STATUS AND SOME SAFETY PHILOSOPHIES OF THE CHINA ADVANCED RESEARCH REACTOR CARR

YUAN LUZHENG
Reactor Engineering Research & Design Department
China Institute of Atomic Energy, Beijing, China, 102413

1. Introduction

The existing two research reactors, HWRR (Heavy Water Research Reactor) and SPR (Swimming Pool Reactor), have been operated by China Institute of Atomic Energy (CIAE) since, respectively, 1958 and 1964, and are both in extending service and facing the aging problem. It is expected that they will be out of service successively in the beginning decade of the 21st century. A new, high performance and multipurpose research reactor called China Advanced Research Reactor (CARR) will replace these two reactors. This new reactor adopts the concept of inverse neutron trap compact core structure with light water as coolant and heavy water as the outer reflector. Its design goal is as follows: under the nuclear power of 60MW, the maximum unperturbed thermal neutron flux in peripheral D_2O reflector not less than 8×10^{14} n/cm^2• s while in central experimental channel, if the central cell to be replaced by an experimental channel, the corresponding value not less than 1×10^{15} n/cm^2• s.

The main applications for this research reactor will cover RI production, neutron scattering experiments, NAA and its applications, neutron photography, NTD for monocrystaline silicon and applications on reactor engineering technology.

By the end of 1999, the preliminary design of CARR was completed, then the draft of preliminary safety analysis report (PSAR) was submitted to the relevant authority at the end of 2000 for being reviewed.

Now, the CARR project has entered the detail design phase and safety reviewing procedure for obtaining the construction permit from the relevant licensing authority.

This paper will only briefly introduce some aspects of safety philosophy of CARR design and PSAR.

2. Safety Considerations in CARR Design

2.1 Coolant inlet

Previously, the coolant inlet of CARR was designed in two opposite pipe legs converging into one, the core housing tube[1]. In this way, it was worried about that something like flow-induced vibration, water flushing impact might occur when two opposite parts of coolant flow together with quite high velocity of flowrate.

Now, the design of inlet structure has been changed into a flow guide tank with an upper inlet plenum. The schematic plan of CARR core is shown in Fig.1.

2.2 Decay Tank Enlarged

In order to decrease the ^{16}N radioactivity, a decay tank is arranged at the bottom of reactor pool underneath the D_2O tank (Fig.1). Based on the radiation shielding calculation, the dimension of the decay tank should be enlarged for extending the retention time to decrease the wall thickness of primary processing rooms to a suitable value of 800mm, concrete with density 3.6 g/cm^3. Now, the outer diameter of the decay tank is identical to that of water pool. This makes the retention time extend from 28 seconds to 40 seconds.

2.3 Running Mode of ECCS

After reactor shutdown, a forced flow through the core fuel assemblies is maintained by the primary pumps in order to remove the decay heat. In case of an accident the primary pumps were not available, two battery-buffered UPS emergency core cooling pumps continue to maintain the forced flow. In CARR design, the emergency core cooling pumps are running so long as the reactor is in normal operation. In this way, the failure on demand of emergency core cooling pump can be avoided. These redundant pumps suck water from the pool, their outlet lines are connected with the primary pump outlet line using check valves against reverse flow, and the cooling water, having passed the reactor core, is fed back into the pool through the strainer which mounted on the top of decay tank.

During the normal operation, because the outlet pressure of the emergency pump is lower than that in main line, it can not pump water into the primary loop. However, this flow enters the heat exchanger of reactor pool water cooling system. Fig.2 shows the flow diagram.

2.4 Emergency Ventilation Design

In case of an accident occurs, e.g., fuel element damage resulting in fission products releasing into the pool water then into the atmosphere of the reactor hall, the normal ventilation system including air sucking system will automatically switch off and the emergency venting system turns on. As low as possible negative pressure is maintained in reactor hall by venting it in a quite few air flowrate via filters and iodine traps to the stack. In order to determine the venting flowrate in this accident, assuming a reactor hall leakage rate of 25 vol.%/d and a little bit more venting flowrate than the leakage is set to keep the reactor hall with a little negative pressure to guarantee the radioactivity releasing into the environment kept in a very low level.

2.5 Secondary Shutdown System

There are two shutdown systems provided in CARR design. The first consists of four hafnium absorber rods in the core region and two safety rods in the reflector tank near the core. All these control rods are of fast response.

The second system achieves shutdown by draining the heavy water moderator to a heavy water storage tank via rather large dimension pipe by actuating an electro-magnetic valve with uninterruptable power supply (UPS). Based on the safety analysis, the system is required that the period of draining the moderator down to half height of the reflector should be less than 30 seconds.

3. ATWS Analyses

Analyses of anticipated transients without scram (ATWS) have been performed for CARR. The ATWS events that are evaluated in the PSAR of CARR include uncontrolled withdrawal of control rod, loss of heat sink, loss of offsite power supply, all without reactor scramming.

In consideration of the low probability of occurrence of ATWS events, we specified that in the analysis of ATWS events all system functions, including control functions, except reactor trip operate as designed, and that assumed initial conditions and system parameters be considered to be those normally anticipated for the reactor state under consideration. These considerations are sometimes called realistic assumption instead of conservative one.

The results of these analyses show that with the secondary shutdown function the minimum DNBR of fuel element for all cases is not less than 1.50, and the maximum central temperature in fuel meat, the maximum temperature on fuel cladding and the maximum coolant temperature at the core outlet are all well within the allowable limits, not result in fuel burnt out.

4. Engineering Verification Test

Because of the rather compact core in high power density and with quite high velocity (9.9 m/s) of the core coolant, the performance of the CARR fuel assembly is always concerned from the very beginning and great attention must be paid to. Now, the fuel design and fabrication investigation of CARR is going on according to the project schedule. An engineering test plan for the verification of fuel design has been carried out in order to guarantee the success of fuel design and fabrication. The items of this plan are set forth just according to the need of CARR project. At present, the main items being and to be conducted are: the thermal property measurement for the fuel meat, the flow distribution experiment for a single fuel assembly, the flow-caused vibration and critical flow rate experiment, the critical hear flux test, the off-pile hydraulic flushing experiment, the pressure drop measurement, the flow leakage measurement at the fuel assembly socket, in-pile irradiation and post-irradiation inspection for single small fuel plates and for the complete fuel assembly.

In addition, relevant experiments will be performed according to requirement for further confirmation, for example, fuel collide impacting test, fuel dropping test and flow distribution measurement among fuel assemblies.

5. Conclusion

From the viewpoint of improving the safety features of CARR design, some changes mentioned above have been made since the project started. Now, having submitted the PSAR, this facility design is subject to a general review in which all systems and components are being examined for finding out whether or not possible to make further changes aiming at more reasonable or a cost reduction. Therefore, it is possible that some items of CARR design may be changed later although the general concept should remain virtually unchanged.

References

[1] Yongkang Shi, etc.: "The China Advanced Research Reactor Project"; Proceedings of The 5th Asian Symposium on Research Reactors; May29-31, 1996; Taejon, Korea.

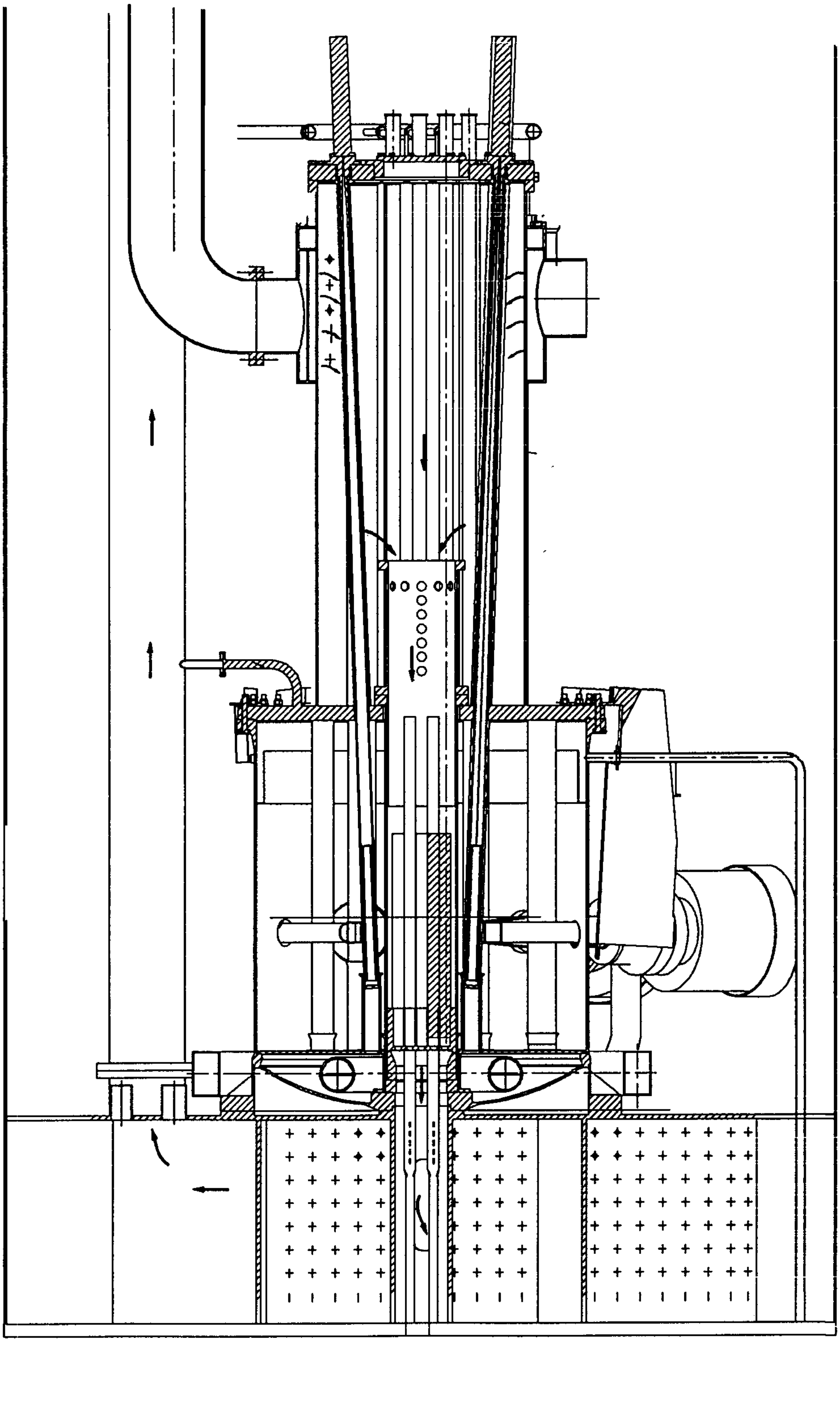

Fig.1 Longitudinal Cut View of CARR Core

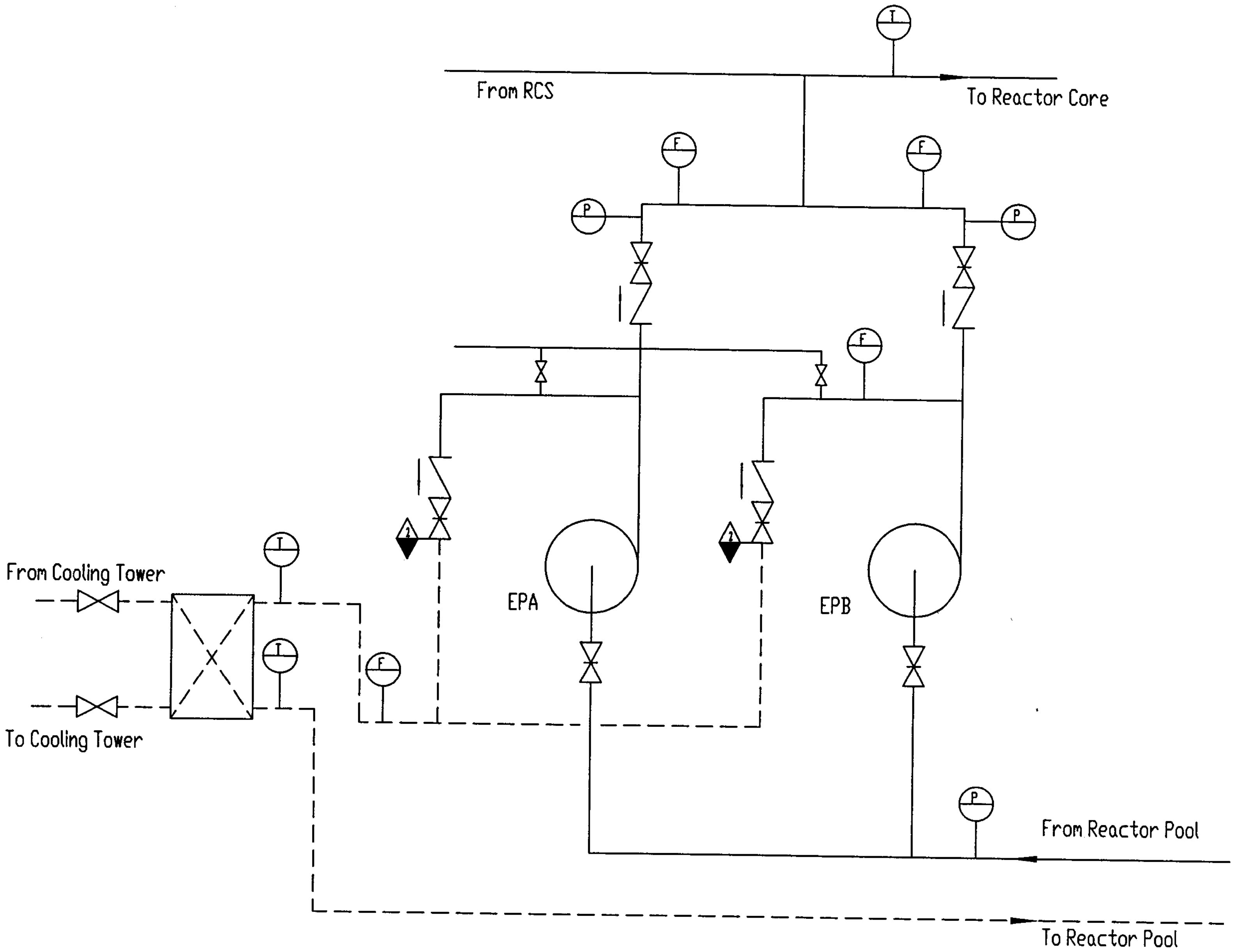

Fig.2 Flow Diagram of CARR ECCS