TECHNICAL RESEARCH ON SAFETY MANAGEMENT AND EFFECTIVE APPLICATION OF CHINA ADVANCED RESEARCH REACTOR

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Abstract

China Advanced Research Reactor (CARR) is a tank in pool type, light water cooled, heavy water reflected research reactor. The maximum thermal neutron flux of the reactor is 1.0×10^{15} $cm^{-2}s^{-1}$, and the reactor power is 60 MW. The reactor was designed and constructed completely by China Institute of Atomic Energy (CIAE). The construction project began on Aug. 26, 2002, reactor criticality was achieved on May 13, 2010, and it is scheduled to complete power increasing tests by the end of 2011. Future operation of CARR is preparing and its utilization program is considered. It is expected that CARR will greatly improve and enhance the comprehensive research capability of nuclear science and technology and push the peaceful use of nuclear technology forward. The paper briefly presents the reactor safety features, the operation organization and responsibilities, the management of operation safety, and the future utilizations. According to national safety regulations of research reactor, evaluation of operation safety of CARR shall be executed after initial operation at power level and submit the revised "Final Safety Analysis Report" (FSAR) to the regulatory body.Ordinary operation shall be approved and operation license shall be issued by the regulatory body after review on the "Final Safety Analysis Report." Vertical and horizontal channels with associated equipment and instruments are installed in reactor core and in heavy water reflector. CARR will be used to produce variety of RIs in comprehensive fields, to meet the requirements of engineering tests and irradiation for developing NPP fuels and materials in China, to apply for NTD of mono-crystalline silicone, NAA, neutron photography and to provide high intense neutron beam for application of neutron scattering experiments in an adequate scale and others, etc.

1. INTRODUCTION

China Insititute of Atomic Energy is synthetic nuclear scientific center in China.Two old Research reactors, HWRR and SPR in CIAE made historical contribution to nuclear science and technology for China. HWRR has been in decommissioning state, SPR are in extended service and facing aging problems. In order to meet the increasing requirements in Sci. & tech. applications of the 21st century in China, and to continue keeping the role of synthetic nuclear scientific center for CIAE

An urgent task to construct a new RR with higher performance for CIAE ,called China Advanced Research Reactor(CARR) has been under-constructed in CIAE site.

2. REACTOR DESCRIPTIONS

China Advanced Research Reactor (CARR) is a tank in pool, inverse neutron trap type, light water cooled, heavy water reflected research reactor. The maximum thermal neutron flux of the reactor is 1.0×10^{15} $cm^{-2}s^{-1}$, and the reactor power is 60 MW.

It is designed and constructed by China Institute of Atomic Energy (CIAE). The construction project began on Aug. 26, 2002, reactor criticality was achieved on May 13, 2010, and it is scheduled to complete power increasing tests by the end of 2011. Future operation of CARR is preparing and its utilization program is considered.

Main Characteristics of CARR are listed in Table 1 below. The structure complex and the layout of reactor core are schematically shown. *(see Figure 1).*

TABLE 1: MAIN CHARACTERISTICS OF CARR

Reactor power	60MW
Reactor type	tank-in-pool
Coolant	H_2O
Reflector	D_2O
Max.thermal neutron flux in core region in reflector region	 1.0×10^{15} n/cm^2·s 8.0×10^{14} n/cm^2·s
Fuel element type number fuel meat ^{235}U enrichment cladding	 plate 21(17 standard,4 CR follower fuel) U_3Si_2-Al 19.75wt% Aluminum alloy
Primary coolant temperature flow rate pressure	 35/56.2℃ 2400 m^3/hr 0.85 MPa

1. Hot water layer inlet pipe
2. Hot water layer outlet pipe
3. Ionization chamber wire tube
4. Primary coolant pipes
5. Flow guiding tank
6. Heavy water tank
7. Horizontal neutron beam tube
8. Decay tank
9. Water pool
10. Concrete shield
11. Hydraulic drive mechanism
12. Vertical tube

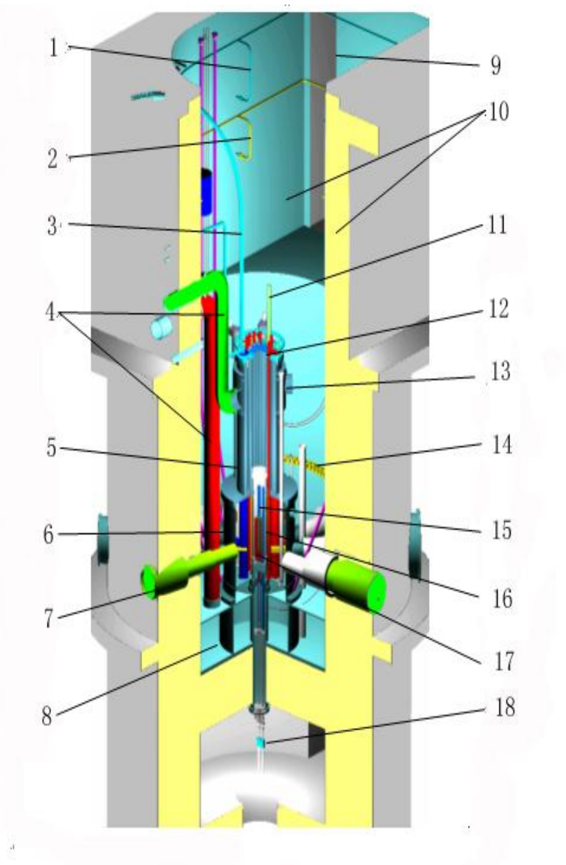

Fig. 1. Schematic of CARR complex structure.

3. APPLICATION OBJECTIVE

CARR will be used for research in fields such as nuclear physics and chemistry, neutron scattering experiments, testing of reactor materials and nuclear fuels, neutron activation analysis, and for the production of radioactive isotopes and neutron-doped silicon. Multipurpose of CARR ia specified below

3.1. Neutron scattering experiments

With 9 horizontal beam tubes and experimental equipments installed at the beam ports, CARR will provide powerful capability for conducting a great deal of studies covering material science, life science, environment science, researches in physic-chemistry fields and in other relevant areas in the future.

3.2. Medical/Industrial radioisotope production (RI)

Vertical tubes with different diameters and different neutron flux levels, cooperating with special handling tools, transportation facilities and cooling systems, can be used for production of various medical/industrial radioisotopes, especially the products with high specific activity in industrial scale, such as ^{125}I, ^{131}I, ^{32}P, ^{35}S, ^{14}C, ^{153}Sm, ^{60}Co, ^{90}Sr, ^{99}Mo, ^{113}Sn, ^{192}Ir, ^{198}Au, ^{210}Po and ^{188}W, etc.

3.3. Nuclear fuel/material irradiation tests and examinations

A high temperature and high pressure test loop is planning to be installed according to a separate program.

3.4. Neutron activation analysis (NAA)

A rabbit system and HPGe spectrum system can be used for NAA.

3.5. Neutron transmutation doping (NTD)

Neutron transmutation doping for large diameter silicon ingots can be carried out for production of Si semiconductors in scale.

3.6. Others

Neutron radiography, technical training, etc.

4. UTILIZATION FACILITIES

The utilization facilities of CARR consists of irradiation facilities and beam experimental facilities.

Nine horizontal beam tubes and beam experimental equipments are used for beam scattering experiment and neutron radiography. The horizontal beam tubes are given in Table 2 below

A total of 24 vertical irradiation channels and associated loops and equipments are used for target irradiation, such as RI production, NTD silicon production, fuel and material tests and neutron activation analysis (NAA) etc. The experiment channels are given in Table 3 below

One physical experimental hall around the reactor body and one experimental hall of neutron beam terminals are provided for installation of the experimental apparatus at neutron beam ports, and conducting beam experiment for users.

One hot lab is used for post-irradiation examinations of fuel and material. Handling machines and transportation facilities for target irradiation.

TABLE 2: Horizontal beam tubes

No.	Name	No. of beams	Experimental equipment	purposes
HT1	CNS beam tube	4	1) small angle neutron scattering spectrometer, 2) Vertical surface polarization neutron reflection spectrometer,	Cold neutron source, Neutron scattering
HT2	Multi-filtration neutron tube	1	Planning	Thermal neutron and KeV neutron radiography studies
HT3 HT4 HT6 HT8 HT9	Thermal neutron beam tubes	2 1 2 1 2	1) high resolution powder neutron diffractometer, 2) Triple axis spectrometer, 3) Time of flight spectrometer, 4) Powder diffraction texture measurement meter, 5) Neutron four circle diffraction meter, etc.	Neutron scattering, Nuclear data measurement, Prompt gamma neutron activation analysis (PGNAA)
HT5	Long tangential beam tube	1	Planning	Nuclear pumped laser (NPL) studies
HT7	HNS beam tube	2	multi-purpose neutron scattering spectrometer	Neutron scattering

TABLE 3: VERTICAL IRRADIATION CHANNELS

Tube name	Number	Inner dia. (cm)	Purposes	Associated facilities
CNS	1	26.0	Installation of Cold neutron source	CNS device and system, experimental equipments
HNS	1	28.0	Installation of Hot neutron source	HNS device, experimental equipments
CI	7	7.0	RI production	Water cooling system
MT	1	5.0	Material irradiation	Water cooling loop
KY	1	12.0	Fuel irradiation test	High temp. and high pressure water cooling loop (planning)
I-125	1	7.0	125I production	Transfer loop and equipments
NTD	5	12.0/20.0	Production of NTD-Si	Hydraulic drive rotating devices
MD	1	7.0	99Mo production	Water cooling system (planning)
AT	1	7.5	NAA	Pneumatic transfer system
NI	3	5.0	RI production	

5.OPERATION MANAGEMENT

5.1. Laws and Regulatory

Laws:

— Environment protection Law of the People’s Republic of China;

— Civil Nuclear facility Safety Inspection Decree of People's Republic of China.

Regulatory requirements:

— Operational Safety Requirements for Research Reactors;
— Safety Guideline for Research Reactors and Criticality Assemblies.

IAEA Documents related to Operation of nuclear facilities.

5.2. Organization and responsibilities

Governmental administration:

— Commission of Science, Technology and Industry for National Defense.

Regulatory body:

— Bureau of National Nuclear Safety.

Operation management:

— CIAE is responsible for planning and execution as well as coordination within the Institute;
— Department of Reactor Engineering Research and Design is responsible for operation management;
— Department of Radiochemistry is responsible for waste management;
— Department of Radiological Safety is responsible for radiation protection, health physics and environmental impact assessment;
— CIAE has accumulated adequate experience of operation and safety management, and well established QA system which has passed ISO9001 verification.

5.3. Existing management systems at CIAE

— Safety management;
— Quality management;
— Health & environmental;
— Security;
— Economic.

6. FUTURE PROGRAMME

6.1.Operation Program

According to national safety regulations of research reactor, evaluation of operation safety of CARR shall be executed after one year's initial operation at power level and submit the revised "Final Safety Analysis Report" (FSAR) to the regulatory body.

Ordinary operation shall be approved and operation license shall be issued by the regulatory body after review on the "Final Safety Analysis Report".

Initial operation will be lasted for one year, from Jan.- Dec.2012. The purposes are:

— Operating performance familiarities;
— Production of RI and NTD-Si;
— R&D work of neutron beams;
— Operation licensing, etc.

Ordinary operation will begin in Jan.2013 for comprehensive applications of CARR. Operating mode is cycle operation, 10–20 days/cycle, 12 cycles/year.

6.2. Strategic planning

Installation of new utilization facilities and experimental equipments according to a short term and a middle-long term programming of the development of application platform of CARR in future 10 years.

— Establishment of a "National laboratory of neutron scattering research" (in progress);
— Establishment of a "Research & Development center of nuclear technology application."

Opening use of the lab, the center and the utilization facilities of CARR for domestic as well as international scientists, researchers, and other users, conducting cooperative R&D work and utilization.

7. FINAL REMARKS — CONCLUSIONS

CARR is a representative of multi-purposes and outstanding performance research reactor. It is believed that the completion of CARR project and its future operation will greatly enhance the capability of basic researches and comprehensive applications in the area of nuclear science and technology, pushing forward the peaceful use of nuclear technology.

The CIAE will sincerely welcome the domestic and the international users from universities and colleges, institutes, business enterprises, and other academic organizations to CARR to carry out researches, development and applications in various areas of nuclear science and technology, to share the sources of the research platform of CARR.

Besides, two research reactors (HWRR, the first research reactor of China, and MNSR, miniature neutron source reactor) and one criticality facilities (heavy water zero power reactor) of CIAE are scheduled to be finally shutdown and to carry out decommissioning in near future years. International cooperation and communications become more and more important to exchange the information and experiences on design, construction, commissioning, operation, decommissioning and utilizations of research reactors.