

SG Tubes with SM-ART™ Technology for Reducing Metal Release in PWR

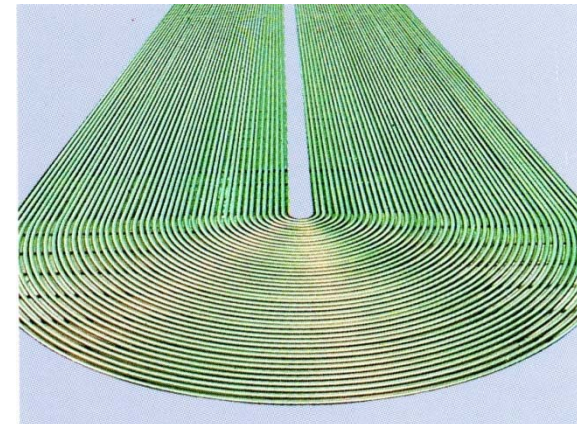
(SM-ART™ :Sumitomo Metals Anti-Release Treatment)

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ISOE Technical Award
to SM-ART™ technology



SMI's Steam Generator (SG) Tubes

Contents

- 1) Background
- 2) Experimental Results of **Steam Generator (SG) tubes** with **SM-ART™** (Sumitomo Metals Anti-Release Treatment) **Pre-Filming** Technology
 - 2.1) **Ni release reduction** from SG tubes by chromia (Cr_2O_3) film
 - 2.2) **Long term stability** of chromia film
- 3) Conclusion

Previous Presentation (ALARA January 2010)

Sheet specimens of alloy 690 were pre-filmed in laboratory and the characteristics were investigated.

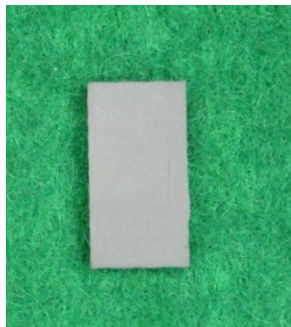


Photo 1 Appearance of
Pre-Filmed Sheet Specimen

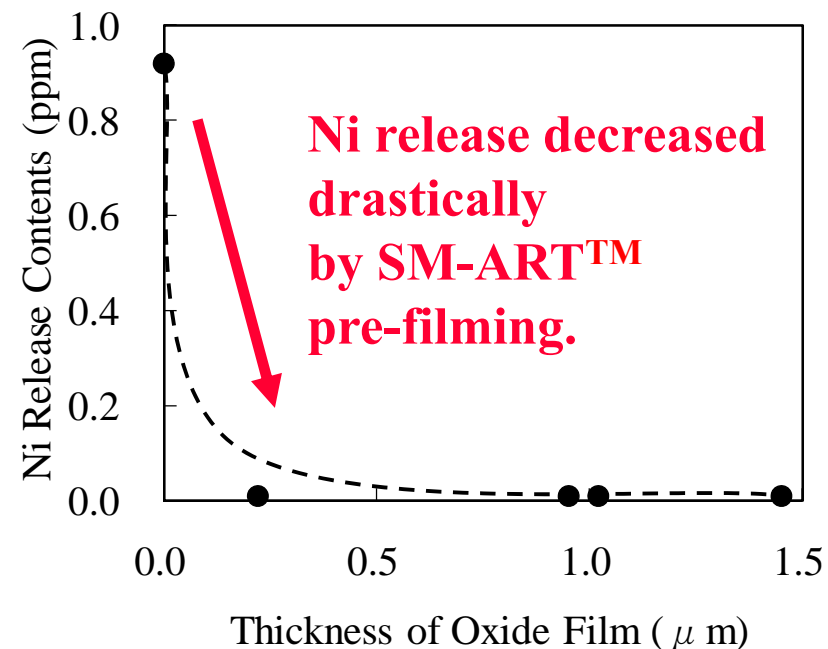


Figure 1 Ni Release Test Result
in Deionized Water
(320°C, 1000hr)

Today Presentation

Inside surface of SG tube was pre-filmed by SM-ART™ in SG tube manufacturing plant.

The characteristics of pre-filmed SG tubes were investigated.

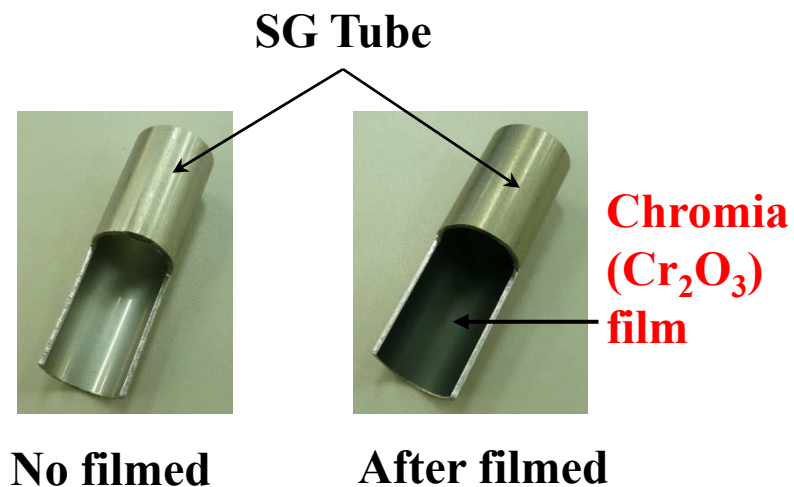


Photo 2 Appearance of Specimens

Ni release content

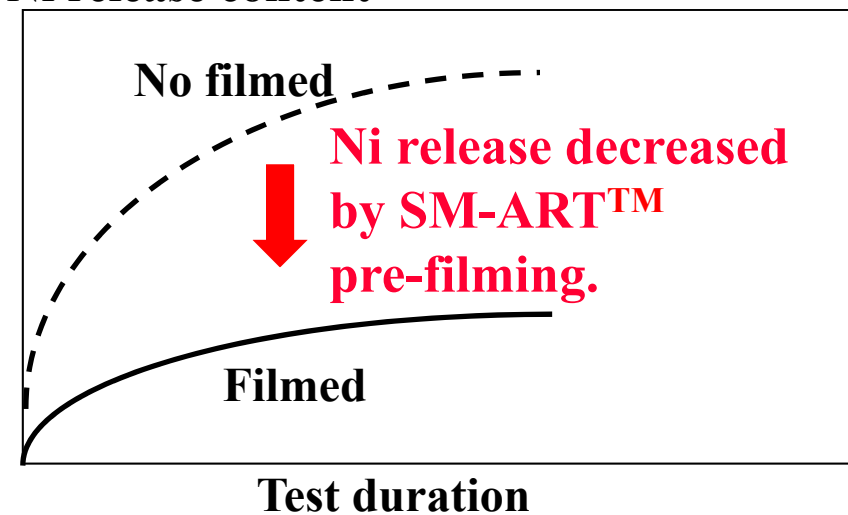
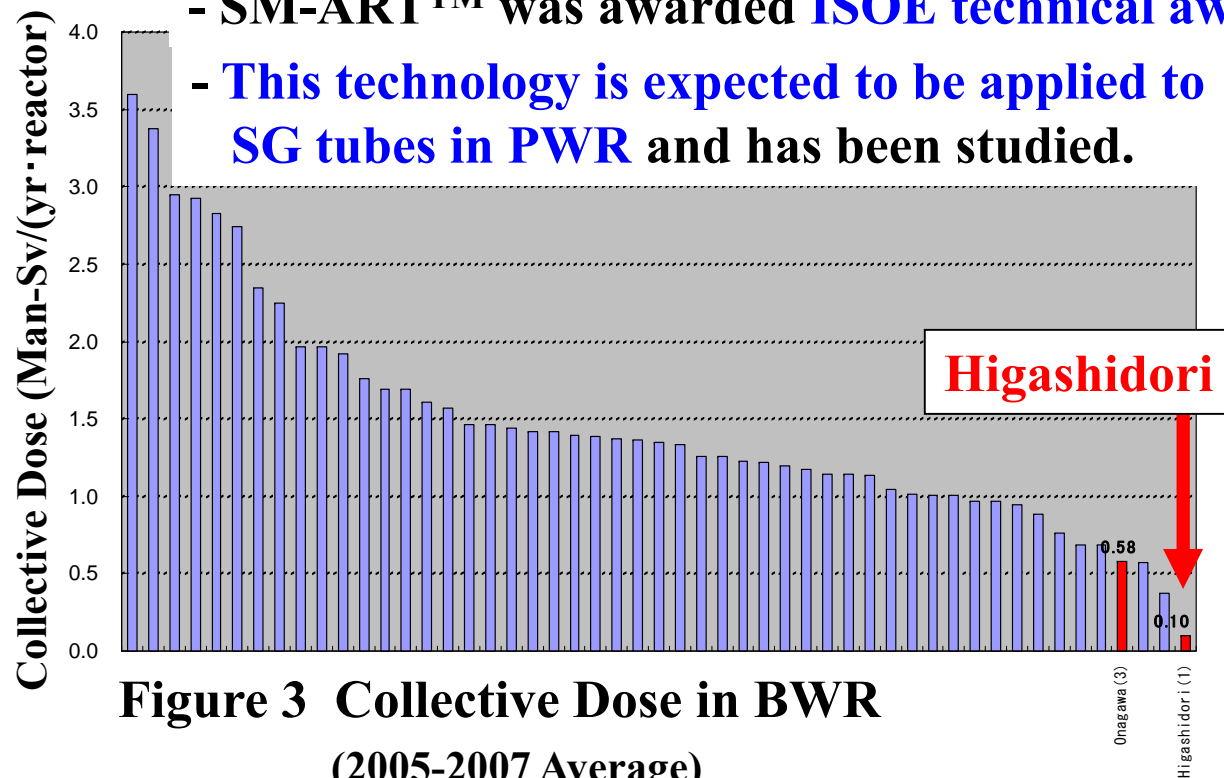


Figure 2 Image of Ni Release Test

Application of SM-ART™ Technology in a NPP

- **Higashidori** NPP, BWR, achieved **the world record dose**.
- **Feed water heater tubes pre-filmed by SM-ART™** were applied and contributed to the lowest dose.
- SM-ART™ was awarded **ISOE technical award**.
- **This technology is expected to be applied to SG tubes in PWR** and has been studied.



ISOE Technical Award
to SM-ART™ technology



Mr. Mizumachi (ISOE) Mr. Nakanishi (SMI)

^{58}Co Increase during Operation Cycle in PWRs

^{58}Co increased from 1st cycle to 2nd cycle
and decreased from 3rd cycle and after.

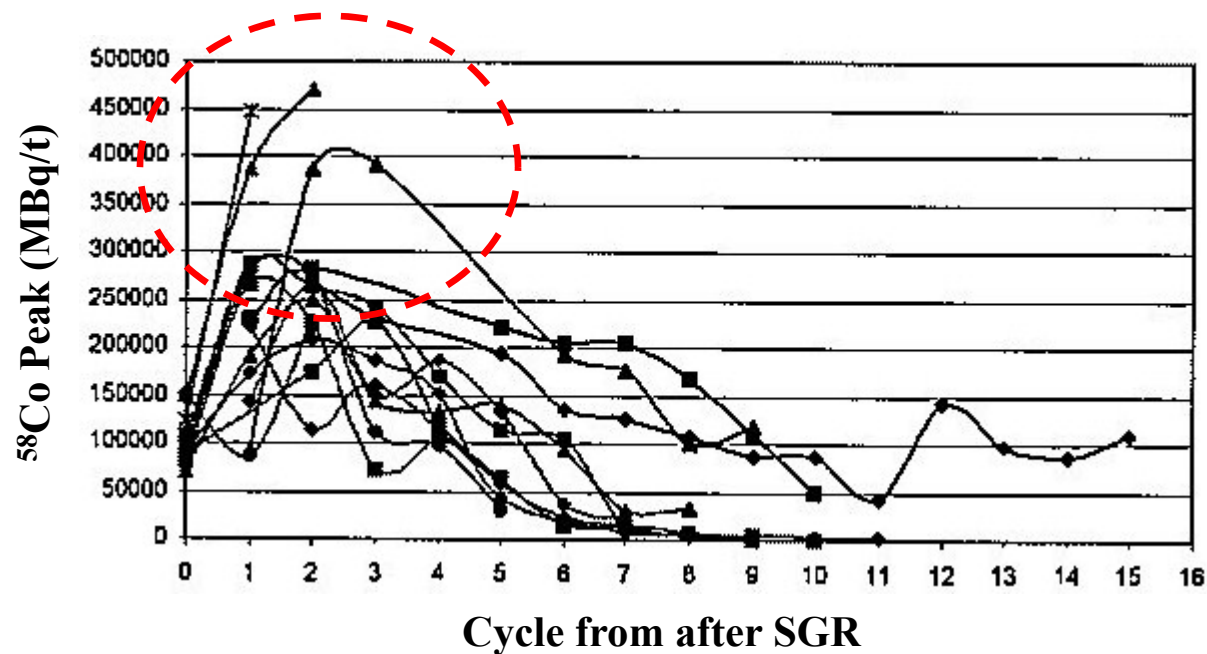


Figure 4 ^{58}Co Increase during Operation Cycle

(F. Carrette et al., EDF, Nuclear Plant Chemistry Conference , 2006)

Ni Release from SG Tubes during Operation Cycle

Main Ni release from SG tubes occurs in the early operation period. Therefore, **reduction of Ni release in the early operation period is the most effective.**

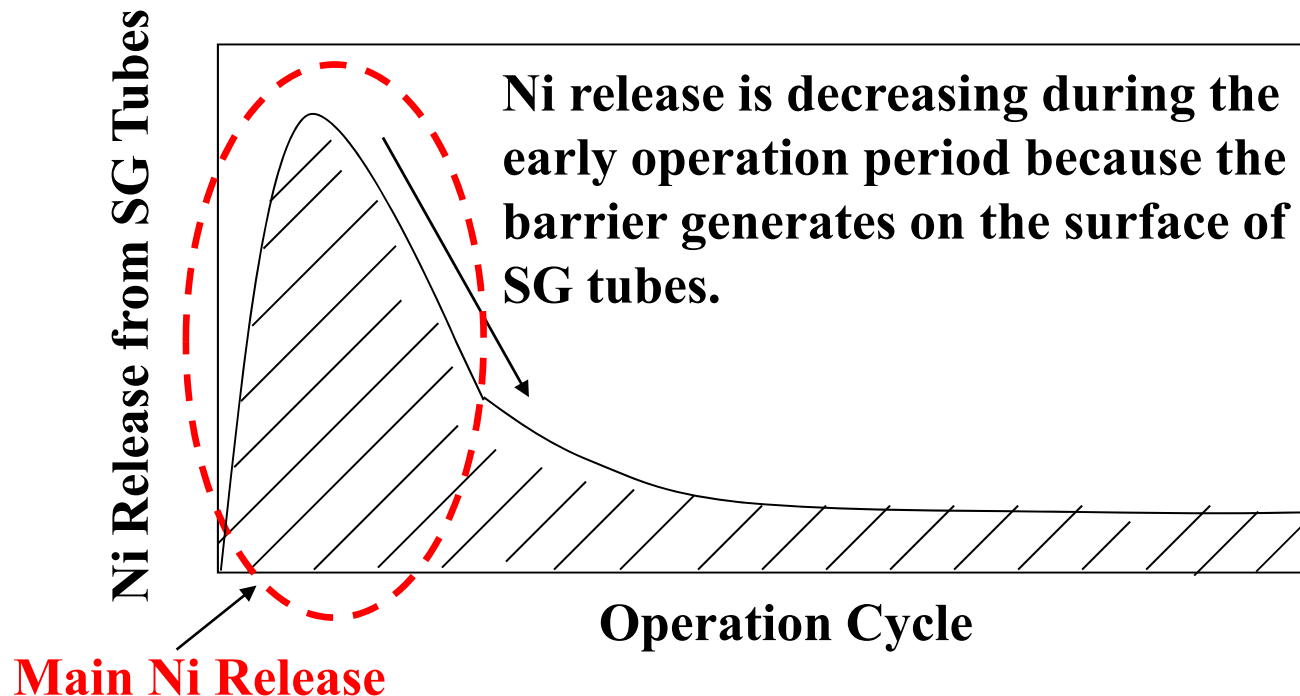
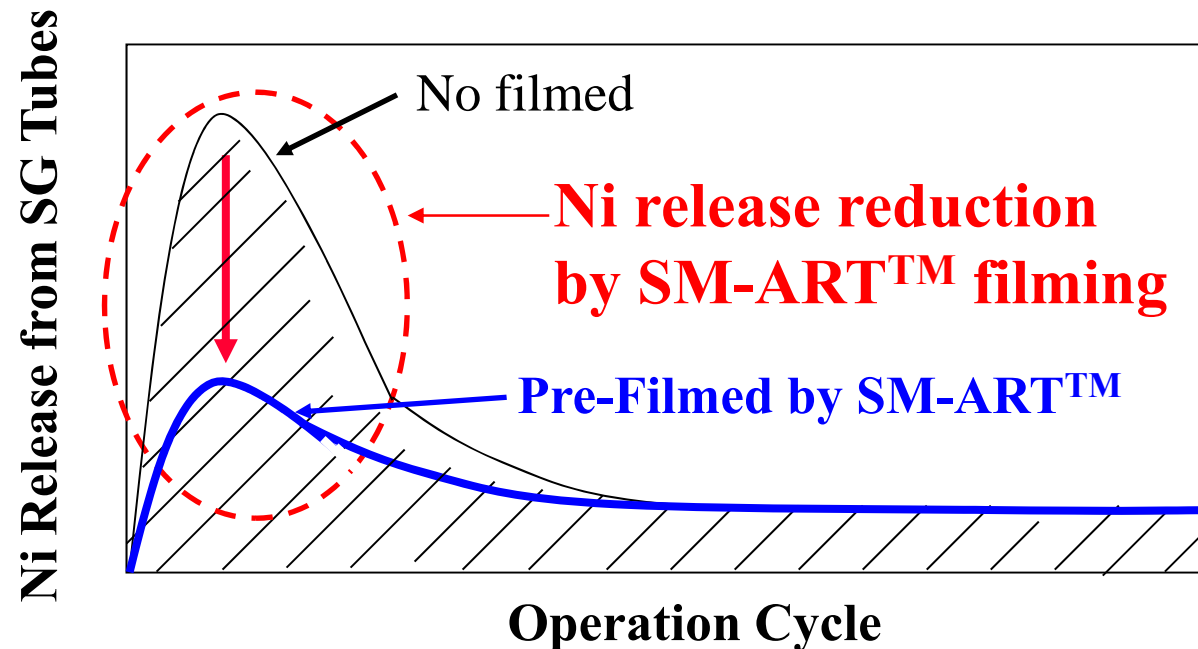


Figure 5 Image of Ni Release from SG Tubes during Operation Cycle

Reduction of Ni Release from SG Tubes by SM-ART™ Technology

1) Ni release of SG tubes pre-filmed by SM-ART™ is expected to reduce from operation starting.



2) The effectiveness of SG tubes filmed by SM-ART™ is expected to continue during the early operation period.

Figure 6 Image of Ni Release Reduction from SG tubes by SM-ART™

Ni Release from SG Tubes

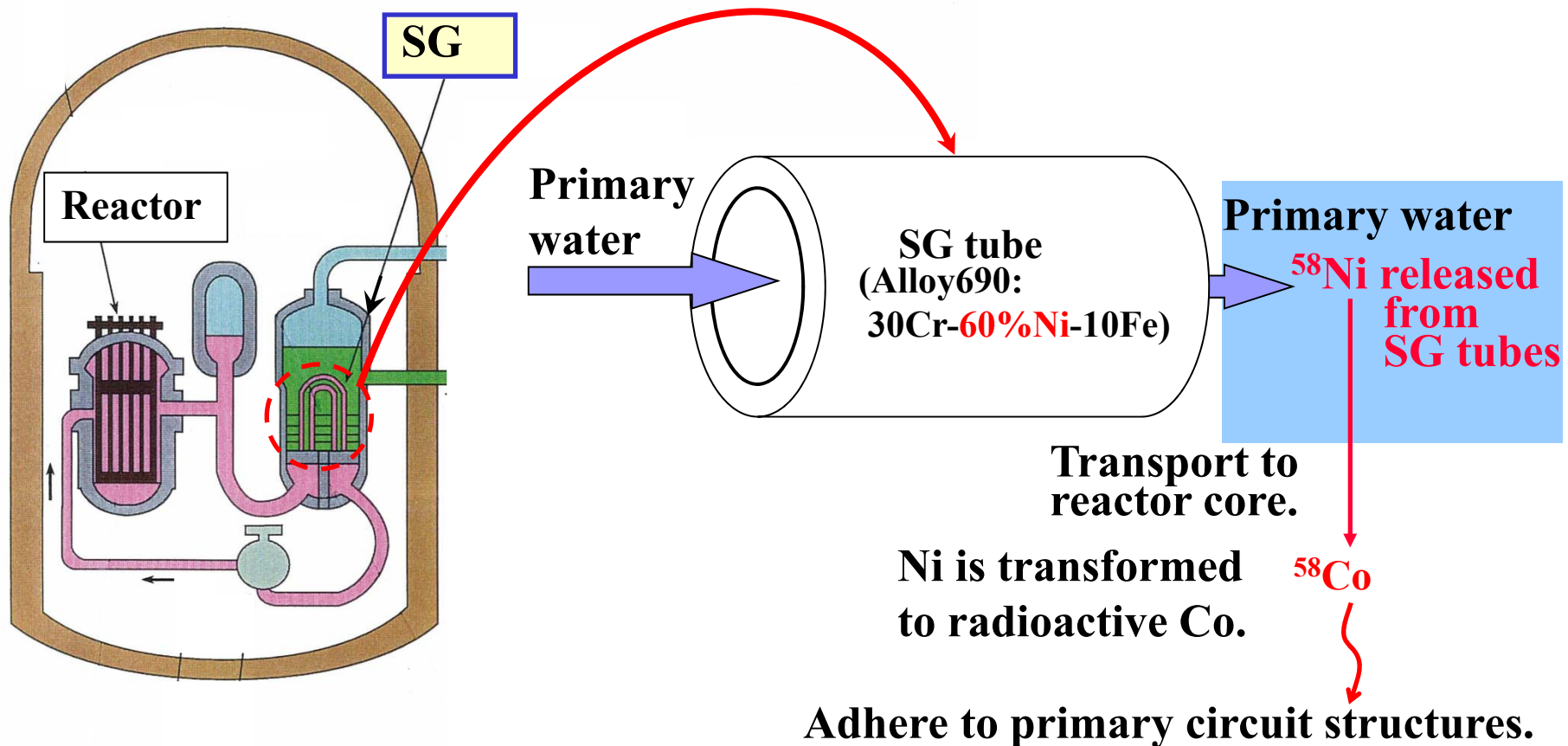


Figure 7 Image of Ni Release from SG Tubes

Ni Release Reduction of SG Tubes Pre-Filmed by SM-ART™

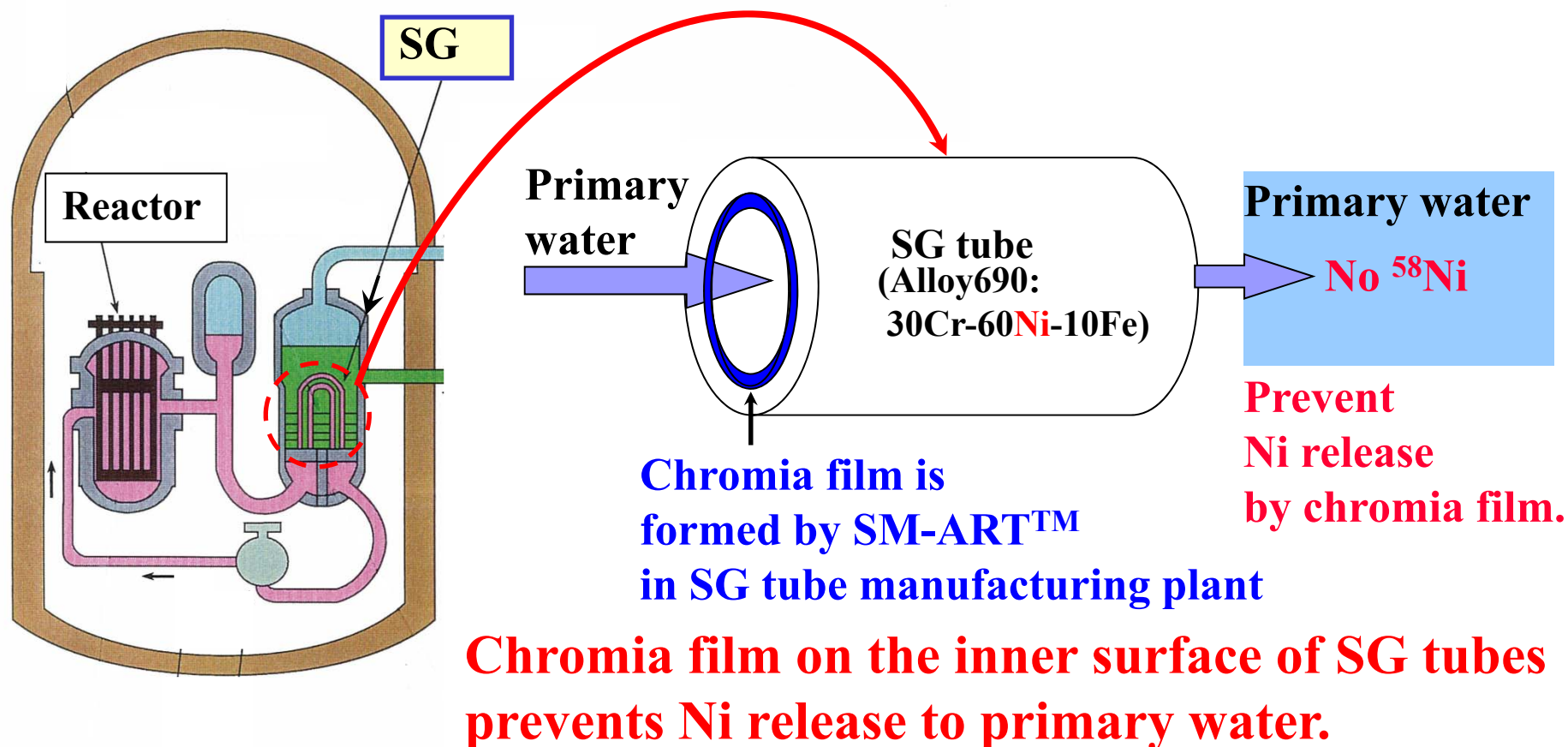
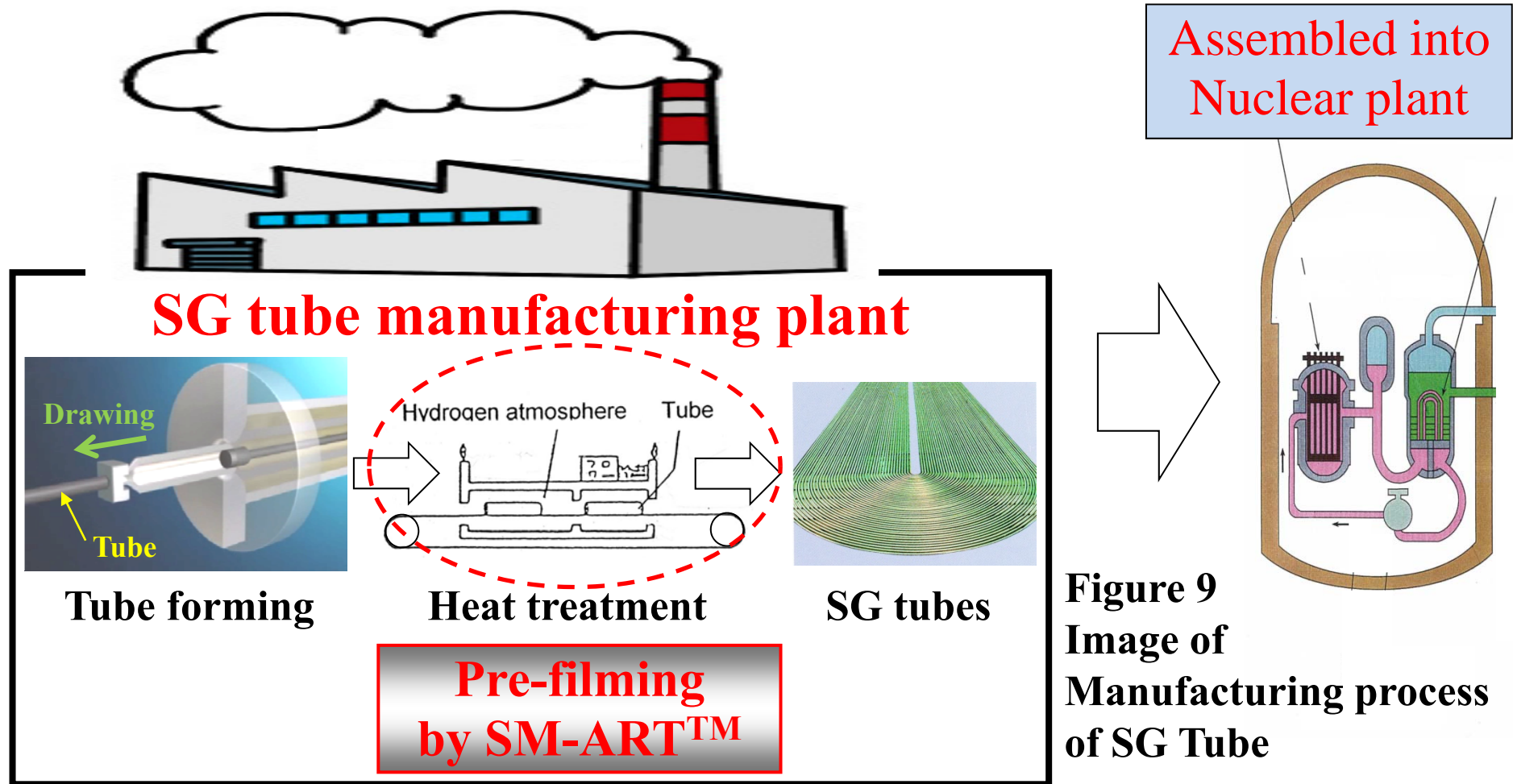


Figure 8 Image of Ni Release Reduction by SM-ART™ Film

Objectives of Experiments

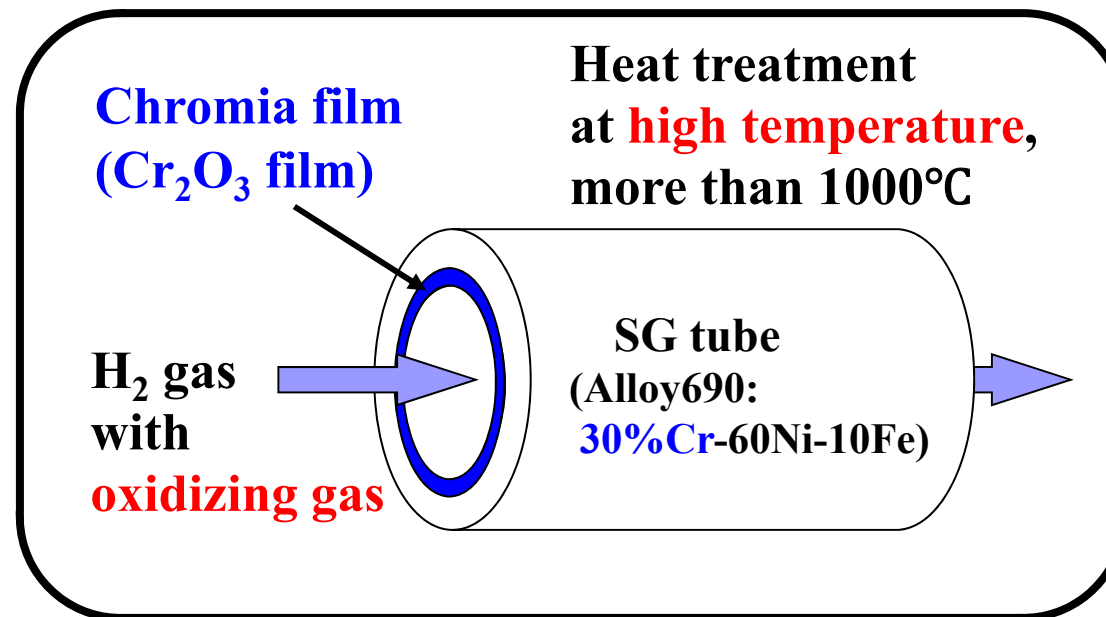
- 1) Clarify the effectiveness of **chromia film** on **Ni release reduction** from SG tubes in simulated primary water.
- 2) Clarify the **long term stability** of **chromia film** in simulated primary water.

Manufacturing Process of SG tubes



Pre-Filming by SM-ART™ during SG Tube Manufacturing Process

Electric furnace with hydrogen atmosphere



Chromia film
is formed
by oxidizing gas
at high
temperature.

Cr is selectively
oxidized
by controlling
oxygen partial
pressure and
temperature.

Figure 10 Image of **Pre-Filming by SM-ART™**

Characteristics of Chromia Film

Chromia (Cr_2O_3) film on the surface of SG tube was mainly formed by oxidation.

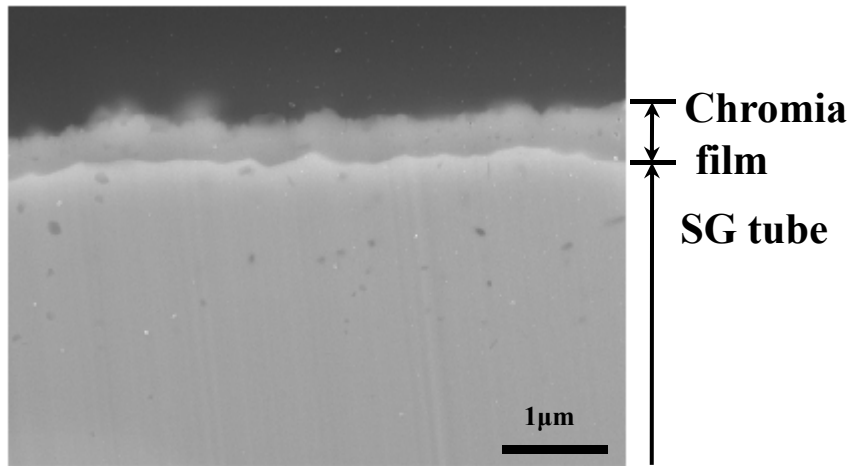


Photo 3 Cross Section Observation

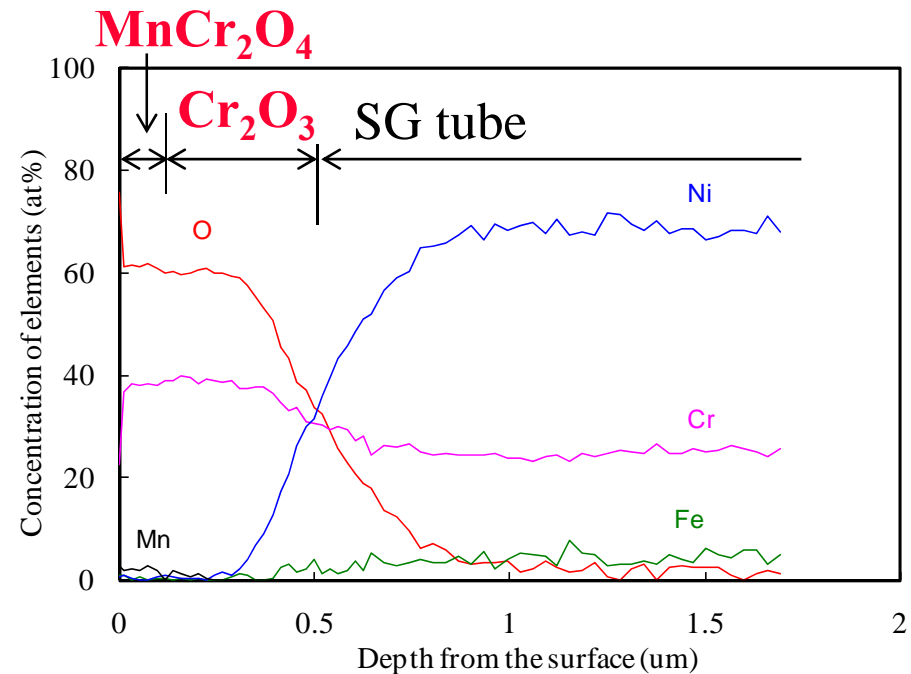


Figure 11 Analysis of Chromia film by XPS

Experimental Procedure and Test Result (1)

1) Ni Release Test

2) Long Term Stability Test

Experimental Procedure and Test Result (1)

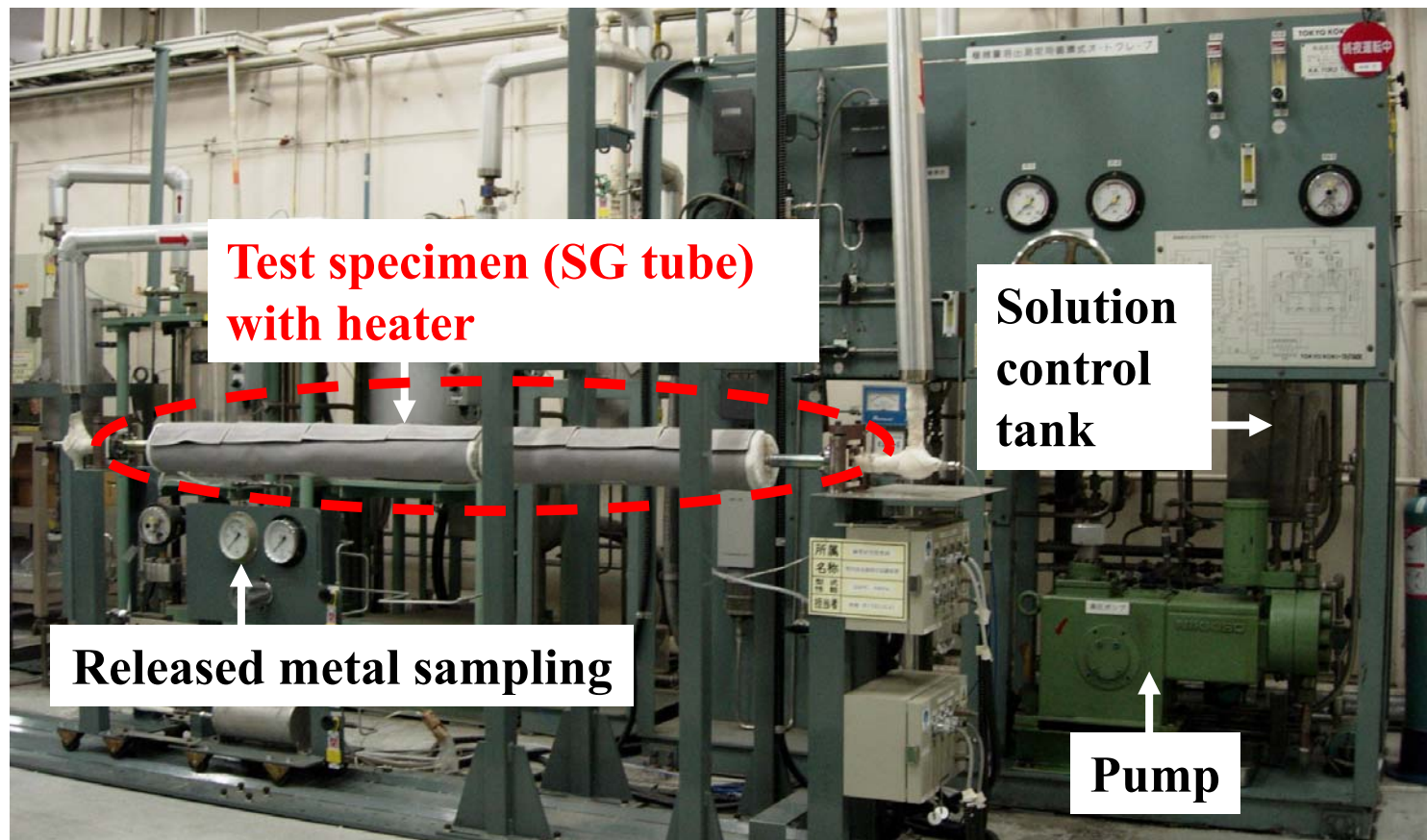


Photo 4 Ni release test equipment (overview)

Experimental Procedure and Test Result (1)

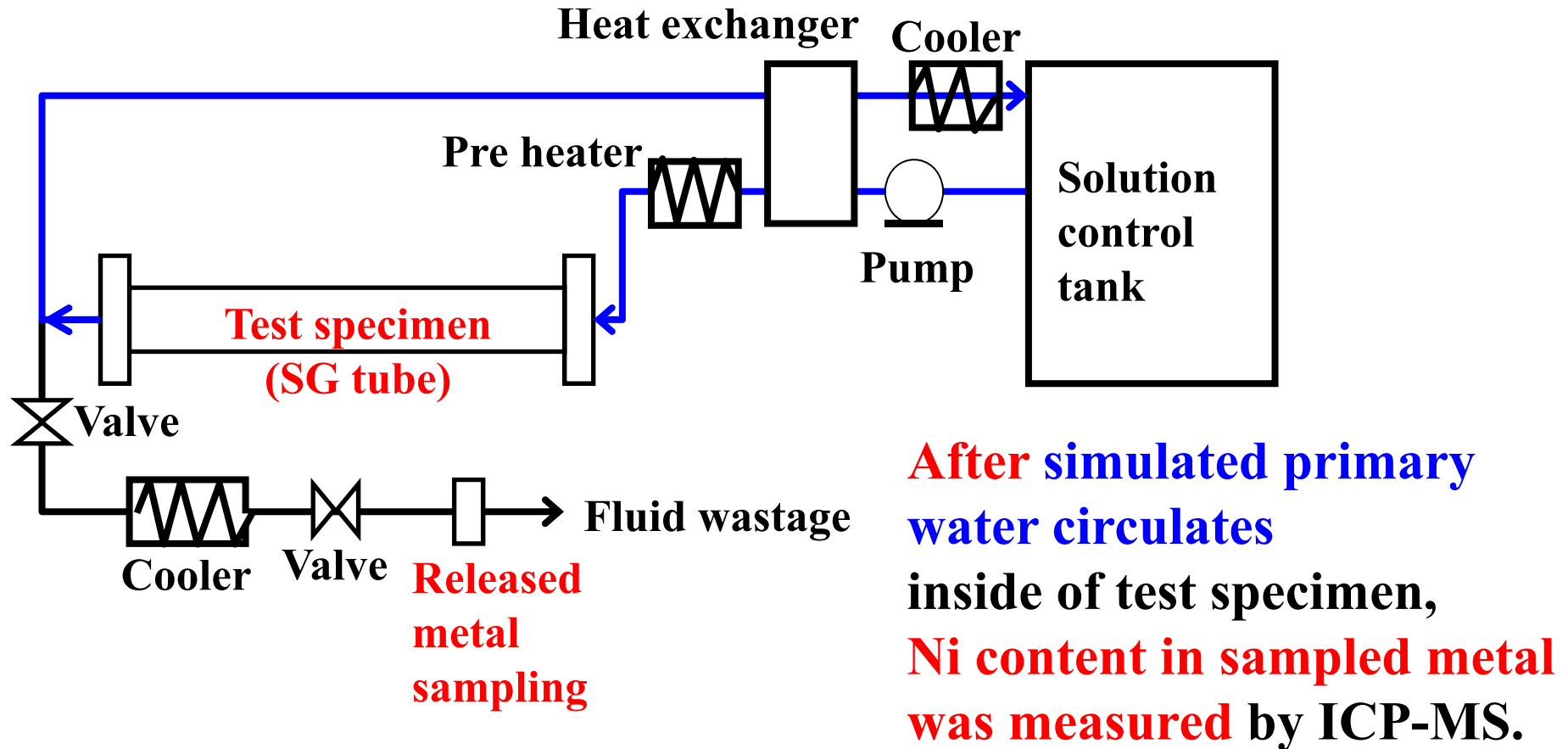
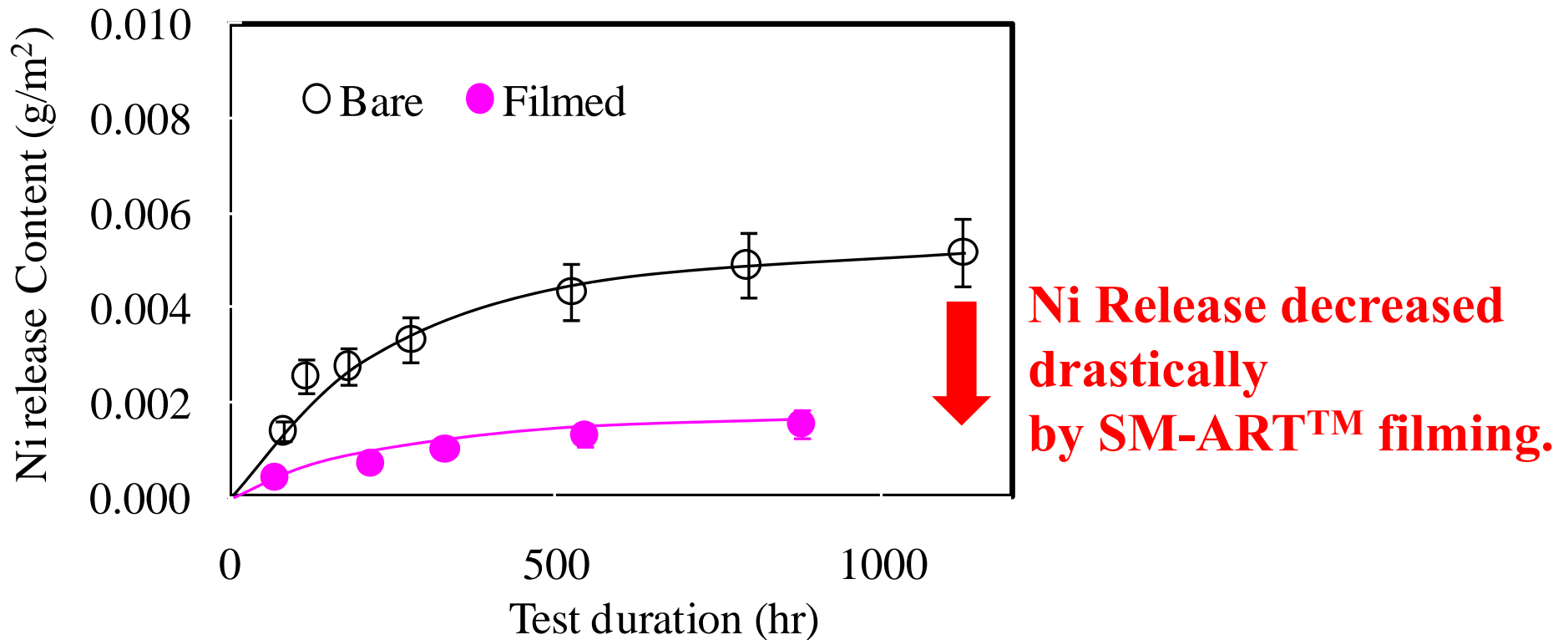


Figure 12 Ni Release Test Equipment

(300 °C, 500ppmB+2ppmLi, 0.02m/sec.,)

Ni Release Test Result



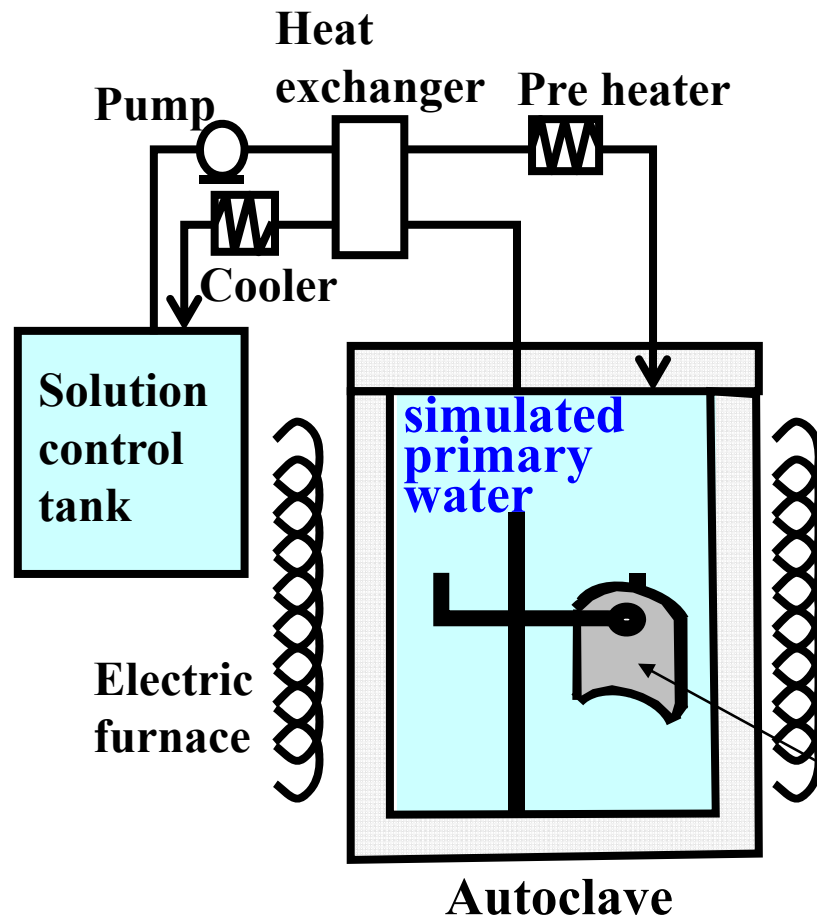
**Figure 13 Ni Release Test Result in Simulated Primary Water
(300°C, 500ppmB+2ppmLi, 0.02m/sec.)**

Experimental Procedure and Test Result (2)

1) Ni Release Test

2) Long Term Stability Test

Long Term Stability Test Method



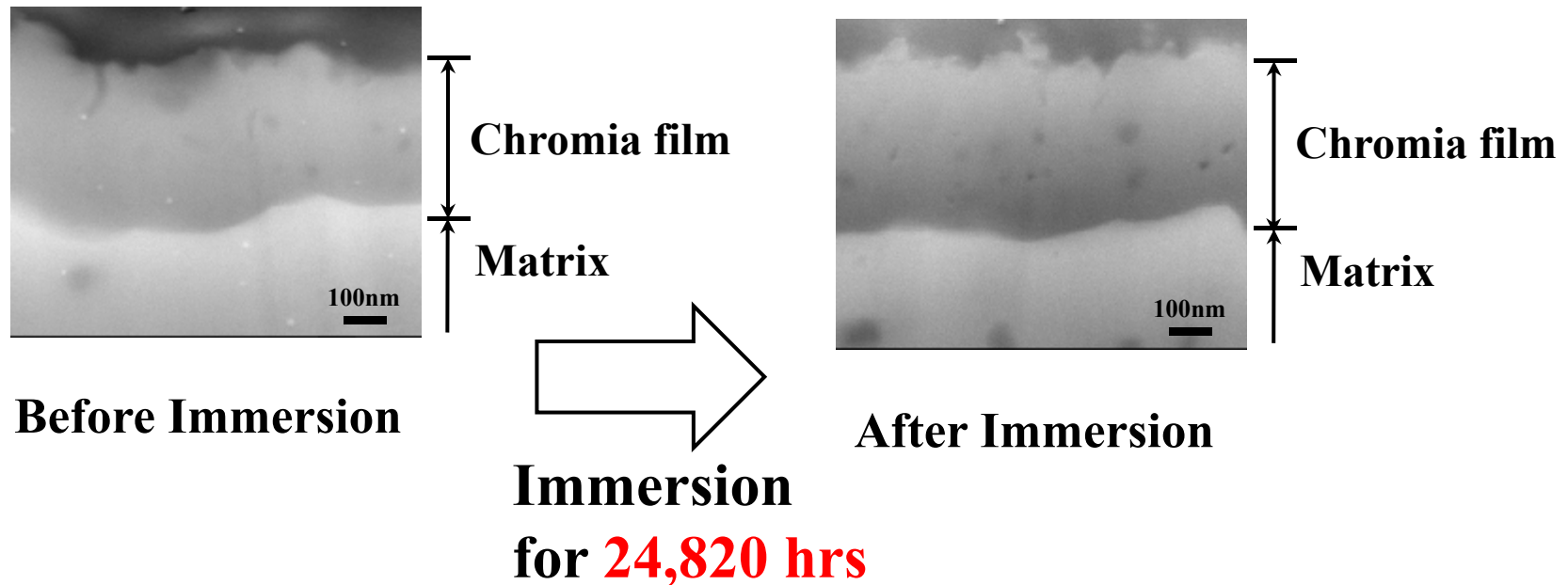
After immersion
in simulated primary water
(500ppmB+2ppmLi)
by circulate type autoclave
at 360 °C for **24,820 hrs**,
cross section observation of
the specimen was
performed by SEM.

Test specimen
sampled from SG tube

Figure 14 Long Term Stability Test Equipment

Long Term Stability Test Result

After long term immersion, chromia film exists.



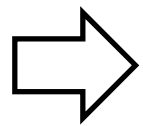
**Photo 5 Cross Section Observation of Pre-Filmed Specimen
(360 °C, 500ppmB+2ppmLi)**

Conclusion

Following results were obtained.

1) **Ni release** content of specimen **pre-filmed by SM-ART™** is approximately **one third** of that of bare specimen.

2) After long term immersion, **the chromia film exists.**



Ni release from SG tubes in PWR can be expected to reduce by this SM-ART™ pre-filming technology.

Future Work

In order to apply SG tubes pre-filmed by SM-ART™ to NPPs, following work will be conducted.

- Investigate characteristics of the pre-filmed SG tubes, PWSCC, thermal conductivity etc**

Additionally, following fundamental mechanism will be studied.

- Prevention of Ni release from SG tube by chromia film**
- Formation of chromia film on the surface of SG tubes**

Advice and cooperation of both Utility companies and SG fabricators would be highly appreciated.