Description of Utilization Program for CARR

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Abstract

CARR is a multipurpose research reactor of high performance. The CARR project is proceeding well up to now. The detail design has been finished, and its construction and installation work are all underway. According to schedule, the commissioning work will be started in the first half of next year.

In order to explore full use of CARR after completing, it's important to program the utilization. Now the preliminary scheme, performance index, capabilities, capacities and future prospects for various facilities are included in the program, the responsible organization, the reasonable time schedule and required budget are also planned.

1. Introduction

The China Advanced Research Reactor (CARR) is a multipurpose research reactor of high performance. Government approved the CARR project formally in July 1997. The engineering construction began on September 27,2001.The project is proceeding successfully up to now. The detail design and planned verification tests have been completed, and its construction and installation are all underway. The reactor is expected to finish the commissioning work and become critical and operational in the end of 2006.

In order to explore full use of CARR after completing, it's important and necessary to program the utilization and develop the utilization facilities with associated equipments and instruments. So, China Institute of Atomic Energy (CIAE) puts forward the proposal of the project of application platform for CARR. The major task of this project proposal includes programming neutron utilization all-round for CARR, installing various irradiation utilization facilities with associated instruments and equipments, constructing cold neutron source and related neutron guide tube. All these facilities make it possible for full use of the intense neutron source generated by the reactor for neutron scattering (NS) experiment, radioisotopes (RIs) production, fuel and material irradiation test, neutron transmutation doping of silicon(NTD), neutron activation analysis(NAA), neutron radiography(NRG), boron neutron capture therapy (BNCT) and personnel training, etc. The project proposal was submitted to the Commission of Science Technology and Industry of National Defense (CSTIND) in July of this year. This proposal may be approved before the middle of 2006. The planned construction time is 5 years.

2. The Main Design Feature of CARR

CARR is a multi-purpose, tank-in-pool, inverse neutron trap type research reactor. The bird's eye view of CARR is shown in Figure 1. A schematic diagram of the CARR proper is shown in Figure 2.

Vertical and horizontal channels installed in the core and in D_2O reflector are shown in Figure 3.

Its main parameters are as follows:

Reactor nuclear parameters

Reactor rated power, MW	60
Maximum undisturbed thermal neutron flux, $n/cm^2 \cdot s$	
in central channel (if central fuel is replaced by channel)	1×10^{15}
in heavy water reflector	8×10^{14}
Height of core active region, m	0.85
Equivalent diameter of core, m	0.399

Fuel assembles

type of fuel assembles	flat plate
lattice pitch, cm	7.72
number of assembles	
standard fuel	17
CR followers fuel	4
material of fuel meat	U_3Si_2-Al
enrichment of ^{235}U, wt%	19.75
cladding material	aluminum alloy

Control rods

absorber material	Hf
number of safety rods	2
number of shim rods and regulating rod	4
driving type of safety rod	hydraulic driving
driving type of shim rod	magnetic driving
worth of control rods, ΔK/K%	36.37

Reflector

material	heavy water
inner diameter, m	0.479
outside diameter, m	2.2
height, m	2.0

Primary coolant system

coolant	light water
flow rate, m^3/h	～2400

number of main circulating pumps 4
number of main heat exchangers 4

Heavy water system
medium heavy water
power in reflector, MW ～3.6
number of heavy water pumps 2
number of heavy water heat exchangers 2

Secondary coolant system
flow rate, m^3/h 7000
number of circulating pumps 4+1(standby)

Emergency core cooling system
flow rate, m^3/h 220
number of cooling pumps 2

Reactor pool
depth of pool, m 15
volume of pool water, m^3 ～700
(including the spent fuel pool water connected)

Reactivity
excess reactivity, ΔK/K% 20.07
reactivity temp. coefficient for fuel, ΔK/K% -2.0417×10^{-5}
reactivity temp. coefficient for coolant, ΔK/K% -7.0617×10^{-5}
reactivity temp. coefficient for heavy water, ΔK/K% -1.4835×10^{-5}
void reactivity coefficient, ΔK/K% -1.949×10^{-3}
balance xenon reactivity, ΔK/K% -3.56

Thermal-hydraulic parameters
inlet/outlet core coolant temperature, ℃ 35/56.2
max surface temperature of fuel plate, ℃ 155.3
max temperature of fuel meat, ℃ 176.1
minimum DNBR 3.23

Experimental channels
number of horizontal channel 9

HT1：Cold neutron source beam tube 1

HT2：Multi-filtration neutron beam tube 1

HT3、HT4、HT6、HT8、HT9：Thermal neutron beam tubes 5

HT5：Long tangential beam tube 1

HT7：Hot neutron source beam tube 1

number of vertical channel 21

CNS：Cold neutron source guide tube 1

HNS：Hot neutron source guide tube 1

MT： Material irradiation monitoring hole 1

KY：Test loop hole 1

NTD：NTD Silicon hole(3, 4, 5 and 6 inches ingots) 5

AT： NAA hole 1

MD、 I-125、CI and NI： Mo-Tc、I-125, ect. Irradiation hole 12

Fig. 1 Bird's Eye View of CARR

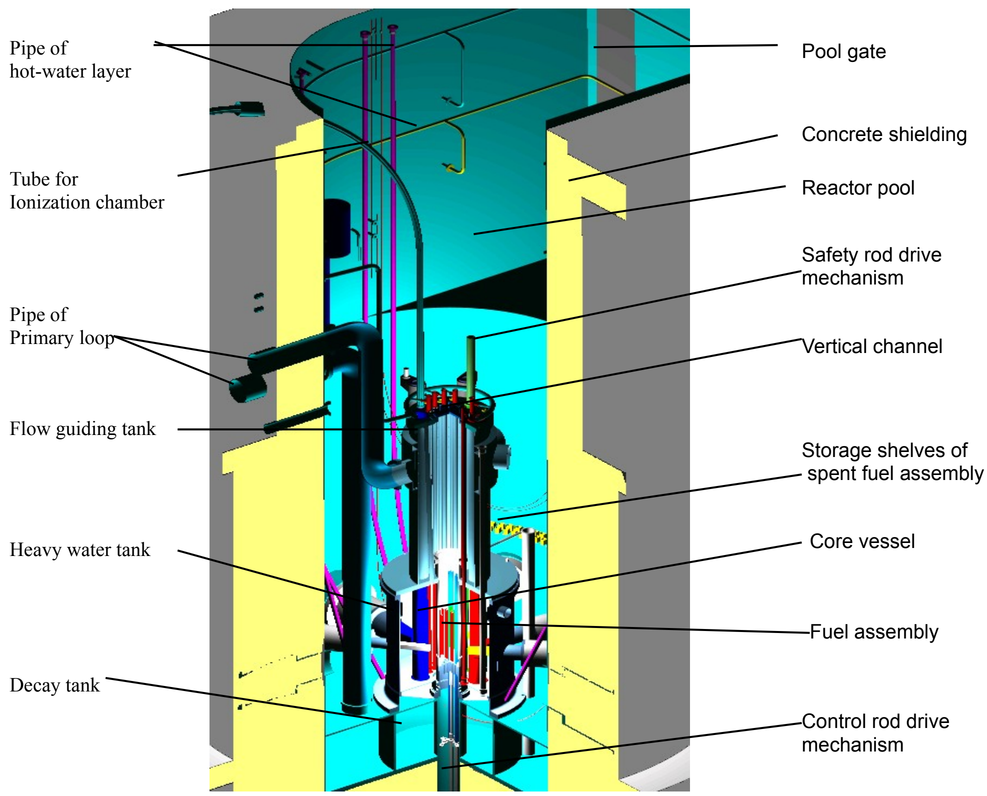

Fig. 2 Three-dimensional view of Reactor proper

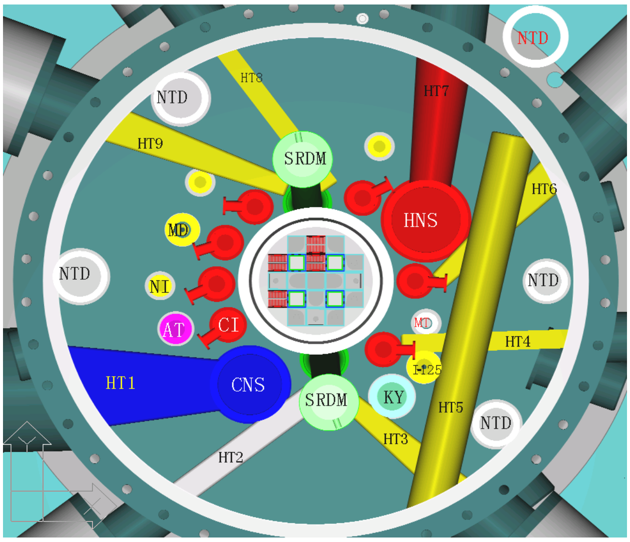

Fig. 3 General Layout of Channel and Beam Tube

3. Irradiation Utilization Facilities Development Plan

The final aim for constructing CARR is to conduct variety research work, such as nuclear science experiment, reactor-engineering technology research, development and application of nuclear technology, etc. However, because of budget problem, only the building, reactor body, reactor engineering system necessary for CARR operation safely, hot cell, etc., are included in the current CARR project, all the utilization facilities are not included. So, it's very urgent to program and develop all these application facilities with associated equipments and instruments.

CIAE put forward the project of development of application platform based on CARR's design characteristics last year. Utilization field planned for CARR is shown in Fig. 4.

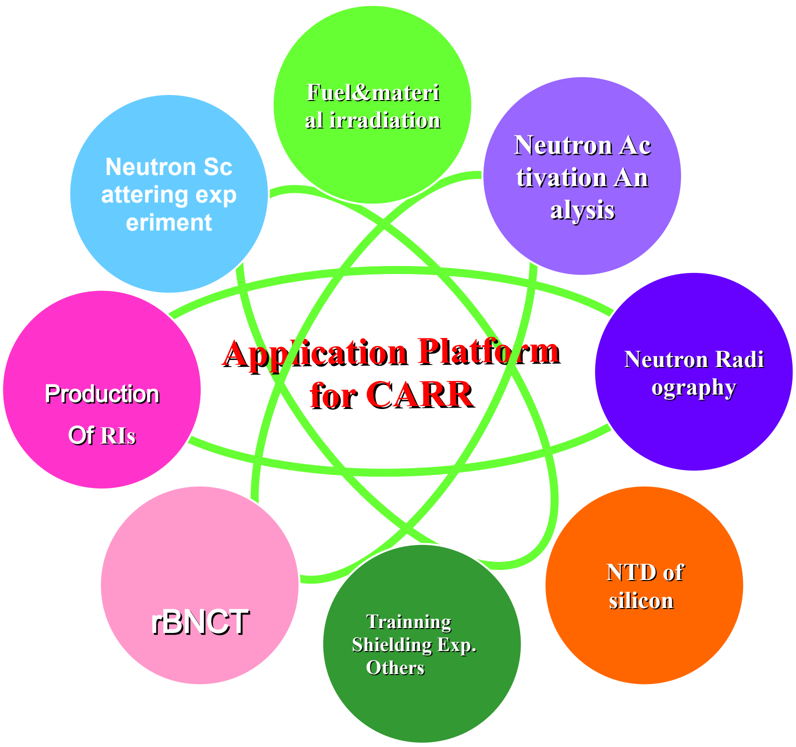

Fig. 4 Application Field Planned for CARR

3.1 Neutron beam experiment facility

As mentioned-above, 9 horizontal channels will be arranged around CARR. In the vicinity of beam ports some experimental devices, used for NS, NAA, NRG, BNCT could be successively installed. Table 1 lists the neutron beam experimental facilities, which will be built at the neutron guide hall.

Table 1 Neutron Beam Experiment Facilities for CARR

Item	Facilities	No.	Status
Cold Neutron Source (CNS)	Liquid hydrogen CNS facility with Helium refrigerator	1	Under-development, now under phase of preliminary design
Hot Neutron Source (HNS)		1	Develop later
Neutron Beam and Guide	Neutron beam tubes	9	Under-development
	Cold neutron guides	4	
Neutron Spectrometer	Triple-axis spectrometer	1	Upgrading from HWRR
	Four Circle Diffract meter	1	Upgrading from HWRR
	Time of flight spectrometer	1	Upgrading from HWRR
	Small Angle Scattering Instrument	1	Upgrading from HWRR
	Powder Diffract Texture Gauge	1	Upgrading from HWRR
	High Resolution Powder Diffractometer	1	Under-development
	Horizontal Reflectometer	1	Under-development
	Diffraction Stress Gauge	1	Under-development
	Spin-Echo Spectrometer	1	Under-development
	Backscattering Spectrometer	1	Under-development
	Vertical Reflectometer	1	Under-development
	Cold Neutron 3-Axis Spectrometer	1	Under-development
	High Intensity Powder Diffactometer	1	Under-development
Neutron Activation Analysis Instrument	Short-lived nuclide NAA System	1	Under-development
	Prompt Gamma Activation Analysis System (PGAA)	1	
	Cold Neutron PGAA	1	
	Neutron Depth Profiling System	1	
Neutron Radiography Instrument	High Resolution Static Neutron Radiography	1	Under-development
	High-frame-rate Neutron Radiography	1	
BNCT	Boron Neutron Capture Therapy Facility with thermal/epithermal neutron beam	1	Under-development
Other Associated Equipments	Monochromators, detectors, sample environments, Omirror devices, collimators, control & data acquisition system, and instrument control program, pneumatic rabbit, dosimetry, filter, irradiation room, etc.		Under-development

3.2 RIs production facility

For CARR, there are 12 vertical channels used for RIs production. Quite high neutron flux in the heavy water reflector is favorable for production RIs of high specific activity. Using these vertical channels and relevant special tools the irradiation work of various industrial and medical radioisotopes, e.g. ^{60}Co, ^{99}Mo, ^{131}I, ^{113}Sn, ^{125}I, ^{32}P, ^{192}Ir, ^{14}C, ^{35}S, ^{210}Po ^{160}Ho and ^{198}Au, etc. can be conducted. Various irradiation target, capsule, lead storage, handing tool, ^{125}I production loop, and $^{99}Mo/^{99m}Tc$ generator, etc., will be developed.

3.3 Fuel and material irradiation test facility

A high temperature and high pressure testing loop with ^{3}He gas-adjusting loop will be constructed in CARR. The performance tests (including steady and transient), high burn-up test, water chemistry activity transport and corrosion test, and fuel integrity and qualification test, etc., could be conducted using the loop and relevant devices.

3.4 NTD silicon production facility

There 5 vertical holes for 3”, 4”, 5” and 6” Si ingots in CARR. Irradiation facilities, including ingot handling equipment in and out of the pool, hydraulic drive mechanism, ingot storage rack during cooling, electric property inspecting equipment, annealing&cleaning equipment, gamma spectroscope system for fluence measurement, etc., will be developed.

3.5 Training center

We will develop a simulation system for CARR. The audiovisuals, networks and necessary training equipment will be also set up. In addition, we will establish a perfect management system for operation and utilization of CARR.

4. Conclusions

The Utilization Program for CARR is critical to the success of neutron applications in China. CIAE is planning and scheming this program, and pushing forward the realization of the program. About research reactor application, we are expecting the experience exchanging in IGORR community. So we greatly appreciate various supports and helps from all over the world.