中核集团 CNNC

中国辐射防护研究院

CHINA INSTITUTE FOR RADIATION PROTECTION

In-situ Gamma Spectroscopy Measurement of Activated Corrosion Products in Nuclear Power Plants and Its Application

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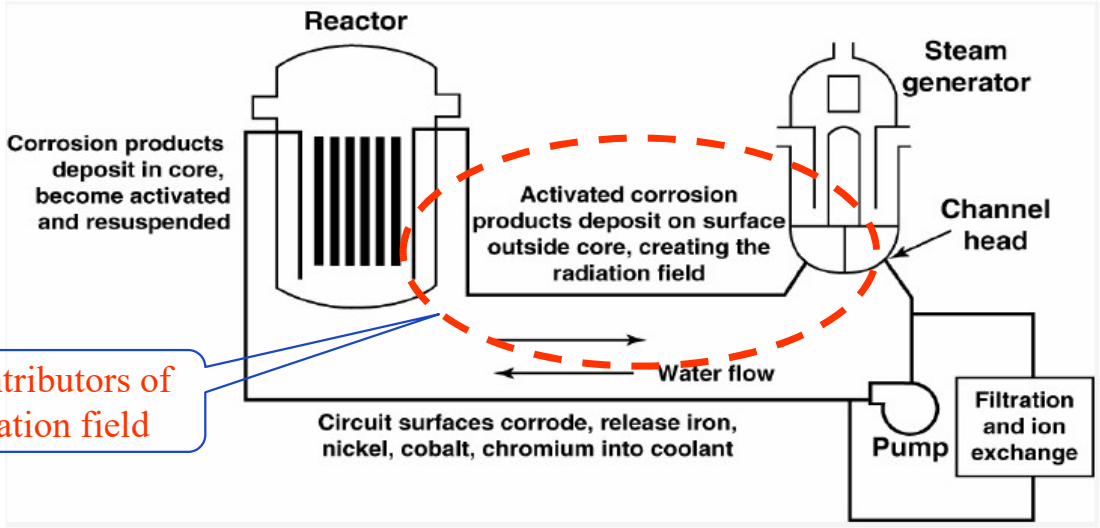
CONTENTS

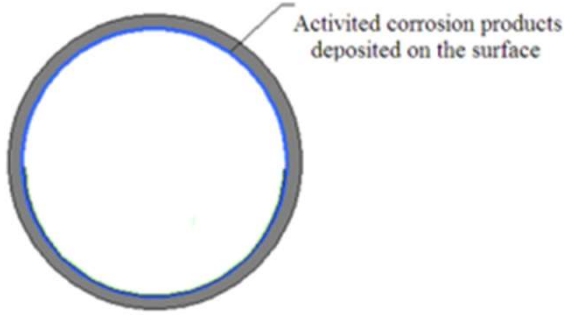
01 Background

Background

- **80% of occupational exposure in PWR comes from maintenance periods;**
- **90% of the maintenance dose comes from Activated corrosion products (ACPs).**



The main contributors of gamma radiation field



^{58}Ni (n,p) ^{58}Co

^{59}Co (n, γ) ^{60}Co

^{54}Fe (n,p) ^{54}Mn

^{50}Cr (n, γ) ^{51}Cr

^{58}Fe (n, γ) ^{59}Fe

Background

Significance of ACPs measurement in NPPs

The "eyes" of radiation protection and optimization in NPPs

- **Mastering the sources of occupational exposure and their composition, including nuclides, dose contributions, and changing trends, provides information for implementing ALARA.**
- **Monitoring the status of radiation safety and detecting abnormal events.**
- **Providing testing methods for the optimization of shutdown water chemistry procedures, filtration, and verification of decontamination effectiveness.**
- **Offering guidance and validation methods for research on source term reduction and dose reduction, such as zinc injection.**
- **Providing calibration data for the study of ACPs mechanisms and the development of computational programs, Optimize reactor design.**

● Monitoring of Activated corrosion products (ACPs) at NPPs.

- Hungary: 40 years (**since 1985**)，more than **100 times** ACPs measurements;
- France EDF: 40 years (**since 1981**)，more than **300 times** ACPs measurements and dose assessment; Since 2011, daily monitoring (58 units, each maintenance);
- China: 20 years (since 2004), more than **80 times** ACPs measurements.

France-EMECC（since 1981）

Hungary（since 1985）

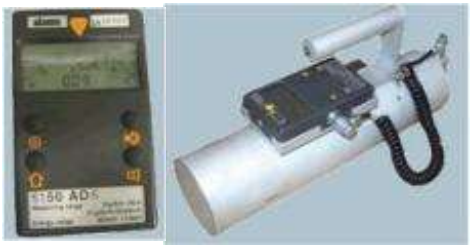
CIRP（since 2004）

02 Technology

Technology

● In-situ Gamma Spectroscopy Measurement Technology

Dose rate — *Single information*



Nondestructive measurement

In-situ γ spectroscopy

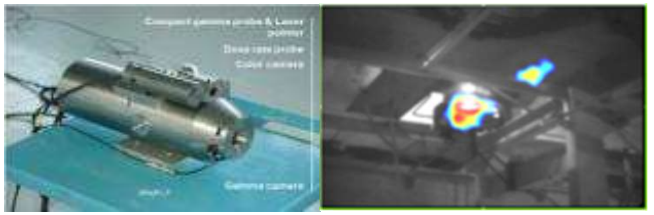
Convenient and fast

Types and activities of nuclides

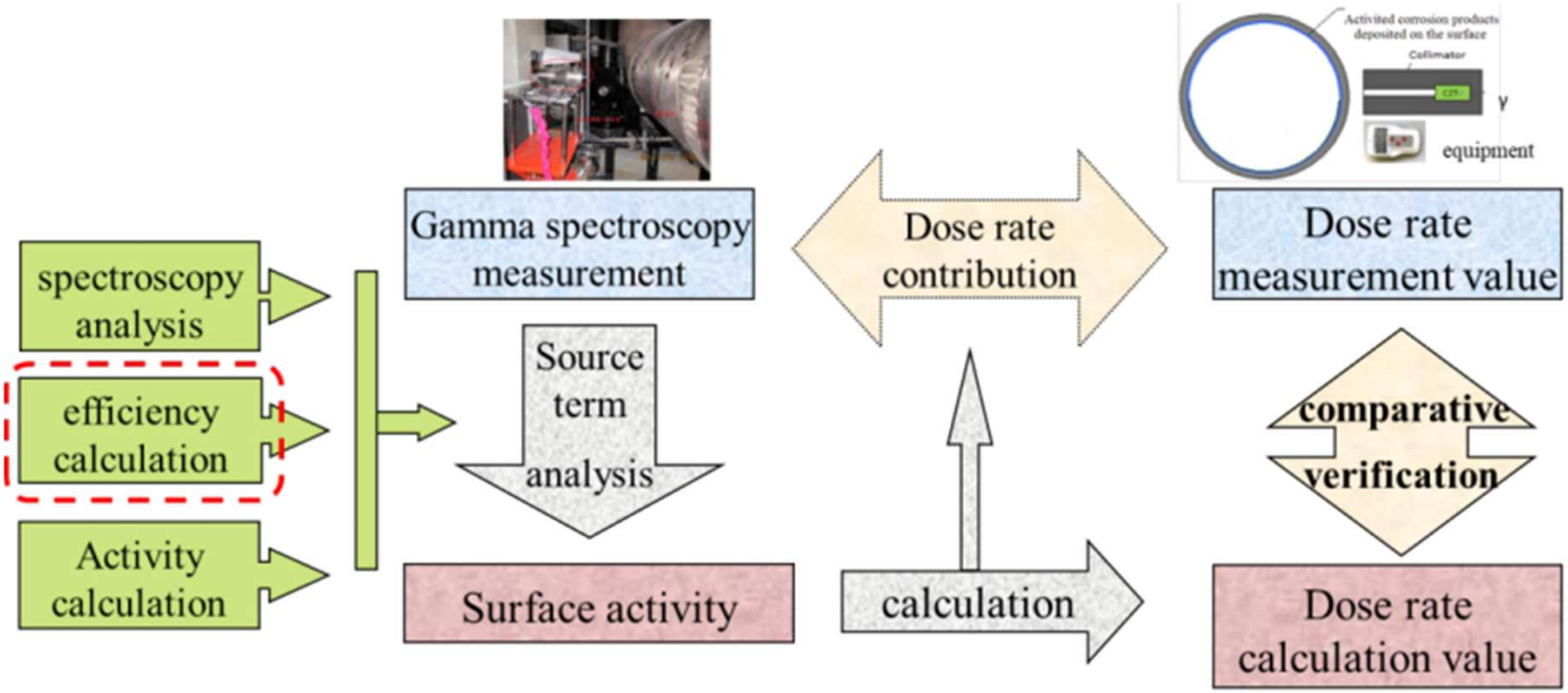
— **γ imaging**

Hot spot location

No nuclide activity



In-situ Gamma Spectroscopy Measurement Technology



Activity calculation method : $A_X = \dfrac{n_0}{\varepsilon \cdot \xi_E \cdot S}$

Technology

Our measurement systems

Sterm-HPGe: Based on HPGe detector (2004)

Sterm-CZT: Based on CZT detector (2005)

STM-GR1: Portable gamma spectrum monitor

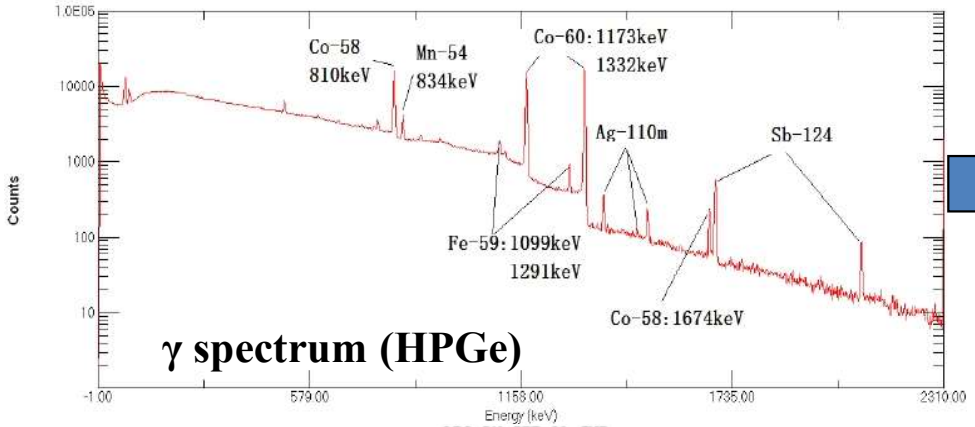
- Composition: CZT detector, Tablet PC, Tungsten shield, Collimator, Tripod, γ spectrum analysis software
- Online monitoring, automated spectrum analysis and activity calculation

Technology

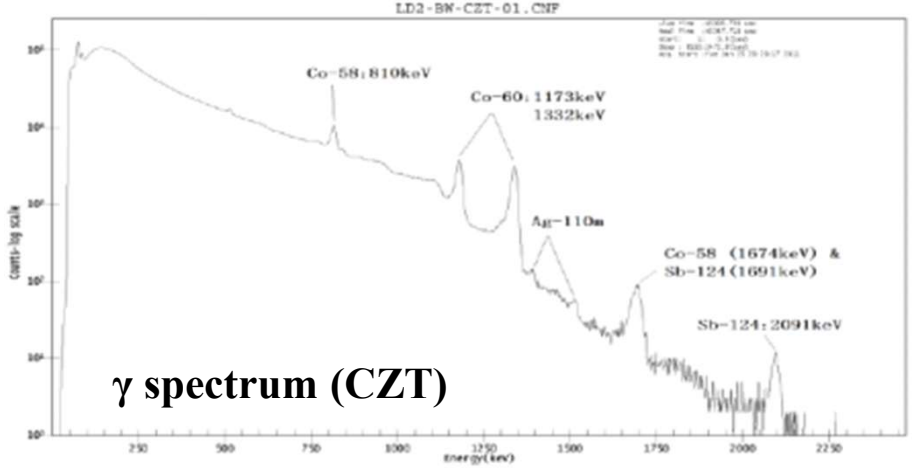
● Data processing

What nuclides? How much? Dose contribution? Trends?

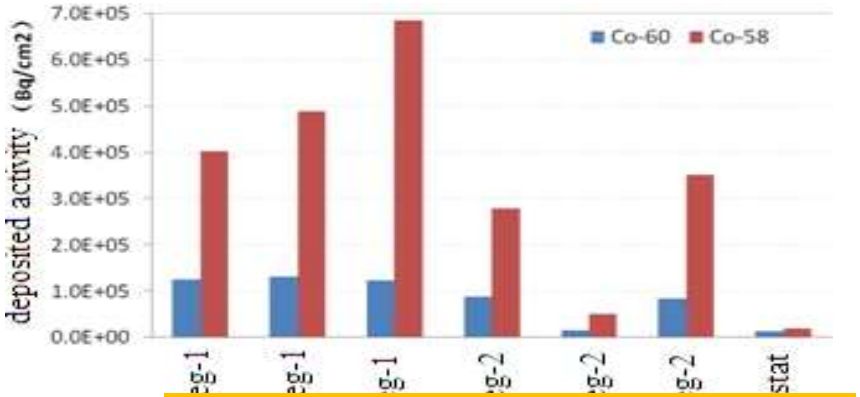
What is the detailed mechanism? How to reduce?



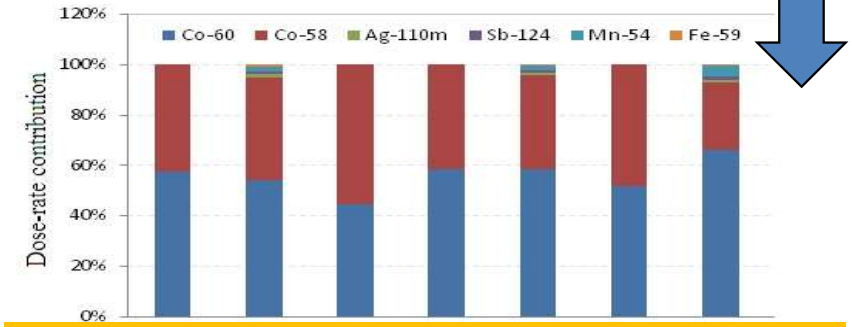
γ spectrum (HPGe)



γ spectrum (CZT)



Deposited activities of the nuclides



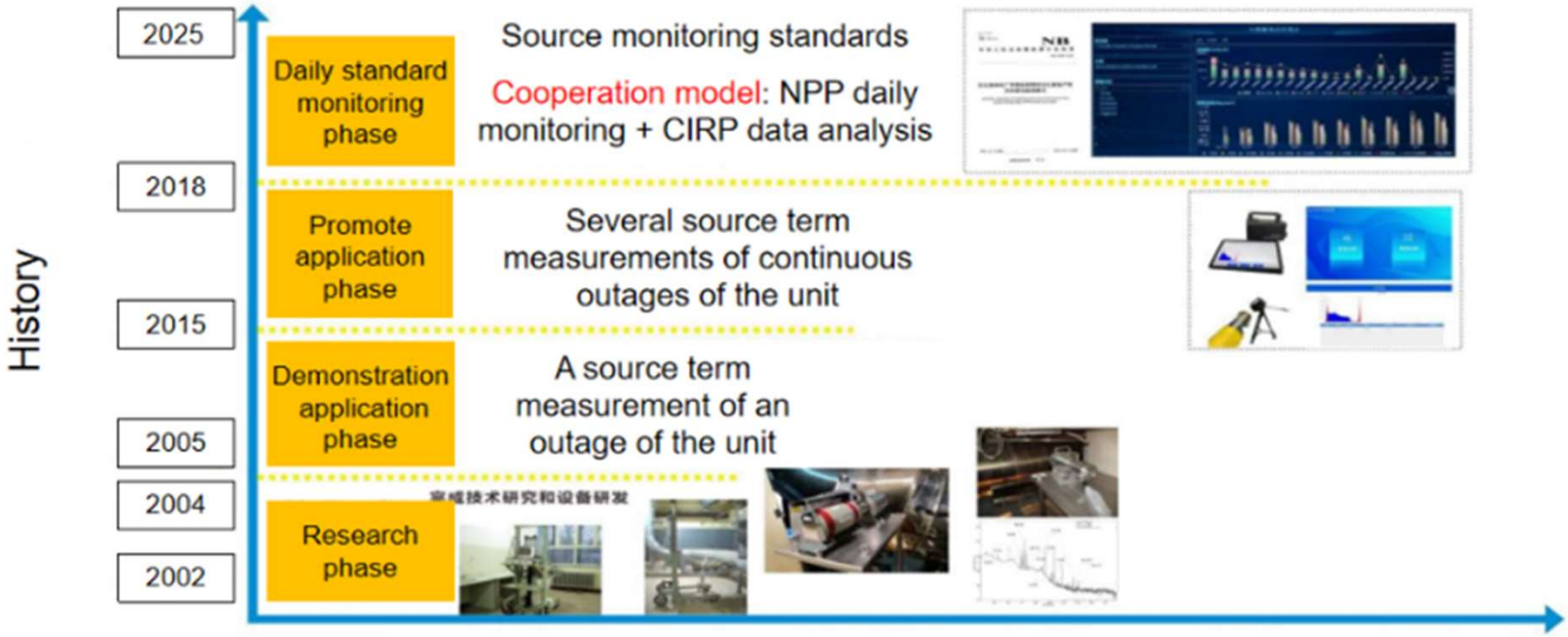
Dose-rate contribution of nuclides

03 Good Practice

Good Practice

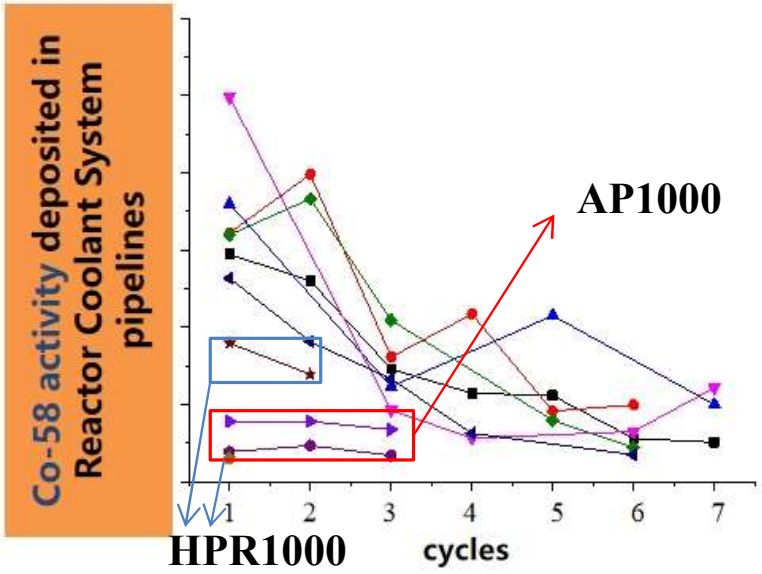
By August 2025, over 80 measurements have been conducted at NPPs in China

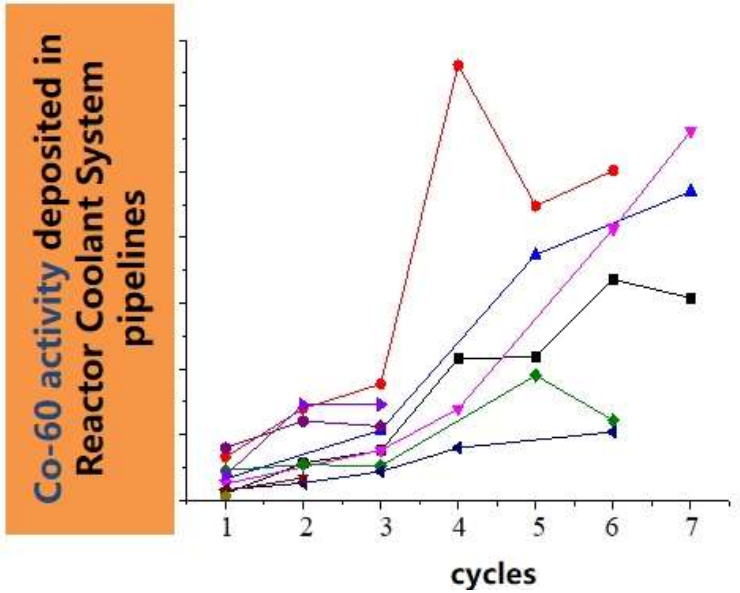
- **CIRP has been engaged in source term measurement of NPPs since 2004, achieving the international advanced level.**
- **CIRP has compiled China's first monitoring standard for deposited activities in PWRs.**
- **China's first portable gamma spectrum monitor for deposited activities.**



Good Practice

Comparison of deposited activities data collected during outages of CNNC units



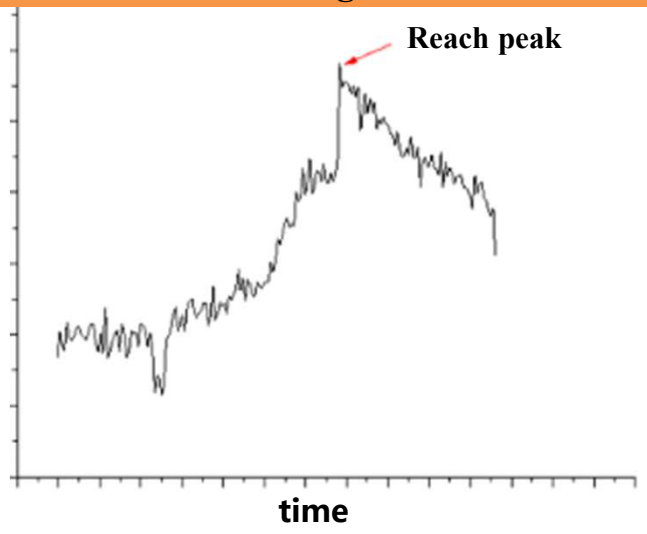


- **Compare the deposited activity levels of different reactor types, trend analysis.**
- **For example:**
  - **AP1000: Due to zinc injection, the deposited activity of Co-58 is relatively low.**
  - **HPR1000(Hualong One): The deposited activities data of other reactor types is used for the design optimization of HPR1000, and its deposited activity level is relatively low.**

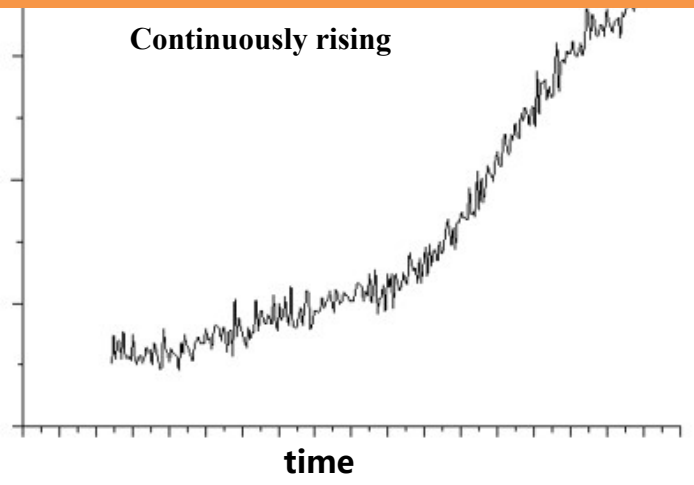
Good Practice

Continuously monitored during forced oxidation of a unit

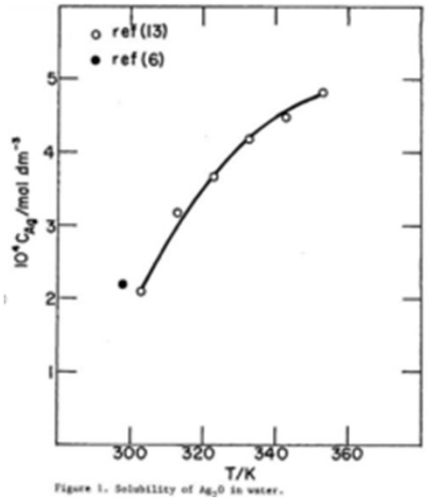
Trend of Co-58 count rate variation in the hot leg



Trend of Ag-110m count rate variation in the Chemical and Volume Control System letdown pipe



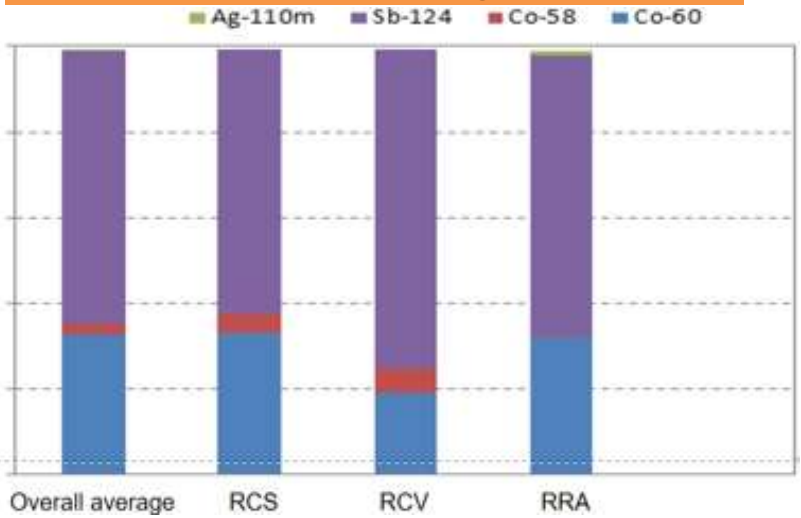
With the temperature increases, the solubility of silver oxide increases.



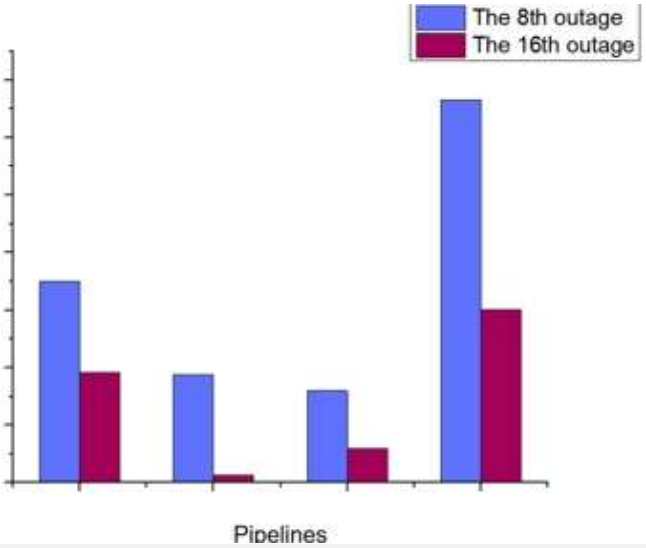
- **Optimize parameters of forced oxidation.**
- **Ag-110m tends to deposit in auxiliary systems with lower temperatures (such as the chemical and volume control system), resulting in significant dose rate contributions.**

Deposited activity reduction of a unit

Major nuclide dose rate contribution ratio in the 8th outage



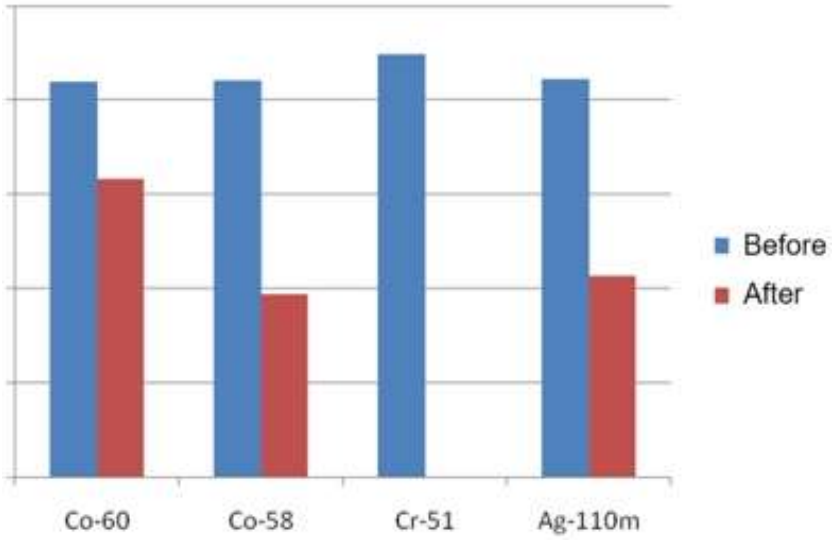
Sb-124 activity reduction



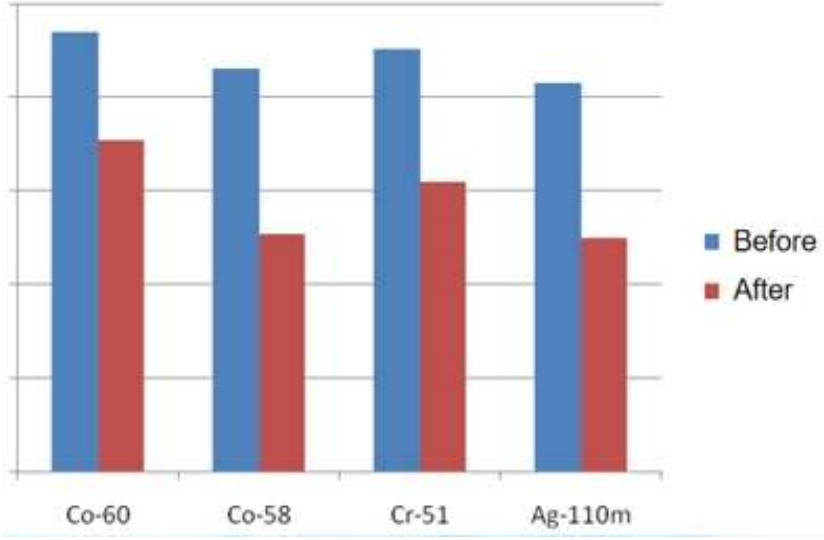
- **Anomaly: During the 8th outage of a unit, Sb-124 activity deposited on the inner wall of the pipeline was abnormally high, and Sb-124 contributed the most to the dose rate .**
- **Analysis: Pump bearings and shaft seal containing antimony (Sb) are used extensively.**
- **Suggestion: Replace the sealing material containing Sb in the primary loop.**

Chemical decontamination verification of a unit

Activity comparison before and after decontamination in a pipeline



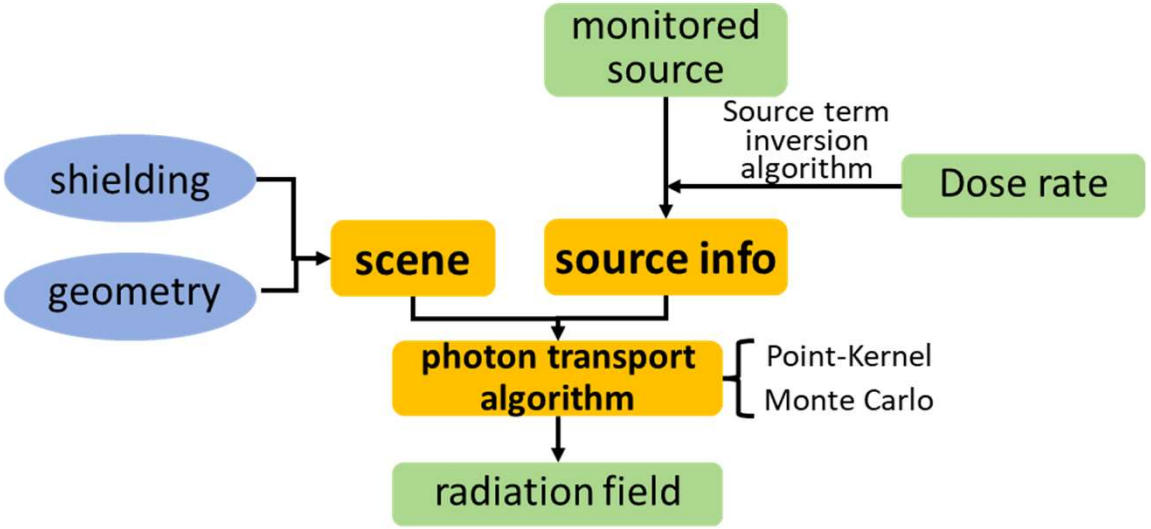
Activity comparison before and after decontamination in another pipeline

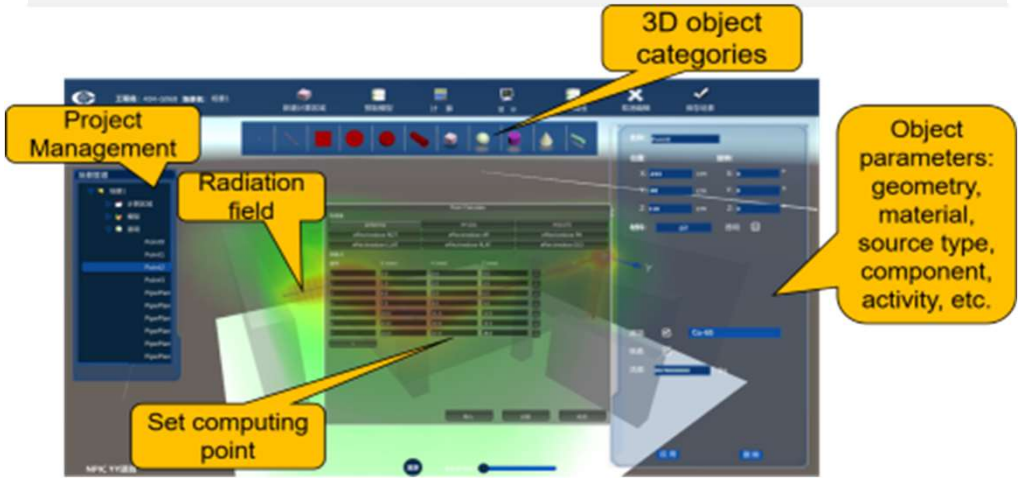


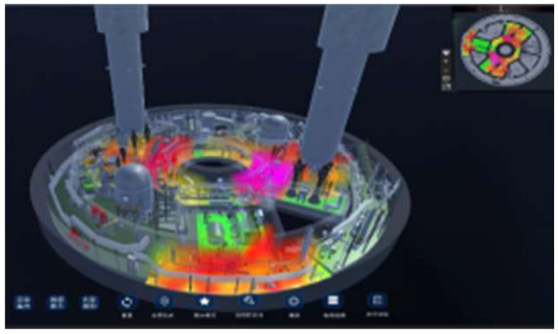
- **According to the measurement results of activity before and after decontamination of the system pipeline, the decontamination effect was analyzed and evaluated.**

Radiation field simulation based on monitored source terms

- The gamma radiation field simulation can be performed based on monitored source terms.
- Based on a interactive modeling tool, it enables radiation scenario modeling, photon transport calculation, and shielding calculation.

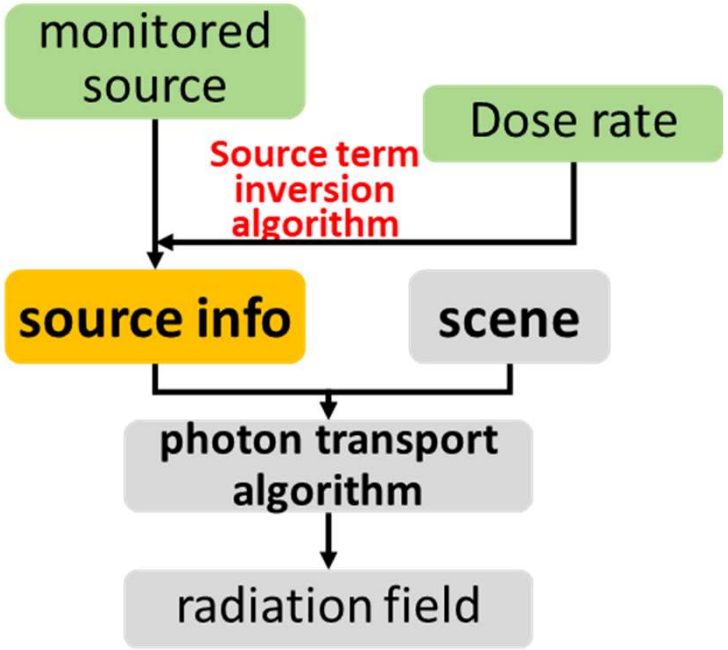






Dynamic update of radiation field based on monitoring data

- **A source inversion technique is used to estimate the source strengths based on a dose mapping and the knowledge of previous measurement data such as the source positions and the isotopic composition. Then it further facilitates dynamic updates of the radiation field.**



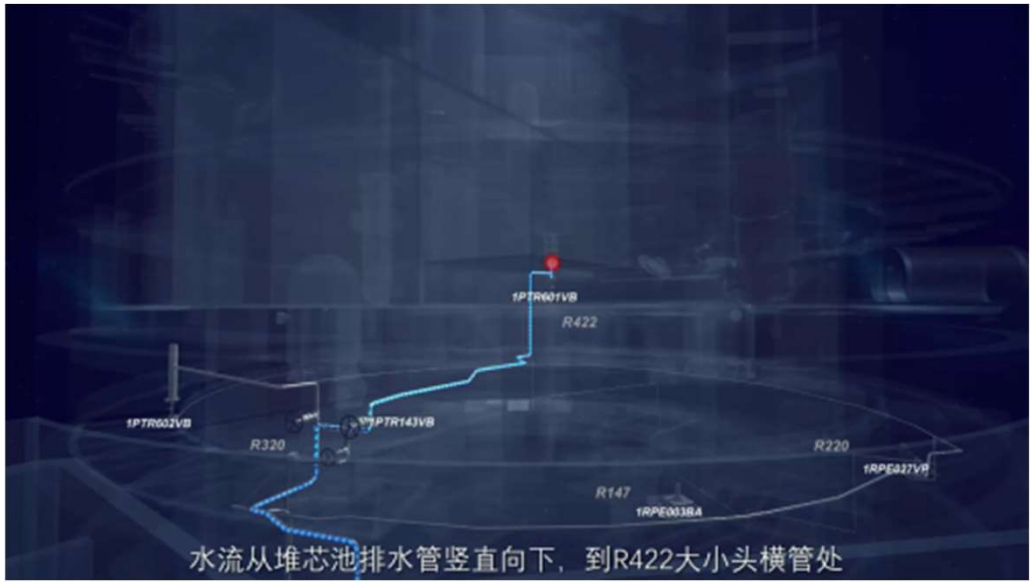
3D visualization of radioactive systems in nuclear facilities

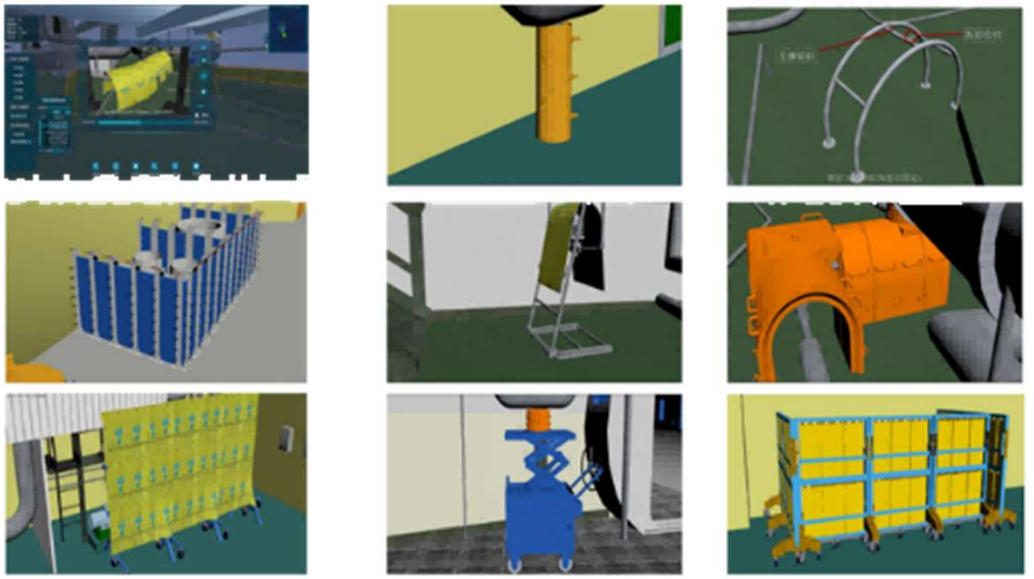
- **Integrated with the radioactive system model of nuclear facilities, it provides 3D visualization of hotspot distributions, employing color gradients to indicate the radioactivity. It shows information of typical hotspots, including source distribution, activity, composition and ambient dose rate data of the locations.**

3D visualization of radioactive systems in nuclear facilities

- **Integrated with the decontamination process of radioactive hotspots in nuclear facilities, it virtually demonstrates the migration patterns of hotspots within the radioactive system.**

- **The system demonstrates the assembly and disassembly procedures of hotspot shielding devices in nuclear facilities, providing virtual training capabilities.**





Summary

- ACPs measurements are the key part of the radiation monitoring for nuclear power plants.
- A series of in-situ measurement systems for radiation source terms have been established to meet the needs of regular monitoring.
- Preliminary application indicates that the current measurement technology and scenario meet the requirements, and the types of nuclides for ACPs mainly include Co-60, Co-58, Ag-110m, etc.

THANKS!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