APPLICATION OF SAFETY STANDARDS AND RULES IN THE SHELTER IMPLEMENTATION PLAN AT THE DESTROYED POWER UNIT OF CHERNOBYL NPP

A. Berthold
GRS (Germany)
Kurfurstendamm 200, Berlin, Germany
bta@grs.de

P. Bogorinski
Riskaudit IPSN/GRS International (France, Germany)
Radgospna 35-37, Kyiv, Ukraine
bog@siple.kiev.ua

V. Bykov, V. Redko
SNRC of Ukraine
Arsenalna 11, Kyiv, Ukraine
bykov@hq.snrc.gov.ua

L. Erickson
Scientech (USA),
Radgospna 35-37, Kyiv, Ukraine
lerickson@siple.kiev.ua

SSTC NRS
Radgospna 35-37, Kyiv, Ukraine
ep_kadkin@sstc.kiev.ua

ABSTRACT

This report deals with the application of safety standards and rules to the Shelter Implementation Plan (SIP) measures.

Since 1998 this plan is being implemented at the Chornobyl NPP destroyed unit (which is now known as the Shelter). It includes a set of various tasks whose performance will help partially achieve the established safety objectives.

The Regulatory Authority should establish for the Shelter safety goals, principles, and criteria in general, while the Operator of the Shelter is free to independently select the optimum method for their implementation. The Operator of the Shelter must demonstrate (in safety analysis report) that established safety goals are achieved and safety principles and criteria are met.

Safety goals, principles, and criteria established for radioactive waste management are reasonable to apply in measures provided for by SIP. However, due to the unique nature of the Shelter, some criteria should not be applied directly and in full scope.

Norms and rules on radiation protection should be applied in full scope. The specifics of radiation protection during each Shelter-related activity are considered individually.
Safety standards and rules related to technical aspects are reasonable only as a basis. Effective resolution of specific technical issues associated with safety assurance is achieved through interaction between the Operator and the Regulatory Authority during design of SIP structures and systems. Hence, effectiveness of the licensing process plays an important role in the success of the SIP.

1 INTRODUCTION

Object “Shelter” (Shelter) was built in 1986 over the remains of the destroyed Chornobyl Nuclear Power Plant (ChNPP) Unit 4 to create barriers to further radioactivity spread and to protect personnel, population and the environment from the impact of ionising radiation.

Shelter construction was completed in a very short time. Because of the high radiation fields it was necessary to apply remote methods for installing structures. As a result, the constructed Shelter has some drawbacks (for example, roof leakage, inconsistency in the design and actual strengths of the concrete and metal structures, etc.). The collapse of these structures could lead to significant release of radioactive material into the environment.

Currently, the Shelter hazards are determined by the following main factors:

− presence of radioactive materials with a total activity of about $10^{18}$ Bq (including long-lived radionuclides) without reliable barriers to prevent the spread of radioactivity into the environment;
− presence of agglomerations of fissionable material without sufficient means for control of subcriticality;
− presence of 400 to 1000 m³ of water, depending on the season. Water infiltration into agglomerations of the fissionable material could lead to an increase in effective neutron multiplication factor and, potentially, to criticality. Water also negatively impacts the integrity of fuel-containing material (FCM), resulting in transfer of dissolved and dispersed radionuclides throughout the Shelter premises and potential transfer into the hydro-geological environment. The water accelerates the deterioration of metal and concrete structures as well;
− presence of a significant amount of radioactive material (including nuclear fuel fragments), which is located at the site around the Shelter under the layers of construction material (sand, broken stones, concrete) without adequate isolation from the hydro-geological environment.

The present condition of the Shelter is unacceptable.

An international expert team developed a plan of action that contains both short-term actions on Shelter stabilization and long-term actions on its transformation into an ecologically safe site. This plan, the so-called Shelter Implementation Plan (SIP) [1], was approved at the highest levels by Ukraine and a broad group of countries under the leadership of the G-7. At present, the first (preparatory) SIP phase has been completed and the work under the second (main) phase has been started.

The SIP has five main objectives:

− reduce the risk of Shelter confining structure collapse;
− mitigate the consequences of the Shelter confining structure collapse, should it occur;
− improve nuclear safety within the Shelter;
− improve the safety of Shelter personnel and protect the environment; and
− develop a long-term strategy for transformation of Shelter to an ecologically safe system.

The following measures have been defined for achieving these objectives:

− integrated stabilization and shielding;
− integrated automated monitoring system;
− water management system;
− FCM removal prototype technology; and
− safe confinement (SC);

It is planned to start FCM and radioactive waste (RW) removal from the SC in 40-50 years, well after SIP completion. The main sources of nuclear and radiation risk should be removed by the end of the SC designed service life and therefore the Shelter transformation to an ecologically safe system should be practically completed.

All activities at the Shelter, as at other radiation-hazardous objects should be carried out according to the laws, norms, and rules in force in Ukraine which regulate safety. Besides, while carrying out activities at the Shelter it is reasonable to apply the recommendatory documents of international organizations and other countries which do not contradict the laws, norms, and rules in force in Ukraine.

The paper reviews briefly the normative base which is applied to the Shelter.

2 REGULATORY APPROACH

In Ukraine safety of nuclear facilities is regulated by the laws of Ukraine and orders of the Cabinet of Ministers, and norms and rules of the safety regulation authority. In Ukraine, there is also a system of standards, which one contain different technical requirements.

In order to determine the list and scope of the regulatory and legal acts (RLA) used for regulating the safety activity at the Shelter, at first, it is necessary to determine the object status. Such determinations are stated in [2, 3, 4].

The Shelter in its current condition covers the remains of the ChNPP Unit 4 which was destroyed by a beyond-design-basis accident and has lost all its functional features [3]. First-priority measures have been taken to mitigate the accident consequences, and activities are being continued to ensure its nuclear and radiation safety. According to [5] all nuclear and radioactive materials of the Shelter are radioactive waste (RW) and they should be removed from it for isolation and disposal. The Shelter is classified as a temporary storage facility for unorganized radioactive waste (RW), which is currently at the stage of stabilization and reconstruction [3, 4].

It follows from regulatory documents that:
− firstly, the activity of the Shelter is RW management, appropriately, regulation of its safety should be conducted by means of the RLA, which cover the field of RW management;
− secondly, the Shelter is not a NPP unit, hence, the RLA which are devoted exclusively to NPPs can not cover Shelter activities.

Internationally accepted provisions for safety of RW management object should be applied to the Shelter, but such principles cannot be implemented fully. Their subsequent implementation is possible only after transformation of the Shelter into a more safe condition.

In order to select a safe variant of possible activities for this transformation, safety goals are established.

The general safety goal of activities at the Shelter is to assure protection of personnel, the general population, including future generations, and the environment against radiological hazards. In other words, the Shelter should be transformed into an ecologically safe system.

This general safety goal can be achieved by reduction of hazards. Ultimately, the nuclear and radioactive material constituting the radiological hazard at the Shelter should be removed and isolated, but this is beyond the scope of the SIP.

The content of the general safety goal is usually covered and interpreted in terms of specific safety objectives. The following specific objectives are applied to the Shelter:
− radiation protection (RP) objectives;
– accident safety prevention and mitigation objectives;
– nuclear criticality safety objectives;
– physical protection objectives;
– RW management objectives.

Safety goals, principles, and criteria are determined in the corresponding laws of Ukraine [6-13]. Besides, these goals, principles, and criteria are established in the documents exclusively dedicated to the Shelter [1-5, 14] and also in the norms and rules on safety (for example [15-16]).

3 RADIATION PROTECTION

Radiation protection objectives are achieved if:
– Exposure of the personnel and population does not exceed dose limits and quotas established in [7, 15] and is as low as reasonable achievable;
– Damage associated with the potential exposure, expressed in units of generalized risk, does not exceed the reference risk levels established in [4, 15] and is as low as reasonable achievable.

During activities at the Shelter, RP should be based on general principles: justification, non-exceeding, optimisation [15].

Justification principle – any practice that causes exposure to people should not be implemented if it brings less benefit to exposed individuals or the society as a whole compared to the harm it causes.

Non-exceeding principle – exposure levels of all significant practices should not exceed the established main dose limits of personnel and public exposure and other radiation and health-safety regulations for certain groups of personnel and the public. Limits of annual effective dose is established for personnel (20 mSv - averaged value for any successive 5 years but not more than 50 mSv during one single year).

Optimisation principle – levels of individual doses and/or the number of exposed individuals in relation to each ionising radiation source should be as low as reasonable achievable taking into account economical and social factors. Incorporation of the optimisation principle at the Shelter should be determined by reducing the collective dose and preventing excess inefficient expenses on protection. Different RP technology variants and measures should be considered in designing.

Radiological consequences for workers shall be assessed for each particular task and in doing so it is necessary to take into account the exposure caused both by workers action while task realisation and their presence in the alienation zone. Radiological consequences should not exceed those which occur at normal operation of the nuclear installation. When carrying out some specific tasks it is admitted reasonable to increase collective exposure dose provided that individual doses remain less than the basic dose limits. In this case the operating organization shall prove that there are no practically feasible options resulting in further reducing of the collective dose.

4 ACCIDENT SAFETY

Accident safety objectives are achieved if:
– Possible radiological consequences (if any) of accidents do not exceed the design indicators for all events taken into account in designs on Shelter transformation;
– Measures on preventing, monitoring, and mitigating accidents can be undertaken so that the consequences of potential accidents are small and so that accident progression does
not make a disproportionately greater contribution to the total risk, relative to other possible ways of accident progression.

The regulation system related to the protection against the potential exposure [4] contains the referent levels of doses and potential exposure risks, as well as the reference probability of critical events. These regulations should not exceed the reference indicators and should be as low as reasonable.

For example, the probability of critical events should not exceed $2 \cdot 10^{-4}$ per year for events which can cause potential personnel exposure of more than 100 mSv but in absorbed dose less than 1000 Gr.

Designs for the stabilization of the Shelter existing confining shell and SC creation should be based, in particular, on the following main criterion related to the protection against potential radiation sources, namely that the assessed probability of critical events that required evacuation of population does not exceed $10^{-5}$ per year after stabilization of the Shelter and $10^{-6}$ per year after SC creation.

Restriction of the main staff exposure involved into emergency works is performed in such a way not to exceed the dose limits [15].

It is allowed to plan increased exposure of persons among emergency staff (apart from women as well as men before 30). In the cases when operations within the accident effected area are combined with the following situations:

(a) intervention to prevent severe consequences for the health of people who entered into the accident area;

(b) reduction of number of individuals who may receive emergency exposure (prevention from the great collective doses);

(c) prevention of accident progression that can lead to disastrous consequences;

At that time all the measures shall be undertaken such that the value of integral exposure does not exceed 100 mSv.

In the exceptional cases, when the activities is performed to save human lives, all possible measures shall be undertaken that the persons among emergency staff should receive an equivalent dose at not more than 500 mSv.

The reduction of radiation danger in case of an accident is provided by implementation of an emergency plan at the Shelter site.

5 NUCLEAR CRITICALITY SAFETY

Nuclear criticality safety objectives are achieved if at least:

− criticality is excluded during routine conditions and in the event of any single deviation, violation, or failure of equipment, monitoring means, or control means;

− uncontrolled accumulations, movements, transfer, treatment, and transportation of nuclear material are excluded;

− the established parameters and limitations on nuclear criticality safety are monitored;

− the complex of technical and administrative means adequately provides for mitigating consequences of criticality origination that should occur.

It has been determined, for example in [2, 16], that the activities on the management of FCM at the Shelter facility shall be directed to developing measures and realizing projects with regard to:

− final identification of FCM location and determination of their quantity, composition and physical and chemical properties;

− measuring and simulating (modelling) physical and chemical processes which take place in FCM in order to predict their behaviour;

Proceedings of the International Conference Nuclear Energy for New Europe, Kranjska gora, Slovenia, Sept.9-12, 2002
– preventive lowering of effective multiplication factor if their quantitative values are not estimated by measurements;
– setting up a reliable system of FCM reactivity control and management.

6 RADIOACTIVE WASTE MANAGEMENT

RW management objectives are achieved if at least:
– the established level of human health and environmental protection is maintained;
– possible consequences for human health and environmental impacts beyond the borders of Ukraine are not more than those acceptable in Ukraine;
– potential consequences for health of future generations are not more than those acceptable at present;
– RW management does not impose an excessive burden on future generations (as far as possible), neither due to the influence of RW on them or due to the difficulties associated with RW management.

The main principles and criteria related to the safety assurance in RW management and which can be used in SIP related activities are determined for example in [2,4, 8, 14, 17].

RW disposal is provided for by their reliable isolation from the environment by a system of natural and artificial barriers. The safety of RW storage and disposal facilities in extreme natural events (earthquakes, floods, tornados, etc) or emergency situations is provided for by the scientifically substantiated design decisions related to the possible scenario of events which will confirm the non exceeding of the limits established by standards and rules.

Over the whole time of RW storage, there is regulatory monitoring for their condition, radiation state in the RW storage facilities and environment.

7 PHYSICAL PROTECTION

Physical protection objectives are achieved if:
– provisions are made to prevent possible nuclear terrorism acts, including nuclear and radioactive material theft;
– required information and technical assistance is available to the authorities that carry out emergency investigation, in the event of missing nuclear and radioactive material.

General principles and criteria are determined for example in [9] as regards the physical protection assurance, which can be used in SIP related activities, in particular:
– all interested governmental authorities and legal persons use a unified nuclear terrorism counteraction system developed in advance;
– physical protection systems of RW management facilities function properly as long as these facilities are operating;
– the procedure for personnel responsibility are established and implemented.

An access control system complying with the requirements should be created at the Shelter within the SIP.

8 TECHNICAL STANDARDS

In accordance with [13] the technical standards should be applied voluntarily, if other is not established by the legislation. This document contains the provisions under which the application of the standards becomes mandatory. In particular, the application of the standards is mandatory for participants of an agreement on development, production, or delivery of products, if it contains references to certain standards.
Technical requirements for structures and systems of the Shelter on the one hand should be specific taking into account the uniqueness of the object as a technical system, and on the other hand there are no reasons to consider that these requirements should differ in principle from the similar requirements established for NPPs and other objects. Hence, in activities concerning the Shelter including the development of designs within the SIP it is reasonable to use the regulatory framework in force with requirements of technical nature. However, it makes sense not to “automatically” apply the whole repertoire of NPP requirements to the Shelter, but rather to consider expediency of application of specific technical requirements depending on specific SIP designs.

At present, the Shelter activities are generally not covered by specific regulatory requirements. In particular, a significant part of the technical requirements similar to the requirements, which are established in regulation documents in force for NPP, is not established for the Shelter. But it is not reasonable to give specific technical requirements for the Shelter the status of the regulatory requirements.

There are the following reasons for this:
- to develop regulatory standards for the activity concerning the Shelter accurate data are required on the object, on the activities underway at it, on the experience gained. There are not sufficient data and experience in this regard.
- the establishment of regulatory standards provides that the object and the activity at it will generally remain unchanged for a long term. Meanwhile, the Shelter and the activity at it will be permanently transformed.

To such unique facilities as the Shelter standard engineering solutions cannot be applied, except for general principles of safety - the principles nuclear and radiation safety, radiation protection, RW management.

Thus, the development of strictly administrative legislative base for the Shelter will not have a sufficient basis, and could cause inefficiency aimed at its transformation. An endless number of overly specific technical requirements established in technical standards would not give a “freedom of choice concerning optimum safety assurance ” to the Shelter operating organization. Besides, a procedure for changing these requirements will take long time, which will cause delays in Shelter Operator activities.

9 LICENSING PROCESS

A different safety regulation approach could be applied to this facility. Under this approach the Regulatory Authority shall establish for the Operator safety goals, principles, and criteria in general, while the Shelter Operator is free to independently select the optimum method for their implementation. The Shelter Operator must demonstrate in a safety analysis report that established safety objectives are achieved and safety principles and criteria are met.

The aforesaid approach provides for urgent resolution of specific technical aspects of safety assurance in co-operation between the Regulatory Authority and the Operator within the established licensing process.

The licensing process for SIP activities established based on the aforesaid approach provides that the Operator is to obtain individual permissions for implementation of each design developed within the SIP. At that, the co-operation of the Operator with regulatory authorities during designing, at its basic stages, is intended to gain confidence that the method for achieving safety purposes was selected correctly.

In this case, standardization is not the only safety regulatory factor, another one is licensing. Wide application of the latter factor for activities on the Shelter seems to be more effective than the first one.
REFERENCES


[10] Law of Ukraine «On Environmental Protection»


Proceedings of the International Conference Nuclear Energy for New Europe, Kranjska gora, Slovenia, Sept.9-12, 2002