# RESULTS OF REACTOR PRESSURE VESSELS ISI

by
Mr. Štefan ČEPČEK
BOHUNICE NUCLEAR PLANT
919 31 Jaslovské Bohunice
Slovak Republic

---

**ABSTRACT**

To find out the possible influence of the annealing process to reactor pressure vessel integrity, a large in-service inspection programme has been implemented as an associated activity to reactor pressure vessel annealing. In this paper the approach to the RPV in-service inspection is shown. Also, the main results and conclusions following in-service inspection are presented.

---

**KEYWORDS**

Reactor pressure vessel, in-service inspection, base metal, cladding, ultrasonic examination, Eddy-current technique.

---

## INTRODUCTION

Inspection of Bohunice NPP, unit 1 and 2 reactor pressure vessels was performed in following stages :

### Incoming inspection

The objective of incoming inspection was to accure required quality of RPVs before the montage. The inspection was performed using by direct visual, dye-penetrant and manual ultrasonic methods.

### Pre-service inspection

This inspection was performed in two stages.

Stage 1 - the first revision - performed after the first hydrotest of the primary circuit

Stage 2 - the second revision - performed after the second hydrotest and so called hot tests, when the parameters (pressure, temeprature) of the primary circuit components reached designed levels.

The main objective of pre-service inspection was to assure the required quality of RPVs before the NPP units commissioning.

In-service inspection

The objective of in-service inspection is to assure the integrity of NPP components during the operational stage.

ISI was regulary performed as follows :

- the first ISI interval (after the commissioning) was prescribed and completed in 2 years and all components had to be inspected in 100 % of prescribed scope
- next ISI has to be completed in 4-years intervals, of course RPVs including

The scope of RPVs ISI connected with the annealing was extended to whole core region.

**REACTOR PRESSURE VESSEL ISI, DESCRIPTION, SCOPE, RESULTS.**

Reactor pressure vessel (see picture) represents the welded pressure vessel with six circumferential and one longitudinal weld in bottom. Pressure vessel is manufactured from low-alloyed carbon steel and cladded with anti-corrosion austenitic cladding.

In the nozzle area there are six hot and six cold nozzles with competent welds.

The standard in-service inspection programme covers :

- ultrasonic examination of all RPV welds
- ultrasonic examination of base metal of ±0,5 width from both sides of weld axis
- ultrasonic examination of the cladding in selected areas
- Eddy-current examination of the cladding in selected areas as a complementary method

- visual inspection of all inner surface and outer RPV surface in the nozzle and bottom area
- dye-penetrant and visual examination of nozzle welds from inside and outside
- nozzle welds examination using by radiography method
- visual, dye-penetrant and magnetic particle examination of RPV flange
- visual and Eddy-current examination of flange thread holes.

The terms of RPVs ISI performed

UNIT 1 : 1981[1], 1985, 1988, 1992, 1993[2]
UNIT 2 : 1982, 1985, 1989, 1992-93[3]

Remarks :

1) In 1981 RPV ISI performed in limited scope due to the fact that manipulator has not been prepared for the inspection.

2) Due to the fact that regular ISI of unit 1 RPV was performed in 1992, in 1993 was performed ISI in scope corresponding to the annealing.

3) Performed full ISI scope according to the standard programme and extended to whole core area as mentioned below.

The ISI scope before and following the annealing :

UNIT 1 :

- ultrasonic examination of 0.1.4 and 0.1.5 welds
- ultrasonic examination of base metal in scope :
  - full examination of ring between 0.1.4 and 0.1.5 welds
  - 0,5 t of weld width above 0.1.5 weld
  - the strip of base metal of 725 mm width below 0.1.4 weld
- visual,Eddy-current and ultrasonic examination of cladding in the same scope as ultrasonic volumetric examination.

same scope was performed both, before and after the healing.

UNIT 2

Before annealing

- full ISI according to the standard programme for the planned large outage
- standard ISI programme extended by :
  - ultrasonic volumetric examination of base metal between 0.1.4 and 0.1.5 welds and of strip of 725 mm width below 0.1.4 weld
  - visual, ultrasonic and Eddy current examination of cladding in the same scope as base metal

After annealing

The same scope of ISI performed as described for Unit 1.

As follows from ISI description, the scope of ISI associated with the annealing is realy large.
The approach to accept such ISI programme was based on these considerations.

1. In core region there has never been performed full volumemetric ultrasonic inspection of base metal and inspection of cladding.
2. Due to thermal affecting of RPV material during annealing, thermal stresses in RPV wall are inducted, which could lead to initiation of new defets and/or to growth of existing defects.
3. To find out the explanation of eventualy defects detected after the annealing, the status of the quality of RPV material in core region had to be known prior to the annealing.

In-service inspection of both units has been performed by Reactortest, plc Trnava (Slovak Republic) by means of "Zentralmastmanipulator" ZMM-5 type of Siemens AG/KWU

production. For ultrasonic examination a multiple probe system was introduced and TIMLOK and ALOK aquistition and processing techniques was applied.

The eddy-current examination and processing has been performed by means of MIZ-18 system.

The ultrasonic inspection results were processed and evaluated using by KTA 32 01.4 standard. In regard to possibility of comparison with previous ISI results and for the calculations of acceptance of RPV for next operation, the re-calculation to PK 15-14/72 acceptance criteria was carried out. It is necessary to emphasize that these acceptance criteria have been developed as the construction standard and for ISI they seem to be very severe. In case of defects detected according to these criteria an additional calculation have to be performed.

For the calculation of acceptance of defects the "Methodics for the determination of defect acceptance in components and pipelines metal during NPP operation" M-01-88 is applied.

Due to a lack of instructions for the cladding defects calculation, ASME Code, Section XI, article IWB-35 10-2 has been applied for the laminar cladding defects acceptance calculation.

**Remarks :**

PK 15-14/72 acceptance criteria prescribes following size of defects (equivalent diameter).

welds : $D_n$ = 3,75 mm - registration
$D_n \geq$ 1,5 mm - acceptance

cladding : $D_n$ = 4,4 mm - registration
$D_n \geq$ 6,0 mm - acceptance

The results of ISI of Bohunice unit 1 and 2 can be summarized as follows.

The comparison of the results obtained in 1992 (and 1993) with previous ISI results showed quite good corelation and

omparison of the results obtained in 1993 before and after the annealing to 1992 ISI of unit 1 RPV showed practicaly fully agreement.
n fact no differencies in ISI results before and after the PV annealing have been observed at unit 2.

Following defects located in core area and weld 0.1.5 have been assessed :

UNIT 1 :

- 3 laminar cladding defects of $D_n$=6mm in 0.1.4 weld area
- 3 volumetric defects of $D_n$=5; 5,3 and 6,7 in weld 0.1.5.

UNIT 2 :

- 2 volumetric defects of $D_n$=5,7 and 8,3 mm in weld 0.1.5.

Calculations and assessment of these defects showed sufficient safety margin for all considered both, normal and emergency operation conditions as well.

**CONCLUSIONS**

1.) ISI of unit 1 and 2 reactor pressure vessel showed a good reproducibility of used inspection techniques

2.) ISI results showed no negative influence of the annealing process to the RPVs integrity. No new defects and/or no growing of existing defects have been observed.

3.) No opened surface defects in the cladding have been observed.

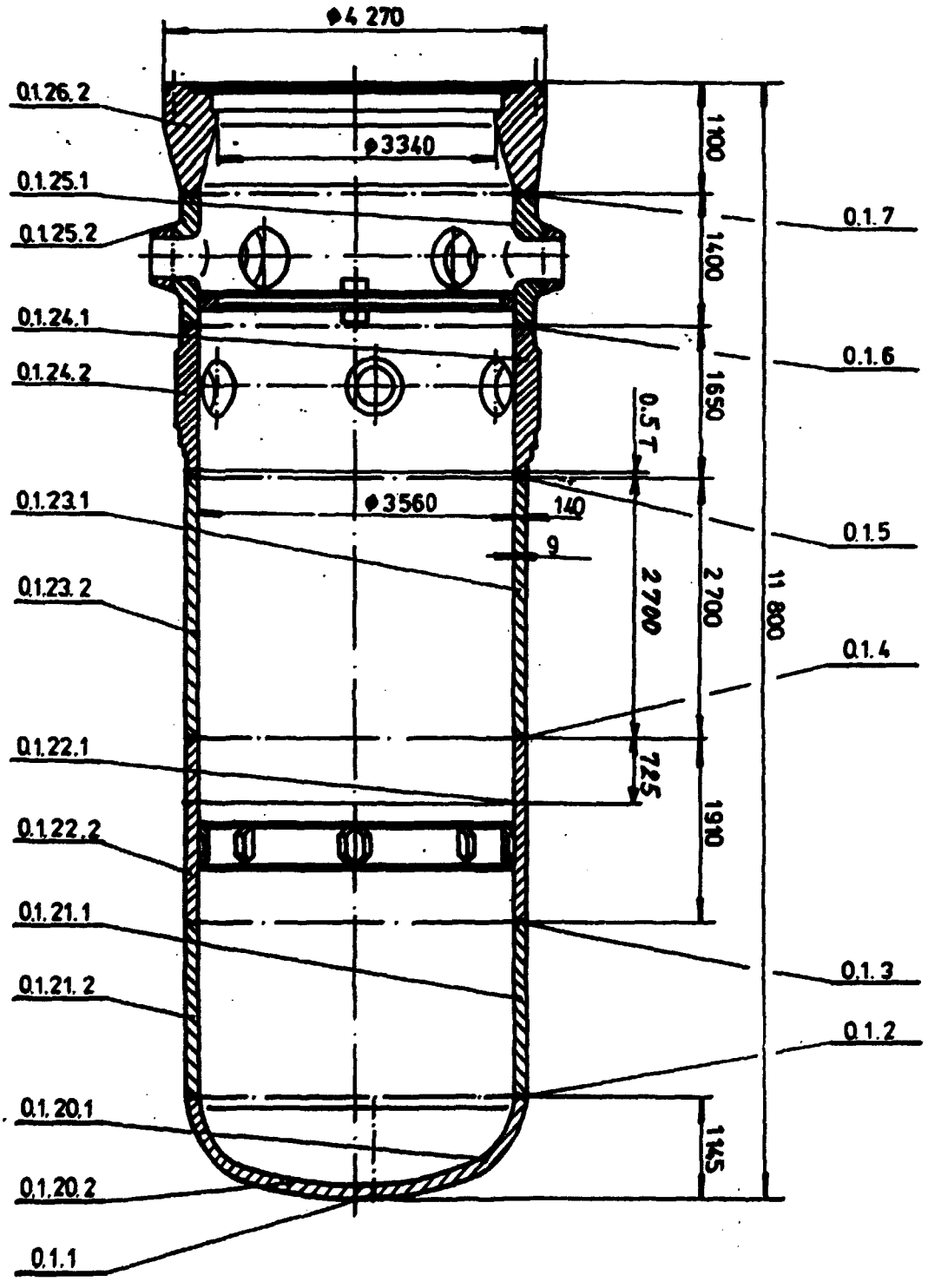
4.) Calculations and assessment of the acceptance of defects detected above PK 15-14/72 acceptance criteria showed sufficient safety margin for all considered both, normal and emergency operation conditions as well.

## REFERENCIES

1. Brumovský, M; Sladký, J : Assessment of acceptance of defects found during in-service inspection of unit 1 RPV of Bohunice NPP in 1992. Plzeň, April 1992

2. Brumovský, M : Assessment of acceptance of defects found during in-service inspection of unit 2 RPV of Bohunice NPP in 1993. Řež, June 1993

3. Final reports from ISI of Bohunice 1 and 2 Reactor pressure vessels.
Reaktortest, Trnava, March 1992, February 1993, May 1993.




REACTOR PRESSURE VESSEL ISI SCOPE