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Waste Management and Disposal in Czechoslovakia: Practices and Proposals

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SUMMARY

An overview is presented on the actual practices and planning for the management of radioactive wastes in Czechoslovakia. Types and specific arisings of wastes, applied immobilization processes, and the planning for disposal of reactor wastes are outlined. A comprehensive R & D programme is focussed on the management of reactor wastes, as the spent fuel is returned to the Sovjet Union after a 10 year cooling time.

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1 INTRODUCTION

The Czechoslovak nuclear power programme is based on the Novovoronezh type of pressurized water reactor (VVER). Units with an output of 440 MWe are in operation and under construction. Units with an output of 1000 MWe are planned and at present time works on design and site investigation and evaluation are in progress. A brief overview of the Czechoslovak nuclear programme is given in table 1.

Table 1 - Brief overview of the Czechoslovak nuclear programme

Site, unit no.		MWe	Stage of implementation	Year of commissioning
Jaslovské Bohunice	1	440	in operation	1979
(Southern Slovakia)	2	440	in operation	1981
	3	440	under commissioning	1984
	4	440	under construction	1984
Dukovany	1	440	under construction	1984
(Southern Moravia)	2	440	"	1985
	3	440	"	1986
	4	440	"	1986
Mochovce	1	440	under construction	~ 1986
(Southern Slovakia)	2	440	"	~ 1987
	3	440	"	~ 1988
	4	440	"	~ 1989
Temelin	1	1000	ordered	1991
(Southern Bohemia)	2	1000	"	1992
	3	1000	"	~ 1994
	4	1000	"	-96
Slovakia -	1	1000	planned	1992
site not yet fixed	2	1000		-95
Bohemia -	1	1000	planned	before 2000
site not yet fixed	2	1000		
	3	1000		after 2000
	4	1000		

On the basis of appropriate agreements with the Soviet Union and the other countries of the Council of Mutual and Economical Assistance (CMEA) there is a variety of manufacturing activities in Czechoslovakia. The main contractor for nuclear and power facilities are the Skoda works. For architecture and construction works appropriate construction companies are engaged, differing from site to site.

2 WASTE MANAGEMENT PRINCIPLES

A uniform approach to the management and disposal of radioactive waste from nuclear power plant operation has been decided by the Czechoslovak goverment in 1981, based on the following principles:

- limited amounts of liquid effluents may be released to the surrounding environment under institutional control

- liquid and solid wastes from reactor operation will be conditioned, immobilized and disposed in ways which assure their isolation from the environment.

Liquid effluents from nuclear power plants include condensates from evaporation processes with H-3 as dominating radionuclide. Its concentration in a near-by recipient is about 3 - 5 orders of magnitude lower then the permissible limit for intake in drinking water.

Basic schemes of management and disposal of reactor waste include the following steps:

1. Liquid wastes-	Solid wastes-
are after some time of delay in tanks (to decay short-lived radionuclides), solidified by mixing with bitumen	are segregated and packed for final disposal-possible ways of treatment are compaction or combustion and solidification of the ashes with concrete

2. Solid and solidified wastes are put in controlled temporary storage at the nuclear power plant before transport to final disposal.

3. Final disposal is carried out in a shallow ground repository which is designed and constructed on the principle of a multi-barrier system to assure sufficient confinement for a period of time which is supposed to be (depending on radionuclide composition and amount) from 300 to 600 years.

3 WASTE CHARACTERISTICS

Thermal reactors of the Novovoronezh type (VVER) produce different types or liquid radioactive waste - main sources are coolant leakage, coolant purification, purification of water from spent fuel storage pools, laundry of radioactive material, sanitary loops, radiochemical laboratories and decontamination (mainly during refuelling). For the treatment of all waste and coolant liquids there is a system of treatment stations with the following arrangement: mechanical filters, evaporators, cation and anion resin filters. Concentrates from evaporators are collected and temporarily stored in five stainless steel vessels, each with a capacity of about 400 m^3 per two units of 440 MWe. Condensate and cleaned water are discharged after control to a near-by recipient (the river). Spent ion exchange resins are also stored in stainless steel tanks, separating medium-level ion exchangers from coolant purification and low-level ion exchangers form other cleaning processes.

Solid wastes originating mainly from operational and maintenance activities are collected and without segregation stored in concrete pits. They include paper, plastic material, rugs, protective aids (gloves, clothes, respirators, overshoes), airfilters, contaminated metal or wooden material etc.

From the operational experience of the first two units in Czechoslovakia and design parameters and experiences form other CMEA countries approximate figures are obtained as input data for an evaluation of the whole management and disposal system.

Cleaning and treatment procedures are similar for both types of power reactors (VVER 440 and VVER 1000). The figures in table 2 correspond to two units of 440 MWe or one unit of 1000 MWe.

Table 2

Main characteristics of Czechoslovak reactor wastes

SOLID WASTE	$\sim 100 m^3 y^{-1}$
- activity	$<10^9$ Bq · m^{-3} (only 1% of amount, in the rest 10 - 100 x lower)
- main radionuclides	^{60}Co, ^{90}Sr, ^{137}Cs

Table 2 cont

LIQUID CONCENTRATES		$\sim 500 m^3 \cdot y^{-1}$
- activity		$< 2 \cdot 10^{10}$ Bq $\cdot m^{-3}$
- main radionuclides		^{95}Zr (40%), ^{60}Co (20%), ^{90}Sr (10%), ^{131}J (10%), ^{137}Cs (10%), ^{106}Ru (5%), ^{144}Ce (5%)
- chemical properties	pH	10 - 12
	content	of salts $\sim$ 200 kg $\cdot m^{-3}$ H_3BO_3 < 120 kg $\cdot m^{-3}$ NO_3^- $\sim$ 60 kg $\cdot m^{-3}$ Na^+, K^+ $\sim$ 50 kg $\cdot m^{-3}$
LOW LEVEL ION EXCHANGE RESINS		$\sim 20 m^3 \cdot y^{-1}$
- activity		$< 4 \cdot 10^{8}$ Bq $\cdot m^{-3}$
- main radionuclides		^{60}Co (70%), ^{137}Cs (30%)
MEDIUM LEVEL ION EXCHANGES RESINS		$\sim 10 m^3 \cdot y^{-1}$
- activity		$< 4 \cdot 10^{12}$ Bq $\cdot m^{-3}$
- main radionuclides		^{60}Co (70%), ^{137}Cs (30%)

4 IMMOBILIZATION AND SOLIDIFICATION OF WASTES

Storage of concentrates, ion exchange resins and solid wastes is considered as a temporary solution, which is not suitable from the points of view of economics and long term safety. As the next step compaction and/or incineration of solid wastes and solidification of evaporator concentrates, sludges and spent resins into a low leachable matrix are accepted.

There are two possibilities of immobilization of solid wastes - compaction and incineration. The final decision to use one of them at Czechoslovak nuclear power plants has not yet been made. The improved volume reduction after incineration and ash immobilization in concrete is considered outbalanced by the economical advantages of compaction. Equipment and facility are developed in Czechoslovakia for both methods with a comparison of the economy and environmental impacts of disposal to be carried out until 1985.

Research and development at the Nuclear Research Institute have provided results initiating the development of Czechoslovak bituminization units for the solidification of liquid concentrates and spent ion exchange resins from reactor operation. These works will be finished during 1985 - 1986 and bituminization units will then start to solidify liquid wastes at Czechoslovak nuclear power plants. The bituminization units use the film evaporator for homogeneous mixing of concentrates and bitumen at a temperature of about 160°C and/or subsequent mixing of resins with bitumen in a special mixing vessel (extruder type). The bitumen product is discharged into steel drums with zinc coating.

Due to lack of experience in the operation of the first nuclear power plant in Jaslovské Bohunice, which lead to the production of higher amounts of liquid wastes with low salt- and activity concentration, the decision was taken to install a waste cementation unit there. This solution is only temporary until the bituminization units are available. Based on offers from

NUKEM, KWU and ASEA-Atom the final choice was to order a cementation unit from KWU because of its homogenization of the product and the possibilities to use some equipment of Czechoslovak origin.

The same type of drums (total volume 230 l, useful volume 200 l, diameter ~ 60 cm, height ~869 cm, wall thickness ~ 0.15 cm) will be used for all waste packages for final disposal in the repository to ensure simple uniform operations at the facilities for immobilization and disposal.

Transport of wastes

After a short period of storage (max 3 months) at the nuclear power plant, the waste drums will be transported in specially constructed containers by road truck to final disposal. For the transportation of the drums with higher activity a cast iron cylindrical container weighting 8 tonnes is proposed. Other wastes will be transported depending on their activity, either in a cylindrical container with a transport capacity of four drums and weighing 5 tonnes, or in a prismatic type container sufficient for a loading of eight drums and weighing 2 tonnes. For road transportation, two containers with wastes of higher activity or three medium active or four lowactive containers can be placed on a trailer. The driver's cabin is shielded by a steel plate.

The conditions for safe transportation are based on international recommendations (IAEA, ICRP), and appropriate rules for road transportation are under preparation and commissioning.

5 FINAL DISPOSAL OF SOLID AND SOLIDIFIED REACTOR WASTES

As a result of preliminary studies and after a comparison of all options mainly from the points of view of radiation protection and economy, the decision was taken to dispose solid and solidified reactor wastes in the shallow ground type of repository.

The selection of suitable sites for shallow-ground disposal was made in three stages. In the first stage a screening procedure was applied in order to select from larger regions all acceptable sites. In the second stage about 20 possible sites were evaluated by means of exclusion and comparison criteria (geography, hydrology, hydrogeology, geology, radiation protection, economy and sociology). In the third stage a preliminary design study of the best four sites was made including a preliminary safety analyses. The safety analyses was based on a suggested technical concept of the repository. Its environmental impacts were assessed by means of a simple hydrogeological model. From the total site selection procedure the decision was taken to build two waste repositories taking into account the location of Czechoslovak nuclear power plants and transport distances, one for Bohemia and Moravia and a second one for Slovakia, both located in the vicinity of nuclear power plants - Dukovany and Mochovce. The start of operation of both repositories (based on the design projects and preliminary site investigations and works) is planned for 1987--88.

Despite unfavourable geological and hydrological conditions in Czechoslovakia and its high population density (the density of population is

> 110 inhabitant/km^2 and the mean distance between the settlements about 3 km in the areas of interest) sufficient and satisfactory solutions for reactor waste disposal were found and verified.

The repository is designed with a series of reinforced concrete (with the incorporation of 10 - 15 % of bitumen) double trenches, each of the dimensions 18 x 6 x 5.3 m (l x w x h). The general layout of a Czechoslovak repository for reactor wastes is given i figure 1.

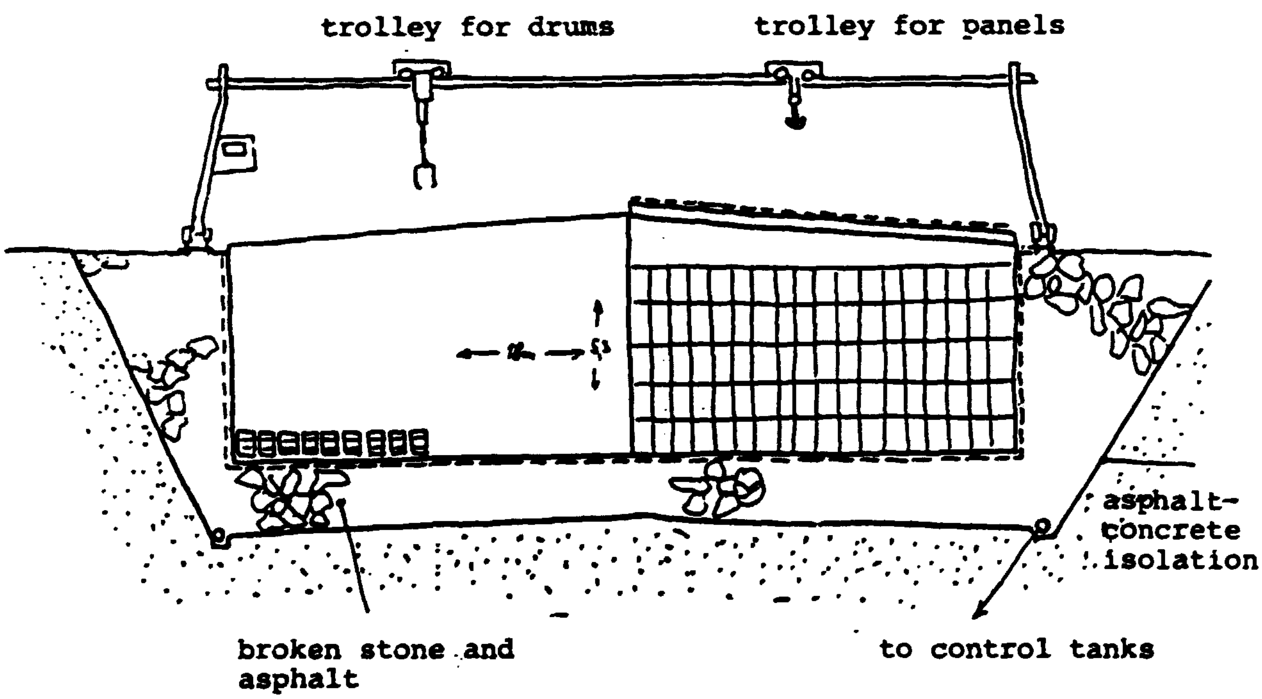

Figure 1 General layout of a Czechoslovak shallow-ground repository for reactor wastes

The bottom and side-walls of the trenches are isolated from water. The loading of drums into the trenches is carried out by means of a full-portal crane, which has tracks on the side-walls of the trenches. Drums are deposited in the trenches in six layers (the crane is equipped with joints for clamping and a telescopic mast for the lift). The filled trench is covered by plastic isolated concrete panels, which are used to cover the trench before filling to avoid water accumulation from atmospheric precipitations.

To prevent release of radionuclides from the repository, the "three barrier concept" is adopted for the final disposal.

The first barrier is the immobilization of radionuclides by means of the bitumen matrix.

The second barrier includes all artificial and engineered barriers such as:

- steel drums with anti-corrosion zinc coating
- reinforced concrete trenches completely isolated against rainwater
- drainage system around the trenches
- base of impermeable concrete-asphalt layer

The third barrier is a relatively or totally impermeable natural geological layer surrounding the repository which has a high retention capacity. After the filling of trenches a protective cement coat is added and finally they are covered with a 60 - 100 cm layer of soil. The sealed repository is then under institutional control, the performance and lenght of which will be set by the regulatory authority.

For installations in the Czechoslovak nuclear power programme until the beginning of the next century and for the operating period 1985 - 2050 disposal of about 200 000 - 400 000 m^3 of waste in each reposity has been foreseen. Total inventory is calculated to about $5 \cdot 10^{15}$ Bq. For the preliminary safety evaluation data given in table 3 are used as input.

Table 3

Radionuclide composition in a Czechoslovak repository for reactor waste and the distribution of activity in different types of wastes.

^{137}Cs		$3.85 \cdot 10^{15}$ Bq
^{90}Sr		$3.15 \cdot 10^{14}$ Bq
^{60}Co		$7.5 \cdot 10^{14}$ Bq
Short-lived radionuclides without importance from the point of view of long-term safety		$1.35 \cdot 10^{14}$ Bq
	Total	$5 \cdot 10^{15}$ Bq

Type of waste	Volume(%)	Activity (%)
medium-level bituminized ion exchange resins	~ 5	> 95
bituminized concentrates	~ 70	> 5
low-level bituminized ion exchange resins	~ 5	Insignificant
solid waste	~ 20	Insignificant

At present time main emphasis is put on the safety assessment of the disposal of reactor wastes to gain the approval for the construction and operation of repositories from regulatory authorities: the Czechoslovak Atomic Energy Commission, the Ministries of Public Health, Forests & Water and the respective local authorities. Part of this process is a wide discussion on acceptability criteria for waste disposal. A preliminary safety evaluation has proved the suitability of this concept for waste disposal, even when very conservative and unfavourable assumptions are used for the consequence calculations. The event leading to a maximum release of radionuclides was defined as a complete flooding of all storage areas, in combination with failure of the drainage system causing a long-term contact of waste with water for a period of about 100 hours. Moreover, assuming 30 years' operation of the repository, the loss of integrity of the concrete isolation (with asphalt coating) and of 10% of the steel drums (by corrosion) was presumed. Conservative data for the leaching of radionuclides out of the matrix, for sorption and migration properties of the surrounding soil, and for the velocity of groundwater flow were used. The final conclusion for the sites chosen for the repositories was that the maximum individual dose through the consumption of water from a reference well (at 300 - 500 m distance from the repository) varies between 10 - 50 µSv/y.

6 RESEARCH AND DEVELOPMENT

6.1 Spent nuclear fuel

Since the reprocessing of spent nuclear fuel from Czechoslovak nuclear power reactors (VVER) on our territory in the near future is not under consideration, there are no significant research and development activities in this field. Research and development on high-level wastes is carried out under agreement with the Soviet Union and is supposed to provide results for decisions in the framework of CMEA.

At present the spent nuclear fuel is stored for three years in water pools in the reactorbuilding.

After this storage period it will be transferred for a period of about 10 years in special temporary storage buildings (wet storage), which are now under construction at Czechoslovak power plants. The choice between reprocessing and direct disposal of unreprocessed spent nuclear fuel after its transport from temporary storage to the USSR has not yet been made.

6.2 Reactor waste

The Czechoslovak policy and concept of reactor waste management and disposal is directed to assure necessary facilities and equipments for the treatment and immobilization of waste prior to its disposal. As the result of these activities there is a manufacturing capacity for units for the bituminization of liquid waste and volume reduction of solid waste combined with research and development to improve these equipments. The construction and commissioning of a shallow ground repository is carried out to assure that no non-acceptable detriment will occur at any time as a result of waste disposal.

A wide range of research and development is underway in Czechoslovakia covering the problems of management and disposal of reactor wastes. In the field of treatment and conditioning of waste from nuclear power plants it is concentrated on the following:

- A systematic collection of data about the function of individual components of the waste treatment systems, and amounts and physical, chemical and radiochemical composition of wastes together with analysis of these data and determination of their basic interrelationships.

- Adjustment of all operations and processes which give rise to radioactive waste to fulfill all requirements for appropriate handling, conditioning and immobilization of the waste to a form suitable for disposal.

- Optimization of waste treatment operations to minimize waste amounts.

- Improvement of decontamination methods to get suitable chemical waste forms for treatment and immobilization.

- Segregation of solid waste for compaction, possible combustion or other volume reducing process (fragmentation etc) and also with regards to the activity level (possible disposal by means of de minimis concept).

Works concerning solidification, packing and machine- engineering development of facilities include:

- Bituminization of liquid wastes with high content of borate salts in film evaporation units.

- Immobilization of all types of liquid reactor wastes by drying-calcination followed by cementation or bituminization.

- Evaluation and comparison of compaction and combustion of solid wastes (radiological and economical) and completion of final examination of incinerator and compaction press; evaluation of results will be followed by the manufacture of suitable equipment for use at nuclear power plants.

- Developments of all necessary equipment for long-term operation of bituminization units (transporters, sealing of the drums, cranes etc).

Works concerning the transport and disposal of wastes are directed to:

- Complete the development of transport containers (the final examination and test based on international recommendations).

- Establish regulations for road transport by truck.

- Design works and site confirmation of the repository for reactor wastes.

- Establish acceptability criteria for disposal and long-term safety of the reactor waste repository.

- Verify models used for the calculation of consequences of releases from a repository (hydrogeological model and model of radionuclide transport by surface water) by variation of parameters and sensitivity and uncertainty analysis.

- Field experiments at repository sites (including hydrogeological surveys) to improve data for geosphere and biosphere in the use of these models.

- Approaches to and concepts of safety analysis and its performance, comparison of its results with acceptability criteria and final confirmation of management and disposal modes.

- Proposals and performance of a complete monitoring programme for the repository and its surrounding for both the operational and postsealing stages.

All these research and development works are evaluated and coordinated by the appropriate commission of CMEA which is giving its recommendation to continue national concepts and approaches in waste management. Under these recommendations, Czechoslovakia will operate the whole system of reactor waste management and disposal by itself. The research and development programme is planned for a period of approximately 5 years. Its ultimate goal includes:

- Treatment and immobilization of reactor waste to waste forms most suitable for disposal.

- Minimization of amounts and volumes of disposed waste.

- Improvements of the immobilized waste quality from the point of view of leachability as the main phenomenon influencing results and environmental impact of waste disposal.