

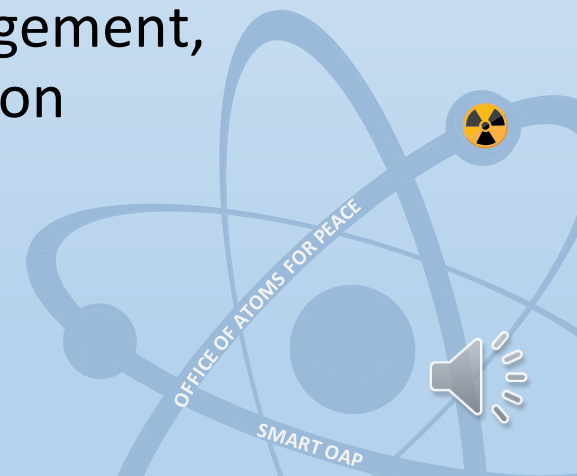
ROLES AND ACTIVITIES OF REGULATORY BODY ON AGING MANAGEMENT OF RESEARCH REACTORS IN THAILAND

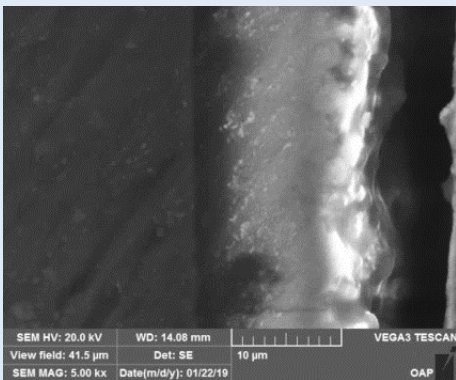
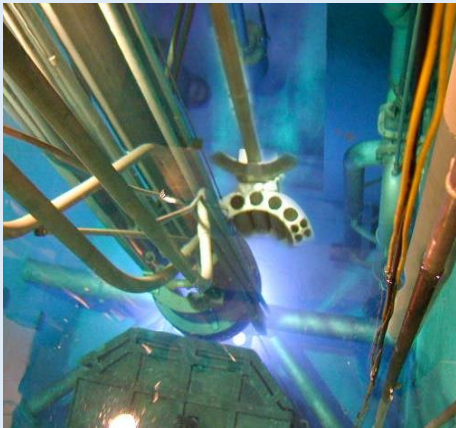
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Office of Atoms for Peace, Thailand

TM on Research Reactor Aging Management,
Refurbishment and Modernization

31 May – 4 June, 2021





- ◆ Thailand has one research reactor, **TRR-1/M1** with 50 years old by **Thailand Institute of Nuclear Technology (TINT)**, 1.3 MW.
- ◆ A new RR project of 45 kW (**SUT RR**) is under construction license application.
- ◆ **Office of Atoms for Peace (OAP)**, as regulatory body, regulates the reactor through new Nuclear Energy for Peace Act 2016.
- ◆ Ministerial regulation on Periodic Safety Review (PSR).
- ◆ Guideline on Aging management of RR.
- ◆ Technical guidance for radiation damage assessment.
- ◆ Investigation of irradiated Al-tube specimen.

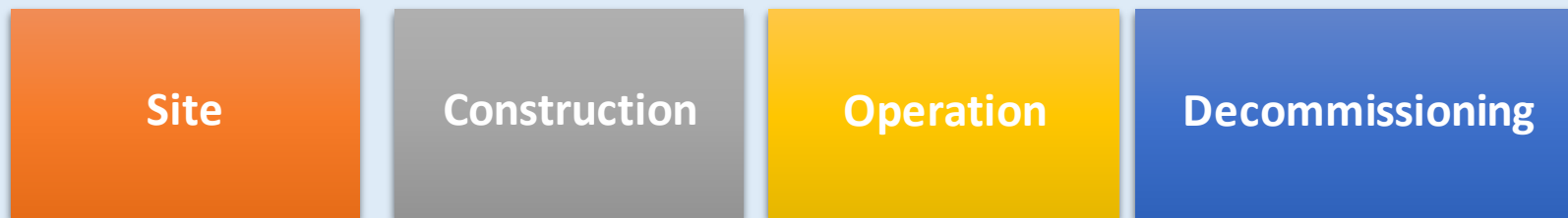




Nuclear Energy for Peace Act, 2016



- **New Nuclear Energy for Peace Act** was approved by the Cabinet in 2016. It was amended from Nuclear Energy for Peace Act 1961 to improve obsolete issues and cover all necessary areas.
- **Nuclear Energy for Peace Act 2016, Chap. 5 Nuclear facilities;**
 - **Article 45:** covers four licenses for nuclear facilities;



- **Article 67:** The licensee of Operation license should review and revise the safety analysis every time period of **10 years**, or under conditions indicated in the Ministerial Regulation (*i.e., modification, changes in regulation, operating experience*).





Regulation on Periodic Safety Review



- **Ministerial regulations on Periodic Safety Review** requires the licensee to;
 - Review and analyze the safety-related factors of a nuclear facility every 10 years, and
 - One of the 15 Safety factors is the “**Aging**” of the facility.
- **Requirements** in other regulations include aging consideration of SSC and in-service maintenance, testing and inspection for new and existing reactors, which covers all of reactor stages.
- **Procedure** (for RB) for technical review and inspection and **guideline** (for licensee) for preparation of aging management program were developed.



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ปรมานุก่อสร้าง

กระทรวงการอุดมศึกษา วิทยาศาสตร์ วิจัยและนวัตกรรม
Ministry of Education, Science and Higher Education





Guideline for Aging Management Program



A. SCREEN: SSC inventory, classification

Complies with IAEA SSG-10

B. IDENTIFY AGING: Service conditions, materials and identify aging mechanisms

C. MINIMIZATION: Prevent and minimize the aging mechanisms

D. DETECTION/MONITORING: inspection

E. MITIGATION: maintenance and refurbishment

F. IMPROVEMENT: continuous improvement

G. RECORD: SSC, operation, maintenance





Evaluation of radiation damage

Objective

- To evaluate radiation damage of core structural materials.
- To predict service-lifetime of core structural materials for new research reactors.

Methodology

- Calculate neutron flux as a function of neutron energy, or divide into several energy ranges (thermal, epithermal, fast neutrons) by MCNP.
- Calculate displacement rate of material using Kinchin-Pease model.
- Calculate displacement per atom (dpa) of material after irradiation for ... years. (by multiplying the neutron fluence)
- Evaluate material properties after irradiation by comparing with literature data.





Evaluation of radiation damage in TRR-1/M1

Radiation damage rate equation

$$R_d = N \int_{E_1}^{E_2} \phi(E_i) \sigma_D(E_i) dE_i$$

Energy transfer dependent cross section

$$\sigma_D(E_i) = \int_{T_1}^{T_2} \sigma_S(E_i, T) v(T) dT$$

Number of displaced atoms:
Kinchin-Pease Model

$$v(T) = \begin{cases} 0 & \text{for } T < E_D \\ 1 & \text{for } E_D < T < 2E_D \\ \frac{T}{2E_D} & \text{for } 2E_D < T < E_c \\ \frac{E_c}{2E_D} & \text{for } T \geq E_c \end{cases}$$

Displacement rate and displacement in 40 years of;

- SS 304 (clad)
~ 17 dpa (0.4 dpa/year)
- Al 6061 (core structure)
~ 4 dpa (0.1 dpa/year)

Changes in mechanical properties due to irradiation (radiation hardening);

- SS 304: YS and UTS increase up to 50 – 70% after 10 dpa.
- Al 6061: YS and UTS slightly increase at 5 dpa.

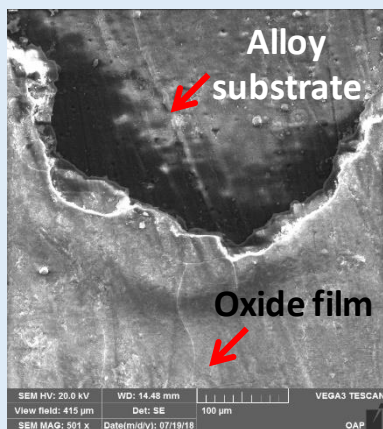


- Specimen is **Al6061** irradiation tube for pneumatic transfer. The tube was used in TRR-1/M1 for **28 years**. (cool down for 10 years before test.)

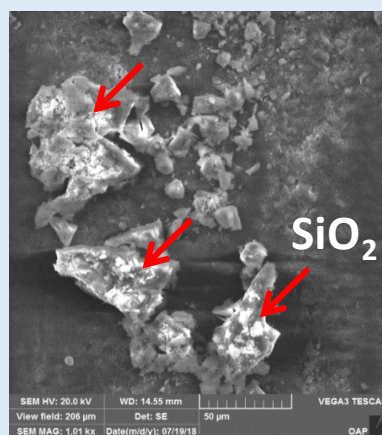


- **Corrosion investigation:** cross section samples, surface analysis, XRD

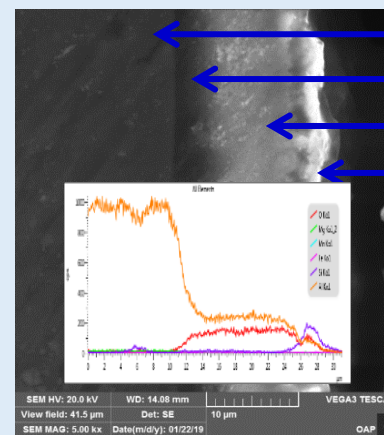
- Oxide thickness: $\sim 13 \mu\text{m}$
- Spallation of oxide film and Si-oxide on surface
- **Three layers** of oxide: transition layer, **Al-oxide:** Gibbsite ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$), Bayerite ($\text{Al}(\text{OH})_3$), **Si-oxide:** Quartz (SiO_2), Kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$)



Oxide film and spallation



Si-rich oxide grains



Three oxide layers





Analysis of specimens from TRR-1/M1 (2)

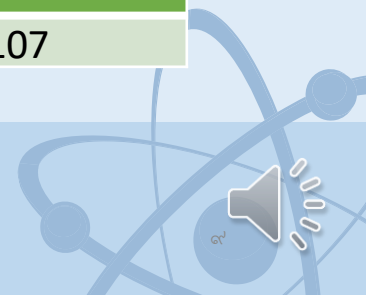


- It is found that **neutron transmutation** plays a major role on mechanisms of corrosion and mechanical property of Al-tube.



- Corrosion:** formation of SiO_2 on the outermost of material. It is easy to spall-off, which can increase coolant conductivity.
- Hardness test:**
 - It was expected to observe the irradiation hardening effect. From the test, we observed **less hardness** on irradiated Al specimen.
 - Strength of Al-alloy is a result from solid solution of Al-Mg. Transmutation of Al into Si could reduce influence of the solid solution strengthening.

	Used (Irradiated) Al6061 tube	New (Un-irradiated) Al 6061 (T651 tempering)	ASM standard
Average HV	90.96 ± 4.27	118.91 ± 3.30	107





Conclusion



- **Regulations** involving aging management and aging considerations of the research reactor have been established.
- **OMARR mission** is on-going. TINT will provide the AMP according to recommendation of the pre-mission (2019).
- **Guideline** to develop the aging management program was developed. It is inline with the IAEA SSG-10.
- **A technical guide** to evaluate radiation damage on structural materials was provided for current and future research reactors.
- **Investigation** of irradiated Al-tube showed that the oxide thickness is within the acceptable limit. However, neutron transmutation on Al reveals a major role on mechanisms of corrosion and material property after irradiation.



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