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ORGANIZATIONAL SYSTEM OF REQUIREMENTS FOR THE CONSTRUCTION OF RADIATION-HAZARDOUS FACILITIES

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Abstract:

Energy-related buildings and structures are designed to meet safety requirements. The greatest danger is a radiation. In Russia there is an advanced system of regulatory documents, which contain thousands of requirements for radiation and fire safety, and layout solutions. During design and construction it is necessary to use the organizational system of checking and compliance of various requirements to the object. An important part of the system is the subsequent processing of requirements at the stages of design and project implementation. The process of processing the requirements consists of research, analysis, formulation and approval of the requirements, followed by tracking their performance in the project, at the construction site and during operation. In the development of basic and detailed documentation, in the construction the list of requirements is used for setting the tasks of the customer, the decision of their designer, the implementation of decisions by builders and installers.

Keywords: Design and Construction; Radiation-Hazardous Facilities; Design and Construction Requirements; Atomic Energy Related Buildings.

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1. Introduction

Modern building facilities are very complex structures. Many of them have a radiation hazard, for example, nuclear power plants, other nuclear energy facilities, medical centers, radioactive waste disposal facilities, etc. [1].

The largest national generating company "Rosenergoatom" operates 35 power units at ten nuclear power plants. Their total capacity is 27.9 GW, and electricity generation is 18.9% of the total electricity produced in the country. In 2018, the first floating nuclear power plant was manufactured. The use of atomic energy reduces the need for organic fuel and the emission of carbon dioxide, which is a greenhouse gas [2].

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The company "Radon" operates in Russia since 1961. It provides centralized collection, transportation, processing and storage of radioactive waste. The company conducts radiation monitoring of construction sites, radiation-hazardous facilities, and the situation of the natural environment. During the construction and operation of storage and recycling facilities must comply with safety requirements [3].

For the needs of modern medicine it must be applied the cyclotrons, gamma cameras, equipment for the production and storage of radioactive pharmaceuticals, positron emission computer tomography etc. For their accommodation and services are essential specially designed medical centers, the security of which must meet strict safety requirements.

Thus, radiation safety requirements, along with other requirements, must be observed throughout the life cycle of the object during design, construction, operation and decommissioning.

2. Regulatory Documents on Safety in Russia

During design and construction of buildings and structures the number of different requirements is calculated in thousands. All requirements for the construction object can be divided into the following classes:

- Safety requirements
- Functional requirements, requirements for building layout solutions
- Technical requirements for strength, stability, durability
- Economic and energy efficiency requirements
- Social requirements and amenities, including the requirements of the disability people
- Environmental requirements
- Architectural and art requirements
- Requirements for transport accessibility, etc.

Types of hazards can be divided into natural and manmade hazards. The main types of natural hazards in construction are:

- Seismic hazard;
- Dangerous impact of soil (landslides, karst, subsidence, etc.);
- Dangerous impact of water (tsunami, mudflow, flood);
- Dangerous atmospheric impact (hurricanes, typhoons, tornadoes, tornadoes, lightning strikes, exceeding the snow load);
- Excessive solar activity.

Dangerous impacts of manmade hazards are:

- Radiation hazard;
- Fire and explosion hazard;
- Electrical voltage;
- Dynamic mechanical impact (falling aircraft, hitting vehicles, terrorist threat, technological equipment accident);
- Static mechanical action (exceeding the static load);

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- Acoustic, electromagnetic, chemical, temperature and humidity effects, dusty air, water pollution, etc.

The general scheme of safety ensuring of building object is presented on figure 1.

During the design and construction much attention is paid to radiation safety. In the Russian Federation there is a large complex of regulatory documents to ensure the requirements of natural, man-made and especially radiation safety. The main documents are Federal laws that contain the basic state requirements for various types of security:
Law of 28.12.2010 No. 390-FZ "On safety"
Law of 10.01.2002 No. 7-FZ "On the protection of the environment"
Law of 21.11.1995 No. 170-FZ "On the use of atomic energy"
Law of 09.01.1996 No. 3-FZ "On radiation safety of the population"
Law of 30.03.1999 No. 53-FZ "On sanitary and epidemiological welfare of the population"
Law of 30.12.2009 No. 384-FZ "Technical regulations on safety of buildings and structures"
Law of 22.07.2008 No. 123-FZ "Technical regulations on fire safety requirements"
Law of 21.07.1997 No. 116-FZ "On industrial safety of hazardous production facilities", etc.

For radiation safety more detailed requirements are contained in the Federal regulations and rules in the sphere of atomic energy use approved by Federal service for ecological, technological and nuclear supervision:
NP-038-11 "Common provisions for the safety of radiation sources"
NP-058-14 "Safety in radioactive waste management"
NP-019-15 "Collection, processing, storage and conditioning of liquid radioactive waste. Safety requirements", etc.

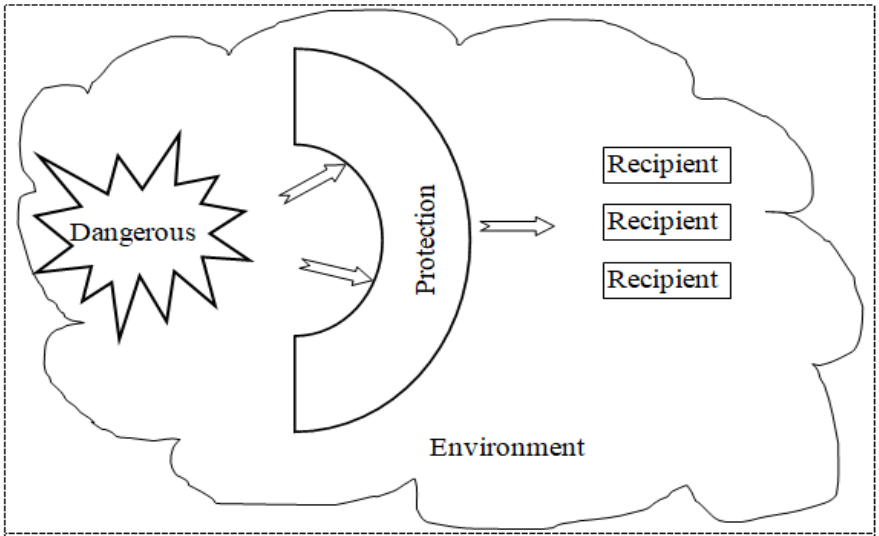

Figure 1: The common scheme of safety ensuring

Activities in the sphere of nuclear energy use in Russia are subject to licensing. This includes the location, design, construction, operation and decommissioning of nuclear facilities and radiation sources. The order of licensing is established by the order of the Russian Federation Government of 29.03.2013 No. 280.

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A significant part of the regulatory documents is devoted to the safety requirements of nuclear power plants:
NP-001-15 "General safety provisions for nuclear power plants"
NP-012-16 "Safety rules for decommissioning of the nuclear power plant unit"
NP-031-01 "Design standards for earthquake-resistant nuclear power plants"
NP-032-01 "Location of nuclear power plants. Basic safety criteria and requirements"
NP-082-07 "Nuclear safety rules for reactor sets of nuclear power plants"
NP-089-15 "Rules of arrangement and safe operation of equipment and pipelines of nuclear power plants", etc.

For example, the regulations specify that the probability of severe accidents at the power unit or in fuel storage facilities should not exceed 10^{-5} per year, and the probability of accidental release – no more than 10^{-7} per year [4]. The temperature of the fuel rods shell should not exceed 1200 °C, and violations of the wholeness of fuel rods in which nuclear fuel is in contact with the coolant – not more than 0.1 % of fuel rods [5].

For medical organizations, including organizations using radioactive drugs and methods there are numerous regulations and guidelines:
MU 2.6.1.1892-04 "Hygienic requirements for ensuring radiation safety during radionuclide diagnostics by means of radiopharmaceuticals"
SanPiN 2.6.1.1192-03 "Hygienic requirements to the device and operation of x-ray rooms, devices and carrying out x-ray examinations"
SanPiN 2.6.1.2368-08 "Hygienic requirements for ensuring radiation safety during radiation therapy using open radioactive sources"
SP 158.13330.2014 "Buildings and rooms of medical institutions. Design rules", etc.

The requirements in the regulations must be specified during the design, construction, and operation of buildings and structures. To do this, it is necessary to create an information technology based on a system of requirements.

3. Organizational and Technological System of Requirements for the Construction

The authors developed an organizational and technological system of requirements, which was used in the construction of a medical center using radioactive pharmaceuticals [6]. The system includes the following types of requirements:

- Configuration requirements: architectural, structural, technological;
- Safety requirements: radiation, fire, physical, environmental, information, as well as requirements for labor protection in construction companies;
- Operational requirements for rooms and equipment.

At the pre-project stage, the requirements for the placement of the object are specified. If the object should have a sanitary protection zone, the construction of other buildings in it is prohibited. When placing the object, transport accessibility, wind direction, soil properties and other parameters are taken into account.

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At the design stage, the basic requirements for the object are set in. Requirements for architectural solutions determine the height of floors, the availability of communications, the placement of heavy equipment, waterproofing above premises with equipment, reserve space for possible changes in technological requirements during operation and much more.

Requirements for structural solutions should take into account the increase of the biological protection thickness (for example, in the canyons for the location of cyclotrons), mounting openings and ways of equipment transporting. By the static calculation it must be take into account the higher level of responsibility for buildings with sources of ionizing radiation.

Requirements to technological solutions are specified for radiation protection, radiometric and radiation monitoring, for the device of vacuum and special sewerage, communication, etc. Requirements for engineering systems in buildings with radiation sources must take into account 100 percent redundancy of ventilation and other engineering systems, the device of air purification systems from radioactive substances, the presence of special sewerage systems, radiation monitoring, etc.

Besides, the kinds, quantity and the storage place of means of individual protection, medicines, the emergency stock of radiometric and radiation monitoring devices, means of decontamination and sanitary processing, tools and stock necessary for carrying out urgent works on elimination of consequences of radiation accident is specified.

Object requirements can be divided into the following groups:

- Requirements of the authorities and the population (environmental protection, social efficiency, architectural expressiveness);
- User requirements (performance, durability, adaptability, maintainability, etc.);
- Investor requirements (economic efficiency, payback);
- Supervision requirements (compliance with standards);
- Requirements of the contractor (technology, labor protection).

However, the list of requirements completely is a customer of the object. Some of the requirements of the customer are individual and even subjective.

An important part of the system is the subsequent processing of requirements at the stages of design and project implementation. The process of processing the requirements consists of research, analysis, formulation and approval of the requirements, followed by tracking their performance in the project, at the construction site and during operation. In the development of basic and detailed documentation, in the construction the list of requirements is used for setting the tasks of the customer, the decision of their designer, the implementation of decisions by builders and installers.

During the research, the identification of initially unidentified requirements, their discussion and specification is carried out. In the analysis phase evaluated the ability to meet the set requirements and the cost of this process. After the analysis, a new or modified requirement are formulated, calculations and design work are carried out, if necessary. The modified design decision, if necessary, passes the examination and is approved by the customer.

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During the reconstruction of the building may be occur a problem of selection of equipment elements in technological and engineering systems. For example, in the design of reconstruction or purchase of new equipment, it turns out that the pump of the technological system installed earlier is no longer produced by the plants and cannot be delivered. In the process of replacing the equipment, the system requirements should prompt that with another pump changes the pressure and fluid flow in the system, the required drive power, which can lead to the replacement of the power distribution and protection system. In addition, the dimensions and weight of the equipment become different, which changes the requirements for building structures.

To check requirements for the appropriate use of information technology, e.g., IBM Rational Doors®, however, full automation of control processes is impossible. To do this, it is necessary to solve many problems of compatibility of software products, formats and databases, data transfer and recognition. At present, to verify the requirements, it is necessary to attract experts in the areas under consideration.

4. Requirements for the Configuration of Radiation Hazardous Facilities

The configuration of the building is the composition and mutual arrangement of premises, structures, engineering and technological systems. The configuration of a nuclear power facility or nuclear medicine also incorporates these elements with its features.

Buildings, constructions and rooms of radiation dangerous objects are very various to destination and according to requirements to them. The constructions of buildings and structures of radiation-dangerous objects may differ significantly from the constructions of civil buildings and structures, so as include the construction of protection against radiation. Construction of concrete in-situ and partial prefabricated structures are common in nuclear power plants. Most of the constructions of the building of medicine, on the contrary, differ little from other buildings. The basic configuration of structures is fully determined by architects and designers in the basic and detailed documentation.

Engineering systems of buildings provide:

- Life activity of personnel and customers (water supply, sanitation, heating, ventilation, refrigeration, electricity, fire extinguishing systems);
- Internal transport (elevators, lifts, moving sidewalks);
- Electronic communication (notification systems, communications, security and fire alarm systems, access control, monitoring, automation and dispatching of buildings, etc.).

Technological systems of nuclear power plants provide power generation, reactor regulation and multiple redundancy safety systems. Nuclear medicine systems are decentralized, as they include a variety of equipment that can operate in isolation and autonomously.

For coordination of mutual arrangement of elements of engineering and technological systems, and also constructions and rooms the means of the automated design possessing ability to trace spatial and technological "collisions", that is situations when the element of system interferes with work of other element of system shall be applied. According to modern design experience, conflict

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tracking is the most effective result of the introduction of three-dimensional computer-aided design (BIM-technologies) after the actual creation of CAD.

Conflict detection at the stage of construction or operation leads to extremely difficult results, sometimes – to the impossibility of operation of the facility as a whole and rework a large part of the work. Therefore, one of the main tasks of the project organization and the technical customer – to detect and resolve conflicts at the stage of project development, in extreme cases – detailed design or adjustment of basic design documentation.

Conflicts can be divided into a number of categories.

Static "intersection" or "touch" collisions can be defined purely by geometric methods, such as finding points of one body inside or on the surface of another body (geometric representation of equipment, piping, constructions). Spatial representation of the body in this case should include positive tolerances for the making (installation, erection) of equipment or structure, and if necessary – the minimal allowable distance between the elements of the equipment, for example, between the electrical wires or pipes. Checking the spatial model for collisions is carried out in a number of program codes.

"Dynamic collisions" are possible contact or dangerous proximity to elements of equipment and structures during installation, transportation or operation of the facility. This check is much more complicated, and requires the design of the route of movement of one element relative to the other. It is the most difficult to model the movement of people of different sizes along the corridors and stairs with a touch of designs; the authors are not yet known successful solutions in this direction.

Finally, "Special collisions" can occur in complex construction projects, such as radiation-hazardous facilities. Finding a person in certain areas of the building can be very dangerous. To check such collisions it is necessary to simulate the location of a person in different poses at acceptable places of residence and to determine the possible radiation damage during normal and emergency operation of the equipment. This task is very difficult technically and has not been automated so far.

Configuration information, reflected in the basic, detailed and execution documentation should be taken into account in the system requirements. In addition, the configuration of documentation at all stages of the lifecycle is considered, which is also included in the requirements.

The goals of the configuration requirements system can be:

- Coordination of the mutual arrangement of rooms and systems;
- Identification of structures, equipment and other elements of the object;
- Configuration management of changes with appropriate documentation.

During implementation of requirements to a configuration accounting of the changes brought in basic design at the statement and examination, at detailed design, and also in the course of performance of construction and installation and commissioning is made. Highlighting changes that require re-examination is also an important task of the configuration requirements system.

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Automation of the process of establishing and verifying compliance with the configuration can save time and money on the selection of documents when putting the object into operation.

Configuration management procedures are set in ISO 10007:2003 "Quality management systems – Guidelines for configuration management" [7].

5. Conclusion

The basis of the organizational and technological system of configuration requirements is the order of identification and documentation of functional, physical, and geometric properties of the configurable element, as well as control of changes in these properties, recording and report on changes of the element status. Organizational processes of creation and presentation of requirements consists of planning, identification, modifications, and check (reporting) of configuration status.

With regard to the construction of a radiation hazardous facility, the system of configuration requirements must contain the configuration management procedures used and a description of the authorities of the responsible persons at all stages of the life cycle of the facility. The system shall provide functional duties of employees of services of the technical customer, the General designer, the General customer, and other interested persons.

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