DEVELOPMENT OF NEW CHEMICAL AND ELECTROCHEMICAL DECONTAMINATION METHODS FOR SELECTED EQUIPMENT OF WWER-440 AND WWER-1000 REACTOR PRIMARY CIRCUIT

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Abstract

Special devices for in-situ application of decontamination technologies assigned for Steam Generator, Pressurizer and Main Circulating Casing of VVER-1000 type were designed, manufactured and tested in real conditions of their use in above Primary Circuit components.

New decontamination technologies like low-concentration process NP-NHN for the decontamination of the Steam Generator, combined chemico-mechanical treatment for the Pressurizer and semi-dry electrolysis for the Main Circulating Pump Casing were developed and approved for their safe plant application from point of view of decontamination efficiency, corrosion influence and processing of secondary wastes.

Main technological parameters were defined to achieve high decontamination efficiency and corrosion-safe application of all decontamination technologies.

1. INTRODUCTION

In 1993, AllDeco gained a contract from the NPP in Temelín (Czech Republic) for the delivery of the complete decontamination technologies, including appropriate application devices designed for the in-situ decontamination of main components of the primary circuit of the VVER-1000 type i.e. Steam Generator (SG), Pressurizer and Main Circulating Pump (MCP).

Appropriate decontamination technologies for the application in the NPP in Temelín were selected on the base of extensive development and application experience of research and realization workers of AllDeco in the area of in-situ as well as bath chemical and electrochemical decontamination of similar components of the primary circuit of the VVER-440 type in Jaslovské Bohunice (Slovak Republic) and Dukovany (Czech Republic).

New decontamination technologies were verified in large-scale laboratory and plant tests and finally, they were approved for their safe plant application from point of view of decontamination efficiency, corrosion influence and processing of secondary wastes.

Simultaneously, the development, design and manufacture of appropriate application devices were in progress as a part of the complex technological solution of the decontamination techniques for SG, Pressurizer and MCP Casing.

This Final Report is the part of the Research Project "**Development of New Chemical and Electrochemical Decontamination Methods for Selected Equipments of VVER-440 and VVER-1000 Types Reactor Primary Circuit**" being defined in the frame of the **Co-ordinated Research Programme on Optimization of Decontamination for Maintenance and Decommissioning (1994-1998)** and realized under the **Research Contracts No.: 7967/RB, 7967/R1/RB and 7967/R2/RB**.

In this Final Report, there is a short overview of all main topics being performed and summarized are results from the 3-year progress of the development and project study of special decontamination techniques for main components of the Primary Circuit of VVER-1000 type. All details can be found in corresponding Progress Reports [1, 2, 3].

2. PROJECT DEFINITION

Following objectives of the research project were stated and realized:

- Development of a low-concentration decontamination redox process for the SG of the VVER-1000 type;
- Development of a combined chemical and chemico-mechanical decontamination process for the Pressurizer of the VVER-1000 type;

- Development of the semi-dry electrolysis for the MCP Casing of the VVER-1000 type;
- Development, design and manufacture of appropriate means for in-situ application of above decontamination technologies;
- Large-scale corrosion and metallographic tests of all decontamination methods;
- Evaluation of secondary radioactive wastes processing;

3. REALIZATION OF THE RESEARCH PROJECT

The realization of the Research Project was performed in 3 subsequent years with the analysis of initial conditions at the beginning and with the manufacture of application devices at the end of this period.

3.1 Characteristics of equipments to be decontaminated

The NPP in Temelín is represented by 2 blocks equipped with light-water reactor (PWR) of the VVER-1000 type (Russian design) of rated electrical power output 981 MWe per block.

There are 4 cooling loops in the primary circuit operating at the pressure of 15.7 MPa and coolant temperature of 290 °C (input) or 322 °C (output) with the coolant flow rate of 84 000 $m^3.hour^{-1}$. Each loop is equipped with 1 horizontal SG with the primary side internal volume of heat-transfer tubes and headers of 20 m^3. In each cold leg, there is 1 MCP with the output of 21 000 $m^3.hour^{-1}$; height of MCP Casing is 2 800 mm, min. diameter 810 mm and max. diameter 1 200 mm. In one of cooling loops a Pressurizer (Volume Control Tank) is placed with an internal diameter of 3 000 mm and height of 12 900 mm.

All above components of the primary circuit were manufactured by the Company Vítkovice, a.s. (CR) and they were made of austenitic, titanium stabilized stainless steels of 17.246 or 17.247 type (Czech Standard) that are similar to original Russian steels of 08Ch18N10T type with average contents of Cr(18%) and Ni(8%).

3.2 Characteristics of primary circuit internal corrosion layers

Contaminated corrosion layers on primary circuit internal surfaces of the NPP of PWR type are characteristic with the presence of the compact corrosion layers adhering to the base metal formed by mixed oxides of the substituted magnetite type with relatively high chromium content and outer, less fixed layers formed by partly separated crystals of oxides with high content of iron.

Contaminated corrosion layers of this kind were found on different surfaces from the PWR primary circuit of the NPPs of the VVER-440 type.

Single crystals or their aggregates mostly formed by magnetite with high content of iron are relatively easy to remove by mechanical or chemical treatment. This outer layer contains 6 - 8 % of total surface contamination as it was found, e.g. by comparison of activities of simple swabs and electrochemical samples taken from various areas on inner surfaces of the Pressurizes in the NPP V-2 (VVER-440) in Jaslovské Bohunice.

Under the porous outer layer a partly amorphous sublayer can be found. This inner corrosion layer is chromium enriched and stable against chemical treatment. The inner corrosion layer grows following crystallic structure of the base metal and the corrosion rate is faster on grain boundaries.

Character and properties of these corrosion layers considerably affect selection of processes and application conditions that would be efficient enough for removal contaminated layers during decontamination.

3.3 Selection of appropriate decontamination methods

Basic requirements of the NP in Temelín on decontamination technologies for selected components of the primary circuit were following:

a) minimization of radioactive wastes production and their processability;

b) achievement of required reduction of non-fixed surface contamination (<37 $Bq.cm^{-2}$) and reduction of dose rates;

c) acceptable corrosion influence of decontamination technologies on the equipment being treated;

These parameters were qualitatively and quantitatively compared with results achieved using decontamination processes from the original project based on concentrated oxidation-reduction solutions (AP-Citrox(20/20) as well as with results from operational decontaminations in the NPP in Dukovany (VVER-440).

Taking into account basic requirements of the NPP in Temelín put on the decontamination of selected components of the primary circuit and on the base of our experience, knowledge and results we have achieved during decontamination works performed in the NPPs in Dukovany and Jaslovské Bohunice, following decontamination technologies were selected.

3.3.1 Decontamination of the Steam Generator

A two-stage, oxidation-reduction process AP (alternatively NP)-NHN has been developed for the decontamination of the SG. This process is based on the oxidation effect of the AP solution (10 g.dm^{-3} NaOH + 4 g.dm^{-3} $KMnO_4$) lasting 6 hours at the temperature 90 °C and on successive action of the reduction solution NHN (mixture of an inorganic acid, reduction and complexing agents with total concentration up to 15 g.dm^{-3}) lasting 3 hours at the temperature 90 °C.

As the alternative to the AP solution, the oxidation solution NP (HNO_3 + $KMnO_4$ with total concentration up to 3.5 g.dm^{-3}) lasting 6 hour at the temperature 90 °C is considered, too.

3.3.2 Decontamination of the Pressurizer

With regard to the total volume and character of inner surfaces of the Pressurizer, a combined, chemico-mechanical decontamination method has been proposed.

a) The chemical oxidation-reduction process AP(NP)-NHN based on an oxidation effect of the AP solution (total concentration up to 14 g.dm^{-3}, 6 hours, 90 °C) and the reduction action of the NHN solution (total concentration 1 - 4.5 g.dm^{-3}, 3 hours, 90 °C) has been chosen for the bottom part of the Pressurizer (about 1/3 of the total inner volume).

   As the alternative to the AP solution, the oxidation solution NP (total concentration 1.5 - 2.5 g.dm^{-3}, 6 hours, 90 °C) can be used.

b) The chemico-mechanical process based on the application of a decontamination gel of GD type on the inner surface was chosen for the upper part of the Pressurizer. After 24-hour gel action, the inner surface of the Pressurizer will be finally treated using high-pressure-water jetting (water pressure up to 8 MPa).

3.3.3 Decontamination of the Main Circulating Pump Casing

Considering the additional requirement of the NPP in Temelín: metallic blank surface of the MCP Casing is to be achieved, and with regard of geometric simplicity of the MCP Casing inner surfaces to be treated, the process based on the semi-dry electrolysis has been selected. This method is based on the anodic treatment of the metallic surface using a movable electrode - cathode equipped with the swab continuously supplied wit the electrolyte solution.

The pH-neutral electrolyte is composed of salts of organic and inorganic acids and does not contain any oxalic acid or oxalates, respectively. The electrolyte composition allows using wide range of current densities (0.05 - 0.5 A.cm^{-2} without any unfavorable specific corrosion attack of the base metal.

3.4 Evaluation of long-term corrosion tests

An extensive program for complex study of corrosion effects of decontamination methods being selected for the SG, Pressurizer and MCP casing of the VVER-1000 type was performed. In frame of this program wide spectrum of qualitative and quantitative parameters were evaluated that cover all important aspects concerning general as well as specific and local corrosion effects, lasting changes of mechanical properties and surface corrosion resistance as a consequence of the decontamination treatment.

All corrosion tests and their evaluation were realized in an independent, authorized institute "Divize Vítkovice Technika" in the Czech republic. Company Vítkovice a.s. is the manufacturer of the SG and Pressurizer of VVER-1000 type and of basic construction materials for other components of the primary circuit of the NPP in Temelín.

3.4.1 Specification of materials being tested

Real construction materials that will contact decontamination solutions were subjected to wide range of corrosion tests to confirm safe application of decontamination processes being developed. Samples for corrosion tests were made of:

- austenitic, titanium stabilized stainless steel 08Ch18N10T (as received, annealing sensitized, low-temperature sensitized, after cold deformation);
- niobium stabilized weld deposit 04Ch20N10G2B or 08Ch19N10G2B;
- isolated δ-ferrite;

3.4.2 Corrosion tests

Experimental observations were divided into two main phases. In frame of the 1st phase, direct corrosion effects of decontamination processes on construction materials were evaluated. The 2nd phase was aimed to the qualification of eventual effects of decontamination processes on resulting corrosion resistance of construction materials being treated.

The standard process AP-Citrox was used in parallel corrosion tests for relative qualification and quantification of corrosion effects.

Following corrosion tests were involved:

Direct corrosion effects of decontamination:

- general corrosion rate (material loss per 1 decontamination cycle);
- metallographic and fractographic evaluation of selective corrosion effects (local corrosion attacks);

Material samples were treated in 7 decontamination cycles or in 3 initial decontamination cycles followed by 3 cycles consisting of the autoclave exposition (500 hours) and the decontamination treatment.

Effects on resulting corrosion resistance after the decontamination:

- multiple oxidation in high-temperature water (HTW) in autoclaves followed by the decontamination treatment;
- sensitivity to the corrosion cracking (evaluation of initiation and spreading of tension processes, exposition of samples under mechanical tension, static loaded specimens with a crack generated);
- resistance to the pitting and crevice corrosion;
- changes in the reactivity of the surfaces (analysis of the base material surface layers, study of oxide layers formation, study of redox processes rate alteration on surfaces being decontaminated);
- stability of minority phases;
- chemical and phase analysis;

3.4.3 Results from corrosion tests

Detailed summary of results from large-scale corrosion tests represents a comprehensive report [4] (over 100 pages with 117 figures and 11 tables).

These corrosion tests and plant verifications confirm suitability of all new decontamination processes for their safe and effective use in applications they have been developed for and these technologies are approved for their routine use in the NPPs.

4. DEVELOPMENT AND DESIGN OF APPLICATION DEVICES

In the frame of the complex technological solution of the decontamination techniques for the Steam Generator (SG), Pressurizer and Main Circulating Pump (MCP) Casing for the NPP in Temelín, special application devices were designed, manufactured and tested in real condition of the use for above Primary Circuit components. These are:

DEZA PG-1000	-	application device for the SG;
DEZA KO-1000	-	application device for the Pressurizer;
DEZA HCČ-1000	-	application device for the MCP Casing;

A common, very important criterion for all application devices was their reliability in long-term and heavy-duty operation.

Decontamination devices had to be made of materials compatible with materials of corresponding Primary Circuit components (composition, corrosion characteristics, surface finishing) and resistant to the decontamination media in heavy operation conditions.

To meet all operation criteria put on the application devices it was necessary to test them in conditions as close to the operational reality as possible. From this point of view, simultaneously with the application devices, testing and training stands were designed and manufactured that were assigned to tests and adjustment of corresponding devices and training of the staff to become familiar with correct handling and servicing.

All above decontamination devices allow to achieve optimal conditions of the application of corresponding decontamination technologies and the design takes into account specificity of the concrete equipment being decontaminated as well as specificity of the VVER-1000 type Primary Circuit (e.g. absence of Main Gate Valves).

4.1 DEZA PG-1000

The decontamination device DEZA PG-1000 (Fig. 1, Fig. 2 in Graphic Inset) is assigned to the application of the two-stage technology of the chemical decontamination named AP(NP)-NHN in the SG in the VVER-1000 type Primary Circuit [5].

The decontamination device DEZA PG-1000 was tested in four full decontamination cycles in the special stand and this time, it is prepared for the 5th "dry" loading into the real SG in the NPP in Temelín.

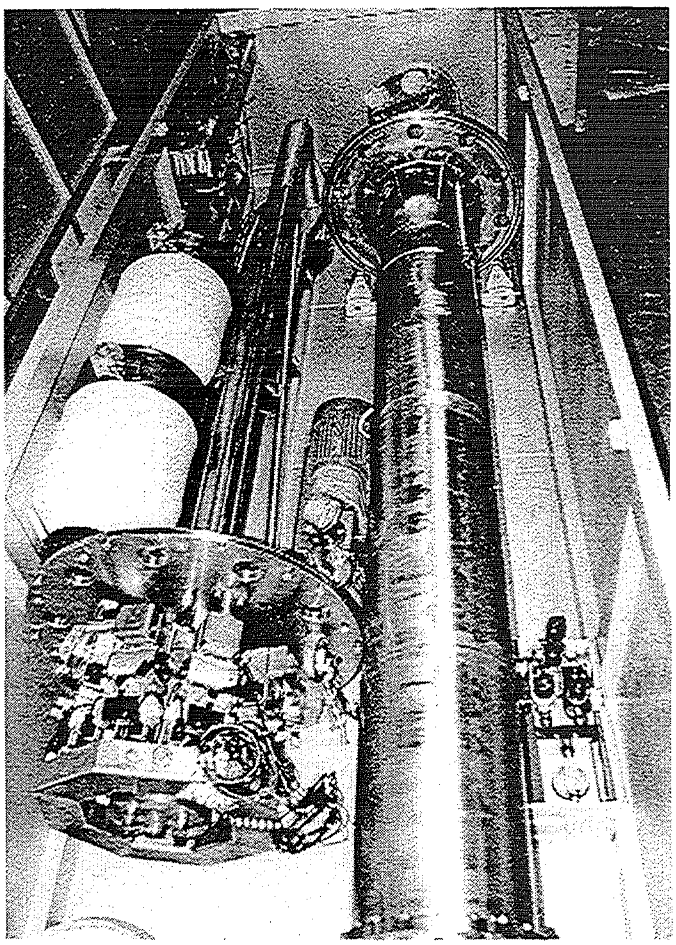

Fig. 1: DEZA PG-1000 - Circulation Unit and Control Unit in the Transport Container

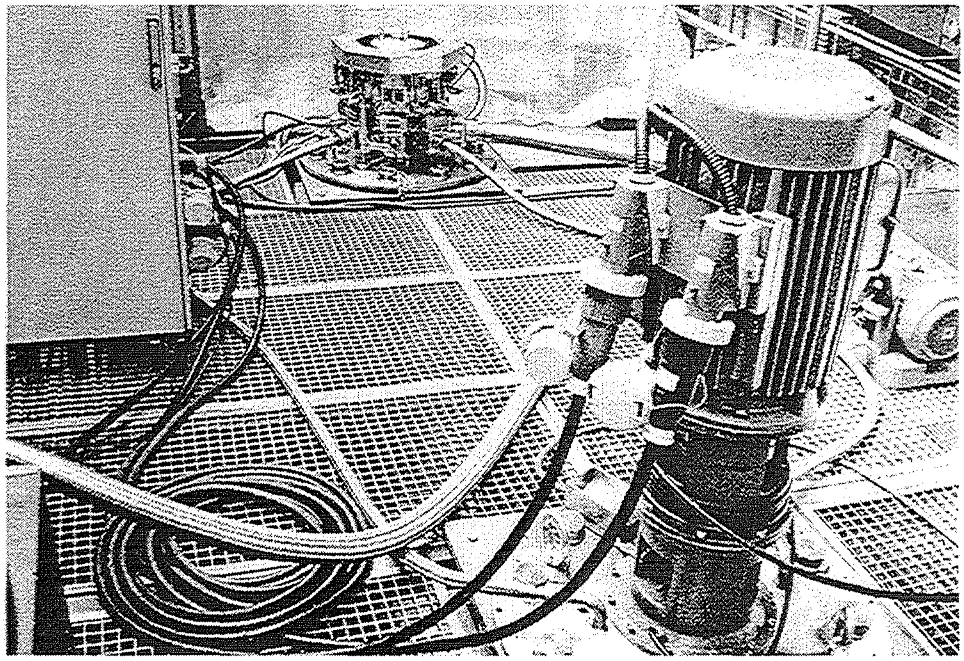

Fig. 2: DEZA PG-1000 - Circulation unit and Control unit loaded in the headers of the Stand

Decontamination equipment DEZA PG-1000 consists of following basic parts:

1. control unit (positioned into the cold SG header);
2. circulation unit (positioned into the hot SG header);
3. control station;
4. connecting hoses;
5. connecting cables;
6. auxiliary dosage pump;
7. auxiliary drainage pump;
8. accessories;
9. transport and storage container;

The **Control Unit** of the DEZA PG-1000 ensures filling of decontamination solutions into the SG, discharge of decontamination solutions from the SG, enables operational sampling and correction of chemical characteristics of decontamination solutions (pH, concentration) by dosage of concentrates of reagents. Control unit also holds sensors for monitoring of liquids (level, temperature) in the SG in different stages of the decontamination.

The **Circulation Unit** of the DEZA PG-1000 ensures circulation of decontamination solutions and uniform distribution in heat-exchanger tubes between the hot and cold headers in the SG.

The **Control Station** enables monitoring of the level and temperature of decontamination solutions in the SG, remote control of the circulation pump, auxiliary drainage and dosage pump, filling, discharge and blow-off valves.

Flexible metallic **Connecting hoses** are made of stainless steel and they are assigned to transfer of the liquid media used for the decontamination of the SG (filling, drainage, dosage, blowing-off).

The **Connecting cables** are used for the power supply of electrical appliances and for signal transfer from sensors held by the Control unit to indicators in the Control station.

The **Auxiliary Dosage Pump** is of a plunger type and it is used for an additional dosage of concentrates of basic reagents into the decontamination solutions in the SG when the effective concentration falls below an acceptable limit.

The **Auxiliary Drainage Pump** is of a centrifugal type and it is used as a main device of the discharge system.

4.2 DEZA KO-1000

The decontamination device DEZA KO-1000 (Fig. 3, Fig. 4 in Graphic Inset) is assigned to the realization of the two-stage technology of the chemical decontamination named AP(NP)-NHN in the bottom part of the Pressurizer and combined chemico-mechanical decontamination in the top part of the Pressurizer in the VVER-1000 type Primary Circuit [6].

The decontamination device DEZA KO-1000 was tested in four full decontamination cycles in the special stand and this time, it is prepared for the 5th "dry" loading into the real Pressurizer in the NPP in Temelín.

Decontamination equipment DEZA KO-1000 consists of following basic parts:

1. basic supporting column (in 5 parts);
2. sealing plug;
3. carriage in transport and stabilization cage holding adjustable arms with application tools;
4. section for airless decontamination gel application;
5. section for high-pressure-water jetting;
6. connection and distribution frame;
7. control station;
8. connecting hoses;
9. connecting cables;
10. accessories;
11. transport and storage container;

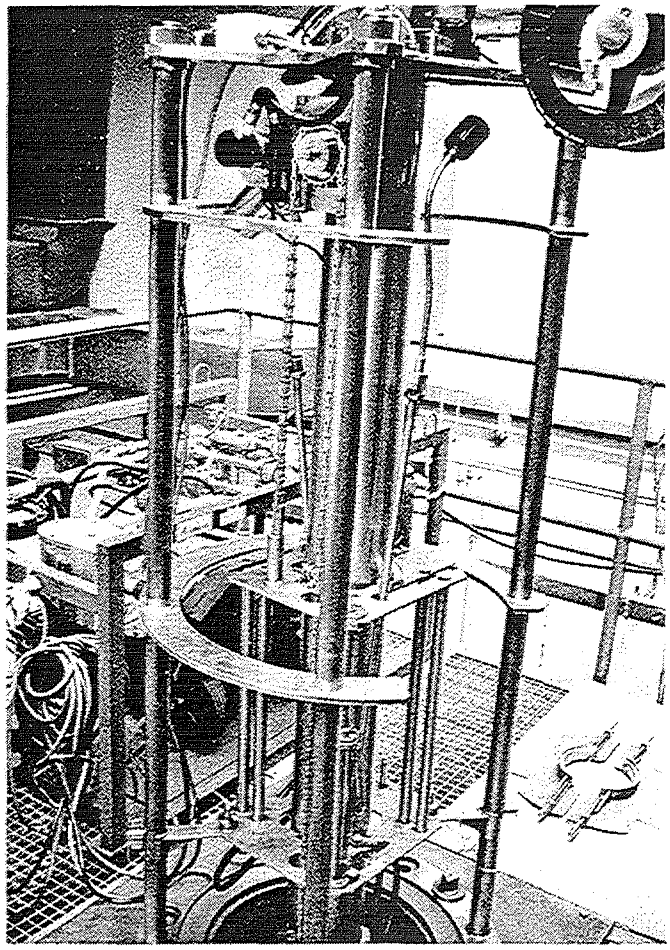

Fig. 3: DEZA KO-1000 - Carriage with Adjustable Arms in the Stabilization Cage

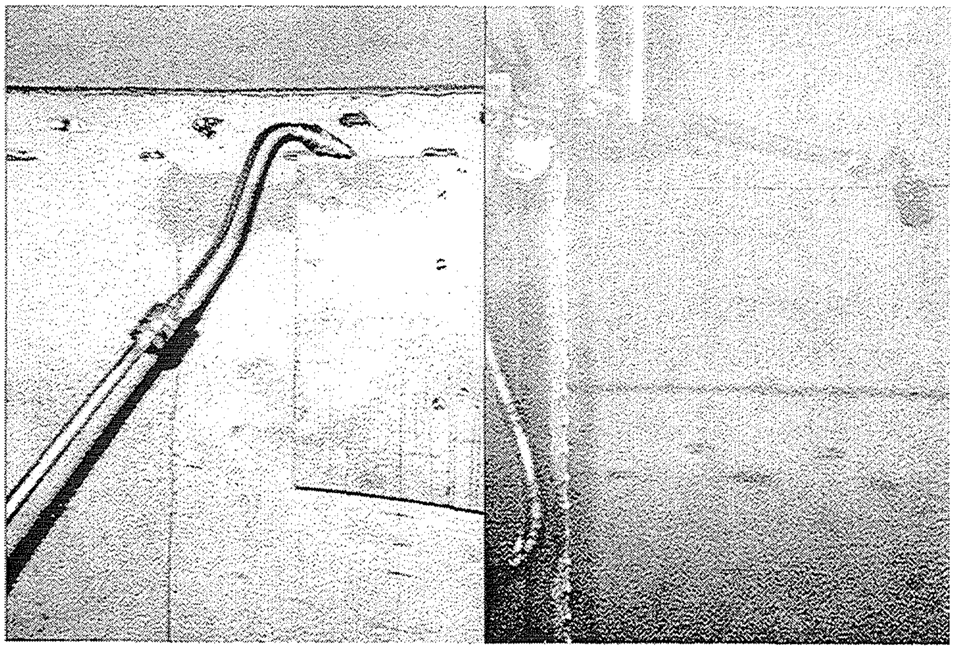

Fig. 4: DEZA KO-1000 - Decontamination Gel Application and High-Pressure-Water Jetting

The basic **Supporting Column** of the decontamination device DEZA KO-1000 ensures filling and discharge of decontamination solutions being used for the decontamination of the bottom part (1/3 of total inner volume) of the Pressurizer in the 1st stage of the decontamination.

In the 2nd stage of the decontamination of the top part of the Pressurizer (2/3 of total inner volume) the **Supporting Column** enables vertical and horizontal movement and positioning of the carriage.

The **Sealing Plug** is mounted on the lowest part of the supporting column and it ensures the reliable separation of the inner volume of the Pressurizer from the rest of the Primary Circulation Loop.

The **Carriage** is carrying adjustable arms with special jets for airless gel application and high-pressure-water jetting. The adjustable arms and jets are exchangeable to ensure their optimum working position in different cross-sections of the Pressurizer. The carriage is normally put and fixed in the transport and stabilization cage for simple and safe handling.

The **Section for Airless Gel Application** is built-up of the reservoir of the decontamination gel, high-pressure piston pump (up to 1.8 MPa) and high-pressure feeding hoses up to sockets on the carriage.

The **Section for High-Pressure-Water Jetting** is built-up of the high-pressure water pump (up to 21 MPa) and high-pressure feeding hoses up to sockets on the carriage.

Both above section are mounted into the common **Connection and Distribution Frame** with valves and piping for correct distribution of decontamination media to the working tools.

The **Control Station** enables monitoring of the pressure in the Pressurizer during the 1st decontamination stage and remote and programmable control of the carriage movement and positioning in both vertical and horizontal direction during the 2nd decontamination stage.

Flexible metallic **Connecting hoses** are assigned to transfer of the liquid media used for the decontamination of the Pressurizer (filling, drainage).

The **Connecting cables** are used for the power supply of the control station and for signal transfer from sensors on the supporting column to indicators in the Control station.

4.3 DEZA HCČ-1000

The decontamination device DEZA HCČ-1000 (Fig. 5, Fig. 6 in Graphic Inset) is assigned to the application of the semi-dry electrochemical decontamination in the MCP Casing in the VVER-1000 type Primary Circuit [7].

This device has to enable proper separation of the MCP Casing from the rest of the circulation loop, precise positioning of working tools, controlled distribution of the electrolyte and operating current into the electrodes, final water rinsing and discharge of the spent liquid media.

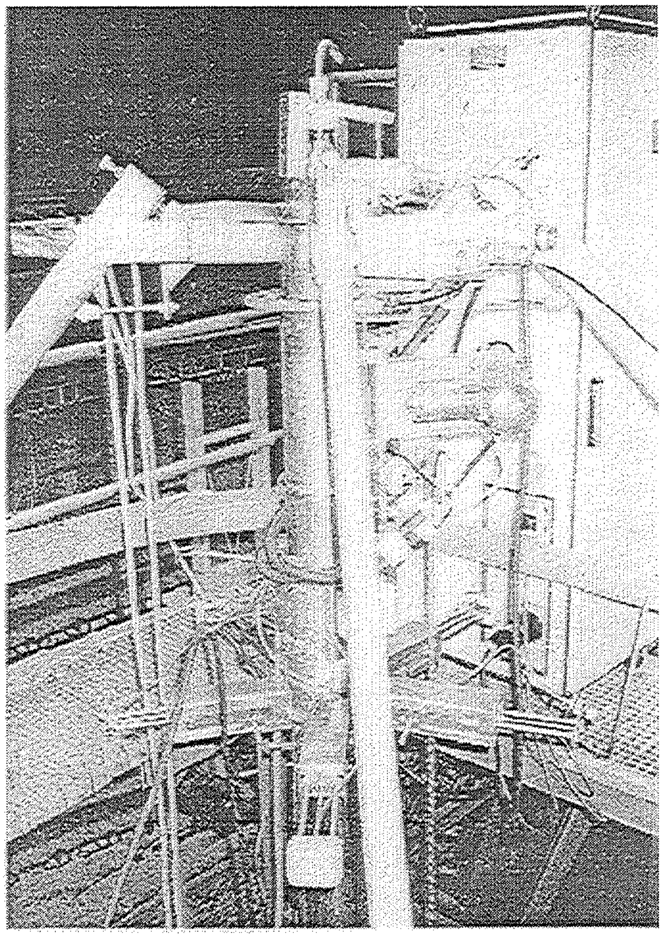

Fig. 5: DEZA HCČ-1000 - Supporting Column with the Carriage in the Upper Position

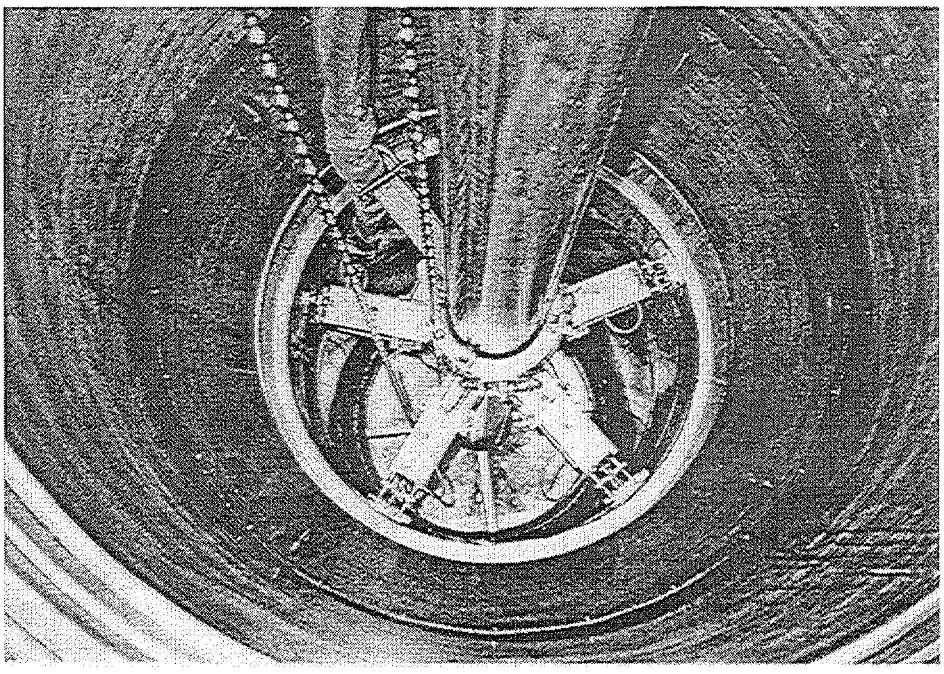

Fig. 6: DEZA HCČ-1000 - Electrodes in the Working Position

The decontamination device DEZA HCČ-1000 was tested in four full decontamination cycles in the special stand and in the additional 5th "dry" loading into the real MCP Casing in the NPP in Temelín.

Decontamination equipment DEZA HCČ-1000 consists of following basic parts:

1. basic supporting column;
2. sealing plug with the spent electrolyte collector;
3. carriage with the set of working tools;
4. section for electrolyte and rinsing water supply;
5. rectifier;
6. pneumatic unit;
7. control station;
8. connecting hoses;
9. connecting cables;
10. accessories;
11. transport and storage container;

The basic **Supporting Column** of the decontamination device DEZA HCČ-1000 enables vertical and horizontal movement and positioning of the carriage in different heights and cross-sections of the MCP Casing.

The **Sealing Plug** is mounted on the lowest part of the supporting column and it ensures the reliable separation of the inner space of the MCP Casing from the rest of the Primary Circulation Loop and it holds the collector of the spent electrolyte

The **Carriage** is carrying adjustable, pneumatic arms with 4 special-shaped electrodes and 1 rinsing jet. The system of adjustable arms allows the working electrodes to reach diameters from 810 mm to 1200 mm. Special-shaped electrodes wearing swaps are exchangeable to ensure optimum treatment of different surfaces in the MCP Casing.

The **Section for Electrolyte and Rinsing Water Supply** is built-up of a reservoir for the electrolyte and the second one for the rinsing water with a pumping system using pressurized air.

The **Rectifier** is a source of the direct current for the electrolysis with the current limit set to 50 A and the voltage limit of 30 V.

The **Pneumatic Unit** allows control and positioning of adjustable pneumatic arms, pumping of the electrolyte and rinsing water into the working tools and regular discharge of the collector of the spent electrolyte.

The **Control Station** enables programming, control and monitoring of movements and working positions of the carriage and parameters of the electrolysis.

The **Connecting hoses** are assigned to transfer of the liquid media used for the decontamination of the MCP Casing (feeding, discharge).

The **Connecting cables** are used for the power supply of the control station, electrical appliances and working electrodes and for signal transfer from sensors on the supporting column to indicators in the Control station.

5. SECONDARY RADIOACTIVE WASTES - BALANCE

New decontamination formulations developed for the SG, Pressurizer and MCP Casing of the Primary Circuit in the NPP in Temelín are based on the use of the liquid media containing various active chemical agents to achieve effective and safe decontamination and low production of secondary radioactive wastes.

The decontamination of the SG will be performed using the chemical, two-stage, oxidation-reduction process based on a basic oxidation solution of AP type and a reduction solution of NHN type. As an alternative an oxidation solution of the NP type may be used in the oxidation stage.

The decontamination solutions for the treatment of the bottom part of the Pressurizer are of the same type as those ones used for the SG; Upper part of the Pressurizer will be decontaminated using special decontamination gel and subsequent high-pressure-water jetting.

The MCP Casing decontamination will be performed using the technology of semi-dry electrolysis.

Basic composition of above decontamination media are shown in the Table 1.

Table 2 shows expected amounts of spent decontamination solutions and the balance of secondary radioactive wastes from the decontamination of above equipments in 1 year period:

1 SG - 2 decontamination cycles;

1 Pressurizer - 1 decontamination cycle;

1 MCP Casing - 1 decontamination cycle;

Table 1: Basic chemical composition of decontamination solutions for the SG, Pressurizer and MCP Casing treatment

Decontamination method	Stage (total concentration / $g.dm^{-3}$)		Basic components
AP-NHN for the SG	AP-oxidation	(14)	$KMnO_4$ NaOH
	NHN-reduction	(15)	HNO_3 Reduction agent Complexing agent
	NP-oxidation (alternative)	(3.6)	HNO_3 $KMnO_4$
AP-NHN for the Pressurizer	AP-oxidation	(14)	$KMnO_4$ NaOH
	NHN-reduction	(5)	HNO_3 Reduction agent Complexing agent
	Decontamination Gel (GD)	(760)	Glycerol Reduction agent Complexing agent
Electrolyte for the MCP Casing	Semi-dry electrolysis	(40)	$(NH_4)_2SO_4$ NH_4NO_3 Complexing agent

Table 2: Expected amounts of spent decontamination media from the SG, Pressurizer and MCP Casing treatment in 1 year period

Equipment - Solution	Volume of spent solutions [m^3]		Total concentration	Final concentration of liquid radwaste from 2 Units	Volume of the concentrate from 2 Units (salinity)
	1 Unit/1 year	2 Units/1 year	[$g.dm^{-3}$]	[$g.dm^{-3}$]	[m^3]
PG - AP	2 x 20	80 + 20 *	14		
- NHN	2 x 20	80 + 20 *	15		
- water	4 x 20	160 + 40 *	-		
		Σ **400**		7.25	14.5
KO - AP	30	60 + 40 **	14		
- NHN	30	60 + 40 **	5		
- GD	0.1	0.2	760		
- water	35	70 + 7.8 **	-		
		Σ **350**		5.86	10.3
MCPC - electrolyte	0.3	0.6	40		
- water	0.1	0.2 + 1.2 ***			
		Σ **2**		12.00	0.12
Total amounts		**750**			**25**

* - increase of the solutions volume ↗ reserve and retention in piping;
** - increase of the solutions volume ↗ reserve and consumption in decontamination baths;
*** - increase of the solutions volume ↗ rinsing water for final cleaning of decontamination devices;

6. MAIN TECHNOLOGICAL PARAMETERS

All new decontamination technologies were successfully verified in many laboratory and plant decontamination and corrosion tests and the full compatibility with construction materials of the Primary Circuit as well as materials of decontamination devices was approved.

6.1 Decontamination of the Steam Generator

Real decontamination conditions:

oxidation solution	-	AP (14 $g.dm^{-3}$)
(alternative oxidation)	-	NP (3.6 $g.dm^{-3}$)
oxidation step	-	6 hours
reduction solution	-	NHN (15 $g.dm^{-3}$)
reduction step	-	3 hours
operational temperature	-	90-95 °C

6.2 Decontamination of the Pressurizer

Real decontamination conditions:

<u>Bottom part</u>

oxidation solution	-	AP (14 $g.dm^{-3}$)
oxidation step	-	6 hours
reduction solution	-	NHN (5 $g.dm^{-3}$)
reduction step	-	3 hours
operational temperature	-	90-95 °C

<u>Top part</u>

decontamination gel	-	GD (760 $g.dm^{-3}$)
gel application time	-	1.5 hour
gel reaction time	-	20-24 hours
high-pressure jetting	-	clear water
time of one step	-	2 hours
operational temperature	-	30-50 °C

6.3 Decontamination of the MCP Casing

Real decontamination conditions:

electrolyte	-	pH=7 (40 $g.dm^{-3}$)
current density	-	+30 $A.dm^{-2}$
treatment time	-	7.5 hours

7. CONCLUSION

In frame of the Research Project new decontamination technologies were developed for selected components of the primary circuit of the VVER-1000 type:

- ☑ Two-stage, low-concentration, oxidation-reduction decontamination process for the Steam Generator;
- ☑ Combined chemical and chemico-mechanical decontamination treatment for the Pressurizer;
- ☑ Semi-dry electrochemical decontamination technology for the Main Circulating Pump Casing;

All above decontamination technologies were tested and approved by the authorized Institute for their routine operational application in NPPs in the Slovak Republic and the Czech Republic.

The Final Report also summarizes basic facts on final design, manufacture and testing of application devices for new decontamination technologies for selected components of the Primary Circuit of VVER-1000 type in the NPP in Temelín. Results from the stand tests being performed have confirmed the reliability of the machinery and the reality of achieving of basic obligatory technological parameters having been defined in the initial project phase.

A specialized authority evaluated contribution of radioactive wastes from the decontamination technologies application and their influence on anticipated radioactive wastes from the NPP regular operation. The detailed analysis of the input data confirmed the compatibility of radioactive wastes originated from the decontamination with other radioactive wastes collected from other sources. The bituminization technology as well as the cementing technology are acceptable for processing of liquid radioactive wastes from the decontamination using new formulations. These processes will lead to the stable and resistant products from the fixation treatment of radioactive wastes.

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