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INITIATIVES ON SAFETY RESEARCH

AERB recognizes the importance of safety research in support of its regulatory work as it helps in obtaining deeper insights into the issues concerning nuclear and radiation safety to arrive at scientifically sound regulatory decisions. Accordingly, AERB has been pursuing such research through a variety of means.

Beginning of such efforts was made in the form of funding of safety research proposals from academic and research institutions and since then it has expanded in scope and size. Parallel to the funding of research proposals, some of the technical divisions of AERB also started safety analysis and research activities to support the safety review activities. Major thrust to the safety research was given in late nineties that culminated into establishment of Safety Research Institute to carry out and promote safety related research and analysis relevant to regulatory work. All these three avenues for R&D efforts of AERB are functioning well. A brief description of these efforts is given below.

Safety Research within AERB

Safety research activities within AERB made a humble beginning with studies pertaining to level-1 probabilistic safety assessments undertaken by the then Nuclear Safety Division (NSD) in the early nineties. Since then, some of the technical divisions of AERB are engaged in safety analysis and research in a number of areas of regulatory interest: probabilistic safety assessment, reactor physics, thermal hydraulics, severe accident analysis, seismic design of structures and components, high performance concrete, long term performance of concrete structures and use of high volume fly-ash concrete in NPP civil structures. The inhouse work carried out on these topics has been extremely useful in reviewing the proposals concerning new projects and the unusual events that take place from

time to time in the operating facilities. Further the development of staff capabilities through these efforts help in assessment of novel designs and also designs that use industry codes not previously used in our country.

R&D activities within AERB focused on issues related to assessment of design safety through independent checks, assessment of plant modifications, accident management evaluation, hazard evaluation, development of safety documents, and dissemination of generic issues. Specific topics that were studied and are being studied as R&D efforts include : passive system reliability, seismic PSA, severe accident analysis, level-1 and level-2 PSA, thermal hydraulic analysis of VVER, hydrogen distribution analysis within containment, core disassembly progression analysis and fuel bundle deformation analysis for PHWR, fire hazard analysis for Kaiga-3&4, fire analysis of lube oil storage room of TAPS-3&4 turbine-building, probabilistic seismic hazard analysis of Kalpakkam site, tsunami hazard assessment, parametric studies on design safety factors for concrete structures, containment behaviour, inter-comparison of structural design standards for safety related structures, seismic –re-evaluation of FBTR, etc.

In order to gain first hand experience on seismic re-evaluation of existing facilities and also to develop AERB staff capabilities, AERB and SRI undertook a major R&D exercise of seismic re-evaluation of FBTR at Kalpakkam in collaboration with IGCAR. This exercise encompassed all the facets of seismic qualification of an NPP, namely, development of review basis ground motion, seismic walk-down, structured analysis and development of seismic fragility curves for structures, system and components (SSC), and strengthening and retrofitting of SSC, whenever necessary.

Safety research within AERB has helped immensely in development of in-house capabilities such as adoption of state of art analysis methodologies, development of in-house computer codes,

participation in international standard problem exercises and IAEA's co-ordinated research programmes.

Safety Research Institute, Kalpakkam

With the vast experience gained from regulatory activities over the years, AERB felt the need for establishing its own institute to carry out and promote safety related research and analysis relevant to regulatory work. P. Rama Rao, the then Chairman, AERB took the initiative and decided to set up the Safety Research Institute (SRI) of AERB at IGCAR campus at Kalpakkam, so that with the readily available infrastructure the activities of the institute could pick momentum in a short time. The SRI was set up in February 1999 during the IXth Five Year Plan period with P. Rodriguez as first Director of the Institute. The following were the objectives set forth for SRI at the time of its inception.

- To carry out and promote safety related research and analysis relevant to regulatory work
- To provide a forum for designers, operators, research groups and regulators to come together for formulation and implementation of research programmes aimed at resolving safety related issues
- To organize conferences/symposia/seminars/discussion meets/ workshops/training programmes on various topics of interest to AERB

Research areas to be undertaken in SRI were chosen keeping in view their importance to safety assessment carried out by AERB as well as to complement the ongoing research and development work in units of DAE. Ready availability of guidance from senior researchers of IGCAR was another guiding element in the selection of work areas to be pursued at SRI.

The work contributions of SRI during the short period of less than 10 years of its existence are described in the following sections.

Light Water Reactor Physics

In order to develop the capability in AERB for thorough regulatory review of the light water reactors, that are foreseen to be increasingly used in the country in the years to come, it was decided to establish in AERB the requisite capacity for reactor physics analysis of LWRs. To start with, the lattice burn up computer code EXCEL of BARC with the 172 group IAEGX cross section library was installed and tested at SRI. The code was used to verify core physics calculations. Next, the 3D neutron diffusion theory hexagonal geometry whole core simulator computer code TRIHEX-FA of BARC was successfully used to obtain reactivity, reactivity coefficients and burn up reactivity loss for cycles 1 to 8 of VVER cores of KKNPP. Further, the KENO-VI Monte Carlo module of the SCALE V.5 Computer Code System of ORNL was commissioned at SRI and run for the KKNPP core as a means of alternate validation of the BARC diffusion theory codes. The ORIGEN module of SCALE system was also used to do independent burn up verification calculations. Work has been also taken up for use of the codes for analysis of alternate fuel cycles like MOX. This work is being done under the direction of S.M.Lee, a Raja Ramanna Fellow at SRI.

Radiation Shielding & Transport and Criticality Computations

This is one area in which SRI used the expertise that was readily available in IGCAR and the following works have been carried out:

- Shield design of the Transfer Arm of PFBR and complementary shield design for radiation streaming of the top shield of PFBR as well as analysis of the shielding benchmark results obtained from the experiments conducted in APSARA reactor, BARC.
- Criticality safety evaluation of stacked PFBR fuel subassemblies during assembly in the Interim Fuel Storage Building
- Analysis of shutdown neutron count rate for external neutron source of PFBR

- Optimization of shield structure design needed in the south and west beam ports of KAMINI neutron source reactor, in view of the space constraints encountered in the facility.
- Shielding design evaluation for some of the particle accelerators in the country and PANBIT blood irradiator, to ensure compliance with AERB requirements

Assessment of Beam Characteristics of Medical LINAC

Beam Characteristics of a 6 MV Medical LINAC was simulated and analyzed to obtain the best design for the target used for electron impingement and the flattening filter, the two main components that decide the quality of X-rays generated and dose profile of the beam which are the parameters of practical significance in therapy and treatment planning.

Reliability and Probabilistic Safety Assessment

Reliability Analysis and Probabilistic Safety Assessment (PSA) provide a systematic approach to determine whether the safety systems are adequate and reliable. Internationally, PSA is increasingly being used as a part of `risk informed` regulatory decision making process for nuclear plant safety. Following are some of the important contributions made by SRI related to this area:

- Estimation of station black out frequency for PFBR and FBTR
- Reliability Analysis of Safety Grade Decay Heat Removal System and Operation Grade Decay Heat Removal System of PFBR
- Reliability Analysis of Shutdown System of PFBR
- Optimal configuration of Real Time Computer System for Core Temperature
- Monitoring System of PFBR
- Estimation of Optimum Test Interval for Maintenance of Standby Systems
- Seismic Re-evaluation of FBTR

Structural and Seismic Studies

Evaluation of performance of nuclear plants and their components under seismic conditions is one important area of work that has been started in SRI. Following activities have been completed in this area:

- Seismic Qualification of Control Room Panel of 500 MWe Nuclear Power Plant by Finite Element Analysis method.
- Structural and Seismic Analysis of north west and south west loops of Safety Grade Decay Heat Removal Fill and Drain Pipelines of PFBR.
- Development of FEM module `MATPIPE' using MATLAB software package, for carrying out static and dynamic analysis as well as seismic response of pipelines using response spectrum method, accounting for multiple support excitations.

RS and GIS Applications

Remote Sensing (RS) and Geographic Information System (GIS) is a powerful tool that makes use of the satellite imageries and other collateral data to carry out site selection and environmental assessment studies to assist in regulatory decision making. This technique has been successfully applied at SRI in the following areas of work:

- Development of inputs for the DAE's `Online Emergency Response System` for Kalpakkam site to facilitate assessment of plume characteristics in time and space and visualization of possible emergency scenarios
- Development of digital database and environmental assessment of Kalpakkam site
- Assessment of morphological changes in Kalpakkam coast due to the tsunami of December 2004, towards mapping of natural hazards.
- Development of methodology for tsunami inundation modeling and its validation
- Flood mapping due to monsoon rainfall

Safety Assessment of NSDF

The safety performance of near surface radioactive waste disposal facilities are influenced by factors such as hydrogeological setting, aquifer characterization, ground water fluctuation with respect to seasons, ground water chemistry, etc. Work done in this area at SRI includes hydrogeological investigations and groundwater modeling using VISUAL, MODFLOW PRO, assessment of groundwater characteristics over different seasons and colloid facilitated transport of radionuclides in subsurface groundwater.

Computer Code Depository

SRI has identified and collected certain computer codes pertaining to safety analysis and has also organized workshops to provide hands on training to participants in handling these codes. Currently available safety analysis codes of different categories at SRI are:

- Radiation Transport Codes: MCNP, KENO, ASFIT, ANISN, SCALE
- Spectrum Unfolding Codes: SAND-II, FORIST, DUST
- PSA Codes: RISK-SPECTRUM, PSA PACK
- Remote Sensing Codes: ERDAS, ENVI
- Hydrogeological Codes: VISUAL MODFLOW
- Fire Hazard Analysis Codes: FIRE DYNAMICS SIMULATOR

Organization of Technical Seminars

Organization of conferences/workshops/Discussion Meets, etc. has been an important component of the activities of SRI. Since its inception, upto March 2008, SRI organized twenty such programmes.

Research Support from other Organizations

AERB obtains substantial research support from its technical support organizations like the Bhabha Atomic Research Centre, the

Indira Gandhi Centre for Atomic Research and other institutions in the country. On certain issues of regulatory interest, AERB impressed upon the utilities/licensee to conduct R & D to bring better understanding of regulatory issues and improve the safety of plants. A few examples of significant use of R & D in regulatory decision making are in the areas of safety of coolant channels of PHWRs (issues related to delayed hydride cracking), safety of TAPS-1&2 under the condition of mainstream line break or recirculation line break with cracked core shroud, assessment of safety of the reactor pressure vessel of KK-NPP with welds in core region, ageing induced deterioration of elastomer components of the unbonded prestressing system of KK-NPP, analysis of causes of reactor power fluctuations in 540 MWe PHWR during initial operation, etc. AERB also maintains strong organic links with BARC, IGCAR and institutes like IIT, Bombay for training its staff in advanced research and analysis work.

AERB Funded Safety Research Programme

AERB decided in 1985 to initiate a programme to fund project proposals coming from academic and research institutions for research in nuclear and radiological safety. AERB brought out a brochure titled 'Safety Research Programme (SRP) of AERB' highlighting the areas of the Research Projects that are of interest to AERB. The brochure also contained information on eligibility, tenure and procedure for applying for the Project, the format of the application and other rules and regulations for funding of projects.

AERB constituted a Committee for Safety Research Programmes (CSRP) to frame rules, regulations and guidelines and to recommend, evaluate and monitor the research projects of the SRP. CSRP is currently chaired by K.B. Sainis, Director, Bio-Medical Group, BARC. The Committee also recommends financial assistance to universities, research organizations and professional associations for holding symposia and conferences of interest to AERB. The organizations seeking support from AERB should have the basic infrastructure and

available facilities to be suitably augmented with the help of research grants from AERB.

The Chairman of the first CSRP was A.K. Ganguly, formerly Director, Chemical Group, BARC. The other members of the first CSRP included experts from AERB and BARC, namely, D. V. Gopinath, V. Venkat Raj, D. Singh and K.S. Parthasarathy.

CSRP members hold interaction meetings with the Principal Investigators from academic institutes for review of potential proposals of research. After discussion, the principal investigators submit formal proposal to CSRP for approval. Two or more experts evaluate the project proposals and their comments are reviewed. Whenever projects are approved, CSRP nominates appropriate co-ordinators for proper implementation of the project.

AERB funded research programmes have been very useful. Many of these projects have generated results that provided important inputs to the safety analysis apart from producing Ph.D scholars in several cases. Few examples of several such projects are:

- Phytoextraction of Caesium-137 from Contaminated Soil carried out at TNAU, Coimbatore
- Investigation & Modeling of the Instability Mechanisms in Core Melt-Jet Fragmentation in a Nuclear Reactor in a Severe Accident Scenario carried out at IIT, Bombay.
- Integrated Studies on Radionuclide Migration at Shallow Land Disposal Facility carried out at IIT, Bombay.
- Development of Newer Interventional Strategies to Counteract the Effects of Radionuclide Fallout carried out at RMC, Mumbai.
- Transfer Coefficient of Radionuclides in Field Crops and in Food Chain Pathways carried out at TNAU, Coimbatore
- Development of Plastic Materials for Nuclear Track Detection carried out at Goa University, Goa

- Biodosimetry Techniques for Assessment of Accidental Over Exposures carried out at SRMC, Chennai & AIIMS, New Delhi
- Coastal Atmospheric Dispersion Studies carried out at IIT, Delhi
- Coupled Neutronics and Thermal Hydraulics Analysis of Pressurised Heavy Water Reactors carried out at IIT, Bombay

AERB recognized the necessity of developing R&D infrastructure to support its regulatory activities in the early days of its inception. It also recognized the role of R&D in developing competency of its staff for independent verification and support for decision making process within the framework of consenting process. This resulted in to a continual improvement in its R&D efforts and using the R&D efforts strategically, in the safety review process. The three avenues on R&D activities of AERB, mentioned above, has been adding to the strength of AERB as an effective regulatory body.

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