Assessment of Core Structural Materials and Surveillance Programme of
The Dalat Research Reactor

TM on Assessment of Core Structural Materials and Surveillance Programme of Research Reactors
14–18 June 2010, IAEA, Vienna, Austria

Nguyen Nhi Dien, NRI, Dalat, Vietnam

Outline of Presentation:

- Brief Introduction of the RR
- Inspection of the aluminium pool liner and in-pool structures
- Some results of visual inspections during last ten years
- Pool water management
- Conclusion

BRIEF INTRODUCTION OF THE RR

- ☞ **Early 1960 - Construction of the TRIGA Mark II reactor started**
- ☞ **26/2/1963 - First criticality achieved**
- ☞ **4/3/1963 - Inauguration of the reactor with the nominal power of 250 kW**
- ☞ **1963-1968 - Reactor operated with 3 main purposes: Training, Research and Isotope Production**
- ☞ **1968-1975 - Reactor was in extended shutdown**
- ☞ **1974-1975 - Fuels were unloaded and shipped back to USA.**

➔ Because of a long extended shutdown, reactor pool water was not maintained in good condition during 1968-1978 period.

BRIEF INTRODUCTION …

- ☞ **15/3/1982 - The project for reconstruction and upgrading of the RR was started. Reactor name was changed to "IVV-9" (Dalat RR)**
- ☞ **01/11/1983 - First criticality of the Dalat RR achieved**
- ☞ **20/3/1984 - Inauguration of the Dalat RR with the nominal power of 500 kW**
- ☞ **3/1984 to present - Reactor has been operating for the purposes of:**
  + Radioisotope production,
  + Neutron activation analysis,
  + Basic and applied researches, and
  + Training.

BRIEF INTRODUCTION …

MAIN ISSUES OF THE RECONSTRUCTION PROJECT (1982-1984):

No-changed Items/Systems:

- **reactor building** (but upgrading roof for water-proof)
- **reactor aluminium tank** (but installing 15-cm stainless steel rotating top lid for radiation protection purpose)
- **reactor concrete shielding** (but adding some parts for radiation protection and installation of new facilities purposes)
- **4 horizontal beam-ports**
- **thermal column**
- **graphite reflector surrounding the core.**

➔ **These items/systems are almost 50 years old up-today. Because of that high age, the operating organization is facing with corrosion issues of the aluminium pool liner and other in-pool structures.**

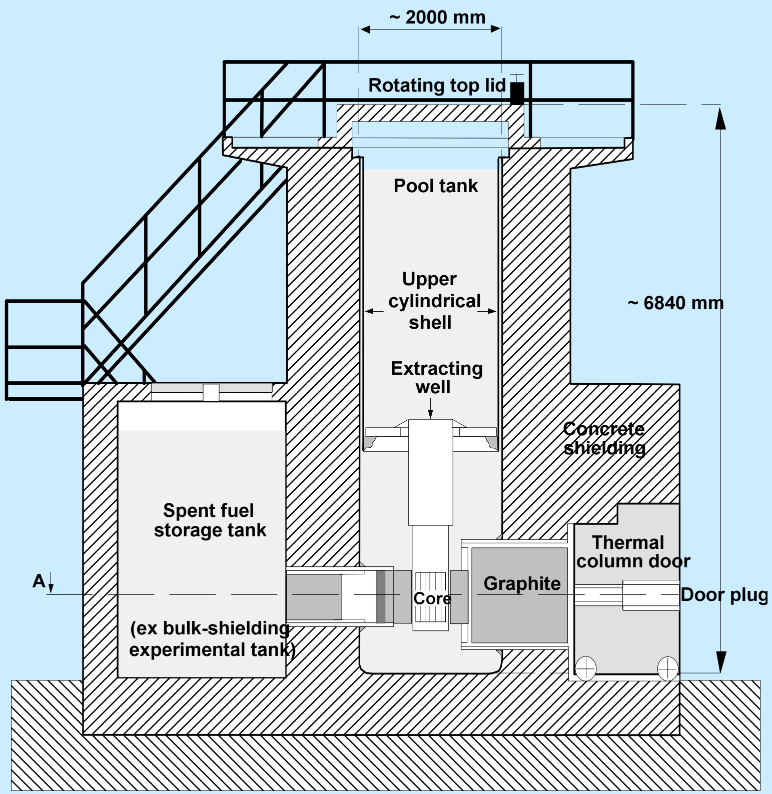
BRIEF INTRODUCTION …

MAIN ISSUES OF THE RECONSTRUCTION PROJECT (1982-1984):

Replaced Items/Systems:

- reactor core and fuel assemblies
- control rods and in-core irradiation facilities
- reactor control and instrumentation system
- reactor cooling systems
- electric system, ventilation system
- Other auxiliary systems.

➔ **These items/systems are almost 27 years old up-today. Ageing management programme is also needed.**



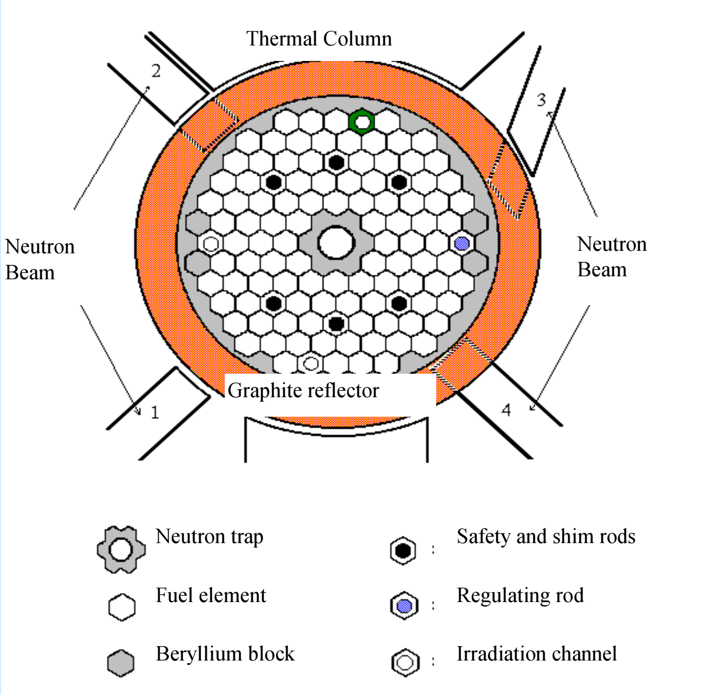
Vertical section view of the RR.

+ The TRIGA core was setting upon an all-welded aluminium frame supported by four legs attached to the bottom of the pool.

+ The new core is now suspended from the top of the reactor pool by three aluminum concentric cylindrical shells.

+ The upper one has a diameter of 1.90 m, a length of 3.56 m and a thickness of 10 mm. This shell prevents from any visual access to the upper part of the pool liner, but is provided with a series of holes to facilitate water circulation in the 4-cm gap between itself and the aluminium pool liner.

+ The lower cylindrical shells act as an extracting well for water circulation.



Horizontal section view of the reactor core.

+ The reactor core has a cylindrical shape with a height of 60 cm and a diameter of 44.2 cm.

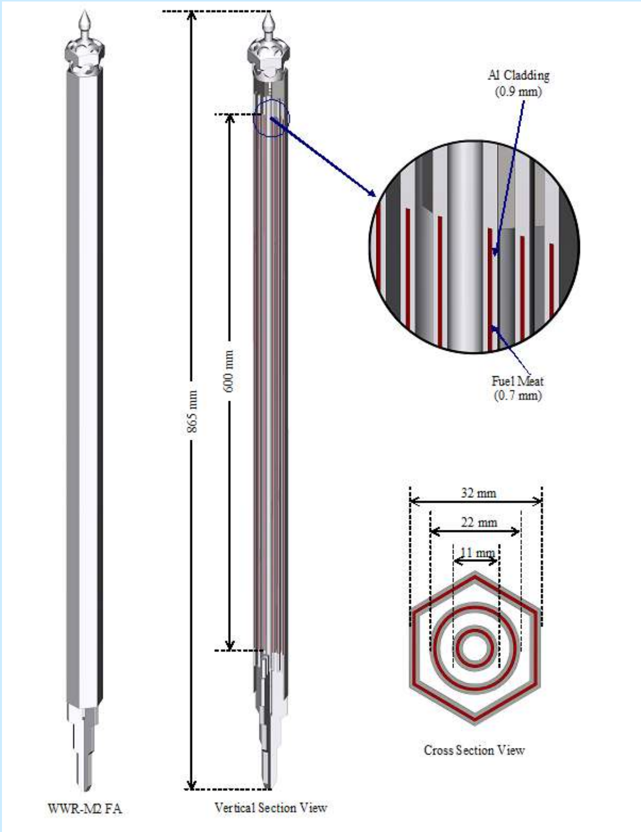
+ It is constituted of 104 VVR-M2 fuel assemblies, 7 control rods, a neutron trap at the core center and 3 in-core irradiation facilities, all of which are fixed by two perforated plate structures (aluminium grid plates) at the core bottom.

+ Each grid plate has 121 holes for positioning the core elements, forming triangular lattice of cells with a pitch of 35 mm.

+ Two types of fuels with 36% (HEU) of aluminium-uranium alloy and 19,75% (LEU) of UO2+Al covered by aluminium clad are used.

+ Each fuel tube is composed of three layers.

Parameter	VVR-M2 HEU	VVR-M2 LEU
Enrichment, %	36	19.75
Average mass of ^{235}U in FA, g	40.20	49.70
Fuel meat composition	U-Al Alloy	UO_2+Al
Uranium density of fuel meat, g/cm^3	1.40	2.50
Cladding material	Al alloy (SAV-1)	Al alloy (SAV-1)
Fuel element thickness (fuel meat and 2 cladding), mm	2.50	2.50
Fuel meat thickness, mm	0.70	0.94
Each cladding thickness, mm	0.90	0.78



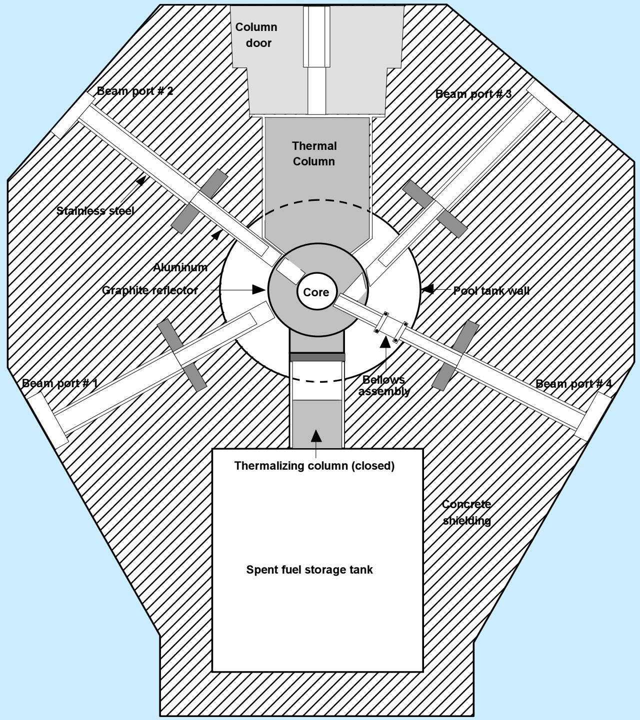
VVR-M2 fuel assembly

+ 4 beam ports of aluminium

+ the thermal column

+ the thermalizing column leading to the former bulk shielding experimental tank has been closed by sheet of stainless steel and the walls of the experimental tank have also been coated with a stainless steel liner.

+ this tank is being currently devoted to spent fuel element.



Horizontal section view of the RR

In-pool Structural Materials

Aluminum alloy used in the structures (reactor pool liner, beam tubes, reflector and thermal column cans) kept from the former TRIGA Mark II is the USA 6061 alloy, whereas in remaining structures and components, the CAB (SAV-1) alloy of the former Soviet Union is used.

The chemical compositions of these alloys are given in Table below.

Materials	Cu	Cr	Mg	Si	Al	Impurities
6061(wt%)	0.25	0.25	1	0.6	> 97.7	Ti, Fe, Mn, Zn
SAV-1 (wt%)	0.0058	-	0.48	0.8	> 98.5	Ti, Fe, B, Ni

Inspection of the aluminium pool liner and in-pool structures (1)

+ In 1982, during the reconstruction and upgrading project, the general survey of the status of the reactor pool liner was done by a Russian-Vietnamese joint group;

+ It concluded that no corrosion effect was observed on the aluminium pool liner and associated components. The reactor pool tank was good enough for further long exploration.

+ Regarding to the old structures of the TRIGA reactor, there were concerned about their material resistance. It is due to that for some years (mainly from 1968-1978) the pool liner and other in-pool structures were not sufficiently and continuously surveyed under appropriate conditions ensuring nuclear safety standards.

Inspection of the aluminium pool liner and in-pool structures (2)

+ In 1989, visual inspections of the reactor pool liner and in-pool structures were carried out by the operating staffs and the experts from the IAEA (Hungarian team) using an underwater telescope.

+ Only about 20% of the pool surface were possible to examine by the telescope. The signs of corrosion attack were detected. According to the IAEA experts, some of corrosion attacked areas were estimated seriously and the penetration of water through the aluminium tank to the concrete shielding would happen.

+ Because of that, the corrosion problem has been more carefully investigated, and ageing management programme was set-up.

Inspection of the aluminium pool liner and in-pool structures (3)

+ In 1993, the examination was conducted by new-designed underwater telescope.

+ It was found out that the corrosion areas had not nature from corrosion attack, just from mechanical defects. Of course, the detected corrosions drawn our attention and required the explanation of the observed phenomena as well as necessary technical solution.

+ In 1998, CEA (France) experts and operating staffs conducted the inspection using an immersed video camera.

+ It was clearly seen the corrosion appearing on some parts of aluminum surface of the in-pool structures. These defects may be a non-negligible risk of leakage, either through welds at the pool liner, the thermal column or the beam ports.

Activities of ageing management programme during the last ten years

+ Some high-resolution underwater camera systems were designed and used. The recent system is composed of a color video head typed SANYO 37008 /3912P, Zoom x 108-80mm TAMRON immersed and coupled to a personal computer.

+ Visual inspections have been carried out regularly (3 times/year)

+ Inside pool cleaning by an home-made system (3 times/year)

+ Reactor water quality and radioactivity monitored regularly (daily, weekly).

The underwater high-resolution Video-camera system:

Remote controller

Camera head of SANYO 37008 /3912P,
Zoom x 108 – 80mm TAMRON

Monitor Magic

The cleaning system was designed for inside pool cleaning:

Suction pump of 5 m^3/h and outside-cover of mechnical filter system

Stainless steel suction head with soft bloom

3 layers of stainless steel filters

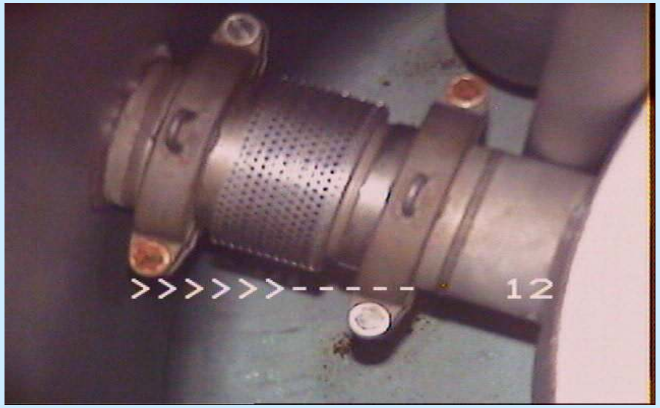
Some main inspection results obtained (1)

+ The most concerns are with beam port No #4 because two of four steel bolts to tighten-up the flexible joint (the bellows assembly flange of beam port) were rusted and the results shown that this rust was slowly developed.

+ It means the electro-chemical corrosion still happens with these bolts.

+ However, it was difficult to explain clearly because only two of four bolts are rusted, but two others still have a shining color of original stainless steel.

Rusts of two bolts tighten-up the flexible joint of the beam tube No.4



(down side)

(up side)

➔ Only two of four bolts are rusted, two others still have a shining color of stainless steel ?.

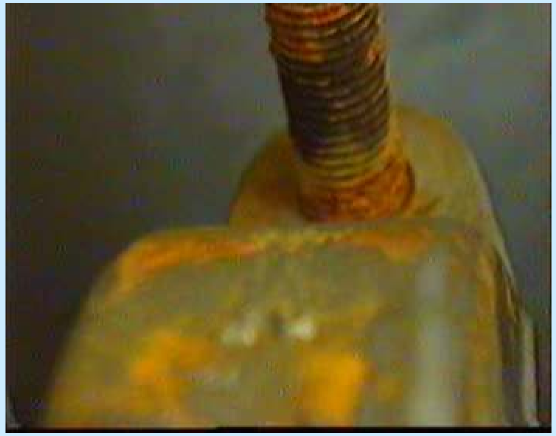
Rusts of two bolts inspected by years

(2009)

(2002)

(2003)

(2004)



(2005)

➔ **It seems to be slowly developed.**

Some main inspection results obtained (2)

+ There were some pitting corrosions with 2-3mm in diameter on the outside surface of beam port No #3.

+ It is due to surface scratches or mechanical defects happened when the re-installation of reactor structures done during the years 1982-1983.

+ Based on the result assessment it could be noted that corrosion phenomenon still happens but slowly develops.

Pitting corrosion on the surface of beam port No #3.

(upper surface)

(side surface)

Pitting corrosion on the surface of the beam tube No.3

(2001)

(2002)

(2003)

(2004)

(2005)

Some main inspection results obtained (3)

+ There are small steel components which have probably fallen accidentally into the pool tank (washers, bolts, etc.), leading to oxide particles deposit on top of the thermal column and beam ports, and on the bottom of the pool tank.

(oxide particles deposit on the pool bottom next to beam port No #3)

(Some defects on the pool bottom around the reflector leg)

Cleaning the reactor pool by home-made system

Mechanical defect on bottom of the pool

On the pool bottom before cleaning (2001)

On the pool bottom after several cleanings (2008)

Some main inspection results obtained (4)

+ There are small defects that could be stress corrosion cracks or mechanical cracks, mainly along the welds, but corrosion products have not been watched.

Defect corrosion on the welding line of beam tube No.4

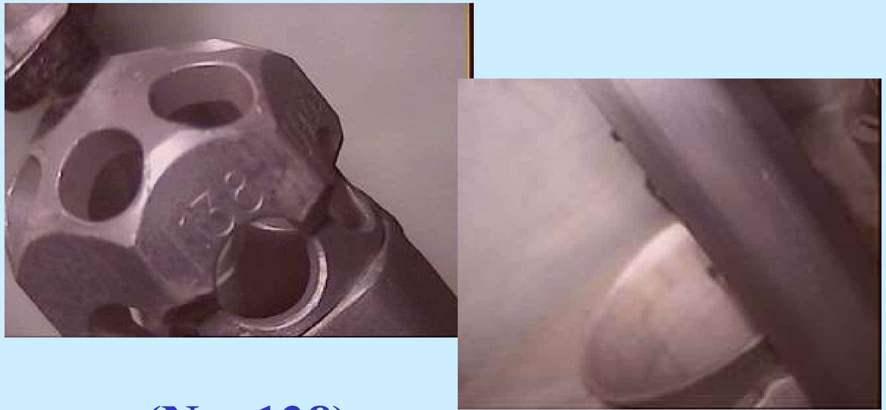
➔ It seems that corrosions were not developed from year to year.

Some main inspection results obtained (5)

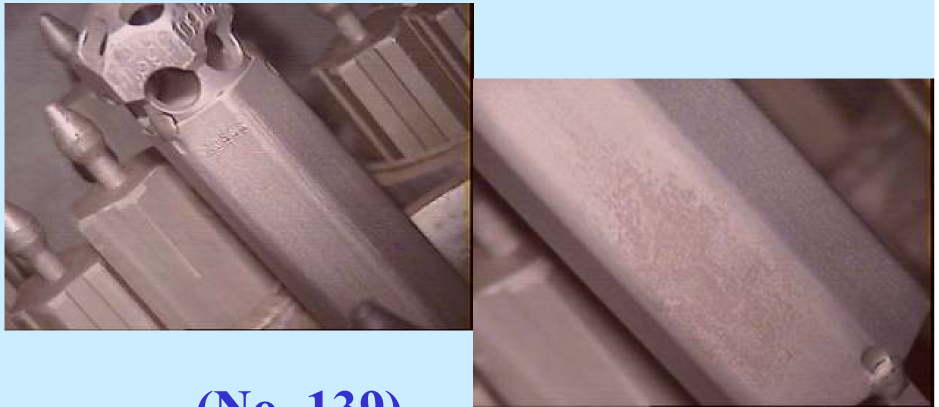
+ There are corrosion phenomena on surface at the bottom part of aluminium detector housings.

(Corrosion on the outside surface at the bottom of neutron detector housing)

Inspection of spent fuels in the pool (2009)

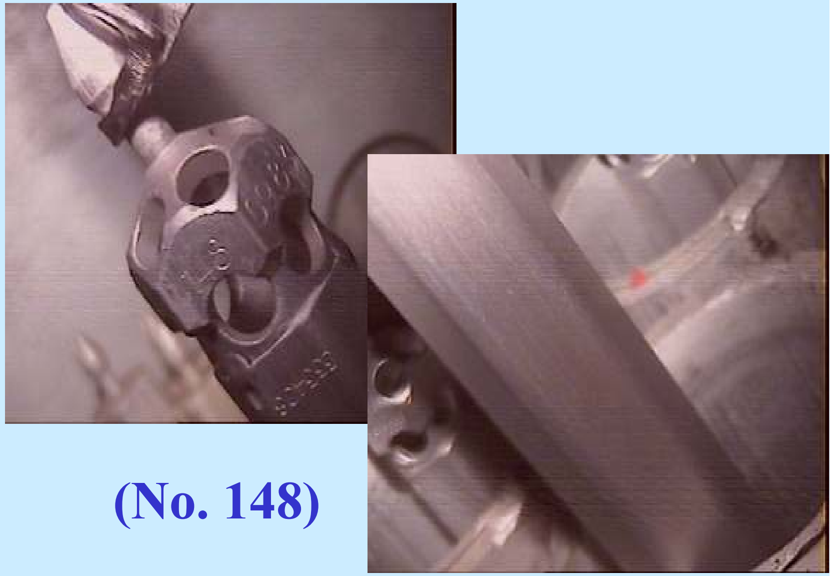


(No. 138)



(No. 139)

(No. 146)



(No. 148)

➔ Spent fuels stored in good condition.

Reactor Water Quality and Radioactivity

Primary coolant quality:

Parameter	In reactor pool		After purification	
	Operational	Standard	Operational	Standard
pH	5.5 – 6.0	5.5 – 6.0	5.7 – 6.0	5.5 – 6.0
Conductivity, µSm/cm	0.6 – 1.0	≤ 2	0.4 – 0.5	≤ 1
Ion Cl^-, µg/1	0-10	≤ 50	0	≤ 50
Ion Al^{3+}, µg/1	< 20	≤ 50	-	-
Ion SO_4^{--}, µg/1	< 20	≤ 50	< 10	≤ 50
Ion Fe, µg/1	< 30	≤ 50	< 20	≤ 50
Oxygen, $mgO_2/1$	-	-	0.2 – 0.3	≤ 1.5
Dry activity, µCi/1	0.1 – 1	≤ 10	-	$\leq 3.10^{-3}$

➔ Pool water is always maintained in good condition.

Reactor Water Quality and Radioactivity

Analysis of pool water samples by gamma spectrometer:

Energy	Isotope	Bq/l	Ci/l
122	Eu-152	36	9.77E-10
145	Ce-141	13.2	3.57E-10
320	Cr-51	97.02	2.62E-09
344	Eu-152	66.08	1.79E-09
889	Sc-46	141.7	3.83E-09
1099	Fe-59	39.63	1.07E-09
1115	Zn-65	97.36	2.63E-09
1120	Sc-46	156.90	4.24E-09
1173	Co-60	318.14	8.6E-09
1332	Co-60	302.76	8.18E-09

➔ **There are some corrosion products of aluminium and other in-pool structural materials.**

CONCLUSION (1)

- Because of reactor high age, we are paying attention on ageing management, including preventive actions, assessment actions and corrective actions;
- Main issue now is corrosion phenomena of pool liner and other in-pool structures.
- Pitting corrosions on surface of the beam tubes were developed by the mechanical defects to destroy the aluminum oxide;
- In order to minimize corrosion effect of the pool liner and in-pool structures, their regular cleaning should be done;
- Water quality should be always maintained in good condition;

CONCLUSION (2)

- Even our reactor has high age, we have a plan to prolong reactor operation at least to 2020.

- The following technical solutions should be rigorously and continuously done to achieve long life of the DNRR pool tank:
  - pH and electrical conductivity of the reactor water are maintained in standard values;
  - The purity of the reactor water is maintained at a high level, especially no water pollution by iron, copper and Cl- ;
  - The concentration of activated isotopes initiated from structural materials such as Al^{28}, Fe^{59}, Mn^{56}, Co^{60}, etc. in the reactor water is periodically checked by the gamma spectrometer;
  - The surface of the aluminium pool liner and in-pool structures is regularly cleaned and deposits fallen objects are removed by a sucking pump;
  - The visual inspections are regularly carried out.

- Getting experiences on RR ageing management from other countries will be necessary for effective ageing management programme of our RR.

THANK YOU FOR YOUR ATTENTION !