NATIONAL
ATOMIC ENERGY
AGENCY

NATIONAL ASSESSMENT REPORT OF POLAND

TOPICAL PEER REVIEW 2023

FIRE PROTECTION

Polish 2nd TPR national report prepared in accordance with the Nuclear Safety Directive 2014/87/EURATOM

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0. PREAMBLE

This report is based on the European Union Nuclear Safety Directive 2014/87/EURATOM (hereafter NSD). The NSD introduced a European system of topical peer review. The purpose of topical peer reviews (hereafter TPRs) is to provide a mechanism for EU Member States to examine topics of importance to nuclear safety, to exchange experience and to identify opportunities to strengthen nuclear safety. First TPR commenced in 2017 with subject of "Ageing Management" and it takes place at least every six years thereafter.

In November 2020, at its 41st Plenary Meeting, ENSREG decided that the topic of the second Topical Peer Review (hereafter TPR II) would be “Fire Protection”. The main objectives of the TPR II which phase no. 1 started in 2022 are as follows:

- enable participating countries to review their provisions for fire protection to identify strengths and weaknesses,
- undertake a European peer review to share operating experience and identify findings: common issues or challenges at EU-level, good practices, areas of good performance and areas for improvement (see Annex II for definitions),
- provide an open and transparent framework for participating countries to develop appropriate follow-up measures to address areas for improvement.

The first step is to make a national report on the assessment (hereafter NAR) of relevant nuclear facilities. NAR for Poland is presented here by national nuclear regulatory body - National Atomic Energy Agency (hereafter PAA). It focuses on the Maria Research Reactor - the only polish reactor which is operated by National Centre for Nuclear Research (hereafter NCBJ). The NAR was is written by both license - NCBJ and regulatory body - PAA representatives in accordance with requirements included in document ‘Report Topical Peer Review 2023 Fire Protection Technical Specification for the National Assessment Reports'.

The goals of National Assessment Report are to:

- describe the general the reactor fire safety system,
- evaluate applications to identify strengths and weaknesses,
- identify actions to address areas that need improvement,
- prepare the report at an appropriate level of detail allowing for substantive peer evaluation.

The final version of the NAR is to be published on the PAA website by the end of October 2023 and accessible through ENSREG website.

1. GENERAL INFORMATION

1.1. NUCLEAR INSTALLATIONS IDENTIFICATION

The MARIA research reactor is located at the Nuclear Center in Świerk. The facility is operated by the National Centre for Nuclear Research (NCBJ). MARIA is a high-flux pool-type nuclear reactor cooled with water, which also serves as a moderator along with beryllium. The fuel elements, in the form of concentric tubes, are placed in pressurized channels of the Field's tube type. The fuel channels, embedded in beryllium blocks, along with a graphite reflector, constitute the core, which is submerged in the reactor pool. The reactor pool and the fuel channels have separate cooling systems. The reactor utilizes low-enriched fuel (<20% ^{235}U) in the form of U_3Si_2 or UO_2 dispersion in Al, shielded with an aluminum cladding. The MARIA reactor is equipped with vertical channels for irradiating target elements, a hydraulic post, and horizontal channels for neutron beam extraction. Nominal thermal power of the reactor reaches 30 MWt.

The construction of the MARIA reactor began in 1970, and criticality was achieved in 1974. The operation of the reactor is based on the authorization of the President of the Polish Atomic Energy Agency issued on March 31, 2015, valid until March 31, 2025. The projected end of the reactor's operation is the 2050s.

The siting of the MARIA reactor facility with respect to property boundaries and adjacent buildings meets the requirements of the legal regulations specified in the Minister of Infrastructure's Regulation on technical conditions for buildings and their location [2]. The location of the facility in the area and with respect to adjacent objects is shown in the graphical part of the NCBJ Fire Safety Instruction (Figure 1), which is binding and available to all NCBJ employees.

In the immediate vicinity of the MARIA reactor facility (building R2-ABCD), within a double-fenced area, the following objects are located:

- warehouse buildings number 45 and 46 are metal structures used for storing various types of materials, mostly non-flammable and non-fire hazardous. They do not store any fire-dangerous materials, and the fire load density does not exceed 500 MJ/m^2,
- building number 32 is a ventilation fan building, while the pumping station and water treatment station serve the operational needs of reactor number 32a. These buildings also do not store any flammable materials, except for small quantities of operational materials that do not pose a fire hazard to the reactor facility.

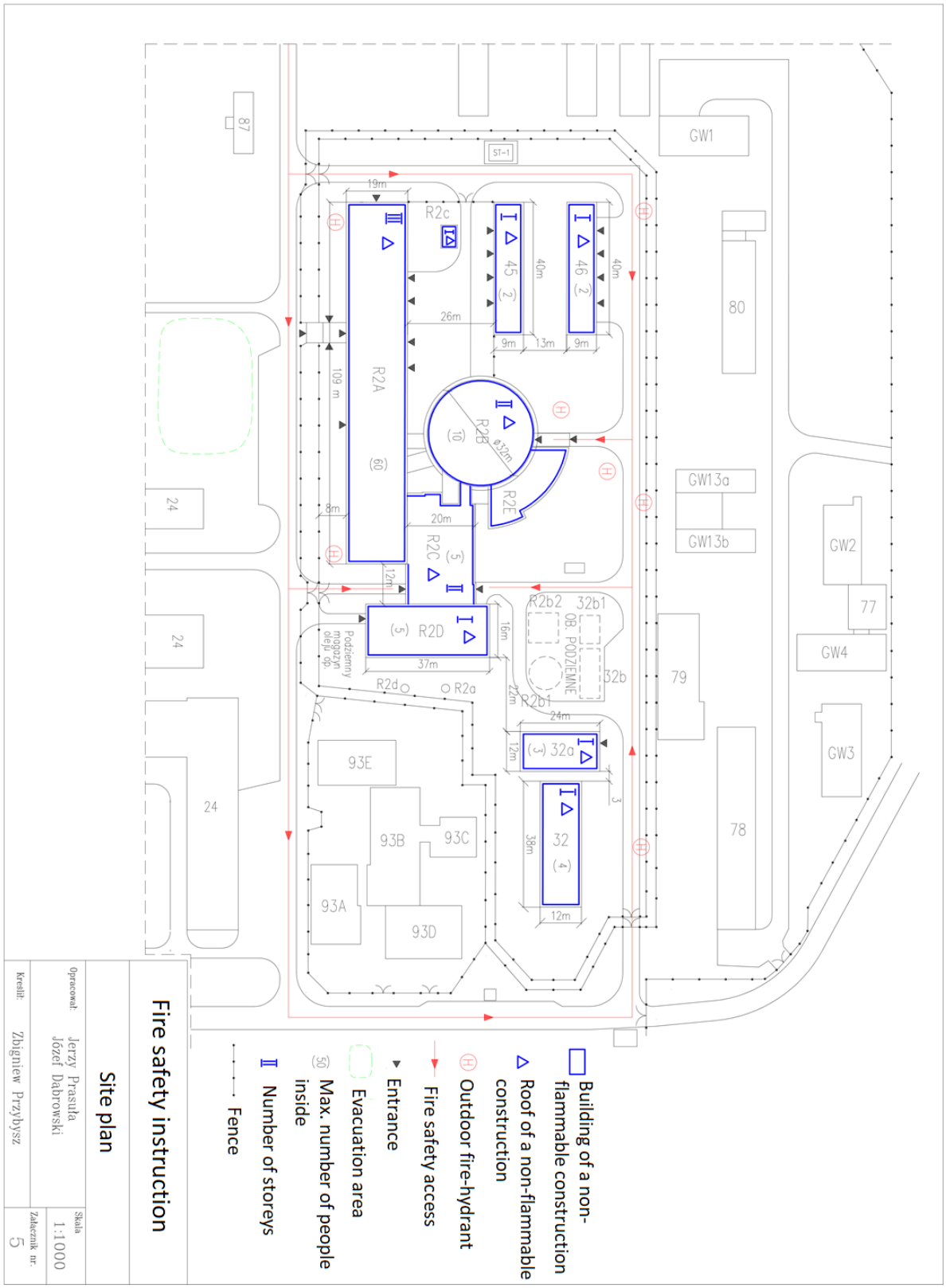

Figure 1. Site plan showing the location of the MARIA reactor (R2B) and nearby buildings of Nuclear Center (NCBJ) as regards to fire protection (from Fire safety Instruction [1]).

In the immediate vicinity of the MARIA reactor fence, there are buildings of the Radioactive Waste Management Facility No. 93-ABCDE, where various types of radioactive waste are stored. According to the Atomic Law, these buildings should meet the Class B fire resistance requirements, they do not store fire hazardous materials, and the fire load density does not exceed 500 MJ/m^2. Therefore, there is no fire hazard for the MARIA reactor from these buildings.

The spent nuclear fuel from the MARIA reactor is stored in the storage pool near the reactor core in Part B. This does not affect the fire safety in the reactor building.

Outside the designated area of the MARIA reactor facility, adjacent to this area, there are buildings of the POLATOM Isotope Center. The nearest is the office building No. 24H, which does not pose a fire hazard to the neighboring facilities.

Further, there are buildings of the production laboratories No. 24-ABCDEF, which house technical rooms, laboratories, radiochemical laboratories, as well as administrative and office and welfare facilities. The laboratories contain radioactive sources with low activities. Gas boilers fueled by natural gas are used for heating. The buildings also contain individual cylinders of technical gases (acetylene, oxygen, argon) used for regular work.

Private companies operating within the National Center for Nuclear Research are not located in the immediate vicinity of the MARIA reactor and therefore do not pose any fire hazard.

The facility is supplied with three 110 kV overhead power lines from the Otwock and Karczew directions, through the 110/6 kV substation (on the premises of facility No. 10). From the substation, 33 cable lines are laid to the 6/04 kV transformers installed in the Facility Transformer Substations. The transformer substations in the reactor facility are equipped with automatic reserve switching (ARS) systems on the low-voltage side. In the event of a power supply failure from the power grid, the backup protections consist of automatically activated diesel generators in buildings 1, 2, 24, 28, and 88. The first backup power reserve is provided by the battery banks installed in buildings 10 and R2, which operate through rotating converters to power the special reception switchgear supplying loads that require non-interruptible power. The second backup power reserve, in case of prolonged voltage loss, is provided by diesel engine generators.

To eliminate hazardous events in the MARIA reactor facility, including effective fire extinguishing, in addition to the reactor's internal services, all services functioning within NCBJ, except for the reactor facility itself, and the entire technical structure of the facility can be utilized. Furthermore, if necessary, forces and resources from the Fire Brigade, Police, and other services, both from the Otwock county and the Mazowieckie Voivodeship, will be dispatched. Specialized units of the State Fire Service, including chemical and medical rescue units, operate in Warsaw and participate in rescue exercises at the reactor facility, organized by both NCBJ and state services on behalf of the voivodeship.

The National Center for Nuclear Research does not have a Fire Brigade unit located on its premises. The closest units within the protected area of NCBJ are:

- Volunteer Fire Brigade in Otwock-Wólka Mlądzka (approximately 2 km away),
- Volunteer Fire Brigade in Otwock-Jabłonna (approximately 7 km away),
- State Fire Service in Otwock (approximately 10 km away).

Firefighters from the State Fire Service in Otwock and the Volunteer Fire Brigades participate in training on conducting rescue and firefighting operations in NCBJ facilities.
The absence of a Plant Fire Brigade unit imposes an obligation on the central emergency services and employees of NCBJ (National Centre for Nuclear Research) to effectively extinguish a fire until the arrival of the Fire Brigade or Volunteer Fire Brigade units. The preparation of the facility for rescue and firefighting operations supports the training of personnel for evacuation and firefighting actions, as well as exercises conducted at NCBJ in cooperation with the State Fire Service and Volunteer Fire Brigade.

An Emergency Service Unit has been established at NCBJ for the purpose of eliminating various types of accidents and hazards, including fire hazards, by taking action to eliminate them until the arrival of the Fire Brigade units. The emergency service includes:

- Emergency Manager Service of the Nuclear Center (KAOJ),
- shift and dispatch services in organizational units and facilities of the Center,
- emergency managers of nuclear facilities and facilities that may pose a radiation hazard (KAO),
- Facility Emergency Groups (OGA),
- Special Intervention Groups (SGI),
- Emergency Consultants.

The emergency structure is presented in Figure 2, and the list of personnel included in the emergency structure is held by the Nuclear Center Emergency Dispatcher (DAOJ). According to the Emergency Procedure Instruction, the dispatcher activates the notification process.

The personnel strength of the emergency services is as follows:

- 1st shift: approximately 50 people,
- 2nd shift: 20 people,
- 3rd shift: 20 people,
- days off: 15 people.

The place of work of the Emergency Dispatcher (DAOJ) or, in the case of an emergency event, the Emergency Manager (KAOJ) is the Emergency Control Room located in one of the NCBJ buildings outside the fenced off area of the MARIA reactor facility and a backup position in the shelter of the same building.

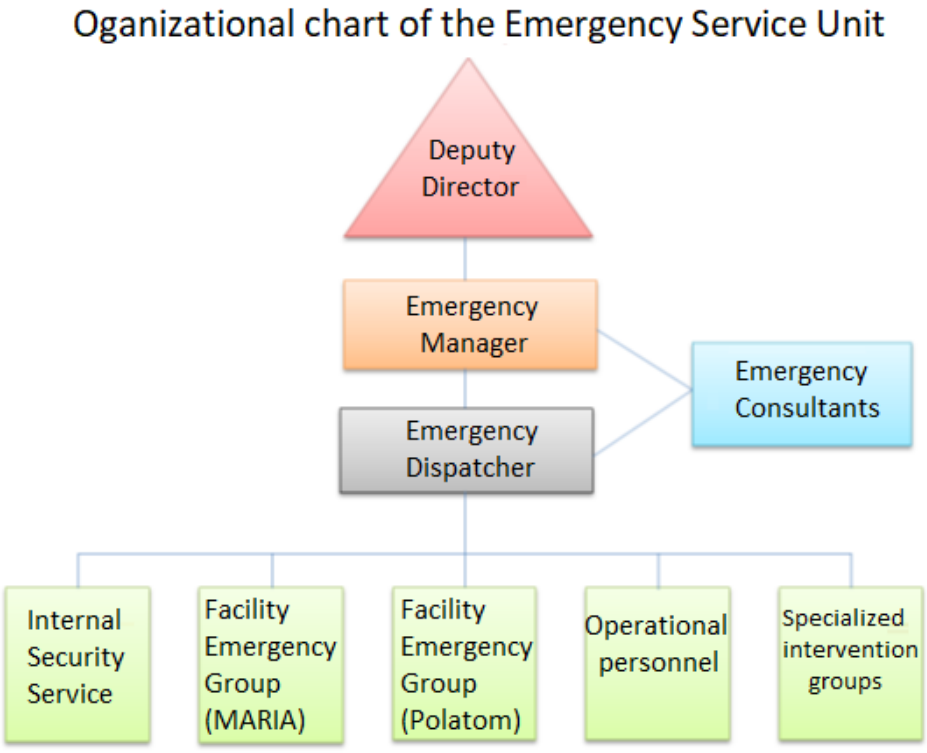

Figure 2. Figure 2. The organizational chart of the Emergency Service Unit of the Świerk Nuclear Center (NCBJ).

NCBJ also has an Internal Security Service (WSO) responsible for the physical protection of the Center and available to the Nuclear Center Emergency Service in case of fire reports or activation of the fire alarm system.

A fundamental element of the technical structure of the facility necessary for effective fire suppression, including the reactor facility, is the water supply installations. The water supply for firefighting purposes in the reactor facility can be provided not only from external hydrants located within the fenced area of the reactor but also from hydrants and a fire reservoir located outside the facility area.

NCBJ is supplied with water from its own sources and the municipal water supply network of the city of Otwock, with a total capacity of 100 m^3/h. For fire protection purposes, the Center and its facilities have been equipped with a hydrant network. Underground and above-ground hydrants (with a total capacity of 104.4 m^3/h) are marked with permanent signs. Additionally, the following water reservoirs are located on the site:

- retention tanks of the water station (facility No. 21): 3 tanks with a total capacity of 1044 m^3 (with a constant water reserve of 212 m^3 for firefighting purposes),
- fire reservoir (facility No. 40): 300 m^3.

The water reserve on the site is 512 m^3. The water station located on the site is equipped with fire pumps (2 units) with a capacity of 120 m^3/h each. In the event of a failure of the hydrant network and water station, water can be drawn directly from the tanks, the hydrant network in the neighboring Wólka Mlądzka housing estate (closest located along Sołtana Street), or from the Świder River (e.g., near the bridge in the Wólka Mlądzka housing estate). Drawing

water from the river requires the Fire Brigade to deploy a water line using fire hoses, with a length of approximately 2 km.

To effectively extinguish fires, communication installations and devices are necessary, enabling immediate mobilization of external forces and resources. Emergency and technical services within the facility are equipped with:

- RRL radio communication (land mobile radio) in the KAOJ network (Emergency Manager of the Nuclear Center),
- RRL radio communication in the MW network (Mazovian Voivodeship - Voivodship Crisis Management Center),
- "Na pomoc" radio communication with the Police (monitoring and, if necessary, the ability to establish communication),
- local dispatcher telephone communication,
- direct telephone line with the district command center of the State Fire Service in Otwock.

According to the definitions of the International Atomic Energy Agency, defense in depth is divided into 5 levels. In terms of fire safety at NCBJ, the following levels and examples of implemented solutions can be mentioned:

- Level 1 – Prevention of fires from starting - achieved through appropriate installation planning and control over the arrangement of materials, minimizing fire loads and ignition sources, as well as following instructions and compliance with procedures,
- Level 2 – Detection of any fire and in case, quick fire extinguishing action - implemented through appropriate monitoring and extinguishing systems and actions by personnel, including routine checks of fire loads and ignition sources, as well as maintaining minimal water reserves,
- Level 3 – Control of the fire area, stopping its spread, especially preventing fire (or its effects) to spread in area which are nuclear safety related - carried out by applying appropriate fire barriers and following established emergency plans [6],
- Level 4 – Control of serious events - achieved through cooperation with external units such as the State Fire Service and Volunteer Fire Brigade,
- Level 5 – Mitigation of event consequences - implemented through collaboration with local and national authorities responsible for emergency planning at the provincial and national levels,

The mutual independence of the successive safety levels with regard to fire protection has been ensured through the use of various ways/methods of implementing the individual levels, including, among others, minimisation and routine checks of fire load, staff and external unit drills in the area, as well as cooperation with units/institutions at various levels at district, provincial and national level - PSP headquarters: district, provincial, main, local government, provincial authorities and ministries.

1.1.1. QUALIFYING NUCLEAR INSTALLATIONS

Nuclear facilities in Poland covered by the NSD (Nuclear Safety Directive), and in accordance with Polish Atomic Law, include only four facilities:

- the MARIA research reactor, together with on-site storage pool facility which is considered as a part of the installation in the NAR report,
- the EWA research reactor (the first research reactor in Poland, operated between 1958-1995 and decommissioned to the brown field since 1995),
- two wet storage facilities for spent nuclear fuel.

All these facilities are situated in Świerk at two separate organizational entities: the MARIA research reactor – at the National Centre for Nuclear Research (NCBJ) and decommissioned EWA research reactor as well as both spent fuel pools at the Radioactive Waste Management Plant (ZUOP).

1.1.2. NATIONAL SELECTION OF INSTALLATIONS FOR TPR II AND JUSTIFICATION (BRIEF SUMMARY OF)

Selection of Polish installation to be reported on in the national assessment report includes only the MARIA research reactor, together with on-site storage pool facility, which was proposed in role of candidate installation. Currently RR Maria is submitted to long term and comprehensive modernization and in the following years there are planned many reconstructions as well as changes to the organization structure. However, the rationale to select candidate status for RR MARIA are high thermal power (30 MWth) and unique construction which is difficult to be represented by any other European research reactor.

The rest of nuclear facilities in Poland was excluded from TPR II as they are not posing a potential significant radiological risk in case of fire. RR Ewa is at the late phase of decommissioning and all the fuel and radioactive materials have been already completely removed. Neither none of wet storage facilities contains spent nuclear fuel and there are no plans to use these facilities to store spent nuclear fuel in the near future. Currently, only some solid waste from the decommissioning of the EWA reactor and spent high-activity gamma radiation sources are stored in one storage. The other storage is empty. Both facilities are expected to be decommissioned.

1.1.3. KEY PARAMETERS PER INSTALLATION

The major areas of the MARIA reactor application are the following: production of radioisotopes, testing of fuel elements and structural materials for nuclear engineering, neutron radiography, neutron activation analysis, neutron transmutation doping, education and basic research with neutron beam application.
The main characteristics of the MARIA reactor are as follows:

- nominal power 30 MWt,
- moderator H2O, beryllium,
- reflector graphite,
- fuel assemblies:
    - material U3Si2/UO2 dispersed in aluminium,
    - enrichment <20% 235U,
    - cladding aluminium,
    - shape concentric tubes,
    - active length 1000 mm.

On-site storage pool facility is considered in the NAR as a part of the installation of the MARIA research reactor.

1.1.4. APPROACH TO DEVELOPMENT OF THE NAR FOR THE NATIONAL SELECTION

On 09.05.2022 the information on 2nd Topical Peer Review (TPR II) of nuclear facilities in Poland was published in Polish and English on PAA's web page. It was accompanied by the announcement of public consultation on the documents related to the TPR II.

On 08.09.2022, the President of the PAA issued a decision to review the current state of safety and fire protection of the MARIA research reactor to the extent corresponding to the requirements specified in 'Report Topical Peer Review 2023 Fire Protection Technical Specification for the National Assessment Reports'.

In October 2022 the final selection of Polish installation to be reported on in the national assessment report was submitted to the Secretary to TPR II Board and the Board's review of all the national selections was published.

The NAR was is written by both license - NCBJ and regulatory body - PAA representatives in accordance with requirements included in document 'Report Topical Peer Review 2023 Fire Protection Technical Specification for the National Assessment Reports'.

On 27.02.2023 the first version of the report of the reactor MARIA inspection carried out by the licensee (NCBJ) was ready. On 30.05.2023, the President of the PAA asked to supplement the report and provide explanations. The updated report was ready on 23.06.2023, and the development of the NAR report began on this basis. In mid-October, the first written version of the NAR report was presented to the licensee (NCBJ) for consultation. The role of the PAA was to, oversight and assess the materials prepared by the NCBJ and present the results and conclusions resulting from the carried out work.

1.2. NATIONAL REGULATORY FRAMEWORK

1.2.1. NATIONAL REGULATORY REQUIREMENTS AND STANDARDS

The fire safety system of the MARIA reactor is primarily based on national requirements, regulations, and guidelines, which include:

1. Act on Fire Protection (Journal of Laws, 1991, No. 81, item 351, as amended),
2. Regulation of the Minister of Infrastructure of April 12, 2002, on technical conditions to be met by buildings and their location (Journal of Laws, 2019, item 1065, as amended),
3. Regulation of the Minister of Internal Affairs and Administration of June 7, 2010, on fire protection of buildings, other construction facilities, and areas (Journal of Laws, No. 109, item 719, as amended),
4. Regulation of the Minister of Internal Affairs and Administration of July 24, 2009, on fire water supply and fire access roads (Journal of Laws, No. 124, item 1030),
5. Regulation of the Council of Ministers of December 14, 2015, on radioactive waste and spent nuclear fuel (Journal of Laws, 2015, item 2267),
6. Regulation of the Council of Ministers of July 12, 2006, on detailed conditions for safe work with ionizing radiation sources (Journal of Laws, 2006, No. 140, item 994),
7. Instruction 221 of the Building Research Institute "Guidelines for the fire resistance assessment of structural elements of buildings.",
8. Instruction 409/205 of the Building Research Institute "Design of reinforced concrete and masonry elements with regard to fire resistance."

The main purpose of implementing and adhering to these regulations is to prevent fires from occurring in the MARIA reactor facility. In the event of a fire, the objectives are to prevent its spread, effectively and quickly extinguish it, and thereby protect the health and lives of individuals present in the facility, as well as those engaged in firefighting and rescue operations, while minimizing material losses.

The key documents that provide detailed descriptions of the requirements contained in the aforementioned legal acts regarding the MARIA reactor facility are:

- Fire Protection State Expertise for the MARIA reactor facility, December 2020, prepared by authorized experts in fire protection and construction security, approved by the Mazovian Provincial Commander of the State Fire Service in Warsaw,
- Fire Safety Instruction [1] of the National Centre for Nuclear Research (NCBJ), developed and regularly updated by the Fire Prevention Department of NCBJ, approved by the Deputy Director of NCBJ for Nuclear Safety and Radiation Protection,
- Site Emergency Response Plan of the National Centre for Nuclear Research, coordinated with the Mazovian Voivode, the Mazovian Provincial Commander of the State Fire Service, and the Mazovian Provincial Police Commander,
- Emergency Plan [6] for the MARIA reactor facility, which is an attachment to the Site Emergency Response Plan.

Documents that are national laws, due to the fact that the MARIA reactor was built when they were not yet in force in their current form, have a general reference to a certain extent and are guidelines for internal documents with a specific reference, such as the Fire Safety Instruction or the Fire Protection State Expertise for the MARIA reactor facility, the implementation of which was necessary due to the excessive discrepancy between the regulations of the 1970s and the current ones.

The current PN-EN technical standards and norms related to fire safety apply to the design and operation of the modern equipment and other fire protection measures with which the MARIA reactor facility is equipped. These are the technical standards/norms for: the SSP fire alarm system, the DSO voice alarm system, emergency evacuation lighting, hand-held firefighting equipment, fire-fighting water supply system for internal hydrants, and the construction standards for materials used in renovations. The evaluation of the overall fire safety system is mainly based on the above-mentioned legal acts - national requirements.

The requirements for the criteria of data selection, methods used and analytical tools applied for the evaluation of the reactor fire safety system were defined by fire protection experts and construction experts in cooperation with NCBJ representatives responsible for broadly understood safety in the Fire Protection State Expertise for the MARIA reactor facility, approved in accordance with the law by the Mazovian Voivodeship Chief of State Fire Service. The expertise sanctions some of the existing construction solutions applied in the 1970s and additionally introduces substitute solutions that are more restrictive than those specified in the current national regulations.

1.2.2. IMPLEMENTATION/APPLICATION OF INTERNATIONAL STANDARDS AND GUIDANCE

The primary source of data for enhancing fire safety for the MARIA reactor is the relevant Polish legal regulations and instructions. However, it should be emphasized that Polish regulations are subject to harmonization in accordance with European Union directives and guidelines.

2. FIRE SAFETY ANALYSIS

2.1. TYPES AND SCOPE OF THE FIRE SAFETY ANALYSIS

Detailed fire safety analyses have been presented in two operational documents: the Operational Safety Report [4] for the MARIA Reactor (OSRM) and the Safety Classification of Systems, Structures, and Components [5] of the MARIA research reactor (Safety Classification). The scope of these analyses primarily includes the possibility of internal fires resulting from equipment operation or potential fire hazards in a given area. The following initiating events (IEs) have been identified:

- internal fire in the control room and switchgear room,
- internal fire in electrical distribution panels,

- internal fire resulting from the operation of main pumps and backup pumps,
- internal fire resulting from the operation of activated carbon filters in the ventilation system.

As part of the work on the Safety Classification [5], a probabilistic analysis was conducted for the aforementioned IEs, considering operational conditions and their potential impact on event propagation or nuclear safety and radiological protection hazards. Analyses involving a combination of different events other than fires resulting from damage to operating equipment were not conducted.

The conducted probabilistic analyses allowed for a graded approach, where the final analysis descriptions take into account the most probable scenarios and their potential development.

2.2. KEY ASSUMPTIONS AND METHODOLOGIES

The fire safety analyses were conducted using a probabilistic analysis methodology, which allowed for the determination of possible paths of development for initiating events (PIE) while considering the failure or damage to systems, structures and components (SSC), including redundant and duplicated systems. Developed event trees also facilitated the identification of relevant safety functions and their allocation to the SSC of the MARIA reactor.

The SAPHIRE software and data from international reliability databases (such as US NRC NUREG/CR-6928, IAEA-TECDOC-478) were utilized as the primary sources for the reliability models of the MARIA reactor equipment during the analysis. The creation of event trees and fault trees followed a standardized methodology described in the IAEA guidelines (Probabilistic Safety Assessment, 1992) and US NRC (NUREG/CR-2300 PRA Procedures Guide, 1983). This allowed for the determination of the probability that a given SEKW would be required to fulfill the safety function according to the requirements of the Atomic Law.

Furthermore, considering the graded approach, comprehensive probabilistic fire safety analyses were not conducted due to the low risk to nuclear safety and radiological protection posed by fires in the MARIA reactor.

The Fire Safety Assessment Report for the MARIA reactor facility was also utilized in the analyses. The report, conducted by authorized fire protection and construction experts, considers the presence of combustible materials, their types, and identifies any fire risk deficiencies in specific situations. The output data from the Fire Safety Assessment Report contributed to complementing the safety analyses.

In the fire safety PZI analyses, information regarding organizational measures was also incorporated, including the availability of operational personnel belonging to the Facility Emergency Group and the arrival time of the fire service (according to the distances indicated in Section 1.1). This data was utilized in assumptions regarding the potential spread of fire and the promptness of implementing intervention actions. Uncertainties are not taken into account in fire safety analyses.

2.3. FIRE PHENOMENA ANALYSES: OVERVIEW OF MODELS, DATA AND CONSEQUENCES

The analyses for the fire safety of the MARIA reactor primarily involve probabilistic analyses conducted using the SAPHIRE software, following the event tree and fault tree methodologies commonly used in Probabilistic Safety Assessment (PSA) analyses. SAPHIRE is an integrated software package developed and maintained by the U.S. Nuclear Regulatory Commission. It is utilized by both nuclear reactor operating facilities and regulatory institutions.

For the identified initiating events (PZI), event trees representing the sequence of accident scenarios were developed using the SAPHIRE software. The nodes of the event trees represent the safety functions of the MARIA reactor that are activated in response to the preceding events (corresponding to the analyzed PZI).

The direct and indirect consequences are assessed based on the potential damage to the safety-related systems, structures, and components (SEKW) resulting from the specific initiating events. However, direct and indirect consequence calculations to determine the specific impacts of a fire are not performed as part of the analyses for the MARIA reactor.

2.4. MAIN RESULTS / DOMINANT EVENTS (LICENSEE´S EXPERIENCE)

According to the analyses presented in the OSRM [4] and Safety Classification [5], the postulated initiating events that could lead to fires do not significantly impact nuclear safety and radiological protection. This is due to the implementation of adequate design solutions, such as fire-resistant structures, sufficient distances or other barriers between safety-related systems and components, and fire detection systems.

2.5. PERIODIC REVIEW AND MANAGEMENT OF CHANGES

2.5.1. OVERVIEW OF ACTIONS

Until the approval of this report for the MARIA reactor, one periodic safety assessment was conducted in 2019. The scope of this assessment was developed based on the Council of Ministers Regulation of December 27, 2011, regarding the periodic safety assessment of nuclear facilities, using a graded approach with the IAEA SSG-25 (Periodic Safety Review for Nuclear Power Plants). The assessment included a wide range of analyses, including verification of design solutions and technical documentation, the current state of the SSCs, deterministic and probabilistic safety analyses, operational experience, and emergency response plans and systems for crisis situations.

Legal framework in Poland does not provide for separate analyses of fire hazards in periodic safety assessments. Fire hazard analyses were conducted within the following assessment elements:

- Assessment Element 5: Deterministic safety analyses,

- Assessment Element 6: Probabilistic safety analyses,
- Assessment Element 7: Internal and external events analysis,
- Assessment Element 12: Emergency response plans and crisis management system.

As part of the first periodic safety assessment, a program of necessary upgrades and corrective actions was identified. This program also included several corrective actions related to fire safety analyses and organizational aspects of fire protection.

2.5.2. IMPLEMENTATION STATUS OF MODIFICATIONS/CHANGES

As part of the Quality Assurance Program, executive designs and comprehensive safety analyses are prepared for all newly introduced upgrades, with one of the objectives being to meet the fire safety requirements adequately in relation to the conducted modernization. Individual solutions are applied based primarily on the conducted fire expertise, which are additionally coordinated with the Fire Prevention Department of NCBJ (National Centre for Nuclear Research).

For SSCs classified as Safety Class 1 and 2, the designing unit is required to possess a quality assurance program or develop a quality plan for the project before commencing the design process. Additionally, for Safety Class 1 and 2 [5], project evaluations are conducted by the Nuclear Safety Commission.

The modernization of the main switchboard for the MARIA reactor has recently been completed. This work carried the highest fire safety risk compared to other planned modernizations.

2.6. LICENSEE'S EXPERIENCE OF FIRE SAFETY ANALYSES

2.6.1. OVERVIEW OF STRENGTHS AND WEAKNESSES IDENTIFIED

Based on previous experiences, the decision was made not to rebuild the discontinued fixed carbon dioxide (CO2) fire extinguishing system, which previously protected the MARIA reactor hall in the 1990s. The elimination of this system was a consequence, among other things, of a fatal accident that occurred at a nuclear power plant in the Czech Republic due to the activation of that system. As a partially replacing solution for this expensive and non-regulatory-required installation, a modern and highly efficient fire detection and alarm system was implemented, enabling immediate actions by the OGA team before the arrival of the Fire Brigade. Additionally, an above-normal quantity of portable fire extinguishers and fire suppression units were provided as a part of the backup firefighting equipment.

In recent years, a series of measures have been implemented to improve fire safety, as specified in the Fire Protection State Expertise and the conclusions from emergency exercises conducted regularly, at least every two years, with the participation of the Fire Brigade. These exercises have highlighted the need to equip the OGA team with necessary personal protective equipment (such as boots, helmets, and firefighting suits) to effectively extinguish fires in the

initial phase, minimizing the risk to the personnel performing the operations. Part of the required equipment for the OGA group has recently been purchased.

The strengths in the use of operational experience to assess the effectiveness of fire protection system components and improve fire safety include:

- constant presence in a 24/7 shift system of internal services capable of taking intervention measures in the first phase of a dangerous event,
- cooperation with the nearest units of the Fire Service (time of arrival up to 10 minutes from the call) in the field of training and joint exercises.

Weaknesses include insufficient focus on more frequent training (as part of NCBJ's internal requirements, e.g. twice a year) for both state and voluntary fire brigades, as is the practice in other research reactors worldwide.

2.6.2. LESSONS LEARNED FROM EVENTS, REVIEWS, FIRE SAFETY RELATED MISSIONS, ETC.

Since the establishment of the National Centre for Nuclear Research (NCBJ) on September 1, 2011, there have been no significant internal fire-related incidents in the MARIA reactor facility. Only a few incidents occurred due to the activation of the fire alarm system during construction and installation work involving tools and materials that caused smoke. The system was triggered due to the lack of smoke detector protection. Regular training and exercises are conducted to enhance the skills of the emergency response personnel.

Monthly training sessions for the Emergency Service of the Nuclear Center include instruction on operating the fire alarm control panels located in the Emergency Control room, which manage all the fire alarm system components in NCBJ buildings, including the MARIA reactor building. Quarterly training sessions are also conducted for the shift workers in the MARIA reactor control room, focusing on operating the fire alarm control panels located in the control room.

These instructions are delivered by the Fire Prevention Department of NCBJ and an external company responsible for maintaining certain system components. After the instructions, practical exercises are conducted involving the Internal Security Service, which include performing the procedure for responding to a test alarm triggered by the fire alarm system in a selected building. The acquired knowledge is assessed through the practical handling of the control panels by initiating a test fire alarm and activating the alarm notification procedure, with the participation of the Internal Security Service.

According to the NCBJ Emergency Response Plan, periodic emergency exercises are conducted every two years. The internal institute services, including the Emergency Service, Facility Emergency Response Group, Internal Security Service, and Dosimetry Service, as well as the State and/or Volunteer Fire Brigade units and evacuated facility employees, participate in these exercises. The scenario for these exercises must be approved by the local Fire Department Commander in Otwock, in accordance with the requirements of the Fire Protection Status Expertise.

2.7. REGULATOR'S ASSESSMENT AND CONCLUSIONS ON FIRE SAFETY ANALYSES

2.7.1. OVERVIEW OF STRENGTHS AND WEAKNESSES IDENTIFIED BY THE REGULATOR

The fire safety analysis is important way to demonstrate that implemented fire protection measures are adequate to hazards and sufficient to achieve the objectives. Therefore the analysis should cover all the necessary aspects and be carried out in responsible and impartial way.

The most important strength was indicated:

- The Fire Protection State Expertise for the MARIA reactor facility was elaborated by authorized fire protection experts in order to overcome the discrepancy between current fire safety regulations and older ones (which were applied for project and construction of MARIA reactor). The suggestions and recommendations given in this Expertise are consequently being implemented.

The most important weaknesses were identified:

- some documents of the current national regulations on fire safety are not directly applicable to the MARIA reactor, as it was built in 1970s under older fire safety regulations,
- the scope of the fire safety analyses performed does not cover scenarios involving combinations of various events,
- neither direct nor indirect consequences for nuclear safety and radiological protection have been evaluated in analysis of impact of a fire (apart from the initiating events themselves),
- uncertainties are not taken into account in the fire safety analyses,
- there is no on-site internal Plant Fire Brigade unit.

2.7.2. LESSONS LEARNED FROM INSPECTION AND ASSESSMENT AS PART OF THE REGULATORY OVERSIGHT

The Atomic Law Act [7] imposes an obligation on an organizational unit carrying out activities related to exposure involving the operation of a nuclear facility to obtain a permit for this activity. Pursuant to Art. 36k, 38b and 38g of the Atomic Law and the regulation of the Council of Ministers [8], the application for issuing a permit is accompanied by appropriate documents, including fire protection program and rescue and firefighting action plan [5]. The PAA makes sure that these documents are updated on an ongoing basis during inspections or periodic reviews, as well as in course of modernizations and in case when the permit need to be renewed.

In forthcoming second edition of periodic safety review it is planned to check the implementation status of several corrective actions related to fire safety analyses and organizational aspects of fire protection which were developed as a result of the first periodic safety review.

2.7.3. CONCLUSIONS DRAWN ON THE ADEQUACY OF THE LICENSEE'S FIRE SAFETY ANALYSES

In order to improve the adequacy of the licensee's fire safety analyses, its scope needs to be extended and include sequences of events as well as take into account uncertainties. Furthermore, the analyses should be the supplemented with an estimate of the impact of the fire (as such) on nuclear safety and radiological protection.

3. FIRE PROTECTION CONCEPT AND ITS IMPLEMENTATION

3.1. FIRE PREVENTION

3.1.1. DESIGN CONSIDERATIONS AND PREVENTION MEANS

In order to prevent the occurrence of fires, the MARIA reactor facility has been equipped with the following technical measures for detecting and extinguishing fire sources in the early stages:

- fire detection and alarm system (SSP) installation, mostly equipped with smoke detectors, designed to provide comprehensive protection for the entire facility,
- internal fire hydrant water supply installation for immediate extinguishing of fire sources in the initial stage, to be used by facility personnel,
- portable firefighting equipment, including portable powder and CO2 fire extinguishers located in corridors and technical rooms, as well as mobile snow-based firefighting units located in the MARIA reactor hall.

Additionally, the reactor facility has been divided into several fire zones, in accordance with the applicable Fire Protection State Expertise, to prevent the spread of fire and smoke throughout the entire building in the event of uncontrolled fire development in areas where flammable and hazardous materials are stored, with a higher fire load. In the reactor, radioactive waste is temporarily stored in the transport corridor in sealed barrels, away from sources of fire, until it is transferred to the ZUOP.

The emergency services of the institute operate according to the rules and procedures described in the NCBJ Fire Safety Instruction [1] and the Plant Emergency Response Plan. Any hazardous event detected by the fire alarm system triggers the appropriate procedure and immediate activation of internal services to eliminate the event before the arrival of the Fire Service.

3.1.2. OVERVIEW OF ARRANGEMENTS FOR MANAGEMENT AND CONTROL OF FIRE LOAD AND IGNITION

To minimize fire loads, in accordance with the requirements of the MSWiA Regulation [3], the principle of prohibiting the storage of flammable materials in the technical rooms of the MARIA

reactor facility is strictly observed. This principle particularly applies to the reactor hall, physics hall, decontamination hall, battery rooms, power generators and converters, electrical substations, Vokes filters, boiler rooms, and fan rooms.

Only small quantities of consumables necessary for daily operations or related to the construction and use of equipment are stored in these areas (e.g., fuel in the tanks of power generators, Vokes filter cartridges).

Compliance with these regulations is monitored by representatives of the Plant Health and Safety Commission and the Fire Prevention Department during inspections and reviews. The management of the MARIA Reactor Operations Department is responsible for daily supervision of compliance with these regulations, both in terms of fire protection and radiological protection.

Non-standard fire-hazardous work involving open flames, carried out by both NCBJ employees and external companies, may only be performed by individuals with appropriate qualifications. Prior to undertaking such work, individuals must complete the "Protocol for the Execution of Fire-Hazardous Work" form, which is an appendix to the applicable NCBJ Fire Safety Instruction. They must also obtain "Permit for the Execution of Fire-Hazardous Work" from the Head of the Fire Prevention Department at NCBJ, specifying the designated day and location.

3.1.3. LICENSEE'S EXPERIENCE OF THE IMPLEMENTION OF THE FIRE PREVENTION

3.1.3.1. OVERVIEW OF STRENGTHS AND WEAKNESSES

Supervision of fire protection throughout NCBJ, regarding preventive actions within the MARIA reactor facility, is carried out by the Fire Prevention Department. The department consists of a three-person team of specialists with several decades of experience (two individuals) and several years of experience (one individual). Two team members have higher technical education, while one has secondary education. Additionally, the Fire Prevention Department personnel are responsible for inspections and maintenance of certain fire protection equipment, such as fire alarm systems, portable firefighting equipment, and internal fire hydrant water supply installations.

Strengths in the implementation and improvement of the fire prevention system include:

- above-standard equipping of the MARIA reactor facility with modern fire protection devices,
- developing and complying with the recommendations of the Fire Protection State Expertise during renovations and modernization of the facility, including necessary reconstructions.

Weaknesses regarding the aforementioned scope include:

- outdated construction of the facility, preventing its full adaptation to the requirements of current regulations,

- in the existing facility, the inability to fully integrate the requirements of fire safety with those of nuclear safety and radiological protection, including the risks associated with the construction of fire dampers in ventilation ducts on the border of fire zones.

3.1.3.2. LESSONS LEARNED FROM EVENTS, REVIEWS FIRE SAFETY RELATED MISSIONS, ETC.

As a result of analyzing the safety status in terms of fire protection and obtaining administrative decisions from supervisory authorities, including the State Fire Service, a decision was made to carry out a Fire Protection State Expertise for the MARIA reactor facility by fire protection and construction security experts. The expertise was approved by the Provincial Headquarters of the State Fire Service in Warsaw with the aim of adapting the facility (buildings from the 1970s) to the applicable regulations and, at the same time, providing legal sanction for alternative solutions that improve fire safety, instead of costly and often difficult or impossible building modifications.

3.1.3.3. OVERVIEW OF ACTIONS AND IMPLEMENTATION STATUS

Currently, after submitting the schedule for the implementation of works at the local District Headquarters of the State Fire Service in Otwock, the agreed and approved solutions are being implemented.

By the end of 2022, approximately 90% of the recommendations specified in the expertise have been implemented. The goal is to achieve 100% implementation of all recommendations by the end of 2023, thereby fully aligning the MARIA reactor facility with the requirements of the applicable national regulations in terms of fire protection.

Currently, the following works are being carried out in the field of implementation and improvement of the fire prevention system:

- modernization of the fire alarm system located in the battery room in order to adapt it to the requirements of the explosion hazard assessment,
- replacement of the internal ø52 hydrants with modern ø25 hydrants with a semi-rigid hose covering the entire area of the ZLIII fire zone,
- replacement of cables supplying circuits guaranteed for correct operation, shutdown and cooling of the reactor with PH90/E90 cables.

3.1.4. REGULATOR'S ASSESSMENT OF THE FIRE PREVENTION

3.1.4.1. OVERVIEW OF STRENGTHS AND WEAKNESSES IN THE FIRE PREVENTION

The level 1 of Defense in Depth approach is based on the fire prevention. Since the real fire safety system starts just here it is very important to have not only sound organization of fire prevention, but also consecutively implement it in use and obey it in uncompromised way.

The most important strengths were indicated:

- the safety culture of the staff is recognized to give much input into fire prevention. PAA observes the safety culture is even improving in RR MARIA as its staff becomes more and more aware of fire safety rules and still better applies them in practice,
- the management of RR MARIA is safety oriented and makes efforts to improve fire safety conditions, which is confirmed by ordering Fire Protection State Expertise for the MARIA reactor facility and implementing its recommendations with full conviction and consistency.

The most important weakness was also identified:

- the construction building and reactor installations, which were designed using old standards and technical solutions, make it difficult to use modern fire protection regulations.

3.1.4.2. LESSONS LEARNED FROM INSPECTION AND ASSESSMENT ON THE FIRE PREVENTION AS PART OF ITS REGULATORY OVERSIGHT

As part of fire safety, PAA conducts inspections together with the Fire Department. This is not a combined (or integrated) control, but the so-called parallel control. Thanks to this, safety is checked in a wide range. The most common detected deficiencies concern housekeeping, i.e. generally speaking, mess and disorder resulting from leaving residues from some work, including flammable materials, in inappropriate places (fire escapes, rooms subject to fire load restrictions). Most often, unnecessary items and remnants of post-modernization and renovation works are removed during the inspection itself. Year by year, there are fewer and fewer such cases and a clear improvement in attitudes towards compliance with fire prevention rules is visible.

3.2. ACTIVE FIRE PROTECTION

3.2.1. FIRE DETECTION AND ALARM PROVISIONS

3.2.1.1. DESIGN APPROACH

The MARIA reactor facility is equipped with an addressable Fire Detection and Alarm System (FDAS). The system has been designed to provide comprehensive protection for the entire facility, with fire detectors located in every room and on all communication routes.

Upon fire detection, the system activates audible alarms, signaling the evacuation of personnel. Additionally, the reactor control room supervisor, after confirming the threat with the appropriate internal services, relays the necessary information through a radio node. The installed radio node in the reactor facility meets the requirements of regulations and standards related to the Audible Warning System in the event of cable burning or speaker damage during a fire.

In addition to the reactor control room operator, the Emergency Dispatcher of the Nuclear Center is responsible for monitoring the operation and performance of the Fire Alarm System.

Both the control room and the Emergency Service Room (the DAOJ workplace) are equipped with fully operational fire alarm control panels, powered by emergency accumulator supply with a backup duration of up to 72 hours. The Emergency Control Room houses a centralized "Master" panel, while the control room houses a "Slave" panel.

In accordance with the requirements of the expertise, and in agreement with the Provincial Headquarters of the State Fire Service in Warsaw, the fire alarm system from the reactor building does not automatically transmit notification to the Fire Service or any other external services. The Emergency Dispatcher of the Nuclear Centre is in communication with the District Fire Service Management Station via a separate direct telephone line.

3.2.1.2. TYPES, MAIN CHARACTERISTICS AND PERFORMANCE EXPECTATIONS

The fire alarm system has been constructed based on a design approved by a fire protection expert, in accordance with applicable regulations and design standards. The wiring and all system devices meet the requirements for environmental conditions. The wiring connecting individual system elements (detectors, manual fire alarms, control modules, audible signaling devices, and others) complies with the fire resistance requirements of Polish and European standards.

Although the facility has been divided into several fire zones, in the event of a fire alarm activation, all audible signaling devices are triggered simultaneously, regardless of the location of the fire. The reactor control room operator, through the radio node/audible warning system, announces a message informing users about the type of hazard, recommended actions, and, if necessary, the location of the fire.

Due to the very low fire load, it is not anticipated that cables will burn or a significant number of components will be damaged to the extent that it would lead to a system failure, impairing its proper operation in individual fire zones as a result of fire development.

3.2.1.3. ALTERNATIVE/ TEMPORARY PROVISIONS

All unusual situations related to temporary lack of proper protection (malfunction of the FDAS, maintenance work requiring partial or complete system shutdown) are reported well in advance to the Shift Supervisor of the MARIA Reactor Control Room and then to the Emergency Dispatcher of the Nuclear Center, who makes decisions and issues instructions to the respective departments responsible for safety (Internal Security Service, Dosimetry Measurement Laboratory, MARIA Reactor Emergency Response Team) regarding the mode, nature, and duration of additional activities related to increased supervision.

3.2.2. FIRE SUPPRESSION PROVISIONS

3.2.2.1. DESIGN APPROACH

The MARIA research reactor facility does not have automatic fire suppression systems. This requirement is not mandated by both national regulations and the Fire Protection State Expertise approved by the Mazovian Regional Commander of the State Fire Service. The only fire suppression system installed in compliance with the aforementioned legal regulations is the internal fire hydrant water supply installation, which enables employees to carry out firefighting actions in the early stages of a fire using compact and dispersed water streams. Additionally, the facility is fully equipped with portable fire-fighting equipment, including handheld powder and CO2 fire extinguishers, portable powder fire-fighting units located in the reactor hall, as well as fire blankets in the boiler room and fan room.

3.2.2.2. TYPES, MAIN CHARACTERISTICS AND PERFORMANCE EXPECTATIONS

Due to radiological protection requirements, the water-based fire hydrant water supply system was designed and installed only in the office-laboratory area and partially in the technical area, in locations where the use of water for firefighting purposes will not pose additional associated risks.

For the protection of other areas, portable fire extinguishers and transportable fire-fighting units are primarily used, employing fire extinguishing agents such as powder and carbon dioxide. These devices are strategically positioned to ensure that the selected fire extinguishing agent is most effective for extinguishing potential fires in their respective locations, while minimizing additional risks and losses associated with their use.

3.2.2.3. MANAGEMENT OF HARMFUL EFFECTS AND CONSEQUENTIAL HAZARDS

In the case of internal fire hydrants, the hazards associated with their use include electrical shock, unintended spread of radioactive and chemical materials, and material losses due to water damage. Therefore, these devices should be used as a last resort, when extinguishing the fire with fire extinguishers proves ineffective.

Internal hydrants are strategically located to minimize risks and material losses in the event of their use or malfunction, such as unintended water release due to a faulty hydrant valve or a cracked pipe.

The use of powder or snow fire extinguishers also carries the risk of spreading chemical or radioactive materials at the fire scene. However, this risk is significantly lower, and restoring the extinguished area to its previous state is much easier, especially in the case of snow fire extinguishers (CO_2), where the extinguishing agent dissipates after ventilation.

Furthermore, both powder extinguishers and carbon dioxide are non-conductive to electricity, and their fire-fighting capabilities cover a wider range of fire groups (types of combustible materials) compared to internal hydrants.

3.2.2.4. ALTERNATIVE/TEMPORARY PROVISIONS

The fact of temporarily disabling the internal hydrant system is also reported well in advance to the Shift Supervisor of Reactor Control Room MARIA and then to the Emergency Dispatcher of the Nuclear Center. In the event of a fire, they take this into account during firefighting operations.

Furthermore, the individuals responsible for carrying out work that necessitates the system's shutdown are required to equip the facility with additional units of portable firefighting equipment, which are obtained from the Fire Prevention Department's firefighting equipment warehouse at NCBJ. The quantity and type of equipment units are determined by the employee of the Fire Prevention Department based on information received from the person collecting the equipment and responsible for the temporary facility protection during the work.

Active fire protection systems, in accordance with applicable regulations and recommendations from the fire protection expert assessment, which has been agreed upon and approved by the Mazovian Provincial Commander of the State Fire Service, are not required in the MARIA reactor facility.

3.2.3. ADMINISTRATIVE AND ORGANIZATIONAL FIRE PROTECTION ISSUES

3.2.3.1. OVERVIEW OF FIREFIGHTING STRATEGIES, ADMINISTRATIVE ARRANGEMENTS AND ASSURANCE

Fire safety strategies for the MARIA reactor facility, including procedures for responding to fires in specific situations and locations within the facility, guidelines for inspections and maintenance of all fire protection equipment, principles and methods for conducting fire safety training and drills, are described in the Fire Safety Instruction of NCBJ [1], the Emergency Response Plan of NCBJ, and the Emergency Plan for the MARIA reactor [5].

The responsibility for organizing these activities and conducting training, inspections, drills, and maintenance of all fire protection equipment in the MARIA reactor facility lies with the full-time employees of the Fire Prevention Department at NCBJ. If necessary, representatives from the local State Fire Service Command in Otwock participate in these activities based on an agreement between the County Fire Commander and the Director of NCBJ.

The principles of technical inspections and maintenance procedures

Technical inspections, inspections, and maintenance procedures for fire protection equipment and extinguishers are described in the Fire Safety Instruction, in accordance with the requirements set out in the Regulation of the Minister of Internal Affairs and Administration of 7 June 2010 on fire protection of buildings, other structures, and areas [3], which specify that inspection and maintenance activities should be carried out according to the principles provided in Polish Standards concerning fire protection equipment and extinguishers, technical-operational documentation, and operating instructions.

Therefore, such technical inspections and maintenance procedures for fire protection equipment and extinguishers are carried out in accordance with the manufacturer's instructions and no less than once a year.

Internal hydrants

Technical inspections and maintenance procedures for hydrants and hydrant valves are carried out at least once a year according to the scope specified in the Fire Safety Instruction. The facility is equipped with internal hydrants with diameters of ϕ25 and ϕ52. Every 5 years, hoses should undergo a pressure test at the maximum working pressure, in accordance with the Polish Standard for the maintenance of internal hydrants. Annual inspections, maintenance, tests of water flow and pressure in hydrants, as well as pressure tests of hoses, are conducted by employees of the Fire Prevention Department.

In case of the need for major repairs, the employee of the Fire Prevention Department marks the hydrant valve or hydrant with a "NOT FUNCTIONING" sign and informs the facility administrator about this fact.

Electrical installations

Technical inspections and maintenance procedures for electrical installations regarding insulation resistance should be carried out according to Polish Standards, no less than once every 5 years. Inspections, maintenance, and measurements of the required parameters of electrical installations are carried out by the Electrical Department of NCBJ and qualified external companies.

Lightning protection system

Technical inspections and maintenance procedures for the lightning protection system should be carried out according to Polish Standards, no less than once every 5 years. Inspections, maintenance, and measurements of the required parameters of the lightning protection system are carried out by qualified external companies.

Fire alarm system

The fire alarm system undergoes technical inspections and maintenance in the following cycles:

- daily: by the user,
- monthly: by the user or by a service company,
- quarterly: by a service company,
- yearly: by a service company.

During the daily inspection, it should be ensured that:

- the control panel indicates the monitoring status,
- maintainer has been notified of any deviations in the operation of the control panels, which should be recorded in the operation logbook,
- after any alarms recorded the previous day, actions have been taken to eliminate the reasons for their occurrence,
- if necessary, to clear the acoustic and optical signaling or even temporarily disable a specific monitoring line in the control panel, the entire control panel (all monitoring lines) has been restored to the monitoring state.

During the monthly inspection, you should:

- check the paper, ink, or tape supplies for each printer,
- conduct a test of the optical indicators in the control panel.

During the quarterly inspection, you should:

- check all records in the operation logbook and ensure that appropriate actions have been taken to eliminate any abnormalities recorded in the book,
- trigger the activation of at least one detector or manual fire alarm in each fire zone to verify if the Fire Alarm Control and Indicating Equipment (FACIE) correctly receives and displays the specified signals, emits an audible signal, and activates all other alarm and auxiliary devices (precautions should be taken to prevent the release of extinguishing agents),
- check if the supervision of FACIE faults is functioning correctly,
- if possible, test the communication with the fire brigade or remote alarm monitoring center,
- identify if any construction changes have occurred that would affect the placement of detectors and manual fire alarms - all observed abnormalities should be recorded in the operation logbook and promptly addressed.

During the annual inspection, you should:

- perform the recommended tests for daily, monthly, and quarterly maintenance,
- check each detector and manual fire alarm according to the manufacturer's instructions,
- verify the ability of the Fire Alarm Control and Indicating Equipment (FACIE) to activate auxiliary outputs,
- visually inspect all cable connections and equipment to ensure they are functioning properly, undamaged, and adequately protected,
- conduct an inspection to identify any construction changes that may affect the correct placement of detectors and manual fire alarms. Ensure that each detector has a clear space of at least 0.5 meters in all directions and that all manual fire alarms are accessible and unobstructed,
- check the condition of all backup battery accumulators. Any observed abnormalities should be recorded in the operation logbook.

The standard requires that all detectors and manual fire alarms be checked at least once a year. Therefore, it is necessary to initiate their operation using a smoke simulator (e.g., aerosol) and visually inspect whether the required clear space around the detector allows free access for smoke.

The maintenance company should possess the necessary theoretical and practical knowledge. They should be authorized by the equipment manufacturer and have all the required documented national qualifications. When conducting maintenance on ionization smoke detectors, it is necessary to have permission from the State Atomic Agency. Inspections,

maintenance, and measurements regarding the required parameters of the fire alarm system are carried out by qualified external companies.

Emergency Evacuation Lighting: Technical inspections and maintenance of emergency evacuation lighting are conducted according to Polish standards, at least once every 12 months. These tasks are performed by an external service company that holds the necessary qualifications based on a contractual agreement.

Emergency lighting devices should have a safety certificate and information from the manufacturer about the device's operating time. If any malfunctions are detected, they should be reported to a specialized company.

Fire Extinguishers: Fire extinguishers installed in facilities undergo annual inspections and maintenance by a Fire Prevention Department employee with the necessary qualifications. Technical inspections and maintenance of fire extinguishers should be carried out according to Polish standards. During internal checks of the extinguishers' condition, it is verified, among other things, whether:

- they are in the proper location,
- the extinguishers are the correct type,
- they are not obstructed, damaged, or corroded,
- the pressure on the extinguisher's pressure gauge is adequate,
- the operating instructions are clean and legible,
- the placement area is properly marked,
- the wall mountings are suitable, not worn out, and secure.

Training and exercises

To familiarize themselves with the instructions and comply with the provisions contained therein, all users of the facilities of the National Centre for Nuclear Research are obliged, regardless of their official position and type of work performed.

Training includes three levels:

- initial training,
- periodic training,
- informational training.

Initial training involves familiarizing newly hired employees with fire protection regulations and the provisions of the "Fire Safety Instructions," particularly with:

- fire hazards present at their workplace,
- principles and conditions of safe evacuation of people and property from the building,
- principles of fire hazard prevention,

- proper use of fire extinguishing and firefighting equipment located in the vicinity of their workplace.

Periodic training is combined with occupational health and safety (OHS) training according to the program specified in the applicable Official Gazette.

Informational training is organized in connection with:

- significant changes in the fire protection of the facility,
- introduction of new technological devices on the facility premises that pose a fire hazard,
- changes in the purpose and area of rooms resulting in increased fire hazard,
- recommendations from fire protection control authorities.

Fire protection training for employees is conducted by authorized individuals who hold the title of fire protection engineer or possess higher education and have completed a fire protection inspector course.

Initial training is conducted by occupational health and safety and fire protection specialists, and it is mandatory for newly hired employees. Periodic training is organized according to occupational groups and conducted by qualified instructors.

Informational training is organized as needed and conducted by competent personnel from the facility or external specialists.

After completing the training, each employee is issued a certificate confirming their participation in the training.

Training documentation includes:

- periodic training documentation consists of a certificate issued by the instructor, which is then included in the employee's records,
- informational training documentation includes an attendance list with the date, location, list of participants, program for occupational groups, and qualifications of the trainer.

On June 8, 2016, an AGREEMENT was signed between the County Command of the State Fire Service in Otwock and the National Centre for Nuclear Research regarding cooperation in operational and training areas. The agreement defines the principles of cooperation between the Command and NCBJ in the following areas:

- conducting joint training for state and voluntary fire brigades from the Otwock County area,
- conducting joint training for selected employees of the National Centre for Nuclear Research, including Object Emergency Groups (OGAs),
- conducting joint evacuation exercises in selected NCBJ facilities,
- securing the NCBJ premises during exercises by special services.

3.2.3.2. FIREFIGHTING CAPABILITIES, RESPONSIBILITIES, ORGANISATION AND DOCUMENTATION ONSITE AND OFFSITE

According to the Organizational Regulations of NCBJ, the personnel of the Fire Prevention Department (JP) within the Department of Safety and Security are responsible for fire prevention activities at the MARIA reactor facility. The JP department also has the authority to conduct inspections and control the facility to ensure compliance with fire safety regulations by the employees.

In accordance with the NCBJ Fire Safety Instruction and the NCBJ Emergency Action Plan, all facility employees, particularly members of the On-Site Emergency Group (OGA), are authorized and obligated to carry out firefighting actions using portable firefighting equipment in the initial phase. They are also responsible for using rescue equipment located in the reactor control room until the arrival of the Fire Brigade units.

The Emergency Dispatcher of the Nuclear Center (DAOJ) is responsible for coordinating activities between internal units (OGA, WSO, etc.) and assigns specific units for action upon request from the On-Site Emergency Manager (KAO). DAOJ is also responsible for summoning external rescue services (Fire Brigade, Ambulance, Police) in coordination with KAO.

KAO, as the head of the OGA, is responsible for commanding the firefighting operation until the arrival of the Fire Brigade, and then providing a detailed report and transferring command to the Fire Commander. Due to the lack of internal fire brigades, the On-Site Emergency Group is established for the MARIA reactor facility.

The On-Site Emergency Group (OGA) is led by the On-Site Emergency Manager (KAO), who is also the Manager of the MARIA Reactor. In the absence of KAO or inability to perform duties, the Deputy Manager of the MARIA Reactor Plant or the Shift Manager takes over, followed by the Reactor Operator. The OGA consists of Shift Team members holding licenses from the President of the Atomic Energy Agency and the Director of NCBJ.

The following personnel are involved in the emergency response:

- Facility Emergency Manager (FEM),
- Shift Team,
- Site Emergency Group (SEG) members,
- Radiation Protection Officers (RPO),
- Emergency Dispatcher (ED),
- any employee designated by the Facility Emergency Manager (FEM),
- other individuals or organizational units designated by the Nuclear Plant Emergency Manager (NEM) upon request from the FEM.

The current list of SEG members along with their contact information is available with the MARIA Reactor Manager, in the reactor control room, at the on-site guardhouse (MARIA Alarm Station - MAS), and with the Nuclear Plant Emergency Dispatcher. Each SEG member is

required to report to the workplace when summoned by the FEM or ED. Once a month, the Facility Emergency Manager attempts random telephone contact with selected SEG members, including outside of regular working hours.

To ensure the preparedness of individuals comprising the Site Emergency Groups to perform tasks under emergency conditions, theoretical and practical training is conducted. Training is carried out at least once every two years.

The theoretical training covers the following topics:

- basic principles of radiological protection,
- information on biological effects of ionizing radiation, including health hazards,
- operation and use of dosimetry instruments,
- intervention measures in the event of radiation incidents,
- basic quantities and units in radiation dosimetry,
- methods and scope of task implementation according to the Site Emergency Plan, applicable procedures and instructions, taking into account organizational changes, communication, transportation, etc.,
- description of significant historical radiation incidents,
- control of worker and public exposure,
- measurement of dose rates and radioactive contamination,
- personal protective equipment,
- basic principles of personnel, area, and equipment decontamination, including removal of contamination from work surfaces and equipment, as well as personal contamination,
- discussion of relevant emergency situations from the Operational Safety Report of the MARIA Reactor [4],
- actions to be taken in the event of emergency situations analyzed in the Operational Safety Report of the MARIA Reactor [4].

The practical training includes the following exercises:

- comprehensive emergency response exercise to test cooperation with the ED, Internal Security Service, technical services, and external institutions,
- exercise on the use of emergency equipment, gas masks, breathing apparatus, and firefighting equipment.

In accordance with the requirements of the Ministry of Interior and Administration Regulation [3], the Fire Safety Instruction for NCBJ, which contains essential information for conducting operations in the MARIA Reactor facility, has been prepared for external rescue services. One copy of the instruction has been provided to the local County Fire Department Headquarters

in Otwock, and another copy is available to the Fire Department on-site at the Nuclear Plant Emergency Dispatch.

In addition to the prepared Fire Safety Instruction for external firefighting crews, the Facility Emergency Dispatcher also has access to the Facility Emergency Plan, which specifies the protection principles for external group members in the event of a radiation incident.

3.2.3.3. SPECIFIC PROVISIONS, E.G. LOSS OF ACCESS

In terms of special solutions implemented at NCBJ, the following can be mentioned: alternative access routes and the possibility of evacuating employees using company buses.

The first solution allows emergency services to reach the facility in the event of the main road being blocked. Regarding access to the MARIA reactor at NCBJ, there are two entrances from the nearest public roads. Additionally, the access from the Fire Department (Komenda PSP) and Volunteer Fire Department (OSP) to NCBJ is facilitated by a network of roads, including service roads along the S17 expressway.

The second solution ensures the possibility of evacuating NCBJ employees using company buses in the event of a combination of a radiological incident and a fire.

3.3. PASSIVE FIRE PROTECTION

3.3.1. PREVENTION OF FIRE SPREADING (BARRIERS)

3.3.1.1. DESIGN APPROACH

The fire separation elements located in the MARIA reactor facility include walls and ceilings with specified fire resistance ratings (REI - load-bearing capacity, tightness, and insulation); fire doors with required tightness and fire insulation ratings (EI), located in walls at the boundary of zones or leading to technical rooms; and fire dampers with fire resistance rating (EI), located in ventilation ducts at the boundary of zones, controlled by the Fire Alarm System.

The type and level of fire resistance for fire separation elements at the boundary of individual zones and in other required locations were determined in the Fire Protection State Expertise and are detailed in the construction designs, which were also approved by the fire protection security expert before the commencement of modernization and renovation works in specific parts of the facility.

The required fire resistance and durability of fire separation elements, mainly walls and ceilings, are ensured through proper operation, maintenance, and repairs in accordance with the Building Law. Positive results from semi-annual inspections of the building facility, conducted by an authorized external company, confirm this. Self-closing devices in fire doors are regularly adjusted and repaired in case of malfunction, and fire dampers in ventilation ducts are checked during the Fire Alarm System inspections and repaired if necessary.

3.3.1.2. DESCRIPTION OF FIRE COMPARTMENTS AND/OR CELLS DESIGN AND KEY FEATURES

According to the requirements of the Fire Protection State Expertise, the facility has been classified into B fire resistance class (R2-B area - MARIA reactor hall) and C fire resistance class (other areas: R2-A, R2-C, R2-D). Based on this classification, the required fire resistance of individual fire separation elements was determined, and two main fire zones were identified:

- Zone FP1 - building R2-A and R2-B,
- Zone FP2 - building R2-C and R2-D.

Additionally, certain rooms with increased risk have been designated as separate fire zones:

- Zone FP3 - boiler room in the basement of building R2-A,
- Zone FP4 - generator and converter room in building R2-D.

The required fire resistance class of fire separation elements and closures in their openings is specified in the following table: Table 1 Required fire resistance class of fire separation elements.

Table 1. Required fire-resistance classification of fire separation elements (barriers).

Fire-resistance classification of building	Fire-resistance classification of				
	fire separation elements		fire doors or other closures	fire vestibule door	
	walls and ceilings (except ceilings in human hazard category ZL)	ceilings in human hazard category ZL		to the corridor and to the room	to the staircase
"B" and "C"	R E I 120	R E I 60	E I 60	E I 30	E 30

The fire resistance limit of a structure is the period of time from the start of fire exposure under standard tests to the onset of one of the limiting states normalized for a given construction: R is the loss of bearing capacity; E – loss of integrity; I – loss of heat-insulating ability due to temperature increase on the unheated surface of the structure to limit values.

In addition to the mentioned fire separation elements, smoke-tight doors have been used as an additional measure to prevent and delay the spread of fire, smoke, and harmful pollutants. These doors divide corridors that serve as evacuation routes into sections not exceeding 50 meters in length. They have been installed in the R2-A building on the ground floor and the first floor, in accordance with national regulations - the Regulation of the Ministry of Interior and Administration [3] and the Fire Protection State Expertise for the MARIA reactor facility.

3.3.1.3. PERFORMANCE ASSURANCE THROUGH LIFETIME

The effectiveness of fire separation elements, including their nominal fire resistance, is ensured through proper inspections, maintenance, and, in the case of walls and ceilings,

construction repairs in compliance with regulations and Polish standards. Additionally, self-closing devices in fire doors are regularly adjusted and repaired in case of automatic failure to close, while fire dampers in ventilation ducts are checked during the Fire Alarm System inspections and repaired if needed.

Fire load in different parts of the facility is not increased beyond the limits specified by regulations, neither temporarily nor permanently. The management and authorized employees of the MARIA Reactor Operation Department oversee the proper storage of various materials within the facility.

The accessibility of fire escape routes throughout the institute, including those to and around the MARIA reactor facility, is ensured through continuous monitoring by the Internal Security Service. Traffic rules and parking regulations within the NCBJ premises are described in the Motor and Material Traffic Instruction available on the intranet for all employees. This instruction places particular emphasis on providing suitable fire access to individual facilities. Parking of vehicles is only allowed in designated parking areas. Security guards from the Internal Security Service regularly patrol the premises, paying special attention to critical areas such as entrance and fire gates, which are additionally described and marked with prohibition signs. Only designated employees, with the approval of the Deputy Director of NCBJ for Nuclear Safety and Radiological Protection, receive permits for vehicle access to the NCBJ premises.

The evacuation routes (Instruction 13-OT) and emergency equipment (Instruction 12-OT) in the MARIA reactor facility are checked four times a year, and the inspections are documented with protocols.

3.3.2. VENTILATION SYSTEMS

3.3.2.1. VENTILATION SYSTEM DESIGN: SEGREGATION AND ISOLATION PROVISIONS (AS APPLICABLE)

According to the recommendations of the Fire Protection State Expertise, the ventilation system, with the exception of the battery room and the upgraded ventilation in the physics hall, does not have fire dampers. However, there are large distances between the reactor hall and the Vokes filters, which serve as effective barriers for preventing the spread of fire through the ventilation system.

For the upgraded ventilation in the physics hall and the existing ventilation system in the basement (battery room), the design documentation specifies the use of fire dampers and partial system enclosures made of fire-resistant mineral wool to isolate passages to other fire zones in the ventilation ducts. The fire resistance rating of the fire dampers in the MARIA reactor facility, according to the design documentation, is EI 120. Therefore, in the designated and designed locations, these fire dampers should have a two-hour fire integrity and insulation rating.

3.3.2.2. PERFORMANCE AND MANAGEMENT REQUIREMENTS UNDER FIRE CONDITIONS

According to the installation protection design for the MARIA reactor facility, fire dampers have been installed in the ventilation ducts that pass through the fire separation walls at the boundaries of the fire zones. The dampers are controlled through the fire alarm system, and their fire resistance corresponds to the fire resistance of the walls they pass through. In the ducts where dampers have not yet been installed (despite being included in the design), their installation is planned to be completed by the end of this year.

The main method of preventing the spread of fire is dividing the facility into fire zones in accordance with the Fire Protection State Expertise. Each zone is separated from the others by walls and ceilings with the required fire resistance rating (REI - load-bearing capacity, integrity, and thermal insulation). The doors located in the fire walls have a fire resistance rating of EI (integrity and thermal insulation) that is half of the fire resistance rating of the wall. All installation penetrations are protected to a fire resistance rating consistent with that of the walls and ceilings. This requirement is also stated in the Regulation of the Minister of Infrastructure [2].

3.4. LICENSEE'S EXPERIENCE OF THE IMPLEMENTATION OF THE FIRE PROTECTION CONCEPT

Identified strengths:

- round-the-clock presence of emergency services and technical personnel in both the MARIA reactor facility and other facilities on the premises, capable of taking emergency actions (OGA group) and promptly dispatching external services,
- the facility is equipped with above-standard fire protection devices (not required by national regulations), including a comprehensive fire alarm system, a sound broadcasting system that meets the standards of an audible warning system, and a larger number of portable fire extinguishing equipment units than required,
- adaptation of the building from the 1970s to current fire protection regulations based on the guidelines of the Fire Protection State Expertise (currently approximately 90% completed, with full completion planned by the end of this year),
- close proximity of the Fire Brigade intervention units (PSP - approximately 10 km, OSP - approximately 2 km) with verified response times not exceeding 10 minutes,
- close cooperation with the local District Command of the State Fire Service in Otwock in terms of training and joint exercises formalized through the Agreement signed in 2016 between the District Commander of the PSP and the Director of NCBJ.

Identified weaknesses:

- lack of full professional equipment for the Emergency Response Group of the MARIA reactor (protective clothing, footwear, helmets) for conducting reconnaissance in fire conditions and effective firefighting actions until the Fire Brigade units arrive. Part of

the required equipment for the OGA group in the form of 2 sets of firefighter's combat clothing and footwear has recently been purchased,

- due to outdated technical and construction solutions, the facility cannot be fully adapted to meet the requirements of current regulations. Only alternative solutions specified in the Fire Protection State Expertise are implemented.

Due to several hazardous incidents caused by individuals performing fire-hazardous work (mostly representatives of external companies) in the initial period after the establishment of NCBJ, a decision was made to install fire alarm systems in the MARIA reactor facility and most other buildings of the National Center for Nuclear Research. These systems detect smoke in the early stages and activate fire alarms as a signal for evacuating employees from the facility.

Furthermore, a requirement was introduced to obtain permits for carrying out fire-hazardous work, after completing the relevant protocols according to the Fire Safety Instruction of NCBJ. Such permits, for both employees and representatives of external companies performing such work, are issued by an authorized representative of NCBJ.

Following internal inspections and audits, as well as recommendations from the State Fire Service, an Expertise on Fire Protection State was commissioned and approved by the Regional Headquarters of the State Fire Service in Warsaw. This expertise was carried out by fire protection and construction security experts.

3.5. REGULATOR'S ASSESSMENT OF THE FIRE PROTECTION CONCEPT AND CONCLUSIONS

The fire protection concept of RR MARIA comprises active and passive approach.

Active approach is based on a fire detection and alarm system and net of manual extinguishing points located in different places (including compact and dispersed water streams, as well as portable fire-fighting equipment). Active fire protection plays a fundamental role in the Level 2 of Defense in Depth approach. Therefore, the implemented active fire protection measures must work quickly and reliably.

The most important strengths of active fire protection were indicated:

- a system of automatic sensors that detect and signal fire occurrence,
- an extensive and intensive training program to prepare each employee to immediately take appropriate steps to report a fire and take fire-fighting action,
- the management attaches great importance to compensate the lack of an automatic fire suppression systems and internal specialized fire brigade unit. For this reason NCBJ organizes and conducts additional joint training and exercises for fire brigades from the Otwock County area and Object Emergency Groups (OGAs) of the National Centre for Nuclear Research.

The most important weaknesses of active fire protection were also identified:

- lack of automatic extinguishing systems wherever there is a risk of fire that could threaten critical infrastructure for nuclear safety and radiological protection, and at the same time, the possible operation of automatic extinguishing systems would not affect the safety functions of SSCs (Structures, Systems, and Components),
- the system of automatic fire detectors is unable to report the location of the fire,
- lack of internal specialized fire brigade unit.

Passive approach to the fire protection concept of RR MARIA is based on fire barriers existing between fire compartments. In this way the deepest, third level of defense in depth line is realized. For ensuring nuclear safety and radiation protection in RR Maria it is really crucial to systematically protect its critical infrastructure from fire and its harmful effects. Passive protection measures should guarantee such protection for a sufficiently long time, needed for performing fire-fighting.

The most important strength of passive fire protection was indicated:

- preparing the Emergency Service Unit to take fire-fighting action in the event of a fire and taking measures to prevent the fire from spreading, especially in relation to the protection of infrastructure and critical areas in terms of nuclear safety and radiological protection. The emergency service training program should be particularly appreciated, as it is intended to ensure quick response and appropriate actions before the arrival of specialized fire brigade units.

The most important weakness of passive fire protection was also identified:

- the construction building and reactor installations were designed using old standards and technical solutions. Some improvements are possible but they need modernization efforts.

3.6. CONCLUSIONS ON THE ADEQUACY OF THE FIRE PROTECTION CONCEPT AND ITS IMPLEMENTATION

In opinion of PAA, it is worth to consider planned modernizations in RR MARIA as a good opportunity for updating fire protection measures. PAA suggests to evaluate items which could be supplemented for or updated during ongoing modernizations.

Finally, it's worth recalling that, if the fire safety analysis is more comprehensive in order to cover all the necessary aspects, then it would be valuable tool to verify adequateness of implemented fire protection measures to existing hazards and sufficiency of implemented active and passive approaches for achieving the objectives of particular defense in depth levels. However, according to Polish law the probabilistic safety analysis is not obligatory for research reactors.

4. OVERALL ASSESSMENT AND GENERAL CONCLUSION

One of the more effective actions taken to adapt the MARIA reactor facility to the current fire protection regulations and thereby improve safety was the development (at a low cost) and implementation of the Fire Protection State Expertise. Due to significant differences between the current Building Law and the building regulations in force during the construction of the MARIA reactor facility, it was not possible to fully adapt it to the current regulations due to structural reasons.

The principle of defense in depth was introduced in accordance with the guideline that potential impacts are limited to a reasonably achievable level taking into account economic, social and health factors. The MARIA reactor, and in particular the possible occurrence of a fire, does not significantly affect human exposure and environmental contamination.

In addition, the indicated safety levels make it possible to state the independence of the various components. Both passive solutions (design and operation or supervision) and active solutions (control of events and cooperation with external institutions) allow for effective security in case of an incident.

To sanction the existing state and improve safety while limiting costs, it was possible to carry out the Fire Protection State Expertise for this facility in collaboration with a fire protection expert and a construction expert. In this expertise, a series of alternative solutions were proposed in agreement with an authorized representative of NCBJ, stemming from both the inability to reconstruct and legal loopholes in national regulations that do not address fire safety in nuclear facilities. The expertise was approved by the Mazowieckie Regional Commander of the State Fire Service, and the implementation of all its recommendations is planned to be completed by the end of 2023.

As a result of discrepancies between fire protection regulations and the requirements of Atomic Law, an administrative decision was issued by the District Commander of the State Fire Service in Otwock, imposing the obligation to install a fire protection power switch (PWP) in the MARIA reactor facility due to the size of the facility and the volume of fire zones exceeding 1000 m^3. Thanks to the alternative solutions proposed in the Fire Protection State Expertise, the Mazowieckie Regional Commander of the State Fire Service agreed to exempt the facility from installing the PWP switch. In the event that the aforementioned decision imposed by the District Commander of the State Fire Service needs to be implemented, the fire safety status would not change (as a qualified electrician on 24-hour duty can disconnect the power if necessary), but the nuclear safety status would likely deteriorate.

To improve active fire protection, the Emergency Response Group of the MARIA reactor facility should be equipped with certified (with a CNBOP-PIB approval certificate) protective clothing, helmets, and footwear for conducting reconnaissance in fire conditions and effective firefighting actions until the Fire Brigade units arrive, using internal hydrants and portable firefighting equipment.

In order to make such a purchase and choose the appropriate equipment, a meeting was held between representatives of NCBJ and firefighters from the State Fire Service at the headquarters of the District Command of the PSP in Otwock.

5. REFERENCES TO THE NAR

For documents, which are available in English versions their titles are given in English. This applies to legal acts mainly. The rest of documents are available in Polish only.

[1] D. Kwiatkowski, Instrukcja bezpieczeństwa pożarowego Narodowego Centrum Badań Jądrowych. Otwock-Świerk: Narodowe Centrum Badań Jądrowych, październik 2021.

[2] Regulation of the Minister of Infrastructure of April 12, 2002, on technical conditions to be met by buildings and their location (Journal of Laws, 2019, item 1065, as amended).

[3] Regulation of the Minister of Internal Affairs and Administration of June 7, 2010, on fire protection of buildings, other construction facilities, and areas (Journal of Laws, No. 109, item 719, as amended).

[4] Eksploatacyjny Raport Bezpieczeństwa Reaktora MARIA - ERBM-2015 tekst ujednolicony z 2021 r., Praca zbiorowa pod redakcją: E. Wilińska, B. Piwowarski.

[5] Klasyfikacja Bezpieczeństwa Systemów oraz Elementów Konstrukcji i Wyposażenia Reaktora Badawczego MARIA z 30 września 2022 r.

[6] Plan awaryjny dla obiektu reaktora MARIA, procedura 06-ZR-23, A. Gołąb, J. Lechniak, P. Witkowski, I. Owsianko, W. Wilińska, Otwock-Świerk: Narodowe Centrum Badań Jądrowych, maj 2023.

[7] Atomic Law, Act of Parliament of 29 November 2000 on the Atomic Law (Journal of Laws 2023, item 1173, as amended).

[8] Regulation of the Council of Ministers on the documents required with the application for the licence for activities involving the exposure to ionizing radiation or with the notification of such activities (Journal of Laws, 2015, No. 1355, as amended).