Qualification of Control & Safety Rod Drive Mechanism and Control & Safety Rod for Prototype Fast Breeder Reactor

EXECUTIVE SUMMARY

Control & Safety Rod Drive Mechanism (CSRDM) & Control & Safety Rod (CSR) form a part of first shutdown system in Prototype Fast Breeder Reactor (PFBR). Since, the safety of the reactor as a whole depends upon the reliable performance of CSR & CSRDM, they are qualified by comprehensive testing carried out in simulated reactor operating conditions. The root cause analysis was carried out on the problems encountered during assembly & testing and necessary modifications were incorporated. The test results are satisfactory and CSRDM & CSR are qualified for use in the reactor.

OUTLINE

CSRDM was tested in Engineering Hall III (43 m tall building). The mechanism was initially assembled in a vessel, called inner vessel and the prototype CSR was mounted at the lower end of the same vessel. Air testing on CSRDM was carried out in the inner vessel. For carrying out testing in argon and in sodium at various temperatures from 473 K to 823 K, the inner vessel with the mechanism was lowered in a 1.0 m dia x 12.6 m long sodium vessel, called Test Vessel-1 (TV-1). Sodium was filled in TV-1 to a specified height and maintained at different temperatures so as to simulate reactor operating conditions.

Initially extensive testing was carried out on prototype CSRDM and CSR to check and ensure all the intended functions in air and then in hot argon at 473 K. Then the whole system was tested in sodium at temperatures starting from 473 K to 823 K.

Subsequent to functional tests, endurance testing was carried out. The mechanism was subjected to endurance testing with respect to scram operation as the damage occurring in CSRDM & CSR is mainly due to fatigue cycles during scram action.

At first, the endurance testing was carried out in sodium for 500 cycles of scram operations maintaining the temperature at 803 K, and 60 cycles of gripper operations at 473 K, keeping CSRDM & CSR (Mark–I) in aligned condition. Based on the test results, the design of CSR was improved. Then endurance testing was carried out in sodium for another 1093 cycles of scram operations, maintaining the temperature of sodium at 823 K, and 120 cycles of gripper operations at 473 K with a misalignment of 30 mm between CSRDM and CSR (Mark–II). In addition to this, tests carried out in air, argon and sodium at different temperatures amount to 450 cycles.

As per ASME guidelines, CSRDM has been so far qualified for 14 years of life in reactor and CSR is qualified for its total life.

CSRDM and CSR were taken out of the sodium vessel and cleaned thoroughly using water vapour-CO_2 process, DM rinsing and drying at sodium removal facility.

Later, the upper part of the mechanism was dismantled fully for inspection. Inspection reveals that no part in CSRDM upper part related to translation and scram action has undergone any deterioration that may affect the satisfactory operation of the mechanism.

Fig. 1 shows the displacement characteristics of CSR and Fig. 2 shows the dynamic oil pressure developed in dashpot during scram action.

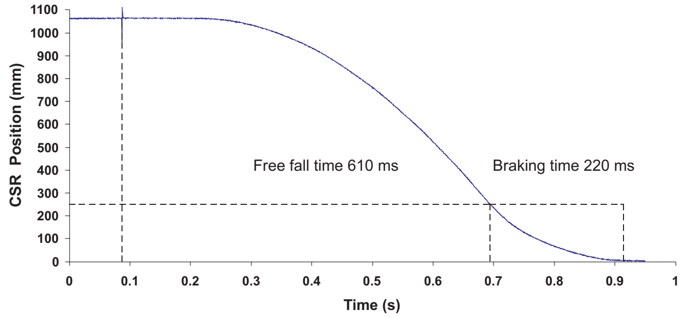


Fig. 1: Displacement of CSR during Scram

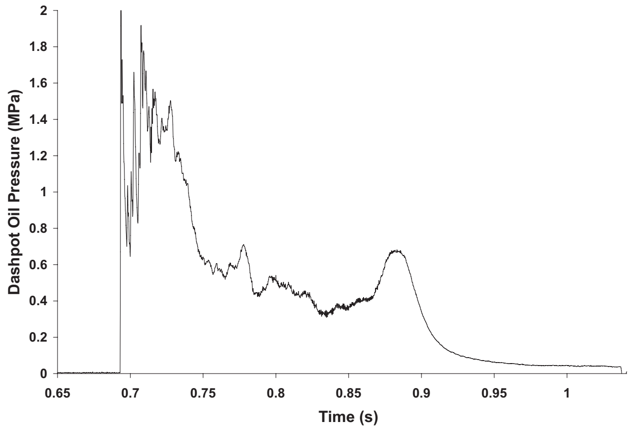


Fig. 2: Dashpot Characteristics during Scram

■ PFBR SHUT DOWN SYSTEMS

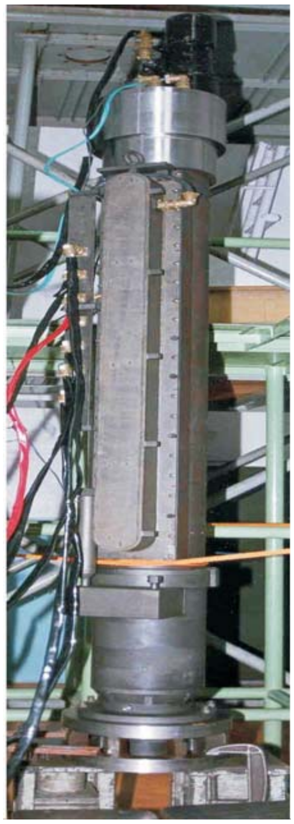
In Prototype Fast Breeder Reactor, there are two independent, fast acting, diverse shutdown systems, each comprising of sensors, logic circuits, drive mechanisms and neutron absorber rods having boron carbide pellets. The absorber rod of the first system is called Control & Safety Rod (CSR) and that of the second system is called Diverse Safety Rod (DSR). The respective drive mechanisms are Control & Safety Rod Drive mechanism (CSRDM) and Diverse Safety Rod Drive mechanism (DSRDM).

■ DESCRIPTION OF CSRDM

The photograph of CSRDM is provided in Fig.3. Overall length of CSRDM is about 12.3 m. The mobile assembly of CSRDM consists of guide tube, translation tube and gripper subassembly. Gripper subassembly having three fingers is attached at the bottom end of the translation tube. Gripper operating rod and sheath are housed in the translation tube, which moves inside tube sheath. The gripper fingers are operated manually from the top of CSRDM at a height of about 12 m during shutdown condition of the reactor.

The mobile assembly of CSRDM is held by an electromagnet (EM). A roller screw-nut mechanism is used for raising and lowering the EM, which is fixed to the nut. Motor drive assembly rotates the translation screw to raise or lower the EM and hence the mobile assembly. When CSR is coupled to the gripper of the mobile assembly, it also translates up or down based on the direction of rotation of the motor. Both the EM and mobile assembly slide over two guide columns fixed to support tube. Teflon bushes are provided at the contact surfaces. The mobile assembly is also guided by two colmonoy bushes, one at the level of V-ring seal block and the other in sodium at the lower end of the tube sheath. The corresponding surfaces of the translation tubes are hard chromium plated. Hence there are guides at four levels for the mobile assembly, when it is coupled with the EM and guides at three levels, when it is released from the EM.

On receiving the scram signal, the EM is de-energised and the mobile assembly of CSRDM along with CSR is released to fall under gravity. It falls down freely from its operating position. At the end of free fall travel, the mobile assembly is decelerated by an oil dashpot for the remaining 250 mm travel.



Upper Part

Lower Part

Fig. 3: Photographs of CSRDM

■ BRIEF DESCRIPTION OF THEORETICAL BACKGROUND

Structural analysis was carried out to find out the frictional forces acting on the mobile assembly with CSR during scram operation. The performance of CSRDM & CSR in sodium was theoretically simulated to find the translational characteristics during free fall and braking travel of scram action. The theoretical results match well with the experimental results.

■ ACHIEVEMENT

The testing has enhanced the confidence level for safe and reliable operation of CSRDM and CSR in PFBR. The testing carried out has qualified the system for use in reactor and provided basis for licensing the erection of CSRDM and CSR on reactor pile.

■ PUBLICATIONS ARISING OUT OF THIS STUDY AND RELATED WORK

V. Rajan Babu, R. Veerasamy, D. Rangaswamy, K. Narayanan, S.C.S. Pavankumar, S.K. Dash, C. Meikandamurthy, K.K.Rajan, M. Rajan, P. Puthiya Vinayagam, P. Chellapandi and S.C. Chetal, 14th International Conference on Nuclear engineering (ICONE-14), July 2006, Florida (USA).

Further inquiries:
Shri V. Rajan Babu, Reactor Components Division, Reactor Engineering Group, IGCAR, e-mail: vrb@igcar.gov.in
Shri R. Veerasamy, Components & Instrumentation Development Division, Fast Reactor Technology Group, IGCAR
e-mail: rvs@igcar.gov.in