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IGCAR FACILITIES

Sodium cooled fast breeder reactors constitute the second stage of India's three-stage nuclear energy programme, for effective utilization of the country's limited reserves of natural uranium and exploitation of its large reserves of thorium. Even in the mid-fifties, when the Department was seriously pursuing the thermal reactor programme, studies on fast reactors were being conducted in parallel by a team of engineers and scientists led by S.R. Paranjpe. DAE chose to have collaboration with France which then had a very strong programme of fast reactor technology. France then had already built and was operating the Rapsodie experimental reactor without a steam generator and was constructing the 250 MWe prototype fast reactor PHENIX. A historic agreement was signed between India and France for transfer of design of Rapsodie and training our O&M personnel. It was a unique cooperation. France was to give all technical assistance but the final responsibility of the project to build and commission the Fast Breeder Test Reactor (FBTR) was with India. This was a radical departure from the agreements for Tarapur and Rajasthan plants. The French Industry transferred the manufacturing technology of critical components to Indian industry. Paranjpe realized that the steam-generator is a critical component for the success of fast reactor programme and decided to include a steam–water circuit in FBTR so that in one go, India could master the full technology needed for setting up a series of Fast Breeder Reactors. A unique small capacity Turbo Generator was also added.

Siting for Reactor Research Centre (RRC)

Sarabhai was convinced of the need for a separate centre dedicated to the development of fast reactor programme. His proposal for the establishment of Reactor Research Centre (RRC) included apart from FBTR, other associated facilities like Reactor Engineering Laboratory (REL) for sodium technology, Radio Metallurgy Laboratory (RML) for post irradiation examination, Reprocessing Development Laboratory (RDL), Radio Chemistry Laboratory (RCL) etc. The location chosen for the Reactor Research Centre (RRC) was Kalpakkam, where the first ever-massive indigenous efforts to build the twin units of MAPP were in progress. Land had been acquired by DAE, north and south of MAPP, beyond the 1.6 km exclusion zone. The availability of land, low population density, assurance of water supply, low seismicity and proximity to MAPP which would facilitate sharing of infra-structural facilities and exchange of knowledge base were the major reasons for the choice of Kalpakkam as site for RRC. There were no formal mechanisms for safety clearance for nuclear projects then. Only site clearance was required from DAE-Site Selection Committee. With MAPP already cleared at Kalpakkam, there was no difficulty in getting the Kalpakkam site cleared for FBTR. Since cooling water requirement was not very large, the terminal sink was a Cooling Tower. Hence, unlike MAPS, it was not required to locate the reactor close to the sea-line. The highest spot within the campus of RRC was chosen for FBTR. The site was at a distance of about one km from the sea.

Beginning of Safety Review

Realizing the need for an independent review of the design and safety aspects of the reactor, a Safety Evaluation & Working Group (SEWG) chaired by D.V.Gopinath was constituted by N.Srinivasan, the then Director, RRC. The committee reviewed all the design and safety aspects of the reactor. Heated debates used to take place in areas where the design was different from that of Rapsodie. For instance, the flooding system, which was there in Rapsodie design, was proposed to be dispensed with in FBTR. It was proposed to inject the secondary sodium into the reactor in the improbable event of leaks from the primary system and its double envelope inside the reactor vault. At the end of an intense debate, it was decided to go in for a dedicated flooding system as in Rapsodie. Since the civil layout had not provided for it, the flooding tanks were located in the ground floor of the maintenance building, unlike in Rapsodie.

Constitution of RRC-CWMF Safety Committee

With the start of commissioning activities, the first RRC-CWMF safety committee was constituted in 1982 with D.V.Gopinath, RRC as Chairman. The safety committee held its first sitting on 30th Jan 1982. The first FBTR item discussed by the committee was in its fourth sitting on 30th Nov 1982, when the safety report on purification of commercial grade sodium to reactor grade sodium in the purification loop at Engineering Hall was reviewed. From then on, the Safety Committee meticulously reviewed all commissioning activities from sodium transportation to first criticality and the Technical Specification document.

The safety report of FBTR was prepared in 1982 and submitted for review by RRC-CWMF Safety Committee and DAE-SRC. With fuel from France becoming a constraint, the indigenous Mark-I carbide fuel was developed. It was a multi-disciplinary effort involving experts from many groups in BARC and RRC. DAE-SRC, understanding the difficulties in getting enriched uranium, cleared this untested fuel as the driver fuel, based on out-of-pile studies and international experience with low plutonium carbide fuel. An addendum was then issued for the safety report for the small carbide core. The real major dialogue with DAE-SRC started just before loading of the subassemblies into the reactor.

Difficulties Faced During the Safety Review

Fast reactor physics is different from thermal reactor physics. Unlike thermal reactors, fast reactors are treated as homogenous for physics calculations. It was hence a testing period for the designers in getting the clearance for first criticality, since DAE-SRC had members steeped in thermal reactor physics. The debates were often heated and acrimonious, especially on issues like shutdown margin and control rod operation. With the first criticality of FBTR on October 18, 1985, the reactor was declared operational. In December 1985, RRC was renamed as Indira Gandhi Centre for Atomic Research (IGCAR). A multi-tier safety review process involving SORC, IGCAR-

SC and SARCOP was established soon after.

The Technical Specification Document for 10.6 MWt was prepared by a team with R.P.Kapoor as convenor, based on similar documents in MAPS and RAPS. M.S.R.Sarma, the then Chairman, DAE-SRC reviewed it in several extended sessions at Kalpakkam before approving it. Unlike other reactors, FBTR does not have a fixed core. It evolved, and continues to evolve, of its own, based on fuel supply. This had resulted in FBTR still not reaching the equilibrium core envisaged while preparing the Technical Specification document. Therefore the reactor power and physics characteristics keep changing with every fuel handling campaign and so the technical specifications. Hence, IGCAR-SC / SARCOP clearance is being obtained on campaign basis.

There are several instances to show the extreme caution with which the safety issues of a nascent technology were initially addressed, both by the designers and regulators, and the open-mindedness and pragmatic outlook to review and relax them based on actual experience feedback. For example, with the three-second interlock on the movement of control rod imposed by SEWG and DAE-SRC, the CRDM motor was getting heated up excessively due to frequent start-ups. More important, the probability of uncontrolled withdrawal of control rod increases considerably due to possible welding of raising contactors. Also, in the steaming phase of the steam generator, the steam water system was operating in the two-phase regime for quite some time, resulting in the erosion of internals of the valves. A proposal was hence put up later to delete this interlock. It was also proposed to manually inhibit the reactivity trip during power raising and to raise the control rod level discordance limit to 40 mm from 20 mm. Ch. Surendar, the then SARCOP member, personally participated in some of the experiments conducted for clearing these proposals, and provided valuable suggestions on the logic modifications.

The commissioning of FBTR was done in phases- initially without the steam generators, then with the steam generators connected to the secondary circuit with sodium alone on the shell side of the steam generator and later with water valved into the tube-side of the steam generators. As of date, the IGCAR-SC has held nearly 250 sittings, i.e. an average of 10 sittings per year.

Over the years, FBTR encountered several major challenges- the fuel handling incident, reactivity transients, Core Cover Plate getting stuck, sodium leak from the purification cabin and leaks from the Biological Shield Cooling Systems. Several modifications have also been carried out in safety critical and safety related systems. These include, for instance, modifications in the CRDM logic (based on an incident of CRDM inoperability), triplication of the Steam Generator Leak Detection system etc. FBTR has benefited by the recommendations and suggestions of the Safety Committee and SARCOP while reviewing these incidents and modification proposals. After the incident of dropping of Capsule Transfer Gripper in 1989, SARCOP stipulated the formation of a separate in-plant committee to review all handling procedures on pile. This has been a rewarding stipulation for the plant, since all handling operations are done with well-written procedures in the form of check-lists, and all handling operations on the reactor since then have been incident free.

Safety Review Benefits

IGCAR has benefited by the regulatory process, in terms of honing the analytical and experimental skills at IGCAR. For example, the core configuration changes for inducting MK-II and high Pu MOX fuel demanded extensive out-of-pile characterisation of these fuels by BARC and IGCAR. They also required revision of safety reports, calling for further safety analysis using latest available codes. While reviewing the results of high power engineering experiments carried out in 1994-95, SARCOP stipulated reconciliation of the test results with the analysis. This led to improved realistic modelling of thermal-hydraulic codes, especially in the areas of natural convection in primary and secondary sodium systems. Similarly, based on SARCOP stipulation, the core temperature anomalies arising out of the stuck position of the Core Cover Plate were analysed by the Thermal Hydraulics section, using different codes. This has given the impetus to plenum hydraulic studies in IGCAR. Several thermal hydraulic problems have been studied in water models in the engineering halls.

While IGCAR in general and FBTR in particular have benefited from the interaction with the regulators, as explained above, the regulators have also benefited by the regulation of FBTR. The operating experience feedback from FBTR has provided AERB the knowledge base required to take on the challenges of regulating future power breeder reactors. Just as AERB got on its roll engineers with PHWR experience from BARC or NPCIL, a few senior officers from IGCAR with fast reactor experience moved to AERB. This experience of FBTR review has certainly strengthened the capability of AERB to take up comfortably the detailed review of Prototype Fast Breeder Reactor (PFBR) coming up at Kalpakkam.

Other IGCAR Facilities

Apart from FBTR, the other major radioactive facilities at IGCAR were RDL, RML and RCL. RDL was intended for development of flow sheets for reprocessing of irradiated fuel from FBTR. Its hot cells were also used for extraction of U-233 from irradiated thorium rods from CIRUS. RML designed for post irradiation examination of FBTR fuel had number of hot cells and alpha tight containment boxes. RCL too had hot cells and series of glove boxes for research and development studies in the areas of process chemistry, non-aqueous processing, etc. SEWG reviewed the safety analysis reports of these facilities. AERB appointed a review Committee chaired by K. Sivaramakrishnan, Radio Metallurgy Division, BARC to review the project and carry out the plant inspection before issuing the authorisation of RML and RCL. Similarly for the Large Component Test Rig Facility of REL involving a large inventory of sodium, AERB constituted another review Committee chaired by L.V. Krishnan, Safety Research Group. T.N. Krishnamurthi of AERB co-ordinated the review activities of these IGCAR facilities. Once operational, these facilities came under the review of IGCAR-CWMF Safety Committee and SARCOP.

KAMINI Research Reactor

KAMINI reactor is a U-233 fuelled, light water cooled/moderated, and beryllium oxide reflected low power research reactor. This reactor has a low fuel inventory of ~ 590 grams of U-233 because of a highly efficient reflector material namely BeO. Designed to operate at a nominal power of 30 kW, this reactor provides adequate fluxes having a proper spectrum for various research activities. As one of the main objectives of this facility was to carry out the neutron radiography of the irradiated fuel from FBTR, KAMINI was installed in a basement cell in Radio Metallurgy Laboratory at IGCAR, Kalpakkam.

AERB constituted a Project Design Safety Committee (PDSC) with G.R. Srinivasan as the Chairman to review KAMINI. The Committee met around twenty times to complete the review. Some of the important issues addressed and resolved by the Committee include the following.

While conducting experiments at low power, it was observed that reactivity variations were taking place due to lateral movement of fuel towards the reflector. Based on the recommendation of the PDSC a core cage was installed to prevent the movement of fuel and arrest any increase in reactivity. It was noted that the locations of pulse detectors and current channels, which were used for the first approach to criticality and low power experiments, needed to be changed subsequently for meeting the requirement of high power operation. It was also noticed that the performance of current channels was not consistent. The problem was identified to be due to degradation of insulation resistance of the detectors, caused by the ingress of moisture through the connector. At low power levels of operation, there was a gross mismatch between the power read by the panel meter and the power calculated based on the measurement. The difference was due to incorrect application of bulk shielding reactor data for attenuation of neutrons in water. The PDSC stipulated that flux power calibration should be done at 10 W. This was done and the mismatch was brought within the acceptable range.

Prototype Fast Breeder Reactor (PFBR)

With the experience and confidence gained from successful operation of FBTR, IGCAR took up the design for a 500MWe pool type prototype fast breeder reactor (PFBR) to be located in Kalpakkam to take advantage of the infrastructure already existing at the site. PDSC for PFBR was reconstituted in February 1997 with G.R. Srinivasan as Chairman. To assist the PDSC in its task, AERB appointed several specialists groups to review various design documents submitted along with PSAR. A Site Evaluation Committee was also constituted with S. Krishnan, NPCIL as Chairman in 1998. Site clearance for PFBR was given in October 2000. An ACPSR for PFBR was constituted in January 2004 with G.R. Srinivasan as Chairman. Later S.S. Bajaj, NPCIL took over as the Chairman, PDSC for PFBR. Till date, PFBR-PDSC has met 84 times.

Authorization for First Pour of Concrete for the raft of Nuclear Island Connected Building (NICB) was issued on December 15, 2004 and the construction of raft was progressing well till the site got affected due to the tsunami event on December 26, 2004. After halting further construction of the raft, the site submitted reports on the incident including an impact assessment, action plan for corrective measures and improvements/changes, in the design/ layout etc. Based on the review of these reports, AERB granted permission for restart of construction of the NICB Raft on April 25, 2005. AERB had granted clearance for construction of Reactor Vault (RV) upto +26.715 m elevation and Spent Sub-assembly Storage Bay

(SSSB) in May 2006. After satisfactory review of relevant documents, mock up trials, clearance for installation of Safety Vessel (SV) and construction of upper lateral upto 31.5 m elevation was granted on February 4, 2008.

Proceedings in the PDSC were often marked by intense debates arising from differences in the design approach followed in PFBR and PHWR. For instance, it took several sessions to accept the proposition that hypothetical core disruptive accident (CDA) in PFBR is a Beyond Design basis Accident (BDBA). Based on the review of accident sequence analysis, reactor containment has been designed for 25 kPa pressure. Similarly, it involved several intense discussions before a set of rods, performing both control and safety functions, were accepted by AERB.

PFBR-PDSC had made a number of recommendations. A few illustrative examples are given here. PFBR design should confirm with IAEA Code NS-R-1, 2000 requirements. For many design basis events, SCRAM action had been considered as a means of reactor shutdown. Designers furnished justification on the time availability for crediting operator action and specify the parameters on which manual SCRAM action would be taken. Complementary shielding was provided over roof-slab as per design to reduce the radiation due to direct streaming along the various penetrations in the slab. A full scale mock up of transport, lifting and placing Safety Vessel (SV) in reactor vault was done by appropriate dummy considering both, its size and weight prior to installation of SV. Designers have also developed a full scale training simulator, the specifications and performance boundaries for which were approved by PDSC.

Demonstration Fuel Reprocessing Plant (DFRP)

IGCAR is setting up DFRP to process spent fuels of FBTR and PFBR. This is a forerunner of the reprocessing facility in Fast Reactor Fuel Cycle Facility (FRFCF) to be setup at Kalpakkam. It is divided into two concrete cell facilities called Head End Facility (HEF) and Process Plant Facility (PPF). After the review of the documents on the civil design and the site by CSED and PDSC-DFRP, clearance for civil construction of HEF was granted in September 2006. Most of the civil construction and installation of equipment and piping for the PPF have been completed at the time of construction of Kalpakkam Reprocessing Plant (KARP). Important recommendations from safety considerations included construction of diaphragm wall before the commencement of work of HEF, proper monitoring of men and materials to prevent contractor workers access to the waste tank and other areas.

Fast Reactor Fuel Cycle Facility (FRFCF)

FRFCF is being built at Kalpakkam near the PFBR site, to meet the fuel reload requirement for PFBR. It comprises of all the component plants of a fuel cycle facility like fuel reprocessing plant, fuel fabrication plant and waste management plant. Based on the review of Site Evaluation Committee chaired by L.V. Krishnan, former Director Health and Safety Group, IGCAR, the site clearance for FRFCF was given in September 2006. One of the important observations/ recommendations made during the process of site evaluation was that civil structures like underground water sump, stormwater drain, Low, Intermediate and High Level liquid waste trenches and DG room (Class III power supply) would be considered as safety related structures/ buildings while reviewing the application for consent of construction. For this project, AERB has also appointed a PDSC chaired by D.S.C. Purushotam, Former Director, Nuclear Fuels Group, BARC and an ACPSR chaired by R.K. Garg, former, CMD, IREL.

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