# New Method for the Decontamination of Labyrinth Seals of Control Rod Drives (CRD) - 14167

P. Baradlai*, G. Patek*, O. Oldal*, A. Kurucz*, N. Kósa*, J. Schunk**, Z. László***, K. Nyitrai***, S. Szabó***, M. Petrik***, Gy. Pátzay****
* MVM Paks Nuclear Power Plant Ltd., H-7031 Paks, P.O.Box 71, Hungary
** MVM Paks II. Ltd., H-7030 Paks, Gagarin str. 1., Hungary
*** Hepenix Ltd., H-2040 Diósd, Petőfi S. str. 39., Hungary
**** Budapest University of Technology and Economics, H-1111 Budapest, Budafoki str. 8, Hungary

## ABSTRACT

The power output of the reactor is regulated by the movement of safety and control rods. During operation - as some areas are in direct contact with the primary circuit heat transfer medium that has a temperature of 296°C (565°F) - the temperature of the control rod drives (CRD) may reach 200°C (392°F). The temperature of the drive motor shall not exceed 100°C (212°F) therefore the space where the motor is located needs cooling. The labyrinth seals reduce the natural circulation forming between the upper cooled area and the lower hot environment, however the continuous extreme heat difference may cause thermic fatigue and cracks in them.

The components of the CR drives that are in contact with the 296 °C water of the primary circuit are decontaminated by moving cathode electrochemical method before material testings and maintenance. Following material testing drives may only be reinstalled after a function test.

Following the year 2000 modernized CRD-s were installed. Two years ago defects were detected in the labyrinth seals of these drives; consequently the condition inspection of these modernized CR drives was called for.

Due to the large number of CR drives, the shortness of the time available, and the relatively long time required for the inspection of each drive, a new method of inspection had to be developed.

The inspection time of the drives can be significantly reduced by their decontamination in vertical position.

Existing methods were inapplicable. The newly developed method contained an electrolyzer cell made of two half-cylinders to be installed onto the control rod drive. The supporting equipment for the electrolyzer cell was installed onto an available decontaminating bath, while the CRD was hanging on the crane during decontamination.

The introduction of the new method proved to be successful, and the application of this new method reduces the time of CRD labyrinth seal inspections by three quarters. Furthermore less radioactive waste is generated and the dose received by personnel is insignificant.

## INTRODUCTION

The safety and control system provides one option to control reactor power output, where special rods provide the necessary power control. Special drives shift the control rods in place.

Control rods are moved by CR drive mechanisms, which transform the rotation of direct-current motors into linear movement of the CR-s through rack gearing.

CR drives are in direct contact with the heat transfer medium of the primary circuit which has a temperature of 296°C, therefore the temperature of the drives may exceed 200°C. However the temperature of the drive motor should not go over 100°C, thus the area where the drive motor is located has to be cooled. Cooling is provided by an external cooling system, which is physically separated from the primary heat transfer medium.

As our cooled area (CR case) is located above the reactor core (cooled section above and hot section below) a natural circulation is trying to develop. Water of the cooled area strives to mix with water from the hot area, which can be prevented by reducing the possibility for blending with the use of labyrinth seals.

The cylindrical surface of the labyrinth seal is the barrier plane between the hot water (296°C) from the upper case of the reactor, and the 80°C water (maximum:100°C) separated by the labyrinth seals. The blending section of the different temperature media is in constant movement due to the pulse and pressure changes of the heat transfer. The continuous relocation of the barrier plane of high temperature difference causes thermic fatigue and crack development in the labyrinth seal threads, as it was detected.

The section of CR drives that is in direct contact with the 296 °C heat transfer medium needs to be decontaminated prior to material testing and maintenance to reduce radiation and for surface preparation. There is a moving cathode electrochemical decontamination process available for this task, to be executed in the horizontal position of the drive [1]. The drive needs to pass a function test following material testing to be returned to operation. These activities can be executed for one drive in an 8 hour shift, if the crane is available when needed.

In the beginning of 2012 during ultrasound testing continuity defects were detected in the lower threads of the labyrinth cases of five modernized CR drives operated for six years, and one modernized CR drive in operation for five years. This was unexpected defect, as the planned operation lifetime of such a modernized drive is 25 years. Previously this kind of defect had only been detected in 7 instances compared to more than 100 years of operation.

The defects can be fixed with the replacement of labyrinth cases in the CR drives, executed according to the relevant maintenance process. Following the detection of the defects an immediate condition inspection of the modernized operating and reserve CR drives was necessary regardless of the maintenance period.

## DISCUSSION

### Decontamination requirements for the labyrinth surfaces of CR drives

During 2012 130 modernized CR drives had to be inspected. The sheer number of drives, the short available time during outages as well as the relatively long time necessary for the inspection of each drive deemed the currently available inspection method unsuitable for the required inspections. Therefore a new condition inspection method had to be developed. The most time can be saved by performing decontamination in the vertical position of the drive, as in case of undamaged drives the time required for moving, laying and lifting, as well as the time for the function test can be saved (several hours) [2].

When planning the condition inspections of CR drives the following requirements for decontamination were defined:

- shortest possible time required for decontamination,
- decontamination in the vertical position of the drives,
- decontamination shall not have an effect on the integral structural elements of the drive,
- decontamination only of the sealing plane of the labyrinth seals, providing clear metal surface,
- dose received by staff during decontamination and material testing shall be reduced to a minimum.

### The decontamination options for the CRD labyrinth surfaces

The already available method of CRD-s offered a number of possibilities:

- One option is chemical decontamination in the vertical position of the CRD. This method requires the work of several shifts and the whole control rod drive is treated when only about half a meter of the labyrinth seals shall be inspected. This method also fails the requirement that the decontamination shall not affect the integral structure of the drive.
- The other method already used is the moving cathode electrochemical decontamination. For this method CR drives had to be laid down into the drive revision bath found in the middle of the reactor hall, where decontamination can be executed. This option was rejected due to its failure for decontamination in a vertical position.

As the available methods for the required decontamination were not acceptable, a new method had to be developed.

In regard of the short decontamination time and decontamination efficiency the electrochemical method seemed the only possible way [3]. Such a method had to be developed, that ensured only the affected areas of the labyrinth seals would be cleaned and decontaminated. First the aforementioned moving cathode electrochemical process was considered, but as opposed to the present practice, in the vertical position of the CRD. The presently available cathode profiles are not effective enough in the grooves of the labyrinth seals, thus the manufacturing of a cathode with the geometrically appropriate profile was considered. The complexity of the device could not ensure success, and due to the shortness of time in case of failure we could not afford to have to develop a new method. For this reason this option was rejected. The required efficiency can be achieved with the immersion method, but with the present technique and available equipment the whole of the CRD is treated. Therefore this method - as it is - is neither suitable [4].

The solution seems to be the combination of the two methods, an electrolyzer cell installed onto the affected area (labyrinth thread) of the vertically positioned CRD. In this method an electrolyzer cell has to be manufactured, which contains two half-cylinders, can be easily mounted onto the labyrinth seal section of the CRD, where decontamination by immersion is possible.

We also had to define a location for decontamination, which provides solution to the following: drainage of the washing liquid or the electrolyte that may escape, shielding of the CRD-s during decontamination and material testing, the protection of personnel against radiation, installation of the electrolyzer cell. The 01-02TU101B001 decontamination baths were selected.

After consideration of the aforementioned aspects and criteria the following solution was proposed:

- production of a cell made of two half-cylinders,
- the cell shall be securely and tightly installed onto the CRD in a way that ensures the electrolyte will not drain away,
- auxiliary components that assist the work of the cell shall be integrated into a complex device,
- the equipment shall be installed onto the 01-02TU10B001 decontamination bath,
- the CRD shall hang during decontamination from the reactor hall crane.

## The description of the decontaminating equipment developed for the labyrinth seals of the CR drives

Figure 1 shows the schematic picture of the equipment. The main components of the equipment: base frame, moving frame, electrolytic tank (electrolyzing cell), electrical connections, and electrolyte-circulation (cooling system).

The fixed frame is the base frame of the decontaminating equipment for the labyrinth seals of the CR drives made of acid-resistant stainless steel. It is installed onto the 01-02TU10B001 decontaminating bath by fixing it through bores in the base plate with two positioning pins and two M16 bolts.

The moving frame contains the electrolytic tank and the connecting components. The moving frame is attached to the base frame with pneumatic cylinders (that act as bellows) and positioning bolts, the connection is not rigid. The task of the pneumatic cylinders is to reduce the effects of a possible vertical movement after the closing of the electrolyzer cell. The appropriate pressure of the pneumatic cylinders can be set with the pressure control manometer.

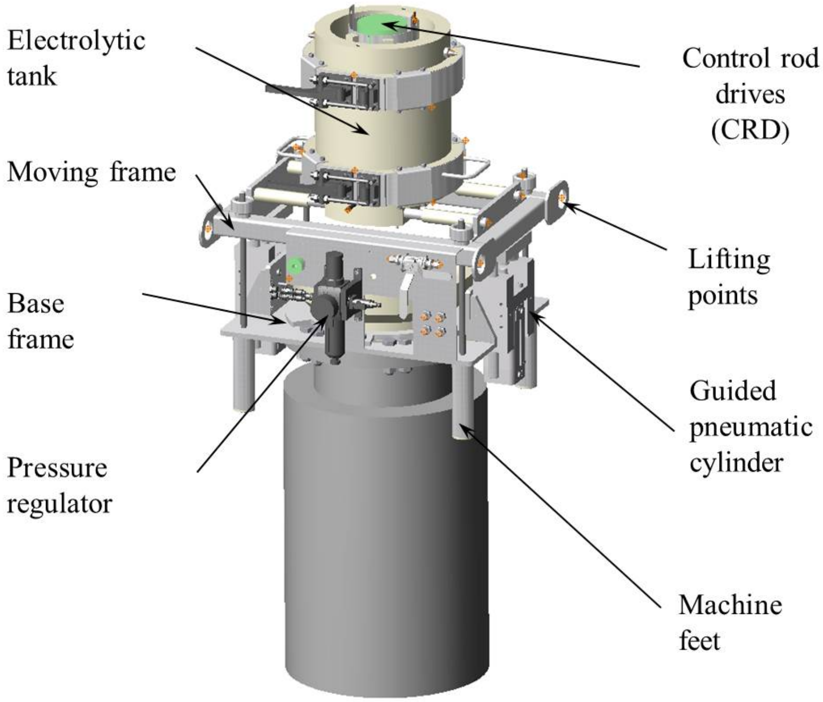


Figure 1. Schematic picture of the decontaminating equipment

The galvanic cleaning process takes place in the electrolyzer cell (electrolytic tank) (Figure 2).

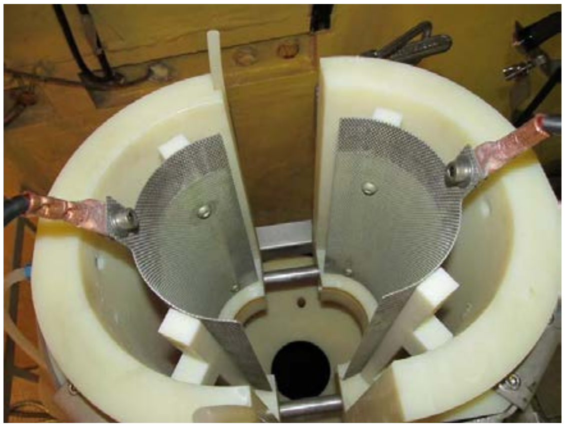

Figure 2. Electrolyzer cell

The CRD to be cleaned is lifted by a crane in between the components which are made of plastic (polyamide) with rubber seals at the joints, surrounded by the liquid electrolyte. The cathode of two halves is located within the cell, it is of a perforated design to improve the flow of the liquid, thus the effectiveness of the electrolysis and also the cooling of the electrodes.

For the process of galvanic removal a direct-current power source of 30V and 60A is used.

Electrolyte-circulation (cooling system) is used to remove the heat generated during the galvanic cleaning process. A peristaltic pump ensures the circulation of the electrolyte between the heat exchanger and the electrolytic tank (electrolyzer cell).

Lifting of the 83kg CRD labyrinth seal decontamination equipment is carried out by one of the reactor hall cranes.

**Experience gained from the application of the new CRD labyrinth seal decontaminating equipment**

Based on experience gained from similar procedures the time necessary for the electrolysis of each labyrinth groove was estimated to be around 15 minutes. This time was sufficient for blackened, highly contaminated drives. For less contaminated, almost metal-colored drives shorter time may provide satisfactory clean metal surface. We were able to reduce the electrolysis time in case of moderately contaminated CR drives.

The labyrinth decontaminating equipment worked according to plans and the effectiveness of decontamination was as required. The clean metal surface of the labyrinth groves was suitable for material testing (Figure 3 and 4).

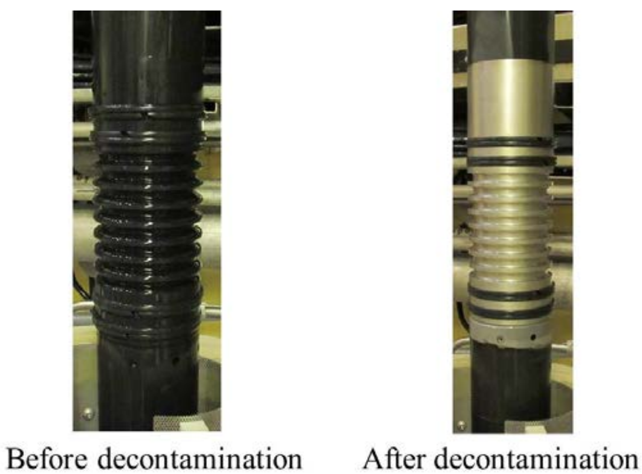


Figure 3. The effectiveness of decontamination

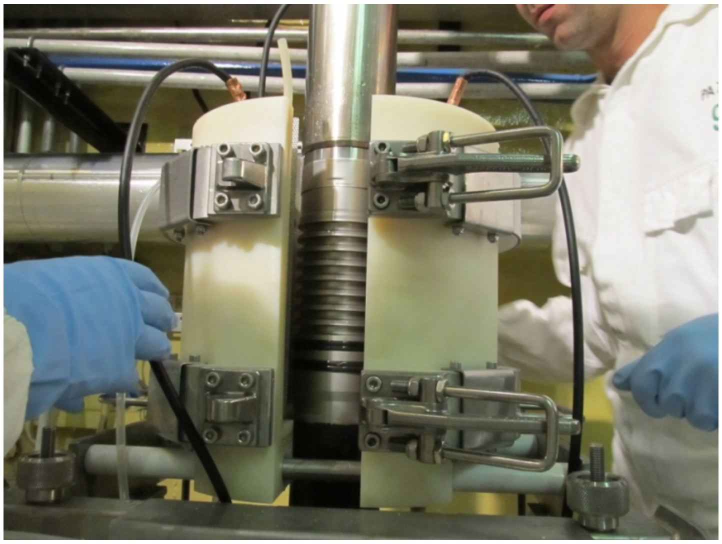

Figure 4. The CRD labyrinth thread after decontamination

During the test run of the new decontamination method the temperature of the electrolyte solution did not increase significantly. The heat generated during electrolysis was absorbed by the mass of the CR drive. As the temperature of the solution increased only about 1-2°C there was no need for the operation of the cooling system. This simplified the decontamination works and reduced the inspection time. However safety consciousness required constant monitoring of the solution temperature.

Experience proved that decontamination and material testing of all the CR drives of a unit (approx. 30 CR drives) takes about 4-5 workdays provided that lifting and operation conditions are optimal. By scale this is approximately one quarter of the time required for decontamination in the horizontal position of the drive.

Decontamination and material testing did not result in additional dose for the executing personnel (Figure 5) due to shielding of high dose areas and the relatively sparse and short manual labor. Those who spent the most time around the CR drives received about 30-40 μSv dose during an 8-hour shift.


Figure 5. Dose measurement during the decontamination of the labyrinth threads

The decontamination with the new equipment did not produce additional low and medium level waste. With the development of the new technology the production of high level waste (dose rate > 10 mSv/h) from felt sheets of the previously used moving cathode process was avoided. For each unit approximately half a cubic meter additional acidic, low level liquid radioactive waste was produced.

## CONCLUSIONS

In the following we summarize the experience gained from finding solution to the task of decontamination and the results of the decontamination process:

In the beginning of the year 2012 failure was found of the lower threads of a number of CRD labyrinth cases. The failure prompted an inspection of all the CR drives, which in turn made the development of a new decontamination technique for the CRD labyrinth seals necessary.

The new decontamination process had to fulfill special requirements. Decontamination had to be performed in the shortest time possible, in the vertical position of the drives without affecting the integral structure of the drives, and provide clean metal surface on the labyrinth seals for material testing.

The previously used decontamination methods had to be rejected as they did not fulfill the special requirements. In the new method an electrolyzer cell of two half-cylinders was installed around the section of the labyrinth seals; decontamination is carried out by immersion electrochemical method.

The labyrinth seal decontamination equipment is installed onto the 01-02TU10B001 decontamination baths. With this method we were able to fix the equipment containing the electrolyzer cell, to provide shielding from the high-radiation areas of the CR drives and to drain away the washing liquid.

CRD was lifted and held between the two half-cylinders of the electrolyzer cell by a crane during decontamination and material testing. There was no need to lay CR drives into horizontal position; therefore the time required for laying, lifting and testing was saved.

During decontamination the temperature of the electrolyte has not increased significantly thus there was no need for the use of the cooling system; however the temperature was constantly monitored. This also reduced decontamination time.

During the decontamination on Unit 4 approximately 2 $m^3$ low level liquid radioactive waste was generated, but no high activity solid waste associated with the previous method (felt sheets from the manual moving cathode) was produced.

Decontamination and material testing did not result in significant dose for the executing personnel; the dose did not exceed 30-40 μSv/person/shift.

The new decontamination method reduced the time necessary for the condition inspection of CRD labyrinth seals by three quarters, which made possible the execution of inspections within the planned outage period of each unit.

## REFERENCES

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