Development of Hot Cell Facility at CIAE

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Abstract

This paper introduces about the status and the development program of hot cell facility for post irradiation examination (PIE) of reactor fuels and materials at the China Institute of Atomic Energy (CIAE).

China now has only four PIE hot cell facilities. Comparing with the advanced hot cell facilities of the nuclear developed counties, these facilities are relatively small in scale and shortage in advanced PIE techniques.

In adapt to the nuclear development program, a multi-function and comprehensive hot cell facility will be designed and constructed in China. Advanced PIE techniques and equipment will be installed at the hot cells. The facility will be used to carry out comprehensive and detailed research work, including the handling and examination of fuel assembly, fuel rod and structure materials from different kind of reactors.

Key words: fuel assembly; hoe cell; post irradiation examination;

1. Background of hot cell facilities in China

Only two organizations in China possess PIE hot cell facilities. One is China Institute of Atomic Energy (CIAE) in Beijing which owns three hot cell facilities named as RFMEF, CARR NDE Hot Cell and CEFR Initial Examination Hot Cell; the other organization is Nuclear Power Institute of China (NPIC) in southwest china. RFMEF and the hot cells in NPIC were built in the nineteen seventies, the two other facilities are coming into operation.

Comparing with the advanced hot cell facilities of the nuclear developed counties, they are relatively small in scale and shortage in advanced PIE techniques.

2. Introduction to the RFMEF

2.1 Description of the hot laboratory

Reactor Fuel and Material Examination Facility (RFMEF) is the hot laboratory which was designed and constructed at the site of CIAE. It is about 40km away from the down town area of Beijing.

The facility was built in conjunction with the two rectors in the China Institute of Atomic Energy (CIAE) in order to carry out comprehensive post-irradiation examination to reactor fuels and materials.

RFMEF consists of two buildings: the main building is for hot cell examination with

construction area of about 1650 m^2, the other is ventilation center.

The facility was designed in 1969, construction began in 1970. For some reason it was suspended for a period of time, reconstruction began in May 1976. It finally came into operation in October 1978. It is the first PIE hot laboratory in China which can perform radioactive handling and examination for fuel rods and materials irradiated in research reactors.

2.2 Layout of RFMEF

The facility is a local two floor building. The first floor includes 9 beta-gamma concrete hot cells, X radiography room, 2 semi-hot cells for mechanical test of materials, operation area, maintenance area, safety guard room, power control room, radiation monitor room, air supply room, entrance for truck, solid wastes storage room, technological rooms, etc. First floor plan arrangement of the facility is shown in figure 1.

The second floor is the transport hall with a 5-ton bridge crane.

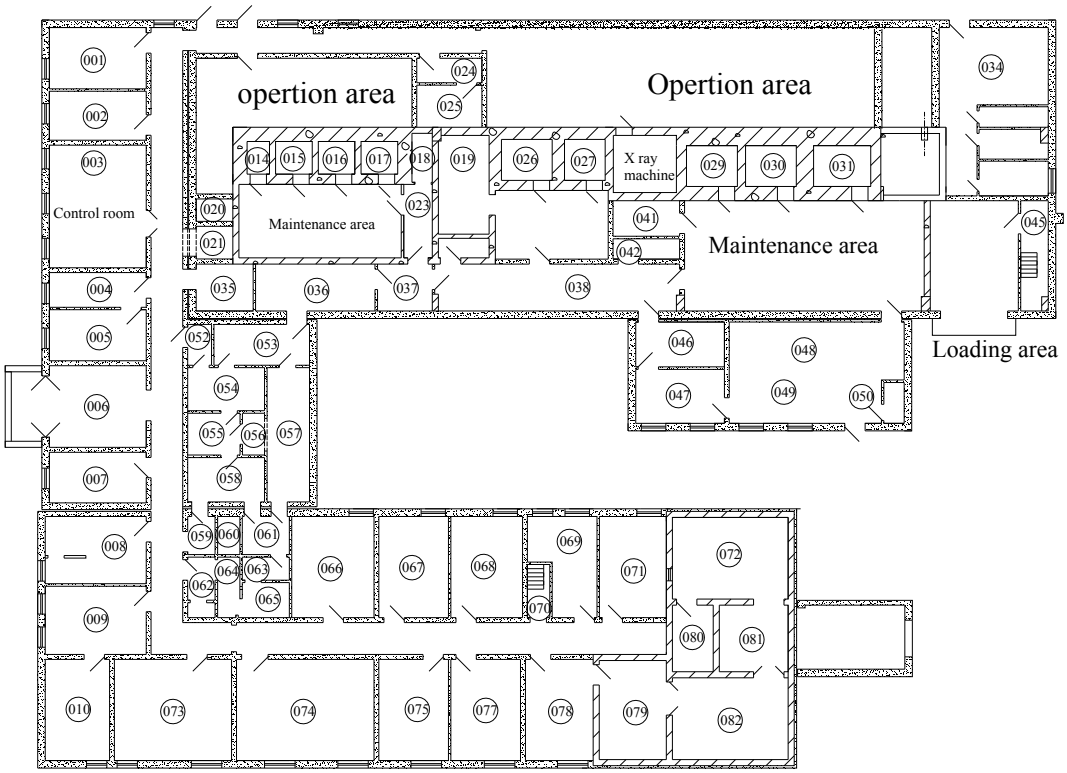

Fig.1 First floor plan arrangement of the facility

The main purpose of establishing the hot laboratory was performing post irradiation examination to reactor fuels and materials tested in research reactors.

2.3 Description of the hot cells

The hot cells are divided into three groups. The first group consists of three cells mainly for the storage, cutting and non-destructive examination of fuel elements; the second group

consists of two cells for mechanical property test; the third group consists of four cells for metallographic and structural analysis. All concrete hot cells are lined with stainless steel. Some technical parameters are listed in table 1.

Table 1 Technical parameters of the hot cells

No. of Hot cell	Inside dimension W×D×H(m)	Shielding capacity （Ci）	Wall thick ness（mm）	No. of windows	Functions
1	2.8×2×3.3	10^4	900	1	Storage of spent fuel, visual inspe dismantling of fuel assembly
2	2.5×2×2.2	10^4	900	1	Rod cutting
3	2.5×2×2.2	10^4	900	1	NDT of fuel rods
4	2×2×2.2	10^2	600	1	Puncture of fuel rods, fission gas re measurement
5	2.5×2×2.2	10^2	600	1	Tensile test
6	1.8×1.6×2.2	10^3	700	1	Vacuum resin mounting
7	1.8×1.6×2.2	10^3	700	1	Grinding and polishing
8	1.8×1.6×2.2	10^3	700	1	X ray diffraction
9	1.1×1.6×2.2	10^3	700	1	Metallographic analysis

2.4 PIE techniques and apparatus

2.4.1 PIE techniques

-Visual inspection and photograph of fuel assembly and rod

-Dismantling of tested assembly

-Crude removal of fuel rod

-Non-destructive examination of fuel rods: including Dimension measurement, eddy current testing, Gamma scanning for relative burn-up measurement and slit scanning X radiography.

-Destructive examination of fuel rods: including puncture and fission gas release measurement, fuel rod cutting, vacuum resin mounting, polishing and etching, metallography and ceramography.

-Mechanical tests: tensile test, micro hardness test, creep test, fatigue test and burst test.

-Microstructure analysis.

2.4.2 PIE apparatus

-Lead cask varying from 3t to 5t.

-Three periscopes for observations of fuel rods, tensile test specimen and metallographic specimen respectively.

-Dimension measurement bench

-Eddy current testing and Gamma scanning bench

-Slit scanning X radiography device

-Rod puncture and fission gas release measurement device

-Gas chromatograph for fission gas analysis

-Sawing and cutting machine
-Tensile teat machine
-Creep test machines: 13 sets, with loading capacity of 30-3000kgs
-Burst test machine
-Vacuum resin mounting device
-Grinding and polishing machine
-X ray diffraction machine
-Remote Control Optical Microscope

2.5 Refurbishment of the RFMEF

2.5.1 Background

RFMEF is a hot laboratory built in CIAE in 1970s for post-irradiation examination reactor fuels and materials. After 30 years of operation, some of the technological system and especially the hot cell auxiliary system were out of age and could not conform with the current laws and regulations. To eliminate the potential hazards and improve the examination process some equipments and systems have been renovated. Refurbishment work began in September 2004.

2.5.2 Contents of modification

-Renovation of power supply system：All electric boards and cables were replaced with new one. A spare system for power supply was established.

-Replacement of Master-Slave manipulators: all 17 M22 manipulators were replaced by domestic made ZC 109 manipulators.

-Renovation of gamma monitor system

-Modification of gaseous effluent monitor system: A PING real time monitor system has been installed at the facility for environmental protection.

-Modification of ventilation system: All motors and filters were replaced with new apparatus. Ventilation pipes were replaced by stainless steel. Programmable Logic Controlled (PLC) system was equipped for the adjustment of air supply and exhaustion.

-Security and protection system is established.

2.4 Research activities conducted

RFMEF has played a very important role for the evaluation of reactor fuel performance and to the development of nuclear industry in China. Research activities conducted are listed below:

- PIE of fuel elements and materials tested in the heavy water research reactor and the swimming pool reactor in CIAE.
- PIE of 3×3-2 fuel assembly simulated to Qinshan NPP.
  The assembly was tested in the HTHP loop of HWRR, with burn-up of 30GWd/tU.
- PIE of spent fuel rods (burn-up 40GWd/tU) from Qinshan NPP.
- Surveillance test of RPV specimen for Qinshan NPP.
- Structure modification to surveillance capsules for Qinshan and C-1 nuclear power plant.
- Failure mechanism study to in-core components from nuclear power plant.

3. CARR NDE Hot Cell

3.1 Functions

CARR hot cell is adjacent to China Advanced Research Reactor (CARR). It is a large non-destructive examination hot cell, shielded with heavy concrete and lined with stainless steel. A slope hole is installed inside the side wall of the cell which is connected with storage pool of the reactor. This hot cell is the first one in China which can perform full size non-destructive examination to the fuel rods from nuclear power plant. This facility was designed in April 2002 and will come into operation in December 2009. Figure2 shows the front area of the hot cell.

Fig.2 Front area of the hot cell.

Besides PIE of fuel assembly, fuel rod and materials irradiated in CARR, PIE of full size fuel rods from PWR can also be conducted in the hot cell. It mainly serves for:

−Transfer of CARR fuel assembly
-Non-destructive examination of CARR fuel assembly
-Non-destructive examination of fuel rods from PWR
-Dismantling and NDE of irradiation capsules for material test
-Dismantling of radioisotope targets
-Transfer of fuel rods, radioisotope targets and irradiated materials

3.2 Technical specifications of the hot cell

Inside dimension of the hot cell is 7m×2.2m×4.1m（L×W×H）.The walls are made of heavy concrete of 4.2 g/cm^3. Thickness of the front wall is 1.3m, which allows a maximum activity of 3700TBq (10^5 Ci) for Co-60.

Three pairs of MT 200 master slave manipulators and three view windows are installed at the front wall. Other basic equipments of the cell consist of:

-Cast iron protection door and sealing door
-A two-direction 2kN stainless steel crane
-One slope transfer tunnel for access of CARR irradiated fuel assembly

-One horizontal transfer tunnel for the access of fuel assembly and fuel rod from PWR nuclear plant.

-Five storage wells are arranged in the rear area of the cell for the storage of spent fuel assembly from CARR. Dimension of the wells is Φ150mm in diameter, 2500mm in depth.

-Equipment transfer tunnel: 1600mm × 1400mm × 800mm, is for the transfer and maintenance of the numerical controlled miller and the multifunctional bench.

-An electric & hand driven trolley for transferring 250kN lead cask from outside to the hot cell.

-Extended chamber for the full size examination of PWR fuel rods and real time X radiography.

-Operation and control boards at the operation area.

3.3 NDE techniques and Examination equipments

A series of test equipments are installed in the cell for the dismantling and non-destructive examination of fuel assemblies, fuel rods and irradiated materials.

In accordance with the nuclear power development program to perform non destructive examination to the full size PWR fuel rods, a multifunctional NDE bench has been designed and installed in CARR hot cell. It can perform NDE to fuel assembly of CARR, fuel rods from PWR and the fuel rods tested in CARR. An external lead chamber is coupled with the bench for the movement of the fuel rod. A real time X radiography system is installed inside the chamber. NDE techniques include:

-Visual inspection and photograph -Multifunction bench for test devise: Visual inspection and photograph

-Dimension measurement

-Eddy current testing for oxide film measurement

-Gamma scanning for relative burn-up measurement

-Real time X radiography

A numerical controlled miller is equipped inside the hot cell for the dismantling of fuel assembly, irradiation capsules and targets.

A Periscope and 2 video cameras are also installed in the hot cell for observation inside.

For transportation of spent fuel rods from nuclear power plant a transport container (R52) has been imported from NCS Company of Germany in September 2002. This container can be used to transport fuel rods of both PWR and BWR including failure fuel rods. It is 21,000 kg with absorbers and 18,290 kg without absorbers. Outside dimension is 5867mm long, 980mm in diameter. The useful inner dimension is 4520mm in length and 220mm in diameter. It can load 40 fuel rods at the maximum.

4. CEFR Initial Examination Hot Cell

4.1 Introduction to the CEFR initial examination hot cell

CEFR initial examination hot cell is built adjacent to the China Experiment Fast Reactor (CEFR). This hot cell is for the initial examination of fuel assembly and materials tested in CEFR. Fuel assembly get into the cell through a Φ150mm vertical transport hole.

4.2 Main technical parameters

-Dimension of the hot cell: 6.6m×2.2m×4.3m

-Shielding wall thickness and density:

-Front wall: 1.2m density: 3.6g/cm^3

-Back wall: 1.1m density: 2.3g/cm^3

-Top wall: 0.8m density: 2.3g/cm^3

-Front wall: 0.4m density: 3.6g/cm^3

4.3 Composition of the hot cell

4.3.1 Hot cell equipment

-Cell linear: 0Cr18Ni9; 6.6m×2.2m×4.3m.

-View window (3 pieces): 1000mm×900mm×952mm (L×W×D)

-Master slave manipulator: 3 pairs, model: MT 200

-Cast iron plate

-Cast iron protection door and sealing door

-Storage wells and shielding plugs (8 pieces): Φ159mm in diameter, 4500mm in depth.

-Equipment transfer tunnel: 1800mm × 1600mm × 800mm, is for the transfer and maintenance of the miller and the testing equipments.

-Vertical transport hole: Φ150mm, for fuel assembly to get into the cell

-Stainless steel crane: 2kN

4.3.2 Test equipments

- Disassembly miller:

-Assembly test device:

-Fuel rod dimension measurement and EC test bench

-Slit scanning X radiography device

- Periscope

-Gamma scanning device

4.4 Examination process

This hot cell undertakes only non-destructive examination to the spent fuel assembly from CEFR. Visual inspection is first performed to assembly. After that it is dismantled and non-destructive examination is taken to fuel rods, which includes visual inspection, dimension and bending measurement, eddy current testing for defects of cladding, X radiography for status of cladding and pellets. Initial performance data is obtained for fuel assembly and fuel rod through NDE. After that fuel rods are loaded into lead cask and transferred to other hot cell facilities for detailed examination.

5. Future designs for the Advanced Hot Cell Facility

5.1 Objectives for the design of advanced hot cell facility

China has a great need for nuclear energy and is developing nuclear power plant with rapid speed. The nuclear power plants now come into operation and under construction have different type of reactors, including PWR, PHWR and FBR.

To match with the nuclear developing program high performance fuel assembly and structure materials are under development. Post-irradiation examination is an indispensable

step to confirm the integrity and in-core performance of fuel assembly and structure materials after irradiation. Advanced hot cell facility and PIE techniques are therefore required.

5.2 Conceptual design of the new hot cell facility

The facility consists of a storage pool and 4 hot cell lines. The first cell line has 7 β-γ concrete cells for examination of fuel assembly and fuel rod of PWR and PHWR, the second cell line has 7 β-γ lead cells for microstructure analysis of fuels and materials, the third cell line has 4 α-γ concrete cells for examination of fuel assembly and fuel rod of FBR, the fourth cell line has 11 β-γ lead cells for mechanical testing of materials. Arrangement of the new facility is shown in figure 3. Advanced PIE techniques and equipment will be installed at the hot cells. This facility will be used to carry out comprehensive and detailed PIE, including the handling and examination of fuel assembly and structure materials of such power reactors as PWR, FBR, PHWR, and fusion reactor in the future.

5.3 Advanced PIE techniques and instruments

-Transport containers will be designed and manufactured for the transportation of spent fuel assemblies from nearly all NPP reactors, including PWR, PHWR, FBR.

-A large storage pool will be built for the storage of fuel assemblies.

-Re-fabrication techniques will be equipped in the facility for ramp and high burn-up irradiation test.

- Advanced microstructure analysis instruments such as SEM, TEM, EPMA, SIMS, X ray diffraction machine will be equipped.

-Mechanical testing machines will be enlarged to instruments such as creep teat, burst test, fatigue test, stress corrosion crack and other mechanical test.