Features of the organization of space-planning solutions for nuclear medicine facilities

Alevtina Balakina¹ and Jury Lempl¹*

¹Moscow State University of Civil Engineering, 129337, 26, Yaroslavskoye Shosse, Moscow, Russia

Abstract: The purpose of this article is to determine the typology of the main functional zones for nuclear medicine facilities (NMF) and the formation of principles that affect the architecture of these typological zones. The methodology of this study is an analysis of scientific works, a generalization of practical experience in the architectural design and construction of the NMF. The result of the study is the definition of the main typological zones of the NMF, the identification of the principles that affect the formation of the architecture of the NMF in relation to each zone. The study is aimed at the formation of the space of the typological zones of the NMF, taking into account the maximum provision of comfort. Keywords: architecture of nuclear medicine facilities (NMF), typological zones of the NMF, principles of the NMF architecture, medical institution, adaptive space, radiation therapy rooms, radiopharmaceuticals production facilities, positron emission computed tomography (PET centers) research rooms, clean rooms.

1 Introduction

Nuclear medicine is actively developing in Russia and is an area based on the use of radionuclide pharmaceuticals and ionizing radiation. It includes diagnostics with radioactive pharmaceuticals and radiation therapy. Nuclear medicine is used in oncology, cardiology, neurology for the diagnostics and treatment of a number of dangerous diseases. Compared to surgical methods, nuclear medicine methods are more effective [1]. A number of works are devoted to the study of the design of nuclear medicine facilities and their features [2-6]. For the needs of nuclear medicine, complex technological equipment is used, such as cyclotrons, gamma cameras, positron emission computed tomography (PET), etc. Modern medical centers are needed to accommodate and maintain them. Nuclear medicine facilities are already operating in many cities of Russia. For example, such as the Research Institute of Pediatric Oncology and Hematology of the Russian Oncology Research Center named after N.N. Blokhin (Moscow, Kashirskoye shosse, 24), reconstruction of building No. 5 with the extension of the Medical Radiology Research Center named after A.F. Tsyb - a branch of the Federal State Budgetary Institution "National Medical Research Center of Radiology" of the Ministry of Health of Russia, development and reconstruction of the republican oncological dispensary in Ulan-Ude (Republic of Buryatia, Ulan-Ude, Pirogov street, 32) and others. Despite this, the issue of designing such facilities is relatively new and has a number of

* Corresponding author: jurij.lempl@gmail.com
features that need to be studied from the point of view of developing principles for the formation of architecture aimed at creating a comfortable and safe environment for patients and staff.

2 Methodology

The methodology of this study is an analysis of scientific works, a generalization of practical experience in the architectural design and construction of the NMF, the study of statistics and scientific works on the design of NMF, as well as the influence of architecture on the psycho-emotional state of a person, an analysis of personal experience in designing a medical institution.

3 Body

Let's consider the features of the design of nuclear medicine facilities on the example of the Research Institute of Pediatric Oncology and Hematology on the territory of the Russian Oncology Research Center named after N.N. Blokhin in Moscow. In 2020, the center was put into operation and is one of the largest pediatric oncology centers in the world [7].

The facility consists of five modules, including the radiological building "A" (Fig. 1). Building "A" accommodates: cyclotron-radiochemical laboratories, departments of PET, radionuclide therapy, radiation therapy, X-ray surgery and minimally invasive methods of treatment; day hospital, administrative and office premises. The building is seven-storey with a total area of about 30,000 square meters.

![Fig. 1. Location of the Research Institute of Pediatric Oncology and Hematology. Location of building "A". Source: Yandex maps](image)

The premises are divided into four typological groups. The first group is the premises in which work with radionuclides with limited access of personnel takes place, the second group of premises is PET centers. The third group of premises is treatment sections. The fourth group is common areas.

Let's consider the premises of the first group.
**Cyclotron** is a room for the production of radionuclides and diagnostics, is usually located in a separate extension - a bunker (Fig. 2 - Plan of the basement at the level of the cyclotron. Source: Archival drawings of LLC «GIPROCON»).

There is an airlock in front of the bunker. The bunker is locked with a special door with a lock, which consists of steel and concrete. Radiation protection of other rooms from gamma and neutron radiation from the cyclotron is envisaged. Bunker wall thicknesses were determined for concrete with a density of 2.35 g/cm³. Constructive measures to ensure radiation safety were calculated and implemented. In this example, the cyclotron is located as an extension to the main volume of the building. There are examples of placing a cyclotron inside a radiological building with the placement of special laboratories for the production and preparation of radiopharmaceuticals around it. (Fig. 3).

---

**Fig. 2.** Plan of the basement at the level of the cyclotron. Source: Archival drawings of LLC «GIPROCON»

**Fig. 3.** Sketch of the placement of the cyclotron in the radiological building. Source: Kraemer Radiation Oncology Center / Yazdani Studio of CannonDesign [8]
The production of radionuclides is carried out in two production laboratories. Adjacent to the production laboratories is a quality control laboratory, in which radionuclide pharmaceuticals are monitored by means of gas chromatographs and high-pressure liquid chromatographs.

The transfer of radionuclide pharmaceuticals from the production laboratory to the quality control laboratory or directly to filling, labeling and packaging is carried out through a ventilated airlock with windows with alternate blocking. Further, radionuclide pharmaceuticals are sent to the product delivery department.

At the exit from the sanitary inspection rooms there is an airlock room, where the injected air provides an air lock that blocks the ingress of contaminants into clean rooms, showers and disinfection rooms for employees leaving the laboratory.

These premises are included in the so-called infectious zone. Stay in these premises is carried out in a special uniform. The structures of walls, floors and ceilings here ensure complete tightness through the use of "clean self-supporting walls and ceilings" or the device of a room in a room. The premises have strictly controlled air exchange. For these areas, all conditions for the stay of personnel are strictly regulated. Radiation safety is ensured constructively.

The next typological group is the premises of the PET center with areas for staff work, doctors' offices, patient rooms, examination rooms, ultrasound examination rooms, etc. (Fig. 4 - Plan of the 1st floor with the arrangement of technological equipment. Source: Archival drawings of LLC «GIPROCON»). There are also technical and auxiliary premises: processing of results and computing hardware. The movement of patients from the upper floors and the movement of employees are separated: each group has its own elevators.

The department is designed to examine patients using the method of positron emission tomography of the whole body, which provides volumetric measurements and images of injected radiopharmaceuticals in the patient's body, obtaining isotope images, their processing and medical assessment.

Data processing and isotope imaging are performed by software engineers at secondary stations of PET cameras installed in programmers' offices. The analysis of the obtained tomograms is carried out by doctors, where viewing stations are also installed to call and send reports on the examination of patients to the archive.

The PET center is divided into an external area (an external corridor for all patients and employees) and an internal area (an internal corridor with access restrictions).

In the external reception area of the PET center, there is a reception for patients, separate waiting rooms for bedridden and walking patients, as well as rooms for examination. (Fig. 5, 6)

The rooms shown in Figures 5,6 belong to the common areas internal to the PET center. This includes only patients who are preparing for the examination. Taking into account the psycho-emotional state of patients before the examination, the architectural solutions of these zones are performed as comfortably as possible, using warm colors.
Fig. 4. Plan of the 1st floor with the arrangement of technological equipment. Source: Archival drawings of LLC «GIPROCON»

Fig. 5. PET Center Waiting Area. Source: Kraemer Radiation Oncology Center / Yazdani Studio of CannonDesign [8]

Fig. 6. Doctor’s Office. Source: Kraemer Radiation Oncology Center / Yazdani Studio of CannonDesign [8]
Patients who have been injected with radionuclides in preparation for a PET-CT examination move in the inner zone.

In the inner area of the PET center there are separate rooms for injection, as well as waiting rooms for patients and their relatives. The injection rooms are located directly next to the freight elevator and the production laboratory to eliminate the need to transport radionuclides through the corridors. All waiting areas for patients are located in rooms with natural light to provide the necessary comfort for patients.

Comfortable conditions are provided in the waiting room of the PET department and in the room where patients prepare for the PET examination procedure and undergo examination (Fig. 7), and then undergo post-procedure relaxation - here each patient is provided with his own separate box.

**Fig. 7.** PET Center Examination Room. Source: Kraemer Radiation Oncology Center / Yazdani Studio of CannonDesign [8]

In the visitor service area, there are places for limited mobility people, located in the area accessible to them and provide a convenient meal. The distance from the place of stay of the limited mobility people to the emergency exit to the outside does not exceed 40 meters.

**The third typological group includes therapeutic treatment sections.** These are such sections as the treatment section of radionuclide therapy, the section of radiation therapy, the section of X-ray surgery and minimally invasive methods of treatment, and a day hospital. Taking into account the specifics of the disease, the hospital rooms are mostly boxed, with the use of clean elements for walls, floors and ceilings. Warm comfortable colors are used for decoration.

**The fourth typological group** includes public spaces. Such premises are available inside the premises of the second and third type. These are reception rooms, waiting rooms for procedures, meal rooms, pantries, meeting areas for patients with visitors. Separately, we can note such premises as entrance groups, halls, the department of advanced training of doctors, offices of researchers, auditoriums, conference rooms.

A feature of space-planning solutions for the radiological building is the separation of flows. Patients do not enter the premises of the first typological group. These are categorized premises where specially trained personnel work in compliance with the necessary safety requirements. The premises of the second typological group are premises for limited access to patients accompanied by doctors. Access control here is carried out using an access control system. The premises of the third typological group are treatment sections with a permanent stay of patients. However, each of the units listed above is isolated from each other. Access
to the adjacent treatment sections is possible only for medical personnel. Premises of the fourth type can also be located inside categorized areas and access to them is limited to patients accompanied by medical personnel. There are also premises with open access. For these premises there is a separate entrance, separate elevator groups and stairwells. Access from these premises to premises of type 1,2,3 is strictly regulated.

The radiological building "A" described above is one of the first experiments in the placement of diagnostic sections, radiopharmaceuticals section and patient stay sections. For its implementation, it was necessary to develop special technical conditions on radiation safety and coordinate them with the Ministry of Construction of the Russian Federation, Rosatom (Russian Federal Atomic Energy Agency) and Rospotrebnadzor (Federal Service for the Oversight of Consumer Protection and Welfare). Its layout can be taken as the basis for the development of principles for organizing space for nuclear medicine facilities.

4 Conclusions

Based on the analysis of the built facilities, using the experience of designing analogue facilities, the typology of the main premises of the NMF is determined, the basic principles of architecture for the selected typological groups are formulated.

References

1. N.B. Kuzmina, What is nuclear medicine. (Moscow: MEPhI, 2012)
3. Kashurnikov S.N. Ensuring the safety of healthcare facilities
   http://www.psj.ru/saver_magazins/detail.phpID=73134
8. Kraemer Radiation Oncology Center / Yazdani Studio of CannonDesign