to increase the efficiency, manufacturability, cost-effectiveness and reliability of an object (project, system, item or product) [1–3]. In the construction industry, this concept is also ubiquitous and is oftentimes applied mostly to buildings and structures, i.e. capital construction facilities [4, 5].

In compliance with the basic provisions [6], the life cycle of a building or a structure is thus conceptualized as the period when engineering surveys, architectural and construction design, construction (including conservation), operation (including ongoing repairs), reconstruction, major repairs, and demolition of a building or a structure take place. The authors of the study [7] call the life cycle of a building the time from the moment of justification of the need for construction to the onset of the economic inexpediency of its operation and identify eight of its stages, beginning with the feasibility study of the construction of the facility and finishing with that of its reconstruction.

Regarding construction sites, engineering systems are the foundation of their infrastructure and are designed to provide comfortable and safe living conditions. However, the issues of modeling the life cycle of engineering systems are not paid due attention to in scientific studies. For instance, based on the "circle of quality", the life cycle of heat supply systems is set forth using the example of a cogeneration plant for a thermal power plant [8], and a methodology for developing a digital information model of heat supply system elements at all stages of its life cycle is shown [9, 10]. The study [11] describes an algorithm for increasing the life cycle of air conditioning systems and [12] develops a model for managing the life cycle of the ventilation system of a construction facility.

As an integral part of buildings or structures, heating systems ensure the required values of microclimate parameters during the cold season are complied with. However, the conducted analytical studies indicate a considerable lack of scientific research dedicated to comprehensive studies of the life cycle of heating systems. Hence investigating the stages of the heating system life cycle model to optimize costs, improve quality and efficiency, as well as ultimately manage it is an crucial scientific and practical task. The productive operation of the heating system is laid at the stage of its design and installation, adjusted and maintained at the stages of operation and modernization, while each stage involves implementing a series of works to achieve certain outcomes.

The lack of a holistic approach to studying the life cycle causes a significant decrease in the quality of decisions made and an increase in operating costs, which is yet again indicative of the need for a comprehensive study of all stages of the heating system as a single technological process.

Based on a detailed study of these stages, the structure of the life cycle of a heating system is set forth as a complex system of engineering and technical support for buildings and structures whose elements must function stably, efficiently and fully throughout the heating period during the entire service life. Knowledge of specific features of each stage of the life cycle makes it possible to manage them and ensure maximum efficiency, adaptability, cost-effectiveness as well as reliability of the system.

Materials and Methods. The use of methods of analogy, comparative analysis and synthesis based on the generalization of scientific and practical research results enabled the authors to design a model of the life cycle of the heating system of buildings and structures as an integral part of a construction site. At the same time, the object of the study was a water heating system, while the objective of the study was to develop a model of the life cycle of a water heating system for residential and public buildings. To this end, the main stages of the life cycle and their stages are identified and analyzed in order to be able to manage them.

Research Results. Conceptualizing the heating system as one of the engineering and technical support systems for buildings and structures, the authors assume that the life cycle of a heating system is a series of interrelated, interdependent and consistent processes of design, installation, operation, modernization and recycling of a system supplying heat to rooms and maintaining the required temperatures during the cold season.

Choosing a schematic diagram of a heating system depends on a whole host of factors: the purpose of the room, the type of a coolant, the mode of operation of a heating system, the method of movement of the coolant, the relative location of the main elements, etc. If a residential or public building is assumed to be as a construction object, a water heating system is the most preferable option according to the set of requirements for heating systems. Water heating systems are extremely diverse (Fig. 1) with each having its own advantages and disadvantages. Accounting for all of its features and customer requirements, choice of the optimal system option for a specific facility is determined by the operating conditions, technical and economic requirements.

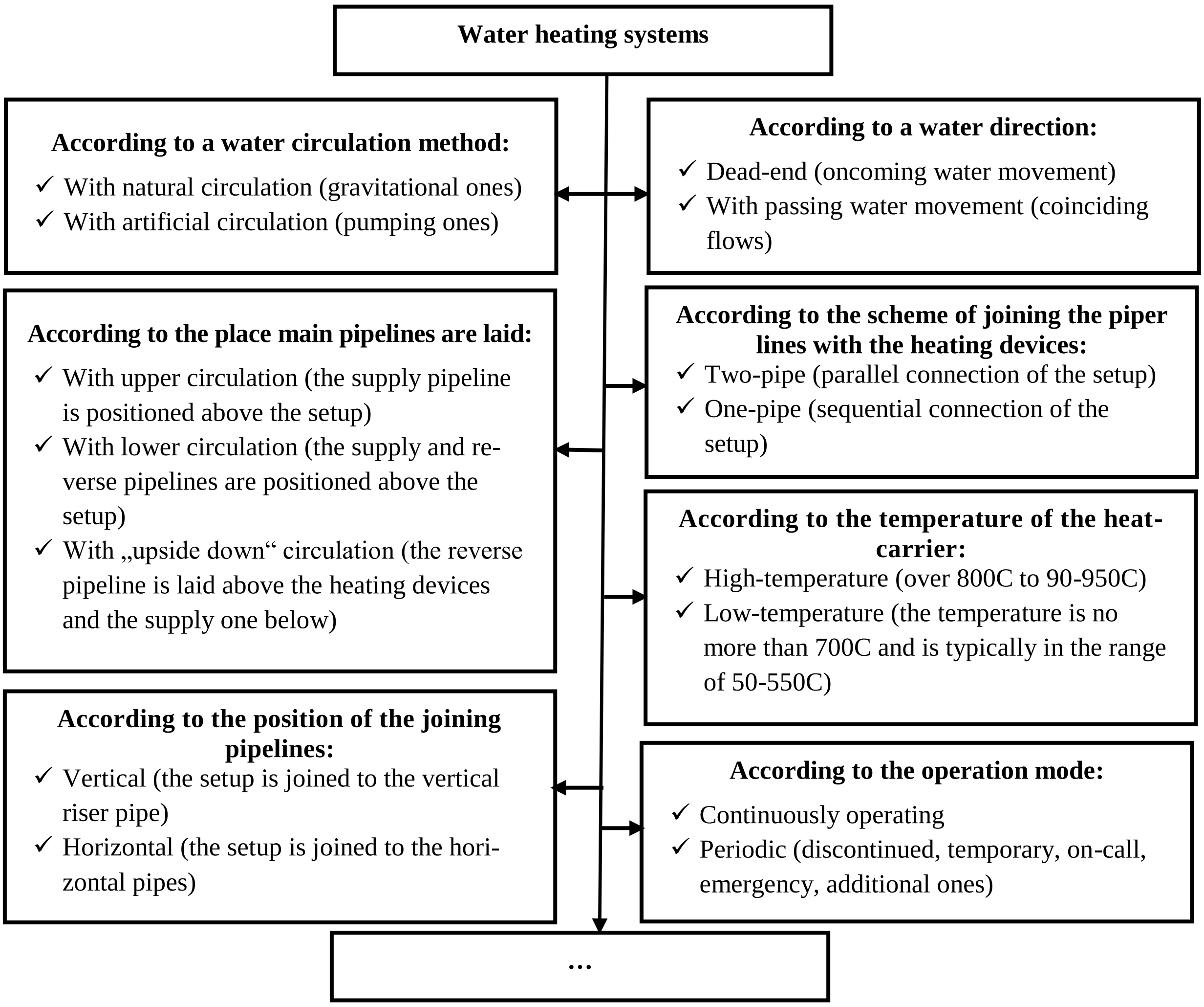

Fig. 1. Classification of water heating systems

Each of the system options assumes the presence of basic and additional equipment (Fig. 2) [13–15] whose composition and configuration features are dependent on the selected water heating system option.

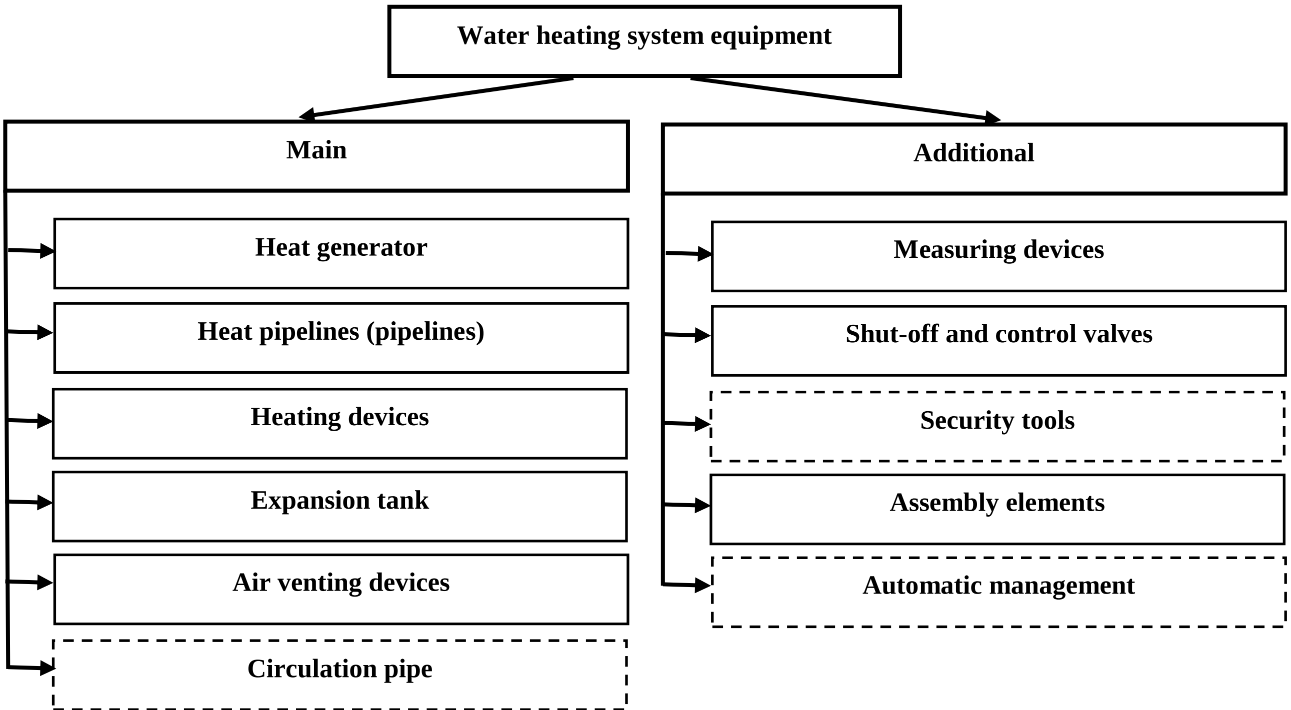

Fig. 2. Water heating system equipment

A range of possible design and technical solutions for water heating systems, a continiously growing variety of basic and additional equipment poses some difficulties in the design, installation and operation, as it requires accounting for numerous parameters and characteristics of each element of the system. The problem of choosing the optimal water heating system, which must comply with the comprehensive criteria of efficiency, safety and economic feasibility, is increasingly relevant.

Therefore the study of the stages of the life cycle of heating systems appears to be methodologically justified and necessary in practical terms to ensure efficient and reliable operation in the long term.

The study of the heating system involves identifying five stages of its operation: pre-design preparation, design, operation, modernization and recycling. Each of them is characterized by implementation stages that are critical to the current state of the heating system, a series of of necessary works and their expected outcomes.

The pre-design preparation stage is when the feasibility of designing a heating system and collecting initial information is identified. This stage includes two consecutive steps:

Step 1 — Request and collection of initial data for design (information on the climatic and meteorological conditions of the construction area, calculated parameters of outdoor and indoor air, information on heat supply sources, parameters of heat carriers, etc.), including initial data from related sections of the design documentation (general plan of a building or a structure, plans, sections, etc.).

Step 2 — development of technical specifications for the design (accounting for the category and functional purpose of the building or a structure).

The design stage of the heating system is critical in designing the engineering infrastructure of a construction facility. It is at this stage that the main parameters of the future system - efficiency, safety and economic feasibility - are specified. The design stage of the heating system life cycle involves the following steps:

Step 1 (3) — analysis of the initial data, followed by the thermal engineering calculation of enclosing structures, calculation of heat losses and identifying the thermal capacity of the heating system as well as of the schematic diagram of the heating system by hydraulic and its thermal calculation as well as the composition, and selection of the basic and additional equipment.

This step is key for the formation of a technically sound and cost-effective solution providing the required indoor climate parameters with optimal energy consumption.

Step 2 (4) — preparation of an explanatory note and development of the graphical part of the project based on the results of calculations.

The result of this stage of the life cycle of the heating system is the design of a future heating system for a construction site.

The stage of technical operation starts with installing the heating system, involves routine maintenance, monitoring the condition of the equipment and timely troubleshooting through the course of the actual system operation. The third stage includes four steps.

Step 1 (5) — assembly, i.e. installation of a heating system by an assembly company involving that of heating devices, pipes as well as connecting the system to a heat source, etc.

Step 2 (6) — pre-launching and launching aimed at checking, configuring and testing the heating system (checking whether it is in compliance with design parameters, performing hydraulic tests, adjusting and fixing the pumping and boiler equipment, etc.).

Step 3 (7) — actual operation of the heating system in an optimal operating mode (efficient heating is combined with cost minimization) that entails coordinated and balanced operation of all its elements during the heating period throughout the entire service life.

Step 4 (8) — scheduled maintenance and preventive maintenance aimed at keeping the heating system in working condition during the heating period throughout its entire service life (prevention, detection and elimination of technical malfunctions and errors to ensure long-term trouble-free use).

Physical wear and outdated heating system elements, a decrease in its heating capacity, changes in the consumers' thermal energy needs, as well as the need to reduce energy consumption and increase the energy efficiency of buildings or structures over time call for the next stage of the life cycle — *modernization* of the heating system. Modernization entails updating the heating system by replacing „physically and morally" outdated components with modern and more energy efficient ones by means of introducing automation and control systems. The modernization stage includes several ones.

Step 1 (9) — formation of technical specifications for modernization, study of modernization options of the heating system and a detailed study of suggested technical solutions (replacement of heating appliances, installation of individual thermostats with an air temperature sensor, etc.).

Step 2 (10) — choosing and implementing a modernization option.

The final stage of the life cycle of the heating system is *the stage of recycling* when the maximum condition of the operational characteristics of the equiment is achieved. In this case, the life cycle of the heating system is completed, the outdated equipment is dismantled and recycled.

Under optimal operating conditions, regular as well as scheduled preventive maintenance, the life cycle of a water heating system is 40–50 years, in actual fact it reaches 25–30 years [16, 17], which corresponds to the minimum service life. These are average figures accounting for the average duration of operation of the main elements of the heating system (for heat generators — 15–25 years, for heating appliances — 20–40 years, heat pipelines — 20–40 years, shut — off valves — 15–20 years, expansion tanks – 20 years, circulation pumps — 10-15 years, heat exchangers — about 20 years).

A detailed study of the stages and stages of the life cycle of a heating system allows one to tackle a few important tasks:

1) forming a comprehensive view of the heating system, which is conducive to making informed management decisions and improving the quality of its operation;

2) capacity to evaluate the efficiency of the system at all of the stages of its existence (analysis, correction and selection of design solutions, assessment of the quality of the installation and subsequent operation);

3) capacity to identify potential problems in a timely manner and prevent them from escalating;

4) cost optimization not only at the stage of system design and installation, but also at the operational stage due to competent maintenance and repair planning based on the actual data on the current condition of the system;

5) extending the service life of the equipment;

6) reducing possible associated emergencies;

7) the capacity to predict operation and modernization (if needed).

Ultimately, a systematic study of the heating life cycle enables an energy-efficient, reliable and economical system to be designed in compliance with the modern operational requirements, improves the quality of its maintenance and makes it considerably easier to manage.

Discussion and Conclusion. The life cycle of a heating system covers all of the stages of its existence, from design and installation to operation and modernization. Understanding and managing these stages appropriately makes it possible to ensure efficient and cost-effective operation of the heating system of buildings and structures, increasing comfort and reducing operating costs.

Life cycle management of a heating system is key to ensuring its efficient and cost-effective operation throughout its entire service life. An integrated approach, including design, installation, operation, modernization and management, maximizes the potential of the heating system, providing comfort and reducing operating costs.

A comprehensive study of each stage of the life cycle of a heating system provides the opportunity to choose the optimal water heating system in compliance with the comprehensive criteria of efficiency, safety and economic feasibility as well as the capacity to predict its technical condition, plan repairs and modernization contributing to increased reliability and economic efficiency in the long run.

Apart from all of the above, the life cycle model provides the opportunity to create a single information (digital) model and allows for intelligent dynamic control at all of the operation stages — from engineering surveys to reconstruction and modernization.

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EP Lysov: formation of the basic concept, analysis of the research results, correction of the conclusions, graphic design, revision of the manuscript.

ON Paramonova: goals and objectives of the research, analysis of the research results, correction of the conclusions.

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О.Н. Парамонова: цели и задачи исследования, анализ результатов исследований, корректировка выводов.

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