Radiation Safety of Population in the Region of NPP-2006/MIR-1200 Site

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***Abstract*—**The main features of NPP-2006/MIR-1200 design are described. Estimation of individual doses for population under normal operation and accident conditions is performed for Leningradskaya NPP – 2 as an example. The radiation effect on population and environment doesn't exceed the established normative limit and is as low as reasonably achievable. NPP-2006/MIR-1200 design meets all Russian and international requirements for power units under construction.

***Keywords*—**Accident release, beyond design basis accident (BDBA), nuclear power plant (NPP), radiation safety.

I. Introduction

NPP-2006/MIR-1200 design was elaborated in JSC SPAEP on the basis of NPP-91 (VVER-1000) design taking into account the experience gained from the construction and operation of these power units.

Today the power units of MIR-1200 design are being constructed at Leningradskaya NPP and Baltiyskaya NPP (Russia), and at Belorusskaya NPP (Belorussia).

The safety concept is based on:

– the modern Russian requirements, standards and codes for nuclear power industry related to safety of population and the environment;
– up-to-date safety principles and philosophy generally accepted in the world nuclear community and stated in IAEA safety guides, publications of International Nuclear Safety Advisory Group (INSAG), and EUR requirements;
– application of proven technical solutions supported by operational experience of NPP with VVER reactors;
– use of verified and qualified calculation methods, computer codes and programs.
– The main features of NPP-2006/MIR-1200 design are the following:
– double containment,
– four trains of active safety systems (4x100%, 4x50%),
– maximum use of well-proven solutions and equipment (reference design - NPP-91 design),
– technical measures for BDBA management based mainly on the passive principles (core catcher, hydrogen removal system, passive heat removal system via steam generators, passive heat removal system from the containment, system of primary loop overpressure protection).

The following provisions limiting environmental effects and radiation doses for population are made in the technical requirements specification for NPP-2006/MIR-1200:

– the sanitary protection zone shall be restricted by the NPP-site boundary;
– the probability of an accident which may cause considerable radiological impact on population shall be minimized (the probability of exceeding the accidental release limit shall be less than 10-7 1/reactor*year). Total (of all accident sequences) severe core damage frequency shall not exceed 10^{-6} 1/reactor per year.

The acceptance criteria for power unit NPP-2006/MIR-1200 related to severe BDBA with residual risk 10^{-7} 1/year are the following:

– Urgent emergency measures including evacuation or long-term resettling of population outside NPP site shall be excluded;
– Long-term restriction on use of vast areas around the NPP shall be excluded;
– Rated radius of obligatory public evacuation planning zone shall not exceed 800 m from the Reactor building [1];
– Radius of protection measure planning zone (PMPZ) shall not exceed 3 km from the Reactor building [1].

The NPP-2006/MIR-1200 is designed so that radiation effects on the environment and population during normal long-term operation, at anticipated operational occurrences and design basis accidents do not exceed the established admissible public dose rates. In the event of a beyond design basis accident, radiation effects are also limited by taking adequate measures.

As the effect of radioactive releases from NPPs depends on the characteristics of the site and the area around it (such as relief, meteorological parameters of release diffusion etc.), in this work the dose rates for population are estimated for Leningradskaya NPP – 2 (LNPP-2). For Baltiyskaya and Belorusskaya NPPs the dose rates for population are approximately at the same level.

II. Normal Operation

The design releases and discharges from LNPP-2 (4 Units MIR-1200) at normal operation are given in Table I.

The individual doses for population around LNPP-2 are evaluated taking into account:

– main aero-climatic characteristics determining local conditions of release diffusion and therefore pollution levels;
– accumulation rate of long-lived nuclides in the components of terrestrial and aquatic ecosystems for the

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plant lifetime (50 year);

– existence of the cooling towers, which may cause no more than double increase of the ground-level concentration (at distances up to 3 km from the plant, if the wind blows in the direction from the cooling tower to the ventilation stack).

TABLE I
DESIGN RELEASES AND DISCHARGES FROM LNPP-2 AT NORMAL OPERATION

Nuclide	Discharge, GBq/(year*4 units)		Release, GBq/(year*4 units)	
	Discharge from LNPP-2	Admissible discharge from LNPP-1	Release from LNPP-2	Admissible release from LNPP-1
IRG	-	-	$1.8 \cdot 10^5$	$6.9 \cdot 10^5$
I-131	$1.4 \cdot 10^{-1}$	63	$2.9 \cdot 10^{-1}$	18
Cs-137	$4.8 \cdot 10^{-1}$	1.1	$1.2 \cdot 10^{-1}$	2
Tritium	$3.6 \cdot 10^4$	-	$1.6 \cdot 10^4$	-

Individual radiation doses for critical group of population (adults) caused by gas-aerosol releases from LNPP-2 at normal operation (μSv/year) are presented in Table II.

TABLE II
INDIVIDUAL DOSES FOR POPULATION AT NORMAL OPERATION (LNPP-2)

Distance, km (direction)	External exposure from the plume and surface deposits	Internal exposure by inhalation	Internal exposure from foodstuffs	Total effective dose	Minimum significant dose (СП АС-03)
0.5 (E)	0.36	0.01	1.16	1.54	10
1.5 (E)	0.44	0.05	1.16	1.66	
5 (NE)	0.05	0.008	1.16	1.22	
10 (NE)	0.03	0.006	1.16	1.20	

So the annual individual dose for population is less than 10 μSv/year, and the design meets all the requirements.

III. DESIGN BASIS ACCIDENTS

The acceptance criteria for NPP-2006/MIR-1200 at anticipated operational occurrences and design basis accidents (DBA) according to technical requirements specification are presented in Table III.

In the preliminary safety analysis report (PSAR) of LNPP-2 all the DBA were grouped depending on the frequency of initial event, fuel damage, radioactive release and radiological consequences for population. For each category of DBA the worst scenario was chosen:

– depressurization of circuits containing radioactive media outside the containment (category 2),
– accidents accompanied by leak from the primary circuit to the secondary circuit (category 3),
– depressurization of the primary circuit inside the containment (category 4),
– accidents at fuel handling (category 4).

For all scenarios the evaluation of radioactive releases was performed. The calculation of doses in each case of DBA was carried out using the maximum diffusion factors (the most unfavorable weather conditions) with probability of 99.5% [2] for the region of LNPP-2. The results are given in Table III.

TABLE III
ACCEPTANCE CRITERIA AND DESIGN LEVEL OF DOSES FOR ANTICIPATED OPERATIONAL OCCURRENCES AND DBA

Event	Frequency, 1/year	Acceptance criterion	Prognosis
Anticipated operational occurrences	$f > 10^{-2}$	100 μSv/year	< 60 μSv/year
Accidents (low frequency)	$10^{-2} > f > 10^{-4}$	1 μSv/event	< 1 μSv/event
Accidents (very low frequency)	$10^{-4} > f > 10^{-6}$	5 μSv/event	< 3.4 μSv/event

In accordance with Russian norms [3] the basic dose limit for population is 1 mSv per year for the period of 5 years, but not more than 5 mSv for a year. It is shown for DBA that this dose limit will not be exceeded, and no protective measures for population will be obligatory outside the LNPP-2 site boundary.

IV. BEYOND DESIGN BASIS ACCIDENTS

Based on the passive principles NPP-2006/MIR-1200 design provides the following technical measures for BDBA management:

– core catcher,
– hydrogen removal system (with passive recombiners),
– system of primary loop overpressure protection,
– passive heat removal system via steam generators,
– passive heat removal system from the containment,
– iodine volatile forms control.

For severe BDBA accompanied by core degradation and slow rising of the pressure inside the containment (with probability of 10^{-7} 1/year.reactor) the estimation of accident releases and their radiological consequences was performed. The calculation of doses was carried out using the maximum diffusion factors (the most unfavorable weather conditions) with probability of 95% [2] for the region of LNPP-2.

The accident release limits at early stage of BDBA (the first 24 hours) are the following:

– Xe-133 – 10^4 TBq,

– I-131 – 50 TBq,
– Cs-137 – 5 TBq.

The accident release limits at intermediate stage (1 – 30 days) are the following:

– Xe-133 – 10^5 TBq,
– I-131 – 50 TBq,
– Cs-137 – 5 TBq.

The expected exposure doses for the first 10 days are given in Table IV.

TABLE IV
RADIOLOGICAL CONSEQUENCES OF SEVERE BDBA

Distance from the Reactor building	LNPP-2 site boundary	3 km from the Reactor building	7 km from the Reactor building
Dose for body, mGy	< 500	< 50	< 5
Dose for thyroid, mGy	< 5000	< 500	< 50

In accordance with the modern Russian and international requirements the radius of the protection planning zone doesn't exceed 3 km. The radius of the observation zone (OZ) is about 13 – 15 km. The OZ is established around the NPP to get necessary information and data, which allow estimating the radiological effect on population and the environment caused by normal operation of NPP and possible accidents at the site.

V. CONCLUSION

It is shown that NPP-2006/MIR-1200 design meets all modern Russian and international requirement related to radiation safety of population. All the acceptance criteria are fulfilled for normal operation, at anticipated operational occurrences and possible accidents.

REFERENCES

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