

Emergency events that occurred at RBMK nuclear reactors

Stanislav Titov^{1*}, Nikolay Barbin^{1,2}, and Anton Kobelev¹

¹Ural Institute of the State Fire Service EMERCOM of Russia, 620062 Ekaterinburg, Russia

²Ural State Law University named after V.F. Yakovlev, 620066 Ekaterinburg, Russia

Abstract. This article provides a systematic and statistical analysis of emergency situations at nuclear power plants with RBMK reactors in Russia for the period from 1974 to 2018. To carry out a system analysis, the main factors were identified: the number of accidents and incidents, the date, the name of the nuclear power plant where the emergency events occurred. Emergency situations are divided into accidents and incidents, the main causes of emergency situations are identified, the consequences of emergency situations are indicated. For statistical analysis, the percentage of accidents and incidents was determined, the number of accidents at nuclear power plants was shown, the causes were indicated, and the consequences of emergency events at RBMK reactors were noted. Keywords: Nuclear power plant, accident, incident, RBMK reactor.

1 Introduction

To date, nuclear power plants (NPP) are operated in 32 countries, their number is 190 units, which include 442 power units with a total electrical capacity of about 393 GW [1]. The most powerful and largest nuclear power plants in the world are: Kashiwazaki-Kariwa NPP (Japan) – 8212 MW, Bruce NPP (Canada) – 6232 MW, Zaporizhia NPP (Ukraine) – 6000 MW, Hanul NPP (South Korea) – 5900 MW, Gravelin NPP (France) – 5460 MW, Paluel NPP (France) – 5320 MW, NPP Ohi (Japan) – 4494 MW, Palo Verde NPP (USA) – 4174 MW, Balakovo NPP (Russia) – 4000 MW, Hamaoka NPP (Japan) – 3617 MW [1].

There are currently 11 nuclear power plants in operation in Russia, which operate 38 power units with an installed electric capacity of 30.3 GW, of which (fig.1): 21 power units with water-water power reactor (VVER) type reactors (of which 3 power units – VVER-1200, 13 power units – VVER-1000 and 5 power units – VVER-440 of various modifications); 13 power units with channel reactors (10 power units with channel-type high-power reactors (RBMK-1000) and 3 energy heterogeneous loop reactors with 6 coolant circulation loops (EGP-6); 2 power units with fast neutron reactors with sodium cooling (BN-600 and BN-800); 2 reactors at a floating nuclear thermal power plant are water-water with a pressurized water of the KLT-40S type with an electric capacity of 35 MW each [2-3].

* Corresponding author: tsa-nhl@mail.ru

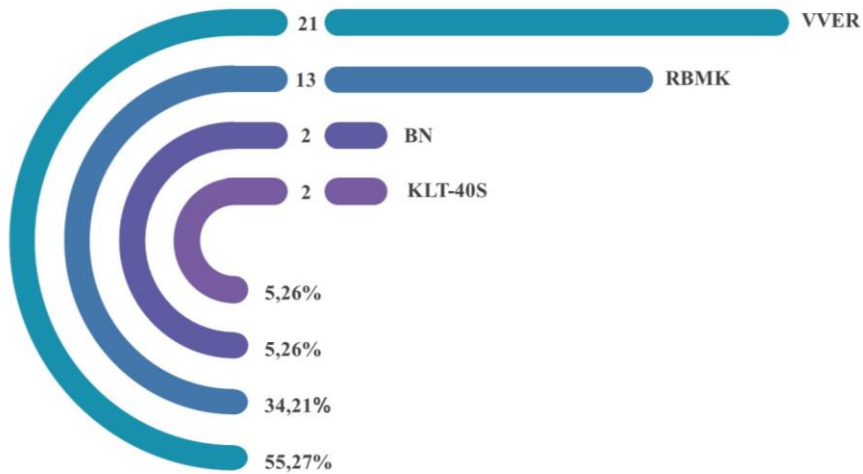


Fig. 1. Reactors operated in Russia.

2 Materials and methods

The work carried out a systematic and statistical analysis of emergency situations: accidents, incidents that occurred at RBMK reactors. Emergency materials were taken from sources [1, 4-10]. When analyzing statistical data, the following programs were used: Microsoft Excel, Microsoft Word. To perform a system analysis, the main factors were identified: the number of accidents and incidents, date, name of the NPP at which the emergency event occurred (Leningrad, Chernobyl, Kursk, Ignalina, Smolensk NPP), emergency situations were divided into accidents and incidents, the causes of emergency situations were identified (technical malfunction, fault of personnel, short circuits unknown causes), the consequences of accidents and incidents are indicated, the most dangerous time of the year for emergencies at RBMK reactors is determined.

3 Results and discussion

In the history of the USSR and Russia, 15 accidents occurred, including 11 accidents and 4 incidents at the RBMK nuclear reactor, which accounted for 73% of accidents and 27% of incidents in percentage terms (fig. 2).



Fig. 2. Percentage of accidents and incidents at RBMK reactors.

The first accident occurred at the Leningrad NPP on January 7, 1974 at the first RBMK power unit, in which, due to a technical malfunction, an explosion of a reinforced concrete gas tank occurred, which led to the ignition of the reactor and the release of radioactive water, three people died in the accident. The second accident occurred on November 30, 1975 at the same NPP, due to a technical malfunction, the technological channel at the first RBMK power unit collapsed, which led to an emergency shutdown and the release of radioactive isotopes into the atmosphere. The third accident was noticed on September 9, 1982 at the Chernobyl nuclear power plant, which was associated with the depressurization of the technological channel of the RBMK reactor, which led to its emergency shutdown with the release of radioactive substances of the radiation dose up to 0.05 sievert (Sv), which further required special work to clean up the territory to its initial state [1,4,5]. The fourth accident occurred on February 27, 1983, also at the Chernobyl nuclear power plant, due to a technical malfunction, a guillotine rupture of the RBMK-1000 technological channel occurred. The fifth accident occurred on April 21, 1983 at the Kursk NPP, due to the fault of the personnel, the destruction of the RBMK-1000 technological channel occurred. The sixth accident occurred on April 26, 1986 at the Chernobyl nuclear power plant, due to the fault of the personnel, hydrogen ignited and the RBMK-1000 was destroyed, which later led to an explosion of the reactor, a fire and the release of radioactive particles into the atmosphere. The most radioactive contamination was received by the liquidators of the accident on average from 100 to 500 millisieverts (mSv). The doses received by residents evacuated from heavily polluted areas reached 33 mSv. The doses accumulated over the years after the accident are estimated from 10 to 50 mSv [4-5]. The seventh accident was registered on March 28, 1988 at the Ignalina NPP, due to the fault of the personnel, damage occurred to the drainage pipeline and the pipeline system for the exhaust steam of the turbine at the first RBMK-1500 power unit. In the same year, on September 5, the eighth accident occurred at the same NPP, due to a technical malfunction, cables overheated at the second RBMK-1500 power unit, which later led to a fire and an emergency shutdown of the reactor. The ninth accident occurred on August 11, 1990 at the Smolensk NPP, due to a technical malfunction due to a water hammer, a steam pipeline ruptured at the third RBMK-1000 power unit. The tenth accident was registered on October 11, 1991 at the Chernobyl nuclear power plant, due to a technical malfunction, a fire occurred at the second RBMK power unit, which led to a major fire and an emergency shutdown of the reactor, followed by the release of radioactive substances into the atmosphere. When extinguishing the fire, 63 participants in the liquidation of the accident received doses from 0.2 to 1.7 mSv [6]. The eleventh accident occurred on March 24, 1992 at the Leningrad NPP, due to the lack of personnel, the technological channel of the RBMK reactor was depressurized, which led to an emergency shutdown of the reactor and the release of radioactivity into the atmosphere of about 50 mSv. The first incident in the history of nuclear power was registered on May 20, 2004 at the Leningrad NPP, due to the fault of the staff, an unauthorized pressing of the emergency button occurred in the operating room of the fourth power unit of RBMK, which led to an emergency shutdown of the reactor and the release of radioactive vapor into the atmosphere [1,5]. The second incident occurred on February 10, 2008 at the Kursk NPP, due to a technical malfunction on the brush-contact apparatus of the generator of the first RBMK power unit, a fire broke out with a subsequent transition to a fire. The third incident was noticed on February 12, 2008 at the Leningrad NPP, due to the ingress of water into the stator winding of the electric motor, a short circuit occurred, which led to the activation of emergency protection at the fourth RBMK power unit, the consequences of what happened led to an emergency decrease in reactor power [2]. The fourth incident occurred on February 18, 2018 at the Kursk NPP, for unknown reasons, a transformer for the station's own needs caught fire, which led to the shutdown of the fourth RBMK power unit [4-10].

During the entire history of operation of RBMK reactors, 15 emergencies have occurred, including 11 accidents and 4 incidents. The very first accident at the RBMK reactor occurred

on January 7, 1974 at the Leningrad NPP. The largest accident occurred at the Chernobyl nuclear power plant on the night of April 25-26, 1986, which belongs to the 7th level of the international scale of nuclear and radiological events (INES) [10].

During the period from 1974 to 2018, 15 emergencies occurred at RBMK reactors: in the Leningrad NPP – 5, in the Chernobyl NPP – 4, in the Kursk NPP – 3, in the Ignalina NPP – 2 and in the Smolensk NPP - 1 emergency situation (fig. 3).

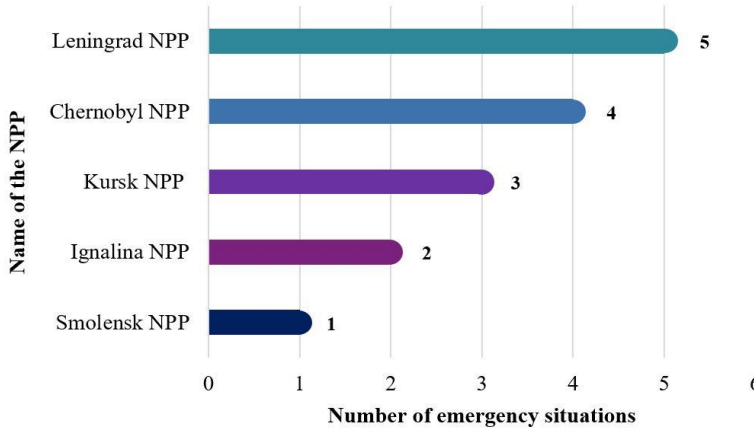


Fig. 3. Occurrence of emergency situations at nuclear power plants.

During this period, emergencies at RBMK reactors most often occurred due to technical malfunctions (fig. 4). The number of emergencies that occurred due to technical malfunctions was 53.34%, due to the fault of personnel – 33.34%, due to short circuits – 6.66% and for unknown reasons - 6.66%. The majority of accidents at RBMK reactors in Russia occurred due to technical malfunctions – 8, due to the fault of the personnel – 5, due to short circuits - 1 and 1, the emergency situation was for unknown reasons.



Fig. 4. Causes of emergencies at RBMK reactors.

Consequences that often occur at nuclear power plants: emergency shutdowns – 7, emissions of radioactive substances – 6, fires – 6 and explosions occurred 2 times (fig. 5)

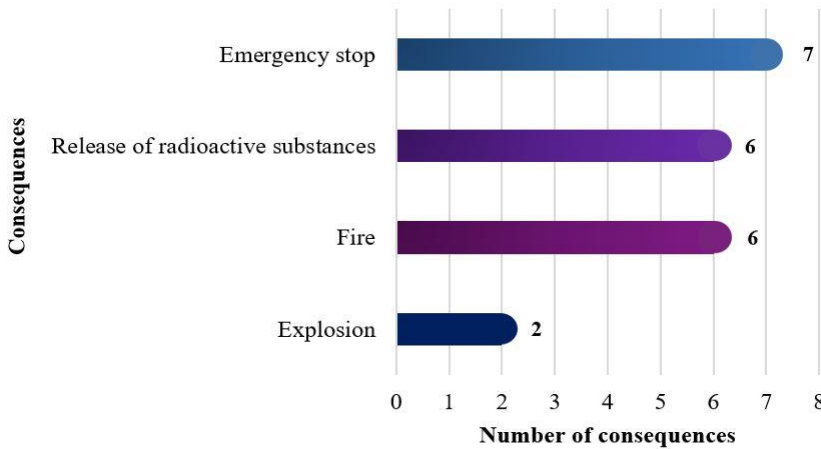


Fig. 5. Consequences of emergency events at RBMK reactors.

Accidents and incidents that have occurred at the RBMK nuclear reactor lead to serious consequences both for the environment and for the person himself. Radioactive emissions negatively affect agricultural lands, lead to serious damage to the agro-industrial complex, pollute the ecology of forests and reservoirs, and bring serious consequences to the animal and plant world [11].

4 Conclusion

Having conducted a systematic and statistical analysis of emergencies at RBMK reactors that occurred in Russia during the period from 1974-2018, we come to the conclusion that the largest number of emergencies occurred at Leningrad NPP – 5. The main causes of accident events were technical malfunctions (53.34% of all emergency situations: explosion of a reinforced concrete gas tank, melting of a technological channel, depressurization of a technological channel, guillotine rupture of a technological channel, overheating of cables in the cable room at the power unit, water hammer followed by rupture of the steam line at the power unit, fire in the engine room, fire on the brush-contact apparatus of the generator). Frequently occurring consequences at nuclear power plants: emergency shutdowns – 7, emissions of radioactive substances – 6, fires – 6. The system and statistical analysis made it possible to identify the main indicators of the occurrence of emergency situations at nuclear power plants operated by RBMK type reactors [12-15].

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