Commissioning of the Jordan Research and Training Reactor (JRTR)

Dr. Khalifeh AbuSaleem

Commissioner for Nuclear Research
JRTR Manager During Construction & Commissioning Phase
Jordan Atomic Energy Commission

Facility Description

Reactor Type	Open Pool
Thermal Power (MW)	5 (upgradable up to 10)
Max. Thermal Neutron Flux ($n/cm^2 \cdot s$)	1.5×10^{14} in the core (central trap) 0.4×10^{14} in the reflector region
Fuel Type & Material	Plate type; 19.75% enriched, U_3Si_2 in Al matrix
Fuel Loading	18 fuel assemblies, 7.0 kg of U^{235} (Equilibrium cycle)
Coolant/Moderator Cooling Method	H_2O Downward, forced convection flow
Reflector	Be + D_2O
Utilization	Multipurpose - Neutron beam applications (n science, n radiography, etc.) - Neutron irradiation services (RI production, NAA, NTD, etc.)

Commissioning Objectives

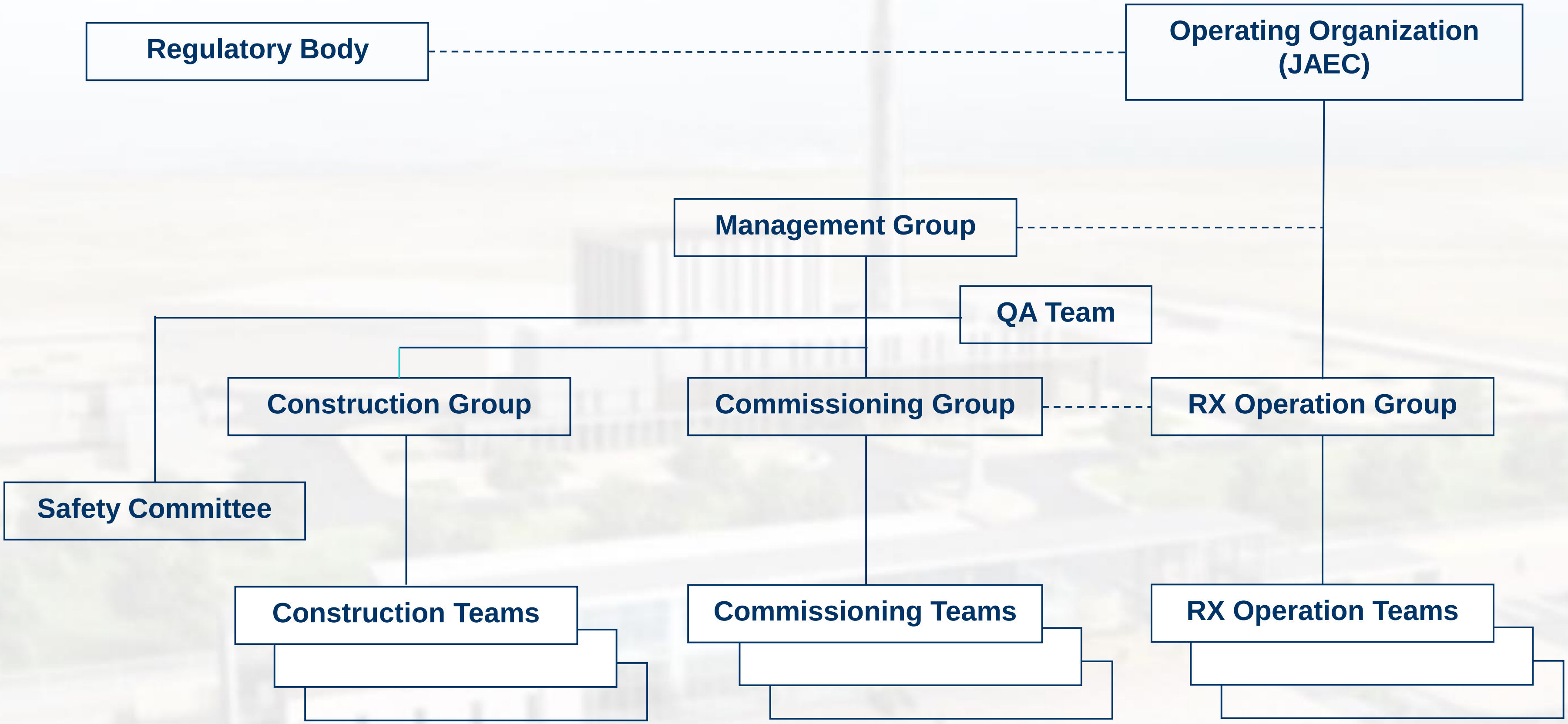
Safety Guide No. NS-G-4.1, Commissioning of Research Reactors, IAEA, 2006

- To verify that the installation and function of Systems, Structures and Components (SSCs) are commensurate with their importance to safety, before the facility is finally turned over to the JAEC;
- To demonstrate that the requirements and intent of the design as stated in the FSAR have been met;
- To ensure that the operation under all anticipated operational modes of the reactor is adequately verified;
- To provide basic data for the safe and reliable operation of the reactor;
- To verify that the documentation is adequate for full facility operation;
- To provide the operations staff with the opportunity for education to ensure the validity of the reactor operation procedures;
- To make the end-users aware of the characteristics of the facility

Commissioning Stages

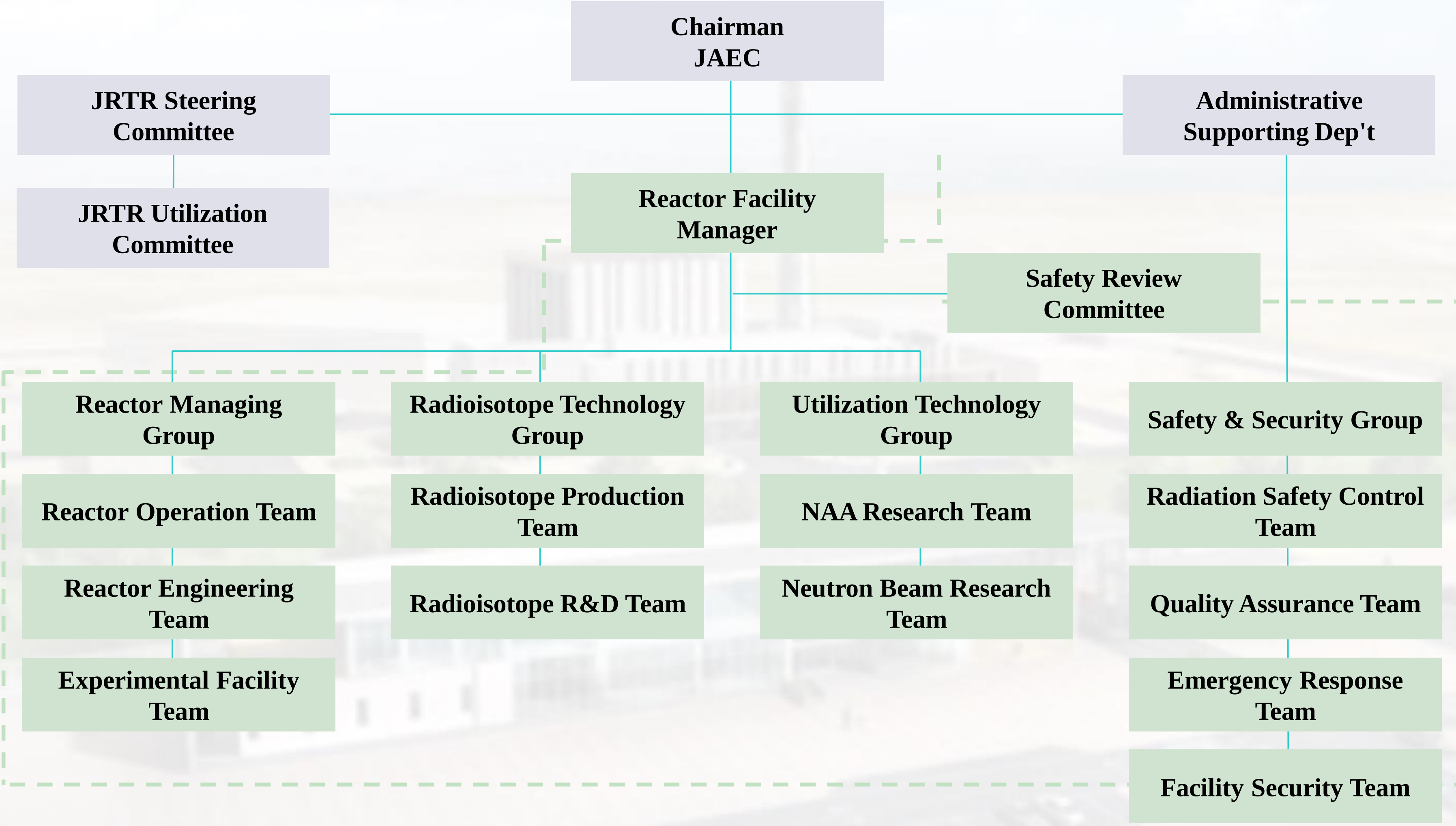
1. Stage A1 : Construction Acceptance Tests (CATs);
2. Stage A2 : Flushing and System Performance Tests (SPTs);
3. Stage A3 : Integrated System Tests (ISTs);
4. Stage B1 : Fuel Loading and Initial Criticality;
5. Stage B2 : Low-Power Tests;
6. Stage C : Power Ascension and Full-Power Tests

Commissioning Organization



Commissioning Organization

Establish Initial Reactor Operation Organization before Fuel Loading



Management Group

JAEC Project Manager (PM), KAERI PM, DAWEOO Site PM, and JAEC Reactor Manager

- **Provide strategic oversight & resources for commissioning:**
  - **authorize the official start of commissioning**
  - **declare the acceptance of commissioning results**
  - **review the commissioning plan and monitor its implementation**
  - **Follow the NCRs and the appropriate corrective actions, and**
  - **coordinate between the commissioning groups.**
- **The group also plays vital role in providing resources and making lines of communication between all relevant groups and parties.**

Reactor Operation Group

- **Participate in Commissioning Activities**
  - **Gain Experience in System Operation & Maintenance**
  - **Ensure Compliance with Design Requirements, Performance & Safety**
- **Reactor and Facility Operation**
  - **Operation Procedures & Direction of Commissioning Group**
- **Implement Radiation Protection Plan & Procedures**
- **Enforce Emergency Plan & Procedures**
- **Secure Facility & Materials**

Summary of CAT tests (A1)	
Area	Number of tests
Mechanical	1563
Electrical	2699
I&C	1443
Total	5705
67 kinds of components and equipment	

SPT (A2)
To check whether the system functions as designed

System	System	System
Switch gear	Load center	Helium gas supply system
MCC	Uninterruptible power supply	Primary cooling system
Process instrument & control system	Radiation monitoring system	Pool water management system
Automatic seismic trip system	Reactor area surveillance system	Hot water layer system
Reactor protection system	Reactor regulating system	Heavy water system
Alternative protection system	Information processing system	Emergency water supply system
OWS & LDP in MCR	Post ac4cident monitoring system	Secondary cooling system
Measurement of RPS response time	Service water system	Solid radwaste system

SPT (A2)
To check whether the system functions as designed

System	System	System
Liquid radwaste system	Active drainage system	Physical protection system
Reactor building HVAC system	RCI ventilation system	Service building HVAC system
Confinement leak rate test	Plumbing system	Fire water and gaseous extinguishing system
Fire alarm and detection system	Material handling system	SSDM
CRDM	Pre-service inspection for reactor components	NAAF
Fuel storage and handling	Pre-service inspection for SC-pressure retaining components and support structure	In-core flow distribution measurement
Raw Water System	Air Discharge System	

SPT

Switch Gear

Objective: To confirm that electric status variables of each switchgear (33kV / 4.16kV) of JRTR are correctly monitored at the OWS in the MCR.

Load Center

Objective: To confirm that electric status variables of each Load Center (480V) of JRTR are correctly monitored at the OWS.

Motor Control Center

Objective: To confirm that electric status variables of each 480V motor control center of JRTR are correctly monitored at the OWS.

Uninterruptible Power Supply

Objectives:

- To check the operating status of the AC Uninterruptible Power System (UPS) by the DC power supply;
- To check the operating status of the regulating transformer and UPS by an emergency AC power supply;
- To check the operating status of battery charger and UPS at the main control room in accordance with the design drawing.

SPT

Process Instrument & Control System (PICS)

Objectives:

- To verify PICS cabinet is according to drawings;
- To verify functions of Power Distribution Unit (PDU);
- To verify functions of the control transfer switch;
- To verify functions of the interface with IPS, OWS;
- To verify the functions of the UPS power supply.

Radiation Monitoring System (RMS)

Objectives:

- To verify that the RMS measures, indicates and records radiation dose rates and airborne radioactive material concentrations in selected areas, process systems and radioactive effluents, are within tolerance level;
- To verify that alert and alarm of the RMS function properly;
- To verify that control, monitoring and diagnostic functions of RMS work properly.

SPT

Automatic Seismic Trip System

Objectives:

- To test the seismic trigger, trip, bypass and automatic trip functions;
- To test calibration of AIM (zero point);
- To test sensor functions

Reactor Area Surveillance System

Objectives:

- To verify that the 14 cameras are in correct places;
- To verify that the 14 camera views are shown on Large Display Panel;
- To verify that the (master control panel) controls all the functions, etc.

SPT

Reactor Protection System

Objectives:

- To check the indication of process values in MTSP;
- To check the function of the reactor trip;
- To check the function of the siphon break valve actuation;
- To check the function of the confinement isolation damper actuation;
- To check the function of the operating bypass;

Reactor Regulating System

Objectives:

- To verify RRS hardware is installed according to drawings;
- To check RRS related sensor signals are normal;
- To verify RPS trip signal handling function;
- To verify SSR withdrawal and CAR manual control function;
- To verify power control function in auto control mode;
- To verify setback/drive-rod-in/training operation switching functions;
- To verify CAR/SSR rod drop test function

SPT

Alternative Protection System

Objectives:

- To check the indication function of the Maintenance Computer (MC);
- To check the function of the Bistable Controller (BC) to generate bistable signals;
- To check the function of the Initiation Circuit (IC) and Actuation Circuit (AC) to generate reactor trip actuation signals including manual trip function

Information Processing System

Objectives:

- To check the function of data communication between the IPS and the interface systems;
- To check the primary display functions (Alarm, PAM, SPD, BISI display);
- To check the functions of information recording and retrieval;
- To check the functions of the Engineering and Maintenance Computer (EMC)

OWS & LDP in MCR & SCR

Objectives:

To test the functions:

- Display of OWS pages onto LDP;
- Display of drawing documents such as CLD (Control Logic Diagram), SLD (Single Loop Diagram), and P&ID;
- Historical data handling;
- Miscellaneous functions

SPT

Post Accident Monitoring System

Objectives:

- To check the function and the performance of the PAMS;
- To check the single component failure of the PAMS;
- To check the common cause failure of the PAMS hardware

Measurement of RPS Response Time

Objectives:

- To check the response time of the reactor trip;
- To check the response time of the siphon break valve actuation;
- To check the response time of the confinement isolation damper actuation

Service Water System

Objectives:

- To check the performance of the demineralized water production facility;
- To check the functions of the Motor Operated Valves (MOV);
- To check the functions of the service water pump;
- To check the functions of the demineralized water pump;
- To check the performance of the DWST purification system;
- To check alarms and discrepancy for the Service Water System (SWS)

SPT

Compressed Air System

Objectives:

- To check the functions of the manual and group control operation;
- To check the function of the after-cooler;
- To check the function of the air dryer;
- To check the function of the Air Operated Valve (AOV);
- To check the function of the Pressure Control Valve (PCV);
- To check alarms and discrepancy for the Compressed Air System (CAS)

Helium Gas Supply System

Objectives:

- To check the functions of the pressure control valve (PCV);
- To check the functions of the moisture detectors (MS);
- To check alarms and discrepancy for the Helium Gas Supply System (HGSS)

SPT

Primary Cooling System

Objectives:

- To measure the system flow rate of the Primary Cooling System (PCS);
- To check the performance of the PCS pumps;
- To check the functions of the siphon break valves;
- To check the functions of the flap valves;
- To check alarms and discrepancy for the PCS

Pool Water Management System

Objectives:

- To check the storage function of Pool Water Storage Tank (PWST);
- To check the performance of the Pool Water Management System (PWMS) pumps;
- To adjust the system flow rate of the PWMS;
- To check the filling procedure of the resin;
- To check the alarms and discrepancy for the PWMS;
- To check the PWMS filter element replacement process

Summary of IST Tests (A3)
Power operation
LOEP test
Training operation

IST

Power Operation

Objectives:

Overall JRTR systems and equipment are integrated and their functions for reactor power operation are tested without fuel in the core.

- System Check before Startup;
- Startup of fluid systems and system check;
- Reactor power operation;
- Trip during power operation;
- Shutdown of fluid systems.

IST

LOEP

Objectives:

Equipment functions required for a safe reactor operation after LOEP shall work correctly:

- Class I, II, and III power work normally;
- All CARs and SSRs are at bottom position;
- Two flap valves and siphon valves are open;
- All I&C systems in MCR work normally.

Training Operation

Objectives:

Overall JRTR systems and equipment are integrated and their functions for reactor training operation are tested without fuel in the core. Training operation procedure is performed by manipulating software variable regarding reactor power

- System Check before Startup;
- Startup of fluid systems and system check;
- Reactor Training operation;
- Shutdown of fluid systems;

Fuel Loading, Low Power, Power Ascension and Full Power Tests

Test	Stage
Fuel loading and approach to criticality	B1
Excess reactivity measurement	B1
CAR/SSR rod worth measurement	B2
Measurement of kinetic parameters	B2
Measurement of void reactivity coefficient	B2
Measurement of flux distribution	B2
Measurement of isothermal temperature reactivity coefficient	B2
Training mode operation	B2
Natural circulation test	C1
Neutron power calibration	C1
Measurement of power reactivity coefficient	C2
Measurement of xenon reactivity	C2
Shutdown and monitoring capability of the SCR	C2
Cooling performance test of PCS and HWS heat exchangers	C2
Cooling tower capacity test	C2
Thermal neutron flux at IR0	C2
NAAF performance test	C2
RI production test	C2
Loss of primary flow test	C2
Loss of normal electric power test	C2
Radiation surveys to determine shielding effectiveness	C1,C2
I&C function tests during operation	C2

Overall Summary of Stage B1 Test Results (BEFORE FUEL LOADING)

Installation and Test of Neutron Source and Commissioning Instrumentation

Objectives:

- To install two BF3 detectors in addition to existing NMS (Neutron Monitoring System);
- To install neutron source into the core;
- To check operability and determine operation condition of 6 NMS channels and two BF3 detectors

Radiation Surveys to Determine Shielding Effectiveness

Objective:

- To obtain base line background radiation level before fuel loading

Test results (no criteria)	
Gamma Survey	0.16 μSv/h Maximum
Neutron Survey	No neutron count
Air and Effluent Survey	Lower than minimum detectable values

CAR/SSR Drop Time Measurement

Objective:

- To verify that CARs and SSRs actually drop within the required time;
- To verify that SSR is withdrawn within required time;
- To verify that RRS software regarding drop test works properly

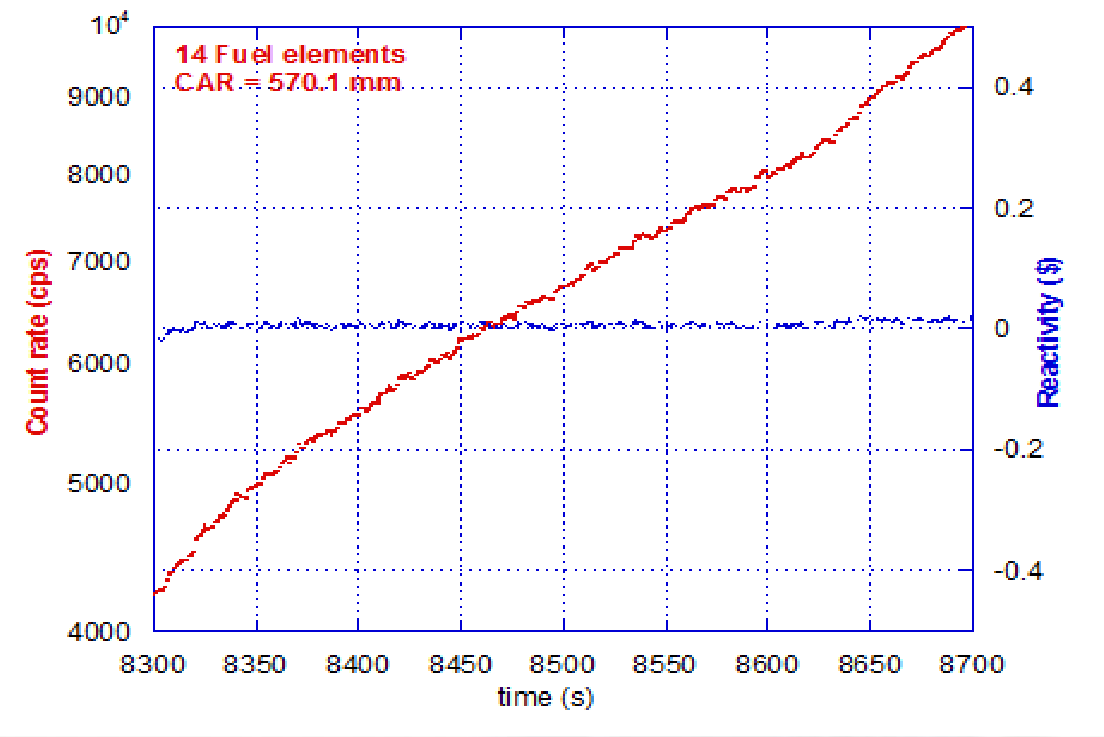
	Time
CAR Initial Delay	< 0.15 s
CAR Pure Drop	< 1.5 s
CAR Full Drop	< 3.0 s
SSR Pure Drop	< 1.5 s
SSR Full Drop	< 5.0 s
SSR Withdrawal	Between 15 s ~ 60 s

Examples from Stage B1

Fuel Loading and Approach to Criticality

Objectives:

- To make the minimum core for criticality;
- To check that the initial criticality can be achieved at the initial core predicted by the calculation



Examples from Stage B1

Excess Reactivity Measurement

Objectives:

- To measure excess reactivity by adding fuel assemblies one by one;
- To measure shutdown capability of CARs and SSRs;
- To measure CAR worth curve while they are at the same height below critical position

Additional FA, sequence	**Measured CAR position (mm)**	**Total CAR worth ($)**	**% Diff. from the calculated**
Critical core, 14	566.6	0.8958	16.09
FA15,1	454.8	2.4866	14.62
FA16,2	399.4	2.150	13.40
FA17,3	346.1	2.8473	13.09
FA18,4	311.5	2.167	11.85

Examples from Stage B2

CAR/SSR rod worth measurement

Objectives:

To measure integral and differential worth of each Control Absorber Rod (CAR) and integral worth of each Second Shutdown Rod (SSR):

a. 1/M measurement for CARs
b. Swap measurement for CARs
c. Drop measurement for CARs and SSRs

Criteria: At least one of the measured integral worth of each CAR from three different methods is within ±15% of predicted worth

Result: CAR worth by rod swap measurement is within ±15% of predicted worth.

Examples from Stage B2

Measurement of Kinetic Parameters (β/Λ)

Objectives:

- To measure the kinetic parameter at critical state using two BF3 detectors;
- To determine the power conversion factors of BF3 detectors and NMS channels

Criteria for (β/Λ): Difference between measured and calculated values is less than 20%

Result: 11.8% difference (calculated is 11.8 smaller than measured)

- Fission power and power conversion factors

The fission rate can be obtained from the measured average count rate and the fission power is determined by using 200 MeV/fission

Detector	Position	W/cps
BF3-1	OR6	2.342×10^{-8}
BF3-2	OR3	1.988×10^{-8}

Examples from Stage B2

Measurement of Void Reactivity Coefficient

Objective: To prove a negative void reactivity coefficient

Criteria: The measured void reactivity coefficient shall be negative

Result: Negative void reactivity coefficient

Measured void values based on measured CAR worth			
	Critical position (mm)	Reactivity worth ($)	Measured Void Reactivity Coefficient [$/%void]
No void	311	0	-
2.37% core	318.1	-0.571	-0.241
4.74% core	325.0	-1.106	-0.233

Measurement of Irradiation Object Reactivity Worth

Objectives:

a. To measure the reactivity worth of irradiation objects for Ir^{192}, I^{131}, and Mo^{99} production
b. To prove the reactivity worth of fixed and on-power loading irradiation rigs to be less than 10 mk and 1.5 mk, respectively.

Criteria:

- The reactivity worth of a fixed irradiation rig (Ir^{192} rig) shall be no more than 10 mk;
- The reactivity worth of an irradiation target during on-power loading and unloading (I^{131}, and Mo^{99} rigs) shall be lower than 1.5 mk

Result: Each reactivity worth of all irradiation rigs including IR0 rig is less than 0.5 mk

Measurement of Flux Distribution

Objectives:

- To measure neutron flux distribution as an indirect way of checking the reliability of prediction on power distribution;
- To get a power value during the irradiation of activation detectors;
- To check linearity of NMS power reading

Criteria: Within 10% difference between measurement and calculation

Result: The largest difference is 4.84%

Au wires and foils are installed at five representative fuel assemblies (FAs)and two RI capsules in the IR0 rig and irradiated at an estimated power 2 kW for 8 h. Polycarbonate

Detector	Position	W/cps	Measurement of Flux Distribution
BF3-1	OR6	2.342×10^{-8}	1.978×10^{-8}
BF3-2	OR3	1.988×10^{-8}	1.969×10^{-8}

Distance from vertical center of fuel [mm]	Fraction of thermal neutron reaction	Thermal neutron Cross section	Measured reaction rate (reactions/s/g)	Thermal neutron flux at 1.820 kW [n/cm2-s]
8.15	0.816	80.4671	6.871E+09	2.279E+10
6.25	0.819	79.6611	7.510E+09	2.525E+10

Measurement of Isothermal Temperature Reactivity Coefficient

Objective:

- To prove a negative isothermal temperature reactivity coefficient

Criteria: The measured isothermal temperature reactivity coefficient shall be negative

Results: Negative isothermal temperature reactivity coefficient

Variation of critical CAR position is measured while the pool water temperature is slowly increasing from 20 °C to around 44.5 °C. The reactor is kept critical by auto-control mode at around 1 W (NMS readings are10 W). The pool water is heated by hot water layer system heaters and PCS pumps. The reactivity effect of temperature is obtained from two CAR worth data -by measured CAR worth and by calculated CAR worth. The isothermal temperature reactivity coefficient which can be obtained by differentiation of the fitted curves is close to a linear function of the temperature.

Training Operation Mode

Objectives:

a. To adjust NMS fission chamber positions for normal power indication;
b. To make training operation possible up to 50 kW

Test: NMS fission chamber position

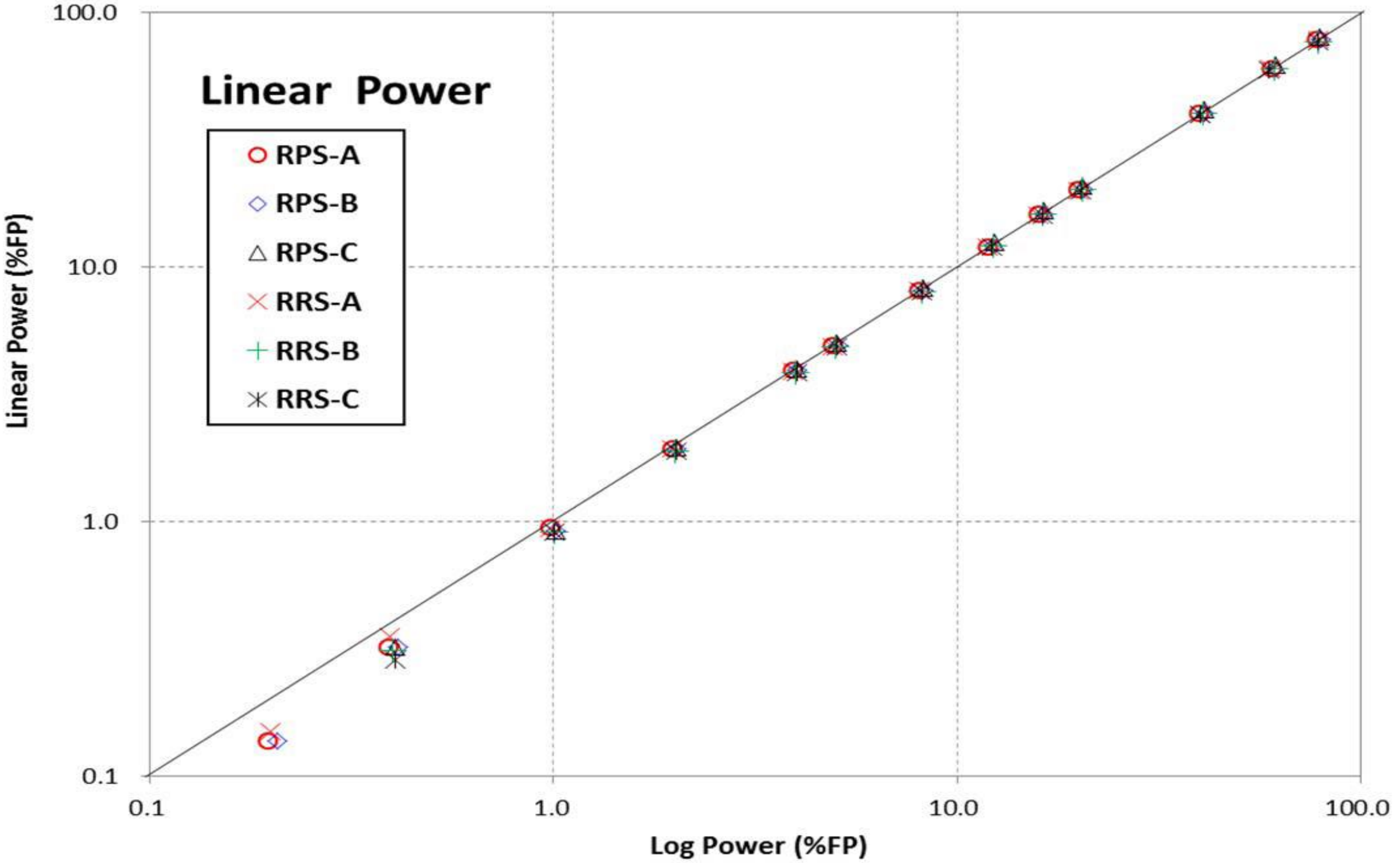
Criteria: Log power signals should be within the range where their calibration is possible without additional adjustment of the detector positions

Result: Log power signals are adjustable.

Test: Log rate

Criteria: When the reactor power varies with a stable period, the average log rate reading on OWS shall match the stable period.

Result: Log rate matches stable period.


Linear Power
RPS-A
RPS-B
RPS-C
RRS-A
RRS-B
RRS-C
100.0
10.0
1.0
0.1
Linear Power (%FP)
0.1
1.0
10.0
100.0
Log Power (%FP)

all

Stage C2 Tests

I&C function tests during operation at power operation

Objectives:

- To check overall functions and performance of equipment during the reactor performance test for "Power Operation".
- Fluid systems startup, reactor startup, power ascension operation up to 100%FP, and reactor shutdown sequentially.

Results:

- Power control performance: Power ascension up to 100%FP by the RRS was accurately and safely achieved. All RPS trip parameters are within safe operation ranges during the whole test period
- Fluid systems start operation before reactor startup. Their performances have been within acceptance criteria during the whole test period

Shutdown and monitoring capability of the Supplementary Control Room,

Objective: To verify that shutdown and monitoring functions of the SCR work as designed.

Checks: Transferring control command from MCR to SCR and vice versa.

Criteria: SCR on LDP is ON

Checks: Reactor trip using manual remote trip switches on the MTSP

Criteria: “Trip” is displayed on LDP

Checks: Monitoring safe shutdown status of the reactor

Criteria: All CARs and SSRs are at bottom position

Results: The control is successfully transferred from MCR to SCR. The reactor is tripped, fluid systems are shutdown and safe shutdown status of reactor is monitored in SCR successfully. After then, the control is transferred back to the MCR successfully

Loss of primary flow test at zero power

Objectives:

a. To confirm that the reactor trips as designed, upon the loss of all PCS pumps.
b. To verify that the fundamental safety functions of the safety systems and components are accomplished after the intentional loss of PCS (primary cooling system) flow at zero power.

Checks and Results:

a. Reactor trip as designed (Reactor trip as designed)
b. Fundamental safety functions working as designed (Working as designed)
c. Related reactor Parameters

Results: When two primary cooling pumps are turned off simultaneously during power operation at 50 kW, the reactor trips automatically and the fundamental safety functions work as designed. All relevant reactor parameters are within the range of the design for the safe shutdown.

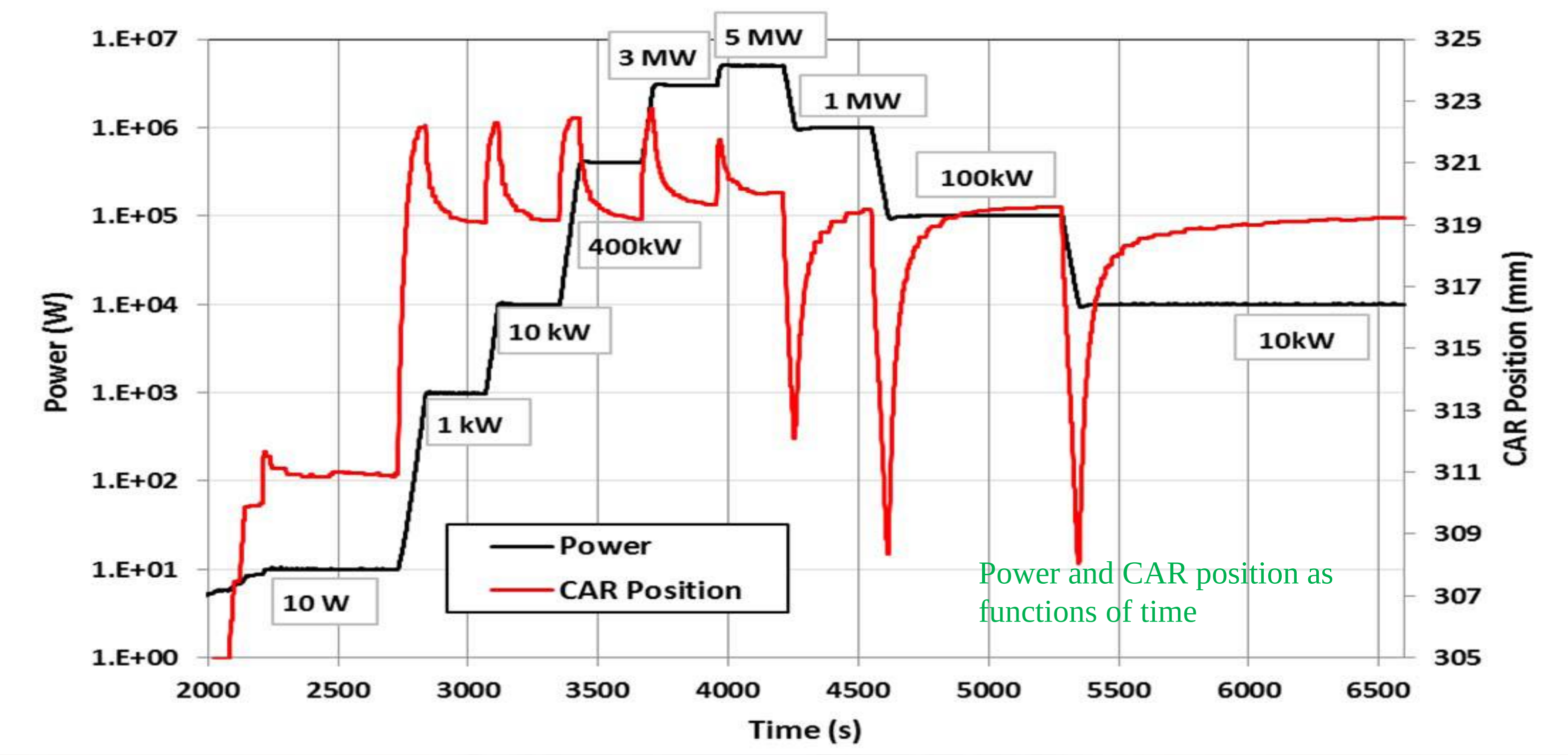
Measurement of power reactivity coefficient

Objective: To prove a negative power reactivity coefficient

Criteria: The measured power reactivity coefficient shall be negative.

Result: All measured power reactivity coefficients are negative.

The power variation is accomplished by the CARs. The movement of CARs is the major factor affecting the reactivity.



Power and CAR position as functions of time

Measurement of xenon reactivity ($\sigma_{E_{th}}$ = 2.65×10^6 barns)

Objectives:

a. To measure reactivity effect of xenon and its variation according to reactor power history
b. To measure xenon buildup behavior after shutdown

Results:

- Calculated equilibrium Xe worth and shutdown peak Xe worth are about 5% and 4% larger than the experimental values, respectively;
- Time to peak Xe agrees very well between calculation and experiment, which are 8.9 h and 8.91 h, respectively.

Thermal neutron flux measurement at IR0

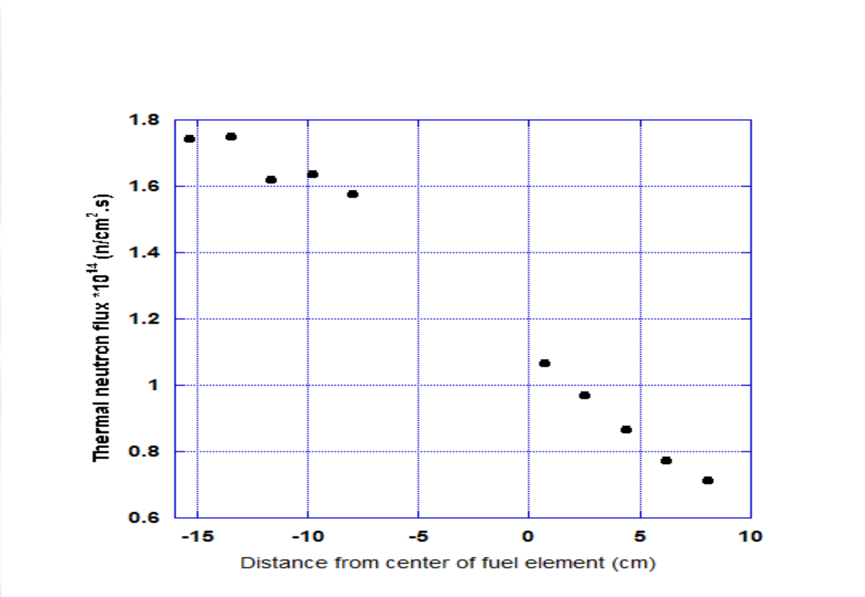
Objective:

To measure the maximum thermal neutron flux in dummy capsule of RI rig at IR0

Criteria: The measured maximum thermal neutron flux shall be at least 1.45×10^{14} n/cm^2-s

Test: The maximum thermal neutron flux of IR0 is measured by neutron activation of cobalt (Co) wires. Co wires are installed at the axial centers of the first and second capsules from the bottom of the RI rig, and irradiated in IR0 for about 30 min at 5 MW.

Result: Deduced maximum thermal neutron flux = 1.743×10^{14} n/cm^2.s



Loss Of Electric Power (LOEP)

Objectives:

a. To verify that the fundamental safety functions of the JRTR work as designed;
b. To confirm that the fuel integrity is ensured after the intentional loss of normal electric power (LOEP) during the full power operation

Check: SSCs to achieve fundamental safety functions

Result: SSCs are working as required

Check: Behavior of reactor power and coastdown flow

Criteria: The reactor power (neutron) and the PCS pumps coastdown flow shall be conservative compared to the results of analysis

Result: Conservative

Check: Fuel integrity

Result: No fuel failure during/after the test

Concluding remarks

Upon the LOEP, the reactor is shut down, decay heat is safely removed by the PCS coastdown flow followed by natural circulation, SSCs work as designed, and the fuel integrity is confirmed. The test also confirms that both post LOEP variations of power and PCS coastdown flow are conservative.

Results-LOEP

Reactivity control

The safety function for reactivity control is verified by checking the power trend, and the positions of the CARs. When LOEP occurs at full power, the instantaneous drop of CARs is identified on the OWS. The power decreases promptly to the corresponding level and monotonically to the level of decay power.

Pool Water Inventory Control

It is verified that there is no change in the pool water level

Core Heat Removal

The safety function for the core heat removal is verified by checking that the flow through the core is well established during this test:

1. The measured PCS coastdown flow meets the input requirement for the safety analysis
2. The flap valves and the siphon break valves are opened as designed

Fuel Integrity

The fuel integrity is ensured by: 1) checking no detectable fission product gamma rays in the sampled pool water and 2) verifying that there is no increase in the PCS neutron and pool surface radiation levels when the reactor is restarted to the full power after the test. The pool surface radiation level has been always less than 1 μSv/hr.

Cooling tower cooling capacity test

Objective:

To measure cooling performance of Secondary Cooling System (SCS).

Criteria: At least 5.2 MW at environmental condition for design

Result: 6.1 MW

Remarks

Measured cooling tower cooling capability is 6.1 MW at wet bulb temperature 30 °C. As the cooling capacity is sufficient and actual wet bulb temperature of the site is much lower than the 30 °C, temperatures of PCS, PWMS, HWS and pool water can be sufficiently lower than the design conditions.

NAAF performance

Objectives:

a. To check the performance of neutron activation analysis facility (NAAF) when the reactor operates at full power;
b. To verify whether the performance of pneumatic transfer systems (PTSs) meets design requirements, and gamma-ray spectrometer generates key data for the NAAF operation;
c. To demonstrate that the NAA can be carried out at the facility

Criteria and results:

1. The capsule transfer time for capsule insertion into irradiation time should be less than 10 s (measured: within 8.5 s);
2. The capsule transfer time for capsule withdrawal from the irradiation site should be less than 8 s (measured: within 5.6 s);
3. The relative standard deviation of the tests should be less than 5% (working as required);
4. In normal operation, the energy resolution and the detector efficiency of the γ-ray system should meet the specifications (Working as required).

RI production

Objectives:

a. To check the performance of the radioisotope production at full power operation;

b. To verify the maximum radioactivity of one irradiated target capsule for each of Ir^{192}, I^{131}, and $M^{99.}$

Criteria and results:

- Ir^{192}: 2,000 Ci (after 24 hours cooling) (2 weeks, 440 discs, produced 2716 Ci)
- I^{131}: $\geq$ 10 Ci (after 24 hours cooling) (one week, produced 14.54 Ci)
- Mo^{99}: $\geq$ 5 Ci (after 24 hours cooling) (one week, produced > 8 Ci)

Loss of primary flow test at full power

Objectives:

- To verify that the fundamental safety functions of the JRTR work as designed
- To confirm that the fuel integrity is ensured after the intentional Loss Of Flow (LOF) during the full power operation

Criteria and results:

- SSCs to achieve fundamental safety functions (Working as required);
- The reactor power (neutron) and the PCS pumps coastdown flow shall be conservative compared to the results of analysis (Conservative);
- No fuel failure during/after the test (No fuel failure).

Conclusions and Remarks

- **All planned experiments have been conducted successfully;**
- **The experiments verified the design parameters of the reactor. Particularly, the nominal power, the reactivity feedback, the thermal neutron flux, the radioisotope production facility capability and the performance of the neutron activation facility have been verified to function as designed;**
- **In some cases, like the thermal neutron flux peak and the radioisotope production capability have exceeded the design prediction;**
- **Therefore, the JRTR has been successfully commissioned and the**

Operational License has been granted.

Thank You