

## NUCLEAR REGULATORY AUTHORITY REQUIREMENTS - FIRST PHASE OF NPP A-1 DECOMMISSIONING

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### ABSTRACT

Pilot nuclear power plant A-1 was a HWGCR (heavy water gas cooled reactor) with channel type reactor KS 150 (refuelling during operation) and power output of 143 MW<sub>e</sub>. This NPP was operated from 1972 and was shutdown in 1977 after integrity accident of the primary coolant system. Significant damage and corrosion of the fuel cladding during the operational accident and during spent fuel storage at NPP A-1 caused consequently to existence of abnormal radioactive waste (containing alpha nuclides) and to the contamination of NPP parts.

However decision on decommissioning of NPP A-1 was assumed in 1979, the start of A-1 decommissioning was delayed and progressing slowly. The start of decommissioning was based on "case by case" strategy for the lack of specific regulations. First activities were focused to the transfer of spent fuel from the site and to dismantling of some non-radioactive parts.

The decommissioning plan for the first phase prepared in 1993 – 1994 was amended in 1995/96. Under Atomic energy act requiring decommissioning plan (1998) the permission for the first phase was issued. The goal of this phase (planned till the year 2008) is:

- a) to transfer spent fuel to Russian Federation or to improve the safety of its storage
- b) to improve the safety standard for storage of radioactive wastes and enable their conditioning and disposal
- c) to remove contamination and prepare some parts for dismantling and demolition

### INTRODUCTION

Nuclear power plant A-1 in Jaslovské Bohunice was commissioned in 1972 and was shutdown in 1977 after primary coolant system integrity accident with local melting of the fuel. Decision on decommissioning of NPP A-1 was assumed in 1979, however, the start of decommissioning was delayed and progressing slowly for many reasons. The main ones were original NPP design and original radwaste strategy based on idea to store the non conditioned operational radwaste till to the decommissioning start. Absence of proper technologies for waste processing and disposal, insufficient interim storage capacity and problems with funding affected significantly the planning and the first period after premature final shut-down of the reactor.

Corrosion of the fuel cladding during spent fuel storage and its damage during the reactor accident caused spent fuel coolant contamination by fission products and by long lived alpha nuclides. Manipulation and handling such radioactive waste has consequently resulted to the contamination of several NPP parts.

The requirements of the Nuclear Regulatory Authority concerning the prioritisation of various decommissioning activities have been dictated by the strong demand to increase the safety features of NPP A-1 and decrease radioactive inventory. The waste management strategy has been significantly changed and the design and construction of supporting treatment, conditioning and disposal technologies were intensified with the goal to operate complex waste management system as soon as possible.

## **DESCRIPTION OF NPP A-1**

Nuclear power plant A-1 with heavy water moderated, carbon dioxide cooled channel type reactor KS 150 was constructed as a pilot plant of a new intended line of reactors for former Czechoslovak nuclear power programme. Gross electric power output was 143 MW<sub>e</sub>, refuelling was carried out during operation. The main building consists of four parts. Reactor, heavy water moderator system and equipment for refuelling, spent fuel handling and storage were installed in the reactor hall. Coolant system (six turbo-compressors, six steam generators, pumps and piping) was installed in the next part of the main building. Turbine hall was equipped with three turbines, three generators and six condensers. The last part of main building was used for completion of fuel assemblies from individual elements.

The supporting systems, e.g. radioactive waste treatment and storage, gas coolant system and some parts of ventilation system including ventilation chimney were distributed in different individual buildings.

## **ACCIDENTS DESCRIPTION [1]**

The first accident (failure of the closing mechanism of technological channel) happened on January 5, 1976. Fresh fuel assembly (together with the non locked technological plug) was rejected to the reactor hall. Carbon dioxide coolant leaked for a short time from the reactor channel under the sub-operational pressure (shut-down of reactor) until the refuelling machine was reconnected to the opened technological channel and stopped coolant leakage. Some fuel assemblies were overheated [3]. NPP A-1 recommenced the operation after channels plug reconstruction and inspection in September 1976.

During refuelling on February 22, 1977, the non-conform fuel assembly (internal cross section partly blocked by silica gel, probably as a consequence of insufficient quality control) was charged into the reactor core. Reduced coolant flow stream caused local overheating of fuel and consequent damage of technological channel and heavy water tank tube. As a result the loss of barriers integrity between fuel, carbon dioxide coolant and heavy water moderator took place. An extensive corrosion damage of fuel cladding by heavy water saturated with carbon dioxide occurred. The integrity of steam generator tubes was also influenced.

## **ACCIDENT CONSEQUENCES FROM THE POINT OF THE VIEW OF DECOMMISSIONING**

Both accidents led to the damage of several fuel assemblies with extensive local damage of fuel cladding. As a consequence coolant system surface (steam generators represent the main part) was significantly contaminated by fission products and long lived alpha nuclides.

During second accident, heavy water circuit was also contaminated – main remaining contamination on the evaporator surface of moderator polishing system. The leakage of moderator and coolant mixture contaminated by fission products through corroded steam generator tubes resulted in the low contamination of the secondary circuit.

### **RADIOACTIVE INVENTORY AFTER NPP SHUT-DOWN [2, 6]**

It is evident that the main part of radioactive inventory (nearly  $10^{17}$  Bq) was represented by the spent fuel.

Two types of spent fuel coolant were used at A-1 NPP. In early phase of NPP A-1 operation, until 1994/95, inorganic coolant based on aqueous solution of  $\text{Cr}^{\text{VI}}$  (prepared on potassium bichromate basis and called "chrompik") was used. Since during spent fuel loading the coolant was saturated under high pressure by carbon dioxide, Mg-Be cladding corrosion occurred during post-irradiation cooling period. This effect was substantially more significant in the case of fuel with cladding damaged during operation in reactor due to overheating and/or higher burn-up [4]. In the last case, corrosion of uranium fuel material took part in entire fuel assembly damage. The corrosion effect was further enhanced by radiolytic decomposition of coolant and, probably, by radiation corrosion effects. In some cases the fuel cladding as well as fuel rod were damaged to the level, precluding further manipulation with the fuel, even restraining removal of spent fuel from the cooling canisters. All these processes led to heavy contamination of "chrompik"; in some cases a sludge-like material was generated. Spent fuel coolant ("chrompik") including sludge represents another significant part of NPP A-1 inventory (more than  $2 \cdot 10^{15}$  Bq).

Several events during spent fuel handling caused the contamination of cooling pond water ( $10^{14}$  Bq), reactor hall and consequently a contamination of water in the supporting systems including concentrates and sludges ( $2 \cdot 10^{14}$  Bq).

Recognising the potential problems with corrosion of spent fuel during a long time storage, aqueous coolant was replaced in 1974/75 by polyphenyl based organic coolant Dowtherm (eutectic mixture of biphenyl and biphenyl-oxide), used further to the end of NPP operation. All fuel assemblies removed from the reactor core after both accidents were placed into this coolant. Since the corrosion of cladding is negligible in this coolant, the resulting radioactivity of Dowtherm ( $2 \cdot 10^{12}$  Bq) was substantially lower than in "chrompik". All fuel assemblies were successfully removed from canisters and prepared for transport.

The estimated radioactive inventory of the reactor structures is in the range  $10^{14}$  -  $10^{15}$  Bq [5,6].

Contamination of NPP coolant and moderator systems as the consequence of accident was assessed approximately to  $10^{13}$  Bq [5,6].

## **THE START OF DECOMMISSIONING – PERIOD WITHOUT SYSTEMATIC DECOMMISSIONING PLANNING**

Because of lack of experience and corresponding regulations, the first period of NPP A-1 decommissioning was based on "case by case" strategy. The main tasks were to improve nuclear safety features and to reduce the radioactive inventory.

There were three main areas of activities during the period of 1980-1995:

- spent fuel management - transfer of vast part of spent fuel (mostly non-damaged or lightly damaged) to Soviet Union / Russian Federation
- support of waste management – improvement of waste treatment, conditioning and disposal technologies
- dismantling of part of the secondary circuit and some auxiliary systems.

### **Spent fuel management**

Transfer of non-damaged or lightly damaged spent fuel (439 of the total 571 fuel assemblies) using standard procedure was started 1984 and successfully completed in 1991.

The new technology was developed for the preparation of damaged fuel for transport. As it was impossible to remove this fuel from the special cooling canisters, two-step technology had to be used for preparation of fuel for transport. In the first step the aqueous coolant, containing cladding and fuel material corrosion products and heavily contaminated by fission products and trans-uranium elements, was drained. In the second step the empty part of original canister was removed and the rest containing fuel assembly was repacked into the new hermetic container. An accident leading to significant contamination of reactor hall occurred during active tests of this facility in 1991. Only 4 fuel assemblies were prepared for transport, and transfer of spent fuel to Russia was interrupted for several years. The decontamination of reactor hall was carried out in 1993 – 1996.

### **Support of waste management**

The bituminization, incineration and vitrification facilities for the processing of the radioactive waste from NPP A-1 were constructed and commissioned at the Bohunice site. Liquid waste evaporation facility was refurbished, new improved tanks for radioactive concentrates storage were constructed. Design and construction of a new radioactive waste conditioning centre and near surface repository was initiated with the aim to create the integrated system for management of waste generated at Slovak NPPs.

### **Dismantling of auxiliary systems**

Dismantling of the significant part of the secondary circuit and the primary and secondary cooling towers as well as the barriers check-up was performed during nineties. The metal scrap from

contaminated parts of secondary circuit was sorted and decontamination facility for low contaminated materials was constructed in emptied turbine hall.

## **DECOMMISSIONING PLANNING**

In 1993, after splitting of Czechoslovakia to Slovak and Czech republics, two national regulatory authorities were established.

One of the highest priority issues of newly established Nuclear Regulatory Authority (NRA) of Slovak Republic was to provide for systematic decommissioning of A1 NPP. Operator was required by NRA to prepare and submit for approval a plan for entire decommissioning process, reflecting specific features of NPP A-1 (mentioned above). IAEA guidelines as well as international experience become a basis for its preparation.

The plan for the "first decommissioning phase (1995-2007)" has been elaborated in details, focused to main safety aspects common for all decommissioning options. The duration of this period was strongly influenced by the need to create complex waste management. This plan was prepared in 1993 – 1994 and amended in 1995/96. As there was still no legal basis for decommissioning licence, some tasks were permitted individually. Environmental Impact Assessment for the first phase was elaborated in accordance with the Act issued in 1994. The conceptual plan for following phases of NPP A-1 decommissioning with several decommissioning options including safe enclosure was issued in 1998. The permission for the implementation of the first phase of decommissioning was issued in 1999 on the basis of evaluation of these documents and other documents required by Atomic Act (issued in 1998).

## **PLAN FOR THE FIRST DECOMMISSIONING PHASE [2]**

The requirements of Nuclear Regulatory Authority for the first phase of decommissioning were directed to the following areas

- spent fuel management - transfer of remaining spent fuel to Russian Federation or spent fuel safe store
- waste management – reactor hall
  - improvement of spent fuel coolant safety features
  - decontamination and/or dismantling of spent fuel pool inside structures
  - dismantling part of heavy water system
  - conditioning and storage/disposal of the operational waste
- decontamination of contaminated facilities outside reactor building.

The way of implementation of NRA requirements was as follows:

### **Spent fuel management**

A new facility for the spent fuel preparation for transport to Russian Federation based on gravitational drainage of residual cooling liquid was commissioned in 1996. A special care was taken

for improvement of safety features, including a fire protection (manipulations in argon atmosphere). A special facility for interim storage of spent fuel prepared for transport was commissioned in 1998.

This facility would be later used for a storage of vitrified waste.

The rest of spent fuel was successfully prepared for transfer. Successful transport of spent fuel to Russian Federation during the period 1997-1999 provided for significant decreasing of radioactive materials stored at the A-1 site.

A new semi-dry storage facility was constructed for the case of cancellation or interruption of spent fuel transport. This facility, commissioned in 2000 can be alternatively used as a storage of highly contaminated/activated items.

### **Waste management**

Several measures were undertaken to support improvement of waste management required by NRA. Second bituminization facility, centralised waste conditioning center at Bohunice site and near surface waste repository in Mochovce were completed and commissioned in 1999-2000. Waste conditioning centre includes liquid waste pre-concentration, cementation facility, incineration facility and super-compactor. The new facility for manufacturing of fibre-reinforced concrete containers was built. Near surface waste disposal facility is able to accommodate low and intermediate level waste from operation and decommissioning of NPP A-1 as well as from operation of other Slovak NPPs.

Bituminization of all concentrates stored at NPP A-1 was performed during 1995/96. Bituminization of organic spent fuel coolant started in 1996. Since 2000 the organic spent fuel coolant is processed also by incineration.

The technologies for sludge as well as other special radioactive waste treatment and conditioning are under development.

Fragmentation facility for metal scrap, improved decontamination equipment and interim storage facility are placed in turbine hall. These facilities were commissioned in 1999.

New tanks for storage of aqueous spent fuel coolant (including coolant and sludge drained recently from storage canisters with damaged fuel) were constructed. Vitrification of this coolant with lower contamination started at 1996. Higher contaminated inorganic coolant could be vitrified only after facility refurbishment.

The dismantling of heavy water coolers was completed.

Decontamination of spent fuel pond water (using selective sorbents) was performed in several steps during 1996 – 1999 and contamination was significantly reduced (removed more than 99.9 %).

Decontamination and shielding of pond structures continues with the goal to reduce significantly the dose rate of the area and enable to remove the spent fuel coolant and transfer it to the new tanks or

for conditioning. Fragmentation facility for highly contaminated parts of spent fuel pool is under development.

### **Decontamination outside reactor building**

The decontamination of auxiliary equipment (radioactive waste tanks, contaminated parts of evaporation plant) started in 2000. The vaults used for operational solid waste storage are stepwise emptied, decontaminated and refurbished with the goal to use this space for interim storage of treated/ conditioned waste.

### **CONCLUSIONS**

The course and the main achievements since the start of the decommissioning and recent status of "1-st phase of decommissioning of A-1 NPP" have been briefly described in this presentation. Radioactive inventory was significantly reduced due to the transfer of spent fuel from the site. Safety features were improved by safe store of liquid waste, by solidification of concentrates and part of spent fuel coolant as well as by polishing of fuel pond coolant.

In the case of a non-predictable event (accident, incident) at a nuclear facility a special, pre-decommissioning activities should be implemented to solve, on urgent basis, the particular problems having direct impact on safety and/or environmental protection. They are usually not covered by a standard decommissioning planning. Experience gained in preparatory phase and in implementation of decommissioning plan of NPP A-1 have also been used for preparation and/or modification of decommissioning plans of another NPPs (PWR type) operated in Slovakia.

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