Technical Design of the National Disposal Facility at Radiana in Bulgaria – 14291

E. Biurrun*, , E. Gonzalez Herranz**, T. v. Berlepsch*
*DBE TECHNOLOGY GmbH, Eschenstr. 55, D-31224 Peine, Germany
biurrun@dbe.de; thilo.berlepsch@dbe.de
**Westinghouse Electric Spain SAR, Padilla 17, E-28006 Madrid, Spain
lazaroa@westinghous.com; miralla@westinghouse.com

ABSTRACT

In October 2011 a Consortium composed by Westinghouse Electric Spain SAU, ENRESA and DBE Technology GmbH was awarded by SERAW with a contract for the design of the Bulgarian low and intermediate level waste repository. The facility will consist of 66 reinforced concrete cells capable of receiving 18,600 conditioned waste containers during 60 years, and the related auxiliary facilities and buildings.

After a comprehensive study of the documentation, SERAW approved the recommended Conceptual Design on December 2012, and authorized the Consortium to start developing the Technical Design. The complete package of the Technical Design documentation prepared by the Consortium consists of 19 separate chapters and fills around 50 folders with approximately 6500 pages. As the general progress of the project lies within the planned deadlines, it is reasonable to assume that a license for construction of the NDF can be expected in the course of 2014.

INTRODUCTION

In the framework of the accession treaty to the European Union the Republic of Bulgaria committed itself to the early decommissioning of the four WWER 440-V230 reactors of the Kozloduy Nuclear Power Plant (KNPP). Due to this early decommissioning large amounts of low and intermediate radioactive waste will arise much earlier than initially scheduled. In order to manage the radioactive waste from the early decommissioning, Bulgaria has intensified its efforts to provide a near surface disposal facility for low and intermediate level waste at Radiana with the required capacity. It is supported in this endeavour by a compensation mechanisms established by the European Union, the “Kozloduy International Decommissioning Support Fund (KIDSF)”, aimed at alleviating the significant impact of the early NPP phase out on Bulgaria`s economy. The fund is managed on behalf of the European Union by the European Bank for Reconstruction and Development (EBRD).

In a series of projects the State Enterprise for Radioactive Waste (SERAW) selected a site for the National Disposal Facility (NDF) at Radiana in the vicinity of the KNPP and also specified Enresa’s facility at El Cabril as reference design for the NDF. 2011 a further project was launched and assigned in international competition to a consortium of DBE TECHNOLOGY (Germany), Enresa and Westinghouse (both Spain) to provide the complete technical planning including the preparation of the Intermediate Safety Assessment Report.

The NDF design work started in October 2011, initially focusing on the repository Conceptual Design. After a comprehensive study of the documentation, SERAW approved the recommended Conceptual Design on December 2012, and authorised the Consortium to start developing the Technical Design. Meanwhile the Technical Design work has been completed and submitted to SERAW for review and analysis. Simultaneously to the preparation of the Technical Design for the NDF, the consortium is working on the Intermediate Safety Analysis Report (ISAR). This key

document is intended to provide convincing proof that the NDF, constructed and operated in line with all requirements of the Technical design, and filled with waste packages in compliance with the Waste Acceptance Criteria prescribed in the ISAR, will be safe according to the present state-of-the-art for a near surface repository.

DEVELOPMENT OF THE TECHNICAL DESIGN

Due to the tight project schedule the development of the Technical Design started even before final approval of the Conceptual Design in December 2012. Some requirements could only be finally defined during the development of the Technical Design (e. g. requirements on the design for physical protection of the NDF) and requirements from a number of authorities have to be complied with. Despite the challenging schedule for the project, the general progress lies within the planned deadlines because of the constructive cooperation between SERAW and the consortium. Hence, it is reasonable to assume that a license for construction of the NDF can be expected in the course of 2014.

In order to assure sufficient quality in the development and review of the Technical Design the document has been structured following Bulgarian requirements for investment projects into 19 separate design parts as listed below. Additionally, in each design part of the Technical Design the documentation, which corresponds to the respective buildings and facilities in the General Layout Plan (GPL), is arranged in up to 23 separate sub-parts. The use of sub-parts is optional, i. e. they are only considered if necessary. For example, is the design part Architecture subdivided into 19 subparts describing in detail the fundamental connections and parameters of the premises and the common areas, while there is only one subpart for the Design Part Geodesy providing the topographical base for the project. In total the Technical Design documentation prepared by the Consortium fills around 50 folders with approximately 6500 pages.

Design Part	Description
General	essential aspects of the design of the NDF
General Layout Plan	basic principles, design parameters and interconnection of the premises and the common areas
Geodesy	topographical base for the project
Roads	conditions for traffic and parking of the motor vehicles, for maneuvering of the fire safety vehicles and for pedestrian movement
Technology	technological process for acceptance of radioactive waste packages into the site, its emplacement in the disposal cells, the circulation of vehicles and people for the operation in the Facility
Architecture	fundamental connections and parameters of the premises and the common areas

Building Structures	general description of the buildings and structures
Power Supply and Electrical Systems	electrical systems of the NDF, their structure and des-cription
Control and Management Systems. Radiation Monitoring	structure of the control and management system, and its design basis and description; overall basic plant control and super-vision system is presented
Water Supply and Sewerage	external and building water supply systems, the sewerage and the rainwater collection pond
Heating, Ventilation and Air-conditioning (HVAC)	technical solutions for conditioning the air in the auxiliary buildings
Energy Efficiency	Demonstration of compliance with energy efficiency requirements
Fire Protection	main functions, design criteria and the technical solutions for the NDF Fire Protection System
Physical Protection	Physical Protection System aimed to prevent, detect and impede malvalicious acts
Health and Safety Plan	Demonstration of compliance with requirements for health and safety at work during construction and installation activities
Organization and Execution of Construction	NDF construction activities and their sequence
Cost Estimate Documentation	Cost estimation reflecting the technical solutions

Table 1: Design Parts of the Technical Design

DESIGN BASIS

The Radiana site, with a surface area of approximately 46 hectares, has quasi-rectangular shape with maximum dimensions of 470 m x 1250 m., It is adjacent to the Kozloduy NPP, located between two roads, one on the north controlled by the NPP and considered as an interplant road which connects the town of Kozloduy with the NPP, and one on the south, a secondary road. Geographically speaking the site is located between the second and sixth loess terraces in the non-flooded right bank of the river Danube.

Fig. 1: General Site Location

The NDF shall be able to accept and dispose of all radioactive waste (RAW) of category 2a arising in Bulgaria from the operation and dismantling of the national nuclear facilities. From a more generic viewpoint, the "Category 2a" waste corresponds to what is usually denominated as Short-Lived, Low and Intermediate-Level Waste (SL-LILRW). According to present forecasts the NDF will receive conditioned waste packed in 18,615 cubic-shaped concrete containers (i.e., waste packages). The waste packages have a side length of 1.95 m and a weight of 20 tones. The total volume occupied by these waste packages will be 138,200 m^3. The radionuclide inventory will be determined more precisely in the framework of the ISAR, but was preliminarily expected to be approximately 2.4×10^{14} Bq.

Long-term waste isolation is best achieved by a multiple barriers isolation system. In such a system the hazardous radionuclides contained in the waste are confined in containment structures consisting of several barriers acting in series. The isolation function is guaranteed by the system as a whole so that possible deficiencies of a barrier or its degradation in the course of time are compensated by the other barriers, thus ensuring that the protection objectives are achieved. The NDF design relies on a multiple barrier isolation system.

The NDF multi-barrier system includes the following parts:

- The first engineered barrier is the waste package, including the cement matrix, the radioactive waste and the reinforced concrete cask. The safety function assigned to the waste package is to ensure the full retention of radioactive waste by maintaining its mechanical integrity throughout a period of at least 50 years.
- The second engineered barrier of the repository includes the reinforced concrete walls of the disposal cells, and the lower and upper slabs. The assigned safety function is the retention of potential releases of radionuclides from waste packages, by maintaining

integrity through a period of 300 years to the extent reasonably achievable.

- The third (external) engineered barrier includes the external loess-cement cushion and the multilayer cover. Apart from being a barrier against the migration of radionuclides, the loess-cement cushion also increase the thickness of the unsaturated zone and improve the overall foundation conditions. The multilayer protective cover is constructed with natural materials (clay, sand, gravel, etc.).

The safety of the facility is based on the defense-in-depth concept, which consists on the simultaneous application of a system of physical barriers and administrative measures. The design of the NDF is aimed to prevent:

- Creation of conditions leading to a break in the integrity of physical barriers;
- Failure of a physical barrier in the case of the above conditions;
- Failure of a physical barrier as a result of failure of another physical barrier.

Radiological safety is of paramount importance in the repository facility. In line with the applicable regulations any unavoidable exposure of the staff and the public must be kept as low as reasonably achievable (ALARA). The design of the NDF ensures that it will keep its function and that the dose limits will not be exceeded during normal. This is achieved by defining the necessary design limits, operational states, safety classification of systems, structures and components (SSCs) and important design assumptions.

All SSCs of the facility have been classified in line with their importance to the nuclear safety and radiological protection of the NDF into Safety Class (SC) and Non-Safety Class (NSC). Furthermore, they have been classified into the seismic categories 1 (C1) and 2 (C2) and the Non Seismic Category (NC). Furthermore, all elements of the NDF have been classified in different Quality Levels to be taken into account during the design, construction, operation and institutional control of the facility. The proposed classification is consistent with the Safety and Seismic Classifications and introduced some additional concepts such as the decision of SERAW about important measures to ensure the quality of all activities in the NDF.

REPOSITORY CONCEPT

Repository Design

For practical and operational safety reasons the repository facilities have been grouped into a

1. Disposal zone, in which the disposal cells are located, and
2. A building zone, in which the Waste Reception and Buffer Storage (WRBS) Building, the site administration, control room and ancillary and support buildings are located.

The general site layout is shown in Figure 2.

To ensure operational safety, and to optimize the protection of the public, it is necessary to consider the effects of direct radiation from the waste packages. The establishment of special-statutory areas around the facilities and building of the NDF takes care of this fact. It is aimed at allow for appropriate radiation monitoring and limiting the exposure of the staff and of the public to radiation during normal operations and in the event of design basis accidents.

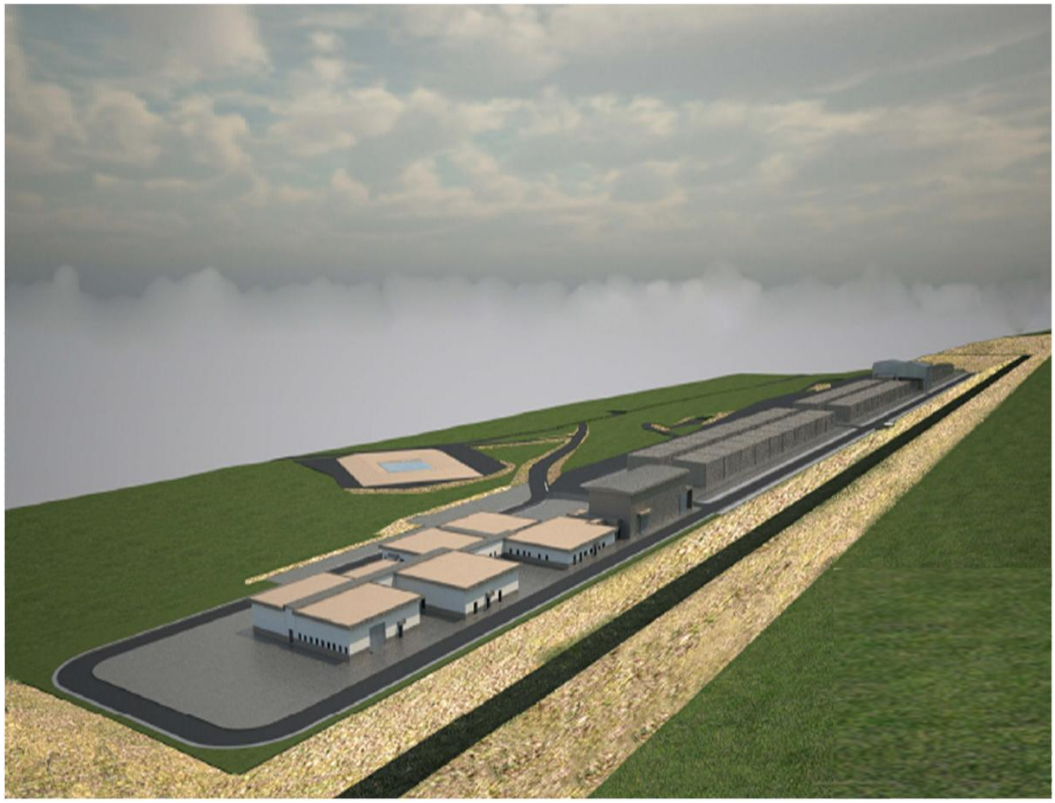

Fig .2: Artistic View of NDF Site Layout

The areas, which are inside the outer fence of the NDF, are subdivided based on the following criteria:

Radiation Protection area:

- Regions where dose rate levels exceed 0.05 μSv/h. This figure results from considering a dose limit of 0.1 mSv per year as the limit for persons with a presence of 2000 hours per year in the area. This corresponds to the limit for non-radiation-exposed workers ("collocated" workers).
- Region where the consequences of the design basis accident may be above of 5 mSv.

Monitored area:

- All the area inside the outermost fence and outside the above mentioned radiation protection areas. The dose rate here is under 0.05 μSv/h.

The Radiation Protection areas of the facility are subdivided into areas according to their radiological conditions, taking into account the external exposure risks that exist for workers entering these areas, as follows:

- Controlled Area: exposures could be higher than 6 mSv/year (3/10 fraction of the exposure limit for workers)
- Supervised Area: dose rates between 1 and 6 mSv/year (that corresponds to the limit for category B workers)

A dose rate assessment is performed for each area considering the layout of the radiation sources and shielding provisions. The criteria for granting access to the different areas is established in line with the radiological protection limits.

The NDF has sixty-six (66) disposal cells (DC) for waste package disposal. These disposal cells are located on three (3) equal platforms, each with twenty-two (22) disposal cells and their related systems. A first disposal platform will be constructed prior to disposal start, the second one approximately after 20 years, the third platform after 40 years of operation. The disposal cells are arranged in two lanes, each with eleven disposal cells. The disposal cells are monolithic rectangular boxes with two inner walls made of reinforced concrete, with a capacity for 288 waste packages emplaced in 3 chambers of 96 waste packages each (8 × 3 waste packages in plan, 4 layers in height). The external dimensions of each disposal cell are 20.15 m long by 17.05 m wide. The height is 9.45 m measured from the foundation level up to the top of a full and sealed disposal cell. Each storage platform will host 6,336 waste packages corresponding to about 20 years of repository operation. The total disposal capacity of the NDF will be 19,008 waste packages.

After a disposal cell is fully loaded with waste packages, it will be closed with a reinforced concrete slab. During the disposal process and the construction of the concrete slab the cell will remain covered by a mobile roof to protect the loading and closing operation works from weather phenomena. The mobile roof also houses the bridge crane used to emplace the waste packages into their position within the disposal cell.

A critical component of the disposal system is the Infiltration Control Network. It consists of a pipe system to collect and control the water that could enter a disposal cell after its closure and interact with the waste packages. The pipes are located in an underground gallery that runs below each row of disposal cells; this gallery is accessible by personnel. The system includes a pipe connection coming from each disposal cell and a collection tank. Water is exclusively driven by gravity.

The Building Zone contains the entire infrastructure needed for the efficient and safe operation of the NDF. The most important structure in this zone is the Waste Reception and Buffer Storage (WRBS) Building located at the entrance of the NDF within the regulated and restrictive area. The WRBS Building is designed to receive the transport vehicles loaded with a radioactive waste package that arrive at the NDF. The waste package is unloaded in this building and the vehicle is decontaminated (if needed) prior to departure. The radiological control of the waste packages arriving at the NDF is performed also here. Another main function of this building is to provide a buffer storage capacity of 120 waste packages that allows for the regulation and optimization of the waste package flow to the disposal cells.

The NDF also includes the following auxiliary infrastructure necessary during the operational phase:

- Checkpoint – provides access control for personnel and transport vehicles to and from the NDF site;
- Administrative Building – provides suitable working conditions for the personnel of the NDF;
- Laboratories – provide equipment for carrying out laboratory analyses of samples from contamination tests and environmental samples as required;
- Auxiliary Buildings – the garage workshops with different purposes and an industrial section which contains facilities for power equipment and other auxiliary systems;
- General Services Building – Include access to the radiologically controlled zones and to public relations services.

These facilities are in separate buildings all connected by a central corridor that also provides access (through a radiological check point) to the WRBS Building.

Repository Operation

The NDF has a single main access that links the Kozloduy NPP road with the Building Zone, thus providing the most direct access for the waste packages. The access of the waste packages to the WRBS Building (restricted zone) is direct after passing the security and control zone, avoiding the circulation near the administrative zone.

The waste package disposal operation begins in the WRBS Building waste package loading/unloading area. Here an internal transport vehicle is loaded with a waste package. This vehicle goes, always through the internal route in the radiologically controlled area, to the assigned disposal cell and parks behind the mobile roof where the portal crane lifts the waste package and hoists it to its storage position within the disposal cell.

Once the disposal cell is filled up with all the waste packages, the reinforced concrete slab is set in place on the top. Before the mobile roof is displaced to the next disposal cell position, a watertight membrane is set over the reinforced concrete surface of the disposal cell.

The process finalizes after the repository is full with the construction of a long-term cover made of different materials arranged to prevent the intrusion of water into the disposal cells during the surveillance phase.

Initially, the NDF will be able to accept up to 800 waste packages per year, i.e., four waste packages per day. When all the waste currently stored in the interim storage facility adjacent to the Kozloduy NPP has been disposed of, the NDF will work single shifts of 7 hours per day, 5 days per week, about 200 days per year, allowing for down time due to severe weather conditions. The disposal rate will then be only one waste package per working day.

PROJECT IMPLEMENTATION

A staggered construction approach has been adopted. The NDF will be built in three stages:

- The auxiliary installations and the first platform of disposal cells will be built during the first stage. This would provide a full compliant disposal facility, fulfilling all the requirements and design criteria, but without the total number of disposal cells.
- During the second and third stage the Facility will expand to come up to its full capacity through the construction of the second and third platforms and their respective infrastructure.

The design of the NDF considers the construction during the second and third stage simultaneously with the operation of the auxiliary buildings and the first disposal cell platform. Once the auxiliary buildings and the first disposal cell platform became operative, it will be possible to proceed with the disposal of waste packages and the construction of the remaining disposal cell platforms simultaneously. For that purpose a temporary road separate from the main entrance will provide direct access to the construction area. This road will avoid interferences between construction vehicles and the transportation of radioactive waste during operation.

The following main phases are envisaged for the NDF Life Cycle:

- Operation: 60 years;
- Closure phase after disposal end: 15 years;
- Institutional control after closure: 300 years.

During the operation phase the waste packages are received and emplaced in the disposal cells. Once a disposal cell is full, the disposal cell will be closed with the upper slab and a protective coating.

In the closure phase the multi-layer cover will be built and the rest of buildings not necessary for the further institutional control will be decommissioned.

During the institutional control period the surveillance of the site will be assured. The only work to be performed will be eventual maintenance or repair interventions, if necessary. The activity content of the NDF will be limited to permit the use of the site without radiological restrictions after the institutional control phase (i.e., after 300 years post-closure).

OUTLOOK

In November 2013 the Technical Design has been approved by SERAW for submittal to the licensing authorities. It is now expected that after a thorough review of the documents very soon detailed technical discussions will commence. Nevertheless, due to the good cooperation between SERAW and the consortium it is expected that generally all requirements are met.

Nevertheless, it is noteworthy that changes in the regulation this year require amendments of the ISAR, in turn having consequences for the Technical Design. Even though the consequences are expected to be very limited only a further revision will be unavoidable.

But it is still believed that that a license for construction of the NDF can be expected in the course of 2014.