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## Progress in the Chernobyl NPP decommissioning and waste management strategy

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**Abstract:** The decommissioning of the Chernobyl Nuclear Power Plant units 1, 2 and 3 is going forward. For this purpose the Ukrainian Nuclear Regulatory Department NRD has prepared – in cooperation with Western partners as GRS and IPSN - a legal framework for the decommissioning and waste management. An official Ukrainian document describing the general strategy is the basis for the delivery of respective documents, which are under preparation for all the three units by the ChNPP.

The necessary new facilities for waste management and disposal (five facilities dedicated to treatment, storage or disposal of burnt fuel and radioactive liquid and solid waste) will now be built, funded by the NSA and the European Commission. Under a Riskaudit contract in the framework of the Tacis program GRS, IPSN, ANPA and AVN together with the Ukrainian SSTC support now NRD in the licensing activities related to the new facilities.

### 1. INTRODUCTION

In the Ukrainian nuclear power program the Chernobyl Nuclear Power Plant (ChNPP) plays a very special role. Unit 1 and 2 are out of operation since several years due to different technical reasons, unit 3 will be finally shut down end of 2000 according to a decision of the Ukrainian government, and unit 4 (sarcophagus) remains as a big technical problem since the accident in 1986. The adequate solutions of this situation in Ukraine, due to the high costs and absence of practice were only possible with international assistance.

For the sarcophagus the European Commission (EC) organised in 1995 an industrial expert team, which developed a set of tasks to consolidate its structure, which does not exhibit the required reliability and maintenance criteria. These tasks, described in the " Shelter Implementation Plan " (SIP), were agreed upon in mid-1997 by the Ukrainian government and the G7 member states.

In parallel, a plan for shutdown and decommissioning of the three other ChNPP reactors has been developed with the support of the international community through the Tacis programme of the European Commission (EC). This plan, which includes the implementation of spent fuel storage and liquid waste treatment facilities for decommissioning activities, will be completed with installations for solid waste management. These new facilities are foreseen for the waste from the units 1 – 3 only, not from unit 4 (sarcophagus) and the consequences of the accident.

In the last years the Ukrainian authorities, especially the Nuclear Regulatory Department (NRD) of the Ministry of Ecology and Natural Resources of Ukraine started to develop the regulatory framework for decommissioning and waste management, such as laws, norms and technical regulations. This has

been done, at least partly, with the assistance of Western experts, mainly in the frame of the Tacis programme.

In the following chapters the general Ukrainian decommissioning strategy, the first practical approach for the Chernobyl units 1 and 2, the planned new decommissioning facilities and the Western assistance to the NRD in the licensing process are described.

## 2. GENERAL STRATEGY

As mentioned in the introduction, some documents had been prepared for the strategy and performance of the decommissioning and waste management of the ChNPP units.

One main document was signed by several Ukrainian ministries and published 1997 (COMPLEX PROGRAM ON DECOMMISSIONING OF CHERNOBYL NPP). This "Complex Program" provides an overview on the planned decommissioning and waste management system for the Chernobyl units 1 – 3 including some specific decommissioning problems of the site in addition to the three units. The following main principles for the decommissioning process were adopted and are exposed in the Ukrainian regulatory document "GENERAL PROVISIONS ON SAFETY ASSURANCE OF DECOMMISSIONING OF NUCLEAR POWER PLANTS AND RESEARCH REACTORS", which has been officially approved.

The main objectives of the decommissioning are:

- to protect staff, the public, future generations and the environment against hazardous impact of ionising radiation,
- to achieve such conditions at the facility site which reduce any restriction on use of the site to the extent possible.

These objectives shall be achieved by a stage-by-stage transformation of the facility in the following way:

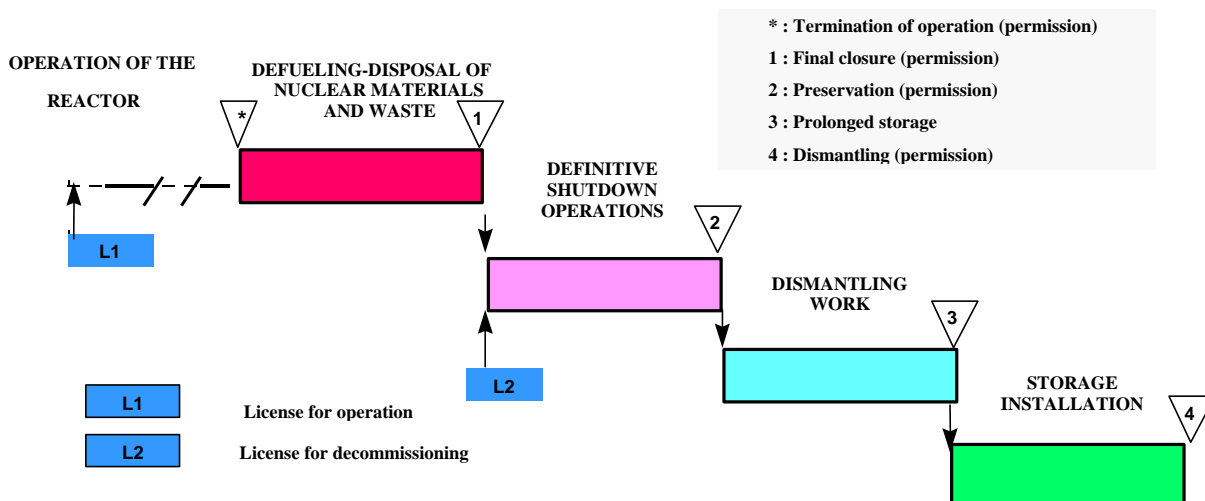


Figure 1: Stages of decommissioning

The single stages (see figure) are as follows:

- **termination of operation**  
This step is carried out within the framework of the licence for operation of the facility (nuclear fuel removal, clearing of the facility from liquid radioactive waste, partial removal of solid ones.); however, for the realisation of this stage, an additional permission is required on the basis of:
  - an operation termination and decommissioning strategy and program,
  - a Safety Analysis Report,

- amendments to technological rules of operation of the facility.

The main objective of this stage is transformation of the facility into a *nuclear safe state* (*The nuclear safe state for the Ukrainian counterpart is defined as a state characterised by the absence of nuclear fuel on the site or its location within the site only inside nuclear fuel storage facilities which are aimed at long-term storage*).

- **final closure**

The goal of this step is to bring the facility into a condition which excludes any possibility of using it again for the purpose for which it was constructed. The work to be done is dismantling of systems and elements external to the nuclear unit, preservation of barriers preventing the release of radioactive substances into the environment....

- **preservation**

At this step the facility will be brought into an appropriate state in order to safely store its own radioactive substances during the prolonged storage (see the definition below). The necessary work must include i.a. reliable insulation of non-being dismantled parts of the facility, tight closure of pipes, tightening of connections,... creation of conditions for a controlled temporary storage of radioactive substances on the facility, collection and conditioning of radioactive waste generated at this stage...

- **prolonged storage**

At this stage the facility shall take benefit from the fact, that the decay of radionuclides reduces essentially the quantities of radioactive substances just present at the preserved facility . For this purpose operation of systems and elements will be needed, ensuring a safe storage of radioactive substances at the preserved facility, periodic inspections of the preserved facility...

- **dismantling**

At this final stage radioactive sources of ionising radiation are removed out of the facility or placed at its site in radioactive waste storage facilities. Main work to be performed includes collecting and conditioning of radioactive waste generated, radiation inspection of the components which are not subject to dismantling, procedures on termination of radiation monitoring previously required....

Action of the decommissioning licence begins only after the stage of termination of operation putting the facility into a *nuclear safe state*. Separate permissions are needed for each of the aforesaid stages of decommissioning.

The decommissioning strategy defines the sequence of decommissioning and therefore the consequences, the duration and the main actions of each decommissioning stage as well as the state of the facility after each stage.

According to the Ukrainian regulatory document the determination of the decommissioning strategy should be carried out by the consideration of various decommissioning variants and by the choice of the optimum among them on the basis of "cost-benefit" method. This corresponds to the balanced account of the following major factors : safety requirements, physical state of the facility including the forecasting changes, required financial costs and their availability, social aspects...

The facility decommissioning must be carried out according to a decommissioning programme that must be approved by NRD. The main items of this decommissioning program are the decommissioning strategy and its substantiation in the decommissioning programme, the measures of safety assurance (programme of radiation protection, minimising the doses received by the staff, the public and the impact on the environment, programme of measures in case of radiation accident, measures of physical protection....), the training and employing of the staff (including responsibilities..), the results expected as well as the criteria for their evaluation....

The regulatory document draws the operating organisation to plan the future decommissioning of a facility as soon as possible at all stages of its life cycle.

Besides decommissioning planning and operation, also a waste management system needs to be developed and installed. Presently the Ukrainian radioactive waste management system is regulated by laws, normative documents and legal regulations in force. A number of normative documents on

requirements and orders in this field is being developed, mostly in accordance with internationally accepted principles :

- to deal with radioactive waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations.
- to include a pre-treatment (collection, segregation, chemical adjustment, decontamination), treatment (volume reduction, radionuclides removal, change of composition), conditioning (transform the waste into a form suitable for handling, transportation, storage and disposal), packaging, interim storage, and final disposal (emplacement of radioactive waste in a disposal facility with reasonable assurance for safety without the intention of retrieval and without reliance on long-term surveillance and maintenance).

These principles are mostly developed in the LAW ON RADIOACTIVE WASTE MANAGEMENT and other regulatory documents as REQUIREMENTS FOR MANAGEMENT OF THE RADIOACTIVE WASTE BEFORE THEIR FINAL DISPOSAL

Safety objectives for the management of radioactive waste arising from decommissioning operations are e.g. to keep the individual and collective doses as low as reasonably achievable, to reduce the volume of material selected to be disposed of as radioactive waste, to reuse to the greatest possible extent exempted material and cleared installations, to decontaminate material in order to increase the accessibility to the work area, to minimise the amount of secondary waste that arises during decontamination and dismantling of installations and buildings.

### **3. STRATEGY FOR CHERNOBYL NPP UNITS 1 AND 2**

Demonstrating its intention concerning assumed commitments on Chernobyl NPP by 2000, Ukraine shut power unit 1 of the ChNPP on November 30, 1996 for its decommissioning before expiration of designed useful life.

The process of decommissioning includes the stages of final closure, mothballing, maintaining and dismantling. Optimization of decommissioning requires to find the best way from the point of view of health, economy and waste generation in order to minimize dose uptake by workers, waste amounts and total costs of the operation. According to the COMPLEX PROGRAM ON DECOMMISSIONING OF CHERNOBYL NPP and the AEA TECHNOLOGY recommendations as a base variant the 30 years mothballing is adopted.

The decommissioning strategy program, which has to be approved by the management of the operating organization, and the decommissioning program, for which NRD approval is required, have to be defined during this stage.

Works regarding termination of operation for unit 1 started mid-1998 with unloading of nuclear fuel from reactor into cooling ponds of unit 1 and transfer from power unit to SFISF-1 (existing fuel storage). At the same time, construction of the second fuel storage (SFISF-2) was launched in order to put it in operation in 2003. This second storage is aimed at receiving nuclear fuel from unit 1 and from SNSF-1 as well as, ultimately, from units 2 and 3. The total expected cumulative dose for the whole process corresponding to unit 1 is 185 man.rem for a 60 person staff per year directly involved.

Some other works related to termination of operation have already been carried out or are currently performed such as, for example:

- repair of buildings and constructions,
- engineering radiation investigation,
- erection and commissioning of industrial heating boiler station,
- development of various design and strategy studies.

Other works which have to be carried out and/or completed in the frame of termination operation between 2000 and 2004 are the following:

- creation of database proceeding from results of engineering radiation investigation of unit 1,
- removal of working media from circuits, pipelines, systems before and after fuel removal, and eventual stopping of some systems,
- surveillance and monitoring of systems still in operation,
- decontamination of systems, equipment, pipelines and premises at power unit,
- liberation of power unit from radioactive waste, .
- construction of SFISF-2 as well as solid and liquid waste conditioning facilities (this process has been started since 1999 in the frame of EBRD and EC contracts),
- development of the SAR for the eventual closure stage (in 2001-2002) and agreement by NRD in 2004, and, simultaneously, development and agreement of associated regulations,
- obtaining the licence on decommissioning in 2004.

In the case of ChNPP unit 2, which was shut down on March 15, 1999, the nuclear fuel unloading work should begin in 2003 when SNSF-2 is ready and beginning of most of the works associated to termination of operation is planned by the operator between 2001 and 2005 in order to get the decommissioning licence in 2005, one year after ChNPP unit 1.

#### **4. NEW DECOMMISSIONING AND WASTE MANAGEMENT FACILITIES**

The following facilities will be built as important parts of the decommissioning and waste management strategy.

##### **Spent Fuel Interim Storage Facility (SFISF)**

Fuel assemblies on the site need to be stored in a dedicated building to allow them to cool down and the fission products to decay under adequate containment. After the Chernobyl NPP units termination of operation, fuel assemblies will mainly be located in the RBMK reactor cores, in the reactor cooling ponds of the three units and in the existing SFISF-1 (KHOJAT-1) fuel storage pond. The limited remaining capacity and design life of that last storage facility requires a new storage building to be built.

This new facility will be divided into two parts : the first one to prepare and condition the fuel assemblies, the second one to store them.

Using the transfer flasks already present on the site, the fuel assemblies will be transported from their intermediate storage areas to a hot cell, where the upper and lower fuel bundles will be separated by dry-cutting. The fuel bundles will immediately be placed into cartridges, while the extension rods will be cut and prepared before transfer to the plant storage facility. Absorber rods will be placed into cartridges and stored in a special vault located next to the processing facility.

The cartridges will be welded shut, filled with argon gas, then placed in the storage canisters. The inner space of the canisters will be filled with inert gas and closure lids sealed by automated welding. Canisters will then be transported to the dry storage vaults.

The required production rate will be 2500 fuel assemblies per year. It should allow to process all the spent fuel bundles and absorber rods over a ten years period. These fuel bundles will be placed in 256 storage casks, each stored in individual vaults.

##### **Liquid Radwaste Treatment Plant (LRTP)**

The liquid radioactive wastes are currently stored in five 5000 m<sup>3</sup> and nine 1000 m<sup>3</sup> tanks placed on the Chernobyl NPP site and in the Chernobyl NPP liquid and solid radwaste storage facility respectively. The major part of the wastes stored in these tanks is composed of low level and intermediate level liquid wastes.

The treatment of the liquid wastes will require retrieval, transfer and processing in a dedicated treatment facility. A few of these waste tanks contain also resins, pulps and sludges which bring some complexity to the transfer and treatment operations.

Moreover, this treatment facility should ultimately process the decontamination effluents from Chernobyl NPP decommissioning. The amount of liquid wastes generated by these operations has not yet been precisely estimated.

The two sets of storage tanks are connected by transfer pipelines which run in a transfer gallery. Transfer of the wastes from the tanks to the treatment facility will require installation of retrieval systems and specific connections between the retrieval equipment and the pipelines to move them from the tanks into the transfer gallery and between the pipelines and the treatment facility. The retrieval system will be composed of agitation devices and pumping systems.

After receipt in the LRTP, the volume of the wastes will, where possible, be reduced prior to the treatment process. Particular wastes such as spent resin and perlite pulp will have to be processed too in this facility. The final process in the LRTP prior to the packaging of the product will be a cementation process in order to immobilise the treated wastes in a matrix.

The final conditioning of these packages will depend on the acceptance criteria of the near surface disposal centre. So, it will probably be necessary to build intermediate buffer storage areas in order to receive these packages before a final solution is reached for disposal of every type of packages

### **Low and Intermediate Level solid Waste Retrieval Facility (LILWRF)**

Low and intermediate level solid wastes are currently stored on the Chernobyl NPP site in an above ground concrete shielded structure, separated into three compartments categorised according to the types of wastes. Their volumes are respectively 1087 m<sup>3</sup>, 1000 m<sup>3</sup> and 1884 m<sup>3</sup>. The two first compartments are 98% and 92% full respectively and the third one, which is reserved for higher level solid wastes, is 18% full. Access to the compartments can be carried out via hatches of various sizes. The solid wastes are composed of " technological wastes " and are in the form of metal, concrete, plastics, wood, paper etc. The content of two of these compartments has been covered with a layer of concrete approximately 1 m thick.

Options for retrieval of the wastes include a mechanical grabber and an overhead crane retrieving waste from above, or using a digger and penetrating equipment to retrieve wastes through the side of the tanks. The retrieval equipment should be capable of breaking and retrieving the concrete cap that has been placed over the top of the stored active wastes and it should be designed to be mobile, so that it can be used to retrieve successively wastes from the three compartments.

Wastes will be put in containers and transported to a sorting and conditioning facility. The retrieval rate should be about 3 m<sup>3</sup> per day.

It is to be noted that wastes stored in the three compartments are not suitably identified and thus presence of high level radioactive wastes will have to be envisaged during the retrieval.

### **Low and Intermediate Level solid Waste Processing Facility (LILWPF)**

The LILWPF will be designed in a first step to process the wastes issuing from the retrieval facility. It could be adapted to the treatment of wastes from decommissioning of Chernobyl NPP reactors.

The facility will be also equipped with an incinerator to burn contaminated oil coming from the turbines of the reactor units (about 300 m<sup>3</sup>).

The solid wastes from the retrieval facility will be transferred to a sorting bay in the LILWPF, where they will be sorted out and categorised in four types :

- compactable wastes for compaction,
- non-compactable wastes for packaging and grouting,
- combustible organic wastes for incineration,
- long-lived wastes for interim storage ;

Compacted wastes and non-compactable wastes will be overpacked into containers approved for final disposal in an engineered near surface facility. Wastes will be grouted into these containers using a facility whose production rate should be approximately 10 m<sup>3</sup> grout per day, allowing typically 20 m<sup>3</sup> of packaged wastes to be grouted.

Some of the wastes retrieved from the solid waste compartments may be too large and bulky to be dispatched directly to an appropriate treatment process. They will require size reduction before compaction or direct packaging.

A part of the retrieved wastes will not be suitable for near surface disposal due to radiological and, maybe, chemical contents. Therefore, it will be placed into dedicated containers and sealed. These containers will be designed for long-term storage.

It is to be noted that categorisation of wastes has not been definitively set up by the Ukrainian government. This could be a major problem to design the waste processing facility and the subsequent near surface disposal area.

### **Low and Intermediate Level Waste engineered near Surface disposal Facility (LILWSF)**

The LILWSF will receive packages containing LILW immobilised in a cement matrix, for final disposal. The packages will be of an approved design, meeting acceptance criteria set up by the disposal facility. All their characteristics will be recorded and filed when arriving on the site.

The design of this disposal will be based on an engineered near surface trench concept. The first phase of the construction will consist of one trench. The following ones will be built according to the waste packages production. Each of them will be capped as it becomes filled. Capping material will be selected so that it will assist in evacuating rainwater towards a surrounding drainage system.

This near surface disposal will be built in the Chernobyl restricted area.

## **5. TACIS PROJECT FOR NRD ASSISTANCE**

On January 7<sup>th</sup>, 1999 a contract has been signed between the European Commission and Riskaudit aimed at providing the Ukrainian Nuclear Regulatory Authority (NRA) with an effective technical assistance for the licensing activity related to the EC and EBRD financed decommissioning facilities within the process of decommissioning of Chernobyl NPP units 1, 2 and 3. The present contract, signed for a 26 month period, corresponds approximately to the phase covering the end of the assessment of the Preliminary Safety Analysis Reports of the SFISF and LRTP facilities.

The leading company and contractor with the European Commission is Riskaudit. The Project Manager and the Administrative Project Manager belong to this company. To provide a team with complementary skills and experience, Riskaudit has built a consortium with IPSN, GRS, ANPA and AVN.

The counterpart and beneficiary is the Department of Regulation on Radwaste Treatment Safety of NRD, technically supported by SSTC which is, in this contract, a Riskaudit subcontractor.

For each of the five installations described before, the licensing steps described in the Ukrainian regulatory documentation are bound to the main industrial steps from siting to operation of the facilities at full capacity. The steps are essentially:

- Siting
- Design
- Construction
- Commissioning
- Operation

The contractor for the SFISF is a consortium composed of Framatome, Bouygues and Campeon Bernard and for the LRTP a consortium composed of Belgatom, Ansaldo and SGN. The tendering

process for the LILWRF, LILWPF, LILWSF, which have been merged into a single package by the OSAT, is in progress.

The work of Riskaudit, related to the licensing assistance, has effectively started in parallel with the steps of construction licences for the SFISF and LRTP. ChNPP/PMU have delivered parts of the PSAR of these facilities to NRD, which asked Riskaudit/SSTC for an evaluation of these documents. The schedule was very tight and it has therefore been necessary to set up a task force to perform this evaluation. The PSAR evaluation for the LILWRF, LILWPF, LILWSF will probably take place during the first semester of 2001, but it will be dependent on the selection of the contractors, the proposed schedule and, probably, the decision which has to be made on waste categorisation.

The work is performed on the basis of existing Western practices (for the TSOs), Ukrainian regulations (for SSTC) and additional regulatory documents prepared by SSTC in the frame of the present contract.

Moreover, Riskaudit in cooperation with SSTC has been involved in a lot of transversal tasks aimed at providing assistance to the NRD in the following fields :

- achievement of the **consistency of the evaluation of the safety related documents** of the five facilities. As the evaluation of the safety documents is to be performed by several organisations, interfacing problems which may evolve from the way the safety assessments are performed in different countries have to be clarified in time to avoid different assessments for similar safety problems.
- achievement of a common understanding of the **general strategy** proposed by the operator. The work consists in assessing the basic approach related to decommissioning and waste management in order to evaluate later the feasibility and the design of the new facilities and their ability to deal with their expected efficiency.
- evaluation of the proposals regarding the **steps of the licensing programmes** for all the decommissioning facilities in detail. This work has been based in a first time on the description of the licensing programmes signed by NRD and Energoatom for the SFISF and LRTP. It will be extended ultimately to the licensing programmes which will be defined for the LILWRF, LILWPF, LILWSF. This evaluation must be performed to clarify whether the steps of the licensing process and the anticipated content of each step will fulfil the requirements of an adequate way to get a licence, taking into account the existing Ukrainian and Western licensing practices.
- development of additional **regulatory and technical documents** associated to the licensing processes. The content of the safety documents which shall be submitted by the operator will be defined (e.g., different kinds of safety analysis reports, general operating rules, commissioning programmes).

These tasks, which cover for some of them the whole duration of the contract, constitute a fundamental work aimed at setting definitively up the licensing procedures related to waste management in Ukraine.

These are the key elements to undertake the huge work consisting in processing and conditioning the waste and spent fuel resulting from the Chernobyl 1, 2 and 3 units decommissioning in a near future.

## 6. CONCLUSIONS

As a result of all the described activities it can be stated, that solutions for solving the problems at the Chernobyl site have been found and are now in the phase of realisation.

- A **general strategy** for decommissioning and waste management has been defined and adopted officially by the Ukrainian government. Some problems remain still open, they should be solved in the future.
- Thanks to the work of the Ukrainian licensing authority NRD, assisted by Western TSOs, a **licensing procedure**, similar to Western practice, exists and a **legal framework** including laws, normative documents, legal regulations and guidelines has been prepared and is in force.

- The operator has prepared documents (**decommissioning program**) for the units 1 and 2, which are now under evaluation and discussion. The same will be done soon for unit 3.
- The **new facilities** for decommissioning and waste management are now under construction or at least under preparation (basic design) and will be available in about one to two years, for the solid waste handling facilities in about two to three years.
- The **licensing of the different steps** of the procedure for the new facilities is going on by NRD (and partly other ministries or state organisations) with the assistance by the Riskaudit consortium (GRS, IPSN, ANPA, AVN) and SSTC.