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DIAGNOSTIC OF THE VVER REACTORS INTERNALS VIBRATIONS

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Abstract: *Integrity of the VVER reactors internals is the important requirement of the NPPs long term operation. Two possible methods how to meet these requirements are: non destructive evaluation and diagnostic of the mechanical vibrations. The second one method is in the next analyzed. As the sensors are obviously used accelerometers, pressure pulsation sensors, ex-core ionization chambers and self powered neutron detectors. The significant changes of the frequency spectra are supposed to be symptom of the integrity changes..*

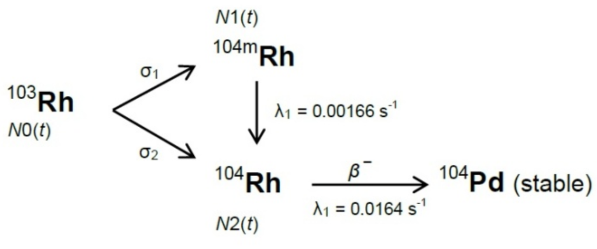
Keywords: VVER type reactors, Accelerometers, Pressure pulsation sensors, Ex core ionization chambers, Frequency spectra.

1. Introduction

Nuclear regulators in all countries require as the part of the PWRs long time operation permission the confirmation of the reactors internals integrity. The term reactor internals include core barrel, block of the protective tubes, and core basket or core shroud. As the part of the preoperation hot tests and initial start up tests the frequency spectra of the reactor internals are measured and evaluated in the form of the power spectral densities -(PSDs).This PSDs represent starting i.e. nonfailed state and all next measured PSDs during operation are with this ones compared. The significant deviations represent symptom of the possible failure.

2. Used sensors

As the sensors are obviously used accelerometers, ex core ionization chambers, pressure pulsation sensors, self powered neutron detectors (SPNDs) and during preoperation hot tests in some cases also strain gauges. In the next the principles of the rhodium SPNDs are described. The schema of the rhodium activation and chargé emission is as follows



where
$\sigma_1 \sigma_2$: capture cross section
$\lambda_1 \lambda_2$: decay time

Emission is used which charges the rhodium electrode to a positive potential. The electrical system is a current generator with a high potential resistance $R_l = 10^8 \Omega$ much higher than the dynamic input resistance of the chargé circuit $R_c = 10^4 \Omega$ .The relationships between SPN detector current and neutron flux are as follows: the activation diagram is expressed by the following equations

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$$\frac{dN1(t)}{dt} = N\sigma 1\varphi(t) - \lambda 1 N1(t) \tag{1}$$

$$\frac{dN2(t)}{dt} = N\sigma 2\varphi(t) + \lambda 1 N1(t) - \lambda 2 N2(t) \tag{2}$$

where
N : number of Rh^{103} nuclei
N1(t): number of the Rh^{104m} nuclei
N2(t): number of the Rh^{104} nuclei
φ (t): neutron flux at time t
The measured current is expressed as
$i(t) = K\lambda 2N2(t)$

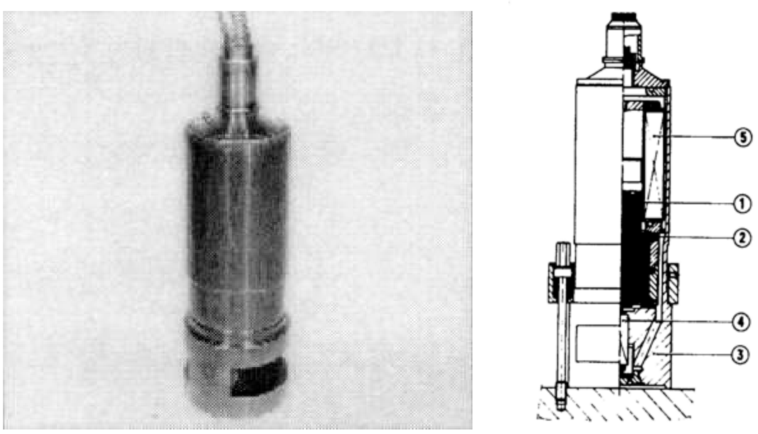
where K is a constant taking into account the emission yield, the transmission of the insulator, the number N0 of the rhodium nuclei and the units (current, charges).When resolving the differential system (1),(2), one deduced (with an appropriated mathematical method)

$$\varphi(t) = \frac{1}{KN\sigma 2\lambda 2}\frac{di}{dt} + \frac{i}{KN\sigma 2} - \frac{\lambda 1}{NG2}N1 \tag{3}$$

an non explicit equation since the term in N1 consist according to equation (1). It is evident that rhodium SPN detectors subjected to a variable neutron flux behaves like first order linear system. This introduces time constants between the output electric current and the input flux. The time laws of the current cannot then be identified with that of the flux and processing of the differential equations system is required to reconstitute the flux. Finally the PSDs of the measured current is evaluated.

3. NPP Dukovany

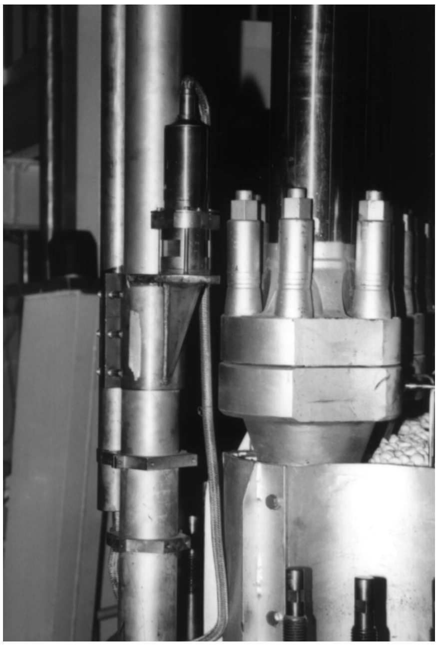
In NPP Dukovany are operated four units of the reactors VVER 440 Model 213 Č. For monitoring of the reactor internals vibrations are used sesmic sensors of absolut displacement and ex-core ionisation clambers. Cross section of the seismic sensor of absolut displacement is illustrated in Fig. 1:



1… inertia mass
2... two springs
3... outer barrel
4... sensor of the relative displacemenet
5... magnetic coil

Fig. 1 : Crosssection of the displacement sensor

Details of the location of the displacement sencor on the reactor pressure vessel are illustrated in the Fig. 2.



General view Detail

Fig. 2: Details of the location of displacement seinsors

Results of measurements are illustrated in the Table 1:

Tab. 1: operational vibrations of the VVER 440 Model 213 reactor

Frequency Hz	Description
6.3	First acoustic standing wave in primary circuit
8.6	RPV and reactor internals in vertical direction
11	nonidentified
12.8	Second acoustic standing wave in primary circuit
16	nonidentified
22.4	RPV and reactor internals in vertical opposite direction
24.8	Pressure pulsations generated by main circulation pump
27.9	vertical vibrations of the upper block
37.5	3/2 ultrasubharmonic to the frequency 24.8
45	nonidentified

RPV ... reactor pressure vessel

4. NPP Temelín

In NPP Temelín are operating two units of the VVER 440/320 reactor. For monitoring of the reactor internals vibrations is installed Reactor Vibration Monitoring System (RVMS) which consist four accelerometers installed on the RVP flange, pressure pulsation sensors (only on Unit 2), eight ex-core ionization chambers and SPNDs 64 fuel assemblies consist 7 detectors and one compensation detector, together 512 detectors. RVMS monitor SPNDs on the levels 1,3,5,7 local repressed 256 signals. They are organized in 16 selected groups with 16 signals. For monitoring vibrations is possible to choice each from these groups. Locations of the accelerometer, ex-core ionization chambers and SPNDs are illustrated in Figs 3 and 4.

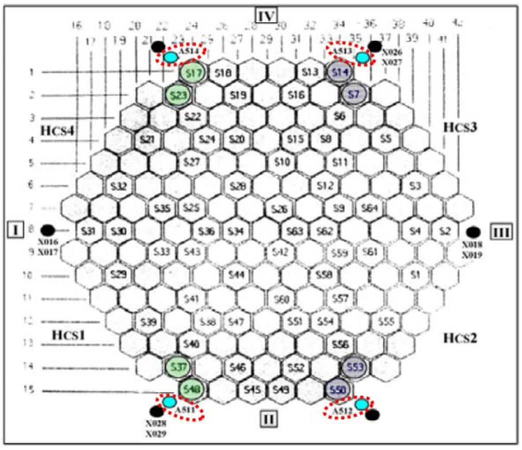


Fig. 3: Location of the accelerometers (Y)

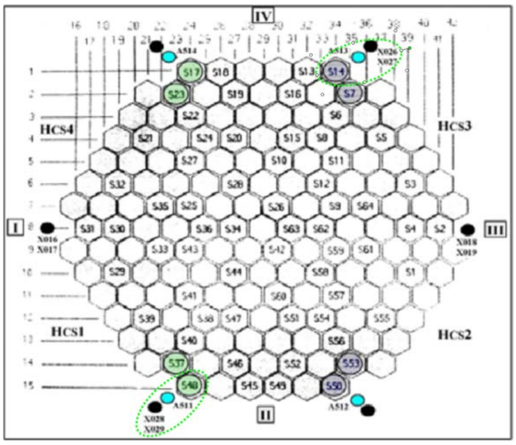


Fig. 4: Locations of SPNDs and ex-core IC (X)

IC … ionization chamber

Results of the SPNDs measurements are illustrated in Tab. 2:

Tab. 2: Results of the SPNDs measurements of the VVER 1000 MW reactor

Frequency Hz	Description
0.76	Standing wave in primary circuit including pressurizer
5.8	Second bending frequency of the fuel assembly
6.5	First acoustic standing wave in primary circuit
9.1	Standing wave in reactor pressure vessel
12.0	Third torsion frequency of the fuel assembly
12.5	Second acoustic standing wave in primary circuit
15.0	Fourth bending frequency of the fuel assembly
16.6	First frequency of the pressure pulsations generated by MCP
18.8	In-phase pendulum motion of the RPV and core barrel
22.5	Third acoustic standing wave in primary circuit
24.9	3/2 ultrasubharmonic to frequency 16.6 Hz
33.2	Second frequency of the pressure pulsations generated by MCP
49.8	Third frequency of the pressure pulsations generated by MCP

5. Conclusions

Monitoring of the reactor internals vibration is a important part of the nuclear safety of the operating PWR reactors. From the point of view of applied mechanics the following disciplines are used and in some cases

-Dynamic of mechanical systems with many degree of freedom as reactor etc [1]

-Acoustic phenomena in complicated piping systems [2].

Thanks to operation of two Czech NPPs in Dukovany and Temelín, many interesting works have been developed in WBU Plzeň. Dept. of Mechanics and ÚJV Řež, a. s.

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