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

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TM on Research Reactor Aging Management, Refurbishment and Modernization

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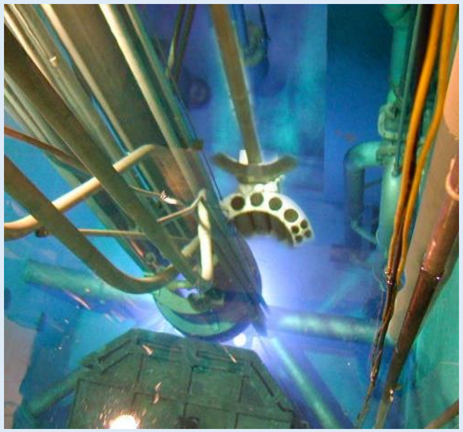
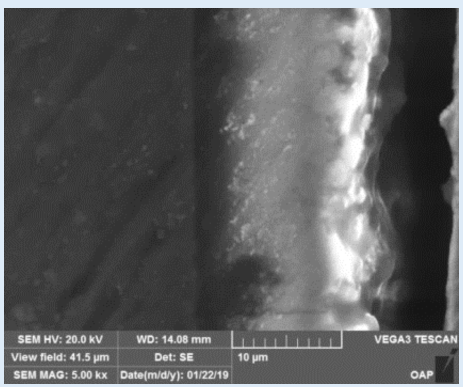
INTRODUCTION





- 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;

Site | **Construction** | **Operation** | **Decommissioning**

  - **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.

Guideline for Aging Management Program

Complies with IAEA SSG-10

A. SCREEN: SSC inventory, classification

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 neuron 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

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

Number of displaced atoms: Kinchin-Pease Model

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

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)

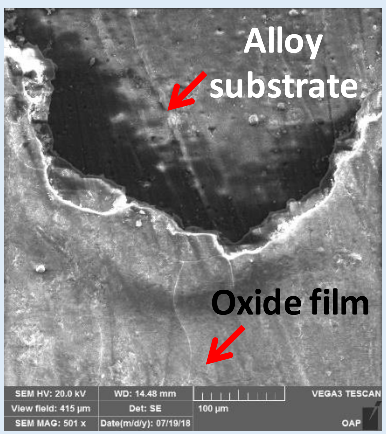
Changes in mechanical properties due to irradiation (radiation hardening);

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

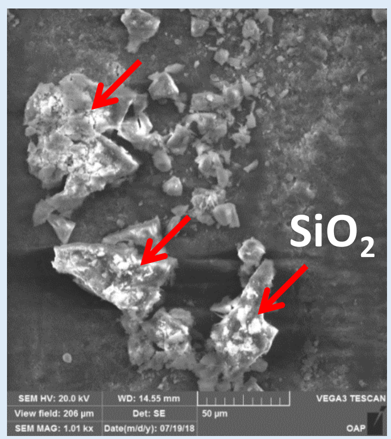
Analysis of specimens from TRR-1/M1 (1)

- 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.)

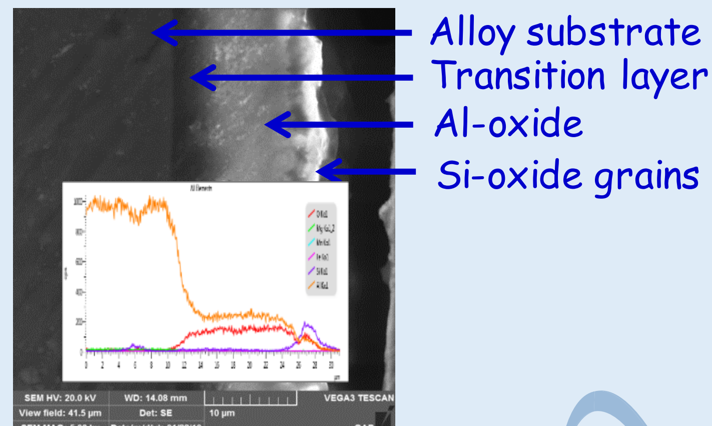
- **Corrosion investigation**: cross section samples, surface analysis, XRD
  - Oxide thickness: ~13 μm
  - Spallation of oxide film and Si-oxide on surface
  - **Three layers** of oxide: transition layer,
    Al-oxide: Gibbsite ($Al_2O_3.3H_2O$), Bayerite ($Al(OH)_3$) ,
    Si-oxide: Quartz (SiO_2), Kaolinite ($Al_2Si_2O_5(OH)_4$)



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.

$$^{27}\mathrm{Al}\ (n,\gamma)^{28}\mathrm{Al}, \qquad ^{28}\mathrm{Al} \rightarrow {}^{28}\mathrm{Si} + \beta$$

- 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.